The U.S. Geological Survey, Branch of Astrogeology—A Chronology of Activities from Conception through the End of Project Apollo (1960-1973)

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INTRODUCTION

Between the early 1960's and early 1970's, a group of young and enthusiastic geoscientists and support personnel working for the U. S. Geological Survey (USGS), Branch of Astrogeology in Menlo Park California, Flagstaff, Arizona, and elsewhere, were destined to play a major role in one of the most remarkable events and most significant achievements in the history of mankind—the manned Apollo expeditions to the Moon. July 20th of 2009 will mark the 40th anniversary of the day the world stood still while everyone watched astronauts Neil Armstrong and Buzz Aldrin land on the surface of the Moon while Mike Collins orbited above them during the historic Apollo 11 mission to the Sea of Tranquillity.

The launch by the Soviets of the first spacecraft to orbit the Earth in October 1957 shocked and deeply embarrassed our nation. However, the stirring *"we will go the Moon"* speech by President Kennedy to a joint session of Congress on 25 May, 1961 (see 1961 discussion below), proved to be the catalyst that was needed to "wake the sleeping giant," and focus the nation's attention—and amazing technical capabilities—on the noble purpose of landing a man on the Moon by the end of the 1960's. That seemingly impossible goal was achieved, remarkably, not just once but six times between July 1969 and December 1972! With the help of scientists and support personnel from the U.S. Geological Survey, as well as many others from institutions and organizations from around the world, the Apollo Moon landings were not just "engineering" feats, but scientific successes as well.

The history of the geologic mapping of the Moon, and the U.S. Geological Survey, Branch of Astrogeology's pure research and outstanding support of the National Aeronautics and Space Administration's (NASA) unmanned lunar spacecraft missions, during the Apollo Era have been well-documented by Don Wilhelms in his two outstanding publications "*The Geologic History of the Moon*" (Wilhelms, 1987) and "*To a Rocky Moon* (Wilhelms, 1993). Don, having spent his career with the Branch of Astrogeology in Menlo Park, California, directing the Survey's lunar-geologic mapping activities, is the first to admit that these publications provide insufficient detail on the concurrent activities of the "Manned Lunar Exploration" group of the Branch of Astrogeology, which, based out of Flagstaff, Arizona (starting in mid-1963), became the Branch of Surface Planetary Exploration in 1967 (until the Branches recombined in May 1974). Therefore, the main objective of the present work is to fill that significant gap in the important documentation of Apollo history with regard to the participation of the U.S. Geological Survey.

The City of Flagstaff, Arizona and its local environs have long played a distinguished role in hosting the development of the relatively new science of astrogeology—the geologic study of the Earth and other solid bodies in the Solar System. Dr. Eugene M. Shoemaker (1928-1997), who coined the term in 1960, first established the U.S. Geological Survey's Astrogeologic Studies Unit in Menlo Park, California. In September 1962, Shoemaker's Astrogeologic Studies Unit formally became the Branch of Astrogeology and on 1 July 1963 moved its permanent headquarters to the 7,000-foot-high town of Flagstaff in the scenic Ponderosa pine forest of Northern Arizona.

While looking for uranium on the Colorado Plateau Gene during his early years with the USGS had fallen in love with Flagstaff and decided that this quiet little town in the mountains was the perfect place to headquarter his new Branch of Astrogeology. Gene also strongly weighed the fact that Flagstaff had important additional attributes. It was centrally located near a number of natural landmarks which would be well-suited for developing both unmanned and manned lunar exploration procedures and for training NASA's astronauts in general geologic field procedures, including first-hand study of landforms resulting from volcanism as well as impact cratering. The landmarks within easy reach of Flagstaff included Gene's favorite astrogeologic feature, Meteor Crater, about thirty-five miles east of town. Also of primary importance in Shoemaker's decision to move the Branch to Flagstaff was the presence of well-established observatories. Gene thus reasoned that Flagstaff was the logical place to build a telescope for the Branch of Astrogeology, one designed specifically for lunar observing and mapping.

Flagstaff and vicinity started receiving scientific media attention in the last decade of the nineteenth century as a result of the rigorous scientific investigations of nearby Meteor Crater by the U.S. Geological Survey's Grove Karl Gilbert (1843-1918), and the telescopic observations of the "Martian canals" by Sir Percival Lowell (1855-1916). Northern Arizona would again attract "astrogeologic" interest during the somewhat more commercial investigation of Meteor Crater carried out by mining engineer Daniel Moreau Barringer (1860-1929), and later with the discovery of Lowell's mysterious planet X (Pluto) by Clyde Tombaugh in 1930. In the early 1960s, a brilliant, energetic, and young Eugene M. Shoemaker with the U.S. Geological Survey would once and for all convince nearly everyone that Meteor Crater was of "extra-terrestrial," or impact origin—not of volcanic origin as was still maintained by some scientists at that time.

Flagstaff would once again attract significant domestic and international science-media attention starting in early 1963, only a couple of years after Project Apollo was boldly set into motion by President John F. Kennedy's stirring *"we will go the Moon"* speech to a joint session of Congress on 25 May, 1961. The media attention focused on Flagstaff starting in the early 1960s was related primarily to two major lunar activities in town by different government agencies. First, there were the lunar cartographic maps being prepared for NASA under the auspices of the U.S. Air Force Aeronautical and Chart and Information Center [ACIC] located on the grounds of Lowell Observatory. Secondly, there were activities starting in 1963 that were related to: (1) lunar geologic mapping, (2) support of NASA's unmanned lunar missions, (3) field development and testing of manned lunar surface exploration methodologies, and (4) the geologic training of astronauts being conducted for NASA by the Survey's Branch of Astrogeology.

These pioneering lunar research activities conducted for NASA largely in and around Flagstaff were in preparation for what many believe was Mankind's single most remarkable accomplishment to date—the manned Apollo Moon missions, during which twelve men explored six areas of the lunar surface between July 1969 and December 1972. Even for the greatest and most powerful nation on Earth, the timeframe seemed impossibly short to design and engineer the massive and technologically complex space vehicles, and to both scientifically and emotionally prepare men to explore the surface of the Moon. The amazing feat took place only eight years and two months following Kennedy's daring proposal in May 1961 that the nation should commit itself to the goal of the landing a man of the Moon by the end of the decade. That this improbable fantasy actually became a reality in July 1969—a year ahead of schedule, and during the costly (both in lives and money) Viet Nam War—is still difficult to believe. However, it is now part of history.

Our story begins with a brief summary (taken from Wilhelms, 1993) of the pioneering astrogeologic research activities that took place at Coon Butte/Coon Mountain, or Barringer Meteorite Crater (Meteor Crater) just east of Flagstaff from the late Nineteenth Century to the Early Twentieth Century. This is followed by a summary of the early considerations by prominent scientists of the Twentieth Century regarding the probable origin of lunar craters (impact versus volcanic) and speculations on the geology of the Moon.

The story then jumps to the spring of 1948 when Eugene Merle Shoemaker, a bright, inquisitive, geologist with the U.S. Geological Survey's Colorado Plateau uranium project became fascinated one evening with a beautiful, nearly-full Moon while working in southeastern Colorado on 28 April 1948—his twentieth Birthday. That first evening of Gene's focus on the Moon, and its then uncertain geologic nature, led that spring to Gene's admitted "epiphany" about going the Moon himself, and exploring its geology as a field geologist. "He said I took the first fork that went to the Moon that Morning" (Levy, 2000, p. 27).

The present story, which really begins with Gene's epiphany, and extends to the end of the Apollo Era (1973), was undertaken both as an important historical record of that incredible period of manned exploration of space, and as a tribute to Eugene M. Shoemaker (1928-1997) (The Father of Astrogeology and Modern Lunar Geology) and the many special men and women of the Branch of Astrogeology and Branch of Surface Planetary Exploration who made the Geological Survey's scientific role in Project Apollo one for which we can all be very proud.

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Chapter 1

Early Astrogeologic Studies at Meteor Crater, Arizona

1.1.-Grove Karl Gilbert

The idea of studying the Moon as a body of "geologic" interest was given little serious consideration in modern times until 1891-1892 when Grove Karl Gilbert (1843-1913), then Chief Geologist of the U.S. Geological Survey, became fascinated with the origin of lunar craters and Arizona's Meteor Crater near Flagstaff. We begin our story there, as described earlier by Don Wilhelms in his book "*To a Rocky Moon*" (Wilhelms, 1993, 477 pages**)** (Fig. 1).

"Grove Karl Gilbert was surely one of the greatest geologists who ever lived, and his genius touched almost all aspects of the science: geomorphology, glaciology, sedimentation, structure, hydrology, and geophysics. His recent biographer Stephen Pyne has applied to him the same term Gilbert applied to the Geological Survey: a great engine of research" (Wilhelms, 1993, p. 7).

"In 1891 while Chief Geologist of the U.S. Geological Survey, Grove Karl Gilbert was attracted by reports of large amounts of meteoritic iron, the Canyon Diablo meteorites, around a crater in Arizona then called Coon Mountain or Coon Butte. Apparently he had been thinking about the possible impact origin of lunar craters, and he alone realized that the Coon Crater might itself be a "scar" produced on the earth by the collision of a "star;" if so, a large iron meteorite might lie buried beneath the crater. He reasoned that such a body should (1) show up at the surface and (2) displace such a large volume that the ejecta of the crater should be more voluminous than its interior.

He tested both ideas and got negative results. In October 1891, he and his assistants carefully surveyed the volumes of the ejecta and of the crater and found them to be identical at 82 million cubic yards (63 million cubic meters). Their magnetic instruments showed no deflections whatsoever between the rim and the interior. Gilbert reluctantly concluded that a steam explosion formed the crater—that is, it was a maar crater. He had to conclude that the Canyon Diablo meteorites fell near the crater by coincidence. There the matter appeared to rest for a while.

But he was not ready to give up on impact. Calling himself temporarily a "selenologist," he observed the Moon visually for eighteen nights in August, September, and October 1892 with the 67-cm refracting telescope of the naval observatory in Washington. A member of Congress assessed this activity and Gilbert's parent organization as follows: "So useless has the Survey become that one of its most distinguished members has no better way to employ his time than to sit up all night gaping at the Moon". But those eighteen nights left a tremendous legacy. The use to which Gilbert put them shows that the quality of scientific research depends first and foremost on the quality of the scientist's mind" (Wilhelms, 1993, pp.7-8).

"Gilbert presented his conclusions in a paper titled "*The Moon's Face*," the first in the history of lunar geoscience with a modern ring. He knew he was not the first to suggest an impact origin for lunar craters; he mentioned Proctor, A. Meydenbauer, and "Asterios," the pseudonym for two Germans. Apparently, however, Gilbert was the first to adduce solid scientific arguments favoring impact for almost all lunar craters from the smallest to the largest; however, he was the first to adduce solid scientific arguments favoring impact for all lunar craters from the smallest to the largest—"phases of a single type" as he put it.

He wrote that the depression of lunar crater floors below the level of the surrounding "outer plain" made them totally unlike most terrestrial volcanoes. He noted that the central peaks are common in craters of medium size but not in those smaller than about 20 km across and rarely in those larger than 150 km; but this is a regular relation and does not destroy the basic unity of form. He pointed out that the largest lunar craters (including those we call basins) far exceed the largest terrestrial craters in size. In his words, "volcanoes appear to have a definite size limit, while lunar craters do not."

He realized that impacts would weaken lunar materials to the point of plasticity (hence the peaks) and could melt them (hence the flat floors). His conclusions were based partly on simple experiments with projectiles and targets composed of everyday materials. He so completely accepted the origin of the "white" rays that radiate from many craters as slashes from impacts that "it is difficult to understand why the idea that they really are slashes has not sooner found its way into the moon's literature."

Gilbert apparently was the first to be impressed by an extensive system of grooves or furrows and parallel ridges that he called "sculpture." He certainly was the first to interpret the sculpture correctly. When he plotted the trends he found that they "converge toward a point near the middle of the plain called Mare Imbrium, although none of them entered that plain." His conclusion ushered in the investigation of lunar impact basins. "These and allied facts, taken together, indicate that a collision of exceptional importance occurred in the Mare Imbrium, and that one of its results was the violent dispersion in all directions of a deluge of material—solid, pasty, and liquid. Solid fragments thrown out of Imbrium gouged the furrows" (Wilhelms, 1993, pp. 8-9).

"He was not an impact fanatic, however. He gave credence to the volcanic camp by calling attention to the similarity of small lunar craters to maars [explosively created volcanic craters] that also have depressed floors. In his words, "limited use may be found for the maar phase of volcanic action in case no theory proves broad enough for all of the phenomena." Possibly, Coon Mountain [subsequently called Meteor Crater] was still on his mind, but, strangely, he did not mention it in his lunar paper. Gilbert started with two working hypotheses, impact and volcanic, but was drawn inexorably to the former as more and more observations fit the impact theory and fewer and fewer the volcanic.

Which brings us back all too briefly to the fascinating story of Gilbert at Arizona's Coon Mountain. His report of his investigation of the crater, published five years after he performed it, is a model of scientific inquiry that is more concerned with methods and the reasoning process than with results. The report's title, "The Origin of Hypotheses, Illustrated by the Discussion of a Topographic Problem," does not even mention the crater, and, also strangely, the text does not mention "*The Moon's Face*." At Coon Mountain, Gilbert quantitatively tested two working hypotheses according to the theory available to him and felt forced to accept the volcanic one against his deepest instincts. He had to conclude that the Canyon Diablo meteorites fell near the crater by coincidence. In retrospect we might say he should have trusted his intuition more than the "so-called" facts.

For the next half century, only a few geologists or astronomers thought about the Moon at all, and most of those still favored origins of the lunar craters as calderas, bubbles formed by bursts of steam or volcanic gas, or ramparts built up when Earth tides kneaded the moon's crust" (Wilhelms, 1993, pp. 10-11).

1.2.-Daniel Moreau Barringer

The next major player in the Meteor Crater story was Daniel Moreau Barringer (1860-1929), the mining engineer and industrialist who became preoccupied, starting in 1903 with the possible impact origin of Coon Mountain (Meteor Crater) (see footnote 2)—a fascination and controversy that would be the focus of his energies throughout his life. Barringer would whittle away at the then majority endogenic view (volcanic) of crater origin. The following story of Barringer's obsession with Meteor Crater is taken from Wilhelms (1993):

"Two intertwined developments during the interlude began to whittle away at the majority endogenic view of crater origin. One came from the intense scrutinyto which Coon Mountain crater was subjected in the course of mining entrepreneur Daniel Moreau Barringer's single-minded search for the large meteorite that he was certain had formed the 1.2-km-wide crater, and which would yield a fortune in iron, nickel, platinum, and iridium.

Barringer heard about the crater and the small nearby iron meteorites in 1902, began the search in 1903, and continued steadily at first, and intermittently later, to drive shafts and drill holes at ruinous cost until his death in 1929. He was an able and observant man, but he was obsessed by the crater. He refused to listen to any evidence against the impact origin or his belief that the impactor was still sufficiently intact to be mineable. His obsession pressured others to examine carefully the nature of the impact process and eventually to find proof that Meteor Crater—Coon Mountain's name since 1907 or 1908—was indeed formed by the impact of a meteorite. When they did, their findings proclaimed that large meteorites (1) do exist, (2) can create large craters on Earth, and (3) should be reexamined as the cause of lunar craters.

The emerging truth was less kind to Barringer's hopes for the condition of the meteorite. The other development in cratering was a new understanding of how violent cosmic impacts are. Interestingly, the often wrong Nathaniel Shaler realized that a cosmic projectile would release enormous energy on impact and would itself be vaporized, although he did not realize that the lunar craters manifested the results. G.K. Gilbert groped for an explanation for the circularity of lunar craters and rejected an impact origin for Meteor Crater because he did not know about the energies. Now, some of Barringer's associates and prestigious consultants were closing in on the truth that would damn the mining project [at Meteor Crater]" (Wilhelms, 1993, p. 11).

"[Astronomer Ernst Julius] Opik (1893-1985), [physicist Herbert Eugene] Ives (1882-1953), [Algernon Charles] Giford, and then other astronomers and physicists [between 1916 and 1924] all pointed out that because of their enormous energies, cosmic objects are much smaller than the craters they create. They blast out circular craters almost regardless of their impact angle; and they are themselves almost completely dispersed or vaporized in the target rock and crater ejecta. Barringer was right in his belief that a meteorite had made the crater; but wrong in his hope that it had survived partly intact" (Wilhelms, 1993, p.12).

1.3- Debate over the Origin of Lunar Craters Heats Up between 1936 and 1948

"In 1936 meteoriticist Harvey Harlow Nininger (1887-1986) made another connection between Earth and Moon that was to significantly influence lunar geology in the Space Age. He suggested that tektites, small glassy objects that evidently were shaped by high-speed flight through the atmosphere, were ejected by impacts on the Moon and hurled through Earth's atmosphere.

At the same time, American geologists John Boon and Claude Albritton broke entirely new ground. They knew that rock would not only be deformed by the shock of an impact but would react violently when the shock had passed. Rebounded central peaks were one result, and another was chaotically broken-up rock beneath the peak and the crater floor. Such chaos characterized peculiar features that the influential geologist Walter Herman Bucher (1888-1965) had called "cryptovolcanic" on the assumption that they were created by subsurface volcanic explosions" [Similar to the steam explosion that Gilbert ultimately—and erroneously—concluded formed Meteor Crater].

Another setback with regard to the origin of lunar craters occurred in mid-century when mining geologist Josiah Edward Spurr (1870-1950) and his biographer (and admirer) Jack Green (b. 1925) dismissed the impact theory in favor of the theory that that all lunar features were created by endogenic melting and fracturing triggered when the Moon was "captured" by the Earth.

Spurr's systematic, minute, and independent examination of the Moon's features generated four privately published volumes under the overall title "*Geology Applied to Selenology*" and dated between 1944 and 1949 that unfortunately gained considerable influence in the small world of lunar observers. A ruling prejudice underlay Spurr's work (and not only his):"that the Moon was a little Earth and could be described in terrestrial term" (Wilhelms, 1993, p.13).

"Not everyone blundered so badly in mid-century. Two papers dated 1946, between the publication of Spurr's second and third volumes, provided relief from his tedious ramblings. The first to appear was by Harvard professor emeritus of geology Reginald Aldworth Daly (1871-1957). Refuting geologists with endogenic views, this great geologist cited Gilbert in support of his own advocacy of impact—which he believed to be consistent with a fascinating impact mechanism for the origin of the Moon itself.

The second prescient paper by a ground breaking geologist was by Robert Sinclair Dietz (b. 1914-1995), who was also cited Gilbert's work but added more of his own observations than did Daly. Dietz listed eight properties of lunar craters that distinguish them from terrestrial volcanic craters and drew the obvious conclusion, which somehow escaped so many others, that these differences indicate non-volcanic origins" (Wilhelms, 1993, p. 14).

1.4-Ralph Baldwin and Harold Urey Lead a Renewed Interest in Lunar Geology at mid-Century

Wilhelms (1993) next introduced us to Ralph Belknap Baldwin (b. 1912), a man who he says for half a century looked up, down, and all around him for clues as to the origin of the Moon's features, the man who introduced lunar science to the twentieth century.

[Author's Note: Baldwin became a major player in lunar science when his first two papers were published in 1942 for *Popular Astronomy* magazine after they were rejected by the major astronomical journals]

"Ralph Baldwin, astrophysicist by education, industrialist by profession, and versatile lunar scientist by avocation, constructed in almost complete solitude what hindsight clearly shows was the most nearly correct early model of the Moon" (Wilhelms, 1993, p. 14).

"During wartime service he prepared a book-length synthesis of his lunar observations, experiments, and literature search. The result is one of the landmarks of lunar literature and probably the most influential book ever written in lunar science, "*The Face of the Moon*." The book opened the modern era of lunar studies when it was published in 1949

Only shortly before press time did he become aware of Gilbert's work, which Reginald Daly called to his attention in the course of asking Baldwin for reprints of his 1942 and 1943 paper. Nevertheless, many of Baldwin's conclusions were the same as Gilbert's.

It was Baldwin, however, who championed the concept that craters were formed by great explosions caused by impact—a fundamental, course-altering contribution" (Wilhelms, 1993, pp. 14-16).

According to Don Wilhelms, the final actor in this drama of early lunar studies prior to Eugene Merle Shoemaker, the Father of Astrogeology, was Harold Clayton Urey:

[Chemist Harold Clayton] "Urey devoured Baldwin's book [*The Face of the Moon*] and the Moon totally consumed his interest for years. His reading of *The Face of the Moon* started a chain of events that eventually led to the choice of the Moon as America's main goal in space. Urey published his meditations in two long works with similar content within 3 years of reading Baldwin's book, and he repeated the same ideas several more times over the next 15 years" (Wilhelms, 1993, p. 19).

"During most of the 1960's Urey clashed head-on with geologists and other "second-rate scientists" (his phrase) because most of us were not "selenologists," knew little basic science, and had published little about the Moon. However, he admired Eugene Shoemaker and his long-ignored Gilbert, and admonished others henceforth to pay more attention to prior work "as in [the practice] in other fields of science. And when lunar exploration finally proved wrong Urey's theories about lunar volcanism, history, and composition, he accepted reality and became friendly with some of us "interlopers" (Wilhelms, 1993, p. 20).

"Gerald Peter (Gerrit Peter) Kuiper (1905-1973) belongs on any list of principal figures of planetary science active before the Space Age given that he almost single-handedly provided the thread of continuity in planetary astronomy during the long dry period in the 1940s and 1950s" (Wilhelms, 1993, p. 22).

"Kuiper's first paper with what we would call a geologic content was published in 1954. He led off with a startling summary of his conclusions: "the Moon was nearly completely melted by its own radioactivity, some 0.5 to 1.0 billion years after its formation, and the maria were formed during this epoch—and not as been supposed—primarily the result of melting caused by the impacts themselves." These conclusions were novel in their day. Kuiper allowed for both impact and internal generation of surface features, and his classification of them into "pre-melting, maximum melting, and post-melting stages" is a fair though overly interpretive description of a stratigraphic classification relative to the maria" (Wilhelms, 1993, p. 23).

Chapter 2

A Young Eugene Shoemaker Dreams about Doing Field Geology on the Moon

We now introduce into our history, Eugene Merle Shoemaker (1928-1997); the brilliant and far-sighted geologist who would be called the modern father of lunar geology (Fig. 2). He would by the early 1960s coin the name for the modern science of "Astrogeology," develop procedures to systematically map the geology of the Moon, and found the Geological Survey's pioneering Branch of Astrogeology that would, in 1963, be headquartered in Flagstaff, Arizona.

Gene knew he wanted to be a geologist by the time he was in high school [Fairfax High in Hollywood]. He loved rocks, minerals and fossils from an early age a tender age" (for more details on Gene Shoemaker's background and remarkable career see (Levy, 2000; 303 pages).

2.1-1947-1948

Gene Shoemaker rushed through high school, and then Caltech, where he was graduated in 1947, receiving his master's degree before his 20th birthday in 1948[1].

[Spaceflight Milestone: On 14 October 1947, Charles "Chuck" Yeager became the first human to break the sound barrier (mach 1.0) in the Bell X-1 experimental rocket plane at NACA's (later NASA/Langley) High Speed Flight Research Center at Edwards, California.

[Author's Note: Amazingly, this first breaking of the sound barrier by Yeager would take place less than 22 years prior to man first setting foot on the surface of the Moon on July 20, 1969 (see

[1] Gene worked with Caltech professor Richard "Dick" Jahns while seeking his Masters at Caltech. Jahns had been working on the pegmatites in the Rio Grande Valley, along with geologists Clay Smith and William Muehlberger. Muehlberger and Jahns would later be asked by Gene to join in the Astrogeology Branch's work on Apollo. Muehlberger would become the Principal Investigator on NASA's Apollo Lunar Geology Experiment Team for Apollo missions 16 and 17.

1969). Chuck Yeager, in 2002, flew a commemoratory flight breaking the sound barrier for the last time.]

Don Wilhelms:
"After a pause to catch his breath, Gene joined the USGS in 1948 at the tender age of 19 to work with the uranium-vanadium deposits of the Colorado Plateau. Among his sources of news of the outside world was the Caltech newspaper, which carried items about its affiliate, the Jet Propulsion Laboratory (JPL). Therein he learned of the experiments being conducted at White Sands, New Mexico, with the V-2 rockets salvaged from Germany. In search of a postwar reason for its existence, JPL had stuck a second stage on the V-2s" (Wilhelms, 1993, p. 20).

"Gene said that for some reason Caltech students have always been space freaks. That is when (at Caltech) he first became interested in the Moon. The Hiroshima bomb greatly impressed Gene with regard to the fact that now everything can be done in science. The V1 and V2 rocket program of the Germans also impressed him. Gene then knew that space travel was possible in his lifetime" (From a filmed interview of Gene Shoemaker in Flagstaff, Arizona, by Harry Ryan on 21 April 1997).

[Author's Note: Gene Shoemaker would not receive his PhD from Princeton until 1960 following his pioneering research on the impact origin and mechanism of formation of Meteor Crater in Northern Arizona. See 1960.]

David Levy nicely documented for us a pivotal event in Gene Shoemaker's career:

"Late in the evening of April 28, 1948, Gene's twentieth birthday, the Moon rose in the southeastern sky. A few days past full, it shone beautifully on the Colorado Plateau near West Vancoram, where Gene was assisting in the preparation for the diamond drilling project that would search for a badly needed supply of uranium ore. Could Gene's single look at that rising Moon have planted a seed in his mind? In any event, that seed germinated one morning that spring as Gene drove the five miles from West Vancoram to Naturita, the headquarters of the Vanadium Corporation of America, for his breakfast. Suddenly, the thought hit him: I want to go there! I want to be one of the first people on the Moon. Why will we go to the Moon? To explore it, of course! And who is the best person to do that? A geologist, of course! I took the first fork that went to the Moon that morning" (Levy, 2000, p. 27).[2]

"At the moment of Gene's epiphany on the Colorado Plateau, he was ignorant about the Moon. The first things he read were G.K. Gilbert's books and papers while still working out of his field camps in New Mexico.

Robert "Bob" Sharp, Gene's professor [earlier] at Caltech introduced Gene to G.K. Gilbert. Bob Sharp, a geomorphologist, was one of Gene's most influential professors and advisors at that time. However [strangely enough] Gene did not learn about Gilbert's work on the Moon until later—until he knew he wanted to work on the Moon! Gene considered Gilbert's papers to be

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2 Unfortunately, Shoemaker's dream of being the first man to explore the Moon was not to be because of Addison's disease diagnosed in 1963 (see 1963).

classics—he said that they make good bedtime reading" (from a filmed interview with Gene Shoemaker by Harry Ryan on 27 April 1997).

David Levy:
"There would be other forks in a road to the Moon that would last the rest of Gene's life. There would be unpleasant lessons learned about why a nation would really want to head for the Moon. But on that morning, the Moon beckoned. It was an uncertain place, its surface carved from forces scientists were just beginning to understand. A look through the smallest of telescopes reveals that craters are the dominant feature on the Moon. But how did they get there? The following year, Ralph Baldwin would publish a logical argument that the Moon's larger craters were formed by impact, but minds were slow to turn and many students of the Moon continued to hold that the craters were mostly volcanic in origin. Gene set about to study those aspects of geology, like volcanoes that erupt in violent explosions, that would help determine whether the craters were volcanic or the result of collisions. For Gene, the thought of walking on another world was thrilling beyond description. It was also so unorthodox that he dared not share it with anyone.

Thus, in the spring of 1948, going to the Moon seemed the dream of science fiction writers and a single young scientist named Gene Shoemaker. The dream would have to remain a dream—a foundation whose stones he would lay, one at a time, as he built his geological career. This was Gene's plan, but his job under Survey scientist Richard Fisher in the search for uranium ore—was down a rather different path.

For a small group of scientists living in diverse locations, the seed of space exploration had already germinated. Time and the Cold War would later cause it to flower" (Levy, 2000, p. 27-29).

During a filmed interview Gene had with Harry Ryan on 27 April 1997, it was learned that even out in the field camps on the Colorado Plateau, Gene kept abreast of what was going on in rocketry, and even subscribed to a trade magazine at the time called *Missiles and Rockets*. Gene did a lot of thinking about how scientists might be selected to go to the Moon, such as through the national Research Council. As fate would have it, Gene would never go to the Moon but would end up chairing NASA's Astronaut Selection Committee years later.

2.2-1950-1951

Miss Carolyn Spellman would first meet Gene Shoemaker in Chico, California, when he came to be best man at her brother Richard's wedding on August 18, 1950. Gene and Richard were roommates at Caltech at that time. Carolyn Spellman and Gene Shoemaker would marry on 18 August 1951.

[<u>Author's Note:</u> Their first child, Christy, was born in early 1953. Christy was soon followed by her brother Patrick and her sister Linda. The Shoemaker family spent much of those early years together in the field on the Colorado Plateau, and elsewhere) (See Levy, 2000, for more details about Gene and Carolyn's early years together "in the field" with their three children Christy, Patrick, and Linda).

2.3-1952

2.3.1-Gene and Carolyn Shoemaker Make Their First Visit to Meteor Crater

David Levy:
"The summer of 1952 closed with a small side trip that, unknown to them at the time, turned Gene's career spectacularly. Gene and Carolyn were completing fieldwork in the Navajo Reservation [Hopi Buttes area] of Northern Arizona with colleague Bill Newman. They left Kendrick Peak and soon found themselves not far from Winslow, and Gene suggested that they try to head for the large structure called Meteor Crater atop Coon Butte. At this time, Gene had little idea that their next stop would focus the direction of his career and of our understanding of how our solar system works" (Levy, 2000, p. 41).

[Author's Note: The geologically unique Hopi Buttes Volcanic Field within the Navajo Reservation in Northern Arizona, that Gene would first study in his search for uranium/Thorium during the early years of his USGS career, would later become a very important training ground for his Branch of Astrogeology to develop the methodology and procedures for project Apollo that would be used by NASA astronauts on the lunar surface on six different manned lunar missions between July 1969 and December 1973 (Fig. 3).

"As a geological icon studied by a geologist he admired (Grove Karl Gilbert), Meteor Crater was high on Gene's list of places to visit. But the hour was getting late, the group was down to pennies, and they had to return that evening to Grand Junction, Colorado. They drove quickly toward the site, but since they could not afford the admission fee, left their jeep and crawled up the hill to the top of the Butte. The Sun was already setting over the structure, and long shadows offered a magnificent view. "The crater was an overwhelming sight," Carolyn says, remembering how they looked quietly across its 1.3-kilometer girth. They stayed just a few minutes, and then began their drive home to Grand Junction" (Levy, 2000, p. 43).

[Author's comment: The historic Apollo 11 lunar landing would take place in July 1969, only 17 years after Shoemaker's initial visit to Meteor Crater. Gene could never have dreamed, while standing on the rim of Meteor Crater that summer of 1952, that a colleague (and not him) from his own future Branch of Astrogeology in nearby Flagstaff, Arizona—geologist Harrison "Jack" Schmitt—would be the first geologist-astronaut (and only one to date) to explore the lunar surface; and the very last of twelve men to step onto its surface during the Apollo Era in December, 1972 (see 1972 below).]

2.4-1953

[Spaceflight Milestone: On 20 November 1953 Scott Crossfield would become the first human to reach mach 2.0—twice the speed of sound) in the Bell D-558-II skyrocket at NACA's High Speed Flight Research Center at Edwards, California.]

[Spaceflight Milestone: On 12 December 1953, Charles "Chuck Yeager would break Scott Crossfield's short-lived speed record by becoming the first to reach the mach 2.5 (two and a half times the speed of sound) barrier in the Bell X-1A rocket plane at NACA's High Speed Flight Research Center at Edwards, California.]

2.5-1954

David Levy:
"Two years after his first brief visit to Meteor Crater, after he read a paper by geologist Dorsey Hager, Gene's attention turned to it [the crater] again. The new research focused on small structures called evaporites that oil diggers had dug up a few dozen miles east of the crater. Evaporites are the signatures of salt flats (domes), and they led Hager to suggest that the crater was the result of one that had collapsed. Although Gene doubted that theory, he was intrigued by the paper and decided to return to the crater and try to test Grover Karl Gilbert's eventual conclusion from several decades earlier that the crater was the remains of a volcanic steam explosion. Hager sent Gene a sample of pumiceous silica glass that they thought could be either volcanic or melted sandstone. Gene arranged for spectrographic analysis. The result was stunning; the glass was Coconino Sandstone, the same rock that is present in such quantities in the Grand Canyon, but its quartz was fused somehow, the end result of a process that involves temperatures of about fifteen hundred degrees Celsius, some three hundred degrees higher than the hottest lava flow. No, the crater could not be the result of volcanism, nor could the dynamics of a collapsing salt dome explain temperatures as hot as this. Gene began to suspect that the only mechanism that could generate this much heat was the explosive impact of an asteroid from space as it struck the Earth at incredible velocity" (Levy, 2000, pp. 73-74).

2.6-1956

David Levy:
"Despite these tantalizing clues leading him toward Meteor Crater, Gene decided to wait on his crater investigations and return to his uranium search on the Hopi Buttes. It was now 1956, and uranium, the magical source for the nation's fledgling nuclear power industry, was proving far more abundant than expected. The problem for geologists in 1956 was no longer uranium, but plutonium, the element first produced in 1940 by a team led by Glenn Seaborg and which formed the heart of the United States nuclear arms race. About this time Gene ran into Ted Taylor—a physicist (one of Gene's "angels") who was sent to Los Alamos after the war where he completely re-designed the nation's nuclear weapons. Gene was eventually asked to work on the classified project code-named MICE (Megaton Ice-Contained Explosion). If successful, a blanket of uranium wrapped around a nuclear device would produce, in a one-megaton nuclear detonation, a supply of plutonium. To be successful, the test needed to occur in a cavern contained by ice. Since the United States had no sufficiently large bodies of ice under its control to work with, the search began for an alternative, in fairly pure bodies of salt. The question Gene needed to explore involved the nature of the underground nuclear blast; would it lead to a surface eruption, a modern remake of the ancient volcanoes of the Hopi Buttes" (Levy, 2000, p. 74)?

When Gene was asked to work on the MICE Project, he said yes because he thought it would teach him something about shock waves and shock processes—related to impact craters.

David Levy:
"In the course of his study [MICE], Gene visited the artificial craters called Jangle-U and Teapot-Ess [on the Nevada Test Site]. The result of a small, 1.2-kiloton nuclear explosion, Jangle U was formed instantly near the end of 1951 and a similar explosion in the early spring of 1955 carved Teapot Ess. These craters are about one hundred meters across. Gene noticed that rocks that had been melted by shock forces were spread out along the floors of these craters, suggesting that whatever plutonium would be produced in a megaton explosion would not be easily accessible on the floor of the explosion cavity but would be dispersed through the broken rock.

But Gene noticed something in those two craters that interested him far more than plutonium—an uncanny resemblance to form and structure of Meteor Crater on Coon Butte. Comparing the kiloton of energy that went into carving out each of these natural craters led him to the near certainty that the Arizona crater was created almost instantaneously, by an impact. "I was astonished to discover that the structure of Meteor Crater was pretty much a scaled-up version of that of Teapot Ess," he remembered. The impact would have been enough to disintegrate the main body of the iron mass that fell there, leaving only a few tons of Canyon Diablo iron meteorite scattered across the landscape. These remaining pieces would have survived by breaking away from the main body seconds before impact. In one intuitive leap, Gene realized why there was so little meteorite left for Barringer to mine, and similarly why MICE wouldn't work to produce a supply of plutonium—it would be widely dispersed and essentially not gatherable. For Gene, the failure of Project MICE translated into a golden key that he would later use to unlock the door to a new science.

If the crater were really the result of some "small star" as Grove Karl Gilbert had put it almost a century ago, what kind of celestial body would have been responsible" (Levy, 2000, pp. 74-75)?

The larger an impacting object might be the rarer is its chance to strike the Earth. In the 1950's the only place where the results of such a hit could be found, possibly, was at Meteor Crater. Gene set out to find the evidence that the crater was indeed of impact origin.

David Levy:
"To intensify his search for evidence, Gene clearly needed more information in the form of other examples. Happily, Earth's nearest neighbor in space and the subject of Gene's growing dream, the Moon, has a large supply of craters. Since erosion on the Moon is negligible compared with that on Earth, once a crater is formed there from whatever cause, it lasts virtually forever. To answer his questions, Gene needed to study the Moon, and in 1956 he spoke with the Geological Survey director, Thomas Nolan, about the possibility of launching a photographic study of the Moon in order to produce the first geologic map ever made of a body other than the Earth. Thus, Nolan became the second person after Carolyn to hear the details of Gene's dream to visit the Moon. Nolan didn't laugh. Instead, he steered the young geologist to those who had already thought of lunar topography" (Levy, 2000, pp. 75-76).

During his meeting with Nolan in 1956, Tom sent Gene to talk with the visionary geologist William Rubey down the hall. Gene realized that this was far-seeing on Nolan and Rubey's part.

Don Wilhelms:
"William Walden Rubey (1898-1974), who contributed in major ways to a number of important geologic topics, kept up with developments in lunar exploration and served on a number of committees, including the Planetary Subcommittee of the Space Science Steering Committee (OSSA). He was also the first (temporary) director of the Lunar Science Institute in Houston. Rubey did not laugh [at Gene] either, and he checked whether anyone else in the Survey was doing lunar work. No one was" (Wilhelms, 1993, pp. 22, 373).

David Levy:
"He [Gene Shoemaker] soon learned that while a topographic map of the Moon had been thought of, a map that emphasized the remote world's geological structures had not. But this part of the Shoemaker dream would bide its time" (Levy, 2000, p. 76).

2.7-1957

David Levy:
"In 1957 Gene's professional time was pretty much consumed by his work on MICE. Besides, the spring and summer of 1957 was not the time to talk about mapping the Moon" (Levy, 2000, p. 76).

[Space Exploration Milestone: On 4 October 1957 the Soviet Sputnik 1 was launched to become the first artificial satellite of the Earth. Sputnik 1 was followed the next month (3 November) by Sputnik 2 carrying the dog Laika as a passenger.]

David Levy:
"October 4, 1957: In the cold light of dawn on a steppe deep in the Soviet Union, a rocket ignited and quickly built up thrust. As hold down clamps fell away, the rocket surged off its launch pad. Slowly at first, then picking up speed, the missile soared into the sky, carrying with it the first artificial moon ever placed into orbit around the Earth. Sputnik, or "Fellow Traveler", caught the imagination of the world and inspired the dread of defense planners throughout the free world. Ostensibly, a Soviet contribution to a worldwide research program called the International Geophysical Year; Sputnik clearly raised the stakes in the Cold War to a startling new level. Questions were raised at once. Were the Soviet scientists so far ahead of their American counterparts that the United States could not be competitive on the stage of space? Worse, was the Soviet Union planning a space platform from which to launch a nuclear attack on the United States?

As the world convulsed under this news, Gene returned from a MICE progress meeting back to camp in the Hopi Buttes and heard the news on a portable radio. Oh hell, he thought as he prepared to rejoin his camp in the middle of the lonely buttes, I'm not ready for that yet! With Sputnik, American space policy changed radically. Instead of no satellite program, there was a frantic race to get the first satellite launched" (Levy, 2000, pp. 77-78).

2.8-1958

[Space Exploration Milestones: On January 31, 1958, Explorer-I became the first U.S. satellite in orbit. It carries a scientific experiment of James A. Van Allen that discovers the Earth's radiation belt. This is followed on 17 March 1958 with the successful launch and orbiting of Vanguard 1 that transmitted signals for three years.]

David Levy:
"In 1958, under the guidance of Senator Lyndon Johnson, the National Aeronautics and Space Administration (NASA) was born. As Gene continued his MICE work, he began to think that a Moon program might come sooner than he had expected. In meetings with the USGS senior staff he talked up the Moon, trying to arouse interest, but despite the rapidly developing space program the tradition-based Survey was loath to take the Moon seriously. But Gene did. His evolving interest was a turn away from his original thesis subject about the Colorado-Utah border salt structure, and it led to an uncomfortable situation back at Princeton, where time was running out for him to complete whatever dissertation he had in mind. As 1957 turned to 1958, Princeton's geology department noted in frequent reminders to Gene that his thesis was overdue. Gene had the best of intentions to write his thesis, but the demands of the Geological Survey and his own expanding interests kept him from finishing it promptly" (Levy, 2000, p. 78).

"In the late 1950's, as Princeton's time limit was drawing close he gave a colloquium about his work on Meteor Crater. In the audience was his friend and thesis advisor, Harry Hess. "That was a good presentation," he told Gene. "It would even be a good subject for a thesis!" The possibility of switching his topic was tantalizing, and Hess worried that Gene's varied interests might mean he'd never finish a thesis on anything. Gene thought he'd better take the hint and get to work. He decided to work on the crater intensely, and in the summer of 1959, submitted his Meteor Crater research to Princeton's Department of Geology" (Levy, 2000, p. 78-79).

Don Wilhelms:
"It was indeed the Survey that introduced and nurtured the modern form of lunar geologic mapping, and Shoemaker who, eventually, sold the technique to NASA and other lunar scientists. In mid-1958 the USGS uranium project was closed down abruptly by the discovery of an overwhelming abundance of the stuff at Grants, New Mexico, creating one of the Survey's recurring shortages of money and surpluses of geologists and occasioning Shoemaker's move to the USGS Pacific Coast Regional Center at Menlo Park, California. The lunar project might be one small way to help alleviate the money and personnel problems. Assistant Chief Geologist Montis Klepper inquired in late 1958 at the Survey headquarters in Washington about who might be interested in lunar work, and shortly afterward pursued the matter during a visit with Shoemaker in Menlo Park. Shoemaker drew up a research plan, but it was consigned to the back burner for a year" (Wilhelms, 1993, pp. 37-38).

[Space Exploration Milestone: Sputnik 3 was launched by the USSR on 15 May 1958.]

[Space Exploration Milestone: NASA is founded, taking over the existing National Advisory Committee on Aeronautics, NACA.]

2.9-1959

[Space Exploration Milestone: Luna-1, the first man-made satellite to orbit the Sun is successfully launched by the Soviet Union on 2 Jan 1959.]

[Space Exploration Milestone: Pioneer 4, the fourth U.S. IGY space probe, is launched on 3 March 1959. It achieves an Earth-Moon trajectory, passing within 37,000 miles of the Moon. Then, it falls into a solar orbit, becoming the first U.S. Sun-orbiter.]

2.9.1-The First U.S. Geological Survey Lunar-Mapping Effort Comes From Within the Military Geology and Photogeology Branches.

Don Wilhelms:
"The meticulous [Arnold Caverly] Mason [1906-1961] plunged into a study of the Moon both on his own time and in his official position as a geologist with the Military Geology Branch of the Survey, whose chief, Frank C. Whitmore Jr., also caught the Moon bug. Whitmore brought in Gerard Kuiper as a consultant and obtained a commercial package of lunar photographs and maps costing a few dollars as initial raw material. It was Mason who conceived of conducting a terrain analysis of the Moon. Mason sought help from the chief of the Photogeology Branch of the Survey, William A. Fischer. Fischer made available his branch's modern stereoplotters and assigned Robert Joseph Hackman (1923-1980) and Annabel Brown Olsen (1922-1992) to the project.

The Survey obtained funds from the U.S. Army Corps of Engineers, who had a long-standing working relation with Military Geology and mutual interest in such matters as terrain analysis and trafficability. Mason and Hackman put the project on the front burner and worked with the Army Map Service (AMS) in preparing the base map. The resulting Engineer Special Study of the Surface of the Moon was first printed in July 1960, although it bears the publication date 1961. It contains four sheets: one detailed text by Mason and three maps at a scale of 1:3,800,000 by Hackman, assisted by Olsen.

One map shows crater rays. Another is a physiographic classification of the surface. The third map is called a "generalized photogeologic map" and shows only three units: "pre-maria rocks, maria rocks, and post-maria rocks." Nevertheless, it deserves credit as the first modern lunar geologic map based on stratigraphic principles. Despite its apparent simplicity, it was an enormous advance over portrayals of the lunar crust merely as a series of structural lines. It shows that the cratered uplands formed first, then the maria, and then a few more craters; something obvious to today's lunar geologists but not to those who followed Spurr and thought of each "lineament" or hill as an independent entity that might have formed at any time in lunar history by any imaginable internal process.

At first, Hackman in fact toyed with the Spurr concept, and the map does feature swarms of straight lines interpreted as faults, which very few of them are. Olsen remembered suggesting to him (Hackman) that the Moon could be better understood in impact terms, although she did not remember whether or not she got the idea from advisors Kuiper, Dietz, or Shoemaker—impacters all. Hackman and Mason ultimately accepted the impact origin of most craters and went as far as to state that “formation by meteoritic impact is (more) commonly accepted” than volcanism. They also correctly interpreted the maria as volcanic lavas; but the old mistake persists: they thought the lavas were released by impacts that formed the surrounding ring mountains” (Wilhelms, 1993, pp. 38-39).

Don Wilhelms concludes his above commentary about the “first” USGS lunar mapping activities with the suggestion that:

“Arnold Mason, Robert Hackman, and Annabel Olsen deserve much credit; unfortunately posthumous in all three cases, for their truly innovative contributions.

Shoemaker was far from idle while Hackman and Mason were stealing the march in geologic mapping [of the Moon]. Few individual scientists have contributed so much of fundamental importance as Eugene Shoemaker did in 1959 and 1960. He had been unlocking the secrets of Meteor Crater since 1957, and in 1959 was ready to report his results” (Wilhelms, 1993, p. 40).

David Levy:
“Half a century after Daniel Barringer first started digging there Meteor Crater was finally coaxed into revealing her secrets. The fieldwork on the Hopi Buttes Gene enjoyed so much was being replaced first with fieldwork around Meteor Crater, and later with a different kind of field study altogether—the close inspection of old photographs of the Moon. The days and weeks in the field with Carolyn and their young children were coming to an end” (Levy, 2000, p. 81).

“With the disbanding of Project MICE in 1958, Gene and Carolyn joined the Survey’s Menlo Park center on California’s San Francisco peninsula. Here, Gene worked with a group of people interested in exploring the Moon and planets, and after a colloquium in early 1959, he began drawing a rough lunar geologic map to demonstrate that one could solve the stratigraphy of rocks exposed on the lunar surface” (Levy, 2000, p. 85).

“Gene’s Menlo Park colleagues thought of Gene’s Moon ideas as a joke at that time. He was the butt of many skits during the famous Menlo Park “Pick and Hammer” shows. In one such skit they named Gene “Bean Moon Shaker.” Gene recalled that he was not high on the totem pole at that time. In fact, Gene said, someone in Menlo Park strongly reminded him of that fact” (from a filmed interview with Gene Shoemaker by Harry Ryan—April 27, 1997).

[Spaceflight Milestone: On 12 September 1959, the Soviet Union launched Luna-2, impacting the Moon on 13 September carrying a copy of the Soviet Coat of Arms, and becoming the first man-made object to hit the Moon. The next month (4 October 1959) the U.S.S.R. again outpaced NASA with the launch of the Luna-3 trans-lunar spacecraft. It orbited the Moon and photographed 70 percent of its far side. Although these latest Soviet feats in space further embarrassed the fledgling NASA, they also acted to intensify NASA’s resolve.]

Don Wilhelms:
“The months following the [Soviet] Lunar flights [late 1959] were also when the mainstream mapping program for lunar exploration began at the U.S. Air Force Chart and Information Center (ACIC) in St. Louis, under the direction of Robert W. Carder. Someone at ACIC suggested that

the best way of portraying the lunar surface with both qualitative fidelity and topographic accuracy was the artistic technique of airbrushing. Keeping her efforts secret from the [rival] Army Map Service (AMS), Patricia Marie Mitchell Bridges (b. 1933) (see Appendices A and B) then quickly prepared the prototype of the chart series that would become basic to the lunar program, the 1:1,000,000-scale lunar astronautical charts (LAC*).* The focus of this first LAC chart was the large and pristine crater Copernicus. The publication of this chart in February 1960 launched ACIC's systematic productions of LACs" (Wilhelms, 1993, p. 37) (see 1960 below**).**

Pat Bridges:
"The first map [the Copernicus region of the Moon] that I did [for ACIC in St. Louis] they wanted me to keep quiet about because there was competition among some of the mapping agencies [mainly the U.S. Army Map Service] (Fig. 4). So, they had me doing some drawings hiding under some stairs [at ACIC in St. Louis] with the door closed because they didn't want it known that there was that kind of work going on in our group. I know that we were competing with the U.S. Army for the projects—and I don't know whom else. Then ACIC started talking about going someplace to do lunar observations using a telescope, and they were casting around for places to go.

[Author's Note: Pat Bridges could not know at that time that she had unwittingly earned herself a permanent place in the history of early lunar exploration by using her cartographic and artistic airbrushing talents to "secretly" draw the very LAC of the Moon (Copernicus region) while working for the Air Force Aeronautics and Chart Center (ACIC) in St. Louis (see 1960 below for more details).]

Don Wilhelms:
"In the summer of 1959, Shoemaker (who already had one Master's degree from Caltech and one from Princeton) sent a long version of his Meteor Crater study to Princeton Geology Department chairman Harry H. Hess (1906-1969) [as his Doctorate dissertation]. He also needed a manuscript for the quadrennial meeting of the International Geologic Congress that was coming up in the summer of 1960 in Copenhagen, and sent off a short version of the study for that purpose" (Wilhelms, 1993, p. 41).

2.10-1960

About this time, interest in the Moon and Gene Shoemaker's proposals for an organized lunar geologic exploration program to support the Moon missions took a giant leap forward. On 24 February 1960 Gene Shoemaker presented his impact interpretation of Meteor crater (Arizona) and lunar craters before a mesmerized crowd at the famous Cosmos Club in Washington, D.C. Gene Shoemaker was always a very effective and passionate speaker who could captivate an audience for an hour or more while talking to only a single presentation slide.

Don Wilhelms:
"John A. O'Keefe (astronomer and geodesist) [who attended Shoemaker's lecture at the Cosmos Club] was fascinated by Gene's impact interpretation of Meteor Crater and lunar craters because impacts were the means (he thought) of throwing "*tektites*" from the Moon to the Earth" (Wilhelms, 1993, p. 44)

[Author's Note: Tektites are small, rounded and pitted, aerodynamically-shaped, black to olive-greenish or yellowish silicon glass bodies believed to be of extraterrestrial origin (e.g., gravity-escaping, shock-melted ejecta following large lunar impact event.]

[Author's Note: John A. O'Keefe (b. 1916) was hired by NASA Administrator, Homer Newell at the end of November 1958 from the U.S. Army Corps of Engineers. At that time Newell had recently transferred to NASA to assume responsibility for the new agency's Space Science Program. In a truly ironic twist of fate, it was later learned (following the analyses of rocks collected by Neil Armstrong and Buzz Aldrin during Apollo 11) that the isotopic chemistry is wrong for the tektites to have come from the Moon. They were subsequently shown to come from terrestrial, not lunar, impacts.]

Don Wilhelms:
"O'Keefe and Lorin R. Stieff [an old friend and supporter of Shoemakers from the Colorado Plateau uranium days] visited William Henderson at the Smithsonian and the three agreed that the Survey [USGS] should make a study of lunar geology that would include *tektites*. Stieff, on the scene in Washington while Shoemaker remained in Menlo Park, walked the proposals through both the USGS and NASA. O'Keefe did his best to promote the proposals at NASA; however, they encountered a stubborn obstacle there. [Harold] Urey was upset because he wanted the study to go to his institution, the University of California at San Diego.

This proposal went forward along with a separate one for geologic mapping and crater investigations prepared by Shoemaker. NASA would put up the money the first year, including some with which the Smithsonian could buy the tektites for distribution. After that, the money would come directly from Congress via the USGS because Steiff feared that NASA would let down the Survey as the Atomic Energy Commission had done when it suddenly cut off funds for the uranium project [in 1958]" (Wilhelms, 1993, p. 44).

David Levy:
"At the Eighth Lunar and Planetary Exploration Colloquium, held in Downey, California, on 17 March 1960, Gene presented the results of his work on Copernicus at the Eighth Lunar and Planetary Exploration Colloquium held in Downey, California, on 17 March 1960. He demonstrated how an ejecta blanket (a covering of material thrown out during the later stages of evacuation after an impact and lying on top of much older blankets and other geologic structures) could provide clues to the relative ages of the craters. These blankets consist of lunar material hurled up and landing again, forming secondary craters that could also help establish the sequence of events during an impact. He suggested that small satellite craters, near the main site, were the results of ejecta hurled out from the formation of Copernicus. These secondary-impact craters, or secondaries, could easily be explained if Copernicus was the result of an impact" (Levy, 2000, pp. 85-86).

Don Wilhelms:
"The Copernicus study soon led Shoemaker in yet another direction. In early 1960 the USGS proposal was still on the back burner and Shoemaker was entertaining two job offers in case the USGS program did not materialize.

One offer was from RAND, whose personnel had seen him in action at the colloquia. The other was from JPL, which he visited, partly to check on the job offer and also at [John] O'Keefe's suggestion. He was astonished to see a copy of the ACIC prototype LAC [Lunar Aeronautical Chart] of the Copernicus region by Pat Bridges[3] lying on a table in the trailer office of his former Caltech classmate Manfred Eimer, assistant chief to Albert Hibbs of JPL's Space Science Division. Robert Carder at ACIC had also turned to JPL in the effort to get a mapping program started. Shoemaker was already studying the Copernicus region intensively with a superb photograph (he had purchased at the Caltech bookstore) that Francis Pease had taken with the 100-inch Mount Wilson reflector on 15 September 1919. Thus, he had the makings of a geologic map; he also had already thought of what he would show on such a map if he were to make one" (Wilhelms, 1993, p. 41-42).

Pat Bridges:
"I made my first trip [from ACIC, St. Louis] to Flagstaff in October 1960. [Bill Cannell from ACIC was also with her in that trip to Flagstaff at that time]. They [ACIC management] were talking to various observatories, but they were close to settling on Flagstaff to set up their ACIC lunar mapping group.

I did a little bit of telescopic viewing and drawing while I was there in Flagstaff. Bill managed to round up an air tank for me, and I did some drawing using the air tank and my airbrush in a room at the Monte Vista hotel downtown. We stayed only a couple of days at the Monte Vista hotel" (From an interview with Pat Bridges by Gerald G. Schaber on 12 April 2001) (Fig. 5).

Don Wilhelms:
"Now was the time. He [Gene] went back to Menlo Park, had a copy of the [Bridges] LAC base [of the crater Copernicus] made, set to work, and a week later had completed the second modern lunar geologic map. There were map units for parts of craters, the maria, the mare domes, and a regional terra-blanketing unit, all of which were arranged in order of age into seven classes packaged into five named age units: the Copernican, Eratosthenian, Procellarian, Imbrium, and Pre-Imbrium systems. Shoemaker sent a hand-colored copy to Eimer and then traveled to St. Louis, where Carder enthusiastically cooperated in printing a trial run of the geologic map in color on the LAC base. Hackman later added some lineaments and the map was ready to show at the International Geologic Congress [in Copenhagen]. Though not the last word, the map marked the birth of the systematic lunar-geologic mapping program that was carried out by the USGS for the next two decades and that continues today in the form of the more general form of planetary mapping" (Wilhelms, 1993, pp. 41-42).

Don Wilhelms:
"In 1960 the Survey still had too little money and too many geologists, whereas the reverse seemed to be true in NASA. In late 1959 or early 1960 Shoemaker had suggested to the Survey's new chief geologist Charles Anderson that the proposal for a small USGS lunar program be dusted off. In early 1960 Anderson turned the matter over to Survey geologist-

[3] Patricia "Pat" Bridges would later follow the ACIC to Flagstaff, Arizona (at Lowell Observatory), and subsequently join the USGS Branch of Astrogeology headquarters in Flagstaff in 1970 (see 1970 in main text). She would contribute her remarkable airbrushing talents and (along with colleague Jay Inge), author numerous lunar and planetary basemaps for many years.

geochemist Lorin Rollins Stieff (b. 1920), who predated even Shoemaker in the USGS uranium project on the Colorado Plateau, and who became his close friend and antiestablishment scientific ally. (Stieff's wife, Harriet, remembers asking Shoemaker in those early days where he wanted to be in 20 years, and receiving the reply "up there!" as Gene jabbed a finger at the Moon.) Anderson hoped to get NASA funding for a geochemical study that would benefit the Survey's well-staffed, but under funded, analytical laboratories (Wilhelms, 1993, p. 43). [Author's Note: Lorin R. Steiff is presently with Rad Elec Inc. in Fredrick Maryland]

Don Wilhelms:
"At this juncture, came along one of those confluences of events and people that reroute history. In 1953 Loring Coes had squeezed quartz in a hydraulic press and created a new mineral, Coesite, with a higher density than quartz. The key to its existence was extreme pressure. In 1956, Nininger had suggested that a search for coesite in the quartz-rich Coconino Sandstone at Meteor Crater "might have significant results." Shock waves were not only a good way, but probably the only way to produce natural coesite at the Earth's surface. Though Steiff did not know of this prediction and Shoemaker had forgotten it, Steiff and O'Keefe obtained some Meteor Crater samples from the Smithsonian just to get studies of moonlike materials started (Wilhelms, 1993, p. 44).

Now there appeared on the scene the third founding father of the USGS lunar program, along with Shoemaker and Steiff, Edward Ching-Te Chao, then of the USGS Geochemistry and Petrology Branch. In May 1960 he was assigned his first Survey project of his own: tektites. A week later O'Keefe gave him one of the pieces of Coconino Sandstone from the Smithsonian and asked him to find out whether glassy material in it had any connection with Tektite glass. Chao crushed part of this already small sample, immersed it in special oil, and saw some grains with an unusually high index of refraction. He immediately X-rayed a powdered sample and obtained patterns that matched those of artificial coesite. He still had not seen a tektite or heard of Gene Shoemaker. His Branch Chief, William Pecora, later a USGS chief geologist (1964-1965) and director (1965-1971), did not trust the finding and asked others to verify it. Steiff told O'Keefe about Chao's discovery, and O'Keefe told Urey in a letter dated 14 June, 1960 (pointing out that the shock overpressures were also a way of creating diamonds found in the nearby Canyon Diablo meteorites, which had always interested Urey). When Pecora was convinced that Chao was right, they held a press conference (20 June) to announce the momentous discovery that would prove the meteoritic impact origin of many terrestrial craters, and Chao authored a paper for "*Science*" [Magazine] reporting it. Chao then visited Shoemaker in Menlo Park, and showed X-ray technician Beth Madsden how to identify coesite. Because the Survey's proposal was stalled, Pecora got Shoemaker and Madsden added as authors of the "*Science*" paper to show that the Survey had a complete team for performing lunar investigations. Although Shoemaker deciphered the geology of Meteor Crater, it is fair to say that it was Chao who set the modern study of impact-shock mineralogy into motion" (Wilhelms, 1993, pp. 44-45) (Fig. 6).

"But the [U.S. Geological] Survey proposal remained stalled. The next act in the drama came in the month the "*Science*" paper appeared, July 1960. Shoemaker was on his way to Copenhagen for the [International Geologic] congress and stopped en route for some geologic sightseeing. This is when he saw the type locality of the explosive volcanic maar craters, whose German or Rhinelander name is derived from some small craters in the Eifel District west of the Rhine.

Even before the coesite discovery, he had figured out from the literature that the Rieskessel surrounding Nördlingen, Bavaria was in no way a caldera or cryptovolcanic feature as was the general assumption, but an impact crater as had been proposed by German investigators as early as 1904, and re-proposed by Baldwin in 1949 and Dietz in 1959. He [Gene] had done his homework as usual, and on arriving at the Ries one evening in July, made a beeline for a quarry (Otting) where he knew he could find the bomb-like, partly glassy material called suevite. He had prepared himself to seize still another opportunity and was the first person to realize what the suevite probably was target rock that had been highly shocked and partly melted by the impact that dug the Ries. Suevite contains silica, so it should also contain coesite. The next day he viewed what are really the best exposures of suevite—the walls of the main church [cathedral] in Nördlingen (St. George's), which are made of rock quarried from the Ries—and mailed seven samples from the quarry to Chao" (Wilhelms, 1993, p. 45).

"As the cliché goes, the rest is history. One of the samples contained enough coesite to be identified. Shoemaker added the result to his Meteor Crater presentation at the congress [in Copenhagen] and Chao wrote the reporting journal paper. The Ries moved decisively from the cryptovolcanic to the impact camp. O'Keefe was vindicated, the NASA obstacle was overcome, and the USGS got its first NASA funding of $200,000" (Wilhelms, 1993, p. 45-46).

2.10.1-A Small Astrogeologic Studies Unit is Set Up within the U.S. Geological Survey in Menlo Park, California

[<u>Astrogeology Milestone</u>: "NASA's money funded [Ed] Chao and five other geochemists in Washington and an equally small Astrogeologic Studies Unit at the USGS center in Menlo Park. The unit began officially on 25 August 1960" (Wilhelms, 1993, p. 46.]

Geologist Elliot Morris (b. 1926-2005) was working with the USGS' Alaskan Geology Branch (Menlo Park, California) between 1960 through 1961 as a WAE (<u>W</u>hen <u>A</u>ctually <u>E</u>mployed) employee while still working on his PhD in geology from Stanford (see Appendices A and B). Elliot, who had become acquainted and interested at that time in what Gene Shoemaker was doing in lunar research, began doing things for Shoemaker, like going with geologist/photographer Hal Stephens [see Appendices A and B] down to Mt. Wilson (near Los Angeles) and copying the best of the extremely high-resolution telescopic plates of the Moon taken early in the Twentieth Century.

[<u>Author's Note</u>: Upon receiving his PhD degree from Stanford in 1962, Elliot Morris formally joined Shoemaker's small—but growing—Astrogeology Studies Unit in Menlo Park; and in December 1963 he would be asked by Shoemaker to move to Flagstaff to lead the effort to design and built a telescope in Flagstaff that the Branch's geologists could use to map the geology of the Moon. See 1962 and 1963.]

Don Wilhelms:
"Although the technique of photogeology led off the new effort, Shoemaker rejected the term as a name for the [Astrogeologic Studies] unit because he wanted to focus on the basic methods of geology. He knew that photogeology as practiced then would have little value without support from terrestrial studies, non-visual remote sensing, and, ultimately, fieldwork and sample

collection on the Moon itself. Hence astrogeology was chosen, even though it agitated speakers of English because stars have no geology (Wilhelms, 1993, p. 46).

"One of Shoemaker's hopes was dashed soon after the Survey's lunar proposal was funded. He had considered Lorin Steiff a likely future chief of the Astrogeology Branch when he (Shoemaker) went off to become an astronaut. Instead, Steiff left the Survey to embark on a career that he hoped would contribute to arms control.

The Astrogeologic Studies Unit embarked on three main tasks that built on the history of its funding. One, of course, was the study of tektites. The tektite study occupied half of the group's first semi-annual report and continued vigorously for another decade, but eventually faded away when Surveyors and Apollo found out what the Moon is made of. The second project was geologic mapping, based on the now-confluent efforts of Hackman and Shoemaker. Hackman incurred Shoemaker's displeasure by refusing to move from Washington to Menlo Park, or later, to Flagstaff. Nevertheless, he added to his "firsts" by completing the first published (1962) geologic map at the LAC scale of 1:1,000,000, that of the Kepler region (LAC 57). The first and second Astrogeology semiannual reports contained pre-publication versions of the Kepler map, in which form I [Don Wilhelms] studied it with fascination during my last year at UCLA, 1962 (see 1963). Inquiries in Washington starting at the end of 1958 had smoked out several other mappers. One was photogeologist Charles Harding Marshall (b. 1916), who was now assigned [Fall of 1960] to Astrogeology by the Photogeology Branch, and who prepared a study of mare-material thickness in his assigned LAC quadrangle (LAC 75, Letronne) (Wilhelms, 1993, pp. 46-47).

Geologist Henry John Moore II (1928-1998, PhD, 1965, Stanford University) was one of the very first geologists to arrive in Menlo Park to work with Gene Shoemaker's fledgling Astrogeologic Studies group in September 1960 (see Appendices A and B). Henry actively participated in lunar geologic mapping, Apollo landing site selection, and geologic field training of the astronauts prior to and during the Apollo Era. He was also a Principal Investigator and Co-Investigator on several important Apollo investigations that analyzed the remote sensing data returned from the Moon by the later Apollo missions.

[Author's Note: Henry Moore would, in the post-Apollo Era, further distinguish himself as a widely-respected scientist by becoming the top expert on physical properties investigations carried out on the Viking-Mars Lander in the summer of 1976. Henry retired from the USGS in 1994, but was called on again by NASA to help select the landing site for the Mars-Pathfinder Rover (1997) and to help analyze the pictures returned by that vehicle from the Martian surface.]

Don Wilhelms:
"Another recruit [for the Astrogeologic Studies Unit] was Richard Elton Eggleton, who came from the Engineering Geology Branch (he had mapped the site of the present Dulles Airport [in Herndon, VA] and was among the most enthusiastic and perceptive of the early mappers (see Appendices A and B). He had already written down his ideas about lunar exploration at the time of Sputnik. He arrived in Menlo Park in October 1960, shortly after Charles H. Marshall and Henry John Moore II (1928-1998), Shoemaker's former field assistant in the uranium project who Shoemaker had hired in September" (Wilhelms, 1993, pp. 47).

[Author's Note: Dick Eggleton's unique experience on the Survey's Stratigraphic Names Committee would later prove to be extremely useful when he became a major player in the Branch of Astrogeology's geologic mapping of the Moon... Eggleton worked closely with Gene Shoemaker, Don Wilhelms, and others in establishing the stratigraphic names that would be used on the Moon.]

Don Wilhelms:
"Another landmark paper, written by Shoemaker and edited by Eggleton as his first task in the Astrogeologic Studies Unit [in Menlo Park in October 1960], was a spin-off of the Copernicus [crater] study. This short but important paper appeared in the first semiannual progress report under the auspices and fully justified title: "Stratigraphic Basis for Lunar Time Scale." In December of that creative and intense year Shoemaker presented the paper at Symposium 14 of the International Astronomical Union at the Pulkovo Observatory near Leningrad (5-11 December 1960), and both it and the Ries coesite discovery were reported in New York (27-30 December). Twelve pages long in its final published form in the symposium volume, this paper laid the foundation for all subsequent studies of the crusts of the Moon and planets based on historical concepts. It shows how the geologic units of the Moon's crust can be recognized, ranked in stratigraphic sequence, and pigeon-holed in systems by methods that are the same, in principle, as those applied to Earth's rocks. The concept of systems and time-stratigraphic units of other ranks (series, stages) is a convenient and powerful way of organizing the many observations about relative age that are made during a geologic study. Once you have decided what system a rock belongs to, you have also shown which ones it does not belong to, and you are well on the way to placing it in its historical content" (Wilhelms, 1993, p. 47.)

David Levy:
"Gene proceeded with his fieldwork in much the same way as he had out on the Colorado Plateau. He couldn't do the fieldwork [on the Moon] himself—not yet at least—with hands, feet, geologist's hammer, compass, and pacer, but he could vicariously with his eyes. Some forty years earlier, on exceptionally steady nights when the 100-inch Hooker telescope at California's Mt. Wilson Observatory was new, Francis G. Pease had taken such high quality photographs of the Moon that they picked up craters as small as one kilometer in diameter. Shoemaker had enlargements made of the region around the crater Copernicus, a hundred-kilometer wide feature that he thought resulted from the impact of an ancient comet impact. From these photographs, his team made the first geologic map of a lunar feature" (Levy, 2000, p. 85).

"When Gene and Carolyn moved to Menlo Park, he was set on two goals. One was to start a new science by founding a Survey branch of astrogeology, and the other was to put that new science into the nation's space program. While just a few years earlier, studying geology on the Moon was looked on almost as a crackpot idea, in the face of the developing space race, it was now taken quite seriously" (Levy, 2000, p. 86).

"Perhaps most exciting for him, Carolyn Shoemaker wrote about Gene at the end of 1960, has been the formation of an Astrogeologic Studies Unit within the Survey—involved with its administration, he [Gene] was busier than ever with moon studies. This led Carolyn to think that "lunatic" is a most appropriate name in this case" (Levy, 2000, p. 86).

Don Beattie:
"The origin and age of the Moon had intrigued astronomers and Earth scientists for many centuries, with theories proposed based on a minimum of hard data. By the early 1960s existing theories had become more sophisticated, supported by ever increasing observational data, and soon, by returns from several of NASA's unmanned programs. Three theories on the Moon's origin held sway: (1) the Moon and the Earth formed more or less simultaneously from the same primordial cloud of debris surrounding the Sun; (2) the Moon had been separated from the Earth either through tidal movements or by the impact of another body (some would split this into two theories); and (3) the Moon had been captured by the Earth's gravitational field in an early close encounter. Based on the information then available, each of these theories could be supported or argued against depending on one's point of view and which data was considered most critical. The date when any of these events took place is conjectural, but it was generally believed that the Moon had become Earth's companion early in the formation of the Solar System, some 4.5 to 5 billion years ago" (Beattie, 2001, p. 14).

[Authors comment: Donald A. Beattie (referenced to immediately above) would become one of the Geological Survey's best friends and supporters at NASA Headquarters. Starting with its first funding transfers to the USGS in 1961, NASA Headquarters (mostly Beattie's office) would eventually transfer over $30 million dollars to the USGS at Flagstaff and Menlo Park for Apollo support and related Apollo research tasks alone! Beattie's book, "*Taking Science to the Moon—Lunar Experiments and the Apollo Program*" is an excellent source of information on NASA Headquarters views and support of the USGS, especially the Branch of Surface Planetary Exploration housed in Flagstaff during Project Apollo].

[Astrogeology Milestone: "Gene [Shoemaker] was asked in 1960 by Gerard Kuiper and Harold Urey (two of the most knowledgeable people about the Moon at that time) to be part of the Project Ranger television team. [The last Ranger launch would not come until 21 March 1965 after many delays due to failures—see below)]. He would also become very interested in Surveyor and Lunar Orbiter, the two unmanned lunar exploration missions that would follow Ranger" (Paraphrased from Levy, 2001, p. 92)].

Gene Shoemaker was awarded the PhD degree from Princeton University in 1960 for his pioneering work at Meteor Crater, Arizona.

[Author's Note: For a better understanding of exactly what was being done at this time with regard to Lunar mapping at the Air Force Aeronautical Chart and Information Center (ACIC) in St. Louis, see the Sunday supplement (Pictures) in the 6 November 1960 issue of the *St. Louis Post-Dispatch* newspaper; specifically the article entitled St. Louis-Made Moon Maps For First U.S. Spaceman.]

2.11-1961

Geologist and cratering expert David J. Roddy (1932-2002) first joined the Astrogeologic Studies Unit of the USGS in early 1961, only a few months after Shoemaker started the Unit in

Menlo Park on 25 August 1960. Dave was Gene Shoemaker's very first Doctorate student at Caltech (see Appendices A and B).

[Author's Note: In September 1967, Roddy moved to Flagstaff to work full time for the Branch of Astrogeology. Roddy served as Project Officer in explosion cratering, ejecta processes, and shock effects, as well as in intelligence studies for the Defense Threat Reduction Agency (DTRA) from 1965 until his untimely death in 2002 as a result of complications from Parkinson's disease. Roddy, like his mentor Gene Shoemaker, was considered an expert in the formation and geology of Meteor Crater, and other impact craters in general. Roddy also served as a Principal Investigator in the U.S. Geological Survey for NASA to investigate impact cratering processes and ejecta formation in the field, in experiments, and in theory and numerical simulations since 1961. David Roddy earned the Barringer Medal in 1994 for exceptional achievement in meteoritics. Dave, who passed away in 2002, will be missed by all of us who were fortunate enough to have known this kind and gentle man who had such a passion and insatiable thirst for knowledge in his chosen field of science, and to which he contributed significantly.]

[Space Exploration Milestone: Coming as a complete surprise and shock to the U.S. Space Program, on 12 April 1961, Vostok 1 is launched by the U.S.S.R. carrying cosmonaut Yuri A. Gagarin, the first man in space. He orbits the earth once.]

Andrew Chaikin:
"Early in the morning of 12 April 1961, [Alan] Shepard's hope of being the first man in space evaporated as the world learned that a twenty-seven-old Russian pilot named Yuri Gagarin had orbited the earth. Shepard fumed that NASA hadn't seized the chance to send him up in March, but there was nothing he could do about it now. Shepard and everyone else connected with Project Mercury were caught up in preparations for the launch. After the May 2 attempt was scrubbed because of the weather, NASA could no longer conceal the pilot's identity. By the time he climbed atop the Redstone on 5 May, the eyes of the nations were on him. So were John Kennedy's. When Shepard flew, the president was already weighing the decision of whether to attempt a Moon program. Shepard's flight put him over the edge. Shepard would always believe that the immense outpouring of pride that greeted his flight made a great impression on Kennedy. If a sub-orbital flight from Florida to Bermuda could so energize the nation, imagine what would happen if America put a man on the Moon (Chaikin, 1994, p. 340).

[Space Exploration Milestone: On 5 May 1961, Mercury Freedom 7 carried Alan B. Shepard, Jr., the first American in space, in a sub-orbital flight.]

Andrew Chaikin:
"By May 25, 1961, less than three weeks after Shepard's triumphant ride down Pennsylvania Avenue, Kennedy had made his decision. That day, as he addressed a joint session of Congress, his closest asides could tell he was nervous by the way he kept playing with the pages of his speech, creasing them, smoothing them. They sensed that Kennedy wasn't sure he was doing the right thing, to ask for such an enormous sum of money for something so audacious. But none of that showed in his voice as he spoke the words that would mark the genesis of Apollo" (Chaikin, 1994, p. 340).

[Spaceflight Milestone: On May 25, 1961 President John F. Kennedy made his famous and incredibly brave speech to a joint session of Congress about committing the nation to landing a man on the Moon in this decade-and returning him safely back to Earth. The President said the following; quote:

"First, I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to Earth. No single space project in this period will be more impressive to mankind, or more important, for the long-range exploration of space; and none will be so difficult or expensive to accomplish. We propose to accelerate the development of the appropriate lunar spacecraft. We propose to develop alternate liquid and solid fuel boosters, much larger than any now being developed, until certain which is superior. We propose additional funds for other engine development and for unmanned explorations—explorations which are particularly important for one purpose which this nation will never overlook; the survival of the man who makes this first daring flight. But in a very real sense, it will not be one man going to the Moon—if we make this judgment affirmatively, it will be an entire nation. For all of us must work to put him there."

Don Wilhelms:
"Shoemaker had long realized that the geologic maps would be needed for selection of scientifically productive and safe exploration sites [on the Moon]. In August 1961 he had performed a three-day helicopter-supported reconnaissance of New Quebec (Chubb, Ungula) Crater in the Canadian Arctic, as an example of how fieldwork might be done during similarly short stays on the Moon. This exploration was included in a 1962 article in *American Scientist*, which he wrote at the request of associate editor A. F. Buddington, as a prototype plan for the next decade. In this generally prescient article Shoemaker predicted that perhaps a thousand scientists and technicians would be required to attack the mysteries of the Moon before the manned landings.

Both reconnaissance maps at small scales and many detailed maps at large scales would be needed. The 1:1,000,000 scale was selected for the reconnaissance because that was the scale ACIC had chosen for its LAC charts. Which areas would be geologically mapped was also determined by which LACs were available [at the time], and this, in turn was dictated by the target zone of the first spacecraft [Ranger and Surveyor]. The first four LACs and geologic maps covered a 960-by-1,200 km rectangle centered on the western equator called the Lansberg region (16º N-16º S, 10º-50º). It had been known at least as early as 1959 that rockets and spacecraft launched from Cape Canaveral would expend less energy in approaching the Lansberg region than any other part of the Moon. Early plans called for Ranger to head for the Lansberg region and for manned landings to follow there, or still farther west" (Wilhelms, 1993, p. 69).

"Shoemaker's geologic map of the Copernicus quadrangle described in Chapter 2 [of Wilhelms' book, *To a Rocky Moon*] was the first one made in the Lansberg region, followed by Hackmann 1962 (Kepler, LAC 57), Marshall 1963 (Letronne, LAC 75) and Eggleton 1965 (Riphaeus Mountains, LAC 76). This first Copernicus map was never published in color except as an illustration in the November 1963 issue of *Fortune*, whose cover bears Hackman's Kepler map.

A completely new version [of the Copernicus geologic map] was later published by [Jack] Schmitt, [Newell] Trask, and Shoemaker (1967)" (Wilhelms, 1993, p. 385n.64).

Don Wilhelms:
"These four geologic maps included estimates of roughness and other terrain characteristics for each geologic unit. Terrain estimates depended partly on geologic interpretations. Impact-crater ejecta would be rough and lava would be smooth, or at least flat. A favorite phrase in the explanations of the maps, repeated to the point of amusement, was "probably chiefly crushed rocks with large blocks." The map texts were simple statements of mapping principles, stressing the then-novel idea that the surface of the Moon is heterogeneous, another phrase that wore thin despite its verity" (Wilhelms, 1993, p. 70).

"Shoemaker and those who worked for him also labored to estimate terrain characteristics from quantitative measurements of one sort or another. In the early 1960s this required extrapolating from telescopic data to the scale of interest for spacecraft landings. Mostly, it was assumed that if the terrain looked rough at the telescopic scale, it was probably even worse at the human scale; relief was additive. How were we to keep track of what was known and what was guessed? The first published map by Hackman of the Kepler quadrangle [in 1962], introduced a major innovation into lunar geologic mapping. The units on Shoemaker's original Copernicus map and also on early versions of Hackman's Kepler map had such names as "ejecta and breccia." Shoemaker knew from the beginning that this would never do, and the forces of scientific purity indeed rose in a protest that I suspect was partly motivated by the then-common skepticism that the Moon could be mapped geologically at all. He [Gene] thus devoted much effort to editing the explanation for the published version of the Kepler map. Henceforth the unit descriptions of lunar and planetary geologic maps of the USGS had two parts:" characteristics," the objectively observable properties, including coarse topography; and "interpretation," the speculations on origin and inferred terrain properties. When honored, this split has served planetary geology well ever since" (Wilhelms, 1993, pp. 69-70).

[Space Exploration Milestone: On 6 August 1961, Vostok 2 is launched by the U.S.S.R., carrying cosmonaut Gherman Titov, the first day-long Soviet space flight

Don Wilhelms:
"In August 1961 the year-old USGS Astrogeologic Studies Unit in Menlo Park was augmented by geologist Daniel J. Milton (b. 1934), who Shoemaker had hired in June to study shocked rocks (see Appendices A and B). Dan, whose father was a USGS mineralogist, had worked for Shoemaker on the Colorado Plateau way back in 1952. Later in 1961, Milton, Shoemaker and Eggleton toured many of the craters and astroblemes in and near the Mississippi Valley and thereby began what developed into Dan's—and Astrogeology's—study of craters on all continents" (Wilhelms, 1993, pp. 51-52**)**.

Geological engineer/geophysicist Carl H. Roach (b. 1926), first met Gene Shoemaker in Grand Junction, Colorado, at the end of Gene's summer field season in 1952 (see Appendices A and B). The Roach's had been renting Gene's house for the summer. Gene and Carl were both working on the Survey's Colorado Plateau Uranium Project, based out of Grand Junction. Carl Roach was formally brought into the Astrogeologic Studies Group by Gene Shoemaker in August 1961 to research the effect(s) of shockwaves (both nuclear and impact) on geologic materials. Of course, Gene's primary focus for this work would be characterizing and quantifying the shock effects on these materials, as caused by impacting bodies.

2.11.1-The Astrogeologic Studies Unit in Menlo Park, California Upgraded to Full Branch Status by the USGS

[Astrogeology and Spaceflight Milestone: The USGS Astrogeologic Studies Unit in Menlo Park, California was upgraded to Branch status on 18 September 1961. At about the same time, greater Houston was announced as the site for the new NASA Manned Spacecraft Center (MSC), after a successful campaign by Texas Congressman Albert Thomas and Vice President Lyndon Johnson.]

2.11.2-Lunar Terrain Mapping Moves to Flagstaff Courtesy of the U.S. Air Force Chart and Information Center, and Lowell Observatory

Don Wilhelms recalls:
"In that same September 1961, ACIC (The Air Force's Aeronautical Chart and Information Center) acted decisively on another bit of advice from astronomer Gerard Kuiper (University of Arizona, Tucson, Arizona) that would change the way we made lunar charts. He had pointed out that the best telescopic photographs can usefully resolve objects on the lunar surface no smaller than about half a kilometer across, whereas visual observations with a big telescope can fix detail down to about 200 m during moments of sharp "seeing" when Earth's atmosphere briefly stops shimmering.

ACIC was then [about 1959] attracted by the availability of the 24-inch refractor at Lowell Observatory [in Flagstaff, Arizona] which Percival Lowell had investigated (and proliferated) the "canals" of Mars. Pat Bridges [an ACIC cartographer based out of St. Louis at the time; see J. 1960 above] used the telescope once in October 1960; then, in September 1961, she moved permanently to Flagstaff along with observers William D. Cannell and James A. Greenacre. Kuiper's wisdom soon became apparent. The group, led by Cannell, eventually grew to 22 people, including a dozen illustrators-cartographers, before it was disbanded in early 1968 [as a result of the successful Lunar Orbiter missions that mapped the entire lunar surface.] The result was superb airbrush charts which have never been superseded by spacecraft data except in a few places such as the narrow strips over flown by Apollo spacecraft" (Wilhelms, 1993, p. 52).

[Astrogeology Milestone: Gerard Kuiper, Harold Urey and Gene Shoemaker were named by NASA as the Ranger Science Experimenters in October 1961.]

Dick Eggleton:
"I became a co-author on the paper entitled *"Interplanetary Correlations of Geologic Time."* Then I did some editing, calculations, and illustration work for a couple of the other early things that Gene was working on at that time. I was doing some crater counts. We also did a compilation of known and probable impact structures on the Earth. I think that study came out as a gray-literature Summer Study Report in 1961-1962. Gene also had me serve as coordinator

for lunar geologic mapping in 1961. Hal Masursky I believe, took that over temporarily, and probably passed it along quickly to Don Wilhelms

“Besides working on my Riphaeus Quad, we were also doing a comparison of the cratering rates on the Earth and the Moon. I think the sequence in which the maps came out were Hackman on Kepler Quad, and then Marshall on Letronne Quad, and then I think Hackman got out the Apennine Mountain Quad. Shoemaker’s Copernicus map was published as a photograph of the map—probably first in his [Meteor Crater] thesis. There is an overlay for that photograph that maps all of the secondary craters. Gene numbered every damn one of them—about 600 of them with pen and ink. So Shoemaker figured out Meteor Crater. He figured out how to do lunar geologic mapping—he did it in the Copernicus area. Also he was doing studies of cratering mechanics from this Copernicus secondary crater study, and relating it to the cratering mechanics that other people at NASA and Ralph Baldwin had worked up” (from an interview with Dick Eggleton by Gerald G. Schaber on 15 March 2001).

Dick Eggleton, Danny Milton and Gene Shoemaker visited several of Walter Bucher’s so-called crypto-volcanic structures (later proved to be impacts) in the Mississippi valley area in 1961 (and extending through the 1962 GSA in Cincinnati, Ohio-see 1962 below). Another group lead by Ed Chao and some others were also traveling around studying these structures for signs of impact shock. They visited Odessa Crater [N. 31 degrees 45 minutes; W 102 degrees, 29 minutes; 0.168 km, < 0.05 m.y.] and Sierra Madeira structure in Texas [near Ft. Stockton at N. 30 degrees, 36 minutes; W. 102 degrees, 55 minutes; 13 km diameter; <100 m.y.] Gene had been there earlier—perhaps back in 1958—to Sierra Madeira collecting shatter cones. Eggleton recalls that they talked to Glen Izett with the USGS, who had done some mapping at Odessa Crater (only a few hundred meters in diameter). They had thought at the time that it (Odessa) might be a companion to Meteor Crater as the meteorites are pretty similar. Generally, it is of that age. Gene and Dick tried to get Glen to get his map published. Glen has a report in that Cratering Conference. The Atomic Energy Commission (AEC) was partly behind that Cratering Conference in which Gene and Dick Eggleton released the global survey of terrestrial impacts.

The following was taken from the Branch of Astrogeology Monthly Report for November 1961 to V.E. McKelvey from the Chief, Branch of Astrogeology; dated 30 November 1961:

In November 1961 it was found by Carl Roach (Branch of Astrogeology, Denver) that thermoluminescence may discriminate between shocked and unshocked samples of rock salt from Carlsbad, New Mexico, by first pre-heating the samples and then irradiating them with Cobalt 60 and shortwave ultraviolet radiation.

Field examination of the Howell disturbance, Tennessee, by E.M. Shoemaker, R.E. Eggleton, and D. J. Milton, in company with C.W. Wilson Jr. of Vanderbilt University, led to the conclusion that if this structure is of impact origin, as has been suggested by Wilson and others, the structure was probably formed at a time when the epi-continental Ordovician sea had significant depth at the site of the Howell disturbance.

Microscopic metallic spherules have been found in the glass of suevite collected by Chao from the Ries crater of southern Germany. Optical examination shows that these could be nickel-iron or kamaeite. Preliminary chemical analysis by E.J. Dwornik and Isidore Adler show that the nickel contents of these spherules have a wide range from background to more than the content of nickel in kamaeite. This finding supplements our previous conclusion that the Ries crater is a meteorite or asteroid impact crater.

Following an observation (and collection) of shatter cones in exploration pits at the Decaturville structure by Allan Neyl, E.C.T. Chao, R.E. Eggleton, Janet Littler, D.J. Milton, and E.M. Shoemaker, they also collected highly-crushed sandstone there similar to that at Meteor Crater, Arizona and the Kentland structure, Indiana.

2.12-1962

Don Wilhelms:
"Lunar geologists increasingly wooed the Moon away from the astronomers and physicists in the early 1960s. We were confident that our science could make the most of the grand opportunity being presented by NASA's lunar program, and eventually we sold NASA on the notion. The wooing and selling was, at first, mostly the work of Gene Shoemaker. Gene was enormously persuasive. When he talked, everyone listened. Gene had a hands-off management style and a way of making his listener feel that he or she is sharing in some grand project on an equal footing. Most of all Gene was passionately devoted to whatever project he currently had in view. The result was a generation of scientists convinced of the value of lunar geology and geologically based lunar exploration" (Wilhelms, 1993, p. 57).

"At the beginning of 1962, the farside flyby by the Soviet Luna 3 in October 1959 still remained the only spacecraft to obtain any significant data about the Moon; but on 28 January 1962 the string of American failures continued as Ranger III missed the Moon by 37,000 km" (Wilhelms, 1993, p. 55).

The following was taken from the Branch of Astrogeology Monthly Report for January 1962 to V.E. McKelvey from the Chief, Branch of Astrogeology; dated 30 January 1962:

C.H. Roach has found that low-temperature (room temperature to liquid nitrogen temperature) glow curves of post-shot samples of rock salt from Carlsbad, New Mexico, vary systematically with distance from the point of the nuclear explosion. The systematic variations have been observed up to 175 feet from the explosion.

Samples of Yule Marble that were exposed to shock stresses of 20 to 100 kilobars for a few microseconds by the Stanford Research Institute have been found by C. H. Roach to have thermoluminescence characteristics that have previously been established to represent high energy shock.

The following was taken from the Branch of Astrogeology Monthly Report for February 1962 to V.E. McKelvey from the Chief, Branch of Astrogeology; dated 27 February 1962:
On the basis of experimental results obtained in a joint investigation of high speed impact by the Survey and Ames Research Center, E.M. Shoemaker, D.E. Gault, and H.J. Moore have shown that the flux of solid particles striking the surface of the Moon is probably more than 100,000

times as great as the flux of meteoroids in interplanetary space at one astronomical unit (93 million miles). This great increase is produced by particles ejected from the lunar surface by impact of the interplanetary particles.

R.E. Eggleton and C. H. Marshall have discovered three stratigraphic subdivisions of the pre-Imbrian which can be recognized in the region around Mare Nubium and Mare Humorum. In the middle of the pre-Imbrian sequence is a unit with mare-like topography. If this unit is of volcanic origin, as the mare is commonly thought to be, then two major epochs of volcanism may be indicated in the early history of the Moon.

[Space Exploration Milestones: "On 20 February 1962 the space race heated up a bit as John Glenn made his famous three revolutions about the Earth. Scott Carpenter followed on 24 March, and that fall, Walter Schirra prepared to lift off into space for a six-orbit swing around the Earth" (Levy, 2000, p. 87).

[Astrogeology Milestone: On March 5 1962, the Branch of Astrogeologic Studies in Menlo Park, California submitted its first Astrogeologic Studies Semi-Annual Report to NASA covering work accomplished during the period 26 February 1961 to 24 August 1961. This report was submitted to Homer Newell, NASA Office of Space Sciences, with a letter of transmittal by Vince McKelvy, Chief Geologist of the USGS. The reports included research results on Extraterrestrial Materials, Crater Investigations, and Geologic Mapping of the Moon.]

The following was taken from the Branch of Astrogeology Monthly Report for March 1962 to V.E. McKelvey from the Chief, Branch of Astrogeology; dated 30 March 1962:
A second USGS, post-shot, drill hole has been started at the Project Gnome Site, Carlsbad, New Mexico, by Carl Roach. The drill hole is located at a distance of 300 feet from the surface ground-zero position of the 5-kiloton nuclear detonation held on 10 December, 1961

Don Wilhelms:
"Lunar geologists increasingly wooed the Moon away from the astronomers and physicists in the early 1960s. We were confident that our science could make the most of the grand opportunity being presented by NASA's lunar program, and eventually we sold NASA on the notion. The wooing and selling was, at first, mostly the work of Gene Shoemaker. Gene was enormously persuasive. When he talked, everyone listened. Gene had a hands-off management style and a way of making his listener feel that he or she is sharing in some grand project on an equal footing. Most of all Gene was passionately devoted to whatever project he currently has in view. The result was a generation of scientists convinced of the value of lunar geology and geologically based lunar exploration.

Not that selling was without obstacles. His survey colleagues used to call him" Super Gene" (a play on the term for a type of ore deposit), partly respectfully and partly in spoof. Survey geologists have a long tradition of chopping each other down to size in annual satirical shows called Pick and Hammer, which are based on kidding-on-the-square that can border on the cruel. They are proud of their debunking of pretentiousness and nonsense but don't always recognize these attributes in themselves. The show of 27 March 1962 in Menlo Park titled: "Circum-Galactic Geological Excoriation", featured one Dream Moonshaker. The sarcastic dialogue went on at a personal level for what must have seemed like an eternity. Snidely commenting on such things as the hot lava beneath impact-advocate Moonshaker's feet" [Thankfully, Gene did not attend the show]" (Wilhelms, 1993, p. 57).

David Levy:
"On the day of that spoof [27 March 1962; mentioned just above] Gene Shoemaker was in Flagstaff visiting with colleague Dan Milton. It was an important trip. Milton made the suggestion that the Branch of Astrogeology belonged in Flagstaff rather than at Menlo Park, and Gene, who loved the small town on the Colorado Plateau had the same thought, ran with the idea. It was the beginning of a plan to bring the new Branch of Astrogeology to the Colorado Plateau town of Flagstaff" (Levy, 2001, p. 90).

[<u>Author's Note:</u> The purpose of the Flagstaff visit on 27 March 1962 (mentioned above) by Gene Shoemaker and Danny Milton (hired by Gene earlier that year) was to visit Meteor Crater and Lowell Observatory in Flagstaff. While having dinner at the old Gables restaurant (presently Mandarin Super Buffet at 702 S. Milton Road) in downtown Flagstaff, Danny Milton is credited with mentioning to Shoemaker "this is really where you should move the headquarters of the Branch."

For the next few years, the Gables would become a favorite hangout and convenient meeting/eating place for early Branch of Astrogeology personnel before any Branch staff transferred from Menlo Park to Flagstaff, or new staff was hired. Flagstaff and its environs possessed everything that the Branch of Astrogeology would require: the lunar-like Meteor Crater (only 35 miles to the east), abundant and diverse volcanic cinder cones, lava flows and craters of many varieties, the Lowell and the Naval Observatories, and Arizona State College (that would become Northern Arizona University in May 1966).

Don Wilhelms:
"Shoemaker, who loved the Colorado Plateau, small towns in general, and Flagstaff in particular, jumped at Danny's suggestion. A partial move from Menlo Park began in December 1962, with Chuck Marshall as the point man. Robert Gilruth and some of the other old Langley hands of the Space Task Group had moved reluctantly from gentle eastern Virginia to the Manned Spacecraft Center site in the smelly wasteland south of Houston proper. Shoemaker felt no similar reluctance, but some of his astrogeologists did" (Wilhelms, 1993, p. 58).

[<u>Author's Note</u>: In the 10 April 1962 issue of the *Arizona Republic* (Phoenix, Arizona) there appeared an article under a byline by Barbara West, entitled "*First Astronaut May Use Map Prepared in Flagstaff,*" that describes the lunar mapping being done under the direction of William Cannel at the Air Force Aeronautical Chart and Information Center, Lunar Observation Office located on the grounds of Lowell Observatory o0n Mars Hill in Flagstaff, Arizona.]

[<u>Space Exploration Milestone</u>: Ranger IV collided with the far side of the Moon on 26 April 1962, but the spacecraft returned no data. Ranger V was launched on 8 October 1962 and, like Ranger III, is now forever in an orbit around the Sun. Another failure! Though its instruments functioned, the craft missed the Moon by just a few hundred miles.]

The following two sentences were taken from the Branch of Astrogeology Monthly Report for April 1962 to V.E. McKelvey from the Chief, Branch of Astrogeology; dated 30 April 1962:
Examination of hypervelocity impact targets by D.J. Milton (USGS, Menlo Park, California) and D.W. Gault (Ames Research Center, Mountain View, California) established energy limits for the shock-melting of quartz. Some vitrification of quartz without liquification apparently occurred.

Geologist Donald Parker Elston (b.1926-2006), who would play an active role in the early initial growth of the Branch of Astrogeology, especially the early Manned Lunar Exploration activities, appeared in Menlo Park for a temporary one-month assignment with the fledgling Branch of Astrogeologic Studies Unit in May 1962 (see Appendices A and B). He transferred to Menlo Park one month later [June] as acting Chief of the Astrogeologic Studies Unit. This took place just three months prior to Gene's departure for Washington and his temporary one-year assignment to NASA Headquarters to help organize the science for Project Apollo.

Don and Gene Shoemaker became close friends and colleagues when they worked together out of Grand Junction, Colorado, during the waning phase of the Geological Survey's Colorado Plateau uranium project that ended in 1958. Gene had been on the project since 1948 when he first joined the USGS; Don began work with the Survey's Uranium Project (Grand Junction) in May of 1953.

[Author's Note: Don would move from Menlo Park to Flagstaff in July 1963 when the headquarters of the Branch of Astrogeology was relocated there. Almost immediately after arriving, Don Elston, geologist Jack McCauley (b. 1932) and photogeologist Charles "Chuck" H. Marshall (b. 1916) negotiated with the City fathers for the present site of the Flagstaff Field Center (see 1963).]

The following was taken from the Branch of Astrogeology Monthly Report for June 1962 to V.E. McKelvey from the Chief, Branch of Astrogeology; dated 29 June 1962:
An astrogeologic instrumentation project will be started in Denver in fiscal year 1963. Ray Barnett, formerly with Isotope Geology Branch, will be project chief, and he will be assisted by Stanley Lassiter.

The following was taken from the Branch of Astrogeology Monthly Report for July 1962 to V.E. McKelvey from the Chief, Branch of Astrogeology; dated 31 July 1962:
E.M. Shoemaker, with M. Dence of the Dominion Observatory, Ottawa, Canada, made a geological reconnaissance of the Clearwater Lake, Quebec. Results of the investigation reveal that this feature is the largest impact structure known in North America, and is of a size that rivals that of the Ries basin in Germany. Separate, independent investigation of shock transition of minerals resulted in the announcement of complimentary findings by E.C.T. Chao, Washington, and D.J. Milton, Menlo Park, California.

In preparation for participation in a field study of the Campo del Cielo meteorite field, Argentina, D.J. Milton searched for two pistols made from one of the meteorites. The pistols, which had been presented to President Madison by the Argentine Government in 1816, were found to be in the James Monroe Memorial Library. Because the meteorite nature of the Camp del Cielo iron was not realized until the 1820's, the origin of the metal in the pistols, undoubtedly rare for firearms, was not known by any of the possessors of the pistols.

[Apollo Milestone Event: "On 11 July 1962 the crucial announcement was made in Washington, D.C. that the vigorous debate about how to get Americans to the Moon had been resolved in favor of rendezvous in lunar orbit, the mode insistently advocated to a resisting though not closed-minded NASA by then-obscure but now-famous Langley engineer John C. Houbolt" (Wilhelms, 1993, p. 56).]

Don Wilhelms:
"What I call mainstream lunar science was only beginning to move from the minds of its investigators onto the printed page at the beginning of 1962. Ralph Baldwin's 1949 book *The Face of the Moon* (Baldwin, 1949) had already unleashed the forces of reason against selenological dilettantism, but what he had been doing since was not yet know to the lunar community. The Soviets had pioneered the Space Age, and a collection of their lunar papers published in Russian in 1960 and in English in 1962 was available to show us Westerners what the competition was doing. Mostly the Soviets were doing "hard science"—traditional astronomical observations of the same emphasis pervades [Gilbert] Fielder's 1961 "*Structure of the Moon's Surface*" (Fielder, 1961) and all sections devoted to the Moon in the third volume of Kuiper's series, *The Solar System* (Kuiper, 1961). The Engineer Special Study by Hackmann and Mason (Hackmann and Mason, 1961) had been published formally, but not the cratering and stratigraphic papers by Shoemaker that really got lunar geology under way" (Wilhelms, 1993, p. 55).

Don Beattie:
"Because the President's mandate [of 25 May 1961] did not require any specific tasks be accomplished once the astronauts arrived on the Moon, the initial spacecraft design did not include weight or storage allowances for scientific payloads. Somewhere, somehow, amid the six million pounds and 363 feet tall Apollo Saturn-5 rocket, we would have to squeeze in a science payload. The earliest thinking was, "We'll land, take a few photographs, pick up a few rocks, and take off as soon as possible." The need to do much more was not considered in the planning. For many NASA engineers and managers the lunar landing was a one-shot affair. After the first successful landing, NASA would pack up its rockets and do something else. Why take any more chances with the astronaut's lives on this risky adventure" (Beattie, 2001, p. xiv)

Don Wilhelms:
"Recognizing the need and overcoming what he called a love-hate relationship between himself and the National Academy of Sciences, Homer Newell (since November 1961 the chief of a new NASA headquarters office called the Office of Space Science, or OSS) cooperated with members of the Academy's Space Science Board in instituting the first of a series of joint summer studies that would punctuate the rest of the Apollo era and beyond" (Wilhelms, 1993, p. 55-56).

Don Beattie:
"The first officially sanctioned attempt to change this thinking took place in March, 1962 when Charles P. Sonett was asked to convene a small group of scientists to recommend a list of experiments to be undertaken once the astronauts landed on the Moon. This meeting, requested

by NASA's Office of Manned Space Flight, was held in conjunction with a National Academy of Sciences Space Science Board Summer Study taking place at Iowa State University in Ames (Iowa) so that the Academy's participants could review and comment on the recommendations Sonnet's team would make. The Sonett Report, submitted to NASA management in July 1962, became the foundation for all subsequent lunar science studies and recommendations. Circulated in draft form at NASA and other organizations throughout the rest of 1962 and most of 1963, the report elicited both support and criticism. It was at this point in the evolution of Apollo science, with a short digression to set the stage, that I [Don Beattie] got involved" (Beattie, 2001, p. xiv and xv).

Don Wilhelms:
"More than 100 scientists convened between 17 June and 10 August 1962 in Iowa City, the home turf of the conference chairman and Space Science Board member James Van Allen. Although the board was now chaired by the foresighted Princeton professor Harry Hess, the conference report reflects the scant attention paid to lunar geology at the time. Reading the Iowa City report reminds today's readers how mysterious and exotic the Moon was perceived to be" (Wilhelms, 1993, p. 55-56).

"Gene Shoemaker was at the Iowa City conference but limited his written contribution to a discussion of the possibility of collecting lunar samples from two points in space (libration or Lagrangian points) where they were thought likely to accumulate. In the spring of 1961 a Polish astronomer Kazimierz Kordylewski had reported brightenings in the direction of the points that might indicate particle accumulation. While the conferees [at Iowa City] were watching fireworks (literal ones) on Van Allen's lawn, USGS geologist Elliot Morris and geologist/photographer Hal Stephens were [at Shoemaker's request] pointing a light-gathering camera through the thin air above Mount Chacaltaya, Bolivia (at an elevation of 17,600 feet), in an attempt to photograph these "Kordylewski clouds." The results were negative, as they were when others tried to photograph them from Earth or through the windows of Gemini capsules. It has proven easier to get lunar samples from the Moon than from the Lagrangian points" (Wilhelms, 1993, pp. 56-57).

By mid-1962, and while still based out of Menlo Park, Gene Shoemaker wanted to set up a program for lunar geologic mapping. Needing a telescope to properly conduct such lunar mapping, Gene contracted with the Lick Observatory in California to use their 36-inch scope. Subsequently, the tight observing scheduling for the Lick 36-inch telescope became a problem and Gene decided that his fledgling group of astrogeologists needed to have its own telescope—one designed "specifically" for lunar mapping.

The first big project assigned by Gene to geologist Elliot Morris, after he completed his PhD at Stanford and officially came on with the Branch of Astrogeology in Menlo Park in the spring of 1962, was a challenging one indeed. Elliot was to design and negotiate construction of a telescope specifically for lunar geologic mapping in the high altitude environment near Flagstaff, Arizona. This was of course something that Elliot had never done before; however, he was up to the challenge.

[Author's Note: This was very typical of Gene's approach to the people he hired for Astrogeology—anyone could do anything asked of them if they put their mind and heart into the challenge. The initial research for the Astrogeology telescope at Flagstaff would actually began quite a few months before Elliot Morris moved from Menlo Park, California to Flagstaff in December 1963. See 2.14-1963]

Gene Shoemaker:
"In the summer of 1962 I had gone down to see Max Faget [NASA/MSC/Houston) at his invitation. Max was interested in trying to get some science started for Apollo. He was the one who had the vision for this. In fact, he designed the landing module with some pretty big bays in it with the idea that there would be scientific instruments in there. He wanted to get the thing going! I think a lot of credit should go to Max for that vision. I think he was the only one, really, at MSC that had that idea that there was some science to do when you got to the Moon. And I was of course very interested in trying to get it started too.

I was doing fieldwork at Sierra Madera, so I drove over to Houston right in the middle of the hottest part of the summer to see Max. Max said that he wanted me to come and work for him—straight out. He wanted me to build up a geology group there [at MSC], to train the astronauts and to build up the whole thing for science on the Moon. So, I was really serious about it. But I thought before making any commitment with Max at MSC I'd better go find out whether science was going to get supported out of NASA Headquarters. So I went to see Homer Newell [NASA HQ].

Homer said "well the first thing that's got to be done is we've got to set up something here at NASA Headquarters to get the funding organized and get the funding to support the science." And he was, at that time, having some difficulties with Brainerd Holmes who was honcho for the Manned Program. Homer wanted to establish some kind of a joint thing with Brainerd so there would be science embedded in the Apollo Project, in the manned effort. He said, first come back to NASA Headquarters. So I did" (From an interview with Gene Shoemaker by William C. Phinney on 21 April 1995).

[Astrogeology and NASA Milestone: In September 1962, Gene Shoemaker left his fledgling Astrogeologic Studies Unit at Menlo Park to take on a temporary (but historically important) assignment at NASA Headquarters to help them set up their Space Sciences Division.]

Don Wilhelms:
"Gene Shoemaker suddenly left Menlo Park in September 1962 for a one-year assignment at NASA Headquarters. It was not preordained that Apollo would be influenced by geology or any other science. Two NASA managers who thought it should be were Homer E. Newell (1915-1984) and his deputy, Oran Nicks, director of the Lunar and Planetary Programs Office that Newell had created in the Office of Space Sciences [at NASA] in January 1960. Newell formed an Office of Space Sciences (OSS)-Office of Manned Space Flight (OMSF) Joint Working Group to develop a plan for scientific manned lunar exploration and asked Gene Shoemaker to chair it. Shoemaker had been dismayed by the anti-science attitude displayed [during the NASA Summer Study on the Apollo Program (June 17-August 10, 1962)] at Iowa City by personnel of NASA's manned Spacecraft Center, and was not about to refuse this golden opportunity to

influence the subsequent course of geologic exploration by Project Apollo—and more than incidentally, to get himself a trip to the Moon [as an Apollo astronaut]" (Wilhelms, 1993, p. 58).

Gene Shoemaker:
"I was TDY [temporary duty] from the Survey to NASA Headquarters for close to ten months. So I went and worked directly with Oran Nicks who was Director of Lunar and Planetary Programs. He was really the daddy of Planetary Exploration—and the daddy of the unmanned flight programs. Tremendously good guy to work with—he was really good. So the idea was that I would work with Oran and then we'd try to set up a new directorate that would be responsible both to Newell and to Brainerd Holmes. We got that going. The interesting thing is that Holmes had sort of had an idea to get somebody himself. It turns out that he brought Fred Eimer from JPL to NASA Headquarters to do it for him. Well, of course that sort of thing had to be thrashed out at the level of Newell and Holmes. Fred Eimer I had known quite well. He was a classmate of mine at Caltech. And I had known him at JPL. He's been very helpful in our getting the whole astrogeology program going. So this was kind of an embarrassing and awkward thing.

Well, as it turned out, the thing was worked out that we go ahead and set up —kind of the way that Newell had been planning. I guess Newell said well you know we're responsible for science. That was his job at NASA—he was the science king. So we went ahead and set up the directorate. I served as its interim director; then when it was established and recruited a staff, Fred went out and ultimately ended up in the disarmament activities.

Well as a part of this deal, time was wasting. I was anxious to get something set up, and when I talked to Max initially I said, well I think I could recruit or bring a top bunch of people from the Survey down directly to Houston and get this thing going. That's the thing I discussed directly with Newell when I got there. So I started that right away.

And that's when Dale Jackson (1925-1978) was recruited to do that [run the astronaut training activities at MSC for Astrogeology]. I thought Dale would be a terrific guy to head that up. Dale then started to pull that group together. So we sent a contingent of guys down specifically to get the ball rolling. What happened in the meantime was that Max wasn't going to wait around. He decided to go ahead and recruit staff directly [at MSC].

Had I know that Max [Faget] was just going ahead and get another independent group [for astronaut training] I wouldn't have done that because that made a very awkward situation. By the time Dale [Jackson], Gordon [Swann], [Dick] Eggleton, and [Don] Wilhelms got there, our expectations, and that's what Dale went down with, was that this would be a group that would work there directly at MSC, and get the science going in-house there and it would be a contingent from the USGS that would be there to do it. That was a real fast way to get underway. But I guess Max had other ideas after that.

Newell was not aware at that time what Max was doing. So Max just went on independently. He recruited Uel [Clanton] and the other guys who were there [at MSC] at that time. So, it made for kind of a funny and awkward situation by the time Dale Jackson actually came onboard" (From an interview with Gene Shoemaker by Bill Phinney on 21 April 1995).

Bill Phinney:
"In talking with Uel, he said some of them at least recognized that they were all a bunch of new PhD's, some had not even finished their Ph.D.s, whereas the USGS guys had the contacts and the knowledge of a more general nature. So he—and I guess some of the others [geologist at MSC]—were strongly in favor of having some USGS folks either there [at MSC] or in close contact because of the nature of the USGS folk's reputations, knowledge of the field and the people that they knew, and all that" (William C. Phinney, submitted; see references).

Gene Shoemaker:
"I went down to MSC myself in 1962 and participated in the first bunch of lectures [to the astronauts]. I introduced them to lunar geology, as we knew it at that time. By then I was in Washington. I traveled down to Houston to do that and set up the first geologic field trip that they had. Their first trip was to Meteor Crater [16 January 1963; with participating astronauts Armstrong, Borman, Conrad, Lovell, McDivitt, See, White, Stafford and Young; see January 1963].

Training for the astronauts was [just] a component of this whole larger effort that was to try to get the whole scientific program going for Apollo. That's what the directorate was then set up for. I didn't imagine that I would stay longer than a year at NASA Headquarters to do it. The idea was to be there, to do it, and get it on its way. Homer wanted me to stay on but I knew Washington well enough. In the meantime as things worked out, we were also planning to move a substantial part of the astrogeology group to Flagstaff because we were building a telescope to prosecute a more vigorous way of lunar mapping. This was all pre-Lunar Orbiter. So, when I left Washington, I came directly back to Flagstaff. We shifted the Branch headquarters there [starting officially on 1 July 1963; see 1963]" (from an interview by William Phinney of Gene Shoemaker on 21 April 1995).

David Levy:
"As Soviet missiles were being placed near launching pads in Cuba [in the fall of 1962], the Shoemaker family arrived in JFK's Washington [for a one-year assignment] to work with NASA. The space agency was considering setting up a separate field center for geology. Gene helped change their minds to permit the USGS to handle the geology program, and according to Steve Dwornik, then program scientist for the Surveyor program, NASA management was very happy that Gene Shoemaker was there. "NASA used Shoemaker as a senior knowledgeable person with no axe to grind," says Dwornik. As in private industry, in Gene, NASA had someone they could trust to suggest what science could be done on their space missions. Gene's superior at NASA was a geologist named Orin Nicks" (Levy, 2000, p. 87).

Don Wilhelms:
"It was not foreordained that Apollo would be influenced by geology, or any other science. Two NASA managers who thought it should be were Homer Newell and his deputy Oran Nicks, director of the Lunar and Planetary Programs Office that Newell had created in OSS in January 1960. Newell formed an OSS-OMSF Joint Working Group to develop a plan for scientific manned lunar exploration and asked Shoemaker to chair it.

Shoemaker had been dismayed by the anti-science attitude displayed at Iowa City by personnel of NASA's Manned Spacecraft Center and was not about to refuse this golden opportunity to influence the subsequent course of geologic exploration by Project Apollo-and more than incidentally, to get himself a trip to the Moon. His plan appeared in a report by the Lunar and Planetary Programs Office, known by the name of its chief scientists, physicist and magnetics specialist Charles Sonett. On 30 July 1963 Newell reorganized the working group as the Manned Space Science Division.

All of this was over the strenuous objections of Newell's counterpart at NASA Headquarters, Dyer Bainard Holmes (b. 1921) an electrical engineer who had been recruited from RCA in October 1961 to head the new office of Manned Space Flight (OMSF). Holmes' attitude to scientists was essentially, "buzz off." The president had directed us to get Americans to the Moon and return them safely to Earth in this decade, but nowhere did he mention picking up stones or taking pictures.

And then there was the devilish problem of the influential space physicists, who scorned rocks and pictures. If Shoemaker had not gone to NASA Headquarters to lobby for geology and Holmes had stayed there (he left in September 1963)—it is entirely likely that we would have no samples or photographs from the lunar surface" (Wilhelms, 1993, p. 58).

[Astrogeology Milestone: In a very hectic September 1962, Gene Shoemaker became the official Chief of the Survey's new Branch of Astrogeology, then still headquartered in Menlo Park, California. Colleague Don Elston became acting Branch Chief of Astrogeology in Gene's absence]

Geologist Michael Harold "Mike" Carr (b. 1935) arrived in Menlo Park in September 1962 and found out that the man who hired him—Gene Shoemaker—was about to head east to accept the one-year assignment at NASA Headquarters (see Appendices A and B).

Don Wilhelms:
"At a Harvard-Yale reunion at the Geological Society of America Meetings in Cincinnati in November 1961 he [Mike Carr] had met Harvard PhD, Dan Milton, who had been assigned by Shoemaker to an experimental investigation of shock processes. Dan did not particularly want to do the project, and Mike Carr was his escape hatch.

Geologist Harold Masursky (1922-1990) also arrived in September 1962 to work for the Branch of Astrogeology in Menlo Park (see Appendices A and B). Hal had attended Yale University on a full scholarship and he earned his BS degree in Geology and Civil Engineering in 1943. After two years with the Army Engineer Corp., where he reached the rank of first lieutenant, Hal returned to Yale and earned his MS degree in geology in 1951. He joined the USGS in 1947. Hal arrived in Menlo Park, California in 1962 to begin work with Gene Shoemaker's new Astrogeologic Studies Unit. Hal would then later move to Flagstaff, Arizona in March 1968 and worked there for the Branch of Astrogeology until his death on 24 August 1990.

Don Wilhelms:
"Hal was more a facilitator of other's work than a contributor of original science. Such was already his reputation in his previous positions in the USGS, and it suited Shoemaker just fine because he needed someone to manage the lunar geologic mapping effort that was beginning. Hal had a good understanding of what geologic maps were all about and how to manufacture them even though he seldom worked on them himself. He soon began to promote the acquisition of cameras for lunar use at Lick Observatory, and to establish ties with non-astrogeologic but pro-moon USGS geologists at Menlo Park who did not perform in the "Pick and Hammer show." Hal's subsequent career was characterized by a similar promotion of cameras for spacecraft, and establishment of ties with NASA movers and shakers and the news media. This perceptive and witty geologist played a major role in keeping disparate scientific and flight organizations aware of one another's activities. Readers may know him from his many television appearances commenting on each new lunar or planetary mission" (Wilhelms, 1993, p. 59).

The following was taken from the Branch of Astrogeology Monthly Report for September 1962 to V.E. McKelvey from the Chief, Branch of Astrogeology; dated 1 October 1962:
Photographic investigation of the libration points of the Earth-Moon system was undertaken in July and August 1962 by E.C. Morris and H.G. Stephens at Mt. Chacaltaya, Bolivia, at an elevation of about 17,600 feet. Examination of five photographic plates of one libration point reveals that if any particular matter is present in this libration region, its maximum luminosity was no greater than 12th magnitude. A program of continuous surveillance of two other libration points is planned for the summer of 1963.

The following was taken from the Branch of Astrogeology Monthly Report for October 1962 to V.E. McKelvey from the Chief, Branch of Astrogeology; dated 31 October 1962:
D.J. Milton of the Branch of Astrogeology, a member of an expedition studying the meteorite craters at Campo del Cielo, Province of Chaco and Santiago del Estero, Argentina, reports that seven craters, all within about one-mile of a line eleven miles long, have been found. More than 400 iron specimens have been recovered. This expedition, sponsored by Lamont Observatory of Columbia University, and supported by a National Science Foundation grant, consists of William Cassidy of Lamont Observatory, as leader, Truman Kohman of Carnegie Institute of Technology, Alvin Cohen of Mellon Institute, and D.J. Milton of the Branch of Astrogeology.

2.12.1-Shoemaker Requests Permission from the USGS to set up a Branch Office in Flagstaff, Arizona

[<u>Branch of Astrogeology and Flagstaff Milestone</u>: On 25 October 1962 Gene Shoemaker sent the following Memorandum through Vincent McKelvey, Assistant Chief Geologist for Interagency Programs to C.A. Anderson, Chief Geologist of the USGS requesting permission to open a Flagstaff office of the Branch of Astrogeology; the complete text of thatr Memorandum is given below:

Subject: Request to establish a Branch Office in Flagstaff, Arizona

In order to meet the schedule for lunar mapping put forth in the Astrogeologic Studies plan of research for fiscal years 1963, 1964, and 1965, and work plan and operating budgets for fiscal year 1963, investigations have been made into the construction of a telescope and an appropriate site for its installation. The need for this instrument has become acute with expansion of the Survey's lunar mapping program at the request of NASA. From preliminary discussions with the Lunar and Planetary programs Office it has been determined that they would favorably entertain a proposal from the Survey to proceed with the construction of an appropriate telescope. A formal proposal to NASA has been prepared.

After investigation of several possible sites in California and Arizona, the Flagstaff area in Arizona has been selected as the most advantageous area for operation of a telescope to be used for lunar mapping. Of all locations in the United States where the general astronomical seeing is adequate to obtain the high resolution information required for the lunar mapping, the Flagstaff area is the only one where sites can be found adjacent to an established community. The operational advantage of immediate and direct access to the telescope in lunar mapping has proven to be very great in the expansion of the Aeronautical Chart and Information Center which is using a 24-inch telescope at Flagstaff at the present time. The Flagstaff area has several further advantages for the Survey's lunar geologic mapping program. Astrogeology Branch staff headquartered in Flagstaff would be in direct day-to-day contact with the field staff of ACIC working on the lunar base maps on which the geology is being plotted by the Survey. Three other major observatories are located in Flagstaff, the Lowell Observatory, the Flagstaff station of the U.S. Naval Observatory, and the Perkins Observatory. The Lowell Observatory is the only observatory in the United States founded for research on the Moon and planets and has a fine astronomical library that would be accessible to members of the Survey.

A new international planetary data center, which will be financed by NASA, is about to be established in Flagstaff under the auspices of the Lowell Observatory. An atmosphere of research already exists at Flagstaff and intercourse with the astronomers there has already proven beneficial in the development of instrumental techniques that can be used in the Survey's program of lunar mapping. During the period in which a telescope for Survey use is being built, some time will be available on other existing telescopes in the area to members of the Survey, as in the past.

Eight possible sites for a telescope were examined in the Flagstaff area, and one site was chosen for preliminary seeing studies. This site is in the National Forest adjacent to a plot of ground used under permits by the Perkins Observatory, about 15 miles southeast of the center of town. The 69-inch telescope of the Perkins Observatory is in operation on this adjacent plot of ground at the present time. The site selected for seeing studies was chosen primarily on the basis of ease of access and low cost of site development required to install a telescope. A brief seeing study had been carried out by C.H. Marshall in cooperation with ACIC personnel, to compare the local seeing at the site with the seeing at the Lowell Observatory. The results have been encouraging and the seeing study is therefore being extended to include a comparison with seeing at the nearby Perkins Observatory. Prior to conducting the seeing study a special use application was filed by C.H. Marshall with the U.S. Forest Service. This application is for the use of a 160-acre parcel under Forest Service supervision as a site for an astronomical telescope. Application was made to assure that the site would be available for this use in the advent of favorable response from the seeing tests.

If the plans for construction of a telescope are approved by NASA, we would like to transfer Marshall to Flagstaff as soon as he can move his family in order that he can supervise some preliminary work that should be carried out. A certain amount of preparation of the ground and construction of a temporary housing for the telescope should be initiated as soon as possible because of the advancing season. Unless major delays are incurred in contracting, we anticipate that the basic telescope would be ready for installation in the early spring. The optics could be ready for installation in late May or early June. Under this plan various members of the Branch staff could be transferred to Flagstaff between January and June so that research could begin on the new instrument as soon as it is ready.

It is anticipated that the telescope will be used actively not only by the Geological Survey but also by various research centers of the national Aeronautics and Space Administration. General policy for the use of the telescope will be worked out by NASA. One of its uses that may be expected to develop at an early stage will be for the training of the astronauts for the manned lunar landing program. The advantages of the Flagstaff area for use in several aspects of astronaut training, including field training in the surrounding volcanic terrain and at Meteor Crater, was described in a memorandum by Shoemaker to NASA Ad Hoc Committee for the Apollo Scientific Mission.

With the growth of NASA's own astronomical research program, larger telescopes than the one we are now planning will probably be built for NASA use. The site at Flagstaff may therefore become a major lunar and planetary research facility for NASA. The specific site which we are currently considering is thus a preliminary site for a complex of telescopes, and the installation of a telescope of modest aperture this fiscal year will serve to test the site for this broader purpose. Continued seeing tests are planned for other potential sites in the Flagstaff area.

Permission to establish an office in Flagstaff is hereby requested. If approved, the staff at the Flagstaff offices is expected to become comparable in size to the Astrogeologic Branch group remaining at Menlo Park at the end of the fiscal year 1964."

[Author's Note: the official date of transfer of Branch Headquarters to, and establishment of research facilities at Flagstaff, Arizona, would be 1 July 1963; See 1963].

The following was taken from the Branch of Astrogeology Monthly Report for November 1962 to V.E. McKelvey from the Chief, Branch of Astrogeology; dated 30 November 1962:
"Seeing" studies at the proposed observatory site on Anderson Mesa 15 miles southwest of Flagstaff, Arizona, have been continued by members of the Branch of Astrogeology. Seeing at least equals that at Lowell Observatory at Flagstaff. A road to the proposed site has been staked and the U.S. Forest Service plans to start grading operations shortly.

The lunar geologic mapping program has been aided by the use of telescope facilities of the University of California at Mt. Hamilton. Visual observations of selected map areas are being carried out at near-terminator positions with the 36-inch refractor of the Lick Observatory.

H.J. Moore and R.V. Lugn resumed geologic mapping of the Mule Ear diatreme near Mexican Hat, Utah, continuing a project initiated by E.M. Shoemaker.

2.12.2- Formal Geologic Mapping of the Moon Takes a Giant Step Forward with the Arrival of Don Wilhelms at the Branch of Astrogeology Office in Menlo Park, California in December 1962

The following was taken from the Branch of Astrogeology Monthly Report for December 1962 to V.E. McKelvey from the Chief, Branch of Astrogeology; dated 31 December 1962:
A cosmic dust project, designed to sample and analyze micrometeorites, has been started under the direction of Michael B. Carr at Menlo Park

Geologist Donald "Don" E. Wilhelms (b. 1930) arrived on the scene with Shoemaker's Astrogeologic Studies Unit in Menlo Park, California on 3 December 1962. Don vividly recounts in his excellent book *"To a Rocky Moon"* his early interest in things astronomical while growing up in Southern California and how he came to join Gene Shoemaker and his fledgling Astrogeologic Studies Unit in Menlo Park (see Appendices A and B). Don would direct the Branch of Astrogeology's heralded lunar geologic mapping program which resulted in 1:1,000,000-scale mapping of the entire nearside of the lunar surface, as well as Western-, Eastern-, and Polar-hemisphere maps of the Moon. (Information from Wilhelm's book *To a Rocky Moon* is quoted extensively throughout the present work).

Don Wilhelms:
"On numerous weekends during my childhood and youth, while my peers were at the beach or wherever, I had haunted the Griffith Observatory above Los Angeles. I discovered both stars and rocks in this beguiling place, but was more inclined to astronomy. Among the many things I remember learning there was that what you see on the Moon depends on how high the Sun is in the sky—the lower the better, down to a point. I even made a (non-geologic) map of the Moon when I was 15 or 16 (Wilhelms, 1993, p. 60).

"With his geologic mapping of the Moon, Don Wilhelms set the methods and standards for planetary mapping. He is author of *Geologic History of the Moon* (1987, USGS Professional Paper 1348; 302 pages plus 24 plates) and *To a Rocky Moon, A Geologist's History of Lunar Exploration* (1993, University of Arizona Press, 477 pages), as well as many other science publications, including lunar and planetary geologic maps."(From a biography of Don Wilhelms by Branch of Astrogeology geologist Mary G. Chapman, dated 15 December 2002; see http://astrogeology.usgs.gov).

[Author's Note: Don Wilhelms did not move from Menlo Park to Flagstaff with some of his colleagues when the Branch of Astrogeology moved its Headquarters there in July 1963, preferring instead to stay on his beloved San Francisco peninsula—where he still resides.]

[Space Exploration Milestone: On 14 December 1962, NASA's Mariner 2, the first successful planetary spacecraft, flies by Venus and enters a solar orbit around it.]

Don Wilhelms:
"A much larger published treasure trove of relevant information was available at the end of 1962 that at the beginnings. We owe a particular debt to the civilized and erudite Czech astronomer

Zdenêk Kopal, who promoted two review volumes whose rich assemblages of up-to-date reviews include the landmark paper by Shoemaker from which lunar geology leapt into the modern era. Then, early in 1963, there would appear what other kinds of publishers would describe as "Sensational! Reveals all"—Ralph Baldwin's richly-documented magnum opus, *The Measure of the moon*" (Wilhelms, 1993, p. 61).

2.13-1963

2.13.1-Initiation of the Geologic Field-Training of the Astronauts around Flagstaff, Arizona

[Author's Note: A total of two hundred geologic field-training exercises planned and led for the most part by geologists and geophysicists from the USGS Branch of Astrogeology and the Branch of Surface Planetary Exploration (created in 1967) in Flagstaff were carried out in many areas of the Western United States, including Hawaii and Alaska; in addition to foreign trips to Iceland, Canada, and elsewhere, between January 1963 and November 1972. A complete listing of all two hundred astronaut field-training exercises, along with dates and astronauts who participated, is given in Table I.]

The very first geologic field training trip for NASA astronauts was carried out at Meteor Crater and the San Francisco Volcanic Field near Flagstaff under the leadership of Gene Shoemaker on 16-18 January 1963 (see Table 1; Fig. 7).

Don Wilhelms:
"Geological training of the astronauts was the result of one of Shoemaker's initiatives at NASA Headquarters. A trial run quickly got under way in January 1963 with the nine newly selected (September 1962) test-pilot astronauts of the second, so-called Gemini group as guinea pigs. Gene subjected them to an intensive two-day field trip in and around Flagstaff that included Meteor Crater, nearby volcanic features, classroom lectures, telescopic observing of the Moon at Lowell Observatory, and little sleep. The astronauts were favorably impressed and seemed eager for more" (Wilhelms, 1993, p. 76).

The headline of Flagstaff's *Arizona Daily Sun* of Wednesday January 16, 1963 read "Astronauts Arrive! Mayor Proclaims 'Space Age' Day". One of the many lead articles in the *Daily Sun* over the next two days read as follows:

"Nine enthusiastic future spacemen spent today in Flagstaff area learning about what things might be like when one of their numbers someday lands on the moon. They got a pretty good idea of what the weather might be like—minus five degrees—when they stepped off Bonanza and Frontier Airlines planes shortly after 7:30 A.M. to be greeted by a Flagstaff delegation of nearly 40 scientists, city officials, and civic dignitaries.

It was "Space Age Day" in Flagstaff by proclamation of Mayor Rollin H. Wheeler, one of the welcoming delegation that crowded into the administration building at Flagstaff Municipal Airport; and who, despite the din, managed a formal presentation of the proclamation to astronaut trainee Charles "Pete" Conrad and Ivan Ertel, information specialist with the Office of Manned Space Flight of the National Aeronautics and Space Administration."

Then, they were whisked to the Century Hi-way House Motel, their headquarters in Flagstaff, where they changed from the light business suits they wore for their flight from Phoenix, to pressure suits, reinforced with thermal underwear for their working sessions in various areas around Flagstaff during the day.

By 9:30 AM, in a motorcade of gray-painted government vehicles, they were on their way to famed Meteor Crater, some 45 miles east of Flagstaff, where they were given a morning-long briefing on the geology of the crater by Eugene Shoemaker and Charles ["Chuck"] Marshall of the U.S. Geological Survey's Astrogeology Branch."

The *Arizona Daily Sun* article of 17 January 1963 goes on to report the following:

"Following lunch at Meteor Crater, the astronauts visited Sunset Crater, some 14 miles northeast of Flagstaff and again were given a briefing by the astrogeologists on volcanic cones and similar landforms that they might find on the Moon, comparing the volcanic cones. Later that night the astronauts gathered at the Lunar Observations Office of the Air Force's Aeronautical Chart and Information Center at Lowell Observatory on Mars Hill to get a rundown on lunar geography and an astronomical comparison of lunar topographic features with those terrestrial features they saw in the Flagstaff area during the day. After this briefing, and starting at about midnight, the nine astronaut trainees will get in three to four hours of actual observation of the Moon, and possibly Mars, using the 24-inch reflecting telescope at Lowell, the 40-inch reflecting telescope at the U.S. Naval Observatory west of Flagstaff, and the 24-inch reflector at Arizona State College"

The following was taken from the Branch of Astrogeology Monthly Report for January 1963 to V.E. McKelvey from the Chief, Branch of Astrogeology; dated 30 January 1963:
E.M. Shoemaker, Chief of the Branch of Astrogeology who is currently on detail to the Office of Space Sciences at NASA Headquarters, Washington, led a one and one-half day field excursion in the Flagstaff, Arizona, area for nine astronauts and accompanying NASA personnel from the Manned Spacecraft Center, Houston, Texas. The astronauts present were Neil Armstrong, Frank Borman, Charles Conrad, James Lovell, James McDivitt, Elliot See, Thomas Stafford, Edward White, and John Young. The astronauts were accompanied by Robert Voas, John Eggleston, Raymond Zedeker, John Dornback, and Ivan Ertel of the Manned Spacecraft Center. R.E. Eggleton, D.P. Elston, C.H. Marshall, H. Masursky, and E.C. Morris of the Branch of Astrogeology assisted E.M. Shoemaker.

The field excursion began January 16 with examination of the geology of Meteor Crater, Arizona, followed by investigation of the Sunset Crater cinder cone and associated lava flows of the San Francisco volcanic field near Flagstaff. Following this, late evening and early morning work was carried out at Lowell Observatory, U.S. Naval Observatory, and the Atmospheric Research Observatory of the Arizona State College, all of which are in or near Flagstaff.

Directors of these observatories, respectively, Drs. John Hall, Dr. A.A. Hoag, and Dr. Authur Adel, extended utmost courtesies to the group, as did the entire community of Flagstaff.

[Author's Note: Astronauts Frank Borman of Phoenix, Pete Conrad and James Lovell stayed on after the training in Flagstaff for a little relaxation as guests of the Arizona Snow Bowl ski resort, high on the San Francisco Peaks north of Flagstaff]

[The Phoenix-based newspaper *The Arizona Republic* on 17 January 1963 also carried extensive coverage of Flagstaff's hosting of the nine NASA astronauts during that initial geologic training exercise; [Also see Flagstaff's *Arizona Daily Sun* issues dated 30 and 31 January 1963.]

The following was taken from the Branch of Astrogeology Monthly Report for January 1963 to V.E. McKelvey from the Chief, Branch of Astrogeology; dated 30 January 1963:
E.C.T. Chao visited the following tektite localities on an extended trip to the Far East during the interval 16 September to 18 December 1962: The Ortigas, Santa Mesa, Kubao, San Francisco Del Monte, Pugad sites near Manila and the Anda sites on the Cagarruyan Island of Luzon, Philippines; the Dalat site of Viet Nam; the Korat Plateau of Thailand; the Sangiran Dome of Java; and the Port Campbell and Stanhope Bay sites of Victoria, Australia. Many tektites were collected.

[Author's Note: At that time, tektites were commonly thought to have been derived from space, possibly the Moon. Tektites were much later thought by most workers to actually be shocked-melted ejecta from terrestrial impacts.]

2.13.2-Gene Shoemaker Becomes Principal Investigator of NASA's Surveyor Project

David Levy:
"In January of 1963 Gene was offered [by NASA] a highly coveted position on the new Surveyor Project, as Principal investigator of the television experiment, a task that would solidify his prominent role in the nation's space program. Whereas Ranger was intended to slam into the Moon, Surveyor would caress it—landing softly—to begin a weeklong exploration" (Levy, 2001, p. 94).

[Author's Note: All of the successfully-landed Surveyor spacecraft operated significantly longer than had been planned.]

Geologist John F. "Jack" McCauley (b. 1932), an exceptionally astute geologist and intellectual who, like Gene Shoemaker, has always been adapt at seeing the big picture in lunar, planetary and terrestrial geology, arrived on duty at Flagstaff in February 1963 (see Appendices A and B). Months earlier, Gene Shoemaker had visited Jack at the University of South Carolina (Charleston) where McCauley had only recently obtained tenure as a professor. Shoemaker—as only he could—got McCauley fired up about his plans for formal lunar geologic mapping, and for moving the headquarters of his Branch of Astrogeology to Flagstaff (from Menlo Park, California) in the near future. He asked Jack to join the Branch in Flagstaff. Jack thought it, albeit briefly, and accepted Gene's offer to be part of the great adventure—and much to the ire of the staff of the geology department at the University of South Carolina. Jack would rapidly become a driving force in the Branch of Astrogeology.

Don Elston recalls:
"I swore in Jack McCauley in a motel room behind the old, Gables Restaurant [presently the Mandarin Super Buffet at 702 S. Milton] in Flagstaff. The motel was crummy, but it was about the best in town. This was February 1963, and it was cold" (from an interview of Don Elston by Gerald G. Schaber on June 18, 2001).

2.13.3-The City of Flagstaff and the U.S. Forest Service Offer Tracts of Land to the USGS for a Headquarters Building and a Lunar-Observing Telescope

McCauley:
"My Geological Survey career began in the newly established Flagstaff office then several months old. I was the second man in a small two person office on the second floor of the Arizona Bank building across from the scenic [Coconino] County Court house (Fig. 8). My senior was a dapper, middle-aged, former photogeologist by the name of Chuck Marshall. He provided me with key reading material and explained the techniques of lunar geologic mapping using telescopic photos and visual observations when the sun angle was low in your quadrangle on the Moon. This was our primary assignment with other duties as they came along. Principal among these was to lay claim to a home for Shoemakers dream that was to have a major lunar research facility in Flagstaff. Gene had cut his teeth on the Colorado Plateau during the Uranium Boom of the fifties and wished to live in this geologic environment. A further and more saleable reason was the proximity to Meteor Crater and the San Francisco Volcanic field. These areas would provide ideal training sites for the Astronauts-an objective for the Flagstaff Center of Astrogeology that Gene was diligently pushing at NASA HQ where he was on temporary duty. Also Gene was sufficiently savvy in the ways of the USGS that he wanted the operation to be away from the somewhat stogy and bureaucratic Regional Centers [of the USGS] such as Menlo Park or Denver. In these establishments there would be interminable backbiting from the old hands who were not convinced we were dealing with reputable geologic problems or that lunar landings would ever occur.

In February of 1963 I had time to go off by myself to see the local geology and the work of Shoemaker and other Colorado Plateau workers. Marshall and I met often with the local establishment i.e. the University and its President, Dr. Walkup who offered us a large part of the" Old Main" Building on the campus with all the necessary renovations for what would have been a modern research of the time facility. Gene Shoemaker and Don Elston turned this down because they felt we would be too [space] constrained in the future' (from an interview with Jack McCauley by Gerald Schaber on 19 February 2001).

Don Elston remembered the following sequence of events associated with the USGS' acquisition of land on McMillan/Switzer Mesa land during his June 18, 2001 interview with Gerald Schaber:

"We found out right about that time [February 1963] that the Forest Service and the City had recently swapped some land. The city had offered some outlying land, and the Forest Service swapped the area that is now Buffalo Park to the city, including the area where Coconino High School is presently located. Jack [McCauley] checked it out and got my attention. So we went up and looked at it, and it looked great. So, we had visions of having houses up there near the Center and everything else. I went over and saw the City Council, and Mayor Wheeler, who had just been elected during our first visit there. Mayor Wheeler and old Maggie Pulliam were sitting there along with some of the others. This was in the little conference room in the building that I think the police occupy now. I asked them, what would you think if we moved a scientific organization here to sort of complement Lowell? God, they thought that would be great! They said how many people? I said somewhere around twenty to thirty people [in the next couple of years] [Authors Note-of course that number was greatly underestimated as it turned out]. They were all for it. I said that we are going to need a place to put a building. That was the beginning of the negotiations for the land on McMillan Heights Mesa [later referred to as McMillan Mesa and Switzer Mesa] (from an interview with Don Elston by Gerald G. Schaber on June 18, 2001).

Jack McCauley:
"Ralph Barney, the City Engineer, said: why don't you guys go up there? I know you guys can do surveying. Survey whatever chunk you want and bring me back a plat. I will take a look at it; check it over, and sign off on it"—which is exactly what we did! This was really my first fieldwork- so to speak—on top of the Mesa there, plane-tabling a 17-acre chunk of ground which we thought would be more than adequate for our needs for the foreseeable future. The City Manager Harry Field, who started the process, ran this thing through the [City] Council. The next thing you know we had a chunk of ground [with a magnificent view to boot!] that we could call our own" (from an interview with Jack McCauley by Gerald G. Schaber on 19 February 2001).

Planetary cartographer Raymond M. Batson (b. 1931), who would for many years lead Astrogeology's "world-renowned" Lunar and Planetary Cartography group (in Flagstaff) in producing high quality cartographic maps of virtually every solid body of any size in the Solar System [except Pluto and its moon Charon], reported to the Survey's Astrogeologic Studies Unit in Menlo Park, California in February 1963 (see Appendices A and B). Ray transferred to Astrogeology from the Photogrammetry Division of the USGS in Denver, Colorado, where he had been working since 1957 doing photogrammetric mapping and field-control surveys. Batson moved to Flagstaff, Arizona in August 1963, about the time that the new Branch of Astrogeology wing at the Museum of Northern Arizona was completed.

Cartographer Russell "Russ" Wahmann (1923-1994) came into the Branch of Astrogeology from the Survey's Topographic Division in Rolla, Missouri—Central Region. He arrived in Menlo Park about six weeks after Ray Batson, but moved to Flagstaff to set up a drafting Unit. Russ moved from Menlo Park to Flagstaff about the same time as geologist Elliot Morris.]

Geologist Gordon Alfred Swann (b. 1931), who would eventually become the Principal Investigator of the Apollo Lunar Geology Experiment for Apollo Missions 14-15, began working with a temporary appointment with the Branch of Astrogeology out of Denver on 18 February 1963; and later became full time. He worked with Carl Roach on Roach's Defense Department-funded (DARPA) project on the effects of high-pressure and high intensity shock on rocks (see Appendices A and B).

[Author's Note: Later (in March 1964), Gordon would be temporarily assigned to the Manned Spacecraft Center in Houston to work with USGS geologist Dale Jackson who was leading the Survey's astronaut training program there at the request of NASA Headquarters. About four months later, Gordon moved back to Denver, and then transferred to Flagstaff, Arizona in October 1964 to begin work with the Branch of Astrogeology Manned Studies Group, working on the Early Apollo and Post-Apollo (AES and AAP) Programs. See 1964.]

[Astrogeology Milestone: Flagstaff's *Arizona Daily Sun* newspaper on Monday March 4, 1963 carried the byline "Astrogeology Unit to use Mesa land"

The article continued:

"Flagstaff's City Council today unanimously approved action that will lead to the establishment this year of a major U.S. Geological Survey facility in Flagstaff that is intimately concerned with America's Apollo-Astronaut-On-the Moon Project.

The Council, at a hastily called special meeting, authorized Mayor Rollin W. Wheeler and other top city officials to negotiate with federal authorities for the lease and eventual purchase of a ten-acre tract of land on the city's McMillan Heights property for the new USGS' astrogeology facility.

The building says Charles Marshall, geologist-in-charge of the USGS Astrogeology Observatory here, will house a Branch Chief's office, electronic laboratories, photographic facilities, shops, and a large lecture room.

Location of the facility in Flagstaff, Marshall also told the Council, will mean an initial annual payroll of about a quarter of a million dollars for some 28 employees. Eventually, he added, a large portion of the USGS' Astrogeology Branch's operation in Washington D.C., Denver, Colorado, and Menlo Park, California will be moved to Flagstaff.

The building, to be designed to be compatible with the forested landscape of McMillan Mesa, will be located some 500 feet back from Cedar Road and will have between 10,000 and 15,000 square feet of floor space, Marshall said. The geologist gave no estimated cost of the facility, which will be linked to lunar research and geological mapping with a new 30-inch telescope to be erected this spring on Anderson Mesa. He said final government approval of the building would take approximately six weeks, after which time, work could be started. He said he expected the building to be complete and ready to go sometime this year. City Attorney Neil Christensen explained to the Council that rezoning of the area is not necessary as it is presently zoned R-1 which allows federal usage.

The Council's unanimous action gives Mayor Wheeler, Christensen, City Manager C.T. 'Maggie' Pulliam, and City Clerk Harry Field Jr. authority to negotiate with the government for the land. The USGS Astrogeology Branch has been working at Lowell Observatory here for a number of months on its lunar mapping project and in January the nine Apollo astronauts [will be here] to brief them on lunar geology and geography" (Arizona Daily Sun, 4 March 1963).

[Important Astrogeology and Flagstaff Milestone—In a letter dated 12 March 1963, Gene Shoemaker wrote the following Memorandum to the Chief Geologist of the USGS through the Assistant Chief Geologist for Interagency Programs and Supporting Activities:

Subject: Transfer of Branch Headquarters to and establishment of research facilities at Flagstaff, AZ

Director's approval is sought in regard to moving Branch Headquarters to Flagstaff, Arizona and to establishing a research facility in that city. It is proposed that a major part of the Lunar and

Planetary Investigations of the Branch and a large part of the Crater Investigations (including Solid State Studies) be carried out in Flagstaff. A third part of the Branch program, field studies in support of the national space flight program, would also be centered at Flagstaff. The effectiveness of the Branch program has suffered to date because people are widely scattered, and efforts that should be closely coordinated are fragmented. The purpose of the proposed moved to Flagstaff is to draw together some of the major pieces of the program at a locality where certain vital research can be carried out efficiently and effectively.

Flagstaff has advantages that lend direct and indirect support to the Branch program. These include (1) observatory locations, observatory facilities, and an astronomical community with its wealth of "know-how," and (2) proximity to a variety of geologic features that might be expected on the moon. Because most geologists in the Branch are responsible for earth-based projects as well as for lunar geologic maps, efforts of individuals can be directed toward "down-to-earth" studies between periods of telescopic observation of the moon needed for the lunar mapping.

A research center that is largely self-sufficient could be set up with little increase in the manpower in Branch, and cost of rental (lease) to house the effort would amount to a few percent of the Branch budget per year.

It is proposed that a facility be built with private capital, be leased by the Government for a 10-year period, with renewable lease option, and that an option to buy be available to the Government. General Services Administration would handle all details relative to final exterior design and architectural specifications (an architect-engineer would be brought in); GSA also would process all specifications and bids, and make the lease arrangements. A representative of the GSA has estimated that, in the case of private construction under $200,000, the building would be completed for us in about six months; if the cost is more than $200,000, an extra three months could be added for paperwork attendant with processing in Washington. Private capital, it was stated, appears to be readily available for this type of investment-all that is needed is assurance of a relatively long lease so that the investment capital can be at least partly amortized. The Government in this case could and probably should retain title to the land [which it never did].

Space proposed to house the center grosses about 17,700 square feet; the building cost might be in excess of $250,000. There are approximately 12,000 square feet of useable space shown in the detailed plan that accompanies the memorandum. At an established lease cost of about $3.50/sq. ft., annual rental for the building would be about $42,000.

Very choice land has been made available to us by the City of Flagstaff for the construction of a research center, (copy of letter enclosed). The site is within the City of Flagstaff and is on a mesa that separates the eastern part of Flagstaff from the western part; the site is centrally located, and is a short distance north of the downtown area. Most parts of town are only a few minutes drive away. There is room for expansion on the site, and water, natural gas, sewage, and power all are available. The site commands a panoramic view of the San Francisco volcanic field.

The following work and activities would be carried out or headquartered at the center:

1. Lunar geologic mapping
2. Lunar photometry
3. Colorimetry
4. Infrared investigations
5. Earth-moon libration region studies
6. Cometary studies
7. Terrestrial impact structures
8. Investigation of diatremes and maars
9. Solid state investigations (Thermoluminescence, exo-electron emission)
10. Shock equation of state
11. Simulated lunar field studies
12. Electronic instrumentation for image enhancement, solid state studies, and simulated lunar field studies
13. Instrument shop for telescope support
14. Astrogeological library
15. Lunar plate library and photographic and photomechanical support

Geologists offices have been designed at approximately 240 square feet each because expensive layout and tack-up space is needed in lunar geologic mapping; the identification of individual features on photographs of the lunar surface is done by reference to many photographs showing the surface and features under conditions of different illuminations. With availability of the Pic du Midi photographs from Lowell Observatory, one of the two international plate libraries, and with lunar photography developed under the Branch program, the numbers of reference photographs will increase. The rooms have been designed so that the geologist can in one part of the room literally surround himself with photographs—both laid out on tables and tacked on a wall board to which there is ready access (the wall board extends the length of one wall). The remainder of the space in individual geologist's offices can be used as more standard office space for other concurrent investigations. In event of an increase in personnel beyond the designed-for space, the individual offices are large enough so that a second geologist can be temporarily moved in, with the removal of some of the furniture.

The cartographic and photographic workshops are designed to enable us to scribe final color separation sheets directly from manuscript maps, and to continue to compile a reference library of lunar photographic plates, as well as to process lunar plates obtained with our own telescope facilities. Photographic facilities will enable us to construct base maps for special detailed investigations.

A machine shop and an instrument maker are needed for telescope and electronic instrument modification. Instrument recording of telescope information requires home designed and hand-fabricated mountings for the instruments.

The electronics laboratory will give "across the board" instrumental support to the Lunar and Planetary Investigations Program, to Crater Investigations, and to Manned Lunar Science support.

The solid-state laboratory will include a rock preparation section, a physical properties section, an electronic-optic section, and an X-ray chemistry section. A supporting core and sample storage building and sedimentary petrology room have been included in the plans. Adjacent to the core storage facility is a pad for the 10' X 30' mobile analytical laboratory, which is designed for on-site solid state investigations.

The timing for the transfer of Branch Headquarters to Flagstaff would be mid-summer to early fall of this year, during which interval several of our geologists would move to the Flagstaff area. Adequate temporary office space appears to be available. A physical move into new quarters for the geologists would take place by late fall to early winter, in part accompanied and in part followed by establishment of laboratory and shop facilities. The end of FY 64 would see the center nearly fully operational."

Don Elston:
"The plan [for Astrogeology's requested 17-acre plot on McMillan Heights [also called McMillan Mesa] went promptly as the city didn't waste any time [see above]. Meanwhile, we had to find other places in town for people who were going to move to Flagstaff before the new building could be designed, constructed, and occupied" (from an interview with Don Elston by Gerald G. Schaber on June 18, 2001).

Jack McCauley:
"I went to see Ned Danson, Director of the Museum of Northern Arizona (MNA). Danson graciously offered to build a wing onto the existing Biology Facility so that we could begin a working presence in the city.

[Author's Note- Ned Danson, who passed away in 2005, is the father of popular television and film actor Ted Danson of "Cheers" fame.}

Jack McCauley Continues:
In the meantime, the few of us that had arrived in Flagstaff left the two person office in the Bank Building and spent the Summer in the Hopi House, a collection of small buildings on the grounds of the Museum. It was a temporary arrangement until the addition to the biology building was completed [see September 1963 below]. In the meantime, negotiations were going along well with the city to obtain a large enough tract of land [on McMillan Mesa] upon which we could build a facility that would enable us to complete the many new tasks we were taking on. Don Elston was commuting back and forth from Menlo Park. He was Acting Branch Chief while Gene was off in Washington lining up new projects.

At the time we were also trying to use the 24" reflecting telescope on the south edge of Northern Arizona University (now engulfed by campus housing). We were attempting to supplement the current catalogs of good lunar photographs with visual observations to prepare geologic maps of the Moon. Also we were to arrange telescope time for other mappers who had joined the Branch some months earlier and who were still quartered in the Menlo Park facilities of the USGS. The new people that Gene Shoemaker brought in were mostly in their early thirties, from good geology departments and full of vitality and talent". (From the memoirs of Jack McCauley, unpublished; and from an interview with Jack McCauley by Gerald Schaber on 19 February 2001).

Jack McCauley:
One of our additional tasks [starting in 1963] was to secure from the local well established Astronomical Community observing time on various telescopes that were not fully booked. This brought me into contact with a very capable group of people who were part of an Air Force lunar topographic mapping unit that was based in St. Louis (ACIC) but operating at Lowell Observatory [see 1960 above]. They were using the famous 24" refractor that was used by Percival Lowell in studies of the telescopic "canals" of Mars. The group was headed by Bill Cannell, whose training was, I think, in cartography. Bill and I became quite close professional friends. He and his group [including Pat Bridges mentioned earlier; see 1960] produced very credible lunar maps at the 1:1,000,000-scale that the USGS people used as base maps for their geologic interpretations. The task was enormous, involving some two dozen mappers working on the 44 Quadrangles that comprised the near side of the Moon. The task was not completed until after the Apollo landings were over.

Chuck Marshall conducted a "seeing" study around Flagstaff and found that the north part of Anderson Mesa—just south of town—was the best location for telescopic observations. Gene was looking forward to the USGS having its own telescope" (see 1964) (from the memoirs of Jack McCauley, unpublished; and from an interview with Jack McCauley by Gerald Schaber on 19 February 2001).

[<u>Astrogeology Milestone</u>: In April 1963, the Branch of Astrogeologic Studies submitted its first Annual Progress Report for Astrogeologic Studies to NASA Headquarters for work accomplished during the period 25 August 1961 to 24 August 1962. The report contained reports on Lunar Geologic Investigations, Crater Investigations, Cosmic Chemistry and Petrography, and Studies for Space Flight Program.]

The following was taken from the Branch of Astrogeology Monthly Report for April 1963 to V.E. McKelvey from the Chief, Branch of Astrogeology; dated 30 April 1963:
D.J. Milton has identified Stishovite in sandstone that had been explosively shock-loaded by P.S. De Carli of Stanford Research Institute (Menlo Park, California). This is the first crystalline phase, other than diamond, to be synthesized by shock in the laboratory.

[<u>Space Exploration Milestone</u>: On 16 June 1963 Vostok 6 carries Soviet cosmonaut Valentina Tereshkova, the first women in space, around the Earth 48 times.]

2.13.4-The Headquarters of the Branch of Astrogeology Moves to Flagstaff, Arizona

[<u>Astrogeology Milestone event</u>: On July 1, 1963 the headquarters of the Branch of Astrogeology officially moved to Flagstaff, Arizona.]

The following was taken from the Branch of Astrogeology Monthly Report for July 1963 to V.R. Wilmarth from the Chief, Branch of Astrogeology; dated 31 July 1963:

Harold Masursky and Elliot Morris worked with Robert Morgan, consulting engineer, on design of a new camera for the 120-inch reflecting telescope at Lick Observatory for lunar photography. With the new design we hope to obtain three times as many high quality photographs which will greatly accelerate the lunar geologic mapping program at the Branch of Astrogeology.

E.D. Jackson and R.E. Eggleton arrived at Houston, Texas to begin a project at the Manned Spacecraft Center. The group, which will eventually number five geologists and one geophysicist, will act as consultants to Space Environment Division, MSC, and will design and teach a program of field geology, geophysics, and astrogeology for the astronauts.

David Levy (Levy, 2000) documented the events regarding the onset of Shoemaker's serious illness:

"In the spring of 1963 the last Mercury flight coincided with a trip Gene took to Houston. It left him exhausted, but a visit to his physician still did not reveal the cause of his malady. In June Carolyn and Gene decided to take a river trip, a total vacation for a few days. By the time they got off the river, Gene was so tired that he could hardly move; his skin became even darker, even on the palms of his hands. Again, his doctor did not have any answers.

By the fourth of July, his weight was down to 128 pounds, and he looked, Carolyn remembers, like a refugee from a concentration camp. It was time to try another doctor. "Oh", the new physician said, "you look like you have Addison's disease. I've seen two other cases like this, and of course they both died!

Named for Thomas Addison, the English physician who recognized it in 1855, Addison's disease is the result of the atrophy of the cortex, or outer layer, of the adrenal gland. Gene shared this disease with another Washingtonian at the time: President Kennedy had it as well, although the fact was not widely known. Before Gene and Carolyn got too discouraged, however, the doctor said that cortisone was showing very promising results for Addison's patients.

The day after he was hospitalized, he underwent several tests that confirmed the diagnosis of adrenal cortex shutdown. The following day he began taking cortisone tablets, and the day after that, says Carolyn, he was a new man. His condition improved dramatically by the hour, and he went home feeling stronger and more optimistic that he had felt in months" (Levy, 2000, p. 88-89).

Shoemaker himself recalled the events in an interview with Bill Phinney:
"By the time I had arrived in Washington in September [1962], I was going down hill. My adrenal cortex just went flooey. It stopped. That's a bad situation and if you don't do something about it you're dead in two years. I went to see a physician and he said yeah, you're anemic, your blood pressure is low and blah, blah, blah; but he couldn't pinpoint what was wrong with me. It took me seven or eight months before I finally figured it out. In the meantime, I was going downhill fast. By spring [of 1963] I couldn't squat down on my haunches, I was losing control of my speech and I had uncontrollable spasms of hiccups, my palms were turning brown, and I had no energy. I'd collapse on the couch when I got back home at night. Thank god it was diagnosed. That just totally transformed my life. In 24 hours I felt like a new human being as

soon as I got some hydrocortisone in me. So by the time that Carolyn and I got back out in Flagstaff [summer 1963—from his TDY at NASA Headquarters in Washington] I was doing pretty well. I was still pretty thin, but by then I went down to about 145 pounds" (from an interview by William Phinney with Gene Shoemaker on 21 April 1995 in Flagstaff).

[Author's Note: Of course his illness dealt a fatal blow to Gene's 1948 vision of being the first geologist-astronaut to explore the lunar surface. Geologist Harrison "Jack" Schmitt, one of the early hires for Gene's own Branch of Astrogeology, would, however, become that first geologist-astronaut to explore the surface of the Moon. The last known interview with Gene Shoemaker took place in Flagstaff on 21 April 1997, just under 3 months before Gene's untimely death in an auto accident near Alice Springs, Australia on 17 July, 1997 (see 4.B.-The Tragic Loss of the "Father of Astrogeology below). Flagstaff resident and amateur historian Harry Ryan asked Gene "what where your thoughts when watching Jack Schmitt launch from the Cape to the Moon for Apollo 17." Gene said "There, but for a damn adrenal gland, go I!"]

[Branch of Astrogeology Milestone- At the end of July 1963, Shoemaker's one year assignment time with NASA Headquarters in Washington D.C. was over. "Despite his poor health, Gene had successfully launched a full Geological Survey Branch of Astrogeology and had persuaded the Survey to locate it in the northern Arizona town of Flagstaff" (Levy, 2000, p. 89).]

Don Beattie:
"At the end of July 1963, as one of his last actions while at [NASA] Headquarters, Gene Shoemaker sent a letter to Wernher von Braun, the Marshall Space Flight Center director, asking MSFC to suggest what types of scientific activities should be undertaken on the ALSS (Apollo Logistics Support System) missions. Verne Fryklund—Shoemaker's successor at NASA continued this effort—and I in turn inherited this inquiry when I informally joined the staff" (Beattie, 2001, p. 29).

Don Beattie:
"When Shoemaker left [NASA HQ], Verne C. Fryklund, who had been working on [Homer] Newell's staff, took his place. Fryklund was definitely from the old school. Gruff, with a bushy mustache and a half-smoked but unlit cigar perpetually in his mouth, he usually looked professorial in a tweed jacket with leather elbow patches. Being detailed from the USGS, he was given the title of acting director, Manned Space Sciences Division, Office of Space Sciences. His primary duty was the same as Shoemaker's—to be the go-between for the Office of Space Flight and the Office of Manned Space Flight. During his shuttle diplomacy, he was to present the interests of the science community to NASA's manned space side, which was not viewed as friendly to science. Fryklund became my unofficial second boss. By Washington standards his title was not imposing, especially with the "acting" designation [see above]. His staff was appropriately small, consisting of several Headquarters staffers and a number of detailees, including geologist Paul Lowman from the Goddard Space Flight Center (GSFC) and several others from the Jet Propulsion Laboratory (JPL). Thus, he was receptive to having me join the office" (Beattie, 2000, p. 6).

Don Wilhelms:
"Dick Eggleton accompanied [USGS geologist] Dale [Jackson] in July 1963 as a temporary assignee [to Astrogeology's astronaut training group at MSC]. In that same month, the telephone rang while I was sitting at [French astronomer] Dollfus's desk in Meudon, France with a call from Shoemaker asking me if I would move to Houston as the resident lunar expert. I had been studying the Moon for six months. I did not hesitate to accept, despite my desire to remain in the San Francisco Bay area, and I arrived at Ellington Field in October 1963 along with geophysicist Marty Kane. One old-fashioned field geologist, Alfred Herman "Al" Chidester (1914-1985) had arrived in August, and another, Gordon Alfred Swann (b. 1931), would arrive in March 1964. Impact expert Dan Milton also arrived in March 1964 to complete the USGS crew for what we all thought would be a two-year stint. An intensive 58 hours of classroom lectures and numerous field trips was planned. The USGS people would take the lead in the geologic aspects of the courses; our NASA counterparts would concentrate on mineralogy and petrology; both groups would conduct the field trips. Dale was to be overall boss but would plan the program jointly with the leader of the NASA group, Ted Foss.

One of the casualties of MSC's newfound interest in geoscience was the Survey's control over sample analyses. Already, by 1964, meteoriticist Elbert King (1935-1998), who had joined the NASA group in August 1963, began to plan what eventually became the Lunar Receiving laboratory (LRL)" (Wilhelms, 1993, pp. 77-78).

Jack McCauley recounts making a trip in July 1963 down to Tucson in the company of Bill Cannel with the ACIC group in Flagstaff to look at the new telescope being built at Kitt Peak:

Jack McCauley:
"We found that the thing they were calling the Solar Telescope was odd in that it was a slanting tunnel that went down to a table at the bottom with a white-circular, reflecting surface on it. And at the top, was a 36-inch mirror that followed the sun during the day. The idea was that you could use this in such a way that you didn't have to look directly at the Sun. We wondered if this thing wouldn't be useful in looking at the Moon. So, we tried that, and darn if it didn't project about a 36-inch wide view of the Moon on this platen table. Then, we got Elliot Morris to build us some little viewers where we put in some slanted mirrors and added an ocular with a magnifying glass on it. You could move this around "on the Moon" and look at areas in detail. Also, a bunch of people could get around the table and look at different parts of the Moon at the same time! We later [20-22 May 1964] used this for an astronaut-training trip where they could see the Moon "live" so to speak for the first time" (from an interview with Jack McCauley by Gerald G. Schaber on 19 February 2001) (See 1964 for more details on astronaut-training trips to Kitt Peak on 20-22 May 1964.]

Geologist Alfred Herman ("Al") Chidester (1914-1985) was lured away by Dale Jackson/Shoemaker from his work for the Survey in Denver by the opportunity to participate with the Branch of Astrogeology's newly organized astronaut training group at MSC in Houston. Al arrived in Houston in August 1963.

The following was taken from the Branch of Astrogeology Monthly Report for August 1963 to V.R. Wilmarth from the Chief, Branch of Astrogeology; dated 29 August 1963:

Study of the extreme western limb region of the Moon by John F. McCauley has revealed a large basin of possible impact origin (Mare Orientale; diameter 320 km), which is surrounded with three concentric scarps that exhibit a radial "groove" pattern and a hummocky surface texture…. If the Orientale Basin is an impact structure of post-Imbrian age as suggested by preliminary study, its regional material may provide a key to the stratigraphy of the southwestern part of the visible lunar surface, and also would provide a means of correlation of units beyond the western limb, into the far side of the Moon, a region for which photography is not yet available.

A regular Branch observing schedule for lunar geologic mapping has been instituted for the 60-inch McMath Solar Telescope at Kitt Peak Observatory near Tucson, Arizona

Jack McCauley:
"During August, 1963 transfers from other USGS offices began arriving as the temporary quarters at the Museum [of Northern Arizona] neared completion. The overflow was housed at the Hopi houses on the Museum grounds, which were built to house the various Indian artisans during the time of their annual show over the July 4 holiday. There was a short stay for some of us in the Burris Building. It is located at 119 E. East Aspen Street, directly behind the Bank of America Building (then, the Arizona Bank Building. It was a rather gloomy place wherein I labored along with Larry Rowan a new hire geologist and Jim Alderman a photogrammetry type from the Topographic Division of the USGS and several others. We had more elbow room than in the Hopi Houses and several major new projects had come to us from NASA wanting to know where it was safe to land with Men on the Moon. These led in the following years coming to an assemblage of different approaches to the problem. These later would become a separate part of the Branch with the title of Terrain Analysis and distinguished from the more academic geologic mapping efforts mostly in Menlo Park. Shoemaker was named as the Principal Investigator on the Unmanned Surveyor Project and this would occupy his talents and those of a sizable team anchored by Elliot Morris and Ray Batson. These were very heady times with projects coming as fast as we could staff them and to produce meaningful data for the engineering people in NASA" (from the memoirs of Jack McCauley, unpublished; and from an interview with Jack McCauley by Gerald Schaber on 19 February 2001).

[Author's Note on the Burris Building: Don Elston had leased the Bank Building around the third week in July 1964 to provide additional space for personnel coming on board to work with the rapidly growing Branch of Astrogeology. The Burris Building, where NACO (National Arizona Council of Governments) is presently located], is located at 119 E. Aspen Street in downtown Flagstaff—directly behind the present Bank of America (then Arizona Bank Building) on Birch Street (see Fig. 8). The Burris building was occupied until about the time that the Astrogeology Headquarters Building was completed on McMillan /Switzer Mesa and a number of Branch personnel began occupying the 4th and 5th floors of the Arizona bank Building.

Geologist Howard Wilshire (b.1926) was transferred from the U.S. Geological Survey's Kentucky mapping project to the Branch of Astrogeology in September 1963. He reported to Denver, Colorado, to work with Carl Roach's solid state/shocked rock investigations. [At Shoemaker's request, Howard moved from Denver to the Astrogeologic Studies office in Menlo Park, California in 1967 and remained with the Branch until 1976 (see Appendices A and B).]

[Astrogeology milestone:-In September 1963, most Branch of Astrogeology personnel moved into the new wing at the Museum of Northern Arizona that Edward Danson (Museum Director) had built for them (from a graph paper sketch given to Ned Danson, Director, only about three months prior).]

In September 1963 Flagstaff's *Arizona Daily Sun* carried a byline: New Astrogeology HQs Completed and Atmospheric Sciences Center started"—"Museum of Northern Arizona Marks Two Milestones." The accompanying article goes on to say the following:

"Flagstaff's Museum of Northern Arizona passed two significant milestones this weekend—completion of a $39,000 facility for the U.S. Geological Survey's Astrogeology Branch and the start of a $35,000 atmospheric sciences research center for the giant State Universities of New York. Museum Director Dr. Edward B. Danson, in an informal ceremony Saturday morning, turned over the keys to the new Astrogeology building to Dr. Eugene Shoemaker, Chief of the Astrogeology Branch of the USGS.

The Branch, which is moving its headquarters here from Menlo Park, California, began moving in immediately, and Shoemaker said "we hope to be operating out of our new building here at the Museum's research Center in the very near future.

Most immediate and most dramatic project to be undertaken at the new facilities involves the Astrogeology Branch, which Shoemaker said, would have at last 20 on its staff in Flagstaff by the end of the year.

This work involves the field testing, in the Flagstaff area, of delicate television camera equipment to be included in the "Surveyor" project, which involves the "soft landing" of an unmanned, instrument-laden, spacecraft on the surface of the Moon.

The "Surveyor" project work is another of the projects assigned to the Astrogeology Branch by the National Aeronautics and Space Administration (NASA) in line with the nations continuing efforts to put a man on the Moon.

For well over a year, the Astrogeology Branch has had scientists in Flagstaff, using facilities at Lowell Observatory, making the first geological maps of the visible lunar surface, following geographical maps also being made here by observers and cartographers of the Air Force's Aeronautical Chart and Information Center [ACIC].

The Branch's new headquarters at the Museum's Research Center is again only temporary and will serve until a major facility, to be located on the city's sprawling McMillan Mesa tract in the center of the city, can be completed. Along with this building, which will include not only office space, but laboratories and a full printing plant for printing lunar geological maps, the branch is currently building its own observatory on Anderson Mesa, some 12 miles southeast of Flagstaff, which will house a 29-in reflecting telescope specially designed for lunar and planetary work.

When the Astrogeology Branch is finally ready to move into its final and permanent headquarters, the building at the Research Center will be taken over by the Museum for use in its many and varied research activities.

Shoemaker, who is Chief of the important, newly-formed Manned Space Sciences Division of NASA's Office of Space Sciences, explains that the Surveyor TV systems tests are vital because the system will serve as the "eyes" of the scientists here on earth in investigating the lunar surface, geologically, topographically, and otherwise, and in preparing for the "climactic" Apollo man-on-the Moon shot.

Working with Shoemaker here on astrogeological research are top scientists from various major universities, including Caltech, where Shoemaker is a faculty member, Stanford University and Rice University, as well as other top geologists who are already working on the lunar mapping phase of the program."

Don Beattie:
"During 1963, the year I came, NASA Headquarters almost doubled in size. Brainerd Holmes, who until September [1963] had been in charge of manned space flight operations as director of the Office of Manned Space Flight, resigned and was replaced by George Mueller from Space Technologies Laboratories. Mueller was given the new title of associate administrator, Office of Manned Space Flight, a third tier of top management just below administrator James Webb and his deputy, Hugh Dryden and associate administrator Robert Seamans. Homer Newell was elevated at the time to a similar position with the title associate administrator, Office of Space Sciences and Applications (OSSA). With his appointment, Mueller introduced a different management style to Manned Space Flight, one that would have a profound effect on Project Apollo's future.

In the wave of reorganization, [Verne] Fryklund's tenure as acting director was short-lived. Homer Newell, in agreement with Mueller, formally established the Office of Manned Space Science, reporting to both his office and Mueller's. Willis Foster was brought in from the Department of Defense as the new full-time director, and Fryklund became Foster's chief of Lunar and Planetary Sciences. After some eight months working for Foster, he [Verne Fryklund] transferred back to Newell's staff, and a short time later he returned to the USGS to work in its military geology branch" (Beattie, 2000, pp. 10-11).

Jack McCauley:
"In October 1963 the Second Meeting of the Working Group for Extraterrestrial Resources was held at Holloman Air Force Base in New Mexico. It was attended by several of the Flagstaffers—Don Elston, Elliot Morris and Jack McCauley—a chance to rub elbows with some of what was then the lunar establishment" (from personal memoir of Jack McCauley, unpublished).

Throughout the decade of the 1960s much to-do was made over "transient phenomena," that is, telescopic sightings of flashes, clouds, and so forth on the Moon's surface:

Don Wilhelms:
"On 29 October 1963, experienced ACIC observer Jim Greenacre at Lowell Observatory [in Flagstaff, Arizona] reported red spots at Aristarchus, the Cobra Head, and Schroeter's Valley on the Moon. The fact that Greenacre's favorite drink was boilermakers aroused some skepticism, but the observations were confirmed the same night by new observer Edward Barr and later by three others, including John Hall, the director of Lowell. I held up the newspaper headline, "Moon 'Eruptions' Seen Here" [See related article in Flagstaff's *Arizona Daily Sun;* 31 October 1963] for viewing of my Menlo Park colleagues arriving at the Flagstaff airport. The Moon seemed to be volcanically active" (Wilhelms, 1993, p.73).

Don Wilhelms:
"We were in Flagstaff at that time [1-3 November 1963] for a three-day meeting of the dozen astrogeologists who then made up most of the Branch's scientific talent pool. The meeting would change the way the Moon was interpreted and manipulated geologically. The old guard of Gene Shoemaker, Bob Hackman, and Dick Eggleton were called on to defend their concepts by the more recent mapping recruits Mike Carr, Don Elston, Hal Masursky, Jack McCauley, Dan Milton, Henry Moore, Spencer Titley of the University of Arizona, and myself [Don Wilhelms]. The fourth early mapper, Chuck Marshall, was probably also present—but during the month ended his three-year association with Astrogeology to pursue art full time.

The [Flagstaff] conference was much concerned with a scheme for conveying age relations of lunar geologic units on geologic maps. In the early 1960s, after two-thirds of a century, the USGS followed Gilbert's lead in establishing the stratigraphic framework of the Moon. Gilbert had divided lunar stratigraphy into pre-Imbrium ("antediluvial"), Imbrium, and post-Imbrium ("postdiluvial") classes. Knowing that the Imbrium differed in age, Hackmann and Mason showed mature mare and postmare units. Most observers—even [Harold] Urey—had realized that rayed craters are the Moon's youngest; and Shoemaker, while mapping the Copernicus region, had seen the rays of Copernicus crossing the (seemingly) non-rayed but also postmare crater Eratosthenes. Add Archimedes and the plains sandwiched between its deposits and the Imbrium basin and you have a quite complete sequence just on these few observations. Shoemaker, first on the Copernicus prototype map and then formally in the Shoemaker-Hackman paper, had attached "system" names to the divisions suggested by these relations: pre-Imbrium, Imbrium, Procellarian (the mare material), Erathosthenian, and the youngest, Copernicus" (Wilhelms, 1993, pp.73-74).

Geophysicist Martin F. "Marty" Kane (b.1928) arrived at MSC in Houston in the fall of 1963 to work for the Branch with Dale Jackson who was heading up Astrogeology's astronaut-training group there (see Appendices A and B).

Sadly, the Survey's Dale Jackson and MSC's Ted Foss [the lead geologist in MSC's astronaut training group who had mysteriously appeared out of nowhere] became engaged in what Gordon Swann refers to as a "turf battle" (not a healthy situation—but rather destructive) with regard to astronaut training leadership in Houston. As mentioned above, the Survey' astronaut training group would be augmented in 1964 with Gordon Swann and Danny Milton who would stay less than one year][See 1964.]

Marty Kane believes that the problem they ran into was that none of the MSC geology-types were trained [or had sufficient experience].

Marty Kane:
"The problem we had was that we couldn't mesh with them. There was also kind of an attitude problem with the two guys there at MSC above Ted Foss. The one I dealt with; I can't remember his name—but he didn't have any experience of any kind. Then, they had a guy above him! He was like a GS-16 [<u>Author's Note</u>: Marty is here probably referring to Max Faget and/or John Eggleston]. He was a competent man, but he laid on us to the effect that we should be so happy to be working with NASA. And we said no, we're experts in what we do and there

was this [real] “need’ for us to be here. There were these two basic things [problems]. One was that we should be kind of differential to them because we had the “privilege” of working with them. That didn’t mean squat, you know, because in the Survey one is so independent that even your Branch Chief has trouble telling you what to do. And the other thing was that the people we were dealing with [down there] were simply not professional and we, I am sure, intimidated them because we knew exactly what we were doing” (from an interview of Marty Kane by Gerald G. Schaber on January 23, 2001).

Gordon Swann:
“Unfortunately it boiled down to a personality clash between two pretty good guys. The people at MSC were very competitive and possessive about who controlled what about going to the Moon. Dale Jackson was a rather senior, well-thought-of scientist with a lot of experience, a good publication record, and a “lot” of confidence. Ted was a young guy just out of school that probably felt rather intimidated. Dale was one of those strong personalities; when he walked into a room, you knew it. He was one of those people whose presence could be felt. At the same time, Ted’s bosses [Max Faget and John Eggleston at MSC] wanted to take over the geologic training themselves, and in my opinion pretty much instructed Ted to give it a shot and try to take it away from the Survey. But our approval to do the geologic training had come out of NASA Headquarters. So that resulted in some rather unhealthy competition that took a while to go away-but it did eventually I believe” (from a filmed interview of Gordon Swann by Harry Ryan in 1996).

[Author’s Note: This situation eventually led Shoemaker to pretty much disband Jackson’s astronaut training group in the fall of 1964; sending most of them back to Flagstaff, Menlo Park, or from whence they came, and bringing Chidester to Flagstaff to try and re-organize the geologic field-training of the astronauts from there.]

Gordon Swann:
“The first geologist in the training group at MSC was Curtis Mason who had a degree in geology. Curtis was a pretty good guy but had some limitations; however, he recognized them. He was their geologist until they hired Ted Foss—who was a good geologist. Elbert King, Uel Clanton, John Dietrick and David Strangway also became part of the MSC geology group. David Strangway was a real geophysicist.

Houston had hired Texas Instruments (TI) to do a study of what type of geologic hand tools would be needed on the Moon. I think that Texas Instruments hired a consulting geologist part time to help them on this project. They had several ideas—and we went to a review [of these ideas]. We were sent over there by our boss [at MSC] Dale Jackson to go listen in.

One of the first things they [TI] learned apparently was that geologists used Brunton Compasses. Everyone knew that the Moon did not have a magnetic field! So, on paper, they had developed a gyroscope kind of thing that ran off a little battery, and the astronaut could carry it around and use it like a Brunton. [Colleague] Danny Milton [who had attended the TI review with Swann] looked at me and said why not use a sun compass? The Sun doesn’t move very rapidly on the Moon, and in addition, we know exactly where it is relative to any place on the Moon at any time.

We also suggested having a thing with a gnomon (a thing that casts a shadow, such as on a sun dial). They ended up taking a gnomon [to the Moon]. It was a three-legged thing with a vertical gimbal that was weighted on the bottom. They [the astronauts] would put it out on the lunar surface; it would seek local vertical, and if it was in the field of the camera—by the shadow you could get both local vertical and the precise pointing angle of the camera lens from the shadow.

Then, they started talking about the need to bring the samples back from the Moon in their pristine vacuum condition—in case Earth's atmosphere would react with them. So they were talking about these little hermetically sealed things about the size of a beer can that you could put a rock in—and seal. I nudged Danny [Milton] and said have they ever heard of a pressure cooker? Why can't they just take along to the Moon a big pressure cooker, take it outside, open the lid and let it out-gas, dump the rocks they had collected in there, and seal it shut <u>before</u> it goes back into the LM (Lunar Module]?

Both of these things were suggested in that "Green Monster" [an early Astrogeology Interagency Report with a green USGS cover sheet]. Both of them flew on the Moon missions. They called the sample box the "Sample Return Containers", or SRCs. As Swann had suggested, they took them outside when they first landed on the Moon—opened them up—let them de-gas to remove any residual gas from Earth to sterilize them, then put the samples in, seal the SRCs, and take them back into the LM for transport back to earth where they were then unpacked in a vacuum environment" (from a filmed interview of Gordon Swann by Harry Ryan in 1996).

[<u>Author's Note</u>:-Gordon recalled to me that every one of the SRCs returned to Earth was found to have a hard vacuum in them when they were opened at the Lunar Receiving Laboratory at MSC in Houston.]

Gordon Swann:
"There were all kinds of problems being dreamed up about using a rock hammer on the Moon—they can't swing the hammer in one-sixth gravity because they would go flying off in another direction! Well, NASA was flying a couple of KC-135 aircraft that could maintain zero gravity for about thirty seconds. A guy named Jack Slight, who was the main guy that ran these tests, had no trouble breaking rocks in a one-sixth gravity aircraft. He just had to be sure and "anchor" himself first.

Well, the next problem that the NASA folks came up with was flying rock chips; they were going to punch a hole in the spacesuit. I argued that I had broken thousands of rocks with a hammer and have had hundreds of rock chips hit me, but they don't even go through a thin everyday work shirt—let alone a spacesuit. However, if that is going to be a problem, let's just take along a little fine-mesh, soft screen. They can lay it on the rock and whack it. Well, it turned out that, with the one-sixth gravity tests and all that, the screen wasn't needed after all" (from a filmed interview of Gordon Swann by Harry Ryan in 1966).

Hoover Mackin, at the Falmouth Conference, wanted his "Hoove Tubes," or the drive tubes. Those things were really embraced [by NASA]. Hoover was a very well-known and well-liked guy. And it turn out [from testing] that you had to have a "hammer" to drive the core tubes. So the rock hammer flew. And of course they didn't use it on Apollo 11 for any other purpose [due to lack of time] but to drive the core tubes.

[Author's Note- At the next LSOP meeting following Apollo 11 some guy asked Gordon Swann what kind of tools do you want to fly on Apollo 12? Swann said a hammer of course. The NASA guy ask "why the need to fly a hammer; you've already done that experiment." Engineers are always thinking like engineers—they will never ever learn to think like a scientist—especially a geologist!]

Geophysicist Marty Kane recalled:
"Our thought during the Houston astronaut training activity was to bring into the geologic field training the best people we could find, besides ourselves; people like Dick Jahns from Stanford—and we [but not the relatively inexperienced MSC geology staff] had the contacts to do this. Anyway, if the MSC geology group had been smart, they would have gone along with us [instead of fighting the Survey group every inch of the way] and —you know—did things a little different, they could have done useful things with us. But they indeed wanted more control of the [astronaut training] program—and we refused to give it to them. And [besides] Dale [Jackson] was pretty feisty! He told them in no uncertain terms. Al Chidester and I just set back, basically. I don't remember any [personal] confrontations with them. However, we would kind of ignore them.

During the little over a year that I [Marty Kane] was in Houston/MSC with Astrogeology's astronaut training group I started negotiations with some of the NASA types for Astrogeology to put together some sort of In Situ geophysics project. [The project was to include the use of seismic techniques, magnetics, gravity, etc. to measure the physical properties of the bedrock and the regolith that they might find on the Moon.] NASA liked the idea in principal. NASA's first offer was $750,000, and then it went down to $500,000. Then, I believe, NASA got it down to $250,000. I told them that we would need at least $250,000 [just] for field expenses. I advised them that the best thing you [NASA] can do is to take your $250,000 and we'll help you find a first-class exploration refraction group. That way your money will be well spent. I told them that we simply couldn't spend your money wisely. Then, I went back and told Dale Jackson what I had told them. Dale was livid! How could you do that [take less money than they offered]? I said to Dale, it's my responsibility and I'm not going to take that kind of money! Well, [NASA] came back with $450,000—and we took it!

We had secured that money while still in Houston; but, of course, the work was not to be done in Houston—it was going to Flagstaff where they could do some of the experimental work. And then, we got hold of Joel Watkins [see Appendices A and B]. Joel agreed to take the program over at Flagstaff (see 1964). In any case, that's how the geophysics group in Flagstaff got started" [paraphrased from an interview with Marty Kane by Gerald G. Schaber on January 23, 2001).

[Author's Note: Marty Kane was supposed to be the chief geophysicist [in Flagstaff], but Dale Jackson had told him earlier that if he would come with the In Situ Geophysics program, then he would help to arrange through the Government-in-training Act for him to go back to graduate school. This was approved by the Survey, so Marty spent two academic years going to St. Louis

University in the geophysics program. At the same time, in part of the summer and some of the holidays, Marty participated in some of the astronaut training exercises in the Grand Canyon, the Philmont Ranch (3-6 June 1964) (the Boy Scout Camp in New Mexico), Katmai, Alaska (21-25 August 1966), the Pinacates Volcanic Field, Sonora, Mexico (29 November-2 December 1966 and 16-17 March 1967), Hawai‘i (12-19 February 1967), Iceland (2-8 July 1967), among others; See Table A)]

David Levy:
"After leaving Washington [NASA Headquarters] in the fall of 1963, Shoemaker returned to Flagstaff, where he had recently moved with his wife Carolyn, and three small children. Shortly after the Shoemaker's arrived in Flagstaff they discovered that scheduled airlines would be inadequate to handle the travel that the Survey work would require. Anticipating that the Survey might buy its own plane, Gene and Carolyn planned to take flying lessons; Gene wanted to show that it was easier for a scientist to learn to fly than for a pilot to learn science. To accomplish this, the couple filled out routine application forms for pilot's licenses. Gene was turned down for medical reasons; some Addison's patients faint unexpectedly, and even though Gene's case was well under control and he never passed out, he was forbidden from piloting a plane. He was told he could appeal this medical decision, but it did drive home the stark reality of his situation: if he couldn't get a license to fly, how would he ever be allowed to go the Moon? It wasn't until Gene was told he couldn't pilot a plane that the real impact of his illness finally hit him.

In 1948, his dream to go to the Moon began; in 1963 he had to accept the fact that his dream would forever stay a dream. "No—I'm not going to the Moon," he reminisced years later, "just at the moment when I was at the head of the list to go to the Moon, my adrenal cortex shut down. I still dream of going there. But no—I just had to do something else" (Levy, 2001, 90-91)

Geophysicist Kenneth Watson arrived in Flagstaff, Arizona in October 1963 and was assigned an office in the Branch of Astrogeology's wing at the Museum of Northern Arizona. His arrival at Flagstaff was greeted by the only three professionals there at the time: Jack McCauley, Don Elston and Chuck Marshall. Ken had just recently received his Doctorate (Geophysics) at Caltech; he had gotten to know Gene Shoemaker who in 1962 was teaching a course there on lunar geology. Ken had also been an officemate with David Roddy while at Caltech.

As a graduate student at Caltech, Ken had researched and published several important papers on lunar volatiles. Ken did his Doctoral thesis on modeling of the cooling characteristics of the Moon during lunar eclipse. His thesis research also included the thermal conductivity in a vacuum of and other types of rock materials processed to various grain sizes. Through his work in interpreting the lunar eclipse data, Ken Watson was successful in modeling the lunar conductivity radiative transfer properties for the lunar surface materials

Gene wanted Ken to work on the physical properties of the Moon—especially in infrared thermal emission. After arriving in Flagstaff in the fall of 1963, Ken did some work on the IR emission from the Moon with Bill Sinton at Lowell Observatory using the 42-inch telescope. This work followed up Ken's earlier interest in measuring the thermal cooling of the lunar surface during eclipse.

About the same time, Ken was asked to join the Branch's latest "effort," in support of NASA's eventual Moon landings—- the use of photoclinometry to measure relief, slope and "roughness" of different lunar surface features using telescopically-measured lunar surface brightness and photometric properties. Jack McCauley, Ann Kelly, Larry Rowan, John Running, and others, were also involved in this effort at that time. Eventually, geologists Maurice Grolier and Jan Cannon also participated.

[Author's aside: In 1968 Ken Watson would publish a *U.S. Geological Survey Professional Paper* on the theoretical basis behind "photoclinometry. About the same time [in 1968], the USGS Chief Geologist Hal James asked Ken if he would start up a terrestrial remote sensing group. This group operated out of the Branch of Astrogeology in Flagstaff for one-and-a-half to two years before leaving Flagstaff in 1970 to become part of the Regional Geophysics Branch in Denver. The Branch Chief [of Regional Geophysics] at that time [in Denver] was Don Maybe; the leader of the Terrestrial Remote Sensing project was Ken Watson (from Astrogeology in Flagstaff). Other Astrogeology scientists initially on this project while it was still in Flagstaff include geologists Larry Rowan, Terry Offield, Howie Pohn, Jan Cannon, Maurice Grolier, and physicist Robert D. Watson [hired by the Branch of Astrogeology in May 1967]. Only Maurice Grolier and Jan Cannon did not go with the group to Denver. Maurice Grolier remained in Flagstaff. Jan Cannon went back to graduate school at the University of Arizona; then he went to Alaska, and eventually back to Oklahoma. The U.S. Geological Survey's Regional Geophysics Branch was later (in 1972) divided into three Branches: (1) Regional Geophysics, (2) Petrophysics and Remote Sensing, and (3) Electromagnetics (or some such name). Ken Watson remained interested in the infrared region of the spectrum throughout the remainder of his career with the USGS while in Denver. He worked on various terrestrial orbital and airborne IR instruments including HCMM, TIMS, MASTER and ASTER. Ken formally retired from the USGS at the end of 1998; but he has since published several research papers, including one with Larry Rowan on the thermal monitoring of Iron Hill, Colorado.]

[Space Exploration Milestones: President John F. Kennedy, who on May 25, 1961 had boldly set forth the goal to send man to the Moon before the end of the 1960s, was assassinated in Dallas, Texas in November 1963. Also in November 1963, Shoemaker's tour of duty at NASA Headquarters ended, and he was succeeded as head of the OSSA-OMSF Manned Space Sciences Division by Willis B. Foster].

The following was taken from the Branch of Astrogeology Monthly Report for November 1963 to V.R. Wilmarth from the Chief, Branch of Astrogeology; dated 30 November 1963:
A [very important] conference on lunar stratigraphy and structure held in Flagstaff, Arizona, 1-3 November 1963, resulted in a revision of the existing nomenclature for the lunar maps that are now in final stages of preparation. The meeting was attended by Michael H. Carr, Richard E. Eggleton, Donald P. Elston, Robert J. Hackman, Harold Masursky, John F. McCauley, Daniel J. Milton, Henry J. Moore, Elliot C. Morris, Eugene M. Shoemaker, and Spencer R. Titley.

As a result of additional mapping in the equatorial belt of the Moon, the stratigraphic nomenclature used in previous maps has undergone extensive review by the entire staff engaged in lunar geological mapping. The most significant change is the reduction of the previously designated Procellarian System, to a rock-stratigraphic unit, the Procellarian Formation.

Experimentation by J. F. McCauley for the purpose of developing a visual observing system for the 60-inch McMath telescope at Kitt Peak National Observatory, 50 miles southwest of Tucson, Arizona, has shown that the large telescope is unusually well-suited for visual work on the Moon. Viewing devices constructed by the Geological Survey have enabled the Branch of Astrogeology personnel to carry out observing with reasonable consistency in the range of resolution necessary for effective lunar geological mapping.

Jack McCauley:
In November 1963, a program to obtain quantitative roughness data began in the Branch. It was approved by Vern Frykland, a former member of the USGS Military Geology Branch. He was at NASA HQ while Shoemaker was also there, and I guess that they cooked this up together. The thrust of the effort was to make photometric measurements on the best available lunar photographic plates so as to yield slope data that could be used in a quantitative search for suitable Apollo landing sites. We acquired a digital isodensitometer and installed it near my office towards the back of the Museum building and began generating numbers. This project was to be an important and well funded part of the Branch up through the early Apollo Landings. Larry Rowan, Ken Watson and Howard Pohn were among the new hires for the Branch who labored on various aspects of this program. The [photometric] technique was invented by a Dutch astronomer by the name of Van Diggelen and refined by Don Wilhelms. Don detested the arithmetic approach to geology and because he was some three months senior to me, managed to pawn the effort off as soon as he could to get back to his love of lunar mapping-the geometric approach" (from the memoir of Jack McCauley, unpublished).

The above study was under the direction of Jack McCauley, and included photometric slope measurements of part of the lunar equatorial belt (10 degrees N. to 10 degrees S. lat and 60 degrees W. to 15 degrees E. long) using a method devised earlier by D.E. Wilhelms. The purpose was to obtain slope frequency distributions over the area studies. The areas of lowest slope frequency distribution would in turn be studied visually at the limit of telescopic resolution at a number of large telescopes by various Branch of Astrogeology personnel. This phase of the study was to hopefully further delineate those areas that have the highest probability of containing safe spacecraft landing sites.

Mike Carr:
"Carl Roach [in Denver] was doing work on thermal luminescence (TL) in 1963 and Gene had this idea that I could take rocks and shock them to some known magnitude, and then send them to Carl in Denver. Then, Carl would look at the effect using thermal luminescence. But I was never able to calibrate things accurately enough that that really worked. Meantime, Carl did show that shock (using a rifle bullet) did have an effect on the TL of rocks (see Carl Roach in 1961). Gene got really excited. So I built this high-shock lab and did experimental work. However, that was pretty well terminated when I had a serious accident (explosion in the lab) and as a result damaged my hand and both eyes—and later would lose one eye permanently.

This occurred just around the same time as President Kennedy died—November 1963. In fact, Mike recalls: "I was in New York at a cosmic dust meeting at the time Kennedy was assassinated because Gene had asked me to take on another project. He was excited about the inflow of cosmic dust into the atmosphere. He had read a paper by a guy I can't recall in New Mexico who had been collecting what he called cosmic particles—iron-rich spherules. This guy had been putting trays out in various places and collecting and sifting through what landed in these trays in isolated areas.

Anyway, Gene thought that this was something we might do. He had also been talking with an ex-Survey guy [Lorin Steiff] who had moved to the Department of Defense and was very much interested in world peace. He had thought that the biggest obstacle to world peace and working with one another was ignorance of opposing technologies, etc. And he had been talking with Gene about the possibility of collecting atomic debris in the upper atmosphere and analyzing it with the hope that one could determine the technology used in making nuclear bombs in different countries, and the technologies that were used for refining uranium, etc.

Anyway, this was a classified project, and Gene was persuaded to establish a large project within the Survey. It was split into two pieces. I headed it here in Menlo Park and Mike Duke headed it in Washington. A substantial amount of money was spent on this project. This was not a small project! A large amount of money was spent especially in Washington by Mike Duke on microprobes and electron microscopes, other instrumentation, and clean room facilities" (abstracted from an interview with Mike Carr by Gerald G. Schaber on 16 May 2001).

Don Wilhelms:
"The dual need to stay objective and to estimate terrain for exploration planning launched Shoemaker and the rest of us on an extended search for measurable properties—measurable, not necessarily significant. Albedo was both easily measurable and significant, standing almost alone in both respects in the early 1960s. The first semiannual progress report of the Astrogeologic Studies Group featured an albedo study, the early geologic maps stressed it heavily, and it was pursued hammer and tong for the rest of the decade (see Table 1).

Most astrogeologists took their turn in the quantitative barrel; I went in twice, once for the polarization study—an excellent example of an easily measurable but unimportant lunar property—and the other time to find an easy way of determining the slope characteristics of geologic units photometrically. Although I regarded the slope study as a distraction from geologic mapping, I engaged in it with some interest. Starting with a suggestion by Dick Eggleton, I sat around coffee houses in San Francisco in early 1963 figuring out how to do it quantitatively and mechanically (two words not usually in my vocabulary), and yet simply and correctly. The result was that I reinvented and extended a technique invented by Dutch astronomer Jan van Diggelen, who used it to determine the slopes of individual mare ridges. He had shown that within a unit with uniform albedo, the brightness varies only with the Sun's elevation (which is known) and slope. My contribution was to compensate for brightness variations due to albedo, which vary among units, by photogrammetrically scanning and comparing low-sun and high-sun photos of the same region.

I was enamored with lunar geologic mapping, so in November 1963 I managed to slide the slope study off onto Jack [McCauley], who, skilled wordsmith that he is, coined the term "photoclinometry" to describe the technique" (Wilhelms, 1993, pp. 70-71).

Jack McCauley:
"In December 1963 the photoclinometry work began to go into high gear. Hal Masursky recruited a dozen main line survey people from Menlo Park to begin visual roughness estimates at the 36-inch Lick telescope of an array of areas in the lunar equatorial belt. Some did this as a lark; others because their regular projects were broke. One of these turned out to be the place where Surveyor I successfully landed almost two and one half years later" (from an interview with John F. McCauley by Gerald G. Schaber on 19 March, 2001).

Geologist Elliot Morris, a Jack of all trades when it came to building things, moved from the Branch's offices in Menlo Park, California, to Flagstaff in December 1963 at the request of Gene Shoemaker. Gene had tasked Elliot with specially-designing and constructing a 30-inch telescope in the Flagstaff area that the Branch's geologists could use to geologically map the Moon.

The initial research for the Astrogeology telescope actually began months before Elliot actually left for Flagstaff in December 1963. Elliot says that they talked to a number of experts, doing the leg work and research necessary before deciding what kind of telescope they wanted [and needed]. They consulted with Bruce Rule at Caltech who worked on the 200-inch telescope at Mt. Palomar. Then came the ordeal of writing up specifications for the telescope. Gene Shoemaker was of course heavily engaged all through the telescope process. They contracted an outfit from Austin, Texas—the Williams Company who submitted the low bid.

[<u>Author's Note</u>: Back in February of 1963, Shoemaker had sent Chuck Marshall and (shortly thereafter) Jack McCauley to Flagstaff and spent several months doing telescope "seeing" studies around Flagstaff. Marshall and McCauley checked the seeing at a number of locations around town and found that the seeing on Anderson Mesa (south of town) was excellent; so they decided to locate the telescope there. The USGS telescope was completed in the summer of 1964 (see 1964 below). The Astrogeology telescope to be placed on Anderson Mesa would be of the Cassagrain type. Pyrex mirrors were the standard at the time; however, they used Haward C-3 glass that someone had determined was best for the cold Flagstaff environment. Elliot picked up the 30-inch chunk of glass for the mirror and took it to Tucson to grind at the University of Arizona. They then took the mirror to the Navy to get the mirror aluminized. Dave Dodgen would be hired by Astrogeology in Flagstaff on 17 March 1964. He had been an optical physicist at the Perkin-Elmer Company. Dave helped design the optical equipment and monitored the installation of the 30-inch mirror on the Astrogeology telescope. Bob Blecha—a machinist with Lowell Observatory—was hired for mechanical work and maintenance on the telescope. Bob went to Austin, Texas with Elliot to see where they were building Astro's telescope and to monitor the mechanics involved.]

Jody Loman (later Swann)-Secretary/personal assistant (b. 1940), a dedicated and crucial link in keeping track of Gene Shoemaker's incredible schedule of activities during Astrogeology's formative years, started work the Branch of Astrogeology at the Museum of Northern Arizona in December 1963 (see Appendices A and B).

Jody Swann:
"When I arrived at the Museum [Museum of Northern Arizona, Flagstaff] I remember Gene's office was on the northwest corner and my office was right next door. On the northeast corner was Elston's office. Right next door to that was Wanda Wilkinson (Administrative Assistant) and Irma DeAmand, whose husband had a security service in Flagstaff at that time. Judy Rockwell, [who also was there at the Museum] was the wife of a forestry student at Arizona State College (in Flagstaff) [later changed to NAU]. Other people at the Museum when I came were Ray Batson, Jack McCauley, Ann Kelly and Ed Gan, our photographer. Bob Mathis was another photographer, and Bob Blecha had the machine shop back then. Bill Mason and Ray Barnett [electronics-types] were in the Museum wing until they got an office down at the "Dance Hall" on Santa Fe Avenue" (see below)] (from an interview with Jody Swann by Gerald G. Schaber on 16 February 2001).

[<u>Author's Note on the "Dance Hall</u>: During late 1963 and most of 1964, photography, electronics, and cartography/drafting personnel from the rapidly expanding Branch of Astrogeology personnel occupied a two story building belonging to the county [Coconino County] on Santa Fe Avenue in downtown Flagstaff. It was then also referred to as the Annex Building. After finding out that the building had also once been a dance hall, branch personnel usually just referred to the building as the "Dance Hall." This building, long since torn down, was located just west of the parking lot of the present (downtown) Kachina [Mexican] restaurant, and just adjacent (East) of the parking lot of the old Baskin-Robbins ice cream store (closed in 2002) at 218 E. Route 66 (formerly Santa Fe Avenue). The old Baskin-Robbins store was occupied by Pay Day Loans in 2003.]

Cartographer/computer programmer Kay [Edwards] Larsen (b. 1942) was another early arrival at the Branch of Astrogeology in Flagstaff, reporting for duty at the Astrogeology wing at the Museum of Northern Arizona on 2 December 1963 (see Appendices A and B). Kay would become a mainstay in the Branch's computer and cartography groups for many years; she would be a driving force in helping to create the excellent reputation of the Branch's lunar and planetary cartography and image processing groups. After working 33 years with the USGS, Kay retired in 1996.

John F. McCauley:
"In December 1963, at Shoemaker's urging, he signed me up to be a Co-Investigator for the Surveyor Lunar Roving Vehicle (SLRV) (Fig. 9). I was closely involved with testing the SLRV.
"The SLRV was a small lightweight (about 45-kg) go-cart, about a yard long and half a yard wide, that would rove around on the lunar surface and it would certify a particular area as being acceptable as far as its soil mechanics for Apollo. Working with me was Ron Scott from Caltech, who was a soil engineer, and Noel Hiners who would go on to become the director of the Goddard Space Flight Center. Ray Batson was also with me on that, along with a guy named Roy Brereton. There was one other guy I can't remember. We were called the "Rover Boys." We had a whole host of meetings that started in 1963, and went through 1964. The Rover was going to carry an imaging system [creating stereoscopic images transmitted from a small facsimile (scanning and digitizing) camera to be built by the Aeronautics Division of Ford Motor Company], and there were two competing vehicle concepts.

The Bendix Corporation had a tracked vehicle, and General Motors (GM) had a wire-wheeled vehicle that was articulated. In other words, it had three sets of wheels—all independently driven" (taken from an interview with John F. McCauley by Gerald G. Schaber on 19 January, 2001) (see 5-7 May 1964 for field-test of the SLRV prototypes at Bonita Lava Flow near Flagstaff).

Chapter 3

Telescopic Moon Mapping and Planning for NASA's Upcoming Unmanned and Manned Lunar Missions Dominate Activities at the Branch of Astrogeology

3.1-1964

[Author's Note: A total of six geologic field-training exercises were carried out in 1964 under the leadership of Branch of Astrogeology personnel for large groups of NASA astronauts (see Table 1).]

[Author's Note: See Table 2 for a listing of Branch of Astrogeology personnel as of 30 September 1964.]

Andrew Chaikin:
"By 1964, at age thirty-six, Shoemaker had put together from scratch, nearly single-handedly, a new scientific discipline called lunar geology. At that time the words lunar geology barely had any meaning to most people, but Shoemaker had made the first detailed geologic map of part of the Moon, and had established a system for delineating lunar geologic time. Working from telescopic photos, Shoemaker and his USGS colleagues had staked out parcels of moonscape the way Survey geologists will tackle the corner of a state" (Chaikin, 1994, p. 385).

The *Arizona Daily Sun* on January 30, 1964 carried the byline: "Astrogeology Facility Waiting for New Telescope (Fig. 10). The article goes on to say:

"The U.S. Geological Survey, usually concerned with things terrestrial, yesterday formally accepted the keys to its first astronomical telescope facility which it plans to use in its new space age investigations into things celestial.

Donald Elston, coordinator of plans and operations of the USGS' Astrogeology Branch here in Flagstaff, and William F. McNamara of the Bureau of Indian Affairs, accepted the circular building in brief informal ceremonies at the branch's observatory site on Anderson Mesa.

The twenty-foot high building, constructed under a $22,000 dollar contract by Taneyhill and Thomas of Phoenix, will house the astrogeology branch's new 30-inch reflecting telescope that the branch will use to probe the geologic secrets of the moon, the nearby planets, and the enigmatic asteroids.

The observatory building, Elston explains, was built on plans and specifications drawn up by the BIA's engineering and construction branch as the USGS has no arm that is concerned with such construction.

Elston said that under current plans, the specially-designed telescope, being manufactured by Astromechanics, Inc. of Austin, Texas, should be assembled in the new observatory building with dummy mirrors and ready for testing in about a month.

The mirrors are being ground to an extremely fine parabolic tolerance by Donald Loomis of Tucson, whom had prepared the mirrors for the 84-inch reflector at Kitt Peak National Observatory, and other major U.S. telescopes. The grinding, Elston says, is now in the final stages.

The Astrogeology's Branch's first telescope is located on a high knoll atop Anderson Mesa, some 800 feet north of the housing of the 69-inch Perkins reflecting telescope jointly operated by Lowell Observatory [here], Ohio State, and Ohio Wesleyan Universities.

The location, Elston explained, was selected for the same reason that the Perkins was put up on Anderson Mesa—to take advantage of the "dark sky" conditions that prevail over the area in making high-resolution astronomical observations of the Moon, the near planets such as Mars, and the asteroids.

Elston said that once the telescope is installed and a ten-foot high silver dome is placed on the housing, tests would be conducted, with actual working observations scheduled to start early this spring. A formal dedication of the facility is tentatively scheduled for late next May, he added" (Arizona Daily Sun, 30 January 1964)."

[Author's Note: Dave Dodgen would be hired on 17 March 1964 by the Branch of Astrogeology in Flagstaff to specifically work on the new telescope. He had been an optical physicist at the Perkin-Elmer Company. Dave helped design the optical equipment and monitored the installation of the 30-inch mirror on the Astrogeology telescope. Bob Blecha—a top-notch machinist with Lowell Observatory—was hired by the Branch of Astrogeology in February 1964 for mechanical work and maintenance on the telescope. Bob quickly became an important cog in the Branch of Astrogeology's NASA-funded projects to design and build prototype Apollo Lunar Tools proposed for use by the future Apollo astronauts on the lunar surface.]

[Astrogeology Milestone- Gene Shoemaker's first Astrogeology Monthly Report was sent to V.R. Wilmarth on 31 January 1964; see below.]

Starting in January 1964, a Memorandum, entitled Monthly Report for Director and Secretary, was sent from Gene Shoemaker to V.R. Wilmarth at NASA Headquarters Washington, D.C. [Unfortunately, these monthly reports were terminated in December 1974.] These monthly reports from the Branch of Astrogeology began the same month (January 1964) that Verl Wilmarth and Ed Chao were temporarily assigned to NASA Headquarters (Washington, D.C.) from the USGS at the request of NASA's Office of Space Science and Applications. Their job was to help NASA address the critical problem of sampling on the Moon, and soliciting the scientists of the world to bid for a piece of the returned lunar samples to come. At Wilmarth's request, he was assisted in this job at NASA Headquarters by NASA colleague Donald A. Beattie.

Below are selected highlights from this initial January 1964 Monthly Report to NASA from Gene Shoemaker of the Branch of Astrogeology:

Highlights and Noteworthy Results:

Apollo Support

An outline of the first phase of an extensive astronaut training course in geology has been approved, and an outline of the course has been formally transmitted to the Director, Manned Spacecraft Center.

In December [1963], the Houston Office was asked by Advanced Spacecraft Technology Division, Manned Spacecraft Center, to prepare an evaluation report on the capability of the presently planned Ranger, Surveyor, and Orbiter programs to provide data for Apollo landing site selection. The report, entitled "Effectiveness of the unmanned lunar program in Apollo lunar landing site selection" (U.S. Geological Survey *Technical Letter-Astrogeology 2*, 55p). by E.D. Jackson, A.H. Chidester, M.F. Kane, D.E. Wilhelms, and D.J. Milton, was completed and transmitted January 11. It concludes that, assuming nominal operation of spacecraft and experiments, the combined programs can provide the bulk of geologic data needed for narrowing down areas suitable for Apollo landing.

Lunar and Planetary Investigations

Preliminary geologic maps of the Moon in the Aristarchus Region by H.J. Moore, Apennine Region by R.J. Hackman, Riphaeus Region by R.E. Eggleton, Helvelius Region by J.F. McCauley, and Mare Humorum by S.R. Titley and C.H. Marshall, have been completed and are undergoing Branch review.

Surveyor Investigations

An extensive test program, in which personnel of the U.S. Geological Survey, Jet Propulsion Laboratory, Pasadena, California, and Hughes Aircraft Company, Culver City, California, will participate, has been started. The purpose of this investigation is to insure that the television cameras of the Surveyor-Lander spacecraft will provide scientific data from the Moon's surface. This program is to include laboratory investigations to be conducted at the Geological Survey Flagstaff laboratories and at Jet Propulsion Laboratory facilities, and field tests to be conducted in the area of Flagstaff.

Field studies in support of the Surveyor spacecraft television system were begun at a test site on the fresh, basaltic Bonito lava flow, about 15 miles northeast of Flagstaff. A preliminary detailed topographic map, which depicts the aa surface in the test area on 0.2-1.0-foot contours, is nearly completed. Photography for the topographic mapping was obtained from low flying helicopter flights. A simulated space frame has been installed on the outcrop and a preliminary photometric survey of the terrain has been made with a telephotometer. The photometric data from this survey have been forwarded to the Jet Propulsion Laboratory for incorporation in the command sequence for a forthcoming field test of the spacecraft camera. Photography of the site from the space frame, using the Surveyor TV format, has been carried out for mosaicking and stereoscopic investigations. In addition, a cooperative investigation for determining test and calibration procedures for the television cameras was begun at the Jet Propulsion Laboratory, Pasadena.

Significant Changes in Projects

The Houston project has requested the Lunar Surface Technology Branch of the Manned Spacecraft Center, NASA, to fund a project to investigate the physical properties of the near-surface rocks using geophysical measurements. The results of the engineering geophysics study would be used to devise lunar geophysical experiments that could be carried out on early Apollo landings and to develop interpretation guidelines for lunar geophysical measurements. As presently presented, the investigation will get underway on or shortly after April 11, 1964. The project is to be headed by J.S. Watkins and operate under the Branch of Astrogeology [in Flagstaff, Arizona].

Personnel

Michael Carr is recovering from a severe accident suffered in December through accidental detonation of explosives in his laboratory [in Menlo Park, California].

Robert J. Hackman will leave the Astrogeology Branch and join the Southern Rocky Mountain Branch on February 2, 1965.

E.C.T. Chao began a tour of Africa and Europe to study meteorite impact craters. At the end of January he had reached Dakar, Senegal, from where he accompanied Professor Theodore Monod, University of Dakar, to Auoelloul crater and the Richat structure

[Space Exploration Milestone: "Ranger VI impacted the Moon on 30 January 1964. It was sending a clear signal as it made its final approach to the Moon. However, when the spacecraft was about a thousand kilometers from the lunar surface, the television cameras failed and JPL engineers could not receive the much anticipated final images from the spacecraft just before it crashed into the lunar surface" (from Levy, 2000, pp. 95-97).]

Jack McCauley:

"In January 1964 I was doing geologic mapping of the Moon at Lick Observatory [California]. And that's the time I first defined the ejecta blanket from the Orientale Basin. I went down to see Bill Hartmann [at the University of Arizona in Tucson] who had done some of the original observational work on Orientale. He had done a very clever thing by taking the limb photographs of the basin and re-projecting them onto a globe so that it rectified the pictures; so you could look at Orientale as if you were looking straight down. Then by re-photographing that you had a rectified image. He first recognized the triple set of rings around the basin; however, he didn't recognize the ejecta blanket because the pictures he was working with were so fuzzy that you couldn't make out the texture on it [the ejecta]" (from an interview with John F. McCauley by Gerald G. Schaber on 19 January, 2001).

Don Wilhelms:

"In January 1964, Surveyor Investigations—a long-awaited passion of Shoemaker—became an official USGS project and the largest item in the unmanned studies docket [for the Branch of Astrogeology]. Shoemaker had been the principal scientific investigator of the television experiment since January 1963. But now an extensive program of testing and calibration of the

Surveyor cameras would demand much effort from him, geologist Elliot Morris, photogrammetrist Ray Batson, and a growing number of able specialists in electronics, optics, and instrument making" (Wilhelms, 1993, p. 81).

Don Wilhelms:
"A new, third group of 14 astronauts was announced in October 1963 and reported for duty at MSC in January 1964, including Buzz Aldrin, who was already working at MSC. At the time of its selection, the group boasted one PhD (Aldrin) and eight master's degrees, but all were trained as military pilots. This was the so-called Apollo group, as opposed to the Mercury (first) and Gemini (second) groups. A month later all the active astronauts of all three groups were sitting in the first geology class [jointly conducted by the Survey and MSC geology groups at that time, as discussed above.] The geology training would gobble up large chunks of the astronauts' valuable time. But they were bright-eyed and bushy-tailed and didn't want to miss nothing. Moreover, the supposedly ailing former Mercury astronaut Donald Kent ("Deke") Slayton required them all, including himself, to attend all the lectures and field trips unless excused by flight preparations or some other unavoidable commitment. Our point of view was that the Moon is made of rock, and a large block of relatively inexpensive shirtsleeve time on Earth might be the key to choosing the most important samples during those precious hours on the Moon" (Wilhelms, 1993, pp. 78-79).

The following was taken from the Branch of Astrogeology's Monthly Report for February 1964 to V.R. Wilmarth of NASA Headquarters; dated 29 February 1964:
In February 1964 Henry Moore [Branch of Astrogeologic Studies, Menlo Park, California] began an experimental study of craters produced by the impact of missiles at the White Sands Missile Range, New Mexico. The services of Reuben Kachadoorian, a crater expert with the Alaska Branch, were employed in this study. The study extended the range of size of craters and projectile energies of data for craters produced by impact.

[Author's Note: Donald A. Beattie (referenced often in this work, starting just below), who served at NASA from 1963 to 1973 in several management positions, and finally as program manager; Apollo Lunar Surface Experiments, would become one of the Geological Survey's best friends and supporters at NASA Headquarters. Starting with its first funding transfers to the USGS in 1961, NASA Headquarters (mostly Beattie's office) would eventually transfer over $30 million dollars to the USGS at Flagstaff and Menlo Park for Apollo support and related Apollo research tasks alone! Beattie's book, *"Taking Science to the Moon—Lunar Experiments and the Apollo Program"* (Beattie, 1993,) is an excellent source of information on NASA Headquarters views and support of the USGS, especially the Branch of Surface Planetary Exploration (1967-1973) located in Flagstaff during Project Apollo].

Don Beattie:
"In February 1964 Will Foster (Chief of Lunar and Planetary Sciences for NASA) sent a set of recommended Apollo investigations and investigators to the Space Science Steering Committee (SSSC), the group Homer Newell had charged with advising him about what science to conduct on all space programs. In his memo Foster listed five areas of Apollo investigations—geology, geochemistry, geophysics, biology, and lunar atmosphere—and named scientists who should be on the investigating teams. As expected, the recommended geology fieldwork team was headed

by Gene Shoemaker. It included Hoover Mackin from the University of Texas, Aaron Waters from the University of California, Santa Barbara, and Edward Goddard from the University of Michigan. The geochemistry planning panel included James Arnold from the University of California, San Diego, Paul Gast, then at the University of Minnesota, Brian Mason from the American Museum of National History, and several other noted geochemists. Related to the geochemistry panel was the petrography and mineralogy team composed of Harry Hess of Princeton, Clifford Frondel of Harvard, Bill Pecora and Ed Chao of the United States Geological Survey, and Edward Cameron of the University of Wisconsin.

Shoemaker's Field Geology Team [in Flagstaff] was responsible for planning the lunar fieldwork, determining the requirements for maps and tools, monitoring the astronauts' training and their activities once they reached the Moon, and preparing the necessary reports. Working with the geochemistry planning panel and the petrography and mineralogy team, the Field Geology Team would plan sample collecting procedures and design sampling equipment that would satisfy the needs of future sample-analysis PIs. For samples that would be returned to earth, the geochemistry planning panel and the petrography and mineralogy team would recommend the protocols for sample preparation. Finally, the geochemistry-planning panel was asked to recommend to Foster's office particular investigations and investigators to study the samples.

Before Shoemaker's appointment [to the geology fieldwork team], two conflicting concepts for field geology instrumentation were under development, one designed by the staff at the Manned Spacecraft Center and the other by USGS in Flagstaff. MSC, led by Uel Clanton, had devised an engineering model of an all-in-one geological tool that the astronauts could use for sampling, drilling, and several other functions, in an attempt to simplify the many tasks they would have to accomplish and at the same time save weight and time by reducing the number of tools needed.

The USGS had similar concerns but thought the biggest problem would be locating and documenting the sites visited, and in particular sampled, so that accurate traverse maps and profiles could be reconstructed back on Earth. The Flagstaff team had devised a surveying staff that would reflect a laser beam from a ranging devise and automatically record the coordinates of a position on the lunar surface. This approach was based on the simulations and exercises we had been conducting for the post-Apollo missions, which suggested that without some type of surveying instrument it would be almost impossible for an astronaut to accurately locate his position on the Moon and associate a sample or observation with a specific point" (Beattie, 2001, p. 108-109).

[Author-Comment- Gene's visionary lunar surveying staff would be a piece of cake with today's technology; however, in the 1960's designing and perfecting a simple, easy to use automated surveying staff was years ahead of the necessary technology to make it come true. "In a NASA Critical Design Review (CDR) at MSC later in February 1967, the Surveying Staff received a careful reexamination. To take full advantage of the capabilities, the astronauts would have to make twelve settings at each station, taking a total of five to ten minutes. We were told that the astronauts thought this was too long, and most agreed; their time on the lunar surface would be our most precious resource. The staff was eventually dropped from the Apollo Lunar Tool pool" (paraphrased from Beattie, 2001, p.113-115. Gordon Swann is convinced that MSC politics had a lot to do with the canceling further development of the USGS' Lunar Surveying Staff.]

The following was taken from Astrogeology's Monthly Report for March 1964 to V.R. Wilmarth of NASA HQ; dated 31 March 1964:
The Astronaut Training Program in principles of terrestrial and Lunar Geology continued in March 1964 with two lectures given jointly by E.D. Jackson and A.H. Chidester on structure and landforms; completion of the first field trip to the Grand Canyon; and a check out trip to West Texas for geologist team leaders in final preparation for the second fieldtrip (Fig. 11).

The field trip to the Grand Canyon was held in two sections, 4-7 March and 11-14 March (See Table I). E. McKee, USGS, who had led the geologists in a run-through the week before, conducted the orientation lecture for the first section at the Yavapai Point. McKee was unable to attend the second section of the trip, and A.H. Chidester substituted for him in the orientation at Yavapai. Team leaders for the first section were D.E. Wilhelms, E.D. Jackson, D.J. Milton, and A.H. Chidester, of the U.S. Geological Survey; and T. Foss, U. Clanton, and E. King of MSC/NASA. In the second section, team leaders were E.D. Jackson, J.F. McCauley, and A.H. Chidester of the USGS, and T. Foss and U. Clanton of MSC/NASA.

Scott Carpenter and Allen Shepard of the Mercury astronauts, Neil Armstrong and Elliot See of the second group, and the entire third group of 14 astronauts, participated in the first section. The remaining astronauts—Wally Schirra, Deke Slayton, Gus Grissom and Gordon Cooper, of the Mercury group; and Ed White, Frank Borman, Jim McDivitt, Jim Lovell, Pete Conrad, John Young, and Tom Stafford, of the second group—all participated in the second section.

Following the orientation talk at Yavapai, the first day of the trip was spent going down the Kaibab trail to the Phantom Ranch—observing lithologies, facies relations, primary structures, and unconformities; mapping contacts of formations; and working out fault relations. The second day was spent in coming up the Bright Angel trail—observing particularly structures in the Vishnu [schist]; the variety of unconformable relations between the Vishnu, the Later Precambrian rocks, and the Paleozoic rocks; faulting in the Precambrian; and the location of contacts between Paleozoic formations.

Both sections of the Grand Canyon trip were highly successful. All the astronauts were extremely enthusiastic, and many expressed a desire for more time in the field. Their rate of progress continued to be very rapid. The readiness with which they grasp geologic principles and geologic methods, and their enthusiasm for field work, has been gratifying.

Detailed accounts of these March 1964 geologic training exercises by the astronauts down into Grand Canyon can be found in the *Arizona Daily Sun* issues dated 4, 7, and 12 March 1964, and 2 April 1964.

Jody Swann recollects:
"So in 1964 when Building-One was just being built [on McMillan Mesa], one of the highlights for me was the time that [astronaut] Gordon Cooper came to talk about what he thought astronauts might be able to do the surface of the Moon, and what kind of room [any geologic

tools] would be needed on the spacecraft—that kind of thing. I remember it was a gorgeous day, and we used the conference room over in the Museum of Northern Arizona itself [where the Branch was located at that time.] Gordon Cooper gave his presentation. I took notes, and we had these big discussions. I thought it was all very exciting, and I was excited to meet an astronaut; but I clearly remember walking back across the driveway to the building where my office was [at MNA], and thinking—a human being on the Moon—that's just not possible! I clearly remember thinking that.

And then I remember sometime later when [one of] the [first large group of] astronauts first came to Flagstaff [for training]. This was when we were still out at the Museum, so it had to be early 1964 [there were two astronaut group trips down into the Grand Canyon during 1964; the first on 5-6 March, the second on 12-13 March.] We had radio communications in our vehicles by then. They called on the radio [on their way to Flagstaff from the Canyon] and said that they were coming by the office [at MNA]. They said that they were really short on time, but if I would go out and stand by the driveway there—they wanted to come by and just say hello because they were trying to get out to the airport. So, Gene [Shoemaker] happened to be in town, and I asked him to go out and meet them with me, because I was kind of timid. Gene said no, they want to meet you; so you'd better go out there. So I did, and shortly thereafter they all arrived and they got out of the trucks. They shook my hand and introduced themselves; and then they headed for the airport. That was a very big event for me. I didn't think I would ever meet an astronaut [of course, this was before Harrison Jack Schmitt arrived on the scene in Flagstaff. [Author's Note: This was before Jody's participation in Apollo, where she met all of the Apollo crews and many other astronauts]" (interview with Jody Swann by Gerald G. Schaber on 16 February 2001).

Jack McCauley:
"The month of March 1964 was a busy one for the Branch. I was asked by Gene to backstop him at the upcoming Ranger IX targeting meetings at JPL. These were charged with emotion and flashes of genuine anger. The argument revolved about whether a legitimate science site would be selected to satisfy the investment of time and effort by the Principal Investigator (PI) Gerard Kuiper (Lunar and Planetary Lab at the University of Arizona), a long-time student of the Moon, and his Co-Investigators the renowned Harold Urey and Gene Shoemaker—the new boy on the block (See Wilhelms, 1993 for details on this struggle). The scientists wanted a site that would reveal new data about a part of the Moon not yet seen in detail—the terrae. Alphonsus, a crater near the center of the Near Side, was an object of interest because its floor had several rilles or linear cracks that contained smooth-rimmed dark craters that looked very much like some of Earth's volcanic craters—thus indicating that the Moon was not a burned out "cinder" totally dominated by a long history of impacts. Urey had taken another tack, and argued that the Moon was a primitive, undifferentiated object that when sampled would tell us much about the early Solar System. The argument went back and forth until, losing all patience, Kuiper announced that unless Alphonsus was to be the target he would resign his appointment and take the argument to the media. The critophobic Apollo types in the room exchanged glances—and Kuiper had his victory" (from the memoirs of John F. McCauley-unpublished).

The following was taken from the Branch of Astrogeology's Monthly Report for March, 1964 to V.R. Wilmarth (NASA HQ), dated March 31, 1964:

"During March 1964 Daniel J. Milton and Gordon A. Swann joined the Branch of Astrogeology's astronaut training program at MSC in Houston, Texas."

Don Beattie remembers his first contacts with Gene Shoemaker and his first visit to Flagstaff: "At the same time that we were conducting our studies at Marshall Space Flight Center, we began to build a strong partnership with the United States Geological Survey [Branch of Astrogeology] under the direction of Eugene M. Shoemaker at Flagstaff, Arizona.

Although Gene was in Washington [at NASA headquarters] for about two months after my arrival, our paths had not crossed. It soon became clear that he was someone I had to meet. As our contract studies progressed and I learned about his work, it seemed there might be a good match between his interests and my office's future needs. His staff was already heavily involved in NASA work, including some projects that could contribute directly to our studies. We talked several times on the phone about the direction post-Apollo planning was heading and agreed to meet and see if we could find areas of shared interest.

My first trip to Flagstaff was in March 1964. In those days the best way to get there from Washington was to catch a late afternoon United Airlines flight to Denver and connect with Frontier Airlines for a milk run to Flagstaff.

Flagstaff's airport, cut out of a stand of Ponderosa Pines, was just a few miles south of town and near one of those towering peaks, Mount Humphrey (12,670 feet). As I walked down the stairs at Flagstaff [airport] on that first trip, I inhaled the aroma of the ponderosas, unlike any forest smell I had ever experienced. It was a crystal clear, cold night with no sky glow from the nearby city. It was easy to understand why Percival Lowell had established his famous observatory near Flagstaff" (Beattie, 2001, pp. 58-59).

"The next morning Donald Elston (Gene's deputy—his real title was assistant Branch Chief) picked me up at my motel and drove me to their temporary offices on the grounds of the Museum of Northern Arizona. Gene met me there, dressed in blue jeans, western shirt, field boots, and bolo tie—the standard uniform for his staff, although a few were not so nattily turned out. My typical Washington uniform of suit, white shirt, tie, and dress shoes drew some wisecracks, dictating a change of wardrobe for my next visits. Gene's offices, in several one-story cinder-block buildings, were not imposing. Furniture was rudimentary and looked like Army surplus. Some of the more innovative staffers had built bookcases out of packing boxes, and recently Gordon Swann reminded me that when he first arrived in Flagstaff the only extra chair in his small shared office was a short plank he laid across his wastebasket. In spite of appearances, you could feel the energy and dedication of the staff Gene was putting together; they hadn't come to Flagstaff for fancy accommodations.

Gene introduced me to those present, mostly young; some of them recent college graduates—and gave me a short tour. Gene had been selected as a Co-investigator for Ranger and the upcoming Surveyor program. Some staffers were busy analyzing the first Ranger close-up pictures, returned only four months earlier and preparing for the first Surveyor landing. In addition to the Ranger and Surveyor work, his office had the lead in making the lunar photogeologic maps that would be influential within a few years in the selection of potential Apollo and post-Apollo landing sites. Most of this latter work, supported by Bob Bryson at NASA Headquarters, was being done at the branch's offices in Menlo Park, California, using the nearby Lick Observatory telescope. Several Flagstaffers commuted to California to work on their assigned quadrangles; Gene had tried to get as many of his staff as possible involved in the mapping, for training and simply because mapping all of the nearside of the Moon was such a big job. Bryson was already upset that the maps were behind schedule. In mid-1964 their commute was shortened to a few miles when NASA, under a program funded by William Brunk of the Office of Space Science and Applications (OSSA), funded the construction of a thirty-inch reflector telescope on Anderson Mesa just south of Flagstaff dedicated to providing geologic maps of the Moon and staffed by personnel from the USGS. David Dodgen and Elliot Morris were the guiding hands while the observatory was under construction and it later became Elliot's small kingdom, supporting many staffers who spent cold nights at the eyepiece to complete their assigned maps.

Although [Bob] Bryson had warned me he thought Gene was overloaded with ongoing projects, I intended to offer to support work at Flagstaff if they could take on additional projects. Our meetings went well, and we agreed to work together on post-Apollo mission planning. The topography and geology of the surrounding area [of Flagstaff] would be ideal for testing some of our ideas on conducting lunar missions with long stay times, and it was obvious that Gene and his staff passionately wanted to be involved in exploring the Moon. To alleviate Bryson's worries, Gene assured me he could hire extra staff for this new work. We shook hands on developing an interagency funding transfer, and I went back to Washington to start the paperwork. Our handshake would lead to almost $1 million a year in cooperative work, with my office covering all aspects of post-Apollo lunar exploration. By the time the Apollo missions were underway, Shoemaker's team would receive almost $2.5 million a year from NASA to cover its many assignments" (Beattie, 2001, pp. 60-61).

Don Beattie:
"With the paperwork in motion to transfer funding to Flagstaff, Gene began to assemble more staff. He did this with new hires, as well as a little Shoemaker "suasion"of USGS personnel at other offices around the country. He had a good nucleus already on site, and to the adventurous recruits this was a mission unparalleled in USGS. A few old hands and a number of younger USGS staff, as well as some new hires, soon signed up. Some reported to the office in Menlo Park, California, to augment the ongoing work there, but most came to Flagstaff (Fig. 12).

The primary ventures my office funded entailed laying the groundwork to justify the longer-duration post-Apollo missions. This effort soon merged with a need to influence how the Apollo missions themselves would be conducted. With funds beginning to come in from other NASA offices, Gene reorganized his staff into three offices: Unmanned Lunar Exploration under the direction of John "Jack" McCauley to cover the ongoing work for Ranger, Surveyor, and Lunar Orbiter; Astrogeologic Studies at Menlo Park under Harold "Hal" Masursky; and Manned Lunar Exploration Studies directed by Don Elston—the last funded primarily by my office.

Our first order of business was to determine what equipment and experiments could or should be included on the post-Apollo missions. We incorporated some of the early results from the MSFC contractor studies as well as the ideas Gene and his staff had begun developing for the Apollo flights. Hand in hand with these studies went the need to define how the astronauts could best accomplish the tasks within the constraints of their space suits and the limitations of their life-support systems. What combination of equipment and procedures would make the most sense from the standpoint of scientific exploration" (Beattie, 2001, pp. 61-62).

Don Beattie:
"Without question, the most important task the astronauts would perform on the lunar surface would be sample collection. There was much debate on how best to do this. How much sample? What types of samples? How should they be packaged for the trip home? How badly would the lunar surface, and in turn the samples, be contaminated by the effluents from the LM descent engines plume? These questions and more faced us as we began to realize that a lunar landing was not far off. The danger of contaminating the Earth was being addressed, but designing the sample containers to minimize this concern still lay in the future. Answers to all these questions could affect the design not only of the sample containers but also of the collecting tools.

To start answering the sampling questions, the Office of Space Science and Applications asked USGS to detail to NASA a person with experience in sample collection and analysis. Ed Chao (USGS, Branch of Astrogeology; Washington, D.C.) was the first to arrive, soon followed by Verl Richard "Dick" Wilmarth, a senior USGS manager. Dick arrived at NASA in early 1964. For the next several months Dick wrestled with his task, and I spent a significant part of my time helping him. Many meetings and consultations with interested parties were needed to be sure we were not overlooking some large or small detail.

Before the sample proposals were received, Shoemaker's Field Geology Team began developing concepts for tools that could collect a variety of lunar samples as well as take the measurements needed to conduct geological investigations. These designs were based on both the Sonett Report and the Falmouth conference report, with the latter providing some specific recommendations: a long-handled trowel (really a small shovel); a rock hammer; sampling tubes to be hammered into the lunar soil to collect small subsurface samples; a hand-held magnifying glass; a combination scriber and brush to mark and clean the samples; and sample bags and special containers—one of them airtight. A camera was also recommended. We began to built prototypes of these tools at MSC and Flagstaff, believing that eventually, regardless of whatever unique requirements we ultimately received from the still to be selected sample PIs, all these tools would be needed" (Beattie, 2001, pp. 110-112).

The following was taken from the Branch of Astrogeology's Monthly Report for April, 1964 to V.R. Wilmarth of NASA HQ; dated 30 April 1964:
Astrogeology's *In Situ* Geophysical studies Project formally began at Flagstaff on 1 April 1964 with Joel Watkins as project chief. This project, supported by the Manned Spacecraft Center, Houston, had as its objective the development of geophysical instrumentation and techniques for use by man on the lunar surface.

The astronaut-training program in principles of terrestrial and lunar geology continued in April 1964 with 3 classroom lectures and a field trip. The lectures, by Don Wilhelms, were on lunar mapping and the stratigraphy, structure, and landforms of the Moon. The fieldtrip was to the Marathon Basin and Big Bend areas in West Texas (see Table I). The trip was in two sections trip (2-3 April and 15-16 April 1964), with sixteen astronauts participating in the first section and nine in the second.

The first day of the trip was spent in detailed examination and mapping of highly folded and faulted Paleozoic rocks in the Marathon Basin. The second day began at Santa Elena Canyon in the Big Bend National Park, where the Rio Grande is superimposed on massive limestones in a fault block that forms a scarp 1,500 feet high; the rest of the second day was spent in examining volcanic rocks in the area between Study Butte and Presidio.

Prof. William Muehlberger of the University of Texas [later to become the Principal Investigator of NASA's Apollo Geology Experiment Team for Apollo missions 16 and 17] served as the consulting expert for the trip. Other field trip leaders were E.D. Jackson, Gordon A. Swann, and Don. E. Wilhelms, Danny Milton and Alfred H. Chidester of the U.S. Geological Survey; and Ted H. Foss, Uel S. Clanton, and Elbert A. King of NASA /MSC

NASA Astronauts attending the field trip to Big Bend on 2-3 April included: Buzz Aldrin, Bill Anders, Charlie Bassett, Allan Bean, Frank Borman, Gene Cernan, Walter Chaffee, Mike Collins, Walt Cunningham, Gordon Cooper, Don Eisle, Ted Freeman, Dick Gordon, Rusty Schweikart, Dave Scott, Allan Shepard, C.C. Williams, and John Young. Astronauts participating in the 15-16 April 1964 fieldtrip to Big Bend included: Scott Carpenter, Wally Schirra, Neil Armstrong, Gordon Conrad, Jim Lovell, Jim McDivitt, See, Tom Stafford, and Ed White.

[Author's Note: The *Dallas Times Herald* for 14 April 1964 carried an article about the astronaut's visit to the Bend area of Texas entitled: "Big Bend Trip- Astronauts Get Geologic Study." The *Wall Street Journal* of 21 April 1964 carried a lead article entitled: "U.S. Geologists Teach Spacemen What Rocks to Pick up on the Moon", with the byline: "Findings May Help Solve Lunar Mysteries: Course Includes Field Trip to the Grand Canyon."]

[Author's Note: See Flagstaff's *Arizona Daily Sun* issue 25 April 1964 for article entitled "Flag Test Area for TV on Moon".]

Don Wilhelms:
"By summer [actually starting in April of 1964 [Surveyor] test cameras built by Hughes Aircraft Company were set upon the Bonita Lava Flow [1064 AD] in Sunset Crater National Monument 25 km northeast of Flagstaff because astronomical data suggested that the rough lava-flow surface would reflect light as does the lunar surface. [Author's Note: How little we knew then about the true nature of the lunar surface!] The tests were conducted in close collaboration with JPL, and the Santa Fe trains and branch planes shuttled personnel and equipment from both organizations back and forth between Pasadena and Flagstaff" (Wilhelms, 1993, pp. 81-82)(Fig. 13).

Ray Batson expands on the Branch's early Surveyor field test at Sunset Crater:
"We had this big field test out on Bonita Lava Flow. And oh, that was a grand whoopti-do. Surveyor I landed in 1966, so we had been out there for a year or more before that [starting the summer of 1964] with a simulated Surveyor camera making survey panoramas and working out

photographic sequences. And it was while we were out there [at Bonita Lava Flow] that Ranger 6 failed. I remember Jay Rennilson [a Surveyor Television team colleague] listening to the radio, and hearing that it failed! That was about the same time that Nikita Krushschev got tossed out in the Soviet Union" (from the interview with Ray Batson by Gerald G. Schaber on 19 January 2001).

Soon after Kay Edwards went to work at Astrogeology for Jack McCauley as part of his photoclinometry project [see 1963 above], she started working for Ray Batson mosaicking test images for the Surveyor Project.

Kay Edwards recollects:
"We did a lot of fieldwork out there on Bonita Lava Flow. We had a camera set up on the [rugged] aa lava and we were taking panoramas. We had the same field of view as the cameras that were going to be used on the Moon [on the Surveyor lander]. We were practicing how to deal with all this stuff [images]; how to map it, what kind of projections we should put on it, and how fast we could do it—because the images were going to come down every 1.6 seconds. We wanted to see if we could keep up with it.

I was working with Ray Batson alone at first; then Henry Holt showed up. Bob Blecha [the Branch's first machinist] was building things for us for Surveyor" (from the interview with Kay Edwards by Gerald G. Schaber on 8 May 2001).

Ray Batson:
"The basic frame for the Surveyor camera test setup had been originally built at JPL (Pasadena, California) for an earlier field test in the Mojave Desert, and was then brought to Flagstaff, along with a whole bunch of engineers from Hughs and JPL, and electronics, camera, and a 35mm film recorder and processor. The test lasted for a couple of months, and resulted in thousands of pictures, which we used for practice mosaicking. Earlier in the year, JPL sent a helicopter out there [to Sunset Crater test site], and we bolted a photogrammetric mapping camera to the skid, and took aerial photos from an altitude of a couple of hundred feet. I made a map with the Kelsh Plotter with a contour interval of 0.2 feet, of the acre or so of aa lava that we placed the simulated spacecraft on.

Don Andrews from the Survey's warehouse in Flagstaff, I believe, was the one who located the military surplus landing mat somewhere, and he, Tommy Weathersby (warehouse man] and I kind of engineered and aligned the "road" over the cinders at the edge of the [Bonita] flow so that we could access the site. A bunch of people built a wooden walkway to a high point on the lava, and from there we strung a steel tram down to the site where we set up the simulated spacecraft. The electronics van stayed on the landing mat, of course, and the camera on the spacecraft was connected to it electronically by a cable. Bob Blecha (USGS machinist) built us a framework that looked very much like the Surveyor. We had the landing pad feet placed the right way so that we knew if we were going to see the feet [landing pads] at a certain camera elevation—and that kind of thing. We had our little USGS van out there with a small photolab in it [for processing the simulated Surveyor images.]"

When Kay Edwards was asked by Gerald Schaber during their interview on 8 May 2001 if they really had the simulated Surveyor cameras set up "on top" of the extremely rough Bonita Lava Flow—and not adjacent to it in the cinders. Kay Edwards said:

"We had it on the [rough aa] flow. That was what we thought [the lunar surface might look like] in those days, as opposed to the powdery, rocky, soil that were actually encountered when Surveyor I landed two years later in May 1966."

The following was taken from the Branch of Astrogeology's Monthly Report for April 1964 to V.R. Wilmarth of NASA HQ; dated 30 April 1964].
"In April 1964, Daniel J. Milton, Gordon A. Swann and Martin F. Kane, prepared a report, at the request of the Space Environmental Division, MSC, NASA on "A Typical Scientific Mission for an Apollo landing."

Geophysicist Joel S. Watkins, Jr. (b. 1931) arrived in Flagstaff to work for the Branch of Astrogeology on 7 April 1964. Watkins was trained formally as a geophysicist specializing in magnetics and gravity techniques (See Appendices A and B).

Joel had original joined the USGS' Branch of Geophysics in Denver in the summer of 1961. Joel met Marty Kane after arriving at the Survey, and they became close friends. After a year or so, Joel discovered that the magnetics program in the Survey was sort of dying out because of lack of funding. He had become involved in ground water seismic refraction work between 1962 and 1963, but then learned from Marty Kane that the Branch of Astrogeology group in Houston (MSC) was looking for geophysicists to help train the astronauts for lunar exploration. Kane asked Joel if he was interested—and he was. Astrogeology's astronaut training group had disbanded before Joel could take an active part, so he moved directly to Flagstaff (April 1964) (from an interview with Joel Watkins by Gerald G Schaber on February 6, 2001).

Geophysicist Richard H. "Dick "Godson (b. 1929) arrived on the scene in Flagstaff with the Branch of Astrogeology on 17 April 1964. Dick was born in New York State and went to the University of Notre Dame, receiving a degree in geology there in 1951. He then went into the Marines as a Second Lieutenant in Korea, and was a forward observer. He spent two years in the Marines and got out in 1953 (See Appendices A and B).

Geologist Howard ("Howie") Pohn (b. 1935) is thought by many, including this author, to be one of the most under-recognized contributors to the success of the Branch of Astrogeology during its formative pre-Apollo years. Howie was the go-between between Bruce Murray's Lunar Lab at Caltech and Gene Shoemaker's fledgling USGS Lunar lab at Menlo Park, California was while he was attending Caltech between 1961 and 1963. Pohn was asked by Shoemaker to come join the Branch of Astrogeology in Flagstaff. Howie entered on duty with the Branch at Flagstaff on 20 April 1964, and he was given an office in Astrogeology's wing of the Museum of Northern Arizona (See Appendices A and B)

Geologist/Driller Norman G. "Red" Bailey (b. 1927) arrived in Flagstaff to work with the Branch of Astrogeology on 2 April 1964. Red had been working for eleven years for the Ohio Division of Water as a Geologist-Aid, and later Engineering-Technician doing ground water studies, ground water investigations, dam sites and building foundation studies, and operating general geologic test drilling. During the Apollo Era, the Branch used Red's rather impressively broad range of knowledge on many subjects, and his enthusiasm and ability to "get tough jobs done" very effectively (See Appendices A and B).

[Astrogeology Milestone- A final test at the Bonita Flow, Flagstaff, Arizona, of the two existing engineering models of the proposed Surveyor Lunar Rover vehicle (SLRV) was conducted on 5-7 May 1964 at the Bonita Lava Flow at the base of Sunset Crater just northeast of Flagstaff. The test was conducted under the direction of L.V. Divone of the Jet Propulsion Laboratory and Jack McCauley of the USGS, Branch of Astrogeology (Flagstaff).

Jack McCauley:
"We took the Bendix and GM prototypes of the Surveyor Lunar Rover Vehicles SLRV (see 1963) out on the Bonita Lava Flow 5-7 May 1964 at Sunset Crater northeast of Flagstaff] and put them through their paces to see which one had the best trafficability (See Fig. 9).

Before the field test, we had to go on numerous trips to Bendix labs in Ann Arbor and the GM labs out in Santa Barbara, California. We were going back and forth, and we had to sit through these engineering meetings where they would have these guys getting up with their parametric equations and what they were going to do. Parametric equations are things in which you put hypothetical numbers, and you develop curves. The curves come out whatever way you want them to. It was a painful experience. Someone would have to look at these estimates of performance [of the SLRV] with skepticism. We believed that only a competitive test of the Bendix versus the GM vehicles would be meaningful. So that is how we got into the business of field-testing the Surveyor Rover vehicles at Sunset Crater. We said so much for your equations—let's have a real field test!

We tested the vehicles around the edges of Bonita Flow, but we had one little section where they could really get into some pretty rough stuff. The GM vehicle was perfect. It got from point A to point B without any mishaps, or turning over. The poor Bendix vehicle had tank-like treads that were made of some kind of a rubber-type thing. They were articulated. There were two in the front and two in the back that kind of turned as they went along. The vehicle just started shredding the treads. In fact, when they finished half way down the course, it had no treads left. So, the GM thing [vehicle] obviously got our blessing.

But the engineering-types back then wanted the thing to go around and take pictures every ten meters, and also to use a penetrometer to see what the strength of the lunar soil was—and to do it in a pre-ordained manner—basically, just to do a grid survey. This was silly! This is a thing that could be controlled from the ground [Earth]. You could send it to where ever you wanted it to go. You could test along the way at suspicious places and cover far more ground than they had planned to do. This would be just a little quarter-mile section; because it would be essentially out of gas after it did all of those manipulations.

We had to scratch our heads after we looked at all the opportunities here; and we had to write a report to NASA that said that this thing [the SLRV] cannot perform the site certification requirements that have been put on it—as it is currently being planned to be used. That did it;

NASA cancelled it" (from an interview with John F. McCauley by Gerald G. Schaber on 19 February 2001).

The SLRV study took a long time to die and would occupy some of Jack McCauley's time through the fall of 1964.

The following was taken from the Branch of Astrogeology's Monthly Report for May 1964 to V.R. Wilmarth of NASA HQ, from Chief, Branch of Astrogeology; dated 31 May 1964:
In May 1964 the Branch of Astrogeology submitted its second Annual *Astrogeology Progress Report* to NASA covering research carried out during the period 25 August 1962 to 1 July 1963. This report was in four parts: Part A- Lunar and Planetary Investigations, Part B- Crater Investigations, Part C- Geochemistry and Petrology, Part D- Studies for Space Flight Program, and a Summary**.**

At the Commencement exercises at Arizona State College at Flagstaff on May 24, 1964, an Honorary Doctorate of Science Degree was conferred on Dr. Eugene M. Shoemaker, Director of the U.S. Geological Survey's Branch of Astrogeology at Flagstaff (see *Arizona Daily Sun*, May, 1964).]

Don Beattie:
"Although in 1964 and 1965, we [i.e., NASA] still did not have any data from direct contact with the lunar surface, information from radar and laboratory studies predicted how the Moon's surface layer would respond to a wheeled vehicle. In spite of Tommy Gold's theories, we were certain that a wheeled vehicle could move around without serious difficulties. But we were not sure how the Moon's almost total vacuum would affect the lunar soil; the high vacuum that would be encountered on the Moon was impossible to achieve on Earth. Studies had been conducted in high vacuum using several types of simulated lunar soil, but their fidelity was open to question because our ideas about the composition of lunar soil (grain size, mineralogy, and other characteristics) were mostly guesses.

NASA Headquarters' first contractor studies of a lunar surface vehicle were undertaken by the Bendix Corporation and the Boeing Company Aerospace Division. They were selected in May 1964 to study ALSS (Apollo Logistics Support System) exploration payloads, including a vehicle we had dubbed MOLAB (for mobile laboratory). Bendix had earlier won one of the JPL design contracts for a small Surveyor rover, so it was well prepared to undertake the study. From taking part in our [i.e., NASA's] lunar base studies, Boeing had a good background that included designing mobility concepts.

The two contractors were also asked to design a shelter that could be delivered by the same type of automated LEM and a smaller, unpressurized vehicle we [NASA] named the local scientific survey module (LSSM).

While all this wheeled-vehicle planning was under way, Textron Bell Aerospace Company was quietly developing a small manned lunar flying vehicle (LFV). A one-man version was demonstrated early in 1964 (see below). (A later generation of this device was demonstrated at large gatherings including the 1984 Olympics in Los Angeles, and a version was flown in the James Bond movie *Thunderball*)" (Beattie, 2001, pp. 53-55)

[Author's Note: A field demonstration of the remarkable Bell Aerospace Rocket-belt vehicle would later be carried out in the Hopi Buttes, Arizona in August 1966; see 1966 below for details.]

Don Beattie:
"In mid-1964 a letter was sent to MSC [Manned Spacecraft Center in Houston], over Vern Fryklund's signature, outlining our need [in Flagstaff] for space suits and support technicians to carry out our planned simulations. It requested an inventory of vacuum chambers where we might test the equipment with suited test subjects."

The situation on space suits was not so encouraging. Borrowing space suits and technicians for simulations away from MSC would be difficult because both were in short supply. Through the intervention of the USGS's Gordon Swann, then stationed at MSC, and others working with the astronauts there, we were able to obtain a surplus Gemini space suit that we trained two staffers at Flagstaff to wear for field simulations. It was not a very satisfactory suit to use in the field, because it was not designed for walking when pressurized, and it was difficult for the wearer to bend at the waist to conduct typical fieldwork. Gemini astronauts either sat in the capsule or, for EVAs [Extra-Vehicular Activity], stood almost upright at the end of a tether. But it was useful, especially in the sense that it drove home how difficult it would be for the astronauts, even in a better space suit, to do the equivalent of routine geological fieldwork" (Beattie, 2001, p. 62-63).

The following quotations are from Astrogeology's Monthly Report for May 1964 to V.R. Wilmarth of NASA HQ; dated 31 May 1964:
The astronaut-training program in principles of lunar and terrestrial geology continued in May 1964 with three 2-hour classroom lectures and a field trip. The lectures were given by D.E. Wilhelms on lunar geologic mapping, A.H. Chidester on terrestrial geologic mapping, and M.F. Kane on geophysical measurements.

All twenty-nine astronauts attended the third field trip of the course, which was given in two sections. On 30 April - 2 May 1964, and again on 20-22 May, the men observed the Moon in groups of six [on the new McMath Solar Telescope] at Kitt Peak national Observatory in Tucson under the direction of D.E. Wilhelms and Harold Masursky. Wilhelms and Masursky pointed out stratigraphic and structural relations on the Moon that the astronauts had been studying in class (See Table 1).

Don Wilhelms:
"Astronomers are jealous of their time on large telescopes, but they could not use the McMath solar telescope at night, so we projected a beautiful "live" 85-cm image of the Moon on its viewing table and spoke thereto. Hal Masursky, geologist Spence Titley from the nearby University of Arizona, Jack McCauley, and I were the Moon experts. Special viewers had been fabricated by Elliot Morris to enlarge parts of the image" (Wilhelms, 1993, pp. 78-80).

Jack McCauley recalls:
"They [the astronauts] were just like a bunch of kids. They were elbowing one another with regard to the limited space around the viewing table [at the base of the Solar Telescope). We only had about six of our viewers available. Elbert King was there from NASA/MSC. He and I were sitting on the floor away from this thing, and were kind of laughing at them, and thinking, here's America's finest squabbling like a bunch of kids on a schoolyard. It was the enthusiasm on their part, because they had not seen the Moon "live." They had [only] seen pictures of it. But they hadn't seen the slight shimmer from the ["seeing"] conditions. Now, they were looking at it in real time as a real magnified optical image of the Moon. You could almost feel that you could touch it. It wasn't like the real telescope where you could only look in one direction" (from an interview of John F. McCauley by Gerald G. Schaber on 19 February 2001).

[See *Tucson Daily Citizen*, 21 May 1964 for lead article "Adventures on the Moon Begins in Viewing Room at Kitt Peak"] (See *Arizona Daily Star*, 21 May 1964 article "Astronauts Get Closest Look at Moon with Kitt Peak Scope"] [See *Arizona Republic*, 22 May 1964]

The following quotation is from the Branch of Astrogeology's Monthly Report for May 1964 to V.R. Wilmarth of NASA HQ; dated 31 May 1964:
"On April 30 and May 1, and again on May 21 and 22, the astronauts traveled from Tucson to Flagstaff and spent one day each in groups of six observing the geologic features of the San Francisco Volcanic Field from light planes. They mapped basalt flows and cinder cones on the ground at Sunset Crater National Monument. J.F. McCauley and E.M. Shoemaker conducted the fly around. The astronauts observed four kinds of circular geologic structures from the air—a caldera, a number of maars, cinder cones, and Meteor Crater. E.D. Jackson, A.H. Chidester, and Jerry Harbour conducted the mapping at Sunset Crater. The problem included stratigraphic problems of multiple flows, flow-cinder relations and recognition of flow surface structures, bombs, xenoliths, etc" (Fig. 14).

[See *Arizona Daily Sun* Thursday 30 April 1964, byline article by McAllister Greenbaum, "Astronauts in Flag Again."]

[See *Arizona Daily Star*, 30 April 1964, "Astronauts Must Wear Many Hats;" Kingsley Wood]

[See *the Houston Post*, 1 May 1964, "Astronauts in Training for Moon", and Astronauts See Moon, Study Arizona Rocks."]

[See *The Houston Post* 3 May 1964 for byline "17 Astronauts Enjoy Geology Field Tour" (in Flagstaff, Arizona)]

[See *The Arizona Republic* 1 May 1964, "Moon Astronauts Study in Arizona."]

[See *The Arizona Republic* 3 May 1964, "Astronauts Visit Simulated Moon."]

[See *New York Times* 11 May 1964 "Astronauts get Geology Course."]

[See *Tucson Daily Citizen* 1 May 1964, Astronauts Take Tour of 2 Arizona Craters."]

Jack McCauley:
"Before that fly-around with the astronauts "I got up there with Hal Stephens (who would later become branch photographer/geologist). We took [aerial] pictures of these various volcanic landforms, and mounted them on cardboard. We then took two astronauts at a time in the Cessna 182's that the branch had rented from the airport. Shoemaker was in the other plane. We gave these guys a visual tour of all of these different types of craters. As I was pointing out, let's say, a particular thing at Sunset Crater, we could go around the thing two or three times. Then, they could look at the photo in front of them and kind of get a feel for what the real thing looks like out the window—and what you get out of the photo. They [the astronauts] really enjoyed that" (from an interview with Jack McCauley by Gerald Schaber on 19 February 2001).

On 31 May 1964, the Sunday Feature Section of the *Arizona Daily Star* (Tucson, Arizona) ran the headlines: "Flagstaff Assumes Big Space-Age Role-City is Frontier in Moon Race" and a corresponding byline story by Carle Hodge, Science Writer for the paper.

Gordon Swann:
"The astronauts never really did train with us at Flagstaff in pressure suits. They did a little bit of work in pressure suits in what we called the "Rock Pile" in Houston. Built in the spring of 1964, it was half the size of a football field with piles of basalt and some craters dug into it. They did some work on that [including some simulations, or SIMS, in which the Flagstaff USGS group participated remotely from Flagstaff.]

[For more details on the Houston "Rock Pile" see 24 May 1964 *Arizona Daily Star* (Tucson) byline by Harold R. Williams: "Piece of Moon to be built at Texas Space Center."]

Then, near the astronaut's living quarters at the Kennedy Space Center (KSC), Cape Kennedy, Florida, NASA tried to simulate yet another lunar surface for training. They scrapped sand and the Palmettos and stuff, and all there were was some blue gumbo mud and sand. They dug some craters. At high tide, the craters would fill with water" (from the filmed interview with Gordon Swann by Harry Ryan in 1966).

[See 1971 for details on how Branch of Surface Planetary Exploration personnel shipped tons of various kinds of rocks to the "lunar surface" at KSC to enhance the geologic training of the astronauts there.]

The first term, or phase, of the Branch of Astrogeology's astronaut training program in principles of lunar and terrestrial geology was completed in June 1964. Martin F. Kane gave a two-hour lecture and a one-hour lecture on geophysical properties of the Earth and the Moon, and on geophysical methods. Don E. Wilhelms gave a one-hour lecture on lunar stratigraphy and lunar geologic mapping.

William Phinney:
"The final field trip of the term was held 3-6 June 1964 at Philmont [Boy Scout] Ranch, near Cimarron, New Mexico (See Table I) (Fig. 15). This trip involved more complex geology that was more difficult to follow than in previous locations; more like typical geologic problems. It

included both igneous and sedimentary rocks, orientation with geologic maps, measuring and describing stratigraphic sections, strike and dip measurements, and recording of field notes. The local expert was G.D. Robinson (USGS) who had just finished a report on the geology of the area. Other geologists present included Dale Jackson, Danny Milton, Don Wilhelms, Chuck Pillmore, Gordon Swann, Al Chidester, Ross Johnson, and Jim Gill of the USGS; the USGS geophysics group included Marty Kane, Joel Watkins, Gordon Bath, and Red Bailey; NASA/MSC geologists participating include Ted Foss, Uel Clanton and Elbert King. There were two astronauts per geology instructor for three days. One day was spent sketching, describing and defining the exposures on Slate Hill. Note-taking and section measurements were emphasized. A second day was spent trying to correlate vertically dipping units on two parallel traverses. Mapping of the units, dip and strike measurements and note taking were emphasized. Half of a third day was spent mapping a dike and sill. The other half was spent taking measurements with magnetometers, gravimeters, and seismometers in an attempt to determine subsurface structure under the instruction of Gordon Bath, Marty Kane, Joel Watkins, and Red Bailey—all of the USGS. On the final day, the entire group traveled by car and made several stops at significant geologic exposures for brief discussions. The trip was finished at noon" (William C. Phinney, submitted).

Twenty astronauts participated in the training at Philmont, including Buzz Aldrin, Bill Anders, Neil Armstrong, Charles Bassett, Gene Cernan, Roger Chaffee, Mike Collins, Pete Conrad, Gordon Cooper, Walt Cunningham, Don Eisele, Ted Freeman, Dick Gordon, Jim Lovell, Allan Bean, Rusty Schweikart, Dave Scott, Elliot See, Edward White, and C.C.Williams.

[See The *Raton Daily Range* (Raton County, New Mexico), 28 May 1964, "Astronauts Visit Philmont Next Week."]

The following is taken from the Branch of Astrogeology's Monthly Report for June 1964 to V.R. Wilmarth of NASA HQ dated 30 June 1964):
"The emphasis [for astronaut training] at Philmont was on geologic mapping. Newly published USGS Professional Paper 505 provided the framework for the field training problems, and its senior author, G.D. Robinson, played a major role in organizing and carrying out the trip.

A new feature of this fieldtrip was the integration of geophysical training with the geologic setting. Martin Kane of the Survey's MSC office in Houston carried out the geophysical program with Gordon Bath of Denver, and Joel Watkins and Norman Bailey of the Flagstaff office. It included magnetometer work, coordinated with detailed geologic mapping of lamprophyre dikes and sills, and detailed gravity and seismic profiles to determine the depth and physical properties of alluvial till in a broad valley."

Gordon Swann recalls:
"On the next to last night at Philmont, the Boy Scout leaders wanted us all to come over; they were very proud of having all those astronauts and all. They presented each of us one of those red Philmont Boy Scout jackets. They wanted to give them to the astronauts, but I guess they felt they had to also give them to the hangers-on. I was sitting next to [astronaut] Pete Conrad; he was such an ornery little bugger anyhow. I was sitting next to him. Well, the first jacket they presented was to Neil Armstrong. They were really proud that Neil had been an Eagle Scout.

Pete whispered to Swann and said "maybe I shouldn't take mine," I made it to Second Class, and then got kicked out of Scouts for smoking" (from an interview with Gordon Swann by Gerald G. Schaber on 2 Jan 2002).

Don Wilhelms:
"That [initial] trip to Philmont closed out both the field season, and after a total of 13 lectures, the residence of the USGS personnel in Houston. The conflict with the NASA geoscience group [discussed above] had proven intolerable. The animosity between Dale and his counterpart, Ted Foss, was particularly severe. Dale could not forgive NASA for going back on the agreement to let the USGS run the entire training program. I cannot recall what Foss's problem was. At any rate, Dale Jackson, Dan Milton and I went back to Menlo Park, Gordon Swann temporally went back to Denver, and Al Chidester transferred to Flagstaff. The jovial Chidester took over management of the USGS end of the training program from the less jovial but better focused Dale. Lectures in Houston would be given by visiting experts. A formal agreement (drawn up without Dale) spelled out that Chidester would recommend training areas and the outside experts in the area's geology. Ted Foss [at MSC] would handle all interactions with the astronauts, and the thorny problem of press relations would be neutralized by telling the reporters that the visiting outside expert was leading the trip" (Wilhelms, 1993, pp.80-81).

[<u>Astrogeology Milestone</u>: The Houston office of the USGS' astronaut training program was closed by order of Gene Shoemaker on 30 June 1964 (primarily because of the increasing bad blood between the USGS' astronaut-training group and the MSC geologists and some of their managers). USGS personnel were transferred to Flagstaff and Menlo Park and began handling the training program from there]

Donald P. Elston conferred in June 1964 with Verne Fryklund, C. William Henderson, Donald Beattie, Paul Lowman, and Edward Davin of the Manned Spacecraft Division, NASA Headquarters regarding a proposal that the Geological Survey undertake responsibility, and become field manager, of a program to develop and test scientific mission profiles for Apollo and post-Apollo manned lunar exploration.

<u>[Astrogeology Milestone</u>-The first field geology exercise using actual NASA space suits took place at the Bonita Lava Flow adjacent to Sunset Crater National Monument, Flagstaff, Arizona, on 15-20 June 1964; see Table I)].

Gordon Swann:
"As far as film documenting these tests, Shoemaker came up with the notion in the spring of 1964, even before Jack [Schmitt] arrived in Flagstaff. Shoemaker said "I want to run a mission out at the Bonita Flow [adjacent to Sunset Crater just northeast of Flagstaff]. I want a suit, and I want to run the tests in suits, and I want it documented—and we'll use this to sell the program [i.e., for us to take on suited field tests in Flagstaff for NASA]. Then, Jerry Harbour and I went over and we talked NASA into bringing up a Gemini suit. At that early stage we had to furnish our own liquid oxygen (LOX)—so we went over to Luke AFB, and yes they would loan us a LOX cart. So Jerry and I went down in the old Dodge Power Wagon to get the LOX—which was in a wagon. It wouldn't fit inside the bed of our truck, so Jerry rented a two-ton Hertz truck.

We hauled that LOX up to Flagstaff. The Gemini suit was a terrible thing; you couldn't stand up straight in it because it was built for sitting only.

We soon after arranged the whole suit business with the Engineering Department down at MSC (Manned Spacecraft Center). They were very cooperative. The final agreement we came to was that if they would furnish suits, the proper technicians and supporting equipment to use the suits in the field, then we would furnish test subjects to do the [suit] metabolic stuff down there [at MSC]. When Joe O'Connor later left the Survey and went out to Berkeley in 1967. That left us with only four test subjects down there [from the Branch of Astrogeology] [G. Swann, D. Schleicher, T. Hait, and G. Ulrich]. And they had I think a total of 23 test subjects doing metabolic rate things on the treadmill. The four of us had the four lowest metabolic rates of any of them. We were the four oldest—-and all of us smoked! And they finally figured out it was because of the altitude we were acclimated to at Flagstaff at 7,000 feet—and we were going through all of those tests at sea level.

The first suited test [that the Branch of Astrogeology ran] was out at Bonita Lava Flow—or out in the cinders adjacent to the rugged aa flow. This test was held on 15-20 June 1964 (See Table I). The only three guys the spacesuit would fit at all were Gene Shoemaker (who wore it only a short time), Jerry Harbor and Gene Phillippi. So they were our astronauts. However, they could only go for fifteen or twenty minutes and they were so exhausted they couldn't even move after that (Fig. 16).

Ken Watson had a tape recorder and he taped everything [at that suited test.] Astro didn't [even] own a camera at that time! We had a photographer named Bob Mathis. Bob borrowed my [personal] 35-mm camera to take pictures of us. He probably took 350 to 400 pictures, and we couldn't use one single one of them! We borrowed Hal Stephens from [the Photo lab] in Menlo Park to run a film camera. Hal ran about 300 feet of film, and out of it we were able to get a ten-minute film that was useful" (from an interview with Gordon Swann by Gerald G. Schaber on 2 January 2002).

[Author's Note: Gordon Swann recalled that it was during this first suited test at Flagstaff that geologist/photographer Hal Stephens—who was brought out from Menlo Park, California to film the activities—was asked to formally join the Branch in Flagstaff [see Appendices A and B].

Gordon Swann continues:
"There was a Museum of Northern Arizona [MNA] photographer named Paul Long, and he asked if he could just come and observe and take a few pictures. At that time, our offices were out there at MNA. We said sure, and he came out and took pictures. He took a bunch of really good ones. We had to "buy" the pictures from the Museum to use in our report! So we wrote this big report—Jerry Harbour, Hank Moore, me—and I think Marty Kane. A big thick report of mission profiles, and put together a documentary film [Astro's first]. The Branch sent it to NASA, and Astrogeology got $600,000.00 for the next year! They [NASA] obviously liked both the film and the report" (from an interview with Gordon Swann by Gerald G. Schaber on 2 January 2002).

The following information was found in the Astrogeology's Monthly Report for June 1964 to V.R. Wilmarth of NASA HQ; dated 30 June, 1964:
"The following people participated in the Apollo simulations tests held in Flagstaff, Arizona, on 15-20 June, 1964: USGS, Gene Shoemaker, D.P. Elston, E.C. Morris, R.M. Batson, Jerry Harbour, E.C. Phillippi, H.G. Stephens, R.F. Mathis, R.H., Barnett, Eric Bramsoe, H.J. Moore, and Kenneth Watson; Jet Propulsion Laboratory, J.J. Rennilson, General Electrodynamics Corporation, Bill Banks and Pat Gambudi, NASA, Willerie Beeson and Carl Huggins. Observing were National Park Service, Carl Degen and Russ Mahan; Museum of Northern Arizona, Paul Long (photographer)"

Also in June 1964, members of the USGS, General Electrodynamics Corporation, Garland, Texas, and Crew Systems, Manned Spacecraft Center, Houston, Texas, participated in an Early Apollo mission simulation experiment on basaltic ash and flow rock of the Bonito Flow, 15 miles northeast of Flagstaff. Scientist-astronauts examined outcrop in a full pressure suit and transmitted information by means of a small soft-link vidicon (TV camera) attached to a prototype lunar Jacob's Staff. Information gained by this work is being included in a report on Early Apollo Mission Profiles being prepared by Gordon Swann, Jerry Harbour, H.J. Moore, D.J. Milton, and Martin Kane."

The following was taken from the Branch of Astrogeology's Monthly Report for July 1964 to V.R. Wilmarth, NASA HQ, from Chief, Branch of Astrogeology; dated 31 July 1964:
"In July 1964, the obstacle of accessibility in the geophysical examination of the S.P. Flow, 30 miles north of Flagstaff, Arizona, was overcome by actually bulldozing a road 1,500 feet long into the interior of the flow. This [remarkable feat] was accomplished in two days under the direction of Norman "Red' Bailey who would a few years later supervise the construction of the Branch of Surface Planetary Explorations three simulated Crater Fields—two at Cinder Lake near Flagstaff and near Black Canyon in the Verde Valley, Arizona].

[Author's Note: Core-drilling under the supervision of Red Bailey began atop S.P. Flow (at the end of the bulldozed road mentioned above) on 12-29 April 1965 in support of the Branch of Astrogeology's In Situ Geophysics Project.]

Members of the Jet Propulsion Laboratory, assisted by Reynold Ask, Research Specialist, USGS, in July 1964 completed the task of photogrammetric alignment of the Surveyor television camera to be used in Field test No. 2, at a site near Sunset Crater National Monument in Northern Arizona. Final preparations were completed for Field Test No. 2. A 1,100-foot access road had been constructed to the test site and had been surfaced with steel landing mat. An equipment shelter, loading and observing platform, and walkways have been constructed.

James Allen and Ralph Christian in July 1964 joined the Branch of Astrogeology's Solid State Investigations Project in Denver (headed by Carl Roach). E.C.T. Chao, of Astrogeology's Washington Office, has been temporarily assigned to work with NASA for Fiscal Year 1965. M.B. Duke, of Astrogeology's Washington group, spent 6-8 weeks in California at the California Institute of Technology, instructing a summer workshop for graduate students.

3.1.1-Geologist and Future Apollo 17 Astronaut Harrison H. Schmitt Arrives in Flagstaff

"In July 1964, as the first phase of the training ended, the Astrogeology office at Flagstaff welcomed the entry on duty of a geologist who would literally leave his mark on lunar geology in a way none of the rest of us could—Harrison Hagan ("Jack") Schmitt (b. 1935) (see Appendices A and B). Jack inherited geology from his father, Harrison Ashley Schmitt, who had been a geologist in New Mexico. Jack had his bachelor's degree from Caltech, his brand-new PhD from Harvard, and bachelorhood combined with what are often described as swarthy good looks; his opportunities seemed boundless" (Wilhelms, 1993, pp 80-81).

Geologist/astronaut "Jack" Schmitt, who would explore the Taurus-Littrow Valley on the Moon with fellow astronaut Eugene Cernan in December 1972, started working with Gordon Swann the Branch of Astrogeology in mid-July 1964 on the development and testing of Early Apollo lunar geologic exploration procedures (see Appendices A and B).

Gordon Swann:
"The idea of developing and testing the pre-Apollo geologic field studies [at Flagstaff] directed at how an astronaut can perform geologic tasks kind of developed from the work that Jack Schmitt and I were doing at the time [in mid 1964]. It kind of grew like Topsy. When I first came to Flagstaff, Elston agreed to do a bunch of time and motion studies—and quite frankly, I didn't think that the Survey should be involved with much of that—and Jack [Schmitt] agreed. We kind of got that thing turned around to where we were doing more field-testing—and doing some time-and-motion along with it. What they had been doing earlier was things like they'd get 15 students from Arizona State College (now NAU) and send them out into the field and tell them go out and break a rock, film it, and describe it. One of the first things we did learn from those early tests was the guys would break a rock and blow the dust off of it. That's not going to work with a spacesuit faceplate on!"

Fern Beeson (Administrative Officer) started work with the Branch of Astrogeologic Studies in Flagstaff on 12 July 1964 (See Appendices A and B). In 1981 she was promoted to the Administrative Officer at the Flagstaff Field Center. Fern retired—as Administrative Officer for the Flagstaff Field Center in March 1985. She now resides in Fischer, Texas.

Fern Beeson:
"When they called me to come in for an interview at the Museum of Northern Arizona—[where the Astro office was then], Gene Shoemaker was in his usual hurry, and told me he had to go downtown to another Astro office—and that was the so-called Dance Hall or Annex Building on Santa Fe Avenue [adjacent to the old A&W root beer stand at that time; presently Payday Loans, Inc.] Gene told me to get in the car with him and Don Elston, and they would interview me on the way down and back. So they asked me a few questions both going down and coming back. Gene asked me why I wanted to leave my present employment. And when I expressed a desire for a position where I would be kept busy and not be bored—his answer was a laugh [as only Gene Shoemaker could]. He said I would never be bored again!"

My first assignment on the day I started with the Branch was a strange one. They handed me processing papers, and I had to do my own employment papers! The second job given me was

Gene Shoemaker's travel for months. His travel file was made up of notes, scraps of paper, and you can guess what it was like.

By the end of my first day, I was a wreck, and ready to quit. Anyway, it took me a few days, of course, to get his travel voucher done, because there were so many other things that needed to be done. The Astrogeology files in the Museum of Northern Arizona were in boxes stacked everywhere—with no rhyme or reason.

I shared an office with four people. There was myself, Don Elston, Jack Schmitt, and one other I can't recall. About the second week I was there [at Astrogeology] Don Elston walked in and told me to get my things together because he was going downtown to find office space to rent for part of us [there at the MNA]. He came back and he said that he found offices in the old three-story building at 119 E. Aspen Street, directly behind the Arizona Bank Building (now the Bank of America Building).]

So we took everything we could find that belonged to the one's who were moving—and moved to the Burris Building downtown. Of course there was no elevator [in the Burris Building], and we were on the 3rd floor!

And of course when Don went in to tell Wanda Wilkerson [Administrative Officer at that time] that he had gotten more space, I can remember Wanda said, you didn't even request it—there is no approval! That is the way we did things in those days. Don told Wanda to go ahead and do your thing—and I'm moving! And of course we didn't have any telephones—or anything else. From The Burris Building, we soon moved into the Arizona Bank Building—and things really got started" (from an interview with Fern Beeson by Gerald G. Schaber on 13 August 2001).

Among the personnel that originally occupied the Burris building were members of the Image Analysis/Terrain Analysis Project (McCauley, Rowan, Jack McCauley's Image Analysis group (later combined into the Branch's Terrain Analysis Project) including geologists Larry Rowan and Howard Pohn, and assistant Ann Kelly, would moved into the Burris Building), in addition to surveyors Jim Crossen and Yukio Yamamoto; photogrammetrist Jim Alderman; and electronics-types Ray Barnett and Bill Mason.]

[<u>Space Exploration Milestone</u>: After six previous failures, Ranger VII impact on the Moon on 28 July 1964.]

David Levy:
"Once again Gene Shoemaker joined an anxious team at JPL. After a successful launch and trajectory to the Moon, the group [at JPL] waited as the spacecraft approached to within six hundred miles of the Moon; at that distance the cameras would turn on. Everyone in the room knew that the future of the Moon program rested on what would happen in the next few seconds. Cautiously, nervously, an engineer dispatched the signal to turn on the camera. "We have video!" It was an incredible moment. Ranger VII impacted near a ray from the crater Tycho, one of the Moon's most recent, large impact crater. When Ranger VII finally returned pictures, Kuiper suggested that walking on the surface of the Moon would be as easy as hoofing through crunchy snow. No more fears of spacecraft sinking in yards of dust [as Tommy Gold of Cornell

University had been predicting]. Harold Urey said that the surface was gardened, or turned over and over by small impacts occurring over the millennia" (Levy, 2001, pp. 98-99)]

During his interview with Gerald Schaber on 19 February 2001, Jack McCauley reflected:
"By late July 1964 I was pretty much burned out and needed a vacation. I went up to Yellowstone Park with my family. We took a trailer. Low and behold, while I was up there at Yellowstone, Ranger VII succeeded [on 28 July 1964] and obtained the first close-up pictures of the Moon. The first ones I saw were in the newspaper up there [at Yellowstone Park]. That showed convincingly—at last to those who had open minds—that the impact crater theory and the business of the saturation of the lunar surface with these impact craters, was the correct interpretation. That was, our model was correct. The craters went down to a condition that was fully documented in the Ranger imagery—of what they called a steady state. In other words, every time you add a new crater, it knocks out some that are already there—and you can only see that at the highest resolution."

Don Beattie:
"As our studies at Flagstaff accelerated, Elston and his staff began to develop several simulation sites nearby. One of these, just east of town, became a convenient place to test our ideas. In July 1964 Bill Henderson and I went to Grumman to have the model shop build a high fidelity, full-scale [painted plywood] replica of the LEM [Lunar Excursion Module] ascent stage as the starting point for our field simulations [at Flagstaff]. The replica was delivered a few months later [see Oct. 1964 below]. We mounted it on a truck bed, and it was carried back and forth to the field when needed"(Beattie, 2001, p 63).

The following information was found in the Branch of Astrogeology's Monthly Report for August 1964 to V.R. Wilmarth, NASA HQ; dated 30 August 1964:
"In August 1964 Harrison H. Schmitt began a recompilation of Gene's geology of the Copernicus quadrangle of the Moon [originally compiled by Gene Shoemaker on a telescopic photograph] using a newly-issued revision of the base map on the Mercator projection prepared by the Air Force Aeronautical Chart and Information Center (ACIC) [on the grounds of Lowell Observatory in Flagstaff]. The first edition of this map, on an orthographic projection, by Shoemaker and Hackman, served as the prototype lunar geologic map and although submitted to NASA, was not issued to the public.

In August 1964, Al Chidester reported that both the Manned Spacecraft Center and Survey geologists will participate in the field exercises for astronaut training; selection and organization of the trips is the primarily the responsibility of the Survey geologists. Six field areas have been selected for the second training series, or phase: Newberry Crater, Oregon; Valles Caldera, New Mexico; Nevada Test Site; Hawaiian volcanoes; Meteor Crater, Arizona; and Medicine Lake Volcanic area, California.

Astrogeology's In Situ project received a new seismic truck from GeoSpace, Inc. of Houston, Texas, on August 14. This unit included a 24-channel amplifier, a 28-channel FM tape recorder, an oscillograph, and associated equipment. The instrument is mounted on a 4-wheel drive Dodge truck capable of negotiating much of the rough volcanic terrain where the project investigations are being conducted.

In August 1964, Dale Jackson left the Branch of Astrogeology's astronaut training program at MSC in Houston to resume duties with Field Geochemistry and Petrology in Menlo Park, California. Alfred H. Chidester has relocated from the Branch's astronaut training program in Houston to the Flagstaff office of the Branch of Astrogeology where he will resume the duties of coordinator for the Survey program in geological training for the astronauts.

Geologist Henry Edward "Hank" Holt (b. 1929) in the summer of 1961 went to work with the Military Geology Branch of the Geological Survey, Washington. D.C. He was transferred to the Branch of Astrogeology and arrived on the scene in Flagstaff on 13 August 1964 (see Appendices A and B). Upon arriving in Flagstaff Hank began lunar geologic mapping at the Branch's new telescope on Anderson Mesa (south of Flagstaff) and was assigned to the Unmanned Lunar Exploration group at Astrogeology. He soon became heavily involved with Gene Shoemaker and crew on Ranger, followed by Surveyor, and spent much of 1966-1968 at JPL with the USGS Surveyor team.

Hank gravitated toward the Apollo Program activities and went down to the Manned Spacecraft Center (MSC) in Houston for all of the Apollo missions as an expert on photometric characteristics of the lunar surface. Prior to each Apollo lunar mission, Holt went to Cape Canaveral to calibrate all of the cameras and the gnomons that would be taken to the lunar surface. [Note-the gnomon is a tripod-calibration devise (with local vertical-seeking staff) developed in Flagstaff that was placed in each lunar close-up scene photographed by the astronauts.] Henry measured the photometric properties of some Apollo 12 and Apollo 14 samples at the Lunar Receiving Laboratory (LRL) in Houston, as well as at the Center of Astrogeology facilities in Flagstaff

Geologist Lawrence C. Rowan (b 1933) arrived on duty with the Branch of Astrogeology in Flagstaff on 26 August 1964 after receiving his PhD from the University of Cincinnati (see Appendices A and B. He would the following year (1965) recruit this author from the same institution for the Branch of Astrogeology.

Larry Rowan:
"Upon arrival in Flagstaff I was assigned to work with Jack McCauley on lunar terrain analysis in the Burris Building in downtown Flagstaff—which was very small quarters. We soon moved to —I believe—the fifth floor of the Arizona Bank Building [just to the north across the street from the Burris Building] (see Fig. 8). My main assistant was Ann Kelly. The rest of the staff on the project included Jack McCauley, John Running, Ann Kelly, Jim Alderman and Warren Borgeson [See Appendices A and B]. This would have been in the Arizona Bank Building in 1965-1966"

Don Wilhelms:
"Larry [Rowan] was destined for a major role in selecting exploration targets. He and [Jack] McCauley took the lead in converting the geologic maps of the LAC areas into separate maps whose units were expressed in quantitative terrain terms understandable to the engineers. Their purpose was not to certify landing areas—the telescope could do that—but to eliminate areas unfavorable for landings" (Wilhelms, 1993, p. 92).

Don Wilhelms:
"The Flagstaff Astrogeology office began to gear up its program of planning and simulating the [lunar] surface missions. Efforts that were part of the original charter of the Houston office but never materialized there beyond the writing of a few reports. When the [Survey's part of the] Houston astronaut training office dissolved, the branch was organized formally into three divisions: one each for support of unmanned and manned missions and a third for "pure science." Shoemaker turned each of the three disciplines over to a coordinator. Jack McCauley coordinated support of the Ranger, Surveyor, and Lunar Orbiter programs under the heading Unmanned Lunar Exploration Studies. Don Elston coordinated Manned Lunar Exploration Studies (or Investigations). Hal Masursky, still in Menlo park, led Astrogeologic Studies, which included outgrowths of the branch's original threefold investigations of lunar, cratering, and tektite/meteorite subjects (Wilhelms, 1993, p. 81).

[Astrogeology Milestone: (Wilhelms, 1993, p. 81) "In August 1964, when about 14 professionals and many helpers were in Flagstaff, ground was broken for a building [Building-One on McMillan Mesa] that the Branch could occupy permanently; thus promising to end the time-wasting game of musical office buildings that characterized its first years on the Colorado Plateau" (Fig. 17)]

[See *The Arizona Daily Sun*, 3-6 August 1964; *The Arizona Republic,* 6 August 1964; Department of Interior Press release 5 August 1964.]

[Author's Note: This is about as good a place as any to tell an amusing story about Elliot Morris and his persistent scrounging of military surplus items for the Branch of Astrogeology in the early 1960s. The story goes that Elliot wanted a tool kit that he saw in a U.S. Government surplus catalogue; probably back in 1963 or 1964. So he ordered the tool kit. A few weeks went by and the Branch got a call from the Santa Fe Railroad station in downtown Flagstaff that the missile that we had ordered had arrived. They wanted to know what we wanted for them to do with it. It turned out that the tool it that Elliot Morris had ordered came with a "large military missile." Apparently, Elliot had neglected to read the fine print in the Government surplus catalog. More than a bit embarrassed, the Branch sent the missile—and the tool kit—back from whence it came.]

Cartographic Draftsman James W. VanDivier (1931-1991) came to Flagstaff from Farmington, New Mexico (Superior Oil) on 24 September 1964 to work with the Branch of Astrogeology. Jim would become the head of the Branch's widely-heralded lunar and planetary map-making group throughout the Apollo Era, and well beyond. This Cartography group would prepare all lunar and planetary maps up to the actual printing and formal publication that was accomplished at the USGS Headquarters in Washington, D.C. (and later in Reston, Virginia).

"The exceptionally able Newell Jefferson Trask (Geologist; b. 1930) entered on duty with the Branch of Astrogeology at Menlo Park in September 1964, and like so many others not hired and inspired directly by Shoemaker himself, never really warmed up to the lunar work. Still, he mastered and advanced it" (Wilhelms, 1993, p. 87).

The following is from the Branch of Astrogeology's Monthly Report for September 1964 to V.R. Wilmarth of NASA HQ; dated 30 September 1964:
The Astronaut Office at MSC gave final approval in late September 1964 to a schedule of six lectures to be held in Houston and six field trips as the training series for the second term of the Astronaut Program in geology. The first field trip will be held near Bend, Oregon, under the direction of A.T. Waters (geologist).

The In Situ Physical Properties project began work in September 1964 on three areas in the mono Craters area in Eastern California. The areas consist of pumice, ash, cinders, and tuffs. All of the rocks in these areas are intermediate-to-felsic in composition in contrast to the mafic composition of the volcanic rocks near Flagstaff.

In September 1964, field sites were selected for Manned Lunar Exploration at the Bonito Flow, the S.P. Flow, the Kana-a Flow, Meteor Crater, Hopi Buttes, all in northeastern Arizona, at Moses Rock diatreme in southeastern Utah, and at Mono Craters, California. These field sites are to be utilized for time and motion studies of field tasks and operations of a geological, geophysical, and surveying nature, and for the development of integrated lunar scientific mission for single stations of limited areal extent (Apollo), and for multi-station reconnaissance-type traverses (MOLAB)

Time and information studies for geological, geophysical, and surveying tasks were conducted in September 1964. Geological studies, using nine semi-trained geologists, have been made at the Bonito Lava Flow, the S.P. Flow, Meteor Crater, and Moses Rock diatreme. Much of the effort was devoted to the development of guides for outcrop and terrain description. Preliminary field simulation tests have shown a need for guides for systematic data acquisition under the physical and mental limitations experienced under suited conditions.

About 9,000 feet of 16-mm movie film was exposed [by Astrogeology's film documentation group] during September 1964 to document the geological, geophysical, and surveying operations for the time and information studies for four sites: 1) Bonito Lava Flow, 2) S.P. Flow, 3) Meteor Crater, and 4) Moses Rock diatreme. The film was also used to document the geomorphologic and geologic character of the test terrain and to record details of lithology typical in specific areas.

The field test of the Surveyor spacecraft television camera continued throughout the month of September 1964 on the Bonito lava Flow [at Sunset Crater National Monument] northeast of Flagstaff. Over 15,000 individual negatives were obtained from 13 photogrammetric surveys and 200 photometric and polarimetric surveys. Stellar measurements were also made with the camera to determine the capability of the system to determine spacecraft location by star sightings. The camera was only able to detect the planets Jupiter, Venus, and the Star Sirius, all of which have magnitudes greater than -1.0

[Flagstaff Milestone: In September 1964 the Branch of Astrogeology took delivery (on the campus of Arizona State College in Flagstaff) of the largest computer in the state of Arizona north of Phoenix at that time. To mark this event the *Arizona Daily Sun* carried a story about the USGS's new Datatron-205 computer (Fig. 18). The article said:

"Last week the first computer north of Phoenix arrived on the Arizona State College campus. The Burroughs Company 205-Datatron, valued at $287,000 dollars is owned by the National Aeronautics and Space Administration, and has been detailed to the USGS for astrogeological studies. The computer was formerly located at the Ames Research Center, NASA, Moffett Field (California) where it was used in testing spacecraft.

The computer will be used to "refine" and detail lunar photos so that when the astronaut hits the Moon 239,000 miles away, he will be thoroughly briefed about its structure.

The USGS computer will be under the direct supervision of Wayne Lowry, an electronic engineer, and former troubleshooter for the company that developed the machine. Lowry talked about the machine much as a teacher discusses a bright pupil. "A problem that would take four mathematicians one year to do can be solved by this machine in 30 minutes."

[Author's Note: computer speed has been increased, and computer size decreased, "just a little" since 1964!]

[Author's Note: Soon after Ranger VII impacted the lunar surface on 31 July 1964, Gene Shoemaker got the idea of making a model of the lunar surface using the last (closest in) television frame (frame 979) acquired just before the spacecraft impacted the surface (see below)].

The following is from the Branch of Astrogeology's Monthly Report for September 1964 to V.R. Wilmarth of NASA HQ; dated 30 September 1964:
A stereographic model of the lunar surface [the first ever] at a scale of 1:20 has been made from a one-foot contour interval topographic map prepared from the high-resolution vidicon photograph, frame 979 taken by the "P-3" camera of Ranger VII. The topographic map was constructed by a photometric technique developed for lunar terrain analysis by the Branch of Astrogeology's Unmanned Lunar Exploration Studies group. Fine detail was added to the model through the use of illumination that duplicated the lighting condition at the time of the Ranger flight. After a mold was made, a number of models were planned to be prepared in November for distribution to NASA Headquarters and Centers (see February 1965 below).

By the fall of 1964, Carl Roach had lost most of his Shock Project funding when the test ban treaty went by the wayside. As a result, most of Roach's group in Denver [including geologists Gordon Swann (See 1963) and Joe O'Connor, and electronic engineer Ray Barnett] was being encouraged to move to Flagstaff to work with Gene Shoemaker.

The following is from the Branch of Astrogeology Monthly Report for October 1964 to V.R. Wilmarth of NASA Headquarters; dated 30 October 1964:
In October 1964 a 16-mm color film of approximately nine minutes duration, with narrative, entitled: "First Apollo Scientific Mission Simulation" was prepared for distribution to NASA Headquarters and other NASA Centers. The film documents a three-day suited and unsuited mission test conducted on the Bonito Lava Flow near Flagstaff. Some possible techniques for conducting geological investigations under suited conditions are shown in this film.

In early October 1964 Gordon Swann, who had been temporally assigned (for four month) to Astrogeology's astronaut training group at MSC in Houston, officially entered on duty at Flagstaff to work on the Manned Lunar Exploration Studies group, headed then by Don Elston.

In October 1964, Mike Carr (Astrogeology's Menlo Park office) had been working with Ed Dwornik [brother of Steve Dwornik of NASA HQ] and Joe Abele (Instrument Shop-Analytical) to prepare a sampling module for the Luster program. This is a sounding rocket program being run by Ames Research (California) to collect lunar material at the outer fringes of the earth's atmosphere. The module was completed and shipped to the White Sands Missile Range for launching.

Personnel entering on duty with the Branch in Washington, D.C. included Peter Robin Brett, Experimental Petrologist (October 1)

In October 1964 a mock-up of the front portion of the LEM ascent stage was received from the Manned Spacecraft Center, Houston, Texas. Mr. John M. Eggleston, Assistant Chief for Space Environment, MSC, arranged for the transfer of the mockup to the Geological Survey in Flagstaff. The mockup has been weatherized and doors and windows added so that the interior is completely enclosed and may be locked. The mockup will be used for Apollo scientific mission development in the San Francisco Volcanic Field and Hopi Buttes area of northeastern Arizona (Fig. 19) (see 1965).

Approximately 1,800 feet of 16-mm color film and 1,300 feet of 16-mm black and white film were used in October 1964 to document the time and information studies made by the lunar Field Geophysical Methods project personnel of the Branch at Mono Craters, California, and by the Lunar Field Geophysical Methods project personnel at Moses Rock diatreme, Utah. The film was taken primarily of seismic set-up and shooting, and of geologic mapping techniques.

Gordon Swann:
"Jack Eggleston of NASA/MSC started counting people and figured that not as many man-years were being accounted for on Astrogeology's part, as had been contracted for [on the astronaut-training program down there]. So I (from Denver) and Danny Milton (from Astrogeology's Menlo Park office) were sent to Houston in March 1964 to fill that square. After spending only four months in Houston before the Astrogeology astronaut training program was moved to Flagstaff, Swann moved 1 July 1964 back to Carl Roach's Astrogeology Defense Department Shock Project in Denver. After DARPA [Defense Research Projects Agency] funding for Carl's project was terminated, I moved to Astrogeology's headquarters in Flagstaff, and joined Elston's Manned Apollo Group. I arrived in Flagstaff in early October 1964" (taken from a filmed-interview of Gordon Swann by Harry Ryan in 1966; and an interview with Gordon Swann by Gerald G. Schaber on January 3, 2001).

Don Beattie recalls:
"Gordon brought his insight on how to meet the astronaut's requirements into everything that we were doing, based on his day-to-day interactions with them on their training trips. Gordon soon

became our primary suited test subject; pouring gallons of sweat into the boots of our borrowed space suits during his many simulations" (Beattie, 2001, p. 63).

About the same time that Gordon joined the Manned Lunar Exploration Group, Joe O'Connor (who had also been working with Carl Roach) likewise moved from Denver to Flagstaff**.**

Geologist Joseph "Joe" O'Connor (b. 1934) became acquainted with Gordon Swann at the University of Colorado, and later worked with him on Carl Roach's Astrogeology shock project in Denver (starting in 1963). Due to an unexpected cutback in DARPA funding, Joe O'Connor, along with Ralph Christian and Gordon Swann were transferred from the Denver thermoluminescence project to the Manned Lunar Exploration project [Advanced Studies Group] at Flagstaff. Their transfer to Flagstaff was official on 1 October 1964 (see Appendices A and B)

Joe O'Connor:
"I would later join the Branch of Astrogeology without even meeting Gene Shoemaker. What I had heard were Carl Roach's stories about Gene. Carl was a really good friend of Genes, but all of his stories were really negative. He used to say you've got to stay away from Shoemaker, because if you get next to Shoemaker—he is so magnetic—he'll just turn you on, and before you know it, you're going to have five times as much to do as you know how to deal with" (from an interview with Joseph O'Connor by Gerald G. Schaber on 9 July 2001).

Photographer Karl A. Zeller (photographer), one of the hardest working and most amiable people that the Branch of Astrogeology ever hired, began working for the Branch of Astrogeology on 28 October 1964 (see Appendices A and B). He was originally housed in the old Dance Hall, or the County Annex Building, in downtown on Santa Fe Avenue (see above). Karl had been in Flagstaff since 1956 and had worked for the old Jean and Trox photography store downtown, and then the Di-Oxygen Company in town.

William C. Phinney:
"Gene Shoemaker, after returning from NASA Headquarters in Washington, D.C., was in charge of the Branch of Astrogeology and its activities in Flagstaff. They [pre-Apollo studies] started in July 1964 under the title of Manned Lunar Exploration Studies (MLES) in which there were five separate projects: lunar field geological methods project headed by Jack Schmitt, lunar field geophysical methods project headed by Joel Watkins, lunar surveying methods project headed by Yukio Yamamoto, electronics investigations for field systems headed by Ray Barnett, and documentation for lunar field systems project headed by Hal Stephens" (William C. Phinney, submitted; included an interview by Phinney with Gene Shoemaker in 1995).

[Author's Note: Gene Shoemaker explained quite clearly to William Phinney [now retired geologist from the Manned Spacecraft Center in Houston, Texas) what he [Gene] had in mind regarding optimal geologic exploration on the Moon during Apollo and Post-Apollo during their 1995 interview; see below.]

Gene Shoemaker:
"One of our mainline efforts here was to try to work out the most efficient way that you could do human exploration. My notion, and this was the thing in the back of my mind all the way along,

was to try to figure out a way to maximize the amount of science return, not just for the samples brought back, but to really try to get a maximum return on what the astronauts themselves could do on the Moon. And I wasn't thinking of ALSEP [Apollo Lunar Surface Experiment Package]; I was thinking about what the astronauts can do as human observers. The basic notion in my mind was, and I put myself in the position of what I'd want if I were the guy on the Moon, you want to offload all of the "Mickey Mouse" stuff. Ideally you'd like to track the astronaut with a little laser system mounted on the LM [Lunar Module]. So, you'd know every point accurately on the traverse. You'd like to have it set up so you'd have a very thorough visual record. So you'd have video of the whole thing. But you'd also have control of it and you'd automatically record where the camera was pointing, not just the video but also the still photography. You'd know exactly where you are looking and you'd know the orientation of the camera. And you'd also know where it is all the time. And you'd like to have a team of people keeping track of you and compiling all the time as you go. So, you'd have an up-to-date picture of what you've seen and you have a context, as nearly as possible, right up to the minute, as you go along. Unload from the astronaut every damn chore that you can so that he, the human observer, can do what he can do best which is to use his eyes and his wits to see things because my notion was that you have a limited number of opportunities to show that you can really make discoveries with a human observer. So the idea was to try to get out of Apollo a test of the concept that it really made a difference to scientific discoveries by having a human being there. That's what we tried to figure out in practice here [at Flagstaff]. And that to me was what it was all about. Gradually, I came to realize that that was not going to happen. If we'd had a few more missions, it might have happened, but we never quite got there" (from interview by Phinney with Gene Shoemaker in 1995 (William C. Phinney, submitted).

The following is also from William Phinney's 1995 interview with Gene Shoemaker:
"Also, according to Shoemaker, the NASA ground rule from the beginning was that you couldn't hang anything on the astronaut. Later it turned out that they did, but that was the ground rule that we were working with at first. We said okay, we'd give the astronaut a staff that he'll walk around with and it would have everything that will do these things. [See 1966.] It would have a transponder on it, corner reflectors so that you could track him, devices for determining the orientation, and it would carry a video camera and a stereo camera. The idea was to use it a lot. All you'd have to do is squeeze a trigger and just keep going. And of course we thought about the tools and things that would be needed to take samples, etc. But the real heart of it was how to get the best value out of a traverse. The plan was to develop a control center, or backroom, for the science activities where all of the TV and other data from the field simulations [around Flagstaff] could be sent by telemetry for the scientists to evaluate and analyze. Gene visualized the "backroom" doing all of this stuff and following the guy who was actually doing the traverse, building a map as he goes, doing all of those things to try to understand how to get the maximum out of a traverse."

Don Beattie:
"Shoemaker and his Field Geology Team also believed that stereoscopic photographs were necessary to document samples and the general geological scene. He enlisted Homer Newell, who agreed and wrote to George Mueller that they were "a necessity on every lunar landing mission." In the summer of 1966 the Manned Space Flight Experiments Board asked Shoemaker to develop the specifications for a stereo camera [see 1966]. Preliminary work was carried out to

develop such a camera, but it was eventually cancelled because of payload weight and EVA time constraints. The astronauts were then trained [by Ray Batson of the USGS-Flagstaff and others] to use the Hasselblads to take stereo pairs" (Beattie, 2001, pp. 119-120).

[Author's Note: Gordon Swann told this author (in July 2002) that he had to correct Don Beattie on one point that he mentioned above. "The lunar stereo camera [that the Branch was developing and field testing in astronaut simulations] was cancelled because development was under Leonard Reiffel [in George Mueller's Office, Office of Manned Space Flight, NASA HQ], who never liked the camera, Gene Shoemaker, or the USGS for that matter. The company chosen to develop the camera really wasn't capable of so complex an undertaking, and eventually went bankrupt; so the camera was never really developed. This is a true, but somewhat incomplete explanation."]

The following extensive quotes are from William Phinney's book (submitted) and his 1995 interviews with Harrison "Jack" Schmitt, Gene Shoemaker, and Gordon Swann:
"Jack Schmitt and Gordon Swann were brought on board by Shoemaker to get these activities underway. They became almost totally immersed in this activity in 1964 and 1965. In Gordie's words he was the first involved with the business of trying to work out techniques on the Moon: that kind of stuff, field tasks and some astronaut training"

Harrison "Jack" Schmitt: When I was hired at Flagstaff I was given the option by Shoemaker of working on Surveyor or setting up a project that was ultimately called the lunar field geological methods project which in a sense was indirectly related to training because Gordon Swann and I, particularly, were trying to figure out what kind of procedures should they actually be learning in order to take samples and photographs and things like that. We started with really some very basic stuff; in fact I even had a group of University of Arizona freshman geology majors that Spence Titley brought in. He was consulting for the Survey at the time, and, not knowing what we were doing (we were just getting our feet wet) we had these kids acting like astronauts in certain types of sampling procedures. We were sort of doing time-and-motion studies trying to figure out just how well certain things work, that is sampling and other things like that. So really in that 1964-1965 time frame some of the crowd of people that later was deeply involved in the actual Apollo missions were trying to figure out what the hell was this thing called lunar exploration. All of that fed ultimately into a lot of the things that happened later on, but it was purely getting your feet wet at that time.

When Bill Phinney showed Gene Shoemaker the above comments by Jack Schmitt, he continued on with his concept of what they were trying to do. Gene commented:

Shoemaker: "That was a small piece of it. I'd forgotten about the students. That was all building up to it. We were really trying to figure out how do you really want to do lunar exploration? Also, a fair amount of our effort was not just Apollo. We were trying to look beyond Apollo. What would you follow Apollo with? So that led to the Lunar Field Geology Experiment. The science program as it got set up and run (in NASA) was the concept that you have an experiment with some danged instrument. But somewhere there had to be some responsibility for what the hell the astronauts did in honest-to-God field geology. That's what I was trying to get at. So that's how it got submitted and it got accepted as a form of "experiment"

[Shoemaker is referring here to his Apollo Lunar Geology Experiment]. And of course, a part of that was trying to understand the details of each (potential Apollo landing) site as best we could beforehand."

To get a better idea of the detailed tasks that were being studied in one of the projects [at Flagstaff] one can study a [USGS] memo to the personnel of the lunar field geological methods project [in Flagstaff] on 13 October 1964 in which Jack Schmitt asks for volunteers in eight different topics that were being developed in the project. These were (1) methods of geological description including transmission and recording of data, (2) making of geological maps by two men on the lunar surface, (3) purposes and methods of geological sampling on the lunar surface, including the role of a mobile laboratory, (4) applications of imaging systems to descriptions and mapping, (5) usefulness and application of petrographical, mineralogical and analytical methods on the lunar surface oriented primarily toward mobile laboratory operations, (6) bearing of LEM and pressure suit design on geological field operations, (7) bearing of mobile laboratory and instrumentation on geological field operations, and (8) preferences of unmanned lunar investigations to manned geological operations on the lunar surface.

Jack Schmitt and Gordon Swann spent nearly all of their non-sleeping hours on efforts for the lunar field geological methods project. According to Gordon, about 16 hours a day!

Gordon Swann: We were sharing an apartment at that time. We had become very close friends even before he [Schmitt] applied to become an astronaut. Technically, until he went to be an astronaut (in July 1965), I guess he was kind of my boss, if there was such a thing. We worked pretty closely on all of that stuff. But Jack and I kind of pooled our energies and got the efforts out of time-and-motion category and into the business of testing procedures and stuff that I think made sense. Then I got more involved—well remember at that time NASA was planning these long-term laboratories, roving laboratories, those kinds of things. At that time I was pretty heavily involved with that kind of stuff. I was pretty involved with some of that and all of that as coming out of NASA Headquarters (not MSC), and a little out of Huntsville. We wrote reports and did these field tests. We'd go out and try different things, and then write these green-backed reports on them [The Astrogeology Technical Letters]. However, as those things began to kind of go down the drain I began to get more and more heavily involved with the Apollo stuff."

[Noteworthy Flagstaff Community Event—The *Arizona Daily Sun* dated 3 October 1964 ran a story titled "Here are the Candidates for Flagstaff School Board"—with their photographs. The 212 candidates included Dr. Doyle Bladon, Robert A. Blaser, William Brechan, Robert Clough, Frank Hoover, William Hoyt, Louis Hudiburgh, Dr. J. B. Hunt, E. Lee Hutchison, Joe Rowan, Dr. Eugene Shoemaker, and Dr. Howard Wren. The article states that "Shoemaker seeks election to the School Board because he feels Flagstaff schools should not "settle for less than the best." It goes on to say that he seeks election because he feels "that the schools can be improved." The article continues: He seeks specific improvement in the areas of the sciences, arts, and the humanities by taking "better advantage of the human resources and talent of the community" in those areas.

The *Arizona Daily Sun* dated 7 October 1964 carried the results of that school board election. . Blaser, Wren and Bladon won the school board seats and Gene Shoemaker came in fourth in the total votes with 560 votes.]

The following is from the Branch of Astrogeology Monthly Report for November 1964 to V.R. Wilmarth of NASA HQ; dated 30 November 1964:
"On 7-9 October 1964 and 15-17 October 1964 two different groups of NASA astronauts were taken to Newbury Crater, Bend, Oregon for geologic training (see Table I). The major objective of this trip was to observe, analyze and discuss various volcanic features in the vicinity of Newbury Crater, a large (50 X 30 mile) shield volcano. This is a complex of nested craters with an extreme range of differentiated volcanic rocks, obsidian flows, pumice cones, and cinder cones and tuff rings. Aaron Waters of the University of California was the local expert. Other geologists present: Dale Jackson, Danny Milton, Don Wilhelms, Park Snavely, and Al Chidester of the USGS, and Ted Foss, Uel Clanton, and Elbert King of NASA/MSC, Houston (taken from William C. Phinney, submitted).

[Astronauts attending these two trips to Newbury included: (on 7-9 October) Eugene Cernan, Roger Chaffee, Michael Collins, Rusty Schweikart, and Dave Scott; and (on 15-17 October) Buzz Aldrin, Neil Armstrong, Charles Bassett, Allan Bean, Walt Cunningham, Elliott See, and C.C. Williams.]

[Author's Note: A third running of this trip for the remaining astronauts was cancelled because of the death of one of the astronauts (Ted Freeman) in an airplane crash on 31 October 1964.]

On 23-25 October, 29-31 October and 13-14 November 1964, three separate astronaut-training trips were run for a total of sixteen NASA astronauts to the Valles Caldera in New Mexico. The objective of this trip was to view the typical characteristics of ash-flow tuffs and another caldera, the 25 X 35 km Valles Caldera in the Jemez Mountains of New Mexico, whose history is somehow different from that seen at Newbury Caldera (see Table I).

The local experts were Roy Bailey, Bob Smith, R. Doell, and L. Cordell of the USGS. Other geologists present were Uel Clanton and Ted Foss of NASA/MSC, Houston and Al Chidester of the USGS.

At the request of the astronauts, and with the cooperation of the Manned Lunar Exploration Investigations documentary unit, the Valles field trip was used to test the feasibility of making a sound-movie documentary of the trip. Documentation was also planned to be tried on the forthcoming Hawai'i astronaut training trip; and if it proved to be feasible, subsequent trips will be similarly documented."

[Astronauts attending the three separate trips to Valles Caldera include (on 23-25 October- Buzz Aldrin, Bill Anders, Allan Bean, Roger Chaffee, Michael Collins, Ted Freeman, and C.C. Williams; (on 29-31 October 1964) Neil Armstrong, Charles Bassett, Eugene Cernan, Walt Cunningham, Dick Gordon, Dave Scott, and Elliot See. Astronauts attending on 13-14 November were Walt Eisele, and Rusty Schweikart.]

The following quotations were taken from the Branch of Astrogeology Monthly Report for November 1964 to V.R. Wilmarth of NASA HQ; dated 30 November 1964:
The Branch of Astrogeology personnel completed the field test of the Surveyor Spacecraft television camera on 19 October 1964. During the two and a half months of the Field test, 20 photogrammetric surveys and 860 photometric and stellar measurements were made with the television camera yielding more than 20,000 negatives. Techniques developed to mosaic the imagery from the field test will be used during the actual mission of the Surveyor Spacecraft.

The highlights for November 1964 of the activities of the various projects under Astrogeology's Manned Lunar Exploration Investigations within the Branch of Astrogeology included: (1) the initiation of the development of sequenced geological operations for Apollo and extended Apollo missions, (2) determination of the relation of operator experience to the speed and the quality of gravity meter traverses, (3) preliminary modification of a four-wheel drive vehicle for mobile surveying studies, (4) establishment of the basic microwave relay link from the field areas near Flagstaff to the base data reception facility, and (5) further filming of geological and geophysical time, motion, and information studies.

The basic microwave relay link from the field areas near Flagstaff to the base data reception facility has been established on Mt. Elden [east Flagstaff], and successful, preliminary tests have been conducted. In addition, installation of a surveillance television system in a mock-up of the front portion of the LEM ascent stage was largely completed in November. This system will be employed in the development of lunar field methods.

Investigations by the Lunar Field Geological Methods project have shown that lunar outcrop descriptions should, in general, include only those features necessary to identify mapable units and features which cannot be obtained from post-mission examination of returned samples and photographs. More description than this is, in general, redundant and requires excessive time to perform. It has also been found that reconnaissance description and mapping of even subtly contrasting rock units in areas of moderate relief can be largely accomplished by use of stereo-pairs of horizontal-axis, color photographs, provided portions of the rock units shown in the photos have been sampled and described in outcrop.

November 1964 field operations have indicated that the basic pieces of equipment for a manually operated surveying staff are as follows:

1. Sun compass with a rear sight
2. Single-axis pendulum clinometer
3. Two opposed-line bubble levels mounted below the sun compass dial. (For lunar work, this arrangement would probably need to be replaced by a hemisphere-ball, multi-axis clinometer; a two-axis, pendulum clinometer; or a gyroscopic clinometer).
4. Film camera with its optic axis perpendicular to the staff and parallel to the sight on the sun compass.
5. Vertically mounted optical rangefinder or a telescope with stadia-hairs.

In cooperation with R.R. Blecha, E.E. Butler, and D.W. Dodgen, the Geological Survey's prototype surveying staff was being modified during November 1964 to include the features listed above. Design studies for a fully automated instrument [surveying staff] are being continued by Dodgen and E.C. Phillippi"

[Astrogeology Milestone: In November 1964 the Branch of Astrogeologic Studies submitted its second Annual Astrogeology Progress Report for research carried out during the period 1 July 1963 to 1 July 1964. The report was in three Parts: Part A- Lunar and Planetary Investigations, Part B- Crater Investigations, and Part C- Cosmo-chemistry and Petrology.]

The *Arizona Daily Sun* of 17 November 1964 carried William Hoyt's Byline: "Astrogeology Unit Here Expands, Reorganizes." The article included a photograph of the nearly completed building [Building-One] on McMillan Mesa (Fig. 20).

The caption to the photograph reads:
"Almost Ready—The new headquarters and laboratory building for the U.S. Geological Survey's Branch of Astrogeology is well on its way to completion atop McMillan Heights, and will be ready for occupancy by mid-February [1965.] The branch's increased responsibilities to the nation's space program, however, will necessitate its keeping its offices in the Arizona Bank Building which cover the entire fifth floor, and two other work and storage sites in the city. The Branch's growth has also required its reorganization into three separate divisions to handle its new and varied research programs."

The text of the article reads:
"The U.S. Geological Survey's Branch of Astrogeology here, its mission in the nation's space program vastly increased, has already outgrown its new headquarters building on McMillan Heights—and the building won't be ready for occupancy until mid-February!

Addition of new and vital research projects connected with the Ranger, Surveyor and Lunar Orbiter programs, and the manned space programs such as the Apollo Man-on-the-Moon project, have boosted the branch's staff here to some 75 scientists and technicians, more than twice the original number planned for the Flagstaff facility.

Now headquartered in a wing at the Museum of Northern Arizona's Research Center, the burgeoning branch will move into its new headquarters and laboratory facility in mid-February, but it will have to retain office and work space it has recently leased in the Arizona Bank Building downtown, and work and storage space in two other buildings in the city. In all, the branch is now working out of four locations in Flagstaff."

[Author's Note: Unfortunately, the game of musical offices within the branch only became worse soon after the occupation of Building-One on Flagstaff's McMillan Mesa in early 1965. It became clear that this facility [with much less space than originally hoped for, and more cheaply constructed than desirable] was not going to satisfactorily house the rapidly growing Astrogeology science staff. This was not only true for the professional staff, but for the even more-rapidly expanding supporting staff that included administrative personnel, machinists, photographers, cartographers, electronics technicians, geophysics support personnel, draftsmen, and surveyors, among others. Also, the plan to relocate the branch's machine shop from the wing at MNA was thwarted by the fact that the new building had a false floor that could not support the weight of the many heavy milling, grinding, and drilling machines which Elliot Morris and Bob Blecha had scrounged mostly from government surplus. The machine shop was relocated from the Museum of Northern Arizona to a building at 1733 N. West Street in the Sunnyside area of East Flagstaff (Fig. 21).

[Astrogeology Milestone- In the December, 1964 issue of *Scientific American* (Vol. 211, No. 6) magazine, Gene Shoemaker published a pioneering article entitled "The Geology of the Moon," based on his analysis of the Ranger images.]

In December 1964, a large contingent of the Branch moved into the entire 5th floor of the Arizona Bank. [Author's Note: We would later occupy much of the 4th and 3rd floor as well) (See Fig. 8)].

Jack McCauley:
"It was about the same time that the Branch was divided into four sections: (1) *Astrogeologic Studies* in Menlo Park headed up by Hal Masursky—and staffed by the recalcitants who refused to move to Flagstaff; (2) *Manned Lunar Exploration* people who were working on the whole problem of trying to do geology on the lunar surface for the upcoming Apollo and Post-Apollo missions headed by Don Elston, and staffed by some of the people who were originally part of the Branch's astronaut-training MSC group; (3) the *Image Analysis section* which was headed by McCauley, and that was shortly renamed *Unmanned Lunar Exploration*, and encompassed the various aspects of the Terrain Analysis effort, and work on the Ranger, Surveyor, and Lunar Orbiter Projects. A fourth, short-lived, Geophysics Group [*In Situ Geophysics*] also operated out of Flagstaff headed up by Joel Watkins" (Memoirs of Jack McCauley, unpublished).

The following was taken from the Branch of Astrogeology's Monthly Report for December 1964 to Dick Wilmarth of NASA; dated Dec. 31, 1964:
In December 1964 Harold Masursky, working with Michael Carr and Henry Moore (from Astrogeology's Menlo Park Office), devised a hypothesis for the development of lunar crater central peaks. The hypothesis is based on high-speed cinematography by Don Gault of Ames Research Center of hypervelocity cratering experiments in rock targets and on field studies of terrestrial craters by David Roddy (Branch. of Astrogeology) at Flynn Creek, Tennessee, and Michael Dence and Willy Manton at Manicouagan Lake, Ontario, Canada. The movies show the development of this peak by violent decompressional uplift of a central column that emerges after the initial cone of ejecta emerges. Supporting evidence at the Flynn Creek crater indicates that the rocks of the central peak are derived from strata that are 900 feet lower than the crater floor.

Approximately three days fieldwork was conducted early in December 1964 for the development of lunar geological mapping methods and for the establishment of geologic control in the Castle Butte area of the Navajo Indian Reservation [for future Early Apollo, Apollo Applications Systems and Advanced Lunar Studies field exercises by the Branch. The reduction of data from field geological operations obtained in the Hopi Buttes area during October and November, and data on geological surveying and field methods obtained in the Flagstaff areas during July, August, and September were also carried out.

Jack McCauley:
"In December, 1964, most of the science and engineering people in Flagstaff had settled into the fifth floor of the Arizona Bank building downtown. These proved to be comfortable quarters. They served the Astro Group up through the completion of most of the work preparatory to the Apollo landings-Ranger, Surveyor, and Lunar Orbiter. Personnel from both the Manned and Unmanned Groups within the Branch occupied much of the three upper floors in the Bank Building for almost ten years (until 1973). A number of more specialized groups such as the rock lab, machine shop, photogrammetry, and photolab were scattered throughout Flagstaff" (from an interview with Jack McCauley by Gerald Schaber on 19 February 2001).

[Authors Note- Flagstaff's *Arizona Daily Sun* carried an article about the lunar maps being prepared at Lowell Observatory (Flagstaff, Arizona) in its issue of 30 December 1964.]

3.2-1965

[Author's Note: A total of nine geologic field-training exercises were carried out during 1965 under the leadership of Branch of Astrogeology personnel (See Table I).]

Don Beattie:
"By 1965 Gene [Shoemaker] had major pieces of many NASA pies: Ranger, Surveyor, Lunar Orbiter, lunar geologic mapping, astronaut training, the job of principal investigator for the first Apollo landing missions, and post-Apollo science planning" (Beattie, 2001, p. 61).

William Phinney:
"At the beginning of 1965 NASA arranged for more contracts with the USGS group at Flagstaff to evaluate the concept of a modified LEM that could serve as a laboratory for two men to explore the lunar surface for periods of up to two weeks. There was also the possibility of having a roving vehicle available. Various types of analytical instruments were to be evaluated as part of the equipment on board this modified LEM. [Joe] O'Connor and Swann made an extended trip to several laboratories in the southern and eastern U.S. to evaluate various types of equipment for petrographic, X-ray diffraction, X-ray fluorescence, and other analyses that might be accomplished on the modified LEM" (William C. Phinney; submitted).

The following was taken from the Branch of Astrogeology Monthly Report for January 1965 to V.R. Wilmarth of NASA HQ; dated 31 Jan 1965:
In January 1965, recommendations for possible Surveyor landing sites on the lunar surface for Surveyor Mission A were supplied to the Jet Propulsion Laboratory. Selection of the five recommended Surveyor landing sites was based on the launch data, the general mission constraints, and on lunar terrain data from current U.S. Geological Survey research projects.

Between 12-24 January 1965, several different groups of astronauts were taken to the Big Island of Hawai'i for their first geologic training exercises there (see Table I) [Also see *Hawaii Tribune-Herald*, 13, 15, 20 January 1965; *The Honolulu Advertiser*, 13, 18 January 1965; *Honolulu Star-Bulletin*, 15 January 1965.

The *Hawaii Tribune-Herald* for 12 January 1965 carried the Headline "Astronauts View Kilauea Features." The text read as follows:

"Two of the Big Island's outstanding volcanic features—Kilauea Crater and Kilauea Iki's lava lake—came in for close inspection by hiking U.S. astronauts this morning. The spacemen strode across the Kilauea Iki Lake which, they found, was still cooling after it had been filled to a 300-foot depth by the 1959 eruption. They studied rifts and upright features of the 1854 flow in Kilauea caldera. Each astronaut saw for the first time an abundance of evidence of Hawai‘i's recent eruptions.

Attending this first astronaut trip to Hawai‘i were astronauts Buzz Aldrin, William Anders, Neil Armstrong, Charles Basset, Alan Bean, Roger Chaffee, Michael Collins, Charles Conrad, Walt Cunningham, Don Eisele, Dick Gordon, Rusty Schweikart, Dave Scott, Elliot See, and CC. Williams, Jr. Local USGS volcanism experts participating were Howard Powers, Director of the USGS Hawaiian Volcanic Observatory, and J.P. Eaton, Don Peterson, Dallas Peck, Dave Hill, and Jim Moore. Other geologists present were Al Chidester, Dale Jackson, Don Wilhelms and Marty Kane of the USGS Branch of Astrogeology's astronaut training unit assigned to MSC/Houston, and Ted Foss and Elbert King of the Manned Spacecraft Center, Houston.

Don Beattie:
"[Even] before Shoemaker's appointment [as PI of the Apollo 11 Lunar Geology Team], two conflicting concepts for field geology instrumentation were under development, one designed by the staff at the Manned Spacecraft Center and the other by USGS in Flagstaff. MSC, led by Uel Clanton, had devised an engineering model of an all-in-one geological tool that the astronauts could use for sampling, drilling, and several other functions in an attempt to simplify the many tasks they would have to accomplish—and at the same time save weight and time by reducing the number of tools needed.

USGS had similar concerns but thought the biggest problem would be locating and documenting the sites visited, and in particular sampled, so that accurate traverse maps and profiles could be reconstructed back on Earth. The Flagstaff team had devised a surveying staff that would reflect a laser beam from a ranging device and automatically record the coordinates of a position on the lunar surface. This approach was based on the simulations and exercises we had been conducting for the post-Apollo missions [at Flagstaff], which suggested that without some type of surveying instrument it would be almost impossible for an astronaut to accurately locate his position on the moon and associate a sample or observation with a specific point. Lunar geologic maps made without such positioning would be seriously degraded in value, since to establish map locations we would have to depend on some type of dead reckoning or coarse Earth-tracking and reconstruction of the traverse based on voice communication.

Our experience during the Martin Marietta contract [in 1964 with regard to astronauts making geologic observations from the Lunar Excursion Module (LEM-later shortened simply to LM, or Lunar Module) (See Beattie, 2001, P. 38), and the growing concern about measuring distances on the lunar surface, led the Branch of Astrogeology to further explore including a periscope in the Lunar Module (LM), as we had proposed earlier, rather than the sextant that was being planned for navigation. In February 1965, Gordon Swann and [optical instrument builder] Dave

Dodgen [from Astrogeology-Flagstaff] visited two Navy periscope suppliers, Kollmorgan and Kollsman Instruments, to discuss their ideas. Besides the concerns arising from the Martin Marietta contract, they wanted to be able to track an astronaut if only one was allowed to leave the LEM. Though both companies thought the Apollo navigation requirements and the surveying ability needed on the Moon's surface could be incorporated in one instrument, no official action was taken. A jerry-rigged optical ranging periscope built by Dave Dodgen and Walt Fahey (USGS, Branch of Astrogeology-Flagstaff) was used during some field simulations to assess the value of such an instrument.

These three pieces of equipment had their advocates and their detractors. At the end of 1965 the MSC engineering model was tested by a joint review team composed of members of Foster's office and several MSC offices, including representatives from the astronaut office, and we agreed to stop work on this tool. Because of its several functions, it was large and cumbersome, with so many batteries, handles, switches, and other components that it looked like a Rube Goldberg contraption.

The USGS surveying staff survived our initial evaluations. In spite of the advertised versatility of these tools, the astronauts would still need additional equipment for tasks that the all-in-one designs could not perform. Converting the LM sextant to a periscope was also finally abandoned because of the added cost and schedule delay entailed by modifying the LM navigation system. For the last three missions, a navigation system on the astronaut's Lunar Rover met most of the tracking and mapping requirements" (Beattie, 2001, pp. 108-110).

William Phinney:
"At the beginning of 1965 NASA arranged for more contracts with the USGS group at Flagstaff to evaluate the concept of a modified LEM that could serve as a laboratory for two men to explore the lunar surface for periods of up to two weeks. There was also the possibility of having a roving vehicle available. Various types of analytical instruments were to be evaluated as part of the equipment on board this modified LEM. [Joe] O'Connor and Swann made an extended trip to several laboratories in the southern and eastern U.S. to evaluate various types of equipment for petrographic, X-ray diffraction, X-ray fluorescence, and other analyses that might be accomplished on the modified LEM" (William C. Phinney, submitted).

In February 1965 Hal G. Stephens changed headquarters from Menlo Park, California, to Flagstaff, Arizona to become Chief for Documentation of Lunar Field Systems for the Branch of Astrogeology.

Photo-mechanical Technician/Cartographer Hugh F. Thomas (b.1943), a Flagstaff native, and another talented, hard-working member of the staff at the photolab at the Survey's Flagstaff Field Center entered on duty with the Branch of Astrogeology on Valentines Day (February 14) in 1965 (see Appendices A and B).

When this author asked Hugh Thomas if he recalls any stories about Shoemaker, Hugh replies as follows:
"I do recall one interesting story [out of many] about Gene Shoemaker at the photolab. I had just started working back there and, of course, everybody wanted everything yesterday—if not

sooner! We had this one project that was obviously related to the Apollo missions. Gene [Shoemaker] had a meeting to go to [as usual for Gene in those days], and we had to have this stuff done. We were just working our tails off and we had worked half the night on it. Gene was leaving about one or two o'clock in the afternoon from the airport in the Branch airplane. I don't remember who was flying it, but we told him there is no way, we just can't get it done! He said I've got to have it! It ended up that we ran out to the airport. I don't know whose car it was, but we were hanging a Cronopaque out the window [of the vehicle] drying on the way to the airport. We actually drove down the taxiway and met the airplane at the end of the runway and gave him the Chronopaque—that was still slightly damp. But you would have thought that it was Christmas when we got him that final Chronopaque that he thought he wasn't going to get for that meeting" (taken from an interview with Hugh Thomas by Gerald G. Schaber on 1 April 2001).

[Author's Note: Events like that described just above were actually quite common during the incredibly busy and hectic travel schedule of the Branch professionals during the pre-Apollo and Apollo Era in Flagstaff.]

[Author's Note: During my interview with Hugh Thomas, I related to him a similar incident at the Flagstaff airport that involved the unflappable Hal Masursky (who hired by Shoemaker at the Menlo Park office in September 1962, would move to Flagstaff in March 1968.) It seems that Hal, who almost daily was flying somewhere throughout his career with Astrogeology, was usually late for his flights. On one such occasion Hal was running exceptionally late for his Frontier Airlines flight out of Flagstaff's Pulliam Airport for Phoenix—and subsequently a very important NASA meeting somewhere that afternoon. By the time Masursky arrived at the airport, his flight had already left the gate and was heading down the taxi strip for take off. Hal told the USGS driver to drive out onto taxi strip and stop the Survey car in front of the plane. Hal then got out and stood in front of the plane waving his briefcase and luggage until they had little choice but to stop and let him inside. In those heady days, all of the pilots and stewardesses knew Hal very well from his nearly daily flights with them—so they knew that they had better stop for him because Masursky would not give up easily. In today's world, Hal and his USGS driver would have been arrested as possible terrorists, and would still be in prison. But thankfully, this occurred in the 1960s—not the new Millennium!]

Hugh Thomas also recalled the day Gene first saw "ChartPak" drafting Tape being used for the first time by the Branch of Astrogeology's cartography/drafting group in Flagstaff:

"We had gotten this new chart tape, the little black tape in varying widths that one could use to curve it, or for straight lines. You didn't have to ink the line any more. And Gene could never edit anything until it was finished! We'd give him final product—and "then" he would edit it again of course! About ten o'clock one night Gene was down there with this diagram. I think Jim [VanDivier] was working on it. Jim did quite a bit of drafting back then too. Shoemaker was hanging over his shoulder, and Jim was just about done. He was ready to send it over to the photolab to copy it. Gene said, well this one line is not quite right. Could you move it over just a little bit? Jim reached down and picked up that piece of tape and just laid it back down. Gene just sort of looked at him and said how the hell did you do that? He had just never seen that before. He was shocked how we could just pick up that line and move it. Boy, that Chart-Pak tape was really something after that" (taken from an interview with Hugh Thomas by Gerald G. Schaber on 1 April 2001).

[Author's Note: In February 1965 President Johnson and Vice President Humphrey were given a briefing on the U.S. Geological Survey's photometric lunar mapping technique by NASA officials in Washington, D.C. One of the models prepared by Branch of Astrogeology personnel in Flagstaff and Menlo Park from Ranger VII photographs was used in the briefing (hopefully, not the reversed one; See below).]

[Astrogeology Milestone: In February 1965 the Branch of Astrogeology submitted to NASA its first Semi-annual Progress Report (180 p.) for "Manned Lunar Exploration Investigations" for research carried out during the period 1 July 1964 to 1 January 1965.]

The following was taken from the Branch of Astrogeology Monthly Report for March 1965 to V.R. Wilmarth of NASA HQ; dated 31 March 1965:
"During February 1965, preliminary design and specifications for a lunar stereographic camera were dawn up, and an engineering study on the special photogrammetric and spectrometric capabilities of this camera system was undertaken by Branch of Astrogeology personnel in Flagstaff"

The 4 X 6-foot plaster relief-model made of the final frame from Ranger VII was completed by the Branch of Astrogeology in February 1965 using the stereo model of that final Ranger frame produced by the Branch in September 1964 (see above).

[Author's Note: See story about Ranger VII relief model constructed by the USGS, see Flagstaff's *Arizona Daily Sun* issue of 19 February 1965].

Both Larry Rowan and Howard "Howie" Pohn recounted to Gerald Schaber a little episode of embarrassment for the fledgling Branch of Astrogeologic Studies with regard to this Ranger topographic model of the lunar surface described above.

Howard Pohn recalls
"Well, Wally Black came in from Menlo Park—and he and I, using photoclinometry that Larry Rowan and Jack McCauley had worked on with the Burroughs-Datatron-205 computer [including hundreds of "vacuum tubes" that the Branch had purchased and had been set up in its own large room at Arizona State College (later NAU)" (see Fig. 18).

They did the photoclinometry, and we built this table-sized [topographic] model from the final frame of Ranger VII. The model was probably 4 X 6 feet or something. And somehow, I was put in charge of making a small model that was going to be printed on plastic—you know—the vacuum-formed plastic maps [like the topographic maps that the USGS had been experimenting with for sale at that time]. The Army Map Service was making such plastic relief maps of that Ranger scene" (Fig. 22) (from an interview with Howard Pohn by Gerald G. Schaber on 6 March 2001).

Larry Rowan recalls the following with some embarrassment:
"We had a big open house [at the Arizona Bank Building] and Bill Pecora [the Director of the USGS at that time] walked through all the demonstration area on the fifth floor on the Bank Building. Then, he came down to our little area on the end of that floor where we had our terrain maps and all sort of stuff laid out—including this Ranger model.

I was standing besides it and he [Pecora] said, that's a nice model—but that's the wrong one, I thought I told you guys to get rid of them. Howie and I made a little mistake in how this thing was distorted. A guy named Len Jaffe at NASA Headquarters, who indeed—although he was NASA—was a very bright guy—had instantly figured out that the oblique shape of this map was the opposite of what it should have been. In order words, you're looking at the Moon from an oblique view as Ranger comes in—and we had gotten it flipped. Quite a few of these models had already been made as vacuum-formed plastic map models similar to some of the Survey's topographic maps—and some of them had, of course, been sent to Washington. And once Pecora heard about this he said "destroy the ones that are incorrect and make new ones." The corrected ones were made, but we still had retained some of the old ones; so, that was my first [unfortunate] meeting with Director Bill Pecora" (from an interview with Larry Rowan by Gerald Schaber on 2 May 2001).

[<u>Space Exploration Milestone</u>: On 22 February 1965, Ranger VIII successfully impacted the Moon in Mare Tranquillitatis less than 70 km from where Tranquillity base would be established less than four and a half years later during Apollo 11]. [See Flagstaff's *Arizona Daily Sun* issue dated 22 February 1965 for article by William Hoyt entitled "Lunar Seas Favorable for Landings."]

Jack McCauley:
"During Ranger VIII there was interest in seeing if the actual impact on the Moon could be seen by telescopes on Earth. Lowell, Lick, and Kitt Peak were selected to have a close look. Despite good seeing conditions at Kitt Peak where I went with Danny Milton, there was nothing to see" (McCauley's personal memoir notes-unpublished as of 2001).]

The following was taken from the Branch of Astrogeology Monthly Report for March 1965 to V.R. Wilmarth of NASA HQ; dated 31 March 1965:
On 17-18, 24-25 February 1965 and 3-4 March 1965 fourteen NASA astronauts were taken to the Nevada Test Site (NTS) for geologic training (see Table 1). The object was to give them field experience with non-volcanic craters to help prepare them for study of the lunar impact craters. This allowed a view of craters that were produced by a force more similar to the impacts that are thought to have produced most of the lunar craters. In addition, the NTS is a volcanic complex, the Timber Mountain Caldera, thereby allowing for a study of volcanic features next to the nuclear craters. Local experts were Will Carr and Bob Cunningham (USGS). Other USGS geologists included Don Wilhelms (Branch of Astrogeology), Al Chidester (Branch. of Astrogeology), Gordon Swann (Branch of Astrogeology), and Uel Clanton (NASA/MSC, Houston). [For more details see *NTS News.* vol. VIII, no. 4, 26 February 1965—Nevada Test Site, Mercury, Nevada].

J.S. Watkins, R.H. Godson, N.G. Bailey, J.H. Whitcomb, R.A. Regan, and the In Situ Geophysics crew from Flagstaff set up a demonstration seismic experiment for the second trip to NTS on 3-4 March 1965. Astronauts laid cable, loaded holes and recorded arrivals of the seismic energy on the In Situ seismograph. They then plotted arrivals and interpreted refraction data in terms of depth to a buried ridge of Paleozoic rocks in Yucca Valley. J.S. Watkins assisted R.A. Hazelwood of the Special Projects Branch with a demonstration gravity survey across the buried ridge."

[Astronauts participating in the three trips to the NTS included: (on 17-18 February- Buzz Aldrin, Neil Armstrong, Charles Bassett, Allan Bean, Eugene Cernan, and Michael Collins; (on 24-25 February- Walt Cunningham, Donald Eisele, Dick Gordon, Rusty Schweikart, and Dave Scott; (on 3-4 March- Roger Chaffee, and Elliott See.]

The following was taken from the Branch of Astrogeology Monthly Report for March 1965 to V.R. Wilmarth of NASA HQ; dated 31 March 1965:
"In March 1965 a detailed topographic map of Meteor Crater, at 1:3,000 scale and 2-meter contour interval with 1-meter supplemental contours was completed [by the Branch of Astrogeology] and field checked. This topographic base map provided control during Surveyor Field Test No 3 and for other investigations, including Manned Lunar Exploration Studies."

[Author's Note: In an E-mail to the author dated 7 June 2002 Ray Batson said "Surveyor Field Test No. 3 never really took place. The Meteor Crater 1:3,000 scale, 2-m contour, map was compiled with the new photography mentioned earlier, by Sam Priebe [Branch of Astrogeology], on our new Kelsh Plotter at the Museum of Northern Arizona. This occurred before Sherman Wu (Photogrammetrist) came to work for us [the Branch of Astrogeology in Flagstaff], and I supervised and managed that project. Only Ozalid copies of that map have survived. The original scribes made by Sam disappeared somewhere, presumably during the move to the "Dance Hall" on Santa Fe Avenue [now the parking lot adjacent to Baskins-Robbins Ice cream store]. Dave Roddy made some use of the Ozalid, as I recall, but we were never able to find reproducibles. It is a pity, because it was a fantastically detailed map. Sam [Priebe] had done a wonderfully meticulous job—as he always did!"]

"During March 1965, astronaut Walter Cunningham visited personnel of the Manned Lunar Exploration Studies personnel at the USGS, Branch of Astrogeology in Flagstaff to confer on the relation of astronaut training to project activities, and to discuss with personnel of the In Situ Geophysics Project a proposed lunar engineering seismic experiment for the Early Apollo landings" (from the Branch of Astrogeology Monthly Report for March 1965 to V.R. Wilmarth of NASA HQ; dated 31 March 1965).

Geologist Robert ("Bob") Leeds Sutton (1929-1982) entered on duty with the Branch of Astrogeology at Flagstaff on 1 March 1965 (see Appendices A and B). Bob was an outstanding field geologist, petrologist, and gentle human being. He spearheaded the geologic mapping of Astro's pre-Apollo test sites in Hopi Buttes. He also played important roles in the geologic training of the astronauts and in Apollo mission operations at Houston—especially in the descriptions, classifications, and photo-documentation of the returned Apollo lunar samples in the Lunar Receiving Laboratory at MSC.

Geologist David Cummings arrived on duty to work with the Branch of Astrogeology's Early Apollo Group at Flagstaff on 1 March 1965. David would work with the Manned Lunar Exploration Group of Astrogeology and would participate in many of the Branch's earliest field exercises in 1965-1967 during which astronaut geologic field procedures and lunar prototype geologic tools were being tested at Hopi Buttes and Meteor Crater. Dave left the Branch in 1967 to teach at Occidental College in Southern California.

Geologic Field Assistant Paula G. Ables arrived to work with the In Situ Geophysics Unit of the Branch of Astrogeology on 3 March 1965. She started out working for Joel Watkins doing seismic reductions. Shortly thereafter, she accepted an opening with the Manned Lunar Exploration Group to do time-and-motion studies. She participated in numerous Branch field exercises out in the field at Hopi Buttes, Meteor Crater, etc., that were carried out to establish exactly what geologic and geophysical tasks an "astronaut" on the Moon could actually do—and how long it would take them to do it. Paula was located on the Mesa (Building-One) when she was working for Joel Watkins, but then moved down to the Arizona Bank Building in downtown Flagstaff when she transferred over to the Manned Lunar Studies Group, that was from the beginning located in the Bank Building. Paula worked for the Branch for just about one year and resigned in February of 1966. Paula and her astronomer husband Harold Ables are both retired and still live in Flagstaff, Arizona.

[<u>Author's Note</u>: Paula Ables would be replaced in the Branch's astronaut time-and-motion studies by psychologist Kenna Edmonds (now Krista Edmonds) who worked for the Branch of Astrogeology in Flagstaff from March 1966 to September 1968.]

Photographer Ramona Boudreau, another talented mainstay in the Branch of Astrogeology's photolab for many years, joined the Branch in Flagstaff on 15 March 1965 (see Appendices A and B). She was preceded in the Branch photolab by photographers Jim McCord (her old boss in Tucson, Arizona) and Karl Zeller. All three individuals became incredibly hardworking and dedicated professionals, turning out a truly amazing number of high quality lunar and planetary photographic products for decades to come.

[<u>Space Exploration Milestones:</u> On 18 March 1965, Soviet cosmonaut Alexei Leonov became the first human to walk in space, and the first manned Gemini, Gemini 3, was scheduled to take Gus Grissom and John Young aloft a few days later.]

[<u>Spaceflight Milestone</u>-"Ranger IX blasted off on 21 March 1965 and coasted to the Moon while Gus Grissom and John Young were orbiting the Earth aboard Gemini III. Through the prodding of Gene [Shoemaker] and his fellow Ranger Television Team members, Ranger IX was pointed directly at one of the most interesting regions of the Moon, the spacecraft crash landed inside the crater Alphonsus" (Levy, 2001, p. 99). Project Ranger came to an end at 1408 GMT on 24 March 1965 as Ranger IX crashed at 12.9 Degrees S., 2.4 degrees W, only 5 km from the pre-selected point [inside the crater Alphonsus]" (Wilhelms, 1993, p. 105). [For selected newspaper reports on the success of Ranger IX, see Flagstaff's *Arizona Daily Sun* issue dated 24 March 1965 for headline article by Mcallister Greebaum entitled "Moon's a Star—on TV!"

Also see the *San Francisco Chronicle* issue dated 25 March 1965 for article entitled “Ranger’s Amazing Lunar TV Show.” Also see headlines —Ranger Data reveals New Lunar Data—in the *Washington Post* Final edition of 25 March 1965—and the byline article by Ralph Dighton entitled “Photos Hint Crater May be Volcanic.” Also, see the *San Francisco Examiner* issue dated 25 March 1965 for article entitled “Best Pictures Ever from the Moon.”]

[Astrogeology Milestone: In March 1965 E.N. Goddard, J.H. Mackin and E.M. Shoemaker wrote a historic report (dated March, 1965) as the Project Apollo Field Geology Planning Team. The title of this report was “Objectives of Apollo Geologic Field Investigations and Proposal for Development of an Apollo Field Exploration System. This report was a precursor for Shoemaker’s formal proposal to NASA that was subsequently submitted in November 1965, for the Geologic Field Investigation for the early Manned Lunar Landing Missions. See below.]

[Author’s Note: Flagstaff’s *Arizona Daily Sun* newspaper dated 15 March 1965 carried an article about the planned expansion of the U.S. Air Force’s Moon-mapping group (the Aeronautical Chart and Information Center, or ACIC) at Lowell Observatory

Don Beattie:
“In [April] 1965 we took delivery of our “Cadillac” lunar rover, a MOLAB (mobile Laboratory) working model that MSFC had built by General Motors, Santa Barbara, California. It was a Cadillac because this MOLAB model cost $600,000 [in 1965 dollars yet] and had a cab so large that two test subjects could live inside and deploy various [types of] geophysical equipment as they drove along, without leaving the cab” (Fig. 23).

When the MOLAB was delivered to Flagstaff, it created quite a stir. It was an ungainly-looking vehicle with four large, tractor-type wheels supporting a fat, cigar-shaped cab with a rather high center of gravity. Shoemaker, watching it being unloaded from the delivery van and thinking ahead to its use in rugged terrain in the field, declared that the NASA-USGS logos painted on the sides would have to be changed. USGS should appear in large letters on the roof, and NASA should be on the bottom. He was sure that during some future field simulation the MOLAB would roll over, and he wanted any assembled reporters to photograph its ignominious fate with the NASA letters showing as the sponsor and USGS safely out of sight. Gene’s recommendation was not followed, but his low opinion of the MOLAB test vehicle design was duly reported to MSFC and caused a few red faces. Unfortunately, funding for the AES lunar base program was reduced two years after we took delivery of this vehicle, and we had few chances to use it in the field. After a short time it was sent to MSFC [Marshall Space Flight Center in Huntsville, Alabama], where it was later put on display” (Beattie, 2001, p. 70-72).

The heralded arrival of the “Moon buggy” to the Branch of Astrogeology in Flagstaff was highlighted by an article by William Hoyt in the *Arizona Daily Sun* of Saturday 10 April 1965 under the Bylines: Nope, It’s Not from Mars! And “Don’t Panic! It’s Not from Mars!” The article goes on to say the following:

“If you should suddenly spot a huge, strange bug-like vehicle bouncing around The Navajo Reservation or the San Francisco Peaks volcanic field this spring and summer, don’t panic!

It won't be men from Mars but rather just a couple of Flagstaff astrogeologists on a scientific outing in their new Mobile Geologic Laboratory testing out techniques and procedures to be used some day in wide-ranging excursions over the rugged surface of the Moon.

The Mobile Geologic Laboratory, or MGL, for short, arrived at Flagstaff this week from General Motors Defense Research Laboratory in Santa Barbara, California, where the unwieldy and unworldly vehicle was built as an experimental "test base" for lunar scientific exploration techniques.

By "test base", Donald Elston, head of the Manned Lunar Exploration Division of the U.S. Geological Survey's Branch of Astrogeology here, it is meant that the MGL will serve to mount feasibility tests of special geological equipment planned for future lunar excursion modules that someday hopefully will roam the Moon gathering the secrets of its 4.5-b.y.-old-life.

The big bug—it is 10 feet high, 9 feet wide, and 17 feet long—will be use in the Peaks area here in the vicinity of the Hopi Buttes north of Winslow on the Navajo Reservation, and in the Barstow-Amboy area of Southern California to test instrumentation and procedures for eventual exploration of the Moon.

Basically, a two-man vehicle, the MGL is crammed with equipment and provides a virtual home-away-from-home for its astrogeologist passengers.

"It can run for a week as a completely self-sufficient unit under normal circumstances", Elston says. "And running straight, with its occupants foregoing sleep and keeping it operating at full tilt all the time, it can go for 72 hours without touching any base."

The awkward-looking vehicle is powered by no less than three separate engines, which not only provide it with motive power, but also with power to operate its extensive electronic instrumentation, and such mundane things as air conditioning, heat, and lights.

It can move over generally level ground at a top speed of 21 miles per hour, although its optimum speed for efficiency is-between 4 and 8 miles per hour. Its huge tires, five feet in diameter, can climb over a "straight step" two feet high. The vehicle has been tested for angular stability—that is sideways—on grades up to 30 percent, and it can in the direction of its motion, negotiate slope grades of 45 percent or more.

Loaded and ready to roll with two astrogeologists aboard, it also carries 72 gallons of fresh water in tanks slung under its high belly, and 130 gallons of engine fuel.

Built on an oversized GM "Sidewinder chassis", the MGL is in effect segmented to give it greater versatility of operation on rough and rugged terrain. A powerful winch allows it to pull itself out of almost any problem it might encounter. Broad front windows give the two scientists in the MGL a wide-range view of the terrain ahead, and a complex instrument panel keeps them informed of the operation of the vehicle and many scientific instruments aboard. The MGL is guided by a steering wheel, just like a truck.

Behind the operator's cabin, the MGL provides space for the delicate scientific instruments, as well as living areas for its two-man crew—full kitchen, sanitation, and sleeping facilities."

On 22-23 April 1965 Gene Shoemaker led eleven NASA astronauts on a geologic training trip to Meteor Crater, Arizona (see Table 1). This was the first experience for the astronauts with the detailed rocks and structures of a real impact crater. Other geologists present included Uel Clanton of NASA/MSC, Houston, and Al Chidester, Gordon Swann, Harrison "Jack" Schmitt, and Joe O'Connor of the USGS Branch of Astrogeology (Flagstaff**)**.

This astronaut training trip consisted of a tour led by Gene Shoemaker, an exercise in geophysics directed by Robert Regan, and a mapping exercise directed by geologists from the Manned Spacecraft Center and the Branch of Astrogeology. The field crew of the In Situ Physical Properties Investigations project from the Branch of Astrogeology demonstrated a method of obtaining shallow reflection data.

[Astronauts attending the 22-23 April 1965 training trip to Meteor Crater included William Anders, Charles Bassett, Eugene Cernan, Roger Chaffee, Michael Collins, Walt Cunningham, Donald Eisele, Dick Gordon, Rusty Schweikart, Dave Scott, and C.C. Williams].

[See Flagstaff's *Arizona Daily Sun* issue dated 23 April 1965 for article by Paul Sweitzer entitled "Mapping Session Concerns Astronauts in Meteor Crater Classroom Here."]

Don Wilhelms:
"Surveyor, Lunar Orbiter, and Apollo were intimately intertwined as the time of the first launches approached. Their needs were to be balanced by Bellcom, Inc. and the Surveyor/Orbiter Utilization Committee (SOUC), but the first grunt work on the landing sites were performed by the USGS and JPL geologists.

Shoemaker had recommended sites to JPL as early as January 1964; and with Elliot Morris, submitted an upgraded list of 5 sites for Surveyor mission-A in January 1965. In June 1965, after Ranger VIII and IX data were in hand and just before the Woods Hole-Falmouth conference [see July 1965 below], the Surveyor project asked Jack McCauley to apply his terrain studies in preparing a list of the safest sites. Jack enlisted the help of Morris, Larry Rowan, Joe O'Connor, and Henry Holt, and the group quickly turned out a list of 74 sites. The landing sites were within target circles 25, 50, and 100 km in radius because the landing accuracy of Surveyor was uncertain. Bellcom submitted lists at the same time, so Morris, Holt, and Alan Filice of JPL collaborated in preparing a consolidated and shorter list. The correct trajectory and lighting constraints were incorporated at a meeting at JPL, and the target circles were reduced to two sizes, 25 and 50 km radius. The final list was readied with amazing speed for presentation by McCauley to the SOUC at that committee's first meeting on 20 August 1965" (Wilhelms, 1993, p. 139)

Don Wilhelms:
"As was true for Surveyor, the search for specific sites [using the Lunar Orbiter photographs] was the job of the USGS. Shoemaker did not follow up his earlier interest in Lunar Orbiter because he was fully occupied with Ranger and Surveyor. He therefore asked Jack McCauley to

ease out of the Surveyor rover study and head the USGS Orbiter Project. This suited Jack's interests in regional geology just fine. The terrain study project led by Jack had already located the potential Surveyor landing sites and was the natural home for the Orbiter effort. Its Apollo support role meant that Lunar Orbiter would have no formal experiment teams or principal investigator as was the practice for Ranger, Surveyor, Apollo, and all subsequent planetary missions. Among the new geologists Jack [McCauley] hired when the terrain project received an infusion of money back in 1964 was Larry Rowan, whose Virginia origins qualified him in McCauley's view to play a key role in a project that would deal with Langley [in Virginia] and the many Virginians and other southerners who staffed LOPO (the Lunar Orbiter Project Office]" (Wilhelms, 1993, pp. 153-154).

The following quoted information was taken from the Branch of Astrogeology Monthly Report for April 1965 to V.R. Wilmarth; dated 30 April 1965.
During April 1965 the first scientific traverse by the Mobil Geological Laboratory (MGL or MOLAB) in the Mojave Desert near Amboy, California was documented on 16-mm color film and with still photography. A gamma ray spectrometer unit was tested under mobile conditions, and the results were later compared with laboratory data on samples collected at observation stations"

Gene Shoemaker and Don Elston went to Huntsville, Alabama to the Marshall Space Flight Center on 26 April 1965 to participate in Apollo Extension System experiment simulations in Gemini-type spacesuits" (Fig. 24).

Photographer Walter Roeder entered on duty with the Branch of Astrogeology in Flagstaff in May 1965. Walt, who had escaped to Finland from Germany in the early 1940's to avoid the Nazi's just before WWII, worked as a photographer in New York and eventually as a photographer in Phoenix and Wilcox, Arizona, just prior to coming to Flagstaff to work for the USGS. Walt would soon be in charge of directing and producing for NASA a series of sound-color 16-mm films documenting lunar geologic surface procedures development, and astronaut training exercises, being carried out by Branch personnel primarily in Northern Arizona.

[Author's Note: Gene Shoemaker had decided that the Branch needed to document our Post-Apollo field tests for NASA using film products, including sound movies. Thus, the Astrogeology photolab was split into two disciplines—a still photo lab under Jim McCord in Building-One on Switzer/McMillan Mesa, and a movie film-documentation unit under Walt Roeder down at the Arizona Bank Building. NASA liked the idea of film documentation of the field tests around Flagstaff, so we had to get some additional film cameramen, film editors, narrators, etc.]

The following is from the Branch of Astrogeology Monthly Report for May 1965 to V.R. Wilmarth, NASA HQ; dated 31 May 1965:
"The third in a series of Apollo field operations tests was conducted at the Meteor Crater test site during May 1965 (see Table 1). This test examined the usefulness of integrated Apollo Operations and involved the use of an exploration periscope [mounted atop the Branch's plywood LEM mockup], a surveillance television system, a lunar surveying staff, an instrument

and sample carrier, and the use of a test [science] control center. The test also provided the opportunity for a further shakedown of the project's field test systems"

[Astrogeology, City of Flagstaff, and Apollo Milestone: In June 1965, astrogeologist Dr. Harrison H. (Jack) Schmitt with the U.S. Geological Survey's Branch of Astrogeology in Flagstaff was selected by NASA to be one of the nation's first six scientist-astronauts (Fig. 25).

[Author's Note: Only two months earlier (April 1965), Jack Schmitt, along with Donald Elston came to the Greater Cincinnati Airport to follow up Jack McCauley's original interview in Miami, Florida, (in October, 1964) with this author for a job with the Branch of Astrogeology in Flagstaff. Jack Schmitt was to be my immediate supervisor upon my arrival in Flagstaff after completing my PhD from the University of Cincinnati in spring of 1965. When I arrived with my wife and daughter Jennifer on 7 July of that year, Jack had already left Flagstaff (in June) and was in NASA flight training at Luke AFB in southern Arizona.]

Flagstaff's *Arizona Daily Sun* for 28 June 1965 included the bylines: "Flag has Own Astronaut," and "Astrogeologist set as Flagstaff's First Astronaut." The accompanying story by William Hoyt goes on to say the following:

"Dr. Harrison H. (Jack) Schmitt, 29-year old Flagstaff astrogeologist, left by plane today for Houston, Texas and the Manned Spacecraft Center there where Tuesday he will officially become one of America's first six scientists-astronauts.

The announcement, to be made at a press conference in Houston, will be something of an anticlimax as the names of the six scientists who will begin training next month for an eventual trip to the moon, were revealed unofficially last Saturday afternoon in Houston.

Schmitt, in Flagstaff when the premature word came, today declined immediate comment on his selection, explaining that he should remain silent until MSC made it official.

The astrogeologist is scheduled to start a year's training as a jet pilot with three other newly named scientist-astronauts at Williams Air Force Base, Chandler, on July 29.

All six will be given intensive preparation to eventually ride, with other astronauts, as "the third" man in the capsule" in a three man Apollo spacecraft to the Moon and to undertake scientific exploration and investigation of the earth's lone satellite. Schmitt and the five other scientists tabbed for the astronaut-training program have had little to say since the premature word leaked out of their selection.

But in Flagstaff, the SUN learned that the handsome young geologist has been working here since July 1964 in the Branch of Astrogeology's Manned Lunar Exploration Studies division under division Chief Donald Elston.

During the past year, he had headed up a special study project in the division designed to help determine the scientific priorities for experiments and researches to be performed by astronauts when they reach the moon.

A bachelor, he lives in a modest apartment at 709 West Grand Canyon in Flagstaff.

Schmitt's colleagues at the Branch of Astrogeology's headquarters here today were enthusiastic about his selection as a scientist-astronaut.

They described the young scientists as "very good-looking and very personable" and as "an extremely hard-working, dedicated scientist. He would work seven days a week, if you let him'" another astrogeologist here marveled. And he's as sharp a cookie as they come.

Schmitt holds a bachelor's degree from the California Institute of Technology and a PhD degree from Harvard University. He has also done a year of post-graduate work at Oslo University in Norway under a Fulbright Scholarship. In Norway, he worked for the Norwegian government in the mapping of Norway's west coast, using the geological data he collected in his doctorate thesis at Harvard.

The young geologist took to geology naturally. His father Harrison A. Schmitt, a consulting geologist in Silver City, N.M., is well known in Northern Arizona and the Southwest for his work in the field. The elder Schmitt has been partly responsible for the recent extensive development of non-ferrous mining enterprises near Kingman in Mohave County [Arizona].

Of his son's selection, the elder Schmitt said: "He's been shooting for this for a long time and has been very enthusiastic about it." "I'm proud that he got what he went after."

[Author's Note: Don Elston recalled to this author (personal communication, 2001) that Jody Swann [then Lowman] typed Jack Schmitt's application to become an astronaut: "I remember because I wrote a letter of recommendation for him. It turns out that we knew about it a couple of days before it was formally announced. Bill Hoyt—who was the Editor, Flagstaff's *Arizona Daily Sun* —called us and said he had heard this rumor. We told him, but it was "keep the lid on it". He was very good about checking stories, and making sure that everything was just right. He didn't publish anything until he checked it."

[Author's Note: Unfortunately, Jack Schmitt's father died in 1966 and, therefore, didn't live to see Jack get to the Moon. For additional information on Schmitt's selection as a scientist-astronaut see the *Arizona Daily Sun* dated 30 June, 1 July, and 15 July 1965; the *Evening Star* (Washington, D.C.) 30 June; the *Arizona Republic*, 29 and 31 July 1965.]

During a 1999 interview with Kirk D. Wolfinger, Director of NOVA's documentary on Project Apollo, *"To the Moon,"* Harrison "Jack" Schmitt reflected:
"My actual interest in becoming an astronaut didn't crystallize until 1964 in November when NASA and the National Academy of Sciences asked for volunteers for the first ever scientist-astronaut selection. My interest though had been piqued when I was a student, a Fulbright Student in Norway in 1957, and experienced the Sputnik, the launch of Sputnik, the first artificial satellite of the Earth that the then Soviet Union put into orbit. I experienced that in the context of the student community at the University of Oslo. And you couldn't be involved in that community and not recognize the profound impact that was having—look what technology has

done unexpectedly—but also look at the apparent threat that free men and women now face from a technologically ascended Soviet Union. Ultimately, that proved not to be quite as great a concern as it appeared at the time—but we didn't know that then. The combination of those two factors excited my interest, and I continued then from that point to sort of keep an eye on what was happening in space-related activities. And when the opportunity to volunteer came along—actually when the opportunity came along to go to work for Gene Shoemaker in Flagstaff—that was partially in the back of my mind. Not to become an astronaut, but because of my intellectual interest in space, and the thought of becoming an astronaut really had not been any more than a sort of a joke among my colleagues and me until there was an actual selection.

The whole idea of volunteering was with the possibility of actually taking my science and my interest to the Moon. But early on in my activities as an actual astronaut I realized that the possibility of that happening at least early on was pretty small. I had no idea in the later 1960s how many times we would have to try to land on the moon before we actually landed there. We had no idea whether scientists would ever be accepted as crewmen—whether the systems that were just in the design and initial manufacturing phases were going to be safe enough for anybody to fly—much less to put somebody on [the Moon]. The scientist-astronauts, although trained as pilots because that's what NASA required at the time, they were still not the experienced test pilots—because that is what we had ready and willing to go into space as part of the Apollo Program.

I understood at the time, and had sort of a turnaround of thought, and said [to myself], well, since I'm here, let's see how much we can see as scientists and as interested parties to enhance the success of the program. And to also begin to interject as much science as possible into the activities of the astronauts [in case] they finally get to the Moon.

The scientist-astronaut class of 1965 started out as about fourteen hundred volunteers. That was winnowed down very quickly in the initial physical that we had to send in with our application. There was what was called a FAA Flight Physical for ordinary pilots, and that came down to about four hundred applicants, as I recall. Out of the four hundred then, we were asked to submit some more detailed information about our lives and careers—and from that the National Academy of Sciences selected about eighty. And out of that eighty then, based an essay and some submission of reprints of scientific articles and things like that; they eventually came to 16 that they recommended to NASA. Those sixteen were then invited to take a physical at Brooks Air Force Base, then the center of that kind of activity for NASA; and out of the sixteen, only fifteen of whom actually showed up for the physical, six were selected.

Out of the six that were finally selected there was 1 geologist (myself), 2 engineering physicists (Garrett and Gibson) and 2 physicians (Kerwin and Graveling). That [selection] was based only on the physical and on the interviews that we had at NASA after the physicals. And then we were shipped off to pilot training at Williams Air Force Base, Arizona. Dwayne Graveling unfortunately, because of publicity and other things that were involved in a pending divorce, did not continue in the program after the first three weeks."

When asked in 1999 by the NOVA interviewer Kirk D. Wolfinger (Director of NOVA's *"To the Moon"* documentary) how well the two cultures of the test pilots and scientist-astronaut intermingled, Schmitt responded:

"The information that I was gradually able to put together over the years suggests to me that the NASA astronauts in the 1964 timeframe, as well as most of the management at MSC, did not want scientists in the program. They felt they could carry out their mandate, which was Kennedy's challenge to go the Moon and return safely to Earth, without any scientist. There were a few though in that group [that supported the scientist-astronaut cause]—namely George Low, who was the Apollo Spacecraft Program Manager, and I think Gene Kranz [the now-famous Flight Director for most of the Apollo lunar missions.] Chris Kraft was also supportive to some degree. Certainly Sam Phillips at NASA Headquarters, who was Apollo Program Manager, felt that if they were successful in their designs for the Lunar Module and other systems to put men on the Moon and return, then they would have a tremendous capability to do other things, namely science. And thanks to those gentlemen, science was brought into the program. And I think that played a great part in the final acceptance of selecting scientists as astronauts."

When asked by Kirk D. Wolfinger: "How did you find the astronauts in general as being receptive to geology training"—Jack Schmitt responded as follows:
"It varied a great deal. But with one or two exceptions, they realized that after Neil and Buzz walked on the Moon they were going to have to do something pretty special to stand out in their own minds as well as in the minds of others—and of history when they went to the Moon. The first man on the Moon will always be the first man on the Moon, and few people really recognize the second, third, fourth and so on. But for the most part, most of the crews were enthusiastic about the training. And we had, as a result from manned portion of Apollo—the field geology on the Moon—Apollo, we developed with the samples a first-order understanding of the Moon as a body—and that was no small accomplishment. And again, I think it's to the credit of George Low, Bob Gilruth, Gene Kranz, and Sam Phillips, and people like that, who realized the opportunity for science was there—and allowed all of these things to come into play. This allowed us, for example on Apollo 17 to basically utilize the capability of the Lunar Module with twenty-two hours outside the spacecraft and to bring back a record payload of samples—all of that sort of culminated the whole science effort that we were allowed to make during Apollo."

When asked by Kirk D. Wolfinger how important was Gene Shoemaker to influencing the program—and influencing you? Jack replied:
"Gene was far more important that I think even Gene realized. He was the first truly world class scientist to get very interested in the geology part of space science, and to try to influence NASA to take into account that there should be a field geology experiment that was integrated into all of the other [lunar] science. Because without that you would not have the context in which samples were collected, and then analyzed back here on Earth. Gene pushed and pushed—and pushed—on that. He was I think disappointed and frustrated that he couldn't get everything that he thought was going to be important to the Field Geology Experiment.

I understand why he left in frustration, but that doesn't mean I wasn't disappointed, and did not have some very nice, and relatively heated, arguments with Gene about it. Because of him, those of us inside would go to George Low and Bob Gilruth and others and say, these kinds of things are possible. Let's do as much of it as we possibly can within the other constraints that we have to live with from the engineering, programmatic, and dollar points of view. And the dollars were still important, even in those days. Most people think that Apollo had all the money in the world. Well, it didn't. It still had to worry about dollars because it had such a tremendous challenge to make this thing happen. The next time we go to the Moon it should be a lot easier than it was the first time; and we'll know exactly what we have to do, and how to do it. But the first time going through it was not easy at all. Because we had the kind of pressure from people of recognized quality—like Gene Shoemaker—we could then make incremental gains within the program that were far greater than we would have otherwise.

Prior to the arrival of the scientist-astronauts in Houston [in 1965], the science training of the astronauts had been aimed principally in the earth sciences, but at sort of a first year geology course curriculum; and my very strong impression was that the pilot-astronauts were bored. It was not very interesting to them. And, after thinking about it and talking with various people around the country, as well as inside NASA, I proposed to Al Shepard that we bring the training program into the astronaut office for overall management. All other astronaut training was part of the astronaut office or Directorate, which was the flight crew support director, Deke Slayton, being the head of that. Al agreed to that, and agreed to my formulation of the strategy. And with that agreement, I then began to call people like Lee Silver, Richard "Dick" Jahns, Bob Sharpe, Jim Thompson, Jim Head, and others around the country to see if they would be willing on a volunteer basis to participate as part of bringing the astronaut science-training program into Apollo. And by that I meant that we were going to begin to teach earth sciences, geology in particular and field geology specifically, in the context of actually running mission-like simulations. And indeed, that's the way the program began to mature. The first crew to really take part in that was the Apollo 13 crew—ironically. And they were by far the best-trained group of astronauts to be sent to the Moon up to that time. Principally, because they were willing to experience—and go out and run this kind of simulation-based geology training. Their interest and enthusiasms for that kind of training was contagious, and it really continued on through the rest of those later missions (Apollo missions 14-17)" (interview with Harrison Schmitt by Kirk D. Wolfinger-director of NOVA's documentary of Apollo "*To the Moon*.")

Mechanical engineer/pilot Rutledge "Putty" Mills (b. 1923), who along with associates Bill Tinnin, Dick Wiser, and Walt Fahey would design and hand build the Branch of Astrogeology's two widely-heralded simulated "lunar vehicles" for astronaut training ("Explorer" in May 1967, and "Grover" in 1970), arrived in Flagstaff in the spring of 1965 (see Appendices A and B). After Apollo, Putty moved to the USGS Center in Denver, Colorado; he retired from the USGS in 1986 and presently lives in Santa Barbara, California.

Mechanic Bill G. Tinnin (mechanic) started work in June 1965 with the Branch of Astrogeology in Flagstaff (see Appendices A and B). Bill resigned from the USGS in December 1965 but was rehired in July 1966 to work with Putty Mills on his Lunar Vehicle Systems, Field Operations, and General Support Project. Bill would immediately be assigned to maintaining the MOLAB and Trespasser vehicles. Bill Tinnin, Dick Wiser (starting in spring 1966) and Putty Mills would together play a major role in the design and constructing of the Branch's two hand-made Lunar Rover Vehicle (LRV) simulators (Explorer and Grover-see below) used extensively in geologic field training of the crews of Apollo 15-17. Bill Tinnin has retired from the USGS and still resides in Flagstaff.

Photographer John Running, presently considered one of the top freelance photographers in the U.S., came to work for the Branch of Astrogeology in June 1965 (See Appendices A and B). He had arrived in Flagstaff earlier that year right after he had been discharged from the Marine Corps. John started work on the 5th floor of the old Arizona Bank building. He worked with geologists Larry Rowan, Ester Holm (in Flagstaff 1964-1965) and Maurice Grolier (arrived in Flagstaff in October 1965) on the Branch's early lunar photometry project. He then worked on the Lunar Orbiter project. Later, in 1965, John would begin to work with Walt Roeder, head of the Branch of Astrogeology's Film Documentation Unit, and Don Hart (Narrator for the Branch's Film Documentation Unit; see October 1965).

[Author's Note: The experienced Walt Roeder took John Running under his wing and taught him everything he knew (which was considerable) about photography. John Running left the USGS in June 1970. Running now has his own internationally known freelance photography business (John Running Photography) which is located at 111 E. Aspen Avenue in Flagstaff.

The following was taken from the Branch of Astrogeology Monthly Report for June 1965 to V.R. Wilmarth, NASA HQ; dated 30 June 1965; and from William C. Phinney (submitted):
"In June 1965 M. N. West and L.C. Rowan compiled a Preliminary Albedo Map of the Moon covering the area 60 Degrees W to 60 Degrees E. and 20 Degrees N to 20 Degrees S. at 1:5,000,000 scale."

Between 29 June and 2 July 1965 ten NASA astronauts were taken to Katmai, Alaska (See Table I). Explosive eruptions in 1912 deposited silica-rich pumice and ash over a large area in the Valley of Ten Thousand Smokes. Therefore, there is well-documented historic data on the eruption. Furthermore, subsequent stream erosion has cut deep gorges through the deposits allowing study and interpretation of details in vertical sections. The astronauts and trainers stayed at a fishing lodge and utilized helicopters from the military Air-Sea Rescue group stationed nearby. Trip leader was Bob Smith (USGS). Other geologists present included: Uel Clanton (NASA/MSC), Dave McKay, Ted Foss, Richardson (MSC), and Don Wilhelms, Al Chidester, Hal Stephens (photographer), and Jim McCord (photographer) of the USGS. Astronauts attending this trip to Katmai included Buzz Aldrin, William Anders, Charles Bassett, Eugene Cernan, Roger Chaffee, Walt Cunningham, Rusty Schweikart, Dave Scott, and C.C. Williams.

In June 1965 the third in the recent series of tests of lunar exploration operations involving a man on foot was held at the Bonito Lava Flow test site. This test was designed to examine five geological operations that could be used by men operating from a stationary vehicle on the lunar surface. The five modes of operation tested are as follows:

1. An excursion by one man using a film camera, clinometer and sun compass mounted on a surveying staff, a pick, scoop, sampling bag rack, and scintillometer mounted on a light-weight instrument and sample carrier; and a gridded photograph for the location of data and sample points. A free description of features and of features necessary to establish the context of

photographs and samples was made and transmitted along with surveying data back to the LEM and to the Command, Data Analysis and Reception Center.

2. An excursion by one man using a camera, clinometer and sun compass mounted on a surveying staff; a pick; scoop, sample bag rack, scintillometer and 80-foot hard-line television system mounted on a light-weight instrument and sample carrier; and a photographic surveying method for the location of data and sample points. A coded description was used to identify features not shown by high-quality photographs and a return sample, to identify data and sample points and to correlate photographic surveying data with other photographs, samples and observations.

3. A two-man excursion with one man using a clinometer, sun compass and an 80-foot hard-line television system mounted on a surveying staff; and the other man using a pick, scoop sample bag rack, and scintillometer mounted on a light-weight instrument and sample carrier, and a chest-slung film camera. The man carrying the instrument and sample carrier gave a free running description of features along his traverse, sampled and photographed these and other features. The second man conducted a fairly complete television survey of the area within 80 feet of the LEM and also gave partial surveillance coverage of the traverse conducted by the other investigator. The location of both TV camera and sample and descriptive data points was accomplished by use of a gridded photograph.

4. An excursion by one man using a clinometer, sun compass and 80-foot hard-line television camera system mounted on a surveying staff; a pick, scoop, sample bag rack and scintillometer mounted on a light-weight instrument and sample carrier; and a chest-slung film camera. A free running description of features encountered along a traverse was made, and the location of sample and other data points was accomplished by use of a ranging and surveying periscope in the LEM.

5. A two-man excursion repeating the operations of (3) except that the location of TV camera and the sample and descriptive data points are accomplished by use of an "automatic" tracking system (a third party on the ranging and surveying periscope). On command, the staff television imagery was alternated with that obtained from a surveillance television system mounted on the LM.

Documentation for Lunar Field Systems received a black and white motion picture film processor on June 10. Tests were conducted to establish quality control and operating procedures. A black and white film record was completed on June 5 of Apollo Test IV conducted on the Bonito Flow at Sunset Crater. The coverage included continuous film camera in the field and a Palmer film Record at Flagstaff (Arizona Bank Building).

A meeting in June 1965 of D.W. Dodgen, R.R. Blecha, and J.R. McCord on the stereometric camera resulted in combined efforts to complete a design and working model for field-testing. It was decided that the Branch instrument shop would fabricate the camera. D.W. Dodgen has begun preliminary sketches for its mechanical and optical design.

Walter Roeder, during June 1965, completed the editing, sound recording, and timing of two documentary films, "Report of Standard Surveying Operations for Vertical and Horizontal Control" and "First Scientific Traverse of the Mobile Geological Laboratory (MGL or MOLAB)". These films were sent to W.A. Palmer Films in San Francisco for an answer print.

Narration and timing was completed in June 1965 on the geophysical film "Report on Standard Operations for Lunar Geophysical Methods"

Don Beattie contributed the following observations:
"We were beginning to make real progress [at Flagstaff]. Not only were we closing in on future tool designs that would work well with a space-suited astronaut, but we were also developing ways for teams back on earth to process the information that would come back from the Moon in the form of verbal descriptions, experimental data, and perhaps television pictures. At this time a television camera for use on the Moon was not a potential payload item for the Apollo missions. But we believed that it would be an invaluable tool for the AES (Apollo Extension Systems, or post Apollo) missions. So we usually carried one during our field simulations. We would review the tapes when we returned to the office to complete the analysis of the simulation. We took the next step and set up relay towers on Mount Elden [9,000 feet elevation] in East Flagstaff. That let us send the pictures back from the field, originally to an office [the Command Data Reception and Analysis, or CDRA] facility in the Arizona Bank Building [fifth floor] in downtown Flagstaff (Beattie, 2001, p. 64) (Fig. 26).

"After we ironed out the kinks of getting voice and picture back from the field, we subsequently (in 1967) started to design a facility we named the Apollo Data Facility (ADF) [eventually built at 2720 East Fourth Street in East Flagstaff]. Here a team of geologists could convert field data in real time into a geologic map" (Beattie, 2001, p. 63) (Fig. 27).

The following was taken from William Phinney's interview with this author in 1995 for his book on Science Training of the Astronauts, submitted for publication):

"By June of 1965 the [Branch of Astrogeology's] CDRA Facility was operating [in a space behind Al Chidester's office on the fifth floor of the Arizona Bank Building], and some of the [USGS] field tests were being monitored at that control center in Flagstaff**.** The use of this facility required some electronic ingenuity. Hopi Buttes and Meteor Crater were as much as 90 miles away and the microwave system was good for only about 60 miles. Johnny Nuttall [head of Astrogeology's electronics group] cleverly found that he could bounce the signal from Hopi Buttes and Meteor Crater off north of East Flagstaff an intermediate ground location to the top of a mountain [Mt. Elden] where the receivers were in East Flagstaff, and pipe the voice down to the CDRA in downtown (west) Flagstaff."

The following was taken from a 1995 interview with Gordon Swann by William Phinney:
"There was also a mobile control center according to Gordie Swann. "It was an old army surplus van. We had two of them on semis. One was what we called the mobile CDRA, and it was primarily a workspace with some light tables and that kind of stuff (Fig. 28). Then the other was an electronics trailer, actually electronics and some analytical stuff. We ran some mission kind of things that were more advanced than Apollo. We actually did analyses. We were also using

that portable outfit with just a TV capability. We did quite a bit of running around the rocks with a man on the TV camera following the guy and plotting his traverse."

Don Beattie:
"With additional help from MSC, we soon graduated [from the Gemini suit] to a prototype Apollo suit [in the Flagstaff suited field tests], which made it much easier to conduct realistic fieldwork, since it incorporated a portable life-support system (PLSS) that let us do away with hoses and hand-carried cooling systems. In June 1965 Gordon Swann and Joseph O'Connor were given their first indoctrination into the use of Apollo-type space suits at MSC. From that point on whenever we could obtain the loan of such a suit, we would rehearse and simulate at Flagstaff all the tasks we were planning for the astronauts.

Our simulations and field tests led to the design of various tools and equipment to ease sample collection, and permit the observation and mapping of geological features. Ideas were tried and rejected and equipment was built and discarded as we learned what would work best. For example, during our field simulations, the USGS "astronauts" practiced viewing the surface from the overhead hatch of the LEM mock-up carried on the back of a truck to obtain, more or less, the correct elevation above ground [Moon] level. Their experience at taking advantage of this high observation point was passed on to the crews and led to David R. Scott's decision on Apollo 15 [July 1971] to stand in the overhead hatch to plan his surface activities and traverses at the landing site. Dave Dodgen and Walter Fahey [talented machinists with Astrogeology at Flagstaff] designed and built a LEM periscope like that recommended earlier for the Martin study (with a few more frills), and it was used successfully during some of the simulations to determine how to study a landing site before the astronauts began their EVAs.

We were beginning to make real progress. Not only would our planned Moon traverses include geologic observations and measurements, but also we envisioned collecting geophysical information along the route such as gravity and magnetic field measurements. We knew that AES (Apollo Extension System) missions would return so much information, collected during miles of traverses by astronauts riding on some type of vehicle, that it would be essential to process the information in near real time. If we could do this, we believed we could redirect the crews or suggest additional surveys to flesh out the picture we were developing of their landing site.

As our CDRA work progressed we brought our ideas to the attention of MSC. This revelation of how we thought the post-Apollo missions should be conducted stirred up a hornet's nest. We were told in no uncertain terms that the idea would never be approved. Scientists on Earth talking directly to astronauts on the Moon? No way! We were told to cease work along these lines. We chose to ignore this "guidance" and continued to improve our vision of how this could be done" (Beattie, 2001, pp. 62-65).

The CDRA (Command Data Reception and Analysis) facility envisioned by the Branch of Astrogeology as a pre-Apollo, MSC-type, science operations center, was first set up on the fifth floor of the Arizona Bank Building in mid-to-late 1965. The original name of Astrogeology's Command Data Reception and Analysis Center created quite a stir with NASA and the astronauts, as Gordon Swann pointed out to Gerald Schaber (author) during their second interview on 26 July 2002 (see below):

Gordon Swann:
"Well, the [Branch] guys who named that thing were Al Chidester and Maury Brock—and I think Thor [Karlstrom] helped a little bit. They named that facility down there (on the 5th Floor of the Arizona Bank Building) Command Data Reception and Analysis, or CDRA. But, of course, NASA just went crazy—and the astronauts especially—about the idea of some dang geologist, especially Gene Shoemaker, telling the astronauts what to do up on the Moon [or "commanding them" about anything]. I was never sure how much Gene wanted to be able to just discuss or suggest things with them [the astronauts on the lunar surface]—the kinds of things we ended up doing anyway, more or less.

But with Al Chidester, there was quite a bit of—we need to tell them because they don't know! I don't think there was as much of that with Gene. However, I always tried to soften that, but they [Al Chidester, Maury Brock, and Gene] said "no we don't want to do that; we want to be able to compile their data, answer their questions, make suggestions, and that kind of thing.

Anyway, I warned those guys that NASA was going to blow a cork when they see our science backroom facility in Flagstaff called "command" something. I said, those astronauts are military-type people and they know exactly what command means. I said they are going to blow a fuse of this idea of some damn geologist looking over their shoulder telling them what to do [on the Moon]... They said no, no—that's what its going to be. I gave in—and the NASA did have a hissy fit about it. Even some of the NASA Headquarters people hollered about it. "What's this command thing—you guys aren't going to command anything!"

[Author's Note: As a result of NASA's anger about the thought that we lowly geologists would even consider "Commanding" the astronauts in any way shape or form during the Apollo lunar expeditions, the USGS quickly abandoned the name [Command Data Reception and Analysis, or CDRA] of that first science backroom faculty in the Arizona Bank Building, at least in our technical letters written for NASA Headquarters or MSC, and simply called the facility the Apollo Data Facility, or ADF, which was much more acceptable to the astronauts and other NASA types The acronym ADF would be carried over to the new and larger science backroom facility that the SPE Branch would have constructed later in 1967 on Fourth Street in East Flagstaff; see 1967].

[Author's Note: Later (in 1967), the Branch of Surface Planetary Exploration considerably expanded the CDRA concept with a specially-built facility that they had constructed in 1967 at 2720 N. Fourth Street in East Flagstaff. This new facility was named the Apollo Data Facility, or ADF (see 1967 for details**)**.]

Don Beatty:
"The ALSS (Apollo Logistic Support System) and AES missions permitted longer surface stay times, but to complete the mission and return home the CSM (Command and Service Module) would have to stay in orbit as long as the astronauts were on the Moon's surface. We began serious study of how we could take advantage of having the CSM in orbit for such a long time.

With modifications, in some respects easier to project than extending the LEM stay time, the CSM could remain in orbit for two weeks or longer. What should we do with a CSM that might make three hundred or more orbits while the astronauts were on the surface? It seemed obvious; map the Moon from orbit with whatever instruments the CSM could accommodate. In the early stages of these studies we looked at fully automating the CSM sensor package and perhaps converting the LEM to carry three people so that one astronaut would not have to remain alone in orbit on board the CSM but could be on the surface to share the workload. All this appeared possible. We then enlisted the aid of the USGS to come up with a conceptual, remote-sensing payload for the CSM. This in turn led to investigating how to tailor the astronauts' surface activities to provide the "ground truth" that would improve the value of the data returned by orbital sensors. The suite of sensors proposed for the CSM included multi-spectral photography as well as spectrochemical, microwave, and radar instruments that would let us extrapolate the data collected at the landing sites to broad regions of the Moon" (Beattie, 2001, pp. 65).

Joe O'Connor:
"Fairly early in this business was when NASA told Gene that all they [the astronauts] could do was plant the flag [during the first Moon landing]. I know that was after Dave Schleicher got there [Dave arrived in Flagstaff on 15 July 1965] because Gordon Swann, Dave and I became the first suit subjects. It was our job to convince NASA otherwise. So we started doing the simulations, and the real early stages of planning for it.

And so the challenge was put out. They [NASA/MSC] would train us in the suits and we had to do the geology of the Clear Lake [MSC] simulated lunar surface (the "rock pile") they had built there. My guess is that it took us about a year to go through the whole program at NASA getting trained in the suits; working out in them, and carrying out a suited training exercise out at their rock-pile site" (from an interview with Joe O'Connor by Gerald Schaber on 9 July 2001).

[Author's Note: Gordon Swann recalls that at about that time in 1965 it was our suggestion to carry out the suited geologic feasibility tests in real terrains, not just at the rock pile at the Manned Spacecraft Center (MSC). So, Swann recalls, NASA co-operated. Thus the Manned Group within the Branch of Astrogeology (with the help of Advanced Lunar Program Studies funding from NASA Headquarters) began its selection and geologic documentation of suitable field sites around Flagstaff for the development and testing of both suited and unsuited lunar geologic procedures studies.]

Joe O'Connor continues:
"But I recall we did one suited test down at Houston. Gordon Swann and I were the two test subjects. We had the whole mob down there. These were modified Gemini suits. You know, they had the big four-pulley thing in the front that you had to crank yourself down with if you wanted to touch the ground; and also, they were all personally made for different astronauts—and all of the astronauts were short.

The day we did the test at MSC it was a Houston "98-98 day"—98 degrees and 98 percent humidity! We each did a 45-minute EVA (Extra-vehicular Activity). This was I believe in 1965. I lost fifteen pounds in two 45-minute EVAs and I think Gordy lost ten pounds. That's damn near ten percent of your body weight. That's very close to lethal! Neither one of us passed out or even got dizzy. We were pretty used to it by that time.

But when I took the suit off in the morning session-you know where the cuff was for the boot—the sweat was halfway between the cuff and the knees—full up. And it was halfway up to my elbows on my arms. So there was a lot of juice cooked out of you! Anyway, we got the job done—and it worked—we got the geology mapped—certainly better than Uel Clanton [an MSC geologist] understood it! So, [even] in the suits, we bettered their geologic map of the site.

So after that [exhausting] day we went back to the motel. Gordy and I had several six-packs of Pearl beer; then we went out to the San Jacinto Inn [a famous local oyster and shrimp restaurant located down where the Battleship Texas is displayed] that night—the whole mob of us. Between Gordy [Gordon Swann] and me, all of our reserves were gone—as far as food—and we were so hungry we couldn't believe it. Between him and me we ate 95 raw oysters and two or three bowls of shrimp—and then had dinner [chicken and all the fixings are the main course at San Jacinto]. The people there were so impressed that when we got desert—which was sherbet—each bowl of sherbet had a raw oyster draped across the top of it" (taken from an interview with Joe O'Connor by Gerald G. Schaber on 9 July 2001).

Joe O'Connor talks about the design of the Apollo Lunar Tools:

"The lunar hammer story was mostly Gordon's. Well, there are two stories that I hold a large part in. One was the magnifying glass (discussed above), and the other was the Lunar Walker — or Lunar Tool Carrier. The walker was kind of fun. Do you remember Max Bender from Bendix [Aerospace]? He was the spy that Bendix sent [to Flagstaff]. They rented an office for him in the Arizona Bank Building. He was supposed to sneak in and look over our shoulder and see what was going on. That was his job description—to be a spy! So, he just walked into the office then—without any announcement—and I think he got hold of Gordon first—and he said hey, I am a spy! Gordy said for whom? He said for Bendix. Gordon said oh, what's your training? Max was a physicist, and had some training. He said I am a geologist. And Gordon says well hell, why don't you come in here and work with us then—which was exactly the right thing to do!

Max [Bender] and I really hit it off very well. In fact, when I left, we were thinking about writing a musical comedy about the Arizona Bank Building. It was going to be funny as hell but we didn't get around to it. We'd sort of do songs and stuff like that.

Anyhow, we were out there one time and Bendix had gotten some of these contracts to work on Lunar Tools. They sent some other guys around with all kinds of engineering drawings of walkers (Lunar Tools Carrier). Man, some of these things had eight legs, and some of them had wheels, and some of them were wheelbarrows. God, there were all kinds of weird things!

One day we were looking at these designs and I said it's 5 o'clock—let's go down and get a beer. So we grabbed the drawings and we went down to the bar at the Monte Vista Hotel in downtown Flagstaff (see Fig. 5). We sat around there getting "mellow", and I said you know—all of these things [i.e., their designs for the Lunar Tool Carrier] have too many legs. I said this looks very clumsy. How do you get from inside this, and what do you do with all this stuff. One of the guys got a little angry, but you know, since they were [actually] salesmen, they weren't showing that they were pissed. He said what do you mean? I said you want three legs for stability.

I got a bar napkin—and I said you want a tripod. That's stable; that's as stable as you can get. I said you don't want a heck of a lot [hung] on it. And on the tripod you probably want a place to put hand sample containers that are easy to get at—not too high so that it screens off the astronaut from what he's seeing, but not too low that he has to do a lot of bending. Having been in a suit myself, that's obvious.

So I sketched out these things on the napkin [there in the bar]—and one of the guys from Bendix said oh, could I see that; would you mind if I keep it? That was the last thing I ever saw of it [i.e. O'Connor's bar-napkin design for the Apollo Tool Carrier] until it came back in the RFP [NASA Request for Purchase]for the actual Apollo Tool Carrier [that would be carried to the Moon].

Well, that's how the Lunar Tool Carrier got designed. So the original Lunar Tool Carrier should have been named the Monte V—for the Monte Vista hotel in Flagstaff' (taken from an interview with Joe O'Connor with Gerald Schaber on 9 July 2001) (Fig. 29).

Mechanical engineer/pilot)Rutledge A. "Putty" Mills (b. 1923), who along with associates Bill Tinnin, Dick Wiser, and Walt Fahey would design and hand build the Branch of Astrogeology's widely heralded "lunar vehicles" for astronaut training, arrived in Flagstaff in mid-1965 (see Appendices A and B). After Apollo, Putty moved to the USGS Center in Denver, Colorado. He formally retired from the USGS in 1986 and presently lives in Santa Barbara, California.

Geologist John W. M'Gonigle (b. 1934) (Ph.D., 1965, Penn State University) arrived in Flagstaff on the 4th of July 1965. John was assigned to work on the development of the Apollo Lunar Tools. He was active in the early Apollo and post-Apollo geologic field exercises around Flagstaff during which Apollo lunar geologic field procedures and communications with a Houston-style, "Science Backroom" concept were being developed by the Manned Lunar Exploration Project in the Branch within the Branch of Astrogeology. John left the Branch of Surface Planetary Exploration in 1970 and, after a number of other assignments with the USGS, retired in 1995.

John M'Gonigle recalls one amusing event when Dave Schleicher was in a space suit on an especially hot day [in 1965 or 1966] in the Hopi Buttes Volcanic Field (east-northeast of Flagstaff) and the bio-engineers from NASA stuck a thermometer in his mouth. "I guess Dave was kind of disgusted with the whole thing anyway. Then they put his suit on him, and later I heard a guy, Earl Lefavores, a suit technician from NASA, say, Dave, what's that in your mouth? [That was the period when we were using pure oxygen.] Dave calmly said that it was a cigarette! About twenty of these NASA guys started racing over to Dave. It was the thermometer! Dave was so disgusted, he hadn't told them that they had left a thermometer in his mouth. I thought I would die laughing (from an interview with John M'Gonigle by Gerald G. Schaber on 10 April 2001.)

[Author's Note: M'Gonigle told this author during our interview that Shoemaker once told him that when you want to so something, don't think of why you can't do it; but think of why you can do it. Let it happen he'd say—let it happen. I thought that was very profound—and so like Gene!]

[Author's Note: Karl Zeller [head of the Astrogeology photolab at the time] told this author during our interview (on 17 October 2001) that during one of these typical rush weekend things when Shoemaker had to have this stuff to catch a plane in order to get down to Houston to get to a Monday meeting, he had all of the photolab staff working all weekend making these large glass slides [as was usually the case]. There may have been one or two of the slides that were sort of out of focus; so they saved them. They had this prank on Gene all figured out. They waited until just about the time that Gene had to leave for the airport. Gene was really sweating bullets. Zeller and one of his people come rushing into Gene's office, and exclaimed we've got em, we've got em Gene. Gene is reaching for them and Karl drops them on the floor [breaking the fake ones]. Gene just turned white. Then Karl said here's the real ones Gene." [Karl didn't tell this author if what Gene's reaction might have been to his "joke"—but I suspect Gene was not amused only for a few seconds, and then probably came out with one of his famous laughs.]

Physicist John D. Hendricks (b. 1941) arrived in Flagstaff to work with the Branch of Astrogeology on 4 July 1965 (see Appendices A and B). His first job at Astrogeology was working with Paula Ables doing time and motion studies in support of developing astronaut lunar surface geoscience activity timelines for the upcoming Apollo Project. From 1966 to 1971 John worked with Bob Regan of Astrogeology doing gravity and magnetic surveys of craters (including Meteor Crater and SP Crater and Flow, and various maar craters in Hopi Buttes). While working for Regan, John received his Master's Degree in Geology from Northern Arizona University in Mathematics and Physics. John still resides in Flagstaff.

Geologist Gerald Gene "Jerry" Schaber (b. 1938) (Ph.D., 1965, University of Cincinnati) arrived in Flagstaff on 7 July 1965 to work with the Branch of Astrogeology, Manned Lunar Exploration Group, on development of analytical laboratory instrumentation for advanced lunar missions that were to be part of NASA's envisioned long-stay-time, lunar base, missions [that, unfortunately, never took place] (see Appendices A and B). Jerry participated at Mission Control in Houston as a member of the Branch's Early Apollo Geology Field Experiment Team (Apollo missions 11-13), a Co-Investigator on the Field Geology Team for Apollo missions 14-15, a Member of the Tiger Team for the Field Geology Investigation Group during Apollo missions 16 and 17, and a Co-Investigator on the Lunar Sounder (deep-sounding) radar Experiment on Apollo 17. Schaber was charged with of seeing to the design and timely production of the Apollo Lunar Surface Map packages to be used by astronaut-crews of Apollo missions 14 and 15.

[Author's Note: Following the Apollo Era, I remained with the Branch of Astrogeology in Flagstaff and made the move to the Branch's rapidly growing planetary studies activities. I worked at JPL with Hal Masursky and others members of the Viking-Mars Lander Site Certification Team in 1976 and did research on the radar imaging and altimetry results from the Pioneer-Venus mission to Venus in 1980. During the 1980's and 1990's I focused my research toward verifying and demonstrating the significance of both airborne and spacecraft-borne terrestrial radar mapping techniques and Earthbased and spacecraft-borne planetary radar mapping techniques for geologic investigations. As a result of these studies, I was selected by NASA as a Co-investigator on the Space Shuttle Imaging Radar-mapping missions (SIR-A, B and C between 1981 and 1994). As a result of my earlier radar-geology research, I was also selected as a Co-Investigator on NASA's Magellan radar-mapper mission to Venus that was carried out between 1990 and 1994. I remained with the USGS in official Emeritus (volunteer) status following my retirement on 31 July 1995 long enough to complete this detailed account of the Role of the U.S. Geological Survey in Man's Greatest Adventure—The Apollo Expeditions to the Moon.]

Geologist David L. Schleicher (b. 1937) (Ph.D., 1965 Penn State University) arrived in Flagstaff on 15 July 1965 (see Appendices A and B). Dave would become one of the Branch of Astrogeology's first "astronaut" test subjects to operate within the difficult spacesuit environment (on pure oxygen at first) during very hot days of the Branch's Early Apollo and Post-Apollo lunar geologic procedures development tests in Hopi Buttes starting in 1965. Dave was also active in the development of the Branch of Astrogeology's "Science back room" communication and recording concept using USGS astronaut test subjects in the field. Schleicher was a member of the Apollo Lunar Geology Experiment Team for Apollo missions 11-13. Following Apollo 13, Dave left Flagstaff and relocated at the USGS Center in Denver, Colorado.

Draftsman and graphic illustrator Ramon "Ray" Sabala (b. 1931), one of the Branch of Astrogeology's hardworking draftsman/illustrators arrived for work in Flagstaff on 27 July 1965 (see Appendices A and B). Ray started work in the old County Annex building, or "Dance Hall," just west of the present Kachina Mexican Restaurant on Santa Fe Avenue (Highway 66) in downtown Flagstaff. Ray started in immediately doing drawings of Apollo Hand Tools for Branch NASA reports in Shoemaker's usual panic deadline status.

[Author's Note: Ray Sabala and his USGS supervisor in Flagstaff, James VanDivier, went to the Jet Propulsion Laboratory to assist in drafting illustrations for Shoemaker's USGS team assembled for each Surveyor lunar landing missions (1966-1968). Ray's contributions included drafting countless items related to the Apollo Lunar Geology Experiment team's efforts, including the Apollo Lunar Surface Map packages (made in Flagstaff) that were carried to the lunar surface by the Apollo astronauts during all six successful Apollo missions. Just days prior to Apollo 12, Ray Sabala and Jim VanDivier were rushed to Cape Canaveral to "secretly" hand color the Apollo 12 landing site geologic maps—at the request of the crew (see 1971). Ray Sabala left Flagstaff in 1990 and moved to Denver where he worked for the Survey's Weapons Program as a draftsman/illustrator. He is currently retired and once again resides in Flagstaff.]

Between 12 and 16 July, 1965, ten astronauts were training in Iceland—a country characterized [within its interior] by beautiful volcanic geology with practically no vegetation cover—probably the most Moon-like of the field areas visited to date (see Table I). Local leaders included Sigurdur Thorarinsson and Gudmundar Signaldson. Other geologists present include Uel Clanton and Ted Foss of NASA/MSC, and Al Chidester and Don Wilhelms of the USGS, Branch of Astrogeology. Film Documentation Unit support personnel from the Branch of Astrogeology (Flagstaff) included Hal Stephens and Tom Lee. Astronauts attending this trip to

Iceland included William Anders, Charles Bassett, Eugene Cernan, Roger Chaffee, Walt Cunningham, Don Eisele, Rusty Schweikart, Dave Scott, and C.C. Williams.

The following was taken from the Branch of Astrogeology Monthly Report for July 1965 to V.R. Wilmarth, NASA HQ, from Chief, Branch of Astrogeology; dated 31 July 1965:
In July 1965 the Branch of Astrogeology's Manned Lunar Exploration Systems projects included the following Project Chiefs and their assignments:

John W. M'Gonigle	Acting Project Chief, Apollo Geological Methods
Gordon A. Swann	Project Chief, Apollo Extension Systems Methods
J. T. O'Connor	Project Chief, Advanced Systems Geological Methods
P.G. Ables	Project Chief, Scientific Task and Biogeological Investigations
E. C. Phillippi and H. E. Holt	Project Chiefs, Lunar Field Imaging Systems
R.A. "Putty" Mills	Project Chief, Lunar Vehicle Systems, Field Operations and General Support

3.2.1-The National Academy of Sciences Summer Conference on Apollo Science is Held at Woods Hole and Falmouth, Massachusetts

The following comments about the historic Woods Hole/Falmouth Conference (summer, 1965) are from Don Beattie (Beattie, 2001, pp. 65-66):

"By 1965, three years had passed since the last National Academy of Sciences summer study that led to the Sonett Report. In the intervening time we had learned a lot. Careful study of the close-up views of the lunar surface taken by Ranger increased our confidence that "normal" geological and geophysical studies could be planned for the astronauts. The summer of 1965 was selected as the date for the Academy to review the status of space science, this time at Woods Hole, near Falmouth, Massachusetts. Dick Allenby and I thought this would be a good opportunity to take advantage of the assembled "Academy experts" such as Harry Hess, Aaron Waters, and Hoover Mackin. I hoped to convene a working group similar to Sonnett's to review our progress and make some specific recommendations for Apollo and post-Apollo science operations. We made a few calls to see if some of the invited Academy members would agree to extend their time at Wood's Hole. Most agreed to stay—it didn't take much persuasion, since it was such a beautiful spot to be working in the middle of summer" (Beattie, 2001, pp. 65-66).

Don Wilhelms:
"A first, more general segment of this summer study sponsored for NASA by the Space Science Board and was held at the Woods Hole Oceanographic Institute under the chairmanship of Harry Hess. The convened scientists looked much more benignly on manned space flight than had the generally hostile physicist-dominated crowd at Iowa City in 1962 and outlined some general goals for lunar exploration.

The second segment of the Wood's Hole Conference study, addressing the role and goals of science in lunar exploration, was held at Falmouth, Massachusetts between 19 and 31 July [1965] under the auspices of an OSSA committee established by Homer Newell to advise the

Manned Space Science Division (under Willis Foster). Both the committee and the conference were chaired by geophysicist Richard J. Allenby, Foster's Deputy" (Wilhelms, 1993, p. 114).

The following extensive quotations about the goals and format of the Wood's Hole Conference are from Don Beattie:
"Developing specific Apollo science guidelines was the first priority of the conference. However, our primary objective for the summer study was to expose the assembled experts to the results of the MSFC contractor studies that we had undertaken for post-Apollo missions. Also, we wanted to show those from the geological community, outside USGS, what we had achieved in more than a year of mission planning and simulation at Flagstaff. During 1964 and 1965 MSC had been steadily adding to its science staff, mostly in the earth sciences, and the friction I mentioned earlier had been growing. Here was our chance to show them we had received the support of the mainstream scientists interested in solving the major lunar problems. Eight of Max Faget's staffers were invited, led by William Stoney, John Dornbach, and Elbert King [all from MSC].

Two important attendees were Walt Cunningham and Jack Schmitt. Walt was an astronaut, and Jack was an astronaut-to-be. Jack's selection in the first scientist astronaut group had been just announced, and his personal involvement in our Flagstaff work would be an important step in getting the astronauts to accept our ideas on what to do on the Moon and how to do it. Jack would soon be leaving to start one year of flight training; this conference would be his last official duty as a member of USGS. Walt's [Cunningham] astronaut group, the third selected, included many that would become well known, such as Buzz Aldrin and Michael Collins. They had all been given specific Apollo system or technology sectors to monitor and become expert in, besides performing their more "mundane" duties of making the transition from military pilot to astronaut. Walt's responsibilities included non-flight experiments, so he was our primary contact in the astronaut corps for any questions about the astronaut's performing experiments on the Moon. Having Walt at Woods Hole lent immediacy to our planning. Here was someone who might actually carry out our recommendations.

Walt's message to us on the first day of the conference, however, was not encouraging. Influenced in part by his training and by his own study and analysis of the preliminary mission timelines, he warned us not to overburden the astronauts with scientific tasks. Housekeeping chores would demand a large percentage of their time on the lunar surface. This was a sobering introduction to lunar science and colored our working group's deliberations and corridor talk in the days ahead.

Working groups were established in eight scientific disciplines: geology, geophysics, geodesy-cartography, bioscience, geochemistry, particles and fields, lunar atmosphere measurements, and astronomy. Astronomy was added at the eleventh hour in order to review the preliminary findings of our post-Apollo telescope study and to look beyond Apollo to lunar bases when the Moon could become the site of large astronomical observatories.

The other seven working groups, however, were asked to review and recommend experiments and operations for the astronauts to carry out on both Apollo and post-Apollo missions, both for two-week stay times and for lunar bases. The number of [conference] attendee's (125) exceeded our initial plans, and to ensure that the post-Apollo discussions would be favorably covered, we loaded the attendance with MSFC and USGS staff who had been participating in our studies.

Each working group submitted a report summarizing the results of its deliberations, and the conference report, compiled by Jay Holmes with the help of many in attendance, was released just before Christmas 1965. I immediately supplanted the Sonett Report as the authoritative reference for Apollo and post-Apollo science planning and, as we had hoped, fully endorsed our approach to the post-Apollo missions

The geology-working group listed two primary questions to be answered by the first Apollo landings: what are the composition, structure, and thickness of the moon's surficial layer? And what are the composition and the origin of the material underlying this layer? Recognizing that time was the most valuable resource in each mission (reinforced by Cunningham's presentation), the group gave a lot of effort to recommending tools and procedures that would permit the astronauts to quickly gather the information needed" (Beattie, 2001, pp. 66-69).

Astrogeology's Joe O'Connor reflects below on some interesting discussions during the Woods Hole/Falmouth Conference in 1965 (from his interview with Gerald G. Schaber on: 9 July 2001): "We got to discussing [at the Woods Hole meeting] whether or not you could use a magnifying glass in a space suit. Now, there really was only one problem [that came up] with using a magnifying glass with a space suit. That was getting the proper magnification and focal length to be useful to your eye—and have a good enough field of view if you are looking through the helmet of a space suit at something you are holding in your hand outside of the suit.

But there was a straw horse that kept coming up with the magnifying glass. That is that people were afraid that a magnifying glass hanging on the outside of the spacesuit would gather enough sun together to burn a hole in the spacesuit—and deflate the astronauts! That was really held out to be the biggest drawback for a magnifying glass, and Houston was completely convinced that you couldn't possibly use a magnifying glass because it would burn up the astronaut.

I think it was Elbert King (later Chief Scientist at MSC) who brought up this problem of burning up the astronauts with the hand lens. I said, well, you know, your hand lens is really pretty damn small in diameter. You're not really going to gather enough sunlight to do a lot of damage unless you've got it on a tripod right at the focal point—and it's directed at the spacesuit for quite a while. Even then, you've got those thermal outer suits on top of the regular spacesuit—you're not really going to do a lot of damage. Elbert King said, yeah but they're very powerful glasses—you know like 15X—and you'll really burn up a lot with that!

I said, King, it doesn't matter what the magnification of the glass is; it depends on what its area is as to how much energy you're going to get. And strangely enough, I believe it was astronaut Walt Cunningham who joined in on King's side. We had a few harsh words where I advised him to go back and read his physics book—and find out how you got energy into a magnifying glass before he came out making pronouncements. [Author's Note: Gordon Swann says that Walt Cunningham was usually anti-geology and anti-USGS in those days!]

Of course NASA got real huffy about that. But when Elbert King went and checked in his—he said oh God, you're right! He didn't say it at that meeting, but later on he came back and apologized—and said, you're right—we were so far off base on that. In any event, the hand lens remained viable, at last for the time being after that discussion."

[Author's Note:-The lunar hand lens was eventually dropped as a viable geologic tool for the astronauts. However, Gordon Swann gave his own personal hand lens to Commander Dave Scott to take to the lunar surface during the Apollo 15 mission in 1971. Dave returned the hand lens to Gordon upon his return to Earth, and today this very special hand lens is proudly displayed on a wall in the Swann home in Flagstaff.]

Don Beattie:
"Having received the endorsement we were looking for at the Falmouth Conference in the summer of 1965, we charged full speed ahead at Flagstaff to further define potential post-Apollo missions. Based on the emphasis at Falmouth, conserving the astronaut's time became a major objective of our simulations [at Flagstaff]. We also addressed sample return from these longer missions. The weight allowance for return-to-Earth payloads would be restricted, yet the astronauts would undoubtedly collect many samples during their two-week stay. How could they be sure to bring back the most important ones? We proposed a small sample preparation laboratory they could use while still on the lunar surface, and one was designed by Joe O'Connor, David Dahlem, Gerald Schaber, and Gordon Swann with the help of other USGS staffers [in Flagstaff]" (Beattie, 2001, p. 70).

[Space Exploration Milestone: "As scientists were meeting at Woods Hole and Falmouth, Mariner 4 showed a moonlike surface as it flew by Mars on 14 July 1965, and [the Soviet's] Zond 3 looped past the Moon on July 20—a date destined to be famous in space exploration [the date of the Apollo 11 landing in 1969]. This first lunar Zond was launched on 18 July into an Earth parking orbit and then shot to the Moon in the very fast time of 33 hours. Zond 3 began a 68-minute photographic run on July 20 when it was 11,570 km above the west limb, then dipped to 9,220 km on the far side before climbing back up relative to the Moon and heading off into space. It dumped its data back to earth on 29 July when it was 2.2 million-km away, apparently because it was originally intended as a planetary probe designed to operate from great distances. The haul was about 25 photographs of western Oceanus Procellarum, the west limb, and the far side, including a previously unseen region as far west as the terminator at longitude 166 Degrees" (Wilhelms, 1993, p.120).]

[Author's Note: For the reactions of several Branch of Astrogeology scientists in Flagstaff to what was revealed on the Mariner 4 Mars images; see Flagstaff's *Arizona Daily Sun* edition of 16 August 1965 for byline by William Hoyt entitled "Mars Photos Aid Astrogeologists Here."]

[Astrogeology Milestone: In August 1965, the Branch of Astrogeologic Studies submitted to NASA its second *Semi-Annual Progress Report on Manned Lunar Exploration Investigation*.]

Don Wilhelms:
"In May 1965, concurrent with the search for Surveyor sites, Larry Rowan's group [at Flagstaff] had begun to identify potential Lunar Orbiter sites on the basis of geologic mapping [from

telescopic images] and terrain studies. The site-selection effort continued during the Falmouth conference, and in August 1965 the planners presented a list of ten sites for the first Lunar Orbiter mission, still called mission A. The job of the scientists and terrain analysis was to pinpoint favorable landing spots within the Apollo constraints. Each mission-A site was assigned to an astrogeologist and described in a form of Astrogeology "gray" literature more precisely referred to as "green horrors" because of the color of their covers and the need to churn out one after the other against deadlines.

[Note: Rowan formally presented the mission-A plan to the Surveyor/Orbiter Utilization Committee (SOUC) on 29 September 1965, five weeks after the overlapping Surveyor list was presented to the committee. Nine prime (P) Apollo sites were to be shot, including three and a half not in the smooth maria. Although there was nothing they could do about it, the Planetology Subcommittee was disturbed that no scientific missions were planned" (Wilhelms, 1993, p. 154.)]

Photogrammetrist S. "Sherman" Shou Chou Wu (b. 1927 in China) came to work for the Branch of Astrogeology on 10 August 1965 (See Appendices A and B). He was recruited while attending Syracuse University by the Branch of Astrogeology's Jim Alderman to help in mapping the Moon. Sherman retired from the USGS in September 1994. He is presently based out of Las Vegas, Nevada where he works directly for Bechtel-Nevada and indirectly for the U.S. Department of Energy and Lockheed Martin on military photogrammetric and remote sensing programs. Sherman completed his PhD at the U. of Arizona in 1976 with a dissertation title "Topographic Mapping of Mars", which was part of his work at Astrogeology. Sherman's most significant contributions to Astrogeology while he was in Flagstaff centered around his pioneering accomplishments in the topographic mapping of the Moon, Mars, and other planetary bodies based on conventional, as well as creative photogrammetric techniques. Sherman S.C. Wu retired from the USGS on 30 September 1994 and re-located to Las Vegas, Nevada where he currently works for the U.S. Department of Energy/Bechtell Nevada Corporation and Lockheed-Martin doing classified research in state-of-the-art digital photogrammetry and remote sensing.]

The following is from the Branch of Astrogeology Monthly Report for August 1965 to V.R. Wilmarth of NASA HQ; dated 31 August 1965:
In August 1965, C. E. Hazelwood, photographer, was transferred from Topographic Division, Menlo Park, California, to the Branch of Astrogeology in Flagstaff.

P.G. Ables, chemist and H.A. Pohn, geologist, received professional ratings in the Branch during August 1965 using data available from the terrain Studies Program at the Branch of Astrogeology in Flagstaff. Descriptions and evaluations of these 44 sites submitted to NASA were prepared by J.F. McCauley, L.C. Rowan, E. C. Morris, H.E. Holt and J. T. O'Connor, and submitted to NASA. The work was a cooperative effort with the Jet Propulsion Laboratory, Pasadena, California, whose personnel provided trajectory and lighting data along with additional geological information for the submitted report.

During August 1965 Gerald G. Schaber and Donald P. Elston began working with the Remote Sensing Group at NASA Headquarters with regard to lunar and earth orbiting platforms.

On 27-29 August 1965 the Mobile Geologic Laboratory (MOLAB, or MGL) was put on display at the Coconino County Fair in Flagstaff.

Geologist/geomorphologist T. N. V. "Thor" Karlstrom (b. 1920) (University of Chicago) transferred to the Branch of Astrogeology (Flagstaff, Arizona) from the Branch of Military Geology, Washington, D.C. in August of 1965 (see Appendices A and B). Gene Shoemaker recruited Karlstrom at the time he was working with the Alaskan Terrain and Permafrost Section of the Survey's Military Geology Branch. Thor had only recently completed compiling the surficial geology map of Alaska using aerial photographs, so he was well aware of photointerpretation. He had also recently finished a job mapping the geomorphology and geology of the northern region of Greenland. Thor was assigned by the Branch of Astrogeology to work on Apollo lunar mission planning right from the start using Lunar Orbiter photographs of the Moon. He was assigned to design and put together the Apollo Lunar Surface Data Packages (the maps the astronauts would carry to the lunar surface) for missions Apollo 11-13.

In August 1965, the Manned Exploration Group at the Branch of Astrogeology in Flagstaff began searching for a building to carry out mineralogy and petrology studies in support of Advanced Systems Geological Methods, Apollo Extension Systems Geological Methods, and the Branch's rapidly growing astronaut training activities for NASA. Al Honka (Branch administrator Officer at that time) was offered the old Switzer Building near the "Ice House" just east of the Arizona Bank Building. Al Honka believed that the $1,000 per month least rate was excessive for that facility. Thus, Al looked elsewhere and found the availability of a suitable building at 16-18 Mike's Pike, located across the tracks in downtown West Flagstaff. The Mike's Pike facility (hereafter referred to as the "rock lab") was leased by Astrogeology, and subsequently modified for sample preparation and subsequently chemical and analytical instrumental analysis (Fig. 30).

The rock lab was set up over the next year by experienced analytical-types—geologists Joe O'Connor, this author, and Dave Dahlem (arriving in October 1965; see below). Physical Science Technician Bert Emmons was the early assistant at the Mike's Pike Rock lab starting in August 1965. Bert was later joined in October 1967 by Physical Science Aid Henry C. Blee (now deceased) who worked primarily on rock preparation and rock thin sectioning (see 1967).

[<u>Author's Note</u>: This author took over the direction of the Mike's Pike Rock Lab in late 1967 or early 1968. I was in charge of the Mike's Pike lab when Carl Roach (Astrogeology in Denver) shipped to the lab two tractor trailer's full of his rock shock laboratory equipment. This would have been about 1968 or 1969. Carl had lost the DOD funding for his shock-rock project and had finally decided to leave the Branch of Astrogeology [in large part because Gene Shoemaker was still insisting that he had to move down to Flagstaff, and he didn't want to]. Carl then transferred over to the Bureau of Mines part of the Survey's Gold Exploration program. Later (in 1975), this author would be asked to design a new rock laboratory for Building-Four (completed in 1976) that would soon begin construction at the USGS Flagstaff Field Center on McMillan Mesa in Flagstaff. The new rock analysis facility was designed to accommodate much of the lab furniture and analytical equipment that was then located at the Branch's Mike Pike lab. The new lab space included a wet chemistry lab, weighing room, x-ray diffraction lab, atomic absorption and transmission-spectroscopy labs, sample preparation facilities, and office spaces.

Over the years, these lab spaces in Building-Four have been significantly altered for other purposes as the Center grew. The wet chemistry lab, however, has more or less survived intact to the present time. All of the original lab space in Building-Four is presently being used primarily by Survey personnel from other Branches within the Geologic Division, Water Resources Division, and the new Biological Division of the Survey.]

The following was taken from the Branch of Astrogeology Monthly Report for September 1965 to V.R. Wilmarth, NASA HQ; dated 30 September 1965:
On 1-3 and 8-10 September 1965, six NASA astronauts were taken to Medicine Lake, California for another geologic training exercise (see Table I). The Medicine Lake Highlands include an 8-km caldera in a large volcanic area with volcanic flows and obsidian flows. The local expert was Aaron Waters (U. of California) for the first trip and Charles A. Anderson (USGS) for the second trip. Other geologists present included Uel Clanton, Ted Foss, and Albert King of NASA/MSC), and Don Wilhelms and Al Chidester of the USGS (Branch of Astrogeology). Astronauts attending the 1-2 September trip to Medicine Lake included William Anders, Allan Bean and Rusty Schweikart. The 8-10 September trip included Charles Bassett, Walt Cunningham, and C.C. Williams.

Between 14 and 21 September 1965 four NASA astronauts participated in another geologic training exercise at Zuni Salt Lake, New Mexico (see Table I). This is a large volcanic area with structurally complex rim material. Geophysical exercises were held with the astronauts helping to lay out the traverses; they also used geophysical instruments to gather data and interpret the results. The geologists present included Uel Clanton (NASA/MSC) and Al Chidester (USGS, Branch of Astrogeology). Astronauts participating in this exercise were William Anders, Allan Bean, Walt Cunningham, and Rusty Schweikart.

On 20 September through 1 October 1965, the Manned Lunar Exploration Group of the Branch of Astrogeology carried out Apollo Extension System (AES) Test 1 at what they referred to as the "Apollo Mesa" dike in Hopi Buttes, Arizona (see Table I). The Trespasser vehicle (a commercially-purchased eight-wheel all-terrain vehicle) was utilized during the test. This was a suited test with test subjects Gordon Swann, Dave Schleicher, and Joseph O'Connor. Other Branch of Astrogeology scientists participating in the test included Al Chidester, Don Lamb, George Ulrich, John M'Gonigle, Bob Sutton, Gerald Schaber, Dave Cummings, and Bob Regan. The "science back room" was located in the field in a trailer modified by the Branch for such a purpose. The science back-room personnel were geologists Red Bailey, John M'Gonigle, Dave Schleicher, Bob Sutton, Gordon Swann, and Dave Cummings; and geophysicist Bob Regan. Support personnel for the test included Yukio Yamamoto, Walt Roeder, Jim McCord, Hal Stephens, Oliver Grieve, Bill Mason, Eric Bramsoe, Tom Lee, Paula Ables, John Hendricks, Jim Crossen and Hugh Thomas. This test included eleven traverses, nine geologic and two geophysical. A total of two hundred and forty-five samples were collected, and two hundred and eighteen photographs were taken (Fig. 31a-f).

The analytical instruments tested included the X-ray diffractometer (51 samples run) (Fig. 31g, h), petrographic microscope (ten samples analyzed), magnetic susceptibility instrument (6 samples) and use of a binocular microscope (nine samples over two days in use). Physical property measurements taken included the scintillation counter, penetrometer, sieve analysis, and color chart. The LM TV camera and the lunar staff camera were used. The TV was relayed to Flagstaff for Palmer Films. Hand tools tested included the tool carrier, power auger, hammer, trowel, gripper, and hand lens. The Lunar Staff included the Sun compass, clinometer and a Pentax 35-mm camera. Geophysics included a gravity meter, scintillometer, and seismics (over a three-day period during the test).

This test was documented in *Astrogeology Technical Letter*- 8, titled Apollo Extension System Field Test 1, September 20-October 1, 1965, Hopi Buttes, Arizona by G.A. Swann et al.; 26 pages; dated 1966." (the above was taken from the Branch of Astrogeology Monthly Report for September 1965 to V.R. Wilmarth, NASA HQ; dated 30 September 1965:].

Geologist George E. Ulrich (b. 1934) (Ph.D., 1963, University of Colorado at Boulder) arrived in Flagstaff to work with the Branch of Astrogeology in September 1965 (see Appendices A and B). George had been with the USGS Regional Geology Group at Hopkinsville, Kentucky, as part of the Kentucky geologic mapping project. George Ulrich would work on the Branch's Early Apollo and Post-Apollo geologic procedures tests in Northern Arizona, and elsewhere. He became closely involved with the "geologist's input" to the engineering design of the Branch of Surface Planetary Exploration's Lunar Roving Vehicle simulators (Explorer and Grover; see below), used to train NASA's astronauts in field geologic procedures for Apollo missions (15-17). George was named a Co-Investigator on NASA's Lunar Geology Experiment Team for Apollo missions 16 (April 1972) and 17 (December 1972).]

George Ulrich
I was assigned space on the third floor of the Arizona Bank Building with Jerry Schaber and Dave Schleicher who had been hired by the Branch that same July (see above). A few days after I arrived in Flagstaff, I, along with you [this author] and Schleicher, was on my way out to Hopi Buttes [Trading-Post diatreme and Castle Butte] north of Winslow, Arizona for a field test. We were doing visual descriptions [as simulated geologist/astronauts], and recording them back to the LM**.** I remember Astrogeology's Film Documentation Unit was documenting the tests for NASA. We were living in motels in Winslow, Arizona, and coming home on weekends. That was a great time" (From an interview with George Ulrich by Gerald G. Schaber on 15 February 2001).

Don Beattie:
"In September 1965, shortly after the Falmouth conference [mentioned above, see 1962], Will Foster sent MSC a second set of guidelines for Apollo science. In his memo he asked Robert Gilruth, MSC center director, and Max Faget to "prepare a Program Plan from which we can establish firm Program Guidelines to which all of us involved in this effort can work. Foster's guidelines included discussions of sample return and lunar sample boxes, the Lunar Receiving Laboratory (LRL), the geophysical ground station, recently named Apollo Lunar Surface Experiment Package (ALSEP), and the geological hand tools and other equipment. He urged MSC to develop the guidelines as soon as possible, since we had little time to deliver the scientific equipment for the first missions.

While these guidelines were being developed we continued selecting the sample analysis PIs. After their proposals were received, Dick Wilmarth, E Chao (USGS) and Bob Bryson spent the next several months visiting the potential PIs and their labs to determine if they were equipped to conduct the analyses they proposed. Some were; some were not.

As part of its responsibilities, the Field Geology Team [under Gene Shoemaker] began a careful review of the proposals by establishing a geology working-group chaired by Shoemaker. In addition to Shoemaker, the working group consisted of Goddard, Mackin, and Waters from the Field Geology Team, Harry Hess (from the Space Science Board), and Ted Foss and Jack Schmitt from MSC. I served as secretary. We met over a period of nine months, and at the end of 1966 we sent our report to OSSA. We recommended that almost all of the [sample analysis] proposals be accepted, a total of forty-one" (Beattie, 2001, pp. 112-113).

(The following was taken from the Branch of Astrogeology Monthly Report for October 1965 to V.R. Wilmarth of NASA HQ; dated 29 October 1965:
[Branch of Astrogeology Milestone; The Branch of Astrogeology on 18 October 1965 dedicated Building-One, the first building at the Center of Astrogeology on McMillan Mesa in Flagstaff. William T. Pecora, Director, U.S. Geological Survey; Willis B. Foster, Director, Manned Space Science Programs, NASA; Oran W. Nicks, Director, Lunar and Planetary Programs, NASA; W. Miller Bennett, representing the Governor's Office, State of Arizona; Rollin W Wheeler, Mayor, City of Flagstaff; J. Lawrence Walkup, President, Arizona State College, Flagstaff, and Edward B. Danson, Director, Museum of Northern Arizona, Flagstaff, spoke at the dedication ceremonies. About 400 persons attended the ceremonies (Branch of Astrogeology Monthly Report for October 1965 to V.R. Wilmarth of NASA HQ; dated 29 October, 1965) (Fig. 32).]

The dedication of Building One at the Flagstaff Center of Astrogeology was fully documented by motion picture and still photography. [Author's Note: The highlight—and most memorable—moment of the formal dedication was when the Survey's Director William Pecora walked to the podium and said [paraphrased] if I had known what Shoemaker was doing out here, I would have put a stop to it. This was a shocking way to begin the dedication].The highlight of the evening dedication program at the Holiday Inn in Flagstaff on 18 October was the first showing of the Hawaiian Astronaut Training film [produced by the Branch of Astrogeology]

A simulated Surveyor spacecraft television system was completed and was demonstrated during the dedication ceremonies of the Center of Astrogeology. The slow-scan television system performs all of the functions that the flight television cameras will perform including pre-programmed automatic control. The simulated Surveyor television system will be used during field and laboratory tests to develop techniques and procedures for reduction of photogrammetric, photometric, colorimetric, and polarimetric data that will be received from the Moon.

Following the dedication of Building One, a symposium on recent advances in Astrogeology was held 19 October in Flagstaff. Harold L. James was Chairman of the morning session. Verl R. Wilmarth was Chairman of the afternoon session. Philip E. Culbertson, Director, Manned Lunar Mission Studies, NASA, and Colonel A.T. Strickland, Manned Space Sciences Division, NASA, were among the 115 persons attending the symposium.

[Author's Note: Building-One (later, named The Gilbert Building after pioneering geologist G.K. Gilbert) unfortunately had to be condemned in 2001 by the City of Flagstaff (which owned the building since 1995) as a result of serious, ongoing roof leaks and major health problems with mold and asbestos in the ceiling and walls. The building was demolished in 2002 to make way for the much larger and more modern, "Shoemaker Building" that was dedicated and occupied by Branch of Astrogeology personnel in September 2002.]

J.S. Watkins of the Branch of Astrogeology Geophysics Group was approved in October 1965 as a Co-Investigator of the Early Apollo Active Seismic Experiment by the Planetology Subcommittee of the NASA Space Sciences Steering Committee. Joel will develop a short-array, active, seismic experiment designed to measure the thickness and to determine some of the physical properties of the low-density layer covering the lunar surface (the regolith). The appointment was made as a result of a combination of two proposed active seismic experiments; a long-array experiment proposed by R.L. Kovach of Stanford University, and the short-array experiment proposed by J.S. Watkins, J. Cl. DeBremaecher, and M.F. Kane of the Branch of Astrogeology.

Geologist David H. Dahlem (b. 1935) (Ph.D., 1965, University of Michigan) arrived in Flagstaff to work for the Branch of Astrogeology in October 1965 and worked under the supervision of Joseph O'Connor on the Branch's Advanced Lunar Programs Project (see Appendices A and B). Over the five years that Dave was with Astrogeology [until August 1970], he was in charge of putting together [for potential use in Advanced Lunar Base missions] an alpha (radioisotope-source) spectrometer (Fig. 33), as well as the small, portable X-ray diffractometer (see Fig. 31g, h) (that was originally developed by Philips Corporation to be part of the instruments on the Surveyor Landers but never flown). These miniaturized analytical instruments, as well as others to be used in analyzing lunar rocks and soil on future lunar bases, were then being seriously studied by NASA.

[Author's Note: Dave Dahlem was part of the Apollo Lunar Geology Experiment Team from Astrogeology (Flagstaff) for Apollo missions 11 and 12, and participated in these two missions down at Mission Control at Houston. Dave's main job during the Apollo 11 and 12 missions was to facilitate and monitor the use of SEARCH, a primitive database program (in Assembler and Fortran IV programming languages) and WLYBUR a large, computer text-editing program, developed primarily by Dave Dahlem and USGS computer programmer Jack Fife in Flagstaff. WYBUR, first used by the LGE Team on Apollo 12) was a large computer text-editing program, then resident in the Stanford University computer system. Both programs were used by the Lunar Geology Experiment Team. [WLYBUR was a pioneering predecessor to the now commonly-used Word Processing programs.]

What Dave and the others attempted to develop with SEARCH for use in early Apollo was a crude, early form of a modern relational database program that today is common place. The whole idea was to catalogue the information, and to be able to search it for data that could be useful, scientifically, in near real-time during the lunar mission. The people in charge of MSC Mission Control even let Astrogeology use one of their five IBM 360-75 (mission backup) computers to install our SEARCH program during those first two lunar missions.

NASA even supplied "live audio" from the lunar surface during the first two Apollo missions to one of the Apollo Lunar Geology Experiment Team's apartments at the Colonnades Apartments on NASA Road One in Webster, Texas, near MSC. Here, the transcripts of the lunar voice link provided by the Lunar geology team's three court stenographers stationed inside MSC Mission Control (Keith Welch, Don Thacker and B.W. Lessman) (more on them later) were physically transported to the apartment where the Lunar Geology team had Branch of Astrogeology Clerk-Stenographers Linda Sowers, Darline Johnson and Fern Beeson typing into WYLBUR the transcript of the lunar surface voice transmissions.

Unfortunately, the future of the SEARCH and WYLBUR programs was limited because almost immediately after Apollo 11, there were word processing systems and database programs coming online commercially. The final word storage program system that transpired was the system Houston was using—one that they had put out on a subcontract. This system bloomed about a year after the Branch of Surface Planetary Exploration started theirs. Dahlem says that he became aware of this about 1970. About that time, there were also rumors that the Advance Lunar Programs Project was going to be cut within the next year or so; and that is when Dave left the SPE Branch and Flagstaff. Gordon Swann tells this author that he believes that the overall system was a huge success for its time. Dave Dahlem later retired from the USGS and now resides in Kingman, Arizona.

Narrator/Scriptwriter Don Hart (1940-2004), who narrated all of the Branch of Surface Planetary Exploration's pre-Apollo lunar surface geologic procedural testing and training films for NASA, started to work for the Branch of Astrogeology's Film Documentation Unit in October 1965 (see Appendices A and B). His family first came to Arizona in the 1880's, when his great-grandfather opened up a gun shop [of all things] in Tombstone, Arizona. Two of Don's brothers, James A. Hart and Robert W. Hart, were earlier employed by the Branch of Astrogeology in February 1964 and March 1965, respectively. James worked with Ray Batson's Cartographic mapping group while Robert worked with Jim VanDivier's cartographic/drafting section. Don Hart passed away in Phoenix, Arizona in March 2004.

The following quotations were taken from the Branch of Astrogeology Monthly Report for October 1965 to V.R. Wilmarth, NASA HQ; dated 31 October 1965:
In October 1965 a 28-foot long trailer van was modified for the Applied Geophysics Project, Branch of Astrogeology, into a rock preparation and physical and chemical properties laboratory. It will be used in field verification of in situ physical properties.

In October 1965 geologic mapping of Zuni Salt Lake, New Mexico, was begun by David Cummings after an inspection trip by David Cummings, J.W. M'Gonigle and D.L. Schleicher. The map was planned for use in astronaut training and in Apollo mission and equipment tests.

Apollo Suited Test 5 was conducted at Hopi Buttes test area, Arizona, 4-7 October 1965. Participating NASA personnel from the Manned Spacecraft Center, Houston, Texas, were: E.V. LaFevers, W.D. Salyer, J.H. O'Kane, J.C. Nuttall, M.L. Radnofsky, Max Kandler, R.P. Willadson, G.F. Zieglschmid, M.D., and D. A. Beattie of NASA, Washington, D.C. Data from the test site were compiled and analyzed during October for a final report issued later in the year (1965).

During October 1965 Advanced Systems Geologic Methods became a project under Advanced Systems Investigations with R.L. Sutton as Project Chief. Advanced Systems Analytical Instruments became a project under Advanced Systems Investigations with J. T. O'Connor as acting Project Chief. Advanced Systems Data Reduction became a project under Advanced Systems Investigations with J. T. O'Connor as Project Chief.

Don Wilhelms (Wilhelm, 1993, p. 154) introduces us to geomorphologist Maurice Jean_Grolier (b.1918), a hardworking, gentlemanly newcomer [to the Branch of Astrogeology] hired in October 1965 by Jack McCauley for the photoclinometry-terrain project. Maurice had emigrated from France in 1936, returned home at the outbreak of the Second World War to take some shots at the Boshes; survived wartime captures and escapes, and returned to the United States after the war. By the luck of the draw, lunar landing site A-3 was assigned for analysis to the careful, scholarly Grolier, who thoroughly and objectively analyzed and described it in a green horror. Although Maurice refrained from praising its virtues, large tracts of A-3 passed the tests of freedom from [crater] rays and visible obstacles [hazards to a manned landing]. It would become famous under a different name on 20 July 1969" [the Apollo 11 landing site, Tranquillity Base].

The following information was taken from the Branch of Astrogeology Monthly Report for November 1965 to V.R. Wilmarth, NASA HQ; dated 30 November 1965:
In November 1965 D. E. Gault of Ames Research Center, NASA, Moffett Field, California, and H.J. Moore II simulated (approximately) the evolution of a lunar surface. One hundred BB's were used for every ten 22-caliber projectiles and for each 30-caliber projectile; these were fired vertically into non-cohesive sand and carborundum powder at selected coordinates using a table of random numbers. The simulation showed that a steady-state surface is reached which does not change its general appearance with continued impact. A film of the simulation ("Mare Carborundum") was completed in November 1965.

Also in November 1965, a portable thin-section fabricator (Fig. 34), slab saw, and field microscope, furnished by Goddard Space Flight Center, NASA, Greenbelt, Maryland, were delivered to the Manned Lunar Exploration Studies group at Flagstaff. Preliminary evaluation of these instruments was begun. They were used for subsequent Apollo Extension Systems and Advanced Systems field tests.

Cartographer Jay Inge came to work in Flagstaff for Lowell Observatory as an airbrush illustrator in November 1965 to work on the LAC Lunar charts that were being compiled by Lowell and ACIC [on the grounds at Lowell at that time] in early support of Project Apollo (see Appendices A and B). Jay would eventually work part time for the USGS Branch of Astrogeology in Flagstaff in 1973 [while still working for Lowell]. Jay was offered a full time position with the Branch of Astrogeology in 1974. Jay quit Lowell Observatory and joined the USGS. See 1973**-** interview with Jay Inge by Gerald Schaber].

[Astrogeology and Project Apollo Milestone: In November 1965 Gene Shoemaker submitted his original proposal to NASA for the Early Apollo Lunar Geology Experiment. His proposal was entitled "*Geologic Field Experiment in Early Apollo Manned Lunar Landing Missions*". Gene was listed as the Principal Investigator. His Co-Investigators were Edward, "Eddy" N. Goddard (U. of Michigan), J. Hoover Mackin (U. of Texas), Harrison H. "Jack" Schmitt (NASA), Aaron C. Waters (U. of California, Santa Barbara)].

[Author's Note: Gordon Swann told this author (personal communication, 2003) that geologist Ted Foss of the Manned Spacecraft Center, Houston, Texas) was also on the proposal (as originally submitted) as a Co-investigator. Swann also recalled that John M'Gonigle (Branch of Astrogeology-Flagstaff) was added later to the proposal; and when John opted out, Gordon Swann was added.]

[Astrogeology Milestone; In November 1965, the Branch of Astrogeologic Studies submitted its fourth Annual *Astrogeology Progress Report* to NASA for research carried out during the period from 1 July 1964 to 1 July 1965. The report was in three parts: Part A-Lunar and Planetary Investigations, Part B- Crater Investigations, and Part C-Cosmic Chemistry and Petrology.]

[Author's Note: In November 1965 the personnel located at the U.S. Air Force's ACIC, lunar and planetary facility at Lowell Observatory in Flagstaff included the following: Bill Cannell, chief, Sharon Gregory, secretary, Leonard Martin, observer, Louis Riley, observer, Fred Dungan, scientific illustrator, Barbara Virgil, scientific illustrator, Bob Maulfair, photographer, Tom Dungan, scientific illustrator, Cliff Snyder, scientific illustrator, Jim Greenacre, observer, Gail Gibbons, scientific illustrator, Terry McCann, observer, Bruce Faure, observer, Pat Bridges, scientific illustrator, and Jim Jennings, observer (taken from the Air Force *Orientor*, 12 November 1965; courtesy of Pat Bridges).]

On 8-10 November, 1965 four astronauts participated in two separate trips to the Pinacates Volcanic Field in Northern Mexico (see Table I). The Pinacates is a volcanic area with explosive craters (maars) and subsidence along ring fractures. Dick Jahns (Stanford University) was the local expert. Other geologists present included Ted Foss and Uel Clanton from NASA/MSC, and Al Chidester of the USGS, Branch of Astrogeology. Astronauts attending this first Pinacates trip included William Anders, Walt Cunningham, Rusty Schweikart, and C.C. Williams.

The following was taken from the Branch of Astrogeology Monthly Report for November 1965 to V.R. Wilmarth, NASA HQ; dated 30 November 1965; and Red Bailey's personal log of his Branch activities for 1965:
In November 1965 the mineralogy and petrology laboratory [at Mike's Pike in West Flagstaff] was completed (see Fig. 30) and was being utilized by manned Lunar Exploration Studies personnel to obtain information regarding the test site areas and to prepare standards for analytical instruments tested. Ancillary equipment is being prepared for use with a fieldable X-ray diffractometer [the never-flown miniaturized X-ray diffractometer by Phillips Electronics that was originally planned for Surveyor] (see Fig. 31g, h). Jet Propulsion Laboratory personnel [specifically, Neil Nickel and Jim Dunne] cooperated with the Branch of Astrogeology on this project.

On 4-14 November 1965, the Mobile Geological Laboratory (MGL or MOLAB) was set up in the Branch of Astrogeology's exhibit at the Arizona State Fair, Phoenix, Arizona [see November 1967 for details on USGS display at the 1967 Arizona State Fair].

On 16-18 November 1965, the Manned Lunar Exploration Group within the Branch of Astrogeology carried out Apollo Extension Systems (AES) Test 2 (also called AAP Test 2) on the south side of Meteor Crater, Arizona (Fig. 35). This test was also referred to as Apollo Application Program (AAP) test 2. Test subjects were George Ulrich and Dave Dahlem. The science back room was in a trailer modified for that purpose in the field. Science backroom personnel included Red Bailey, Dave Dahlem, Dave Schleicher, Shirley Patrick, John M'Gonigle, and Bevan French. Support personnel included Hugh Thomas, Bill Mason, Eric Bramsoe, and Paula Ables (time and motion studies). The test included use of the LM TV camera, three geologic traverses, and three runs of the new miniaturized thin-section grinding machine. The Lunar staff consisted of a 35-mm Pentax camera, Sun compass, and clinometer. Physical property measurements included the use of the penetrometer and scintillation counter. Hand tools utilized included the hammer, trowel and scribe.

During AAP test 2—a run-through for AAP Test 3 (7-9 December, 1965; see below)—was carried out 16-18 November 1965 between the rock lab at Mike's Pike and the Command Data, Reception and Analysis (CDRA) facility at the Arizona Bank Building. The main objective of this test was to ascertain the degree of success one could have using radio and TV links to communicate sieve analyses, thin section/microscope analyses, and sample descriptions to a science backroom (the CDRA) facility.

For this test, [photographer] T.J.W. Lee III [hired by the Branch of Astrogeology on 14 August 1964; see 1964] and geologists George E. Ulrich and Gerald Schaber of the Apollo Applications Program of the Branch of Astrogeology prepared a preliminary staff-video and petrographic microscope set-up which provides excellent resolution and image detail on a TV monitor. This technique was thought to be feasible for use on subsequent Apollo Applications Program test operations.

The following quotations were taken from the Branch of Astrogeology Monthly Report for December 1965 to D. R. Nichols, NASA HQ; dated 31 December 1965, and Red Bailey's personal log of Branch activities for 1965:
In December 1965, the Field Imaging System Project of the Branch of Astrogeology was terminated and incorporated into the Apollo Applications Program Geological Instruments Program.

In December 1965 a new project, Orbiter Site Evaluation, was created under Unmanned Lunar Orbiter Investigations. A program of detailed investigation for each of the ten target areas for Lunar Orbiter, Mission A, was initiated. Investigations will include study of the stratigraphy, structure, and terrain characteristics.

Experimental Photometric Investigation became a new project for the Branch of Astrogeology during December under H.E. Holt. The purpose of this project was to evaluate the relative accuracy of the photogrammetric and photoclinometric mapping techniques as applied to the lunar surface.

During December 1965, Early Apollo Geological Methods and Early Apollo Geological Instruments, J.W. M'Gonigle, Project Chief, and Early Apollo Photogrammetry with R.M. Batson, Project Chief, are new projects under Early Apollo Investigations.

On 7-9 December 1965, Gerald G. Schaber directed Apollo Applications Field test-3 out of the Command Data Reception and Analysis (CDRA) facility on the fifth floor of the Arizona Bank Building in downtown Flagstaff. The test—part of the post-Apollo series—included the making and microscopic analysis of rock thin sections, and sieve analysis from a remote location at the Branch's Mike Pike Rock laboratory (at 16-18 Mike's Pike) on the West side of downtown Flagstaff (Figs. 30, 36). Test subjects (analytical) included Gerald Schaber, George Ulrich and Dave Dahlem. CDRA personnel included Dave Schleicher, Red Bailey, Gerald Schaber and Dave Dahlem. Support personnel included Bert Emmons (in rock lab). A 16-mm movie was made for NASA by the Branch of Astrogeology's Film Documentation Unit to document this test.

The pictures obtained during AAP test 3 through the TV camera inserted into the petrographic microscope were sent by microwave from the Rock Lab [at 16-18 Mike's Pike, downtown Flagstaff] to the CDRA facility in the Arizona Bank Building via the relay station on Mt. Elden in East Flagstaff.

AAP test 3 was documented on 16-mm color film and on Kinescope film. A 10-minute film report showing the operation of a rock thin-sectioning machine (see Fig. 34) and transmission of the microscope image by video was prepared over the next few weeks**.**

Referring to the test mentioned above, Don Beattie made the following comments:

"In an undated Astrogeology Technical Letter [*Astrogeology Technical Letter-11*], Jerry Schaber reported on the results of one of the field tests, probably in 1966 [author-actually it was AAP test-3, carried out on 7-9 December 1965]. The test confirmed that thin sections of the samples for microscopic study could be prepared in this small laboratory, giving the astronauts, who were receiving some rudimentary training in petrology, a first-order idea of what they had collected. (A thin section is made by sawing rock so thinly that light can be transmitted through the slice, telling a trained geologist its mineralogical composition and something of its history). On that particular test, Schaber reported on, they had included a microscope-television system that permitted simultaneous viewing of the thin sections by both the "astronaut" test subject and geologists back in the CDRA (Command Data Reception and Analysis) facility in the Arizona Bank building [also about that time referred to for the first time as the Apollo Data Facility, or ADF]. As Schaber reported, "It became apparent during the test that such remote petrographic techniques could provide a great quantity of information—far more than could possibly be returned to Earth in the present LEM vehicle concept… The test indicated that the thin section image alone could be interpreted with surprising accuracy by the CDRA/ADF personnel.

Instrumentation that we studied as part of a small portable laboratory included rock-cutting and thin-sectioning equipment, a petrographic microscope, several spectrometers, a gas chromatograph, and an X-ray diffractometer [originally designed by Phillips Electronics for use on the Surveyor missions]. This concept was presented a year later [actually the summer of 1967] at the Santa Cruz summer conference with the recommendation that the images seen in the microscope be beamed back to Earth so that they could be analyzed by experts, thus reducing the time the astronauts spent studying the thin sections" (Beattie, 2001, pp. 70-71).

The following was taken from the Branch of Astrogeology Monthly Report for December to D.R. Nichols Assistant Chief Geologist for the USGS, and to NASA, from Chief, Branch of Astrogeology; dated 31 December 1965:
On 27-29 December 1965, a second make-up trip was conducted to the Pinacates Volcanic Field (Mexico) and to Zuni Salt Lake, New Mexico for astronauts Charles Bassett, Eugene Cernan and Roger Chaffee.

Geologist Mortimer ("Tim") Hait (1931-2003) (Penn State University), an especially kind and pleasant person, arrived in Flagstaff to work with the Branch of Astrogeology a few days before Christmas in 1965 to work with the early Apollo Group designing Apollo hand tools (see Appendices A and B). Tim would become a space suit test subject for several of the Branch's Apollo field tests in Hopi Buttes and (starting in 1969) at the Branch's Cinder Lake Crater Field near Sunset Crater National Monument. Tim would be a team member of Apollo Lunar Geology Experiment Team (Mission 11-15) and serve in that capacity at Mission Control in Houston, Texas. Tim's specialty in the Science Support Room (SSR) (earlier called Science Operations Room, SOR) was to "sketch" or visually document geologic information being communicated (orally and via TV pictures) from the astronauts on the lunar surface. Tim passed away during the writing of this work; he will be missed by everyone who knew him.

The following is taken from Branch of Astrogeology Monthly Report for December 1965 to D.R. Nichols of the USGS, and to NASA, from Chief, Branch of Astrogeology; dated 31 December 1965:
"In December 1965 [geologists] J.F. McCauley and Mareta N. West with the Branch of Astrogeology in Flagstaff completed a plot showing the numerical range in relative albedo for each of the major stratigraphic units shown on the 1:5,000,000-scale geologic compilation of the lunar equatorial belt. It was expected that this information would be circulated in the coming months and prove to be useful in improving the accuracy of the description for geologic units on the 1:1,000,000-scale map explanations"

Don Beattie:
In 1965 Mueller also established the Apollo Site Selection Board (ASSB). In the beginning, the board was chaired by Sam Phillips and included members from [NASA] Headquarters and center offices. Its initial function was to set priorities for Lunar Orbiter photographic coverage to ensure that the pictures needed for selecting Apollo landing sites were adequately identified and scheduled. After Lunar Orbiter successfully completed its objectives, the ASSB turned its attention to the more difficult task of choosing the first and subsequent Apollo landing sites" (Beattie, 2001, p. 88).

[Astrogeology Milestone: In 1965, the *In Situ* Geophysical Group of the Branch of Astrogeologic Studies submitted an Annual Report for FY 1965 to NASA titled "Investigation of *In Situ* Physical Properties of Surface and Sub-Surface Site Materials by the Engineering Geophysical Techniques Project." Joel S. Watkins, Jean Cl. De Bremaecker, Robert A. Loney, James H. Whitcomb, and Richard H. Godson authored the report. Included in this report was a proposal to NASA (Part A-II) titled "Examination of the Lunar Near-surface Rocks by Engineering Seismic Techniques during Early Apollo Landings." The proposal was by Joel S. Watkins (Branch of Astrogeology-Flagstaff), Jean Cl. De Bremaecker (Geological Survey and Rice University, Houston, Texas), and Martin F. Kane (Branch of Astrogeology-Flagstaff).]

The distribution of Branch of Astrogeology Offices around the country, and the staff at each location, in 1965 is shown in Figure 37.

3.3-1966

[Author's Note: See Table 3 for the Organizational and Project Directory for the Branch of Astrogeology for Fiscal Year 1966 (as of 17 January 1966)]

The following was taken from the Branch of Astrogeology Monthly Report for January 1966 to D.R. Nichols, the Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 January 1966:
In January 1966, the 16-mm color-sound astronaut training film "Hawai'i Volcanoes Astronaut Field Trip," prepared by the Branch of Astrogeology's Documentation Group, was transmitted to the Astronaut Office (MSC/NASA), Houston, Texas. The film is 37 minutes long.

During January 1966, H.A. Pohn, R.L. Wildey and P.E. Christy made photoelectric observations of the full Moon from phase angles of 3.5 Degrees to 4.1 Degrees.

A 4X4-foot model of the lunar surface was prepared by personnel from Ray Batson's Cartography Section during January 1966 for testing photogrammetric mapping techniques in the immediate vicinity of the Surveyor spacecraft. The model was constructed out of medium-to-fine-grained sand, which was sprayed with water glass to help preserve the surface features. Craters were constructed in the model according to an extrapolation of the size-frequency curve determined from the Ranger photographs. The smallest craters are 5 mm in diameter and increase by powers of 2 up to 32-cm. There are approximately 16,000 of the smallest craters and 3 of the 32-cm craters. A time relationship was built into the model. Older craters have subdued rims and the youngest have sharp, fresh rims. A gradation from the oldest to the youngest exists.

A map showing bedrock geology of the Hopi Buttes test site by R.L. Sutton, David Cummings, D.L. Schleicher, and J.W. M'Gonigle, and a map showing surficial deposits by Thor N.V Karlstrom were completed in January 1966. The maps (scale=1:8,535) of the 10-square mile area will be used as a reference standard to aid in evaluation of the later mapping by test subjects during simulated lunar traverses in Apollo Extended Systems Test I and Apollo Test 5. The area is located about 30 miles northeast of Winslow, Arizona.

The range-finding periscope originally designed for and installed on the mock-up of the lunar shelter (LEM) was modified, and now can be used in either the LEM and/or the mobile Geologic Laboratory (MGL or MOLAB) vehicle [at Flagstaff].

Final editing on the 2-minute color-sound 16-mm film, "Apollo Extension System Test-1", and a 10-minute color-sound 16-mm film, "Apollo Applications Program Test 3", were completed in January 1966. Editing on the 25-minute long color-sound 16-mm movie "Apollo Operations Test 5," a space-suited test at Hopi Buttes, was also in progress during January 1966."

[Space Exploration Milestone: "On 3 February 1966, the Soviet Luna 9 lander dropped from a carrier rocket just above the surface, and landed safely on Oceanus Procellarum 97 Degrees N., 64 Degrees W.) at 2145 Moscow time (1845 GMT). Panoramic pictures from Luna-9 were built up as a mechanical scanning device nodded up and down rotating slightly between each scan. On Feb. 4-6 the images were transmitted in digital form in four bursts of about 100 minutes each. Before the Soviets could report the results, Westerners jumped the gun, providing some amusing vignettes in the history of lunar exploration. Sir Bernard Lovell, director of the Jodrell Bank radiotelescopes in Cheshire, England, smugly stole the march by intercepting the signals from Luna 9. The Soviets had provided their transmission frequency in advance, yet were accused of withholding their data as usual. Gene Shoemaker told the press that the United States had also snatched the pictures but could not release their version because the interception technique was secret" (Wilhelms, 1993, pp. 125-126).

The following was taken from the Branch of Astrogeology Monthly Report for February 1966 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 28 February 1966:
During February 1966, the Luna 9 photographs released by the Soviet News Agency, TASS, were compiled into a mosaic in Flagstaff by the Branch of Astrogeology's Surveyor mosaic team. The photographs from Jodrell Bank (England) were rectified to bring into coincidence the aspect ratios of both the Soviet and British releases. Detailed examination of the mosaics and individual photographs by E.M. Shoemaker, R.M. Batson, and H.E. Holt permitted generalized conclusions to be drawn about the pictured lunar surface, assuming the camera height above the surface to be about two feet.

The surface viewed by Luna 9 contained numerous craters of varying size, from tens of feet in diameter to only a few inches across, and the larger craters contain fairly large blocks. The rubbly-appearing surface was found to be composed of coarse fragments with sufficient strength to support the rocks sitting on the surface. The fact that the blocks have been thrown out upon the surface suggested [to the Astrogeology personnel studying the pictures] that the local surface material is fairly strong.

[Author's Note: The Soviet's landing of Luna 9 came as a mighty blow to the prestige of the United States in its own race to the Moon. NASA's first successful lunar landing would come with Surveyor 1 only four months after Luna 9 on 2 June 1966.]

Kay Edwards recalls one incident with Gene Shoemaker during their somewhat secret work on the Soviet's Luna-9 images, showing how oblivious Gene sometimes seemed to be of people's emotional or physical condition, especially when he was exceptionally preoccupied with his work.

"I was working on the Luna 9 project. I was doing the drafting of the illustrations for a paper and I couldn't get the perspective right on part of the spacecraft. You know we were working all kinds of crazy hours, and getting exhausted and everything. And I did it over and over—and you know—Gene is a perfectionist—and so he kept asking me to change it over and over. And finally, I am so exhausted, I'm crying—okay? But I'm still working! And Gene comes in and wants me to change it again. He wants simple—simple—So I'm fixing it again. As Gene is getting ready to leave he says, "I hope your COLD gets better" (from an interview with Kay Edwards by Gerald G. Schaber on 8 May 2001).

The following was taken from the Branch of Astrogeology Monthly Report for February 1966 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 28 February 1966:
Suited tests of the Early Apollo Active Seismic Experiment thumper device were successfully completed at the Manned Spacecraft Center, Houston, Texas during February 1966. Tests included firing of the device, laying out the cable, emplacing the geophones, and operational procedures.

Object distances for three-zone focus steps were derived [a field test at Meteor Crater] in February 1966 for a field-test model of the proposed Apollo stereometric camera designed by C. J. Hawkins. The steps are such that objects from 1 meter to infinity can be put into focus within a theoretical 30-micron blur circle at f5.6 by selecting the appropriate step. Final fabrication of the camera will be by W.E. Fahey in the machine shop of the Branch of Astrogeology in Flagstaff. E. E. Butler of that shop completed (in February 1966) fabrication of mock-up hand tools; and modified the tool-and-sample carrier, all of which are proposed for use in lunar exploration.

A field test using a total field magnetometer mounted on booms extending from the Mobile Geological Laboratory (MOLAB) and the Trespasser vehicles was conducted by the Branch of Astrogeology Geophysics personnel (Bob Regan and others) during February 1966 in a volcanic field near Amboy, California. Heading errors were measured on both vehicles and several test traverses were conducted, matching ground traverses against vehicle traverses; the agreement between the two methods was found to be excellent.

A truck-mounted van was completed [in Flagstaff] during 1966 by [the Branch of Astrogeology's] W.E. Rust (carpenter/field cook), and equipped for field documentation of Apollo tests. Primarily, it provides for field installation and operation of a TV Kinescope recorder complete with self-contained power source. The unit also provides for recording of audio from field tests and power for operating electrically powered cameras with synchronized sound tracks. The van will also serve as a field base for photo-documentation project needs, such as storage of sensitized [film] materials, facilities for special field processing, and emergency repair and maintenance of photographic and audio equipment. T.J.W. Lee III (Photographer) supervised the building of the van and installation of the equipment.

An early-Apollo TV camera image resolution test was carried out by John M'Gonigle and Tim Hait of the Early Apollo Investigations Group (Branch of Astrogeology, Flagstaff, Arizona) at Meteor Crater, Arizona on 23 February 1966 (Fig. 38).

Geologist Terry W. Offield (1933-1999) (PhD, 1962, Yale University) joined the U.S. Geological Survey in 1961 where he worked on mineral resources of the outer Himalayas and on mineral surveys in Brazil for the Surveys Branch of Foreign Geology. Offield transferred to the Branch of Astrogeology, arriving in Flagstaff in February 1966 and began serving as a photo-mission advisor for Lunar Orbiter missions and participated in lunar geologic mapping, astronaut training trips, development of the Branch's Lunar Science Operations room concept during field exercises in and around Flagstaff.

Cartographer Roger Carroll (1942-2002), a talented, friendly, and dedicated member of the Branch of Astrogeology's Cartographic Support Unit throughout the Apollo era and well beyond, arrived in Flagstaff on 14 March 1966. Roger was first located at the old city Annex Building [or Dance Hall, see above] which the Branch had leased for a short time on Santa Fe Avenue (now re-designated Route 66) in West Flagstaff. He started out working there along with James VanDivier, Ray Sabala, and James Hart. Roger, who retired in 1997, unfortunately passed away while working on his commercial Salmon fishing boat in Alaska in June 2002.

Psychologist Kenna V. Edmonds (now Krista Edmonds) arrived in Flagstaff to work with the Branch of Astrogeology in March 1966 to replace Paula Ables who had resigned. Kenna left Flagstaff in September of 1968 (see Appendices A and B). Kenna worked on time-and-motion studies timing the activities of the Branch's simulated astronauts while they did various geologic activities out in the field (mostly Hopi Buttes and Meteor Crater) in preparation for planning for the eventual manned lunar missions.

The following was taken from the Branch of Astrogeology Monthly Report for March 1966 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 March 1966; and Red Bailey's personal log of Branch activities in 1966:
An AEI EM6-G electron microscope and a MAC model 400 electron microprobe were installed in March 1966 in Menlo park for support of the Cosmic Dust Project there (Mike Carr and associates). Both instruments are operational and are being used for routine examination of dust collected in the atmosphere and for examination of the samples collected above the atmosphere in Project Luster (led by Mike Carr).

On 1-4 March 1966, the Manned Lunar Exploration Group at the Branch of Astrogeology carried out Apollo Applications Systems (AAP) Field Test 4 on the south side of Meteor Crater, testing out the mobile science backroom (trailer), the eight-wheeled "Trespasser," vehicle, LEM EVA, and the LEM TV camera. The field test was snowed out on 2 and 3 March. The CDRA person was Red Bailey; the lead field support person was Jim Crossan (Branch surveyor). Two traverses were successfully accomplished.

On 14-18 March 1966, the Manned Lunar Exploration Group at the Branch of Astrogeology carried out Apollo Applications Systems (AAP) Test 5 at French Butte in the Hopi Buttes, Arizona, using the Trespasser vehicle and Rock-Lab trailer for remote rock analysis (Fig. 39).

Personnel manning the science recording trailer (in the field) were Red Bailey, Don Lamb, Dave Dahlem, Terry Offield, Dave Schleicher, Gordon Swann, Tim Hait, and Carol Lowrey. Support personnel for the test included Bill Mason, Eric Bramsoe, Oliver Grieve, Putty Mills, Walt Roeder, Bill Rust, Jim McCord, Tom Lee, Bob Regan, and Joe O'Connor. There were five traverses, four geologic and one geophysical. A total of 93 samples were collected. Geophysical instruments tested included the magnetometer.

This test included the petrographic microscope for remote study of thin sections prepared at the site (see Fig. 36, 39f), and remote compilation of information resulting from several magnetometer traverses across a discontinuous basalt dike. This test is documented in *Astrogeology Technical Letter 27*, "Apollo Applications Test 5" by G. Swann, Red Bailey and Robert Regan.

The following was taken from the Branch of Astrogeology Monthly Report for April 1966 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 30 April 1966:
Construction of the proposed stereometric camera for the Apollo missions was completed
in April 1966. The camera was sent to Phoenix, Arizona, to be anodized and returned to Flagstaff for assembly (Fig. 40).

Mock-ups of the Apollo tool carrier and camera staff were used during April 1966 by a space-suited scientist on the 1/6 Earth gravity simulator at Northrop Space Laboratory, Hawthorne, California, as a preliminary step in developing a transfer function to allow for correlation between experiments on the 1/6 gravity simulator and earth gravity field tests

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Geologist Keith Howard (b. 1939), who was offered a job with the Branch of Astrogeology in late 1965, arrived for work in Menlo Park in April 1966 (see Appendices A and B).

Keith Howard:
"Upon my arrival at Menlo Park, I started working on the geologic map of the Ptolemaeus Quadrangle of the Moon that Hal Masursky had begun, and then dropped for bigger and better things—and he was involved in administrative things. I was doing observations at Lick Observatory. I was a little frustrated frankly. The Branch Chief at that time was Gene Shoemaker.

A few months after I got to Menlo Park I applied for NASA's astronaut program. I thought this was fun! I later discovered that it was a lot of fun. I got into the finalist program there, but didn't get selected. I was in the next go-around following Jack Schmitt. There was one geologist chosen with my group, [geophysicist] Anthony "Tony" England" (taken from an interview with Keith Howard by Gerald G. Schaber on 1 February 2002:

The following was taken from the Branch of Astrogeology Monthly Report for April 1966 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 30 April, 1966:

A topographic map was made during April 1966 by R.M. Batson, K.B. Larson, and C.A. Melissare from the Soviet Luna 9 panorama. The scale is 1:1 and the contour interval is 1 cm. The map covered an area roughly 100cm by 5 cm, beginning at about 100 cm from the capsule.

The Mobile Geological Laboratory (MOLAB), built by General Motors (see Fig. 23), was utilized in April 1966 during a test of remote geological operations in the S. P. Flow area (North of Flagstaff). A stereo periscope was mounted on the MOLAB to allow a better field of view than is normally available. The periscope increased the field of view but it was concluded that its optics must be improved before it will materially aid observation. A magnetic susceptibility bridge supplied by Texaco Research Company was mounted in the vehicle during this test. It proved to be capable of making repeatable measurements but the techniques would have to be improved before it would be a useful adjunct to lunar exploration.

A three-channel FM/FM telemetry system for the remote recording of gamma ray spectra was assembled during April 1966 by personnel from the Branch of Astrogeology in Flagstaff. A microwave link was established between the Rock Lab laboratory (at 16-18 Mike's Pike) and the Command Data and Reception and analysis (CDRA) room on the 5th floor of the Arizona Bank Building in downtown Flagstaff. Gamma ray spectra from the miniaturized alpha-source X-ray spectrometer (through a multi-channel spectral analyzer) were transmitted by David Dahlem from the rock laboratory and recorded in the CDRA facility. The spectra were simultaneously recorded on magnetic tape and re-played and recorded again on a graphic x-y recorder. The system was being tested for use in upcoming field tests (9-20 May, 1966).

Apollo Operations Test 5, an eighteen-minute 16-mm color-sound film report, was completed and distributed to NASA during April 1966. A 27-minute geological lecture film titled "Kilauea Volcano: Geophysical Studies and Structural Relations" was also completed and distributed during April 1966.

The following was taken from the Branch of Astrogeology Monthly Report for May 1966 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 May 1966; and Red Bailey's personal log of Branch activities for 1966:
In May 1966, Ray Barnett of the Field Electronics Project of the Branch of Astrogeology, in cooperation with the Command, Data Reception, and Analysis (CDRA) project, established an 80-mile telemetry link between the field test area at Hopi Buttes, Arizona and headquarters in Flagstaff. This telemetry link completed the communications capability that provides radio, television, and telemetry signals during the tests.

The Manned Lunar Exploration Group of the Branch of Astrogeology held Apollo Applications Program (AAP) Test 6 [erroneously referred to as AAP Test 8 in Monthly report for May 1966] on the southeast side of Chezhin Chotah Butte in the Hopi Buttes, Arizona between 9 and 20 May 1966 (Fig. 41). Branch Astronaut test subjects were Dave Dahlem, George Ulrich, Dave Schleicher, Bob Sutton, Bob Regan, Gerald Schaber and Max Troyer. CDRA personnel at the Arizona Bank building included Dare Hough, Orin Mauran, Ray Barnett, Dale Bremmer, Dick Jahns, John Murphy, Elizabeth Dubrinsky, Red Bailey, Terry Offield, Dave Cummings, Don Lamb, Gordon Swann, Tim Hait, Carol Lowrey, and Thor Karlstrom. Support personnel included Putty Mills, Bud Dahl, Bill Slocum, Bill Mason, Walt Roeder, Eric Bramsoe, Jim Crossan, John Hendricks, Kenna Edmonds, Joe O'Connor, and Bill Rust

The primary objective for this test was to test several types of analytical and field instruments, including the TV-mounted petrographic microscope, miniaturized X-ray diffractometer (provided by the Jet Propulsion Laboratory) (see Figs. 31g, h), an alpha-source X-ray analyzer (furnished by Goddard Space Laboratories) (see Figs. 41d-f); sieve analysis, and the Petra-lab semi-automated thin section machine (64 rock thin sections were made during the test) (see Fig. 34). An additional objective was to study data handling requirements for information received during such tests so that scientific results could be fed back into succeeding days of testing. The test included the use of the CDRA (simulated Houston "science backroom") in Flagstaff, the Trespasser Vehicle, a rock lab trailer, LM television (with relay of picture to CDRA in Flagstaff), and seismics. Eight traverses were carried out with a total of 140 stations. A total of 239 samples were taken, as well as 61 photographs during six of the traverses. Hand tools tested included the tool carrier, hammer, 35-mm Pentax camera and penetrometer. Physical property measurements included the use of the penetrometer, and sieve analysis. A magnetic susceptibility device (furnished by Texaco Instruments), and tracking laser (furnished by Northup Space Laboratories) were also tested during this field test (see Fig. 41h).

Geologic mapping was conducted only to the extent that it would support analytical instrumentation and geophysical techniques. Samples collected on traverses were analyzed and the results were sent to the control center in Flagstaff via communication link. The reduction of geophysical data during the test was useful to the conduct of the remainder of the test. Telemetry (FM/FM) of gamma ray spectra and X-ray diffraction patterns was successfully transmitted, received, graphically reproduced, and tape-recorded during a laboratory test of the analytical instruments.

The four-day Early Apollo Field Test 8 was held 23-27 May 1966 at Hopi Buttes, Arizona following the Apollo Applications Field Test 6 (9-20 May 1966 described just above) (Fig. 42). The performance of the space-suited test subjects (Gordon Swann and Joe O'Connor) during the geologic traverses and the performance of various hand tools, tool carrier, and a version of the Early Apollo stereometric camera, when these were used by the suited subjects, were of particular interest. The space suit support was provided by John Slight and personnel, Manned Spacecraft Center, Houston, Texas. Northrup Space Laboratories, Hawthorne, California, provided several of the hand tools tested. Personnel of the Branch of Astrogeology in Flagstaff fabricated other tools used in the test.

Don Wilhelms:
"Seven Surveyors were launched between 30 May 1966 and 7 January 1968. Two failed, but five successfully returned the impressive total of almost 88,000 high-resolution surface pictures, three chemical analyses, and valuable tests of the mechanical properties of the lunar surface.

To the surprise of JPL engineers steeled by Ranger [by its many earlier failures], the first Surveyor launch led to the first success. Surveyor 1 left Cape Kennedy at 1441 GMT on 30 May 1966 and almost two days and 16 hours later (2 June 1966; late on 1 June at JPL) sensed the lunar surface with its radar and touched down gently at 3-4 m per second, then bounced a few inches.

The outstanding success of the soft landing on the Moon's surface by Surveyor I involved many of the Surveyor Television Investigations staff in Flagstaff. A mosaicking team from the Branch of Astrogeology headed by R.M. Batson and composed of A. E. Dale, K.B Larsen, C.A. Melissare, and C.A. Wheeler, assisted by R.L. Boudreau and Russell Wahmann during the last few days, assembled in analytical mosaics all of the 10,338 wide-angle and narrow-angle photographs as fast as they were received from the spacecraft. Improved mosaics were made from over 150 pictures, and 3 spherical mosaics were displayed during a press conference held in Washington, D.C. on 16 June 1966.

Jack McCauley, Larry Rowan [from the USGS Branch of Astrogeology, Flagstaff], and other terrain analysts and Surveyor people gathered in a house in Flagstaff felt not so much elation as relief that nothing they had done had scuttled the mission. The [Surveyor-1] landing point was in Oceanus Procellarum at 2.5 Degrees S.; 43.2 Degrees W. within the almost buried 112-km crater Flamsteed P, usually referred to as the Flamsteed Ring.

The unbelievably successful achievement (which coincided with Gemini 9 and 10) generated more public interest than any other lunar mission between Ranger VII and Apollo 8, and the press rose to the occasion. There was the usual chauvinistic media crowing about how many more pictures were transmitted from the Free World's Surveyor (more than 11,000 ultimately) than from the Communists' Luna-9 four months earlier. Ours had succeeded on the first try whereas They had required at least a half a dozen. Ours was powered by solar panels rather than Their batteries, and landed softly on its own rather than being dropped from a carrier rocket and allowed to roll as was Theirs" (Wilhelms, 1993, pp. 140-141).

The following was taken from the Branch of Astrogeology Monthly Report for June 1966 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 30 June 1966; and Red Bailey's personal log of Branch activities for 1966:
On 2-3 June 1966 geologic field training began for the fourth and fifth group of twenty-four of NASA astronauts. Like their predecessors, they were first taken down into the Grand Canyon, Arizona (See Table I). Grand Canyon expert Edwin McKee led this trip. Other geologists present included Ted Foss, Uel Clanton and McKay from NASA/MSC, and Al Chidester from the USGS, Branch of Astrogeology. Astronauts participating in this trip included Vance Brand, John Bull, Jerry Carr, Charles Duke, Joe Engle, Fred Haise, James Irwin, Don Lind, Jack Lousma, Ken Mattingly, Ed Mitchell, Bill Pogue, Stewart Roosa, Jack Swigert, Paul Weitz, and Al Worden.]

On 23-24 June 1966 there was an astronaut geologic training exercise to West Texas led by local expert William Muehlberger (U. of Texas, Austin) (See Table I). Other geologists present included Ted Foss, Uel Clanton, and Ted McKay from NASA/MSC, and Al Chidester, Gordon Swann from the USGS, Branch of Astrogeology. Astronauts participating in this trip include Vance Brand, John Bull, Charles Duke, Joe Engle, Ron Evans, Ed Givens, Fred Haise, James Irwin, Joe Kerwin, Don Lind, Jack Lousma, Ken Mattingly, Bruce McCandless, Curtis Michel, Ed Mitchell, Bill Pogue, Stewart Roosa, Harrison Schmitt, Jack Swigert, Paul Weitz, and Al Worden."

The following was taken from the Branch of Astrogeology Monthly Report for July 1966 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 July 1966; and Red Bailey's personal log of Branch activities for 1966: On 27-29 July 1966 there was geologic training trip for the 4th and 5th group of astronauts to Bend, Oregon (see Table I). Geologist Aaron Waters (U. of California) was the local expert for the training trip. Other geologists present included Ted Foss, Uel Clanton and Dave McKay from NASA/MSC, and Al Chidester, Maury Brock, and Dave Dahlem of the USGS, Branch of Astrogeology-Flagstaff. Astronauts participating in this trip included Vance Brand, John Bull, Jerry Carr, Charles Duke, Joe Engle, Ron Evans, Owen Garriott, Ed Givens, Fred Haise, Jim Irwin, Joe Kerwin, Don Lind, Jack Lousma, Ken Mattingly, Bruce McCandless, Ed Mitchell, Bill Pogue, Stuart Roosa, Jack Swigert, Paul Weitz, and Al Worden.

Relative normal albedo maps of nine Lunar Orbiter (Mission A) sites were prepared during July 1966 at the scales of 1:500,000, 1:1,125,000, 1:2,500,000 and 1:5,000,000. Absolute albedo calibration of the nine sites is in progress.

Chapter 4

Lunar Orbiter and the Search for Apollo Landing Sites

4.1-Brief Background on the Lunar Orbiter Project

Don Beattie:
"Although the Ranger and Surveyor missions had sent back many close-up views of the lunar surface, they were never intended to provide all the photographs we would need to select the Apollo landing sites. That was to be the job of Lunar Orbiter. Conceived in 1963, the objective was to obtain detailed photographs of the whole Apollo landing zone" (Beattie, 2001, p. 189.)

Don Wilhelms recalls:
"This coupling [between the Surveyor and orbital photography] had [actually] been recognized in JPL's original plans for the Surveyor program in May 1960. Five Surveyor orbiters were to attain resolutions on the order of meters on the central near side to support the Surveyor Landers and on the order of a kilometer on the entire far side and limbs to provide the kind of general reconnaissance that geologists knew was needed.

In June 1962 OMSF [Office of Manned Space Flight] specified to Homer Newell's OSS the orbital data then thought necessary. It wanted better resolution than the [proposed but later abandoned] Survey orbiter was capable of delivering and far more coverage than the drop in the bucket Ranger could squeeze out. In September 1962, Oran Nicks, director of lunar and planetary programs in OSS, requested a study of a whole new kind of lightweight orbiter to be launched with an Atlas-Agena combination that was less powerful than the Atlas-Centaur planned for Surveyor. Nicks asked U.S. Navy Captain Lee Richard Scherer, Jr. (b. 1919), an honors graduate of the Naval Academy then on temporary assignment to NASA, to direct the study" (Wilhelms 1993, p. 150).

Don Beattie:
"We needed high resolution in order to pick areas free of large boulders or small craters that would be a hazard to the astronauts guiding the lunar module to a safe landing. Obstructions of this size could not be seen on photographs taken from the earth, even by the largest telescopes. The Lunar Orbiter program was managed by the Office of Space Sciences (later the Office of Space Science and Applications), but the photographic design requirements were dictated by the Office of Manned Space Flight and in particular the engineers at the manned Spacecraft Center. Langley Research Center (LaRC) was selected to be the day-to-day manager, and the request for proposal was released by LaRC. The RFP called for building six to eight orbiters; it was possible that the final ones in the series would include other experiments in addition to cameras. OSSA released an announcement of flight opportunities to solicit experiments for these last missions and received over one hundred proposals or inquiries.

The competition to build the spacecraft and cameras was won by the Boeing Company as the prime contractor, supported by two major subcontractors, RCA and Eastman Kodak. Langley's program manager, Clifford Nelson, put together a superb team to oversee the program; many years later, when NASA management called for a review of lessons learned from all the completed programs, Lunar Orbiter was judged the best managed. If for some reason it had not been successful, the entire Apollo project would have been in jeopardy, at least, delayed beyond the date President Kennedy had called for" [for the first manned lunar landing] (Beattie, 2001, pp. 189-190).

[Space Exploration Milestone: Lunar Orbiter I was successfully injected into lunar orbit on 14 August 1966. Photography at site A-0 from a perilune of about 190 kilometers was received 18 August. Shutter settings for the other nine low orbit sites were determined using photoelectric albedo data recently derived by H.A. Pohn and. R.L. Wildey of the Branch of Astrogeology, Flagstaff, Arizona. L.C. Rowan, T.W. Offield, and H.E. Holt from the Branch of Astrogeology (Flagstaff) acted as mission advisors at the Space Flight Operations Facility, Jet Propulsion Laboratory (Pasadena, California). Lunar Orbiter I did not perform completely to specifications, but it returned a total of 422 medium and high-resolution photographs of potential lunar-equatorial landing sites, as well as some photographs of the Moon's far side.]

Don Wilhelms described the problems NASA had with Lunar Orbiter I:

"An overheating problem showed up on Lunar Orbiter I but was overcome. New and worse troubles, however, showed up when the first photos were read out on 18 August 1966. Two pre-launch problems reappeared when the H frames were hopelessly smeared because the V/H sensor and the shutter of the 610-mm lens were out of synch. The original mission plan called for the spacecraft to descend from its initial high orbit with a 189-km perilune to one with a 58-km perilune to photograph fine-scale hazards at the Apollo sites. This plan was obviously futile now. That being the case, any reasonable scientist would recommend keeping the spacecraft in the high orbit and photographing large swatches of the Moon at 20- or 50—m resolution. USGS mission advisors Jack McCauley and Larry Rowan [both USGS] so suggested. They showed that this first Lunar Orbiter could achieve the entire task of eliminating unfavorable terrain in the Apollo zone if it stayed [in orbit] where it was. In the early evening of 20 August 1966, McCauley, Rowan, and representatives from Bellcom, Inc. presented the plan to Langley project people, who saw its wisdom and Lee Scherer shook hands on the deal.

At about 9:00 or 9:30 P.M., Jack and Larry went out to eat and otherwise celebrate what they considered a major contribution to spaceflight sanity. They returned to the SFOF [at JPL] about 10:30 or 11:00 A.M. the next morning, expecting to have little to do because the high-altitude mission would require little intervention from the ground. They found the spacecraft in the orbit with a 58-km perilune. Only 38 frames had been exposed in the higher orbit. Cliff Nelson had vetoed the change with the concurrence of Helberg and other Boeing managers. They hoped that the higher orbit of scenes passing under the V/H sensor at the lower altitude would jar it into activity so that Lunar Orbiter I could fulfill its original mission. The ploy did not work, however, and all but about a dozen of the 205 H frames were useless.

After this unfortunate event with Lunar Orbiter I, Jack McCauley never again showed much interest in spaceflight mission support until he switched planets and became geology team leader for the Mariner 9 Mars orbiter in 1971 (for McCauley's personal version of these events, see his memoir narrative included as part of his biography in the 1963 discussion in this work).

The mission was not a complete loss. The early M frames and even some of the later ones of the near side proved useful. More importantly, several excellent M frames of the east limb and far side, some with nested H frames, were welcomed by the geologists and still provide the only coverage of these areas. Lunar Orbiter I also acquired the first images of the whole earth, with novel and ghostly oblique views of the moon in the foreground.

The news media showed some interest, quoting Larry Rowan liberally and reporting that "30 analysts from half a dozen federal agencies were examining 200 miles of film (maybe they meant meters) and finding some rocks. They were referring to the massive screening effort that was under way between 25 August and 4 November 1966 at Langley. Geologists, terrain analysts, and technicians from MSC (the largest staff), the USGS, LOPO, and the two military cartographers agencies (ACIC and AMS-Army map Service) were confronting the wholly new type of data.

Representatives from Bellcom and the Surveyor project made sure that the interests of OMSF and Surveyor were considered. The analysts were drawing ellipses in smooth-looking places for more detailed study back home and found 23 of them. The USGS drew terrain maps resembling those that they had drawn from telescopic data in Flagstaff, and the other agencies outlined terrain units according to their own concepts" (Wilhelms, 1993, pp.155-156).

The following was taken from the Branch of Astrogeology Monthly Report for August 1966 to the Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 25 August 1966:
H.A. Pohn and R.L. Wildey in August 1966 completed preliminary data reduction on the first photoelectrically-calibrated full-Moon photograph (1.52-degree Phase angle). The photoelectric measurements were made at the Geological Survey's 30-inch reflector telescope on Anderson

Mesa (just south of Flagstaff) at the same time as the full-Moon plate was being taken at the Naval Observatory in Flagstaff by Harold Ables on the 61-inch reflector.

On 2-3 August 1966, the Bell Aerospace Corp. "Rocket Belt", a prototype Lunar Flying Vehicle (LRF) was demonstrated for NASA and the USGS, Branch of Astrogeology out in Hopi Buttes, Arizona east of Flagstaff. The rocket belt could stay aloft for about 21 seconds. Given instructions from Supervisor Maury Brock, Astrogeology's Film Documentation Unit made a 16-mm film of this test. However, NASA quickly nixed distributing the film saying that it could be seen as NASA favoring one particular company (Bell Aerospace in this case) in any future competition for the LFV design and contract **(**Fig. 43).]

[Author's Note: Gordon Swann told this author (personal communication, July 2002) that he really had a "go-around" with Branch of Astrogeology geologists Maury Brock and Al Chidester about producing a film about the rocket belt test, because it was obvious how NASA would take it [given that such a movie would seem like NASA was favoring Bell Aerospace over any other potential contractors). Swan said "I argued high and low about that but Al Chidester and Maury both overrode me on that one. We spend probably $30,000 on that film, and it got thrown in the trash can. When NASA got word of it they instructed us to destroy all existing copies—and not even to keep one." The Branch of Astrogeology "somehow" ended up keeping a single copy of this rather fascinating and historically significant film demonstrating the Bell Aerospace Lunar Vehicle, or rocket belt- in Hopi Buttes. It turns out that this "Rocket Man" film is one of the most requested from our Lunar and Planetary Data Facility at the Flagstaff Field Center by the news media and other sources.]

The following was taken from in the Branch of Astrogeology Monthly Report for August 1966 to the Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 25 August 1966:
On 21-25 August 1966 astronaut groups 4 and 5 were taken to Katmai, Alaska for geologic field training (see Table I). Geologists present included Ted Foss, Dave McKay and Uel Clanton from NASA/MSC, and Al Chidester, Marty Kane, Gene Shoemaker, Robert L. Smith, Roy Bailey from the USGS; Aaron Waters (U. of California), and Vic Rhoder, Ray Zedekar and Ream from NASA/MSC. The field trip was under the guidance of Robert L. Smith, and Roy Bailey, both of the U.S. Geological Survey. Astronauts participating in this exercise were Vance Brand, John Bull, Jerry Carr, Charles Duke, Joe Engle, Ron Evans, Owen Garriott, Ed Gibson, Ed Givens, Fred Haise, Jim Irwin, Joe Kerwin, Don Lind, Jack Lousma, Ken Mattingly, Bruce McCandless, Curtis Michel, Ed Mitchell, Bill Pogue, Stewart Roosa, Jack Schmitt, Jack Sweigert, Paul Weitz and Al Worden.

The following was taken from the Branch of Astrogeology Monthly Report for September 1966 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 30 September 1966; and Red Bailey's personnel log of events for 1966:
Mock-ups of Early Apollo Lunar Hand Tools were tested during September 1966 at 1/6 g by space-suited subjects in a KC-135 aircraft. The activities included hammering, coring, scooping, walking with tool carrier loaded with 40 pounds of samples, transferring samples from carrier to the sample return container, and assembly and disassembly of various instruments. Each activity uncovered problem areas of the tools; design changes would then later be made at the Manned

Spacecraft Center (Houston, Texas) as a joint effort of the Experiments Program Office (MSC) and the Branch of Astrogeology, Flagstaff, Arizona.

On 25 September 1966 the fourth and fifth Groups of astronauts were taken to the Valles Caldera, New Mexico (see Table I). Geologists present were Ted Foss, Uel Clanton and Dave McKay from NASA/MSC, and Al Chidester, Tim Hait and Gordon Swann from the USGS. Robert Smith from the USGS was the area expert. Astronauts attending this field exercise were Vance Brand, John Bull, Jerry Carr, Charles Duke, Joe Engle, Ron Evans, Owen Garriott, Ed Gibson, Ed Givens, Fred Haise, Jim Irwin, Joe Kerwin, Don Lind, Stuart Lousma, Ken Mattingly, Bruce McCandless, Curtis Michel, Ed Mitchell, Bill Pogue, Stuart Roosa, Jack Schmitt, Jack Sweigert, Paul Weitz, and Al Worden.

On 25-28 September 1966 the Surface Planetary Exploration (SPE) Branch carried out AAP Test 7 at the Trading Post diatreme in Hopi Buttes, Arizona. The astronaut test subjects for the test were Branch geologists Bob Sutton and George Ulrich. This time the simulated Houston science backroom facility was remotely located 70 miles away to the west of the test site in the CDRA facility on the fifth floor of the Arizona Bank Building in downtown Flagstaff. CDRA personnel for this test were Dave Schleicher, Bob Sutton, John M'Gonigle, Red Bailey, Terry Offield, Gerald Schaber, Joe O'Connor, Gordon Swann, Maryellen Bailey, and Mel Briggs (secretary). Support personnel included Putty Mills and John Hendricks. Four traverses were undertaken plus two for Early Apollo—for a total of thirty-five stations.

Apollo and post-Apollo Equipment tested during this field exercise included the "Trespasser" vehicle, a surface penetrometer, Torvane (to measure soil shear strength), bulk density, sieve analysis, magnetometer, seismics, LEM TV (transmitted to the CDRA in Flagstaff), and the Staff camera. Analytical instruments tests include the alpha-source X-ray analyzer, miniaturized X-ray diffractometer, and a TV camera mounted on a petrographic microscope (with pictures sent to the CDRA in Flagstaff).

[<u>Space Exploration Milestone:</u> Surveyor 2 was launched from the Cape on 20 September 1966. However, a problem during the mid-course course correction caused the spacecraft to tumble, and it failed to land (See 1967 for information on the remaining Surveyor and Lunar Orbiter flights).

[<u>Author's Note</u>: The Surveyor and Lunar Orbiter projects would overlap in time. The first Lunar Orbiter was launched in August 1966, and the final one in August 1967. The first Surveyor was launched in May 1966, and the final mission was in September 1967.]

Geologist Desiree E. Stewart-Alexander (Ph.D., 1967, Stanford University) arrived in October 1966 to work part time as a Physical Science Tech (PST) for the Branch of Astrogeology in Menlo Park (see Appendices A and B). She became full time with the Branch in 1967 following the completion of her Doctoral dissertation. Des worked on various lunar geologic maps, including the map of the Apollo 17 landing site (Taurus-Littrow). Des was a member of the Lunar Sample Preliminary Examination Team at the Lunar Receiving Laboratory (LRL) at MSC, Houston, Texas for Apollo missions 16 and 17. She was also a member of the Apollo Lunar Geology "Tiger Team" at Houston during Apollo 16 and 17.

Cartographer/photogrammetrist Raymond Jordan (b. 1937; BS in physics with math minor, 1960, Sienna College) arrived in Flagstaff, Arizona to work for the Branch of Astrogeology in October 1966 from the U.S. Air Force Aeronautical Chart and Information Center (ACIC) in St. Louis, Missouri. He was hired by Ray Batson and would work with Batson's cartography group during the Surveyor program. Jordan provided significant help in Surveyor camera calibration, mission operations at the Space Flight Operations Center at JPL, and contributed to application of innovative mapping techniques to produce detailed topographic maps of the Surveyor landing sites using images from the two onboard cameras. When Jordan later worked with Sherman Wu's photogrammetry group at Flagstaff, he used the Branch's new AP/C stereo-plotter and helped compile a topographic map of the Apollo belt of the Moon using the Metric Camera photographs. He was also successful in using the high-resolution Apollo Panoramic Camera photographs obtained by Apollo missions 15-17 to compile detailed topographic maps of selected areas of the Moon. Ray played a major role in compiling the first global topographic map of Mars using stereo images from Viking Orbiters I and II. Now retired, Ray Jordan still resides in Flagstaff.

The following was taken from the Branch of Astrogeology Monthly Report for October, 1966 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 26 October 1966:
The photography obtained from the Lunar Orbiter Mission-A was utilized in preparing recommendations to the Lunar Orbiter Utilization Committee, NASA, for the selection of sites to be photographed during Mission B. The recommendations presented to the committee in October 1966 by L.C. Rowan and Harold Masursky (Branch of Astrogeology, Flagstaff) were accepted with minor revisions.

A field test was held at White Sands Missile Range, New Mexico, during the last week in October 1966. The purpose of the test was to apply general descriptive techniques and geologic methods developed for early Apollo lunar missions to impact and explosion craters.

In October 1966, a dead-reckoning land navigation system (Bendix-Aviation Electric) was installed and calibrated in the Branch of Astrogeology's Lunar Mission Development vehicle Trespasser (and later the "Explorer" vehicle; see May 1967). Homer Powers of the Astrionics Group, Marshall Space Flight Center, Huntsville, Alabama, performed the calibration work and instructed Branch personnel in the calibration and operational procedures. The system was found to be operating well within the contractor's specifications (indicating close closure errors less than 1%) and was deemed ready for participation in Branch Manned Lunar Exploration tests.

The following was taken from the Branch of Astrogeology Monthly Report for November 1966 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 30 November 1966:
During November 1966, seven astronauts were assigned by the Astronaut Office, Houston to participate in the evaluation of procedures in simulated lunar exploration exercises being conducted by the Surface Planetary Exploration Group, Astrogeology Branch in Flagstaff. They are William A. Anders, Alan L. Bean, Joe H. Engle, Don L. Lind, Jack R. Lousma, Harrison H

Schmitt, and Paul J. Weitz. They were to be directly involved in the field exercises as test subjects, and will also aid in retrieving and compiling geological and geophysical information as it is transmitted via radio, television, and telemetry to the Branch of Astrogeology's Data Facility from remote test sites. These activities were to be coordinated with the Astronaut Training Program in Geology. The tests, which involve Apollo as well as the post-Apollo Studies, are conducted several times each year for the purpose of developing methods, instruments, and equipment suitable for a program of geological exploration on the Moon's surface.

This participation began when Red Bailey and George Ulrich directed what was called Saturn Apollo Applications (SAA, or AAP) Test 8 at a large dike south of French Butte in the Hopi Buttes test site on 7-10 November 1966 (see Table I). NASA astronauts Harrison Schmitt, Joe Engle and Paul Weitz participated in the field test and as evaluators in the Flagstaff data center. The field test included the use of the Branch of Astrogeology's eight-wheeled LRV vehicle Trespasser. Audio from the field was relayed to the CDRA facility on the fifth floor of the Arizona Bank Building, some 70 miles away in downtown Flagstaff. The CDRA personnel for this test were Dave Schleicher, Red Bailey, Gerald Schaber, Nancy Cozad, Jim Crossen and Carol Lowrey. Support personnel were George Ulrich, Bob Skinner, Bill Tinnin, Bob Sutton, Kenna Edmonds, Eric Bramsoe, Oliver Grieve, Putty Mills, Bud Dahl and Walt Roeder. There were three geologic traverses and two navigational traverses during the test. Hand tools used were the tool carrier, hammer, and scoop. No analytical instruments were involved in the test.

The field test included the use of LEM TV and the Apollo lunar hammer and scoop prototypes. This was the first field test of an X-Y plotter navigation system (from a military tank provided by Marshall Space Flight Center Astrionics Laboratory) which was mounted on the Trespasser vehicle. A transparent topographic map mounted on the plotter showed the astronauts—as they were driving—where they were along the traverse. It had a built-in gyroscope. The navigation system turned out to be quite precise and the test team performed precision analysis using it in the field at Hopi Buttes. This test was documented as *Astrogeology Technical Letter*-26, "Apollo Applications Program Field Test 8" by N.G. Bailey and G.E. Ulrich, 47 p., including three folded maps and a test section on task analysis by Kenna (Krista) Edmonds.

Don Beattie:
"Our mobility studies at MSFC were providing us with concepts for several types of vehicles that could be carried on the AES (Apollo Extension Systems) missions. In Flagstaff, [the Branch of Astrogeology's] Rutledge "Putty" Mills [See 1965], with the help of others, translated these ideas into a working model by modifying a truck chassis to carry two test subjects. Once we had this vehicle, which we named Explorer, we planned all our simulations around its use [Explorer is described and illustrated below; see May 1967).

While Gene and his staff were on the front lines trying to shape lunar exploration, we were dealing with the USGS management back in Washington in the persons of the USGS Chief Geologists, first with William Pecora then with his successor Harold "Hal" James. Our relationships were always friendly, but although it was clear that they liked this infusion of new money, they never seemed quite comfortable with the assignment. Exploring the Moon didn't quite fit into the mission of an old-line government agency that had helped open the West a hundred years earlier. This attitude was evident even though at the turn of the century, Grove K. Gilbert had been a pioneer in lunar studies.

Shoemaker was considered a bit of a free spirit within the USGS [to put it mildly], and all the money he was receiving from NASA, not through his own congressional appropriation channels, was making him rather independent of his Washington superiors. With his successful creation of the Branch of Astrogeology, Gene decided to relinquish his day-to-day management role and once again reorganized by setting up two branches, Astrogeologic Studies under Hal Masursky and Surface Planetary Exploration (SPE) reporting to Alfred H. Chidester. By this time, starting with the first funding transfers in 1961, NASA had transferred almost $14 million to USGS for its various activities, and the action was just beginning to heat up for it to support the Apollo landings. Overall, NASA transferred over $30 million to the USGS" (Beattie, 2001, pp. 71-72).

Don Wilhelms:
[Space Exploration Milestone: "Lunar Orbiter II was successfully launched on 6 November 1966, and when photography began on 18 November, the telemetry showed that the v/h sensor (and everything else) was working. Lunar Orbiter II continued the mapping of potential landing sites within the Apollo landing zone. During Lunar Orbiter II, Doug Lloyd of Bellcom got the idea of taking a north-looking oblique shot of Copernicus. The result of his idea was the famous "Picture of the Century" that appeared on front pages around the world and excited even the general public" (Wilhelms, 1993, p. 157).

"The site-screeners [for Lunar Orbiter II] descended on Langley again. With 26 participants, the USGS contingent, led by Larry Rowan, now outnumbered those from MSC. The 26 included me [Don Wilhelms], making my first appearance at a screening effort. In the 1960s few people involved in the lunar program gave much thought to such things as holidays or overtime, and we worked pretty much straight through the period between 5 December 1966 and 3 February 1967. This time we had far better photos on which to draw terrain maps. I performed my usual duty of setting up a scheme of map units and mapping conventions for the geologic work. Dick Eggleton [USGS, Branch of Astrogeology-Menlo Park) devised a method of estimating the thickness of a regolith above the bedrock layer on the basis of crater profiles, based on observations by Henry Moore [USGS, Branch of Astrogeology-Menlo Park] and Jack McCauley of missile craters at White Sands (NM) and from experiments by Don Gault, Bill Quaide, and Verne Oberbeck using Gault's crater-making gas gun [Ames Research Center, Mountain View, California]" (Wilhelms, 1993, p. 158).]

On 29 November through 2 December 1966, the 4th and 5th Groups of astronauts were taken to the Pinacates Volcanic Field, Mexico (See Table I). The local expert was Dick Jahns (Stanford University). Other geologists present included Ted Foss, Uel Clanton, Laidly, and McKay from NASA/MSC; Al Chidester, Gordon Swann, Marty Kane, George Ulrich, Hal Masursky, Bill Rust (camp cook/carpenter), Red Bailey, Putty Mills, and Olsen Begay of the USGS, Branch of Astrogeology; and Aaron Waters of the U. of California. Others present included Jack Riley, Ray Zedekar, Vic Rhoder, Charles Nelms, and Jack Eggleston of MSC and Don Beattie of NASA Headquarters (Washington, D.C.; See field trip of 8-10 November 1965 for additional details). Astronauts attending this trip include Vance Brand, John Bull, Jerry Carr, Charles Duke, Ron Evans, Ed Gibson, Fred Haise, Jim Irwin, Don Lind, Jack Lousma, Ken Mattingly, Curtis Michel, Ed Mitchell, Bill Pogue, Harrison Schmitt, Jack Sweigert, Paul Weitz and Al Worden."

[Author' Note: During his interview with this author on 2 January 2001, Gordon Swann tells one story about this 29 November-2 December 1966 Pinacates trip. It appears that Astrogeology's camp cook (also carpenter and branch clown) Bill Rust, along with Red Bailey and Olsen Begay, thought it would be very funny if after everyone (including all 29 or so astronauts) fell asleep on their cots out there on the cinders they would use two full five-gallon Jeep cans to make a ring of gasoline around the whole camp—then light it and yell "fire" and "Indians," while banging on pots and pans. Gordon said that the astronauts thought it was hilarious; although, he couldn't recall exactly how Beattie or Eggleston—the NASA HQ-types—reacted].

Geologist George William "Bill" Colton (b. 1925-2005; BS, 1950, Yale University) arrived at Flagstaff in November 1966; and in August 1969 began as acting Assistant Chief of the Branch of Astrogeologic Studies (see Appendices A and B). He headed up the Technical Reports Unit at the Flagstaff Field Center. Bill was appointed formally as Assistant Chief, Branch of Astrogeologic Studies in November 1969 under Branch Chief Hal Masursky see 1969). Bill worked with David Roddy on three of his explosion cratering test in Colorado, Utah and Nevada (Nevada Test Site), and participated in Roddy's drilling program at Meteor Crater, Arizona. Bill participated in geologic mapping of some of the Viking-Mars landing sites and various craters on the Moon.

[Author's Note: Bill left the Branch of Astrogeology In 1978 and returned to the Branch of Oil and Gas—but stayed in Flagstaff. He eventually ended up in the Branch of Central Environmental Geology while in Flagstaff. Bill retired from the USGS in June 1980 but couldn't live with retirement, so he went to the Arkansas Geological Division. He left Flagstaff in March 1981 and lived in Arkansas. Bill finally did retire for good near Christmas in 1997. He had served a remarkable 48 years in Government service all together and now resides in Cottonwood, Arizona]

Geologist Ivo Lucchitta (b. 1937; Ph.D., 1966, Penn State University), an articulate European- and American-educated intellectual with proven talents in field geology and geomorphologic evolution of landforms, in addition to impressive oral and written communication skills, arrived in Flagstaff with his equally-talented geologist wife Baerbel (or Barbara) (and their young daughter Mya) in October 1966 to work for the Branch of Astrogeology (See Table I). Baerbel K. Lucchitta would formally join the Branch of Astrogeology in 1967 (see 1967).

Ivo would be instrumental in the early research of the Branch's Manned Lunar Exploration Studies (MLES) group. During the Branch's early field testing of manned lunar geologic procedures in nearby Hopi Buttes, Arizona (and elsewhere), he would help develop entirely new procedures for how the astronauts could most efficiently and effectively communicate what they are observing on the Moon to geologists and other geoscientists gathered together in what was envisioned as a Science Backroom in Houston. Ivo left Astrogeology in the mid-1970s to work for the Survey's Branch of Central Region Geology, and then the Branch of Western Regional Geology—all while remaining in Flagstaff. Ivo and Baerbel Lucchitta both retired from the USGS in 1995 and still reside in Flagstaff.

The following was taken from the Branch of Astrogeology Monthly Report for November 1966 to the Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 29 November 1966:
Advanced Systems (AS) Test 1 was held 16-18 November 1966 at the Hopi Buttes test site using the Mobile Geological Laboratory (MGL or MOLAB). The Land Navigation System with gyrocompass and location plotter, which worked so well on the "Trespasser" vehicle in SAA Test 8 (7-10 November 1966; see above), was mounted in the MGL, but due to a power-train breakdown in the MGL during the test, reliability of this system was not determined. However, a periscope aircraft sextant mounted in the roof of the vehicle (MGL) proved valuable in determining location by resection from know topographic features. This permitted personnel at Astrogeology's Data Facility to know the location and vehicle heading as well as elevation at the geologic stations. Vertical angles and map distances were used to check elevations of geologic contacts and topographic features with fair results.

A set of screen sieves and an arm balance were used to determine bulk density and the percentage by weight particle size distribution of grains in the soils of geologic units sampled. Because of recent snow in the test area, however, the soil samples were too moist to obtain accurate results.

The Jet Propulsion Laboratory's nondispersive Alpha K Alpha Spectrometer and supporting electronics were mounted in the MGL for the test, and a Na (TI) detector was suspended from the floor of the vehicle for natural gamma counting.

A decision was made in November to eliminate experimental neutron activation work as a part of the Advanced Systems planning because of the excessive weight required for proper shielding for sample analysis during manned missions and the cost of outfitting a laboratory for testing of neutron activation techniques: $60,000 to $80,000

Time data was collected on tasks performed during the field tests held in the Hopi Buttes area by personnel of the Saturn Apollo Applications and Advanced Systems programs of the Branch of Astrogeology.

Two documentary films covering the field exercises in simulated lunar exploration were completed in November 1966. One titled, "Early Apollo Investigations Test 8" in color with sound is 12 minutes in length. The second film, "Apollo Applications Program test 6" is a 26-minute color and sound film.

The following was taken from the Branch of Astrogeology Monthly Report for December 1966 to the Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 30 December 1966:
During December 1966, T.N.V. Karlstrom, Branch of Astrogeology, represented the U.S. Geological Survey at the Space Flight Operations facility, Jet Propulsion Laboratory, Pasadena, California, during the photographic mission of Lunar Orbiter II. Preliminary geologic evaluations of the photography were made as a basis of news released by the Lunar Orbiter Project Office. Karlstrom acted as coordinator for preliminary screening and evaluation of Lunar

Orbiter II photographs by Branch personnel at Flagstaff and the University of Arizona (Tucson, Arizona). Preliminary reports of selected prime sites were transmitted to Langley Research Center from Flagstaff and Tucson, Arizona.

The following attended Orbiter II screening at Langley: D.E. Wilhelms, M.J. Grolier, L.C. Rowan, M.H. Carr, Anne Kelly, and for short periods of attendance, J.D. Alderman, Daniel Olivas, Raymond Jordan, J.J. Woolridge, and J.W. Ridgley, Jr.

Apollo Lunar Hand Tools were tested during December 1966 by space-suited subjects under 1/6-g in KC-135 aircraft flights at Wright-Patterson Air Force base, Dayton, Ohio. Most of the tools functioned properly, although some difficulties were met with the sample bags and with the aseptic sampling tool. It was decided that the sample bags would be modified for ease in opening and holding. Modification of the aseptic sampling tool was also recommended to permit collection of more material.

Geologist David Holcomb Scott (1916-2000; Ph.D., 1966) arrived at Menlo Park to work with the Branch of Astrogeology in December 1966 (see below). Dave would author more formal lunar and planetary geologic maps than anyone else in the Branch of Astrogeology.

Don Wilhelms recalls:
"The Branch of Astrogeology was at full steam in 1966 and was still recruiting new geologists—the last year that new hiring slots could be obtained from the Survey without undue begging. So it happened that we were able to consider hiring David Holcomb Scott, a former oil company chief geologist and chief of exploration. Geologist Scott (unrelated to David Scott the astronaut) came up to me after a talk I gave in February 1966 at UCLA—which he missed—and said that he wanted to do something new and interesting. He hurried through his Ph.D., entered on duty at Menlo Park in December 1966, and in a few years took on a mapping load [with the Branch of Astrogeology] that three ordinary geologists could not have upheld. Dave illustrates an important point about the transferal of skills from terrestrial to lunar and planetary geology; if you are good at one you can be good at the other" (Wilhelms, 1993, pp. 132-133).

[Astrogeology Milestone; In December 1966, the Branch of Astrogeologic Studies submitted its fifth *Annual Astrogeology Progress Report* to NASA covering research carried out during the period 1 July 1965 and 1 July 1966. The report was in three parts: Part A- Lunar and Planetary Investigations, Part B- Crater Investigations, and Part C- Cosmic Chemistry and Petrology.**]**

"The Soviets closed off hyperactive 1966 by soft-landing Luna 13 on 24 December to obtain surface pictures in another part of Oceanus Procellarum (19 Degrees N., 62 Degrees W.), north of the Luna 9 site" (Wilhelms, 1933, p. 133).

4.2-1967

[Author's Note: A total of six astronaut geologic field-training exercises were carried out in 1967 under the leadership of Branch of Surface Planetary Exploration personnel (see Table I).

The following was taken from the Branch of Astrogeology Monthly Report for January 1967 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeology; dated 30 January 1967:
AAP Test 9 was run by Branch of Astrogeology personnel (including this author) 24-27 January 1967. Not many details on the test remain, but likely it was an analytical instrument test run between the rock lab and the CDRA/ADF in the Arizona Bank Building.

Preliminary geologic evaluation of six Lunar Orbiter II prime sites were completed and transmitted to Langley Research Center in January 1967. These site reports were completed by geologists at Flagstaff and Tucson and edited by R. Eggleton and J.F. McCauley under the general supervision of T.N.V. Karlstrom. These reports would be assembled at Langley research center by personnel of the Branch as part of the Orbiter II screening and evaluation reports."

[Astrogeology Milestone: In January 1967, local Flagstaff contractors Buttrum and Jamison completed two adjacent buildings at 2717 and 2720 N. Fourth Street in East Flagstaff for the Branch of Astrogeology. The larger of the two buildings at 2717 Fourth Street would house Astrogeology's photogrammetry group, surveying personnel, electronic support group, in addition to drafting and photolab personnel. The smaller of the two building (at 2720 N. Fourth Street) was specially designed and constructed to be the Branch of Surface Planetary Exploration's new, and larger, simulated Apollo science support room, or Apollo Data Facility (ADF) (Fig. 44; also see Fig. 27).

[Apollo Setback and Tragedy: During a routine ground test on 27 January 1967 the Apollo 1 Command Module, with Gus Grissom, Roger Chaffee, and Ed White locked inside, caught fire in the [then] pure oxygen environment of the capsule. The three astronauts were dead long before the capsule hatch could be opened from the outside. "The disaster led to an expensive redesign of the spacecraft, tightening of safety precautions, an interruption of the fast-paced program of testing, and doubts about the wisdom of the whole Moon program. The Soviets soon underwent a parallel halt. Soyuz 1, the first of the long and still-continuing series of piloted spacecraft, was launched on 23 April 1967 and carried cosmonaut Vladimir Komarov to his death when his spacecraft parachute fouled during reentry the following day" (Wilhelms, 1993, p. 135).

[Author's Note: In January 1967, Joe O'Connor left the Branch of Astrogeologic Studies and moved to Berkeley, California to work at Livermore Labs/Berkeley; he later studied law at UC/Berkeley. His interest was mainly in environmental law and the bridging of the communication gap between lawyers and geoscientists. He received his law degree in 1975.]

The following was taken from the Branch of Astrogeology Monthly Report for February 1967 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeology; dated 28 February 1967:
R.A. "Putty" Mills and George E. Ulrich assisted in the selection and layout of test courses for the Lunar Surface Mobility Test Article vehicle (MTA) at the Yuma Proving Grounds, Yuma, Arizona. The MTA vehicles program has as its primary objective the testing and evaluation of the mobility of the lunar vehicle concept as proposed by Bendix and Boeing-General Motors. The test courses were selected as being representative of surface details obtained from Lunar

Orbiter II photographs. Branch personnel observing the tests were J.D. Crossen, R. A. Mills, B.G. Tinnin, and I.L. Wiser.

Electronics Expert John C. Johnny" Nuttall (1927-1986; Electronics Instrument-Maker Certification, 1955, NACA Electronics School, Langley, Virginia) arrived in Flagstaff in February 1967 on what was supposed to be a one-year loan from NASA/MSC (Houston, Texas) to the Branch of Surface Planetary Geology (see Appendices A and B). Johnny had since 1965 been participating with the Branch as a spacesuit biomedical technician from Baylor University and NASA/MSC in support of the Geological Survey's suited field exercises [for the development of astronaut lunar geologic activities] in the Hopi Buttes Volcanic Field north of Winslow, Arizona. After three years on loan from MSC to the USGS in Flagstaff, Johnny was hired fulltime by the USGS. Johnny Nuttall was the innovative, talented, and charismatic leader of the Branch of Planetary Exploration's Electronics Field Support Group until his retirement in 1977. Johnny Nuttall participated with the Apollo Lunar Geology Team in Houston during all of the Apollo lunar missions; making [then new] video taped kinescopes from the video downlinked from the lunar surface.

Don Beattie:
"In February 1967, a critical design review (CDR) of the Apollo lunar hand tools was held at MSC. Because several of the proposed hand tools were not ready for the review, it was decided to designate a "hand tool pool." From the pool, a total of about twenty pounds of equipment could be selected for each mission, tailored to the mission's specific needs. A tentative priority list was established: tool carrier, sample bags, (100-200), maps, tongs, hammer, scoop, drive tube number 1, extension handle (used with several tools to eliminate bending over), gnomon, drive tube number 2, surveying staff (later dropped from the pool), color chart, drive tube number 3, sample bag dispenser and sealer, aseptic sampler, spring scale, and combination brush/scriber/hand lens.

The Tool Carrier, a three-legged stand, allowed the astronauts to carry their tools from station to station with one hand and then reach them without stooping. It was used on only two missions, Apollo 12 and 14. A second design carried on the J missions held the tools so that they could be mounted on the rear of the lunar rover.

The gnomon, a unique device, was devised by the USGS [Flagstaff] to be placed in the field of view of the cameras the astronauts used on the lunar surface. It provided geometric and photometric control so that the photographs could be used to make analytical measurements. It consisted of a tripod about fourteen inches high supporting a gimbaled weighted rod that would hang vertically. The shadow cast by the rod (hence gnomon) showed the direction the camera was pointed so that the astronaut need not estimate it and transmit it by voice. A gray scale on the rod was used for photometric calibration of the black-and-white photos, and a color chart on one leg helped us calibrate the color photos. With all this data available, we were eventually able to make stereo pairs from the photos and produce contour maps of the areas where the photos were taken" (Beattie, 2001, pp. 113-114).

[<u>Space Exploration Milestone</u>: In February 1967, Lunar Orbiter III completed a successful mission of continued mapping of potential landing sites within the Apollo landing zone.]

Don Wilhelms, recalling the role of Astrogeology personnel in Lunar Orbiter II, stated:
"The [Lunar Orbiter] screeners attacked again [at Langley, following Lunar Orbiter III]. Newell Trask [USGS, Branch of Astrogeology-Menlo Park] replaced Larry Rowan as the overseer of the USGS part of the screening report and escalated the investigation. He began with the Ranger data of the engineering properties of the regolith that can be inferred from crater sizes and morphologies. Lower sun angle than that used on the two preceding Lunar Orbiters added sharpness to the Orbiter 3 frames" (Wilhelms, 1993, p. 160). M.J. Grolier and T.W. Offield (Branch of Astrogeology-Flagstaff, Arizona) acted as mission advisors for Lunar Orbiter III at the Space Flight Operations Facility, Jet Propulsion Laboratory, Pasadena, California, and did preliminary mapping of the Orbiter sites."

Don Beattie:
"Lunar Orbiters II [November 1966], and later Lunar Orbiter III [September 1967], were so effective that all the Apollo landing site photographs requirements were completed. The engineers and mission planners had enough photographs in hand to permit detailed landing site analysis, and they released the final two spacecraft for science site selection for potential post-Apollo missions. (The last three Lunar Orbiters were eventually cancelled, and the experiments solicited for those missions were put on the shelf to be resurrected later" (Beattie, 2001, p.190).

On 12-19 February 1967, members of the 4th and 5th astronaut groups were taken to Hawai‘i (see Table I). Howard Powers, Director of the USGS Hawaiian Volcano Observatory, was the local expert. Other geologists present include Ted Foss, Uel Clanton, and Dave McKay from NASA/MSC, Al Chidester, Gordon Swann, Maury Brock, Gordon Eaton, Dick Fiske, Marty Kane, Bill Rust (Astrogeology's amiable carpenter and camp cook), and Tom Wright of the USGS. Others present include Bob Workman and Jack Ottinger of MSC. Howard Powers, Willie Kinoshita, Richard Fisk, and Jerry Eaton, then presently or formerly at the Hawaiian Volcano Observatory, participated with the geologists from Flagstaff, Arizona and Houston, Texas (MSC) in the training program. Astronauts participating in this Hawai‘i trip included John Bull, Jerry Carr, Charles Duke, Joe Engle, Bill Pogue, Owen Garriott, Ed Gibson, Fred Haise, Jim Irwin, Jack Lousma, Ken Mattingly, Bruce McCandless, Curtis Michel, Ed Mitchell, and Al Worden.

The following was taken from the Branch of Astrogeology Monthly Report for March 1967 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 March 1967:
In March 1967, *Technical Letter: Astrogeology 28* was published on AAP test 8. The results of this test indicate that two astronauts can complement each other's work of a two-man geologic traverse with little or no time lost by one subject waiting for the other. A traverse timeline is included.

On 16-17 March 1967, a makeup astronaut-training trip was undertaken in the Pinacates Volcanic Field, Sonora, Mexico for astronauts Joe Engle, Owen Garriott, Joe Kerwin, and Bruce McCandless (see Table I). Geologists present on this trip included Al Chidester, Gordon Swann, Bob Regan and Marty Kane of the USGS, Branch of Astrogeology-Flagstaff.

On 20-24 March 1967, a makeup geologic training trip to Hawai‘i was carried out for the benefit of astronauts Vance Brand, Joe Kerwin, Don Lind, Stuart Roosa, Harrison Schmitt, Jack Sweigert and Paul Weitz (see Table I). Geologists present included John Dietrich and McEwen of NASA/MSC; and Gene Shoemaker of the USGS (See 12-19 February 1967 astronaut trip to Hawai‘i for more details).

[Space Exploration Milestone: Don Wilhelms: "Surveyor 3 brought another success as it landed in a part of Oceanus Procellarum [at 2.99 Degrees Lat.; 23.37 Degrees Long] on 19 April 1967. Before settling down on a crater wall that would later be trod by the two Apollo 12 astronauts [Allan Bean and Charles Conrad], it jumped twice because its vernier control engines did not shut off immediately. Surveyor 3 brought a new tool into use on the Moon, officially called the soil-mechanics surface sampler and unofficially called the "scratcher arm." The was a scoop mounted on a pantograph arm that could reach out about 1.5 m and dig trenches, break rocks with its blade as a geologist would with a geologic hammer, and generally pick up or shove rocks and scrape the surface for the benefit of watchers back at JPL's mission control center, the Space Flight Operations Facility (SFOF)" (Wilhelms, 1993, p. 141).]

The following was taken from the Branch of Astrogeology Monthly Report for April 1967 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeology; dated 30 April 1967:
Harold Masursky was appointed during April 1967 to the Surveyor Science Working group.

A program of geologic mapping of potential manned landing sites for the Manned Spacecraft Center (MSC), Houston, Texas, was started in April 1967 based on analysis of Lunar Orbiter photographs. A total of about twenty maps will be produced at scales of 1:100,000, 1:25,000, and 1:2,000. Work was begun on the following nine maps, all at a scale of 1:100,000 and based on medium resolution photography:

Site	Mapper
1. III P-1 (II P-2)	M.H. Carr
2. III P-2 (I P-1)	T.W. Offield
3. III P-5 (I P-3, II P-6))	M.J. Grolier*
4. III P-7 (I P-5, II P-8)	L.C. Rowan
5. III P-8 (II P-11)	H.G. Wilshire and K.A. Howard
6. III P-9 (I P-7)	H.A. Pohn
7. III P-10 (II P-13)	S.R. Titley
8. III P-11 (I P-8)	David Cummings
9. III P-12 (I P-9)	T.N.V. Karlstrom

*[Author's Note: Maurice Grolier would be fortunate enough to have mapped the site eventually chosen for the first manned lunar landing on July 20, 1969—Apollo 11.]

G.E. Ulrich and G.A. Swann worked outside in the hot Houston Sun during April 1967 as pressure-suited test subjects at the Manned Spacecraft Center's Human Factors Section, performing various lunar surface activities and procedures. George Ulrich informed this author (personal communication, July 2002) that he had the pleasure of wearing Gus Grissom's Gemini suit during those suited tests.

J.W. M'Gonigle, M.H. Hait, Ivo Lucchitta, D.L. Schleicher, and Harry Smedes (Northern Rockies Branch) held a field test during April 1967 in the Frenchman Mountains, Nevada. The primary purpose of the test was to evaluate description guides and checklists and their application to terrestrial and lunar geological exploration. The test site was chosen for its good exposure, structural complexity, and because the persons involved were unfamiliar with the area—and hence descriptions made in the field would not be biased by prior knowledge of the geology.

The following was taken from the Branch of Astrogeology Monthly Report for May 1967 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 May 1967:
During May 1967, a development vehicle, "Explorer" intended to simulate tasks performed by a lunar surface vehicle, was designed and constructed by R.A. Mills, B.G. Tinnin, and I.L. Wiser of the Field Test Systems project of the Branch of Astrogeology in Flagstaff. The four-wheel drive vehicle features electric and manual steering, provides for easy maneuverability with the driver in a space suit, and—with the addition of another electric steering control unit—can be driven both forward and reverse equally well with the driver seated at controls at either end of the vehicle. It is to be used in the development and testing of lunar exploration procedures for post-Apollo mission (Fig. 45).

Don Wilhelms:
"[At] the Falmouth conference (July 1965), Ralph Baldwin, Don Wise, and Norm Crabill all proposed this mission plan [for Lunar Orbiter IV], and the rest of us certainly were in favor of it. Eighty percent of the near side would be covered at 50-150 m resolution from near perilune, and as much of the far side as could be worked, would be shot at lower resolutions from near apolune. Our present understanding of the Moon's geology would have been impossible without Lunar Orbiter IV, whose global coverage has yet to be repeated or excelled. Geologists and chart makers would no longer need to peer through telescopic eyepieces hoping for the atmosphere to settle down or try to discern the reality concealed by fuzzy telescope photos. Lunar Orbiter IV was successfully launched from the Cape on 4 May 1967 and soon thereafter began "to obtain the coveted global coverage of the Moon. Lunar Orbiter IV's orbit was inclined 85 degrees to the equator and to have perilunes 50 times higher than the previous three missions" (Wilhelms, 1993, p. 161).

D.E. Wilhelms, K.A. Howard, H.A. Pohn and M.H. Carr acted as mission advisors at the Space Flight Operations Facility (SFOF) at JPL, Pasadena, California. The photographs from LO IV were evaluated by the lunar geologic mapping staff for the design of Mission V targeting.

Don Wilhelms recalls Astrogeology's Howard "Howie" Pohn Comes to the Rescue of Lunar Orbiter IV:

"I reckoned that I could pack up a set of Orbiter IV photos and conduct the rest of my career from a café in Paris. All went well with this plan at first. The initial north-to-south photographic pass, on 11 May yielded good images of Mare Australe and Smythii on the east limb, territory that had been only glimpsed with the telescope at times of favorable lighting.

I was among the mission advisors in the SFOF [Space Flight Operation Facility at JPL] when a voice from the flight controller's room came loud and clear, "thermal door closed." The door was supposed to be open during photography and closed between shots. I was watching G. Calvin Broome, chief of the photo-subsystem section of the Langley LOPO [Lunar Orbiter Project Office], who was watching LOPO's telemetry teleprinters in our room. Cal exclaimed, no, and drew his fingers across his throat. Prospects for the Parisian café and for lunar geology suddenly faded.

Needless to say, all the Boeing and LOPO engineers and the USGS mission advisors followed the ensuing drama with considerable interest (I did so indirectly; I came down with the flu and was replaced in the SFOF by Mike Carr [Branch of Astrogeology, Menlo Park]). Commands from the ground might close the thermal door, but would it open again? You didn't want to fly one of your two remaining Lunar Orbiters with the lens cap on. On the other hand, a door left open might allow the lens to fog or direct sunlight to leak in and degrade the film. Skillful maneuvering and partial closing and opening of the door stopped the light leakage, but the lenses were still fogging.

There was a puzzle here; some frames were better than others were. USGS mission advisor Howard Pohn came to the rescue with the answer. Howie simultaneously watched the television monitors and the telemetry printouts and realized that the fogging appeared only when the temperature of the lenses fell below a certain value. The temperature depended on the orientation of the spacecraft. To visualize the orientation, Boeing made a model of the spacecraft complete with a movable thermal door, out of a plastic coffee cup and a couple of pencils (contrasting amusingly with the gleaming multi-thousand-dollar machined replica of Surveyor built by JPL, for a similar purpose and set up in another room at the SFOF). The solution emerged; orient the spacecraft to warm the lens then quickly reorient it to take each picture. This was done after orbit 14, and good images were obtained west of about 45 Degrees East Longitude.

Howie calculated that at about $100,000 per frame, he saved the taxpayers some $10 million. Cliff Nelson thanked him in writing, but Branch Chief Hal Masursky squelched his outstanding performance rating because (he said) "Howie talked too much! The lunar scientific community owes LOPO, Boeing, and Howie Pohn a debt, although I had to give up Paris and settle for examining the pictures in my bullpen office at Menlo Park" (Wilhelms, 1993, pp. 161-162).

The following was taken from the Branch of Astrogeology Monthly Report for July 1967 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 July 1967.
On 16-19 May 1967, field exercises involving 21 astronauts from groups 4 and 5 were held at Zuni Salt Lake volcanic center in New Mexico; Hopi Buttes volcanic field, Arizona, and Meteor Crater, Arizona (Fig. 46; see Table I). The exercises were under the leadership of E.M. Shoemaker, David Cummings and R.L. Sutton. Other geologists participating were Al Chidester, Dave Dahlem, and Hal James of the USGS; Aaron Waters of the University of

California; Uel Clanton, David McKay, Mike McEwen, and Dick Laidley of MSC, Houston. The trip stressed a variety of volcanic features and the genesis and morphology of craters. Astronauts participating in the above trip included: Vance Brand, Jerry Carr, Charles Duke, Ron Evans, Owen Garriott, Fred Haise, Jim Irwin, Joe Kerwin, Don Lind, Jack Lousma, Ken Mattingly, Bruce McCandless, Curtis Michel, Ed Mitchell, Stewart Roosa, Jack Swigert, Paul Weitz, and Al Worden.

The following was taken from the Branch of Astrogeology Monthly Report for May 1967 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 May 1967:
On 31 May through 2 June 1967 a makeup geologic training trip to Zuni Salt Lake, New Mexico, and Hopi Buttes and Meteor Crater, was carried out for astronauts John Bull, Joe Engle, Ed Givens, and Bill Pogue (see Table I).

A television feasibility test was held 2-12 May 1967 at the Hoskietso diatreme, in the Hopi Buttes. Test subjects included Bob Sutton, and perhaps others, who were testing the real-time hand-held TV camera while in a "spacesuit" provided by Walt Disney Productions (Hollywood, California) for PR purposes.

Both television cameras were found to be extremely useful. For example, the surveillance camera gave a continuous view of the test subject's progress, reduced the amount of verbal information the subject must relay by providing pictures of the broad terrane framework into which the Data Facility (scientists in the "backroom") can put geologic data, and helps the Data Facility to advise the subject on advantageous changes in a pre-planned traverse. It was found during the test that the hand-held camera complemented the surveillance camera. First, the hand-held camera provides a continuous detailed record of the subject's traverse and shows the geologic information at essentially the same scale as seen by the subject, thus reducing effort and saving time on descriptions. Second, the hand-held camera shows important geologic relationships not seen by the surveillance camera and which are otherwise very difficult and time consuming to relay verbally.

Ivo Lucchitta (Branch of Astrogeology), during his interview with Gerald Schaber on 8 February 2002, recounted the following "Rattlesnake City" story that took place during the test at Hoskietso Diatreme between 2 and 12 May 1967 (described above):
"I remember a story about one of the astronaut trips in the Hopi Buttes [2-12 May 1967 near Hoskietso Diatreme north of Holbrook, Arizona]. It was right at the foot of one of those old volcanic necks. Dave Schleicher and I at the end of the day climbed up the old volcanic neck to look at the sunset—in shorts, because it was hotter than a pistol. It gets dark and we start back down again—and damn it, no matter which way we went there would be a rattlesnake buzzing, and you couldn't see them of course. We finally made our way down into the camp, and Bill Rust [Astrogeology's carpenter and camp cook] was busy doing this weird stuff banging on pots and pans, etc. We asked him what he was doing; he said he was "deporting rattlesnakes". They were all coming into the cook's area. That test site was definitely Rattlesnake City!"

Gordon Swann also contributed to this story about the rattlesnake problem during the 2-12 May 1967 field test at Hoskeitso Diatreme. During his second taped phone interview with Gerald Schaber on 26 July 2002, Swann reported the following:

"I think we dispatched eleven rattlesnakes there. I remember they came down from the hills [buttes] at night. We were sitting around the campfire and I said let's go out there and get us some rattlesnakes. We went about ten steps from the fire when one started buzzing at us. Then, we got just a few more steps and another started buzzing at us. We killed both of them and said the hell with this! We went back to the fire and John M'Gonigle and I kept going to the other side of the camp in the flats, just outside of the firelight ring, to take a piss—and there was a damn rattlesnake right there by our truck buzzing at us. We dispatched three rattlesnakes in about five minute there.

Johnny Nuttall and I went back to his electronics van and put our beds in there—instead of sleeping on the ground with the rattlesnakes. I think it was the second day of the field test. There was a real dust storm. Johnny and I went over to our tent before supper, and there was a damn rattlesnake right under our ladder. So we dispatched him and we started back toward the camp down this little dirt road in the sand. It was really blowing, and Red Bailey was walking a few steps ahead of us about ten or twenty feet. And there was a pretty good sized one [rattlesnake] coiled up right beside the road. So Red walked right on by him and never did see him or heard him buzz. The wind, of course, was blowing so danged hard you couldn't hear him buzz."

[Author's Note: I insert here yet another story about rattlesnakes—-this time involving Gene Shoemaker (at Meteor Crater during one of our field exercises with a large group of astronauts) that Gordon Swann recounted for Harry Ryan during their filmed interview in 1995]:
"A couple, Mr. and Mrs. Foster Thompson, used to run the museum at Meteor Crater. They were extremely cooperative with the USGS with regard to astronaut training, etc. So we were going to take a bunch of astronauts down into the crater. I went out the day before to tell Mr. and Mrs. Thompson that we were going to bring these guys out—and they were glad that we were coming. Mr. Thompson said, incidentally, when the guys come out tomorrow you might tell them to watch out where they put their hands and feet. We've seen more rattlesnakes out there this year than normal. I said, is that right? He said yes, we've killed four here in the parking lot so far this year.

So, we got out there the next day [with the astronauts] and Gene Shoemaker did his usual pre-traverse briefing of what the crater was about, some things to look for, and what we were going to do for the day. I told the astronauts, incidentally, Mr. Thompson said that you might kind of watch out for rattlesnakes-careful where you put your hands and feet; they've seen more than usual this year out here. Gene said there are no rattlesnakes out here. During all of the work I've done out here I've never seen a rattlesnake—in fact, rattlesnakes are notably scarce on the Colorado Plateau.

So, we started out into the crater. I remember that Al Chidester was leading the gang and I was behind Al, Jim Irwin (later Apollo 15 LM Pilot], and the rest were scattered on up the crater's inner slope wall. There were a total of probably forty people with the astronauts, geologists, trainers, photographers, etc. Gene was probably half way up in the group. We got almost to the bottom and a nice three-footer [rattlesnake] was sitting there just buzzing away. I said don't scare him—just leave him alone. I yelled hey Shoemaker—there's a snake down here and he's making a funny noise at us, and I don't know what kind it is. Can you come down and identify him for us? Gene came down and looked at the snake and said, "Well I'll be damned" (from a filmed interview with Gordon Swann by Harry Ryan in 1996; also see Levy, 2000, p. 121).

The following was taken from the USGS Center of Astrogeology Monthly Report for July 1967 to the Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 July, 1967:
In June 1967 and July 1967 the maneuverability of the "Explorer" vehicle was tested on the extremely blocky and rough S.P. Lava Flow north of the San Francisco Peaks jus west of Hank's Trading Post off US Highway 89 (Fig. 47).

On 2-8 July 1967 members of astronaut groups 4 and 5 participated in a geologic training exercise in Iceland (See Table I). Leaders of the exercise were Sigurdur Thorarinsson and Gudmundar Signaldson who led the 8-day field trip into the central interior of Iceland. Other geologists present included Uel Clanton, Ted Foss, Dave McKay, and Dick Laidley of NASA/MSC, and Al Chidester, Jack McCauley, and Marty Kane of the USGS Branch of Astrogeology-Flagstaff. Film Documentation was provided by Hal Stephens and Tom Lee of the USGS, Branch of Astrogeology's Film Documentation unit in Flagstaff. Others present were Vic Rhoder, Pat Riley, and Charles Nelms of NASA/MSC. The trip included field exercises in the spectacular Dyngjufjall Caldera and in a complex series of sub-glacial and sub-aerial volcanics near Thorisvatn Lake. Astronauts attending this exercise included Bill Anders, Neil Armstrong, Vance Brand, Jerry Carr, Charles Duke, Joe Engle, Ron Evans, Owen Garriott**,** Ed Gibson, Fred Haise, Don Lind, Jack Lousma, Ken Mattingly, Curtis Michel, Ed Mitchell, Bill Pogue, Harrison Schmitt, Jack Swigert, and Al Worden.

A proposal recommending map scales, areal coverage, formats, and onboard geologic maps to be used by astronauts for location and traverse planning during the early Apollo missions was presented in July 1967 by T.N.V. Karlstrom, G.A. Swann, J.W. M'Gonigle and Harold Masursky to a NASA working committee in Houston, Texas. The U.S. Geological Survey recommended data package was provisionally accepted by the committee as a basis for immediate NASA action designed to: (1) determine the best materials for onboard maps to be part of the Data Package; (2) reassess the operational and scientific needs for rapid and precise location of the Lunar Excursion Module (LEM) after landing; and (3) provide estimates of the cost of various types of base maps, at 1:5,000-1:2,500 scales and the capabilities of NASA to supply such bases, for geologic compilation purposes in time for the first scheduled mission. The U.S. Geological Survey was requested to continue research on the formats of the proposed large-scale maps and to prepare a sample of the proposed data on an uncontrolled photomosaic base. Another meeting of the working committee was scheduled in a month or so.

[Spaceflight Milestone-"Surveyor 4, with the same instrumentation as Surveyor 3, tried again on 14 July 1967 for Sinus Medii, and made it to the target. It ceased transmitting two and a half minutes before touchdown though, and was never heard from again" (Wilhelms, 1993, p. 142).]

[Astrogeology Milestone: Hole-digging, loading of dynamite and ammonium nitrate fertilizer bags, and blasting of the first 47 craters was completed 28-31 July 1967 in a volcanic cinder field (from the last eruption of Sunset Crater in 1064 AD) near Flagstaff (at Cinder Lake) in an attempt to reproduce a portion of the lunar surface from one of the smoothest mare landing sites so far photographed on Lunar Orbiter missions. It was designed to duplicate, as nearly as possible and at 1:1 scale, a selected area from Lunar Orbiter II, Site P-6-1, in Mare Tranquillitatis. The test area is 500 feet on a side selected from within the landing ellipse. The 47 craters from 5 to 40 feet in diameter are distributed geographically to compare with an enlargement of high resolution Lunar Orbiter photography. Norman "Red" Bailey with the Branch of Surface Planetary Exploration in Flagstaff supervised the digging, loading of explosives, and blasting of the craters at Cinder Lake Crater Field-I (just east-northeast of Flagstaff near Sunset Crater National Monument. Cinder Lake Crater Field #1 would be expanded 3-12 October 1967 with the blasting of an additional 96 craters making the final Crater Field (# 1) 800 X 800 feet in size (Fig. 48).

[Author's Note: After consideration of several alternate sites (Black Point Flow—adjacent to the Babbitt's Spider Web Ranch and S.P. Cone and Lava Flow area off U.S. 89 N. north of Flagstaff), construction of a second crater field—Cinder lake Crater Field #1 was carried out by Red Bailey and colleagues between 8 and 26 July 1968 at a site adjacent to Cinder lake Crater Field #1; See July 1968 for additional details.]

The crater fields constructed by the Branch of Astrogeology at Flagstaff in 1967-1968, and later in the Verde Valley south of Flagstaff (see February 1970), became by far the favorite geologic training areas for the astronauts (especially the later Apollo 15-17 crews) given the realistic lunar-like landscape—and the fact that they could explore the crater field using Astrogeology's Lunar Vehicle prototypes, Explorer and [later in 1970] "Grover." A primary purpose of the simulated crater field was to obtain factual data on the problem of location of Early Apollo missions. Tests were then planned to simulate a LM touchdown in a cratered area with no other distinctive features as reference points. The test subjects will experiment using Orbiter Photographs of various size areas in which the crater field is included. Their eye height above the ground will range from standing position to the height of the landing craft (LEM).

Secondary purposes of the crater field were to include experimentation with other Early Apollo methods such as description of crater morphology and stratigraphic relationships in unconsolidated materials, and analysis of hand tools and the scientific experiment package deployment methods. Geophysical techniques and mobility runs with lunar test vehicles are other tests which were planned to be performed using the crater fields.]

[Spaceflight Milestone-Surveyor IV was successfully launched for the Moon on 14 July 1967; however, telemetry from the spacecraft was lost just two minutes prior to touchdown, and was not re-established.

The following was taken from the Center of Astrogeology Monthly Report for August 1967 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 August 1967):

[Branch of Astrogeology Milestone: The Branch of Astrogeology has been reorganized to establish under the Assistant Chief Geologist for Engineering Geology two branches—Branch of Astrogeologic Studies and Branch of Surface Planetary Exploration. Alfred H. Chidester has been appointed Deputy Assistant Chief Geologist for Astrogeology to assist Dwight Lemmon in the direction of the activities of the two new branches. Harold Masursky has been appointed Chief, Branch of Astrogeologic Studies. Arnold Brokaw will assume the position of Chief, Branch of Surface Planetary Exploration in September 1967. A Technical Support Unit has also been established with Max L. Troyer as Chief. The Astrogeology Center at Flagstaff now comprises the aforementioned organizations, plus the Flagstaff Technical Reports Unit, Library, the Remote Sensor Applications Section of the Branch of Regional Geophysics, and the Flagstaff Computer Facility of the Computer Center Division. With the reorganization, the Branch of Astrogeology was abolished.

Don Wilhelms:
"Shortly thereafter there appeared in Flagstaff, without forewarning, one Arnold Leslie Brokaw (1911-1990) (geologist), a man with no previous connection with the lunar program but who was to be SPE's Branch Chief [starting in September 1967]. Hal James had sent the gruff Brokaw, an American Indian, to remind the freewheeling Flagstaff office that they were part of the United States Geological Survey and to find out what they were up to [and much to the dismay and disbelief of the scientists assigned to the SPE Branch at that time]. Chidester, no longer so amiable, was kicked upstairs to the position of deputy assistant chief geologist for Astrogeology (July 1967), nominally the coordinator of both branches and Brokaw's boss. The wound never healed" (Wilhelms, 1993, p. 174).

Don Beattie:
"Brokaw's appearance altered the dynamics of our work [NASA HQ's] with SPE, and though we maintained cordial relations with him, we found that the best way to get things done was to work around him and go directly to the staff we had come to know so well over the past three years. The personnel changes made at SPE soon after Brokaw's arrival put our studies in some disarray. Al Chidester, with whom we had cooperated closely, was transferred and no longer had any role in our work. But with the perseverance and cooperation of Gordon Swann and others, we managed to keep things on track, with our eyes focused on the first landing mission and the hoped-for expansion of our ability to conduct exploration in the post-Apollo era" (Beattie, 2001, p. 73).

The following was taken from the Center of Astrogeology Monthly Report for August 1967 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 August 1967:
In August 1967 the Center of Astrogeology participated [in a big way] in the XII Boy Scout World Jamboree held at Farragut, Idaho from 1 August through 9 August, by setting up and manning an exhibit explaining the function of the Center. The exhibit consisted of two lunar development vehicles, the Explorer and the Mobile Geological Laboratory (MGL), each accompanied by an explanatory panel, and of several additional panels, which illustrated the activities of the Center, and were located within a small three-sided building designed and constructed especially for the Jamboree grounds. The exhibit was located within the conservation area of the Jamboree grounds. Personnel manning the exhibit (H.G. Stephens, Ivo

Lucchitta, R.L. Sutton, A.E. Dale, B.J. Tinnin, and Henry Alcott) answered questions, gave brief presentations, and handed out literature. Visitors to the exhibit were estimated at several hundred per day, as a minimum. The vehicles, panels, and building were transported to and from the Jamboree site through the courtesy of the U.S. Air Force (Fig. 49).

[Space Exploration Milestone: In August 1967, Lunar Orbiter V successfully mapped many exciting science sites on the Moon that were photographed as potential targets for post-Apollo missions (unfortunately, later cancelled).

The NASA Summer Planning Conference in Santa Cruz, California was attended by A.H. Chidester, D.H. Dahlem, M.H. Hait, M.F. Kane, E.M. Shoemaker, G.A. Swann, and Kenneth Watson from the Branch of Astrogeology, Flagstaff, Arizona.

Don Beattie:
"The site selected for the 1967 [National Academy of Science] summer conference was the new University of California campus at Santa Cruz [between 31 July and 13 August 1967]. Aaron Waters, a noted geologist and Co-investigator on Shoemaker's Apollo Field Geology Team, had just joined the staff at Santa Cruz and served as the unofficial host. Over 150 people joined us at Santa Cruz, representing all the geoscience disciplines and including a few astronomers. MSFC sent only two observers to the conference, because by this time the decision had been made to manage all Apollo science at MSC, and MSFC quickly phased out of most lunar science studies. Goddard Space Flight Center was well represented, led by Isadore "Izzy" Adler and by Jack Trombka, who has returned to GSFC, after his stint at [NASA] Headquarters. They wanted to map the lunar surface extensively from orbit using newly developed sensors. Thirty MSC staffers from various organizations attended, including [Max] Faget himself, as well as three astronauts: Deke Slayton, Jack Schmitt, and Curtis Michel (a member of Jack's 1965 scientist-astronaut class).

Our daily sessions were divided into eight working groups, which reported on their findings at the end of the conference. I attended as secretary of the Geology Working Group, which was led by Gene Shoemaker and Al Chidester (one of Al's last duties before his transfer) and was dominated by USGS staff and university professors who supported the work we had been conducting at Flagstaff. Major recommendations coming out of this working group included: (1) increasing the astronauts' radius of operation beyond walking range, estimated to be five hundred feet, by providing wheeled and flying units, (2) developing a dual-launch capability as soon as possible, (3) creating a sample return payload for four hundred pounds, (4) making the geophysical station flexible so we could react to new opportunities, (5) providing an early manned lunar orbital flight to further map the lunar surface in the visible part of the electromagnetic spectrum (and other parts as well), and (6) sequencing orbiter and landing site missions that would include landings at the craters Copernicus and Aristarchus. In general, all of the recommendations supported the Post-Apollo planning that we had undertaken in the past four years" (Beattie, 2001, pp. 74-75).

Don Wilhelms:
"The 28-member geology working group at Santa Cruz (the largest of eight groups; four geoscience and four nongeoscience) was co-chaired by Gene Shoemaker and Al Chidester.

Shoemaker had long been spread too thin, and a year earlier had given up his administrative duties in Astrogeology to an acting Branch Chief (Max Troyer) and a number of administrative assistants who dealt with fiscal and organizational realities. Santa Cruz also promised to provide a good learning experience for Chidester, who, as chief of the manned lunar exploration group in Flagstaff, seemed destined to expand his role in human lunar exploration. Chidester also seemed destined to rise higher on the Survey organizational chart. At the time of the conference, USGS Chief Geologist Harold James officially split the six-year old branch of Astrogeology into two branches corresponding to the scientific and mission-oriented subdivisions that already existed" (Wilhelms, 1993, p. 174).

Don Beattie:
"By the summer of 1967, with the studies at MSFC and USGS described above under way or completed, we had what I considered to be all the key scientific and operational answers needed to justify more extensive exploration, and eventually, lunar bases" (Beattie, 2001, p. 73).

"Although the Santa Cruz conference [summer, 1967] endorsed the need for missions after the scheduled Apollo flights, time was running out for AAP (the Apollo Applications Program). The Santa Cruz attendees, representing many renowned scientists, had proposed important studies on the Moon that were not planned for Apollo. These experiments would require payloads and resources beyond what was anticipated for the Apollo flights. By the time the conference came to a close we knew that NASA budget submittals for fiscal year 1969 would not include funds for missions beyond the already funded Apollo flights. What exquisite timing" (Beattie, 2001, p. 76)! [More below on the fallout of the Santa Cruz Conference]

Don Wilhelms:
"Scientific studies that entailed looking down on the Moon's surface from above went to the Branch of Astrogeologic Studies, with Hal Masursky as its Chief (Hal was on both the geology and the geodesy/cartography groups at Santa Cruz). Preparations for Apollo and any other mission-related geology done on the surface of a Moon or planet were gathered in a new branch with the appropriate although grammatically ambiguous name Surface Planetary Exploration (SPE). The work of Astrogeologic Studies was conducted in Menlo Park, Flagstaff, and Washington, D.C., while SPE operated entirely in Flagstaff. Chidester was to be SPE's chief, fulfilling a lifelong ambition to be a Survey Branch Chief, or so he thought" (Wilhelms, 1993, p. 174).

Don Beattie:
"At the end of the Santa Cruz conference, in the summer of 1967, Bill Hess established an interdisciplinary Group for Lunar Exploration Planning (GLEP). Its objective was to integrate the science planning for each mission and offer an overall strategy to ensure that the missions complemented each other for the maximum scientific return. With the AAP missions at least on hold, GLEP focused on coordinating the planning for the Apollo missions. Planning centered mainly on selecting landing sites. Each site's unique characteristics would dictate the experiments to be carried out and how the geological surveys would be conducted.

To do the staff work in support of GLEP, a small group of scientists and engineers that we dubbed the "rump GLEP" met to put all the pieces together for presentation to GLEP. The rump

GLEP initially included (besides me) Hal Masursky and Don Wilhelms form USGS; John Dietrich and John "Jack" Sevier from MSC, joined at times by Jack Schmitt; several scientists from outside NASA, including Paul Gast and Eugene Simmons; and two Bellcom staffers—Farouk El Baz and Noel Hinners, the latter chairing the meetings. For the next two years we met regularly to plan each of the upcoming flights, updating our recommendations as more and more information became available.

Site politics could rear its head at times; but fortunately consensus prevailed, though for several landings we chased the ephemeral "recent volcanics" advocated by a small USGS clique and others. As Noel Hinner's staff gained strength with the addition of James Head and others, they worked closely with USGS in Menlo Park and Flagstaff and took the lead in providing site rationale for GLEP" (Beattie, 2001, pp. 103-104).

Don Beattie:
"After much give and take on how the experimenters and the science community would interact with mission controllers and the astronauts in real time during an Apollo mission, MSC agreed in 1967 to build an experiment room in the mission control building. Christopher Kraft and his flight controllers in FOD deserve the credit for recognizing the wisdom of having such a facility, but the intervention of Jack Schmitt, Donald Lind, and other astronauts who had worked with the training and simulation teams assembled by USGS was critical to getting the agreement. They had first-hand knowledge of how valuable it would be for the crews on the lunar surface to have experienced scientists backing them up.

The arrangement was [actually] formalized in April 1967, when FOD issued its "Flight Control Handbook for Experimenters." It called for an experiments room, later named Science Support Room (SSR), to be located in Building 30 near the Mission Operations Control Room (MOCR). The MOCR was the large room, filled with banks of monitors manned by engineers in short-sleeved white shirts and ties, seen by everyone who watched the Apollo space missions on television. During initial discussions it was proposed that the experiments room be located with other support teams in Building 226 [at MSC], a few blocks away, and for Apollo 8 that was its location. However, we were able to convince Chris Kraft that for the landing missions it had to be nearer the action, like other critical Staff Support Rooms (SSR again), so that the displays and other information we planned to coordinate would be accessible to those who might have to make quick decisions. This would be especially important for the later missions.

As important as it was for the experiments to have assigned SSRs, the handbook also formalized the procedures for simulations with the flight controllers. This was another major step forward and for the first time placed experiment simulation in the mainstream with all the other simulations carried out for the missions. Simulations would cover normal and abnormal situations that might require consultation with the SSR, and the flight controllers were given particularly wicked problems as they gained experience. The schedule called for the experiment simulations to start four weeks before launch, so beginning in June 1969 we had to man the SSR with the staff that would be present during the actual missions" (Beattie, 2001, p. 94-96).

Don Wilhelms:
"An active year in space [1967] concluded when the last Lunar Orbiter V frame was read out on 16 August 1967 and the spacecraft, like its predecessors, was deliberately crashed on 31 January 1968 to clear the deep-space airways for future flights.

The [Langley] screening effort [for Lunar Orbiter V] was dominated by science in general and USGS Astrogeology in particular, and it incorporated up-to-date interpretations of all lunar features thought important at the time; too bad it was buried in the gray literature" (Wilhelms, 1993, p. 165).

The following was taken from the USGS Center of Astrogeology Monthly Report for August 1967 to the Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 August 1967):
"H.A. Pohn, G.G. Schaber, and D.E. Wilhelms were on duty [for three weeks] at the Space Flight Operations Facility (SFOF), Jet Propulsion Laboratory, Pasadena, California, as photographic mission advisors for Lunar Orbiter V. This final flight of Lunar Orbiter was an unqualified success. It secured photographs of the remainder of the lunar farside, completed coverage of candidate Apollo sites and returned high-resolution photographs of more than 30 frontside sites of unusual scientific interest. Preliminary interpretations indicated that striking evidence of geologic processes has been obtained, and would be used in planning future lunar exploration"

[Spaceflight Milestone: Surveyor V landed with its analytical minilab on target on 10 September 1967 at 6:47 P.M. MDT in Mare Tranquillitatis at 232 Degrees E. longitude, 1.5 Degrees N. latitude. The target this time was only 60 km from the Ranger VIII impact point and 25 km from the future Tranquillitatis Base" [of Apollo 11]. The Surveyor Television Experimenter Team was present in the SFOF at the Jet Propulsion Laboratory, Pasadena, California for spacecraft touchdown and subsequent mission operations.

"After preliminary examination of the television pictures, E.M. Shoemaker concluded that the spacecraft had landed on the south rim of a crater about 10 m in diameter and about 1 meter deep. The spacecraft was also found to be tilted in a northerly direction approximately 19 degrees. Focal range television surveys designed and interpreted by R.M. Batson and Raymond Jordon confirmed this judgment" (Wilhelms, 1993, p. 142; and Branch of Astrogeology Monthly Report for September 1967 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 29 September 1967).]

Don Wilhelms:
"John O'Keefe tells the story about picking up renowned chemist Harold Urey (1893-1981) at the Los Angeles airport just after the first results from the alpha-scatterer [from Surveyor V] were decoded. As O'Keefe was excitedly enumerating the probable elements and their abundances, Urey commented glumly, "It's basalt, isn't it,"—and added, "You are a very poor driver" (Wilhelms, 1993, pp. 143) (see below).

[Author's Note: Harold Urey had previously strongly maintained that the surface of the Moon was covered with deep dust created by eons of meteorite bombardment, and that the Moon was formed by cold accretion—and stayed cold (no internal differentiation)—so there would be no basaltic lava flows found on the low-albedo mare floors there—contrary to what everyone else then believed. He was wrong!]

Don Wilhelms:
"Don Gault [Ames Research Center, Mountain View, California] remembers Urey remaining silent during a presentation by Turkevich (P.I. for the Alpha-scattering experiment) and for about two days more. Then he admitted, "Maybe Mother Nature knows best." Hal Masursky (USGS Branch of Astrogeology) remembers him [Urey] saying, "If this happens again, I'm in trouble." It is indeed basalt, and of a type commonly found on Earth. Surveyor V also sent back almost 19,000 pictures of what later was determined to be the oldest mare surface visited by any Surveyor.

The release of Surveyor VI to perform the original objective of the Surveyor project, scientific exploration, was considered for a while. Gene Shoemaker, John O'Keefe, Harold Urey, Hal Masursky, and several others all came out strongly for a terra site [in the lunar highlands], each for his own reasons. Shoemaker's favorite was the Fra Mauro Formation [thought to be ejecta from the Imbrium basin impact]. Other science sites were suggested at a June 1967 meeting of the Surveyor Scientific Evaluation Advisory Team chaired by JPL project scientist Len Jaffe. Two unsurprising [crater] entries were Copernicus and the perennial candidate Alphonsus. A newer but also longer lasting candidate was the Marius Hills, brought to the attention of lunar scientists by Jack McCauley. The crater Aristarchus was there. And Hal Masursky added to the list the special-feature favorites Aristarchus Plateau and Hyginus Rille. Less "special," but more suited to Surveyor's landing accuracy, were the relatively smooth and level floors of the craters Julius Caesar and, especially, Hipparchus, a favorite for a Surveyor and early Apollo mission at least since the Falmouth conference because it offered a big (150-km) nonmare target. Keith Howard, an able field geologist hired for the Menlo Park USGS office [of the Branch of Astrogeology] in April 1966, proposed a similar terra-plains site inside the 75-km crater, Ptolemaeus. The voting at a 24 September 1967 meeting of the advisory team favored Hyginus, Copernicus, Aristarchus Plateau, and Hipparchus, in that order; Masursky was very persuasive.

For the time being, the targeting exercise was futile. NASA headquarters sent the word that Surveyor VI had to try again for Sinus Medii to please the manned program" (See Spaceflight Milestone for November 1967 below) (Wilhelms, 1993, pp. 143-144).

Clerk Typist and Computer specialist Lynda Sowers (later Lynda Ballisime), for many years one of the key players in the Survey's image processing group at Flagstaff, began work with the Branch of Astrogeology on 11 September 1967 (see Appendices A and B). She started working with Gordon Swann and Tim Hait on the 5th floor of the old Arizona Bank Building in downtown Flagstaff. Lynda shortly thereafter started working with George Ulrich and Red Bailey on the Branch's WLYBUR and SEARCH computer program in preparation for Apollo missions. Between 1967 and 1969, Lynda [from the ADF on Fourth Street] also practiced inputting the verbal input from the astronaut's EVAs in the field during the SPE Branch's pre-Apollo field tests in Hopi Buttes and other local test sites. In November 1969, Lynda participated with the Survey's Apollo Lunar Geology Experiment Team in Houston during Apollo 12, inputting astronaut verbal information from the lunar surface into the Branch's SEARCH program. Lynda transferred to the Survey's EROS Data Center in Sioux Fall, S.D. in January 1972, but returned to Flagstaff soon after Apollo 17 to work for Larry Soderblom (originally in Astrogeology, and then the Computer Division in Flagstaff). She managed image and data processing for various planetary missions, including Viking, Voyager, etc. Lynda retired in 1996 and moved to Cottonwood, Arizona, and then Las Vegas, Nevada, where she still resides.

The following was taken from the Center of Astrogeology Monthly Report for September 1967 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 29 September 1967:
J.F. McCauley returned from leave at the Northern Arizona University (NAU in Flagstaff) in September 1967 after co-directing the first short course in Astrogeology for University teachers.

A much-refined example of the U.S. Geological Survey's recommended Data package [for use in early Apollo manned missions] was presented to the meeting of the Lunar Excursion Map Group at the Manned Spacecraft Center, Houston, Texas, and accepted for immediate operational testing by the Lunar Surface Operations Office. Important progress was made in (1) determining both operational and scientific justifications for accurate location of the landing craft on the lunar surface during the early Apollo Missions, and (2) establishing procedures and responsibilities in base map procurement and geologic compilation that should satisfy training and onboard requirements for the first Apollo Mission.

G.A. Swann and M.H. Hait participated during September 1967 in 1/6-gravity flights in the KC-135 aircraft at Wright-Patterson Air Force Base, Dayton, Ohio. The purpose was to find out how the present automated staff could be handled at 1/6 g by a man in a pressure suit. The staff used is a 30-lb, mockup weighted and balanced to simulate the prototype model now being built at the Manned Spacecraft Center, Houston, Texas. J.B. Slight (MSC) tested the staff in the pressure suit through about 10 parabolas (4-5 minutes at 1/6-g) and reported that the staff handled very easily during normal carrying, changing hands, and changing positions during use. The inertia of the staff was a problem only during very abrupt movements. The flights showed that the present design of the staff is very satisfactory except for minor changes on location of buttons and switches.

N.G. Bailey (Branch of Surface Planetary Exploration) during September 1967 completed preliminary location tests with 28 test subjects at the simulated crater field (Cinder Lake Crater Field #1) first described in July 1967. The tests consisted of placing each test subject in the mockup of the Lunar Module (LM, earlier called Lunar Excursion Module, or LEM) at the site and giving them one-half hour with either a 1:2,500 or 1:5,000 scale Orbiter photo encompassing a 1 sq. km area. Each subject was also given a measuring scale and pencil and paper for sketching if desired. The problem was to locate the LM position on the Orbiter photo using any method practicable. At the end of the first 1/2 hour, the test subject who hadn't located the Lm position were given a 1/4 sq. km area Orbiter photo at the same scale and another 1/2 hour to locate. Successive 1/16 sq. km and 1/64 sq.-km area photos for 1/2 hour each completed the test sequence for any subjects still unable to locate. Initial results indicated that with the proper training and experience, the astronaut could reasonably expect to locate his position on the lunar surface within 1/2 hour if his search area is narrowed down to 1 sq. km. Inasmuch as the present test area is a "worse case" example, location time could take less than 5 minutes with a "best case" test site. Also, the test subjects have been instrumental in conceiving new ideas to enable rapid location of the landing site. These ideas were used to plan and establish constraints for more detailed tests of this type in the future. This Field location test at Cinder Lake was documented in USGS Interagency Report; *Astrogeology 2* (Cinder Lake Crater Field Location Test, by Norman G. Bailey, dated November 1967*)*.

On 14 September 1967 a traverse test was run on the newly-created Cinder Lake Crater Field I with John M'Gonigle and Ivo Lucchitta acting as the unsuited astronauts. Kenna Edmonds provided time-and-motion studies on their activities and tasks.

Field testing of the Branch of Planetary Exploration's "Explorer" vehicle continued during September 1967 at the Cinder Lake Crater Field and S.P. Mountain (and lava flow) test sites near Flagstaff. The vehicle, which would serve as an excursion vehicle in the Branch's lunar exploration development program, was fitted during September with optional large wheels and very low-pressure tires to permit exercises over cinder-covered slopes and very rough surfaces of lava flows. The vehicle easily negotiated a 40-foot diameter conical crater excavated into unconsolidated cinders.

A significant meeting was held 27-29 September 1967 in Menlo Park, California, to define the stratigraphic and structural conventions, format of explanations, and schedule for the 1:25,000 and 1:100,000 scales geologic maps of the Lunar Orbiter sites selected as candidate Apollo landing sites. Attending the meeting were L.C. Rowan, D.E. Wilhelms, N.J. Trask, M.H. Carr, H.A. Pohn, T.A. Mutch, T.W. Offield, M.J. Grolier, P.J. Cannon, Jerry Harbour, R.S. Saunders, H.J. Wilshire, David Cummings, S.R. Titley, D.E. Stewart-Alexander, and Phoebe Bernat (the above was taken from the Center of Astrogeology Monthly Report for September 1967 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 29 September 1967).

Geologist Baerbel Koesters Lucchitta (b. 1938; Ph.D., 1966, Penn State University arrived in Flagstaff with her husband Ivo Lucchitta who had been hired by the Branch of Astrogeology in October 1966 (see Appendices A and B). Baerbel herself joined the Branch in the fall of 1967. Baerbel started working with Robert Wildey and Howard Pohn on Astrogeology's photoclinometry project at the Branch's recently constructed building at 2717 N. Fourth Street in East Flagstaff. She was assigned to do various geologic maps of the Moon, including the 1:50,000-scale geologic map of the Taurus-Littrow region of the Moon that would eventually include the landing site for Apollo 17 in December 1972. Baerbel also worked on the Mariner 9 images of Mars, was an active team participant on the Viking Mars mission (summer 1976), as well as on the subsequent Voyager missions to Jupiter, Saturn, Uranus and Neptune. In the later phase of her career she was very active in geologic studies of Mars, and in monitoring the ice sheets in Antarctica. Baerbel, who published extensively throughout her career with the USGS, retired along with her husband Ivo in 1995 and still resides in Flagstaff. Baerbel was still officially in USGS Emeritus status at the time of this writing.

The following was taken from the Center of Astrogeology Monthly Report for October 1967 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 30 October 1967:
During October 1967 T.N.V. Karlstrom (Branch of Astrogeology-Flagstaff) completed a photogeologic map of the simulated lunar crater field prepared by the Branch of Surface Planetary Exploration in the Cinder Lake area near Flagstaff (see above). The crater field simulates a portion of an Orbiter photograph and contains a wide range of features. These features include: single-rimmed and double-rimmed craters ranging from less than 10 feet to more than 50 feet in diameter; superimposed ejecta blankets and secondary-crater ray patterns that should provide clues to underlying stratigraphy and subtle lineaments and ground patterns, reminiscent of lunar surface features, that in part cross and modify crater morphology.

[Significant Early Lunar Scientific Observation- K.A. Howard and D.E. Stuart-Alexander (Branch of Astrogeology, Menlo Park, California) reported during October 1967 on their study of the distribution of large circular basins and maria using the complete photographic coverage of the moon available from Lunar Orbiters IV and V. Twenty-eight basins covering 7,300 sq. km were located and ranked in a general chronologic order according to size of superposed craters, degree of obliteration of ring scarps, circularity, and other factors. The basins appear to have a Moon-wide random distribution in both age and position. On the other hand, Howard and Stewart-Alexander found that the mare material is not randomly distributed, but is concentrated in a large region of the northern frontside, is absent in a region of the northern backside, and is scattered in small areas over the rest of the Moon. They reported also that all basins >520 sq. km contain some mare material. They suggested that deep impact basins might primarily control the mare distribution if Oceanus Procellarum and Mare Australe are old impact sites. Alternately, the regional pattern of maria may reflect an internal control such as convection currents, as others have suggested.]

The Film Documentation Unit of the Branch of Surface Planetary Exploration (Flagstaff) completed during October 1967 the color-sound film “Explorer.” The ten-minute film documents the construction, function and performance of the Explorer vehicle. The Explorer vehicle was only recently completed for use in the lunar exploration development program by the Field Test Systems Project of the Branch of Surface Planetary Exploration.

Apollo Field Test No. 13 was carried out on 24-26 October 1967 by the Surface Planetary Exploration (SPE) Branch at the Cinder lake Crater Field about 10 miles northeast of Flagstaff. This was a full-up suited test making use of two geologists (Tim Hait and David Schleicher) from the Branch of Surface Planetary Exploration (Flagstaff) playing the part of the “astronauts” (Fig. 50**)**.

The purpose of the test was to evaluate the use of various kinds of Apollo lunar traverse maps of the type that have been proposed to NASA for the Geologic Field Experiment [for Early Apollo landing]. Specifically, the test gave data relating to (1) operational constraints affecting the use of maps both during traverse-planning sessions after landing but prior to egress from the LM (Lunar Module) and during the ensuing ground traverses, and (2) the comparative use of aerial photographs, geologically annotated photos, or no maps or photos at all during ground traverses. The maps were used under field conditions that simulated an Early Apollo lunar mission in as many respects as possible. The general approach was to send out the two space-suited subjects on a series of traverses through the crater field. The subjects carried the traverse maps, lunar hand tools, and a camera and attempted to integrate the use of the maps with other tasks such as sampling, photography, and verbal description.

Crew Systems Division, Manned Spacecraft Center (MSC), Houston, Texas supplied spacesuit and backpack support. The main test constraints included using two test subjects at the same time, each in a space suit pressured to 3.7 psi by a liquid air supply. On one traverse, subjects carried an aerial photo of the crater field, on two traverses an aerial photo with geologic annotations, and one two other traverses neither photo nor map. The subjects had voice communications with the data facility. The data facility was restricted to voice communications and to indirect observations via the TV camera.

Facilities at the test site included a mock-up of the LM (Lunar Module) ascent stage and a data facility trailer. The data facility trailer housed three geologists who were responsible for communicating with the test subjects and plotting geologic data as it was reported. For the test, photos and maps were prepared at scales of 1:1,000 and 1:5,000 each with coordinate grid overlays. The 1:1,000 map was used in the data facility for data compilation; the 1:5,000 map and photo were used by the test subjects during traverse planning in the LM and during the traverses in the crater field. The data facility crew devised traverse plans for the test subjects, monitored the subjects' traverse information, prompted them on traverse objectives where necessary, and attempted to keep track of all the geologic data radioed in by the subjects. On the traverses the test subjects attempted to follow the preplanned routes and to gather the requested information while taking samples and photographs and giving verbal descriptions. Records were kept for each kind of traverse activity: walking, sampling, describing, photographing, and using map or photo.

Preliminary evaluation of the test results relating to map use suggested the following conclusions:

1. Physical manipulation and readability of the 1:5,000 scale map and photos was no problem under the suited constraints that prevailed during the traverses. Because of the small areas likely to be covered by foot traverses during Early Apollo missions, and the small size of features that will be observed and sampled, maps larger than 1:5,000 scale should be considered if volume and weight restrictions can be eased

2. Both the photo and the map served the very useful purpose of providing a "common ground" from which the data facility crew and test subjects could effectively plan and discuss the details of the traverses.

3. Geologic annotations helped to "clue" the subjects to what they were looking for and eliminate the need to search the photos for problem areas; the annotations provide a convenient summary of existing geologic interpretation and thus focus the attention to specific features, and give the subjects specific interpretations to attack by supplying "ground truth" to photogeologic hypotheses.

4. Both photos and maps were useful to spark subjects' memories toward the end of traverses when the original plans begin to fade because of stress and fatigue. Most lunar landing sites will likely be more complex than that reproduced in the test site, and the functions of maps as important traverse guides will be correspondingly increased.

[Spaceflight Milestone: On 9 November 1967 Surveyor VI landed safely on a nearly level area of Sinus Medii (Central Bay) at 0.5 Degrees N., 1.4 Degrees W, next to a mare ridge. During its lifetime of one Earth month it transmitted almost 30,000 pictures, a third of the project's total. E.M. Shoemaker, E.C. Morris, H.E. Holt, and R.M. Batson worked on the TV Team. On 17 November 1967 the SFOF controllers re-fired the engines of Surveyor VI to hop it 2.5 m to a new spot.

Don Wilhelms:
"Surveyor VI carried another alpha scatterer, which found more basalt. It had "happened again" upsetting Harold Urey's convictions even further. Shoemaker turned the primary reporting responsibility for Surveyor VI over to his faithful colleague on the Surveyor project, Elliot Morris. Polarization measurement had survived into the Surveyor era as an objective because they are easily performed. Surveyor VI carried polarizing filters instead of color filters, and Henry Holt [USGS Branch of Astrogeology]; the inheritor of the study begun by me at Meudon [France], and continued by Newell Trask [USGS Branch of Astrogeology-Menlo Park], interpreted the meager results.

Even the ravenous Apollo project was satiated by four successes [by Surveyor] in the potential Apollo landing site zone on the maria. NASA, possibly embarrassed by their caution, now threw it to the winds. Surveyor VII [that would eventually land on the rim of the crater Tycho in January 1968; see 1968], the last of its program, would be devoted to science. The list of scientific landing sites was reviewed again. The Surveyor V and VI analyses had confirmed the long-held majority views that the mare rock is basalt, implying that the Moon had differentiated. Urey's long-sought primitive, undifferentiated, presumably chrondritic material had therefore not yet been found. Dick Eggleton [USGS, Branch of Astrogeology, Menlo Park] suggested that this primitive rock, or at least residues left by the partial melting that created the basalt, might have been brought to the surface from depths as great as 70 km in the Fra Mauro Formation [Imbrium Basin ejecta]. He picked a point where Surveyor had a good chance of landing safely even without great accuracy.

But an even bolder suggestion, apparently arrived at almost unanimously among the experimenters, finally won: the north rim of the crater Tycho in the southern highlands. Here at last was pure Terra and Pure Science. There was little chance an Apollo could ever land at Tycho, and none ever did. Tycho was an obvious impact crater to all people but people like [geologist] Jack Green (b. 1925), and yet Lunar Orbiter V revealed some material with flat, fractured, sparsely-cratered surfaces "ponded" or "pooled" in depressions in the rim. Some of the pools were fed by leveed channels and clearly were formed by a very fluid material [now thought to be impact melt rock]. In the spirit of the times the knee-jerk interpretation was hybridization of the crater by volcanism" (Wilhelms, 1993, p. 144).

The following was taken from the Center of Astrogeology Monthly Report for November 1967 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 30 November 1967:
The Geological Survey's Center of Astrogeology participated as an exhibitor at the Arizona State Fair held 3-12 November 1967 in Phoenix, Arizona. Two developmental lunar simulator test vehicles, the "Mobile Geologic Laboratory" (MGL) and the "Explorer", were on display together with nine panels depicting the lunar research program of the Survey. Several thousand persons viewed the exhibit and received USGS leaflets (Fig. 51).

Between January 1967 and November 1967, David Dahlem and Joe O'Connor of the Branch of Astrogeology's Advanced Lunar Systems Project continued their evaluation of an alpha-source X-ray analyzer (spectrometer) to be tested during actual field exercises for Advanced (Post-Apollo) Systems and AAP projects in the near future (see Fig. 41).

The following was taken from the Center of Astrogeology Monthly Report for December 1967 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 December 1967:
On 11-15 December 1967, branch members, some of whom were to become the Apollo Lunar Geology Experiment Team (ALGE) during the Apollo 11 mission at Mission Control in Houston, attended NASA's Flight Control Orientation and Indoctrination Course at NASA/MSC at Houston, Texas.

During the period of 13-19 December 1967, a record snowfall of 87 inches paralyzed the Flagstaff area and closed all businesses. During this period, some 70 volunteers from the USGS Center of Astrogeology served as drivers and dispatchers for emergency duty. Drivers in vehicles equipped with 2-way radios were assigned to the Flagstaff Police Department and the Sheriff's Office, or dispatched directly from a control center on the 5th floor of the Arizona Bank Building. The Electronics Section of the Center of Astrogeology set up a separate control center at the police station so the police could control the movement of vehicles assigned to them. Astrogeology personnel helped in the delivery of food, medicine and supplies; and taking workers and patients to and from the hospital; they assisted the Post Office Department in the delivery of Christmas mail. The also made countless stops to help dig or pull automobiles out of the snow that were holding up traffic. The work was carried out on a 24-hour basis; and although 8-hour shifts were scheduled, several people worked for 16 to 20 hours without a break.

[Author's Note: Red Bailey noted to this author that in February 1970, when requesting the state Highway Patrol's help in controlling traffic on SR 179 for the Black Canyon crater Field blasting, the Highway Patrol official in charge remembered the USGS' service during the "big snow" and said their cooperation would be a pleasure.]

[Astrogeology Milestone: In December 1967, the Branch of Astrogeologic Studies submitted its seventh *Annual Astrogeology Progress Report* for research carried out during the period 1 July 1966 to 1 October 1967. This report (containing unauthored research reports this time) is in four parts: Part A- Lunar and Planetary Investigations, Part B- Crater Investigations, Part C- Cosmic Chemistry and Petrology, and Part D- Spaceflight Investigations.]

Don Beattie:
"As 1967 was winding down and we were assimilating the advice we received at Santa Cruz, the last major organizational change involving Apollo science was made at NASA headquarters. By December 1967 Mueller established the Apollo Lunar Exploration Office, reporting to Sam Phillips, and put Lee Scherer in charge. Lee had just finished up tying up loose ends from the Lunar Orbiter Program, and his appointment gave him a chance to expand his management role. His new office combined the responsibilities of [Willis] Foster's office and some of the post-Apollo lunar exploration duties of Advanced Manned Missions. He inherited most of Foster's staff as well as other headquarters staff who had become involved in lunar science, including William "OB," O'Bryant, and Richard Green. They had been managing the development of the Apollo geophysical station (ALSEP) in the Office of Space Science and Applications. As part of the agreement to establish this new office, OSSA continued to fund the lunar programs it had started through the end of FY 1969. O'Bryant was named assistant director for flight systems and continued to be in charge of ALSEP. Noel Hinners and his growing Bellcom group also switched hats and supported our new office. Will Foster was given a staff position within OSSA to oversee Apollo experiment selection.

Scherer's appointment was a management masterstroke by Mueller. He was well liked and trusted by John Naugle (who had replaced Homer Newell just three months earlier) and by the science side of NASA, having managed the highly successful Lunar Orbiter Program" (Beattie, 2001, p. 100).

"Mission Control interactions with the experiments to be conducted on the journey to the Moon or on the way back home, as well as those conducted in lunar orbit, were not completely defined in 1967, but the groundwork had been established" (Beattie, 1993, p. 97-98).

Don Beattie continues:
"In mid-September 1967 I attended a dry run at MSC of a session on Apollo mission planning that would be presented later to MSC senior management. At this meeting we were briefed for the first time on the development schedule that MSC expected to follow leading up to the first landing, which was now designated the G mission. Joseph Loftus discussed three types of missions that were possible when we reached the final level: (1) touch and go—this mission might stay on the lunar surface for as little as two hours with no EVA (extra-vehicular activity) permitted, have an umbilical EVA of half an hour, or have an EVA of an hour and a half with the astronauts using the portable life-support system (PLSS) within a limited radius of the LM; (2) limited stay—structured around twenty-two and a half hours on the lunar surface, one EVA, and no deployment of the Apollo Lunar Surface Experiments Package (ALSEP), an automated geophysical laboratory or ground station; and (3) maximum stay—with four EVAs, each lasting up to three hours.

During discussion of these three options, ASPO made it know that it favored the limited stay mission for the first landing. Thomas Stafford, representing the astronaut office, pointed out that on Mercury and Gemini flights it was only after the fourth flight that the spacecraft became really operational, and he expected the same for the LM. He mentioned that LM propellant leaks might restrict the surface stay time and said he thought this situation would improve as LM production continued. He also was concerned that with all the other high priority training they would need, the crew for the G mission would have a hard time completing the required training to carry out a multi-EVA mission. For these reasons he also supported the limited stay as the best that could be accomplished on the first landing. A few days later, at the MSC director's briefing, the limited stay mission was endorsed with one modification; ALSEP deployment would not be deleted. Thus, some two years from the date the first landing would be scheduled, we saw that planning for man's first lunar landing would continue to follow a conservative mission profile. A small victory at the time, ALSEP would still be a part of the science payload.

Soon after this decision was announced, the MSC Crew Systems Division began regular monthly meetings to review and highlight any new problems that could affect the astronauts' EVAs. This new group was named the Lunar Surface Operations Planning Committee and was chaired by Raymond Zedekar. The meetings were well attended by the various MSC offices that had a finger in any of the EVAs. We had established a good working relationship with Ray, so our office was invited to attend as well as staff from Bellcom and USGS. These meetings covered a wide range of topics, including the latest results of space suit simulations and their implications for the astronauts' ability to perform certain types of surface tasks, and we reviewed all other EVA concerns such as PLSS power budgets, tool design, and sampling procedures. These meetings continued through 1968 and were later replaced by another planning process" (Beattie, 2001, pp. 98-100).

Don Beattie:
"Another advance for science was the promotion of scientist-astronauts to be mission scientists and Capcoms during the lunar landing missions. Capcoms were the only ones allowed to speak directly to the astronauts during missions, and they had to be astronauts themselves, a rule still followed for all manned missions. This change went a long way toward reassuring us, especially the field geology PI, that the best advice would be quickly available if the astronauts met with some unexpected discovery or predicament on the lunar surface. We had always hoped that the PIs, and other Earth-bound scientists, would be able to communicate directly with the astronauts, but this never happened except for one instance" (Beattie, 1993, p. 98).

[Author's Note: This was when Caltech's Lee Silver, a member of the Apollo Geology Experiment Team, actually had the opportunity to speak directly with Dave Scott, Commander of the Apollo 15 crew after their return to lunar orbit from the surface (see Beattie, 2001 p. 232).]

[Author's Note: By late 1967, geologist Dave Dahlem (see October 1965) and computer programmer Jack Fife began to dedicate much of their time setting up the IBM-360/30 computer in the new Apollo Data Facility (ADF) at 2720 N. Fourth Street in East Flagstaff (see above). In addition, they began working on the development of the SEARCH and WYLBUR FORTRAN programs being developed for use in data retrieval (primitive word processing program) during the upcoming Apollo missions. They were joined in this work by Red Bailey in January 1968.]

V.S. "Steve" Reed (b. 1947; Physical Science Technician; MS, 1974, Northern Arizona University, Flagstaff, Arizona) arrived in Flagstaff, Arizona (from Midland, Texas) in 1967 to work for the Branch of Astrogeology. Steve began working for Ray Batson's Apollo TV documentation subgroup of the Apollo Lunar Geology Experiment Team at Houston, Texas. He also helped perform photogrammetric calibrations on three cameras that would be flown onboard

Apollo 13 in early April 1970. Reed joined the other SPE personnel in May 1971 for the final session; a simulation of the Apollo 15 planned first EVA. During this simulation the Apollo 15 prime and backup crews carried out science and engineering tasks at Kennedy Space Center, Florida [the "sand pile training site], using pressure suits, science equipment, the lunar rover training vehicle, and the TV camera. The operations and planning teams carried out their mission activities of data compilation and synthesis and used the TV mosaics provided by R.M. Batson and crew for redirecting the TV camera to zoom in on geologic targets of opportunity. Steve worked with the Astrogeology TV-Experiment Team at JPL during Mariner-9 in 1971. Steve Reed left the Branch of Astrogeology in 1975 and moved to Texas.

4.3-1968

[Author's Note: Primarily because of fallout from the tragic Apollo 1 fire at Cape Canaveral in January 1967, only one geologic field-training exercise was carried out for the NASA astronauts by the Branch of Surface Planetary Exploration personnel during 1968 (see Table I).]

A field test of the electronic components for the proposed Apollo Active Seismic Experiment was held during January 1968 at the Cinder Lake test area near Flagstaff. The test compared the lunar prototype geophones and amplifiers against the standard exploration seismic equipment operated by the Branch [of Surface Planetary Geology's] Geophysics Group. The prototype equipment is under development by Bendix Corporation, Ann Arbor, Michigan, and the visiting participants included: R.L. Kovach, Stanford University, (Palo Alto, California) as Principal Investigator; E.M. Davin, NASA, Manned Spacecraft Center, Houston, Texas; J.S. Watkins, University of North Carolina, Chapel Hill, North Carolina, and John Zimmer, Bendix Systems Division, Ann Arbor, Michigan.

[Spaceflight Milestone: Surveyor VII successfully landed on the Moon 10 January 1968, on a smooth area in the Tycho crater ejecta blanket at coordinates 11.4 Deg. W, 40.89 Deg. S. The spacecraft carried a soil mechanics-sampling device, an alpha scattering instrument, a magnet, and polarizing filters on the television camera.]

The following was taken from the Center of Astrogeology Monthly Report for January 1968 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeology; dated 30 January 1968:
Members of the Surveyor Television Investigation staff and other members of the U.S. Geological Survey (Flagstaff, Arizona) who participated in the Surveyor VII mission are: E.M. Shoemaker, R.M. Batson, H.E. Holt, E.C. Morris, R.A. Henry, JoAnne Jordon, K.B. Larson, W.E. Miller, K.L. Stice, B.J. Stokes, Betty Bachstein, J.L. Baugh, and N.L. Langbecker (Fig. 52).

Terrain Analyst Richard Joseph "Dick" Pike (b 1937; Ph.D., 1968, University of Michigan), whose Dissertation Committee at the University of Michigan had included Ralph Baldwin (one of the earliest of the modern lunar geology pioneers-even prior to Gene Shoemaker), spent the summer of 1965 in Flagstaff with the Branch of Astrogeologic Studies as a guest scientist (see Appendices A and B). Pike was hired in 1967 by Hal Masursky to work for the Branch of Astrogeologic Studies on lunar terrain analysis (Lunar trafficability), and Photoclinometry in preparation for the upcoming landings of the Surveyor spacecraft. Dick, who thought he would be going to Menlo Park (not Flagstaff), arrived in Flagstaff just following the great 87-inch snowfall during the period 13-19 December 1967. Dick would officially enter on duty at Flagstaff with the Branch in January 1968. Dick would later transfer to the Menlo Park office of the Branch of Astrogeology in June 1970.

Mathematician Wesley A. Rozema (Professor, Northern Arizona University, Flagstaff, Arizona), who started work at the Branch of Astrogeology back in July 1964, also played a very important role in the terrain analysis work that Dick Pike accomplished during the two and a half years he was at Flagstaff, and in subsequent years. Wes was a professor of Mathematics at Northern Arizona University (NAU) in Flagstaff at that time. The Survey had hired him to do some work even before Dick's original summer of research in Flagstaff. Rozema applied the power spectrum, or Power Spectral Density (PSD) to Pike and Wilson's (already complex) terrain analysis program. PSD is the descriptive technique that comes out of signal processing. It essentially breaks down features along a topographic profile into sine waves of different amplitude and frequency. Wes wrote a program for Dick that takes a lunar terrain, or any profile—and produces this power spectrum. Dick and Wes did some real topography out east of Flagstaff to help calibrate the technique. They had the Surveyors from Astrogeology gathering topographic data out near Roden Crater [currently a local work of art/sculpture] and other places (paraphrased from an interview with Dick Pike by Gerald G. Schaber on 18 May 2001).

Don Beattie:
"As mentioned above (see 1967), the arrangement with MSC Flight Control personnel was formalized in April 1967, when FOD (Flight Operations Division) issued its Flight Control Handbook for Experimenters. It called for an experiments room, later named Science Support Room (SSR), to be located in Building 30 near the Mission Operations Control Room (MOCR).

In 1968, as we continued to refine our activities in the Science Support Room (SSR) at MSC in Houston, it became clear that we needed more space to accommodate all the people and equipment we required to follow the action. Another small SSR was added in the [Mission Control] building.

Ray Batson from the Branch of Astrogeology in Flagstaff recalls that during Apollo 11 this auxiliary SSR got so crowded you could hardly move around. In addition to Ray's crew, who were monitoring the television pictures coming back from the Moon and the air-to-ground conversations with the astronauts, Bendix engineers were at their consoles keeping track of the data transmitted from the deployed experiments. Court reporters [Keith Welch and Don Thacker brought down to MSC from Flagstaff (and later Ben Leesman from Washington, D.C.) by the USGS Team] were also taking down the voice communications so this historic record wouldn't be lost if the tape recorders malfunctioned, as they frequently did in NASA's early days. Later in the program, for the final landings, three SSRs were staffed, two for surface science and one for orbital science" (Beattie, 2001, p. 94-96).]

[<u>Author's Note</u>: Gordon Swann suggested to this author that the main reason for the court reporters was to have a near-real-time printed transcript. After Apollo 11 the auxiliary SSR was moved to a larger room where a plotter allowed Ray's crew to create in real-time map of each landing site showing where the astronauts were and had been. They would supplement the map with Polaroid panoramas captured from the TV pictures sent back to Earth. Based on all this information, the staff and PIs in the SSR would formulate questions and send them to the capsule communicator (CAPCOM), who would then decide whether to pass them on to the astronauts.]

Gordon Swann:
"The science back room concept I think was originally developed by Gene Shoemaker as a place where a bunch of scientists, in this case particularly geologists, geoscientists, geophysicists, would sit and try and assimilate the data as it was coming from the moon. In fact, Gene envisioned it as being a situation where somebody, I think he hoped him, would talk directly to the astronauts back and forth. This was never allowed; it always had to go through a capsule communicator (Capcom). A lot of people, including a few of the astronauts, took this to mean Gene wanted to sit there and tell them everything to do. Well, that's really not what he wanted—and that's not what developed. What developed into a back room was the idea that we could assimilate data and sometimes give them suggestions or answer questions, but as far as telling them what to do, we never tried to tell them what to do. We made suggestions. We couldn't make them do anything they didn't want a quarter of a million miles away, and they're a pretty independent bunch of guys!

They also had some pretty independent people that were running the mission in the control center, and it wasn't the people in the [science] back room that were doing it. So everything we did, or thought, or wanted to send up there went through kind of a laundering process though eventually through the Flight Director to the Capcom, and then on up to the astronauts. Sometimes, this turned into a bit of a game of gossip where we would want to ask a question, and by the time it went through all these filters, the question we originally asked was quite different. But that's the way it was" (from a 1996 interview with Gordon Swann by Kirk Wolfinger from Lone Wolf Productions in preparation for the NOVA documentary "*To the Moon*").

Don Wilhelms:
"The popular media have left us a record of the enthusiasm for Surveyor of the ebullient, articulate, flamboyant Shoemaker and three of his nine or so USGS Surveyor henchmen - photogrammetrist Ray Batson, and geologists Elliot Morris and Henry Holt. Just after midnight on 7 January 1968 they came roaring up in an automobile only a few thousand feet away from the launch pad 36A where an Atlas-Centaur was waiting to fire Surveyor VII toward the Moon. It was their last chance to see a launch of their favorite machine, and the most scientific one to boot. Security guards made sure they saw it from a safer place. They would have plenty of opportunity to vent their enthusiasm in the Space Flight Operations Facility at JPL during the mission operations, and more than plenty in the long-drawn-out process of preparing reports, which for the interesting Surveyor VII were particularly voluminous" (Wilhelms, 1993, pp.145).

The following was taken from the Center of Astrogeology Monthly Report for February 1968 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 29 February 1968:
The first routine rock analyses were completed during February 1968 at the Flagstaff Petrology Laboratory (16-18 Mike's Pike in downtown Flagstaff, Arizona) under the direction of Gerald G.

Schaber (SPE Branch). Atomic adsorption is being used as the main analytical technique with x-ray emission as backup.

Astronauts for the Apollo 8 and Apollo 9 crews participated on 13-14 February 1968 in a refresher geology fieldtrip in the Big Bend National Park area of west Texas. The astronauts included Frank Borman, E.E. Aldrin, J.A. Lovell, N.A. Armstrong, Michael Collins, and W.A. Anders. Instructors for the trip were J.W. Dietrich, D.S. McKay and R.B. Laughon from the Manned Spacecraft Center, Houston, Texas, and M.H. Hait from the U. S. Geological Survey (SPE Branch, Flagstaff, Arizona). The field trip emphasized rock identification and interpretation of field relationships. On part of the trip, the astronauts followed procedures similar to those they will use on the Moon: they used aerial photographs as a basis for planning geologic traverses, and then carried out the traverses collecting samples, taking photographs and giving verbal descriptions.

The [Surface Planetary Exploration Branch's] data storage and retrieval program SEARCH-I was completed in February 1968 by J.B. Fife and is operational on the IBM 360/30 computer [at Building-Four on Fourth Street in East Flagstaff, Arizona]. This program will provide cross-indexing and recall of verbal geologic descriptions entered from data cards. Recall is accomplished from either the card reader or the console typewriter by typing phonetic code words equivalent to standard geologic jargon in the following format, for example: <u>B</u>asalt, <u>B</u>Lack, <u>and LOcation</u>. The answer to this question would be a list of the locations of all black basalts catalogued in the system printed on the on-line printer. The program is an up-dated form, which will be used to recall geologic descriptions during the Apollo missions.

[<u>Author's Note</u>: The above may seem very crude and quite funny to today's' computer-wise students and professionals; but the assembler and FORTRAN IV language program SEARCH should actually be thought of as a rudimentary precursor, the very inventive ancestor of modern database programs in many ways. It is still remarkable to me—and I was there—that we ever got to the Moon with computers still being in their infancy—or did we get there BECAUSE that was true? That is a very Interesting question!]

The following was taken from the Center of Astrogeology Monthly report for March 1968 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 29 March 1968:
A major review of the Apollo Lunar Geology Experiment was held in Flagstaff, Arizona during March 1968. Members of the Investigator team present included Principal Investigator, E.M. Shoemaker, Center of Astrogeology, Flagstaff, Arizona and Co-investigators: G.A. Swann and M.H. Hait, Jr., Center of Astrogeology, Flagstaff, Arizona, J. Hoover Mackin, University of Texas, Austin, Texas, and Harrison H. Schmitt, NASA, Manned Spacecraft Center, Houston Texas. Other attendees included members of the Center of Astrogeology and representatives form the Manned Spacecraft Center, Houston, Texas, NASA Headquarters, Washington, D.C., Bellcom, Inc., Washington, D.C., and Marshall Space Flight Center, Huntsville, Alabama. The meeting had two prime objectives: first, to conduct a comprehensive review of the experiment and the necessary background information and, second, to review and complete for the National Aeronautics and Space Administration the Definitive Experiment Plan which defines all the operational requirements of the experiment.

The meeting included discussion of all the topics important to planning and implementing the geologic parts of the main phases of Apollo missions: Pre-flight preparation, lunar surface operations, and Post-flight analysis.

The investigator team succeeded, through resounding discussions, in arriving at a consensus for the Definitive Experiment Plan so that the Plan was soon submitted to NASA for consideration and implementation.

The following outline of topics (and who discussed them) indicates the scope of the above meeting and the breadth of the Lunar Geology Experiment:

<u>Apollo landing sites</u>

Site selection (Harold Masursky)
Small scale geologic maps (L.C. Rowan)
Large scale geologic maps (N.J. Trask)

<u>Detailed problems of lunar maria</u>

General geologic features and origin of maria (J.F. McCauley)
Details of Surveyor sites (E.M. Shoemaker)
Polarimetry and photometry of Surveyor sites (H.E. Holt)

<u>Apollo mission profile</u>

Summary of the lunar surface mission—detailed description of operational and scientific activities on the lunar surface (H.H. Schmitt)

<u>Demonstration of Apollo lunar hand tools</u>

Hand tools, sample bags, sample return containers (M.H. Hait, Jr.)
Stereo and other photographic techniques (R.M. Batson)

<u>Film and television cameras</u>

Apollo TV camera (G.A. Swann)
Hasselblad camera (W.T. Borgeson)
Data reduction of Hasselblad photos
    Photogrammetry (R.M. Batson)
    Photometry (H.E. Holt)
    Interpretation (E.M. Shoemaker)
Time sequence camera (M.H. Hait)

Geologic field procedure, traverses, and traverses planning

Traverse planning

- Problems of locating Lunar Module (N.G. Bailey)
- Nominal vs. contingent traverses (J.M. M'Gonigle)
- Lunar surface geologic maps (T.N.V. Karlstrom)
- Field geology guides (Ivo Lucchitta)

Traverse techniques (T.H. Foss)
Sampling (E.M. Shoemaker, J.H. Mackin)
Vision problems on lunar surface (K.V. Edmonds)

Field simulation of Apollo traverses

Demonstration of simulated scientific support room, Mission Control Center, Houston, Texas (D.L. Schleicher, D.H. Dahlem, N.G. Bailey, G.G. Schaber, R.L. Sutton, G.E. Ulrich)

Experiment requirements for preliminary sample examination

Activities of preliminary sample examination team (J.H. Mackin)
Stereo photography of returned samples (W.T. Borgeson)

Experiment requirements for astronaut time

Astronaut training (A.H. Chidester, T.H. Foss)
Astronaut debriefing (E.M. Shoemaker)

Data analysis and reports

Preliminary report, mission report, scientific papers (E.M. Shoemaker)

[Astrogeology Milestone: On 14-15 and 21 March 1968 an important Apollo Data Facility (Science backroom concept) test and Apollo suit demonstration (by Tim Hait) was carried out for NASA and various NASA contractors at Cinder Lake Crater Field # 1 (Fig. 53).]

R.A. Mills, B.J. Tinnin, and I.L. Wiser participated during March 1968 in the geomagnetic field work conducted by H.L. Krivoy in the Hopi Buttes area involving the Branch of Surface Planetary Exploration's Explorer vehicle.

Gerald Schaber, Red Bailey, David Dahlem and David Schleicher (SPE Branch, Flagstaff) were at the Marshall Spaceflight Center (Huntsville, Alabama) 25-29 March 1968 to critique their "virtual" lunar rover vehicle system. One could "drive" on the lunar surface via a television camera suspended over a conveyor belt on which a simulated Moonscape had been created.

During March 1968 the Film Documentation Unit of the SPE Branch completed the color-sound motion picture "Early Apollo Test No. 13." The film documents a test conducted in late 1967 at the Cinder Lake area, near Flagstaff, Arizona. Two suited test subjects (Tim Hait and Dave

Schleicher) conducted geologic traverses carrying maps and photographs in order to define graphic aid criteria for lunar exploration. The film also documents the building of the crater field on which the test was conducted, describes graphic aids, results of test, and suggestions for lunar use. The running time of the film is approximately 12 minutes.

The following was taken from the Center of Astrogeology Monthly report for April 1968 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 30 April 1968:
In April 1968 Court reporters Donald R. Thacker and Keith E. Welch, Coconino County Superior Court, Flagstaff, Arizona, participated in a brief test to study court-stenographer techniques as a means for quickly getting a complete typed transcript from a geologic field description. Mr. Thacker stenographically recorded descriptions from an audiotape made during a recent field test, and Mr. Welch translated the stenographic notes into a typed record. The reporters had not worked together in this way before and they were unfamiliar with geologic terms and were hampered by the occasionally poor quality of the recorded radio transmissions. Even so, the typed record typically lagged behind the oral description by less than 80 seconds, and there were only a dozen or so significant errors in roughly a half-hour's description. [See 3-5 June 1968 ADF Demonstration below.]

The following was taken from the Center of Astrogeology Monthly Report for May 1968 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 May 1968:
Construction work was completed in May 1968 on the Astrogeologic Data Facility (ADF) trailers. The field test systems group will continue on this project until electronics outfitting is completed, assisting in construction and installation of console mounts, antennas, tripod bases and related accessories.

The following was taken from the Center of Astrogeology Monthly Report for June 1968 to the Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 30 June 1968:
On 3-5 June 1968, a simulation was held demonstrating the latest version of the Apollo Scientific Support Room [the Surface Planetary Exploration Branch's recently completed Apollo Data Facility (ADF) at 2720 N. Fourth Street in East Flagstaff (See Fig. 44) that has been suggested in the Definitive Experiment Plan (Fig. 54).

The system consisted of four main groups; (1) The ADF crew, (2) the computer crew, (3) the Investigator Team for the Field Geology Experiment, and (4) the field men. The first three groups occupied the ADF building and were connected by radio and television links to the field men at the Cinder Lake Crater Field.

The purpose of the simulation was to try out the present system to see to what extent it would work for compiling and analyzing, in real-time, the type of geologic data to be sent back from Apollo missions. This means, more specifically, finding out problem areas that exist in the data flow between groups and individuals within the ADF building and between the ADF building and the field men.

During the simulation the general activities consisted of data compilation by the ADF and computer crews and data analysis by the Investigator Team. From this, geologic questions were raised, arranged in priority, and fed back to the field men at appropriate times. Overall, this procedure worked quite well and the simulation is considered a success. In detail, several kinds of important problems were clarified: (1) intercommunication needs within and between the groups, (2) design and placement of display panels, (3) placement of individuals, (4) appropriate kinds of questions to relay to the field men, (5) redefinition of tasks within groups, and (6) methods of data recall from the computer and cross-indexing data not applicable to computer storage.

During the simulation, the SEARCH computer program was used to store and retrieve oral geologic descriptions similar to those expected in Apollo and Post-Apollo missions. Data input consisted of phonetic abbreviations (e.g., crater=CTR, etc.) entered on coding sheets and then punched on data cards; data output consisted of answers to questions, and was obtained from the computer printer. The time lag between data origin and storage was approximately ten minutes and was the only major operational problem encountered in data storage and retrieval. With the aid of input devises such as the IBM 1092-3, this time lag should be reduced to several seconds.

With the assistance of T.L. Youd from the Engineering Branch in Menlo Park, California, G.E. Ulrich (SPE Branch) in June 1968 conducted experimental measurements in the Cinder Lake Crater Field, Flagstaff, to investigate the correlation between near-surface pyroclastic stratigraphy and engineering properties of the surface materials. Tests included bulk density, bearing capacity, penetrometer, vane shear, direct shear, and grain-size distribution analyses.

The following was taken from the Center of Astrogeology Monthly Report for July 1968 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 30 July 1968:
Beginning 5 July 1968 Gene Shoemaker (as a much-needed diversion from Project Apollo) set out on a three month, one thousand mile journey with a U.S. Geological Survey expedition down the Green and Colorado Rivers to retrace the pioneering Grand Canyon expedition of John Wesley Powell 100 years earlier and to duplicate (hopefully from the same photo-locations) as many of E.O. Beamans and John K. Hiller's historic 1871-1872 photographs of the Canyon as possible (Stephens and Shoemaker, 1987, 286 pages). The primary objective of trying to exactly duplicate the 100-year-old photographs was to provide an unprecedented record of exactly what happens in a century of geological time. "The answer—in the unblinking black and white objectivity of the photographs—is not very much" (Stephens and Shoemaker, 1987, p. vii).

[Author's Note: As of August 1 they have progressed to Vernal, Utah, and have recovered 95 percent of the Beaman-Hillers camera stations (see Stephens and Shoemaker, 1987).

The following was taken from the Center of Astrogeology Monthly Report for July 1968 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 30 July 1968:
In July 1968, W.T. Borgeson (Branch of Astrogeologic Studies, Flagstaff, Arizona) reported that he had developed and tested detailed photogrammetric calibration procedures for the Apollo Hasselblad camera. The methods were tested with a prototype of the flight camera. The focal

length, distortion characteristics, and location of the point of symmetry were determined from data taken on the U.S. Geological Survey camera calibration at the Branch of Research and Design in Mclean, Virginia. These data were reduced with a computer program written by W.T. Borgeson. The reduced data were referenced to a coordinate system based on the location of the image of the frame corners, because fiducial marks have not yet been incorporated into the test camera.

J.T. O'Connor reported during July 1968 having completed the first stages of an X-ray diffraction data-smoothing computer routine that will provide clean data to an American Society for Testing Materials' mineralogical data search program presently being developed. This data handling system will be used in conjunction with the Phillips's "Surveyor" diffractometer presently being evaluated and calibrated in the Flagstaff Petrology Laboratory (16-18 Mike's Pike in downtown Flagstaff) by G.G. Schaber and R.L. Swenson.

The Survey's "Explorer" lunar mission development vehicle had several additional pieces of instrumentation fitted to it during July 1968 in preparation for upcoming field tests. The most significant piece of equipment is the gyrocompass navigational system. Other new installations include a communications repeater, a gravimeter, and a new control station for the magnetometer gear. A wide range of adjustment in the positioning of the navigation system map plotter and control panel allows for operation of the vehicle by either shirt sleeve or pressure suit methods (Fig. 55).

[Astrogeology Milestone: On 27 July 1968, Norman "Red" Bailey (Branch of Surface Planetary Exploration) directed the firing of three separate groupings (354, 61, and then 11 shots) of ammonium nitrate fertilizer (trade name, Nitro-Carbo-Nitrate-) and dynamite charges in order to create simulated impact craters of various sizes and three distinct ages at the Cinder Lake Crater Field #2 (1,200X 1,200 feet in size) just east of Flagstaff. A total of 1,153 pounds of dynamite, 28,650 pounds of nitro-Carbo nitrate, and 40,000 feet of Primacord were used to construct this field. Crater field #2 was located just south of Sunset Crater and just north-northwest of the original Cinder Lake Crater Field #1 constructed by Bailey and others in July 1967; see 1967 and Fig. 48). On 24 July-26 August 1968, Red Bailey leased a burner to burn off the grass from both Cinder Lake Crater Field #1 and #2. The Film Documentation Unit of the SPE Branch produced a rather dramatic 16-mm film of the crater field being created entitled "Mare Tranquillitatis, Flagstaff, Arizona; available on loan at the U.S. Geological Survey's Flagstaff Field Center, Flagstaff, Arizona) (Fig. 56).

[Author's Note: On 17 January 1969, Cinder Lake Crater Field #2 was "salted" with rocks from outside the crater field area to make the astronaut-training experience more realistic and educational with regard to geologic rock types; see January 1969 for more details).

In July 1968 there was an extremely important (as it turned out) meeting that Tim Hait [Branch of Astrogeology-Flagstaff] attended in Houston—probably alone—of Ray Zedekar's LSOP (Lunar Surface Operations Planning] meetings.

Gordon Swann:
"I think that is where Tim met John Cooper and Bruce Walton who were flight operations guys. Tim talked to them about how we [the Apollo Lunar Geology Team from Flagstaff] would like to work with the Control Center—and they introduced Tim to their boss, Jim Saultz. And a few days later, Shoemaker, I [Gordon Swann], Tim Hait—and I think maybe Dave Schleicher—were invited by Saultz over to his house one evening for snacks and cocktails; a fairly long session as I recall.

Gene Shoemaker held forth on the kind of things we'd like to do in the Control Center—and really wowed Jim Saultz. So that was our nose into the Control Center. Those guys were very supportive of us. And it wasn't very long after that that they got us involved in some simulations. That's when the Flight Director's started getting supportive of us—and particularly I think that Gene Kranz, Jerry Griffin, and Glynn Lunney, were very good friends of ours in the Control Center, as was Chris Kraft" (from an interview with Gordon Swann by Gerald G. Schaber on 16 February 2001).

The following was taken from the Center of Astrogeology Monthly Report for August 1968 to the Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 August 1968:
On 1 August 1968, Red Bailey, Rick Hoffman and Bill Brown (NAU student) conducted the explosion of a rather large test crater on Black Point Lava Flow (Babbitt Spider Web Ranch area, U.S. 89 N. of Flagstaff (Fig. 57). Other USGS personnel possibly witnessing this test shot were Dave Haines, and members of the SPE Branch's In Situ Geophysics group. Black Point Flow had been in contention as an alternate site for the second crater field in the Flagstaff area before it was decided to construct Cinder Lake Crater Field # 2 adjacent to Cinder Lake Crater Field #1 (see above).

On 11-15 August 1968, Red Bailey (SPE Branch- Flagstaff) participated in a test demonstration of the Martin-Marietta 10-foot lunar drill near Bakersfield, California. Also attending the test were Lee Thompson (Martin-Marietta), Dick McComb and Jack Sleight (NASA), Mark Langseth, Dick Perry, and Harry Gibbons (Lamont Oceanographic Institute), Keith Peacock, Hayden Grubbs, (Bendix Corporation). Discussed details and observed lunar drill test at the Button willow site west of Bakersfield. [<u>Author's Note</u>: Red Bailey informed this author that—at their request- he dug a solar still to demonstrate survival techniques while at the lunar drill test site.]

A meeting of the Apollo Lunar Geology Experiment Team was held in Houston, Texas, August 12-13, to review the 1:5,000 scale Apollo site maps being prepared by Astrogeologic Studies Branch personnel in Flagstaff. Authors of the maps, representatives form the Mission Planning Project of the Branch of Surface Planetary Exploration, and representatives from the Science and Applications Division, Manned Spacecraft Center, Houston, Texas, were also present. Present plans are to carry these maps (overprinted on Orbiter photo bases, of the chosen landing sites), aboard the Apollo spacecraft during Apollo lunar landing missions.

Revised maps of the five prime sites for early Apollo landings, at scales of 1:100,000 and 1:25,000 were completed and transmitted in August 1968 to the Manned Spacecraft Center, Houston, for inclusion in the data package to be used during the early Apollo missions and during training for the missions. Continued detailed study of the sites had brought out significant differences between the sites that will be important in interpreting the results of the Apollo Field Geology Experiment. Preliminary versions of 1:5,000 scale annotated mosaics for the sites have been completed; these will be made consistent with each other and with the smaller scale maps during September 1968.

[Astrogeology Milestone: In August 1968, (unofficially during January 1967) Hal Masursky becomes Chief of the Branch of Astrogeologic Studies (albeit only until June 1969 when Jack McCauley took over).]

During August 1968 Bob Sutton and Al Dale (USGS) acted as the suit subject during evaluation of a mock spacesuit suit brought over by the Walt Disney Studios in California. It was evaluated in conjunction with a geophysics field demonstration using the Explorer vehicle at Cinder Lake Crater Field #2. There is very little documentation of the details of this demonstration or of the Disney suit. However, there were photographs taken of John Hendricks in the Disney suit being at the Cinder Lake Crater Field in December 1968 (Fig 58).

The following was taken from the Center of Astrogeology Monthly Report for September 1968 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 30 September 1968:
The Huntsville (tank type) vehicle navigation device was installed on the Explorer vehicle in September 1968, and was tested 24 September 1968 on traverses up to 13 miles in length in the Cinder lake area near Flagstaff, Arizona. The plans are to develop a computer program to automatically correct the telemetered coordinate data so that accurate traverse locations can be plotted on the Milgo plotter immediately after data acquisition.

G.G. Schaber, Project Chief of Post-Apollo Geological Instruments project reported in September 1968 that he was currently investigating the use of an available silicon detector X-ray spectrometer system for application to a lunar and planetary x-ray diffractometer. This new technique, recently announced at the Denver X-ray Diffraction Conference in August, utilizes the white or background radiation from an X-ray tube to provide variation in wave length resulting in the possible design of an X-ray diffractometer with reduced number of moving parts, but with satisfactory resolution for the lunar and planetary application.

The Film Documentation Unit of the Surface Planetary Exploration Branch reported in September 1968 that it had completed the color-sound film "Mare Tranquillitatis, Flagstaff, Arizona." A model of one part of the lunar surface, Apollo landing site II-P-6, was "duplicated" in the form of Cinder Lake Crater Field near Flagstaff, Arizona. The 13-minute film is a documentary on the planning and construction of the crater field.

[Space Exploration Milestone: "As if to heighten the sense of urgency surrounding the circum-lunar missions, the Soviets achieved a notable advance in mid-September 1968: an unmanned spacecraft called Zond 5 flew a figure eight loop to and around the Moon and splashed down in the Indian Ocean, all under automatic control" (Chaikin, 1994, p. 76).]

The following was taken from the Center of Astrogeology Monthly Report for October 1968 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 October 1968:
A series of field tests was held in the Cinder Lake area during the month of October 1968, which culminated in a demonstration for NASA's Lunar Roving Vehicles Working Group on October 17. This series of tests utilized the "Explorer" vehicle, simulating a manned lunar roving vehicle. Navigation unit and rubidium vapor magnetometers were mounted on the vehicle, and geologic observations and gravity readings were relayed to the Astrogeologic Data Facility, where they were reduced and displayed in real-time. Samples at the end of each traverse were analyzed by X-ray diffraction and spectroscopy—simulating analysis on the Moon—and the information used to help plan sampling activities for the succeeding traverses.

The geologic descriptions and analytical data were stored, for rapid access and cross-referenced in the IBM 360/30 computer by means of the SEARCH II program. The magnetic readings were corrected by the 360/30 computer, and plotted and displayed in real-time in relation to the photogeologic map of the area. The navigation unit was used to determine the location of data-collection points on the map.

Personnel changes during October 1968

<u>Office of the Deputy Assistant Chief Geologist</u>
Bruce R. Julian, Geologic Field Assistant, resigned, Flagstaff, Arizona

<u>Astrogeologic Studies Branch</u>
Clarence J. Casella, Geologist, entered on duty, DeKalb, Illinois
Baerbel K. Lucchitta, Physical Science Technician, resigned, Flagstaff, Arizona
John Matzko, Geologist, entered on duty, Washington, D.C.
Charles E. Meyer, Geologic Field Assistant, entered on duty, Menlo Park, California
Grace A. Thornton, Clerk-Typist, entered on duty, Washington, D.C.

<u>Surface Planetary Exploration Branch</u>
Richard W. Brown, Geologic Field Assistant, resigned, Flagstaff, Arizona
Leland Dexter, Physical Science Aid, entered on duty, Flagstaff, Arizona
Richard H. Godson, Geophysicist, transferred to Computation Branch, Flagstaff, Arizona
Aaron C. Waters, Geologist, entered on duty, Santa Cruz, California

[<u>Space Exploration Milestone</u>: In November 1968, the Soviet Spacecraft Zond 6, like Zond 5 had done two months earlier, looped around the Moon from the northern near side to the southern far side before returning to Earth for a braked landing.]

The following was taken from the Center of Astrogeology Monthly report for November, 1968 to the Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 30 November 1968:
[<u>Astrogeology Milestone</u>: During November 1968, the following investigators from the Branch of Astrogeologic Studies were appointed for the Mars Mariner 1971 programs by the National Aeronautics and Space Administration: Harold Masursky, Principal Investigator; J.F. McCauley,

D.E. Wilhelms, D.J. Milton, R.L. Wildey, and W.T. Borgeson, Co-Investigators. R. Batson was also appointed Co-Investigator at a later date.]

In addition, the TV teams composed of five principal investigators and 27 Co-Investigators were also organized along discipline lines:

Team Leader:	Harold Masursky, U.S. Geological Survey, Flagstaff, Arizona
Geology:	J.F. McCauley, U.S. Geological Survey, Flagstaff, Arizona
Variable Features:	Carl Sagan, Cornell University, Ithaca, New York
Exobiology:	Joshua Lederberg, Stanford University, Palo Alto, California
Hardware/Data Processing:	B.C. Murray, Caltech, Pasadena, California
Geodesy-Cartography:	Gerard de Vaucouleurs, University of Texas, Austin, Texas

D.E. Wilhelms and Harold Masursky, Astrogeologic Studies Branch, U.S. Geological Survey, and J.W. Dietrich, manned Spacecraft Center, Houston, gave a briefing at Cape Kennedy during November 1968 on photography to be acquired on the Apollo 8 mission in December. The briefings were given to astronauts W.A. Anders, LM pilot of the prime crew, and F.W. Haise, Jr., LM Pilot of the backup crew.

Ivo Lucchitta, Chief, Apollo Geologic Methods project, held a meeting in November 1968 with appropriate personnel of the Surface Planetary Exploration Branch in Flagstaff to discuss inadequacies of our present crater fields, improvements that can be made, and what other test sites might be needed for Apollo Investigations. As a result, it was decided to improve the newer of Astrogeology's crater fields—which is somewhat lacking in geologic diversity—by suitably "salting" it with fragments and blocks of rocks of varied lithology, arranged to reflect both a specific stratigraphic sequence and geologic processes that would have acted on this sequence. The geologic model is being devised, and soon the appropriate rocks were indeed collected for distribution around the craters.

The sound-color film entitled "The Geology of Zuni Salt Lake Maar" was completed in November 1968 by the Film Documentation Unit of the Branch of Surface Planetary Exploration in Flagstaff, Arizona. The film describes the geologic history of this area in New Mexico, with emphasis on the crater-forming mechanics. The running time is 15 1/2 minutes.

The Director, USGS, approved the following films during November 1968 for Open-Filing:

Hawaiian Volcanoes—Astronaut Field Trip
Production Number 6501-2B

Kilauea Volcano—Geophysical Studies and Structural Relations
Production Number 6501-2B

Katmai! Astronaut Training Trip to Katmai, Alaska
Production Number 6506-2

Early Apollo Test Number 13
Production Number 6710-2A

During November 1968, D.E. Elston, Chief, Post-Apollo Geologic Methods project, was given the added responsibility for the development of all ELM (Extended Lunar Module) mission plans. G.E. Ulrich, Chief, Advanced Systems Research, was given the added responsibility for the development of mission plans concerned with dual-mode lunar roving vehicles

The following was taken from the Center of Astrogeology Monthly Report for December 1968 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 December 1968:
Members of the Survey's Apollo Field Experiment Team, with the support of the Photographic and Photogrammetric Support Units, provided in December 1968 a suite of 18 samples to the Lunar Receiving Laboratory at the Manned Spacecraft Center, Houston, Texas, for analysis during a "dry run rehearsal" in preparation for the first lunar landing mission.

The samples were collected from the ejecta blanket and underlying materials near one of the craters in the Cinder Lake Crater Field Number One just northeast of Flagstaff, Arizona. Brief descriptions of each sample and its geologic setting were tape-recorded in the field to provide field data comparable to that expected from the astronaut's lunar observations. The sample areas were photographed before and after sampling with prototypes of the camera and gnomon that will be carried on the lunar missions. The photographs will provide additional descriptive, location, and orientation data.

The descriptions and photographs, together with large-scale geologic maps made from the descriptions and photographs, will be supplied to the Lunar Sample Preliminary Examination Team during the "dry run." This will allow the geochemical and mineralogical analyses to be conducted in light of the geologic setting of the samples in the same way that the lunar samples will be analyzed and the results interpreted.

H. Chidester, G.A. Swann, and G.E. Ulrich were participating observers of a field test conducted in December 1968 by the Advanced Lunar Studies Team of the Jet Propulsion Laboratory, Pasadena, California. The test was one of a series held in the Mojave Desert and was designed to evaluate speed and accuracy of determining location by resection using a remotely controlled television camera. Positions within an area of one-half mile were determined with moderate confidence after several hours. As a more realistic simulation of lunar navigation problems the U.S. Geological Survey group recommended the use of high altitude aerial photography, rather than topographic maps.

Description of rocks and soils by television and use of the Surveyor scoop sampler and a "hard rock" helical screw sampler for use on a Lunar Roving Vehicle (LRV) were also part of the experiment.

[Space Exploration Milestone: At Christmas 1968, the Apollo 8 crew (James Lovell, Frank Borman and William A. Anders) became the first humans to reach and orbit the Moon, and gave a stirring reading of Genesis out of the Bible on Christmas Eve. Apollo 8 was originally supposed to be an Earth orbital mission, but was upgraded to a lunar orbiting mission by NASA headquarters when it was thought that the Soviets were nearly ready to try for the Moon themselves. Apollo 8 was launched on 21 December 1968. For details on the reasoning behind Apollo 8 becoming a trans-lunar flight instead of an Earth orbital mission, see Chaikin, 1994, pp. 56-134].

During 1968, the "Terrestrial Remote-Sensing Group" was put together by several personnel from the Branch of Astrogeologic Studies. This group operated out of the Branch of Astrogeology in Flagstaff for one-and-a-half to two years before leaving Flagstaff in 1970 to become part of the Regional Geophysics Branch in Denver. The Branch Chief [of Regional Geophysics] at that time [in Denver] was Don Maybe; the leader of the Terrestrial Remote Sensing project was Ken Watson (from Astrogeology in Flagstaff). Other Astrogeology scientists initially on this project [while it was still in Flagstaff] included Larry Rowan, Terry Offield, Howie Pohn, Jan Cannon, Maurice Grolier and Bob Watson who was hired later. Only Maurice Grolier and Jan Cannon did not go with the group to Denver. Maurice Grolier remained in Flagstaff, and Jan Cannon went back to graduate school at the University of Arizona; then he went to Alaska, and eventually back to Oklahoma. [See 1963-Ken Watson's biography.]

David Levy:
"Gene rejoined the California Institute of Technology (Caltech) as a research associate in 1968. During the last years of the 1960's, virtually all of his time was spent, vicariously at least, on the Moon, with the exception of some field trips to Meteor Crater with Caltech undergrads. The chairmanship of the Division [of Geological Sciences], however, was not a task that he could do remotely. It would require his full attention, and his moving from Flagstaff to California at least while the Institute was in session" (Levy, 2000, p. 138).

[Branch of Astrogeology Milestone: On 18 December 1968, Flagstaff's civic and scientific leaders honored Dr. Eugene Shoemaker as "the father of astrogeology" at a testimonial banquet in his and his wife, Carolyn's honor on the occasion of Shoemaker's [temporary] departure from Flagstaff to take the chairmanship of the Division of Geologic Sciences at Caltech (Pasadena, California) (Fig. 59) The article goes on to say:

Dr. Edward M. Danson, director of the Museum of Northern Arizona, said in tribute "Flagstaff has greatly benefited by the mental abilities of Dr. Eugene Shoemaker." It was the coming together in Gene's mind of the scientific opportunities in Northern Arizona—of Lowell Observatory, NAU, Meteor Crater—that led to the USGS Center of Astrogeology and brought together the scientists, students and extra fine citizens that changed the tenor of this community, "Shoemaker, who almost single-handedly developed the concept of a study of astrogeology and sold the USGS on taking such a branch under its wing, is leaving Flagstaff to become chairman of the division of geological sciences at the California Institute of Technology."

"This venture called astrogeology really has two prime ingredients—people and dreams", Shoemaker said. "We are really at the threshold now", Shoemaker said, and "I hope you keep an eye on those unfinished dreams and not worry too much about everyday problems." It was some of those everyday problems such as budgetary worries, Shoemaker said, that "kept us hanging by our fingernails" in the early days of the Center.

[Author's Note: The December 18, 1968 *Arizona Daily Sun* (Flagstaff, Arizona) featured an article by Sun Staff Writer Jane Pritchett on the USGS Center of Astrogeology. The article was entitled "Flag Facility Guides Footsteps of Spacemen." The article also featured a full page of photographs depicting various research activities at the Center of Astrogeology with the caption "Groundwork Vital to Apollo Mission."]

4.4-1969

[Author's Note: A total of 13 geologic field-training exercises were carried out in 1969 for NASA astronauts (See Table I).

David Levy:
"The chairmanship [of the Division of Geological Sciences at Caltech] was offered to Gene by an almost unheard of unanimous vote of the professional staff of the geology division, a real honor from his alma mater and not an offer to be taken lightly. Since joining the Geological Survey in 1948, Gene rather missed the academic life, and early in the 1960's he considered leaving the USGS, and explored the possibility of a professorship at Berkeley. With the pressures of Apollo, the prospect of returning to academia in 1969 was too great to resist. Moreover, Robert Sharp and Lee Silver helped ease Carolyn's reluctance to move to the Los Angeles area; Sharp sent pictures of the local area in an attempt to show that it rivals the Colorado Plateau in interest and beauty, and Silver stopped by at the Shoemaker's residence in Flagstaff with a very large bouquet of flowers.

But as usual in Gene's life, there were complications. When Gene seriously began negotiating with Caltech, he expected that Apollo would be well underway by 1969, and that he could simply switch off his role in the space program and switch on his new role at Caltech. However, the January 1967 Apollo command-module fire set the whole schedule back far more seriously than Gene had figured, and he was faced with completing his work as principal Investigator of Apollo's geological field investigations, and beginning his new Caltech position at the same time.

Regardless of Apollo's schedule, on January 1, 1969, the beginning of Apollo's most historic year, Gene began his new work at Caltech without yet moving to Pasadena.

Gene now had three somewhat incompatible jobs—Apollo, Caltech, and family. With his oldest daughter away at school and the rest of the family settled in Flagstaff, it made sense for the family to wait until the fall of 1969 to make the move to Caltech. Meanwhile, a vacation trip down the Green River through Lodore Canyon during that summer was precious time spent with Carolyn's brother Richard and his family, as well as with friends" (Levy, 2000, p. 138-139).

David Levy:
"When the Shoemaker's finally arrived in Pasadena, they found themselves in the largest house they had ever seen. The place at 312 South Holliston was near the heart of Pasadena, and only one block from the Caltech campus. It seemed intended for a division chairman; the house had a formal dining room and a rose garden" (Levy, 2000, p. 142).

The following was taken from the Center of Astrogeology Monthly report for January 1969 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 January 1969:
S.S.C. Wu, Branch of Astrogeologic Studies, Flagstaff, reported in January 1969 that one model of Hasselblad photography obtained from the Lunar Receiving Laboratory at MSC in Houston, Texas, has been successfully tested on the analytical plotter [at Flagstaff]. A form-line map with a contour interval of 5 cm has been compiled. This photography is intended to simulate the actual photography that will be taken on the early lunar landing missions. No ground controls can be used. A gnomon device placed in the field of view and appearing in each photo is designed to serve as the control for absolute orientation.

T.N.V. Karlstrom (SPE Branch, Flagstaff, Arizona) reported in January 1969 that the final decisions were made by the Early Apollo Map Committee on the design of the maps to be flown in the data Package of the first lunar missions. Survey recommendations on geologic map design were accepted by the committee and will be followed in producing the data package maps [in Flagstaff] for the first lunar landing mission.

Compilations of operational geologic maps for Early Apollo landing areas II-P-2 (by D.E. Stewart-Alexander, M.H. Hait, Jr., and G.A. Swann) and II-P-6 (by J.W. M'Gonigle and M.N. West) have been completed and transmitted to the Science Mapping Branch, Manned Spacecraft Center (Houston, Texas). Jerry Harbour and R.L. Sutton have completed compilation of site III-P-13 and compilations are well along for site II-P-8 by Gerald G. Schaber and N.J. Trask and for site III-P-11 by P.J. Cannon and T.N.V. Karlstrom. It is anticipated that the U.S. Geological Survey will meet its schedule of providing NASA with operational geologic maps of the five landing sites considered for the first landing mission before the end of the month (January 1969).

The northwest quarter of the new Cinder Lake Crater Field # 2 was "salted" during January 1969 with several hundred rock fragments of varied lithology by N.G. Bailey, Ivo Lucchitta, and J.W. M'Gonigle, assisted by E.E. Caddell and B.C. Justus. The fragments range from less than one inch to more than one foot in size, and were distributed (on the basis of a geologic model by Ivo Lucchitta) to reflect geologic events acting on a specific geologic terrane. The area will be used for simulations of Apollo-type traverses.

Walt Roeder (USGS; Flagstaff, Arizona) reported in January 1969 that the Film Documentation Unit of the SPE Branch completed the color-sound motion picture, "When the Astronaut Speaks." The projection time for this film is approximately 23 minutes. This production demonstrates a proposed system for acquiring and manipulating geologic data during Apollo missions through the use of a scientific data facility. It also shows how exploration time can be condensed by swift data handling and feedback to the astronauts, thus assuring the return of the greatest amount of significant data on the most relevant geologic problems.

R.A. Mills reported in January 1969 that the Field Test Systems shop has completed construction of the automatic tracking magnetometer mast on the Explorer vehicle. Heading lock-on is achieved by an arrangement of photocells and shutters attached to an air-driven directional gyrocompass. Servo power for rotating the mast is provided by a reversible electric motor coaxially mounted on the base of the mast.

During January 1969 a field demonstration using MGL, Explorer and a suited test subject (identity unknown at this writing) was carried out for the benefit of film documentation by the National Geographic Society (Washington, D.C.) (Fig. 60). [Author's Note: Little besides photographs could be found to further document the full scope and purpose of this exercise]

[Author's Note: Geologic training exercises in the field at various locations accelerated considerably as the actual crews for Apollo missions were selected, starting in February 1969 (See Table I)

The following was taken from the Center of Astrogeology Monthly Report for February 1969 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 28 February 1969:
A three-day field test on 12-14 February 1969 was run by the Advance Systems project of the SPE Branch at the new Merriam Crater test site near Flagstaff, Arizona. Continuously telemetered magnetometer data were transmitted from the Explorer vehicle to the mobile Astrogeologic Data Facility (ADF trailer). The exercise was a partial simulation of manned Lunar Rover vehicle traverses in volcanic terrain of lava flows and sedimentary rock buried by pyroclastic and alluvial deposits of varied thickness. The north orientation of the magnetometer on a vertical boom was kept constant by a TV antenna motor controlled by an aircraft gyro. When used in conjunction with the gyro-compass navigation system and observations by the geologist, the telemetered magnetometer data enabled definition of buried flow fronts with significantly greater precision than by surface observation and photo-interpretation combined.

In February 1969, D.P. Elston, U.S. Geological Survey (Branch of Surface Planetary Exploration, Flagstaff), G.J. Wasserburg, Caltech, Pasadena, California, and Professors Eduardo Schmitter and Rafael Rodriguez Torres, Instituto de Geologia, U.N.A.M. Cuidad Universitaria, Mexico briefly surveyed part of the strewn field of the "Pueblito de Allende" meteorite fall, about 25 miles east of Hidalgo del Parral, Chihuahua, Mexico. Several specimens were recovered with the aid of local residents, and two specimens could be fitted to their penetration craters and the general direction of fall determined. The work supplements that of Brian Mason and Roy Clark, Smithsonian Institution, who collected extensively in the area prior to the arrival of Elston and Wasserburg. The meteorites fell in an elongate northeast-southwest trending field, about 15 miles long and perhaps 4 miles wide, at about 1:09 A.M. (CST), February 8, 1969.

During February 1969 E.C. Morris (Astrogeologic Studies Branch, Flagstaff) was appointed to the Imaging System Development Team of the Viking-Mars lander 1973 [both Viking spacecraft actually landed in the summer of 1976].

Geologist Michael Joseph Boyce (b. 1946; BS-geology, January 1969, Northern Arizona University; and University of Colorado), who was born in Mesa, Arizona, joined the Branch of Astrogeology as a Physical Science Tech (PST) in February 1969 (see Appendices A and B). Joe started out working in the Branch's Lunar and Planetary Image Data Facility that was then set up on the Fifth floor of the Arizona Bank Building in downtown Flagstaff. Boyce was soon assisting several of the more senior geologists in the Branch, such as Dave Roddy, Bill Colton, Dick Eggleton, Jack McCauley, Larry Soderblom, Ivo Lucchitta, and others. Joe participated in the geologic mapping of—and the geologic training of the Apollo 14 astronauts on—Astrogeology's Black Canyon Crater Field in Verde Valley, Arizona. Working with a technique that Larry Soderblom had originally developed that used crater shadow lengths and photometric properties to relatively date surfaces on the Moon (the so-called DL technique), Joe extended this research and, in collaboration with Larry, eventually contributed several widely referenced and important publications on this subject. He would later work on the Mariner 9 and Viking-Mars missions at JPL in Pasadena.

[Author's Note: In the summer of 1976 Boyce replaced Russ Wahmann (Astrogeology-Flagstaff) as Steve Dwornik's USGS Staff Scientist at NASA Headquarters for two years. Then in 1979, just as Joe was starting to plan to come back to Flagstaff, Steve Dwornik took early retirement and asked Joe to take his place as Discipline Chief for the Planetary Geology Program (later renamed the Planetary Geology/Geophysics Program) at NASA Headquarters. From 1983 through 1992 he stayed on at NASA Headquarters and became Chief of Planetary Geoscience which included the Cosmochemistry Program, Geology/Geophysics Program. In 1992 Boyce took over NASA's Outreach Program at NASA Headquarters, and became its Director. In 1995 Boyce became the Mars Program Scientist at NASA headquarters. In 1997, Joe Boyce became manager of NASA's Cosmo-chemistry and Origins of the Solar System program. Joe retired from NASA in August 2002 and became a member of the research faculty at the University of Hawai‘i.]

The following was taken from the Center of Astrogeology Monthly report for February 1969 to the Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 28 February 1969:
The Science and Traverse Planning Panel for the Lunar Roving Vehicle study met in Flagstaff, Arizona, on February 12-13, 1969, to formulate its contribution to the developing Lunar Rover Vehicle (LRV) Program and to the contractor of the phase I Lunar Roving Vehicle design study.

Persons attending included the following:

A.H. Chidester, A.L. Brokaw, and G.A. Swann, G.E. Ulrich, and R.J. Pike, U.S. Geological Survey, Center of Astrogeology, Flagstaff, Arizona

J.M. Goldberg, NASA Headquarters, Washington, D.C.

R.G. Brereton, Jet Propulsion Laboratory, Pasadena, California

W.M. Greene, R.A. Potter, O.H. Vaughn, Jr., and W.R. Perry, Marshall Space Flight Center, Huntsville, Alabama.

The following was taken from the Center of Astrogeology Monthly Report for March 1969 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 March 1969:
Ivo Lucchitta, G.G. Schaber, D.P. Elston, and D.L. Schleicher collaborated during March 1969 with E.N. Goddard, M.H. Hait, and G.A. Swann in a test run of one of the procedures that will be used in the Lunar Receiving laboratory, Manned Spacecraft Center, Houston, Texas, for

processing geologic samples returned from the Moon. This procedure involves hand specimen study and geologic description of the area from which the sample was collected, which will serve as background for other analyses and procedures carried out in the Lunar Receiving Laboratory. The samples used were collected from the area of the Cinder Lake Crater Field near Flagstaff, Arizona. Convergent stereo photographs were taken of each face of the samples in directions corresponding to the six faces of a cube. The test group made photogeologic maps of each of these faces and of the collection site as seen in oblique field photographs. A written description of each sample and its surroundings was made on the basis of photographic information. Results and procedural recommendations were then presented to the Manned Spacecraft Center, Houston, Texas, there to be integrated with other procedures used in the Lunar Receiving Laboratory.

A report entitled "Lunar Terrain and Traverse Data for Lunar Roving Vehicle Design Study" by H.J. Moore, R.J. Pike, and G.E. Ulrich was completed in March 1969 in response to a request in January from the Lunar Roving Vehicle Study Management Team at the Marshall Space Flight Center, Huntsville, Alabama—through NASA Headquarters in Washington, D.C. The report was prepared under the auspices of the Science and Traverse Planning Panel.

The following was taken from the Center of Astrogeology Monthly Report for April 1969 to Assistant Chief Geologist for Engineering Geology, and to NASA, from Chief, Branch of Astrogeology; dated 30 April 1969):
D.H. Dahlem reported that during April 1969 test studies were conducted at the Manned Spacecraft Center, Houston, Texas, to see if a data storage routine could be set up for the Geological Field Experiment activities during the July G-mission [Apollo 11]. The computer system used was the Com-share time-sharing system based in Houston, Texas, and access was via Teletype. A skeletal storage/retrieval program for geologic map description was written and tested, and demonstrated to be adequate for mission support. Collaborating geologists from the manned Spacecraft Center were J.L. Warner and C.D. Anderson.

Dahlem also reported in April 1969 that the SEARCH storage/retrieval program for oral geologic descriptions was being altered by Jack Fife [USGS, Flagstaff] to take full-word, variable field data from either teletype (or IBM 2741 terminal) or card entry. Until now all data had been entered in acronym or abbreviated fashion in a fixed word format. The changes will give the program the required flexibility for a much wider variety of uses. [Red Bailey recalls that the IBM 2741 typewriter-terminal was used by the LGE Team at Webster, Texas during the Apollo 12-17 missions, and at Flagstaff offices from 1969 on.]

H.D. Ackerman reported during April 1969 that a simulated field test was conducted to test the ability to handle and interpret gravity data. Thirty stations at 500-ft intervals were occupied along two lines normal to each other over the Merriam Crater tuff ring [northeast of Flagstaff]. These data were reduced successfully.

George E. Ulrich reported in April 1969 that a Post-Apollo field test of the quality of geologic observation using fast-scan television transmitted from the Explorer vehicle to the Astrogeologic Data Trailer was held in the Merriam Crater area on 21-22 April 1969. Descriptions based solely on the television picture (525 lines) with various lenses, sun angles, and distances to outcrops were compared with descriptions of the same features observed by a second geologist stationed near the TV camera. Monoscopic vision, limited resolution, lack of color distinction, inability to look around corners, and unfavorable sun angles are the primary handicaps of geologic interpretation by television. Experiments in maneuvering the Explorer vehicle by the interim remote control system added recently by R.A. Mills provided a realistic simulation of some of the problems that will be encountered with the automated lunar Roving Vehicle.

J.D. Alderman reported in April 1969 that a trouble-plagued abbreviated field test of the Philco Ford facsimile camera system was concluded at a site 8 miles southeast of Camp Verde, Arizona. The camp Verde site was occupied instead of a prime Hopi Butte site and secondary Merriam Crater area because of bad weather conditions.

[Astrogeology Milestone: In April 1969, the Branch of Astrogeologic studies submitted to NASA its Seventh Annual Astrogeology Progress Report, for research carried out during the period 1 October 1967 to 1 October 1968. Unauthored reports were in four parts; Part A- Lunar and Planetary Investigations, Part B-Crater Investigations, Part C- Cosmic Chemistry and Petrology, and Part D- Space flight Investigations.]

The following was taken from the Center of Astrogeology Monthly Report for May 1969 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 May 1969:
G.G. Schaber (listed as Principal Investigator), and R.E. Eggleton (listed as Co-Investigator), submitted a proposal in May 1969 to the National Aeronautics and Space Administration (NASA) entitled Apollo CSM Radar Geology. The investigation was intended to provide preflight and mission operations geologic support and post-mission geologic interpretation for a radar study of the moon to be conducted from the Apollo Command and Service Module (CSM). The radar experiment, to use 30-m and 25-cm wavelengths, is being proposed under the leadership of Walter E. Brown, Jr., Jet Propulsion Laboratory (Pasadena, California). Potential results include detection in the subsurface of ices, voids, and interfaces (layering, etc.) - possibly to depths of a few hundred meters using the 30m wavelength.

[Note: Although their original Lunar radar proposal was not selected in 1969, Both Schaber and Eggleton would eventually be appointed as Co-Investigators on the University of Utah's Apollo Lunar Sounder Experiment that would eventually fly aboard the CSM on the final Apollo lunar mission—Apollo 17 (December 1972).]

On 8-9 May 1969, a field test at Cinder Lake Crater Field-1 was carried out. Participating were Al Chidester, Thor Karlstrom, Gordon Swann, and Tim Hait, among others.

[Space Exploration Milestone: On 18 May 1969, the Apollo 10 spacecraft (Eugene A. Cernan, John W. Young and Thomas P. Stafford) was launched to the Moon. This crew became the first manned spacecraft to undock and dock in lunar orbit. "Tom Stafford and Gene Cernan would take the Lunar Module (LM) and descended to within 50,000 feet above the lunar surface, where they would make a critical test of the landing radar. Then, from this close vantage, they would scout Apollo 11's proposed landing site in the Sea of Tranquillity before rejoining Young in the Command Module" (Chaikin, 1994, p. 152).]

The following was taken from the Center of Astrogeology Monthly Report for June 1969 from Chief, Branch of Surface Planetary Exploration to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeology; dated 30 June 1969:
W.T. Borgeson and R.M. Batson (SPE Branch, Flagstaff, Arizona) in June 1969 used the U.S Geological Survey camera calibrator at the Branch of Research and Design in McLean, Virginia, to calibrate two Apollo flight cameras. The cameras are electric Hasselblads with specially designed 60-mm Biogon lenses and with reseau plates on their film planes. A total of 74 glass photographic plates were exposed with the cameras while they were oriented on the calibrator. These plates contain images of the reseau marks and those of the collimator targets as imaged by the lens. Borgeson and Batson reported that preliminary data indicated that maximum distortion in both camera lens-systems is on the order of 5 or 6 microns.

During June 1969, R.M. Batson completed a study of problems associated with image resolution in pictures taken with hand-held cameras on the lunar surface. The range of object distances is greater than the depth of field of the camera lens under these conditions. The depth of field of a camera lens is increased by the use of small lens apertures, but image resolution is decreased because of diffraction limitations. The purpose of the study, therefore, was to compute image resolution as a function of optical resolving power, camera tilt, and object distance, for various film types and aperture settings, and to present these data graphically as percentages of picture area with varying degrees of resolution. The study indicated that the resolving power of a high resolution, slow-speed film such as Eastman 3400 would be useful over a very small area of a picture taken by a hand-held camera, and that the higher-speed, lower resolution Eastman 2405 film, exposed at f/8 and with a 60-mm lens, would have high resolution in the center of the field and degraded, but still useable resolution near the edge of the field.

The Apollo gnomon, serial number 1003, which was used by the Apollo 11 crew, was photometrically calibrated at NASA, John F. Kennedy Space Center (KSC), Florida, in June 1969 by H.E. Holt, R.E. Russell, and G.H. Loring with assistance from J.J. Rennilson of the Jet Propulsion Laboratory, Pasadena, California. Calibration data, consisting of over 5,000 reflectance measurements, were obtained over the range of illumination and viewing geometry that will be present on the lunar surface during the planned surface activities of the astronauts. The gnomon was found to have adequate calibration to serve as a luminance and calorimetric standard on the lunar surface under conditions set forth in the Apollo 11 lunar surface photographic plan.

The Hasselblad electric camera, serial number 1016, and Hasselblad reseau camera, serial number 1003, were photometrically calibrated at Flagstaff, Arizona on 9-12 June 1969. The calibration team consisted of H.E. Holt, R.E. Russell, G.H. Loring, D.A. Kellogg, Center of Astrogeology, Flagstaff, Arizona, J.J. Rennilson, Jet Propulsion Laboratory, Pasadena, California, J.H. Hoskins and H.R. Jones, Manned Spacecraft Center, Houston, Texas. Measurements were made from the frame shading, iris repeatability, veiling glare, shutter constants, and spectral transmission for each camera, which involved recording over 16,000 measurements. Light transfer characteristics and spectral sensitivity of Eastman 3400, 3401, and 2405 films were obtained with both cameras. The calibrations were observed by G.R. Blackman, Manned Spacecraft Center, Houston, Texas, A.F.H. Goetz, Bellcom, Inc. and F.L. Billingsley, Jet Propulsion Laboratory, Pasadena, California.

D.H. Dahlem, D.L. Schleicher, N.G. Bailey, G.G. Schaber, R.M. Batson, Bob Sutton, G.A. Swann, M.H. Hait, A.C. Waters, L.N. Goddard, and E.M. Shoemaker participated in Apollo 11 mission simulations at the Manned Spacecraft Center, Houston, Texas, on June 18, 24, and 28, 1969.

The following was taken from the Center of Astrogeology Monthly report for July 1969 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeology; dated 31 July 1969:
On 1 July 1969 Arnold Brokaw leaves Flagstaff and goes to Reston, Virginia (USGS Headquarters) to be the Deputy Acting Chief Geologist for Astrogeology.

NASA's Science and Traverse Planning Panel for Dual-Mode Lunar Rover Vehicle Studies met in Flagstaff, Arizona on 1-2 July 1969. The attendees were as follows:

<u>U.S. Geological Survey, Flagstaff, Arizona</u>
R.D. Regan, D.H. Dahlem, A.H. Chidester, H.J. Moore, G.A. Swann, G.E. Ulrich, R.J. Pike
<u>NASA Headquarters, Washington, D.C.</u>
J.M. Goldberg
<u>Manned Spacecraft Center, Houston, Texas</u>
E.M. Crum, J.W. Dietrich, A.P. Sanders
<u>Marshall Space Flight Center, Huntsville, Alabama</u>
W.R. Perry, O.K. Hudson
<u>Jet Propulsion Laboratory, Pasadena, California</u>
R.G. Brereton
<u>Bendix Aerospace Systems, Ann Arbor, Michigan</u>
H.D. Faram, D. Marjaniemi
<u>Grumman Aircraft Corporation, New York, New York</u>
W.C. Schoen

U.S. Geological Survey personnel, Flagstaff, Arizona, participated with Manned Spacecraft Center and Lockheed personnel, Houston, Texas, in a field trial of an engineering model for a Lunar Surveying System on the Manned Spacecraft Center Lunar surface model at Houston, Texas, 1-10 July 1969. Test runs were designed to collect data of the accuracy and precision of tracking and orientation systems, and on the clarity, resolution, and usefulness of surveillance and staff television images under various static and moving traverse conditions. Analyses of results were to be incorporated with results of the upcoming field tests at Flagstaff, Arizona; preliminary examination of data indicates that the tracking system worked well, and that the television resolution was good. A short 16-mm documentary motion picture showing the equipment [i.e., Lunar Surveying System] and its function was prepared at the request of MSC's Spacecraft Electronics Systems Division, Houston, Texas, for presentation to NASA Management.

The Apollo Lunar Geology Experiment Team (Gene Shoemaker, Swann, Batson, Schleicher, Dahlem, Hait, Schaber, Sutton, Bailey; plus court stenographers Keith Welch and Don Thacker) from the Branch of Surface Planetary Exploration, Flagstaff, participated in a simulation of the geology experiment for Apollo 11 at the Mission Control Center, Houston, Texas, on July 15 1969—as a last minute dress rehearsal for the upcoming attempt to land Man on the Moon during Apollo 11.

During the lunar landing and brief surface stay by the crew of Apollo 11, the Apollo Lunar Geology Experiment Team compiled, in the Mission Control Center, Houston, Texas, the geologic data being transmitted by the astronauts. The location of the landed Lunar module was found using Lunar Orbiter photographs, and from the astronauts geologic descriptions shortly following lunar liftoff and rendezvous with the Command Module

Chapter 5

Two Americans Land on the Moon before the End of the1960s—as Promised by President John Kennedy in 1961

5.1-Apollo 11

(Launched 16 July 1969, lunar landing on Mare Tranquillitatis 20 July 1969; Astronauts were Neil A. Armstrong, Commander; Michael Collins, Command Module Pilot; Edwin A. Aldrin Jr., Lunar Module Pilot)

[For details of the timelines and science results of all the Apollo lunar missions (Apollo 11-12, 14-17), the reader is referred to *"To a Rocky Moon"* by Don Wilhelms (1993, 477 p.), and "*A Man on the Moon*" by Chaikin (1994, 670 pages). Edited versions of all Apollo lunar surface transcripts can be found on the NASA site*: The Apollo Lunar Surface Journal* [http://www.hq.nasa.gov/alsj/].

On July 20, 1969—one of the most significant dates in human history—the Apollo 11 Lunar Module (Eagle) carrying Neil Armstrong (Commander) and Buzz Aldrin (LM pilot), landed safely on the Sea of Tranquillity, while Michael Collins (Command Module Pilot) manned the Command/Service Module in orbit high above them.]

Spaceflight Milestone for the USGS, Center of Astrogeology, and Flagstaff, Arizona

As the entire world anxiously waited, and prayed for, a successful landing on the lunar surface by the crew of Apollo 11 on July 20, 1969, the Science Support Room at the Mission Control Center Manned Spacecraft Center, Houston, Texas, was occupied primarily by Co-Investigators, other team scientists and support staff from the Apollo Lunar Geology Experiment Team led by Gene Shoemaker, Principal Investigator. The formal investigators and other team members on the Field Geology Team were dominantly from the Center of Astrogeology, Branch of Surface Planetary Exploration, in Flagstaff, Arizona (Fig. 61).

5.2-The Town of Flagstaff, Arizona is in the Media "Spotlight" During Apollo 11

While the Lunar Geology Field Experiment Team was busy with mission operations for Apollo 11 at Mission Control in Houston, Flagstaff became one of the centers of attention during the CBS-television coverage of the historic Apollo 11 landing with CBS anchor George Herman in constant communication with one of our nation's biggest Space fans—Walter Conkrite, who was anchoring from the Manned Spacecraft Center (MSC) in Houston, Texas (Fig. 62).

George Ulrich (personal communication on 27 July 2002):
Other CBS personalities present were John Hart, and anchorman Mike Wallace's son, Chris. Days before the landing, there were numerous interviews at the Center of Astrogeology and displays of all of Putty Mills' test vehicles at the Cinder Lake. During the Apollo 11 landing and EVA, there was an impromptu backroom team in Al Chidester's office [in Building one at the Survey's Center of Astrogeology in Flagstaff], trying to determine the landing location. [Author's Note: It should be noted that the "landing location" problem was solved by the LGE team in at the SSR in Houston soon after Apollo LM rendezvous with the Command Module, and very soon after the onboard astronaut debriefing and Neil's description of his last minute visit to a 10-m diameter crater near the landing site]. Following liftoff, the CBS threw a huge party for all Survey personnel at the Flagstaff Elk's Club."

For days prior to the Apollo 11 landing, CBS brought to Flagstaff a "fleet" of television vans, equipment, along with a large cadre of engineers and other staff technicians and supporting personnel (see Fig. 62a). The then "town" of Flagstaff, Arizona suddenly became extremely visible as a major player in Project Apollo to the entire world watching the Apollo 11 coverage. Live broadcasts for the CBS coverage originated from the Center of Astrogeology on McMillan Mesa (Fig. 62b-g), Astrogeology's Cinder Lake Crater Field just northeast of town (Fig. 62h-j), and nearby Meteor Crater (Fig. 62l, m), among other locations in and around Flagstaff.

CBS engineering crews setup high television relay towers at the Center of Astrogeology, as well as at the cinder lake Crater Lake Field and Meteor Crater that were used in many live broadcasts from those locations that were fed through CBS at Houston to people around the world (Fig. 62n).

[See Flagstaff's *Arizona Daily Sun*, 21 and 22 July 1969 for more details on CBS coverage of Apollo 11 at the U.S. Geological Survey Center of Astrogeology in Flagstaff.].

The principal "story" for the CBS crew and the Center of Astrogeology staff on the day of the Apollo 11 landing (20 July 1969) was the difficult task of determining exactly where the Apollo 11 Lunar Module (Eagle) had actually landed. Some wrong numbers were punched into the LM's computer late during the landing sequence. As a result, the LM [on automatic pilot at the time] over flew the landing site. In order to avoid the very blocky ejecta from a moderately large crater (which turned out to be "West Crater" just to the east of their eventual landing site in mare Tranquillitatis) a quick thinking Neil Armstrong was forced [every pilot's dream of course] to manually "fly" the spaceship laterally for some distance past their targeted landing site (Fig. 63).

[Author's Note: This author finds it worthy of note here that those of us who were actually members of NASA's Apollo Lunar Geology Experiment Team for the historic Apollo 11 mission (and the subsequent Apollo missions) were confined within the Science Support Room in the windowless Mission Control Building (Building 30) at MSC in Houston during the actual manned lunar activities. Therefore, we never actually had the opportunity to experience first-hand the network TV coverage of the missions—as most everyone else in the world did. We were extremely busy helping to make the first lunar landing a scientific, as well as an engineering success. Given that media-types and their cameras and microphones were banned from the mission control and the Science Support room. Therefore, our Apollo 11 Lunar Geology Experiment Team at MSC did not share in the media exposure that the ad hoc team of our colleagues remaining in Flagstaff did during their excellent support of the CBS activities there. The CBS exposure for the Branch of Astrogeology at Flagstaff during Apollo 11 was obviously a shot in the arm for the USGS—and for the City of Flagstaff. Of course none of us from Flagstaff at MSC would have traded places with any of our colleagues in Flagstaff during the historic Apollo 11 mission for all the money in the world].

[Author's Note: Jody Loman (later Swann) was the only Branch secretary to actually come to Houston to assist the Geology Team for Apollo 11—and that was immediately following the mission. According to Jody, regular typists used by the Branch of Surface Planetary Exploration—in Flagstaff—following the Apollo 11 mission included Lynda Sowers, Darline Johnson, and Fern Beeson. Typists used by the Branch of Surface Planetary Exploration to work in Flagstaff with the Apollo 11 and later mission transcripts included Juanita Esquibel, Mary Hopper, Cyndee Baker (later Condit), Lynda Sowers, Jean Fisher, Jody Loman, Darline Johnson, and Ellen Sanchez. According to Red Bailey, computer terminal typists (using the Branch's SEARCH and WYLBUR programs; see above) were not used during Apollo 11, but started with Apollo 12. During that mission, Lynda Sowers participated in the LGE apartments in Webster, Texas, and Darline Johnson at the USGS Center of Astrogeology in Flagstaff.]

Jody (Loman) Swann, secretary to Gene Shoemaker, recalled to the author during our interview on 16 February 2001, how she was fortunate enough to be brought down to Houston for Apollo 11, even thought she had earlier moved to Albuquerque, NM.

Jody recalls how she and her first husband Sam (Loman) moved to Albuquerque, New Mexico, just before the Apollo 11 mission. This was the summer of 1969. Gene [Shoemaker], his wife Carolyn, and their kids, came through and stayed with them in Albuquerque on their way driving down to Houston for the Apollo 11 mission. Even though Gene had left the Survey for Caltech [temporarily as it turned out], he was still Principal Investigator (PI) for the Apollo Lunar Geology Experiment, and was to be in Houston for that. He was still WAE with the Survey however.

Jody:
I was working for the Atomic Energy Commission in Albuquerque, and Gene called me from Houston and asked if I could come down there and be his secretary for the Apollo Lunar Geology Surface Experiment (ALGSE) Team. I was very excited about that.

Oh, it was a fantastic opportunity. My Branch Chief at the AEC was very excited about it, but he said I don't have a clue about how to get you down there. If you can work out the logistics, and how to get it paid for, I would be tickled death that my secretary is being asked to come down there and work for the Apollo mission. Al Honka was the Administrative Officer (AO) for the Branch of Astrogeology [in Flagstaff] back then—and he could work miracles. So I called him, and he said that's not a problem. He got it all done, and my Branch Chief was tickled to death that I was going to get to go to Houston [for Apollo 11].

But on a personal note, not one female in that building [where I worked] and it was a three-story building—would speak to me. I was a newcomer there; and the fact that I got this opportunity was absolutely ridiculous, and they wouldn't speak to me. Oh well, I went to Houston and I worked —and it was very exciting of course" (Taken from an interview with Jody Swann by Gerald G. Schaber on 16 February 2001.)

Jody recalls another occasion when Gene had to fly to Houston to work during the Apollo 11 mission:
Carolyn [Shoemaker] and I were taking him to the airport and Gene didn't have any money. Having "filthy lucre" for Gene was just a necessity. It wasn't something you had to worry about! It was a minor problem.

Anyway, we were late getting out to the airport, so I took Gene's checkbook, wrote a check—signed it, and took it to the bank—got it cashed-and gave him the money. Gene was amazed that I could sign his check and get the money for him. But I had learned to forge his signature pretty well by then!

I know of a few times when Jim Lovelace, the Branch pilot then, would fly Gene down [to Phoenix]—and sometimes I would go along just to get things done on the trip down in the airplane. Gene would get there with no money and very often both Jim Lovelace and I (and I was very poor) might have $5.00—but Gene would leave on his trip with $10.00 in his pocket—five from me and five from Jim Lovelace. We got the money back; it's just that wasn't one of the priorities that Gene had, i.e., making sure that he had cash (from an interview with Jody Swann by Gerald G. Schaber on 16 February 2001).

[Author's Note: Don Beattie (personal communication, 2003) recounted to this author another example of Gene's total focus on his many activities and forgetting to keep some spending money in his pocket. It appears that while Gene was still on his temporary appointment at NASA Headquarters (fall of 1962 to fall of 1963); Don had invited Gene over to his home in Maryland for dinner. Gene came over (from D.C.) on the subway; but did not have even enough money on him to take the subway back to D.C. Don said he lent Gene $5.00. Don did not say whether Gene ever paid him back—but it is doubtful that that was a high priority in Gene's mind during those hectic days prior to Apollo. This author finds it rather amusing that it was Don who would soon start transferring the first of many millions of dollars to Gene's Branch of Astrogeology for pre-Apollo, Apollo, and post (or advanced) research in Flagstaff. Perhaps the $5.00 was only a down payment!

The following are some personal recollections by this author regarding his personal experiences being a Member of the Apollo Lunar Geology Experiment Team in the Science Backroom in Mission Control at MSC during Apollo 11 (See Appendices A and B for additional details):

Gerald G. Schaber:
Being in the Science backroom in Mission Control at MSC during Apollo 11 in July 1969 could best be described as living in a trance-like state—in a science fiction fantasy or dream world of some kind. Some of this state of mind could have been the result of working 18 to 22 hours a day at the time!

Despite the fact that we had planned and rehearsed for this historic day for the past four years (since 1965) during Flagstaff field tests, and had several pre-launch Apollo 11 mission SIMS at Houston, everything that was happening around us seemed too fantastic to actually be related to reality. Here we were about to (hopefully) witness one of history's greatest events (or disasters!) Amazingly, we were part of it in Mission Control—as close as one could get without actually being with the crew! One's brain can only assimilate so much I guess. I was barely 31 years old at the time.

My job during Apollo 11—as a member of the Lunar Geology Experiment Team—and subsequently on Apollo 14 and 15—was to keep track (on a map table plotting board) where the astronauts were on the surface at all times (see Fig. 61e). For Apollo 11, my map just consisted of a large Chronopaque sheet (the plastic-like material that Astrogeology had also made the crew's Lunar Map Package out of) printed with concentric circles representing distances from the LM, located in the center. I used small cutouts of the Commander (Armstrong) and the LM Pilot (Aldrin) that could be moved around the landing site as they moved within view of the (stationary and really lousy) black and white television camera. My map table had a small vidicon camera mounted directly over it. Thus, my display of the astronaut's position on the lunar surface could be projected, at the discretion of Flight Director Gene Kranz, on one of the several 10 X 10-foot screens in the Mission Control Room across the hall from our "Science Backroom.

I vividly recall during the very exciting—but incredibly tense—landing of the Apollo 11 LM, the Eagle, I had made a personal decision to watch the heartbeats of Armstrong and Aldrin on the large TV monitor mounted near my map table. We had all heard that one of the reasons that Armstrong had been selected for the first lunar landing was his nerves of steel, including his unflappable heart rate. The stories were all true.

As I watched the TV monitor, the descent to the lunar surface began following the separation of the LM and Command Module. I recall that Armstrong's heart rate was considerably lower than Adrian's—from the start of the descent to the lunar surface. However, as the descent progressed, the difference became even more pronounced.

After already having several disturbing alarms go off on their console and running low on fuel, Armstrong spotted the very blocky ejecta field from West crater in the western 1/3 of the landing ellipse (see Fig. 63). While Houston was deciding whether they should abort the landing because of the alarms, Neil decided to take over manually and move the LM laterally some distance to avoid landing in this potentially hazardous location. It was then that the well-rumored steel-like nerves of Neil Armstrong began to really show. As Houston continually pressured Neil to “land the LM” because his fuel was at the critical level, Neil continued to move horizontally with little vertical descent. As I watched their heart rates, I was absolutely amazed to see Aldrin’s racing like he had just run 30 miles, while Neil’s heart rate was remarkably slow (relatively) and steady—even at the actual landing which did not come until all telemetry showed that they were essentially out of fuel. If they had any left—they said it was less than 6 seconds. I personally believe that only Neil Armstrong—of all the astronauts at the time—had the remarkable internal calmness and skill under pressure to have pulled off such a remarkable feat! I may be wrong, however, as all of the astronauts were heroes to me at the time—and still are.

My “other-worldly” state of mine during this whole experience became even more pronounced after the landing—when the crew actually left the rather safe confines of their LM and walked for the first time on a planetary body other than Earth!

I am certain that everyone else in the world watching this historic event felt a real sense of pride in America—and Mankind—mixed with both awe and disbelief. Imagine actually being there in the Mission Control building at MSC at that event—it was a feeling that those of us who were lucky enough to have participated in will never forget. It is a fact that many people around the world still do not believe that the Moon landing(s) actually happened; many have said that it was all faked from the U.S. Geological Survey’s simulated crater field at Flagstaff, Arizona. Take it from me, who was there, it really happened—and ON THE MOON!

I also recall that time became sort of non-existent in the Mission Control Room during all of the Apollo missions, given that it was based from the time of launch (i.e. day/hours/seconds from lift off). I recall that during one of the later J-series missions, I and several Geology-Team colleagues had decided to go out for dinner when one of them noticed from their wristwatch that it was close to 6:30. We went outside the Mission Control Building and noticed that it was 6:30 AM not 6:30 PM—so I remember saying—so we will go out for breakfast! That was just one aspect of the bizarre life in Mission Control during the remarkable Apollo Era.

I remember especially well a memorable, hot, August day in 1969 when the Apollo 11 crew was released from biological isolation in the Lunar Receiving Lab. Totally unexpectedly, Harrison ‘Jack” Jack Schmitt showed up with Neil Armstrong that very day at the Apollo Experimenter’s mobile offices (trailers) parked at the back of the Manned Spacecraft Center (near where the present Gilruth Recreation and Conference Center is now located), where the Field Geology Team had their MSC office space. Neil was obviously very anxious to see what things of geologic interest we may have learned as a result of the job they had done for us during their very brief stay on the lunar surface.

Schmitt proceeded to walk Neil around the trailers and introduced him to each of us. I had been putting the final touches on a Preliminary Traverse Map of the Apollo 11 Landing Site, which myself, Tim Hait, and Ray Batson (in collaboration with Gordon Swann) had compiled after repeately going over the audio and TV-video tapes from the EVA, and the crew’s photographs. This was the first such map (crude geologic map in a sense) ever made from the surface of another body in the Solar System outside earth (Fig. 64).

As Jack brought Neil up to my desk in the trailers, I remember being quite nervous and awestruck, as anyone would be under similar circumstances. I had actually not previously met Armstrong face to face. From the moment Neil walked in our trailers I was thinking how I could get Neil's autograph without seeming like a nerd—instead of a scientist. On my desk at the time was an Ozalid print of the Apollo 11 Preliminary Traverse map that we had only recently completed (in first draft) as a result of detailed studying of video tapes from the lunar television camera, photographs taken by the astronauts, and educated guesses based on what the astronauts reported from the Moon. The Ozalid paper (reeking of ammonia), on which the traverse map on my desk was printed, was not the quality of course that one would opt to have such a famous autograph placed on—to preserve for posterity. However, it was all that I had at hand; and it did have my name on it as senior author!

Well, I could not muster up enough nerve to ask Neil for the autograph while he was standing in front of my desk; however, I did get up enough nerve to ask him just before Jack was ready to take Neil out of our trailer. I asked Neil, and he agreed graciously. At that point, Jack Schmitt sneered in my direction something to the effect, Schaber—this is a scientific organization!

To this day, I am ever so happy that I found the nerve to ask Neil for that autograph. Neil, always known to be sort of a loner, never really signed a lot of autographs after the mission. These days, Neil lives in the small town of Lebanon, Ohio, and now is reluctant to sign autographs at all. He just wants to be a farmer! Neil could be the Webster definition of the reluctant hero.

Today, I have that signed 16 X 20-inch *Preliminary Traverse Map of the Apollo 11 Landing Site* framed and proudly hanging on the wall in my home office in Flagstaff. I was honored to find out that Don Beattie included the map as one of the illustrations in his book (Beattie, 2001, fourth photo following page 226).

I did not know of the "heights to which this Preliminary Traverse Map of the Apollo 11 landing Site had gone following Apollo 11 until I read the following story in Don Beattie's book *Taking Science to the Moon*)

Don Beattie:
"On August 23, 1969, one month after Apollo 11 splashed down and the date when the astronauts were released from quarantine, George Mueller forwarded a memo to Clare Farley, James Webb's executive officer, to be included in the report being sent to the president [Nixon] summarizing the results of man's first foray to the Moon. In his memo, drafted in part by our office, he described the initial scientific results of Apollo 11 and summarized the program adjustments that would be made as a result of the mission. Included with the memo was the very same *Preliminary Traverse Map of the Apollo 11 Landing Site* compiled by Gerald Schaber, Ray Batson, and Tim Hait of the United States Geological Survey (see Fig. 64).

The map sent to the White House had been further updated during the astronaut's debriefings while they were still in quarantine. By this time photographs of the astronauts on the Moon and a few photographs of "Moon rocks" had circulated in all the newspapers and some magazines, so

Mueller didn't include any photographs of the astronauts with his memo, but he did include a photo of one of the returned samples. The Schaber-Batson map had just been completed and represented new information not yet made public, tying together everything the astronauts had done during their brief stay" (Beattie, 2001, p.p. 202-203).

One of the most memorable things following the Apollo 11 splashdown were the crazy, out-of-control parties around MSC—especially the one that took place around the pool at the Nassau Bay hotel, directly across from the main entrance to MSC on NASA Road One. There were an estimated 5,000 people at the Nassau Bay Hotel that night according to the many media people who were there.

Gerald Schaber:
Virtually everyone was holding a large plastic or glass container of some sort filled with spirits of one sort or another. The major TV networks had all organized large parties of their own, usually in someone's hotel or motel suite nearby MSC. The word got around where these parties were being held. Starting with Apollo 11, Tim Hait, a colleague on the Lunar Field Geology Team who was sort of our media guy, seemed to get advance word, as well as tickets for all such media and company parties, for the entire Geology Team.

I was standing by USGS colleague Ray Batson at the Nassau Bay pool that night of Apollo 11 splashdown when two rather tipsy girls walked up holding out rather large Thermos bottles. They informed us that they were begging drinks from anyone who would feel the need to pour some of whatever they were drinking into their Thermos bottles. They said that it didn't matter what the drink was! So, Ray and I contributed to their cause.

As the drinking and celebrating continued into the night, nearly everybody, of course, got thrown into the pool. I remember standing by my USGS colleague Ray Batson—and the next thing I know I was in the pool myself. I know it was Batson, but he still (tongue-in-cheek) denies it to this day."

I remember seeing a lot of our other USGS-Flagstaff colleagues in the pool with him. Bob Sutton was one. About that time there were dozens of network news, and other media personnel, taking picture about that time of the pool nonsense. A couple of days later I saw the special Apollo 11 issue of *Time* magazine. There on the cover was a color photograph of the Nassau Bay pool with Bob Sutton clearly in the picture. The way I see it, I just missed being on the *Time* cover picture by a few feet. That was a very good thing because, as I recall, I was dog-paddling with a drink in my hand very close to Bob at the time. My parents didn't need to see that.

On 23 July 1969 a field test was carried out at Cinder Lake Crater Field II with Al Chidester, George Ulrich, John M'Gonigle, Hans Ackermann (geophysicist), Red Bailey, and Jim Crossan (surveyor) (No more details available on this test).

[Space Exploration Milestone—On July 31 1969 the Mariner 6 spacecraft took vidicon television images of Mars during a flyby of the planet Mars on July 31, 1969. Seven days later, on August 6, the Mariner 7 spacecraft accomplished a similar feat.]

[Author's Note: *The Arizona Daily Sun* of 7 August 1969 included (on page 2) a feature story ("Moon Role 'Thrilling' Experience") about official Coconino County Court Stenographers, Keith Welch and Don Thacker, and the important role that they played in the Mission Control Center, Houston, Texas, while working with the Apollo Lunar Geology Experiment Team during the recently completed Apollo 11 lunar mission (see Fig. 54d).

Gerald Schaber:
One of the grandest celebrations in Houston following the success for Apollo 11 was the big "Salute to the Apollo 11 Team" luncheon and program for the Apollo 11 crew (and their wives) held 12 August 1969 at the Rice Hotel in downtown Houston. As I recall there were only 400 people invited from all of the almost 200,000 persons who actually helped (to some degree or other) make this mission a success. Getting tickets for this bash we thought—as lowly geologists—would be almost impossible—even for Tim Hait—our media party ticket guru. Somehow, Tim Hait and/or Gordon Swann came through with tickets for this historic affair for every member of the Lunar Geology Experiment Team who wanted to attend. The Apollo 11 crew and their wives sat up on the dais along with the various NASA dignitaries.

The "cutesy" menu printed with the program I brought back from the Apollo 11 luncheon included the following delights:

Cape Kennedy Fresh Fruit Supreme

Columbia Roast Sirloin of Beef
Bordelaise Sauce

Neil Parisienne Saute Potatoes

Buzz Miniature Glazed Carrots

Mike Tossed Green Salad [referring to Mike Collins, the Command Module Pilot]
Thousand Island dressing

Eagle Tia Maria Parfait
With Moon Rock

Hornet [the recovery ship]
Coffee

The luncheon program led off with Apollo 8 astronaut Frank Borman giving the Opening Remarks. This was followed by a welcome by MSC Director, Dr. Robert Gilruth, followed by an address by NASA Administrator Dr. Thomas O. Paine.

The highlight of the evening followed with remarks by the Apollo 11 crew, first Neil Armstrong, then Buzz Aldrin and Michael Collins.

At the end of the crew's remarks, someone said that the crew and their wives would be willing to stay up on the dais for a few minutes to sign some autographs. Well, that was a big mistake! All of a sudden, this rather sophisticated and well-dressed group of 400 or so, slowly—then quickly—stormed the dais with their programs in hand. In fact, the program even had space marked for autographs on the back page!

Here were people who lived with the Space Program around Houston every day—and some of them actually lived among the astronauts in Clear Lake City and Nassau Bay. Nevertheless, this large group of people suddenly became possessed with the need to shove their way up to the dais and get those autographs of the Apollo 11 crew and their wives."

I will admit to being one of those "possessed" people that afternoon. "I politely" shoved my way through the now scary elite of Houston society, and finally got the autographs of at least the three crewmembers on my program from that evening. I don't think any of the planners of this sophisticated affair ever dreamed that the autograph session would turn out to be more or less out of control.

On 14 August 1969 the Apollo 14 crew (Al Shepard, Ed Mitchell, and backup LM pilot Joe Engle) participated in a geologic training exercise at the Cinder Lake Crater Field near Flagstaff (See Table I).

The following was taken from the Center of Astrogeology Monthly report for August 1969 to Assistant Chief Geologist for Environment Geology, and to NASA; from Chief, Branch of Astrogeologic Studies; dated 31 August 1969:
Henry Moore reported that examination of sixteen craters at the Cinder Lake Crater Field in Flagstaff by astronauts Alan Shepard, and Ed Mitchell on 14 August 1969 illustrated the principle that can be used to sample lunar near-surface materials and methods of estimating depths to various layers. The craters, which were engineered by Hans Ackerman (In situ Geophysics Group, SPE Branch, Flagstaff, Arizona) to show that debris on the rims of progressively larger craters were derived from progressively larger depths and that sections through the ejecta showed inverted stratigraphy—as Gene Shoemaker had first observed at Meteor Crater year earlier. Most of the blocks ejected from the craters could be associated with the craters that produced them. Hence, it was possible to tell that blocks of type one (red tabular blocks) came only from the largest crater and only blocks of type two (gray blocks) came from the next largest crater. For the smaller craters, no blocks were ejected.

Moore stated that the astronauts really understood the principles involved and were able to work out age relationships and block-crater associations using rays, secondary impact craters and boulder tracks, superposition, and relative freshness of craters.

[Space Exploration Milestone: In August 1969 the Soviet Zond 7 spacecraft, as had its predecessors Zond 5 and 6, looped around the Moon once from the northern near side to the southern far side before returning to earth for a braked landing.]

The following was taken from the Center of Astrogeology Monthly Report for August 1969 to Assistant Chief Geologist for Environmental Geology, and to NASA; from Chief, Branch of Surface Planetary Exploration; dated 29 August 1969:
An evaluation report on the Lunar Geology Experiment from Apollo 11 was submitted in August 1969 to NASA for incorporation in the Apollo 11 Mission Evaluation Report ("45-day report"). Traverse map and a photographic station map on the landing site were produced for this report.

Several rocks have been identified as having been sampled; and G. Schaber has specifically identified a few with specimens in the Lunar Receiving Laboratory, Houston, Texas.

[Author's Note: To be honest about it, there was very little actual science that could have been accomplished during the very short time that the Apollo 11 crew stayed outside the LM. Gene Shoemaker, as PI of the Lunar Geology Experiment Team, had however the job of writing the required 5-day, 45-day and 90-day mission reports for NASA (Fig. 65). Gene was desperate to find something that we could call a scientific breakthrough from the crew's activities while on the surface. Of course, they had only traveled a few tens of meters from the LM during the entire EVA].

Gerald Schaber:
One of the things that Gene wanted most was for one of us on his team to find a photograph of a rock on the lunar surface that the crew had actually brought back to Earth. His reasoning was clear. Prior to Apollo 11, Gene and others interested in the size-frequency distribution of lunar craters had sufficient data on craters with diameters down to perhaps ten meters or so. However, it was very important to know what that size-frequency distribution looked like down to the micron scale. This was our first chance to find out. The Apollo 11 crew actually wanted (as Gene had insisted) to photo-document the rocks before and after they collected them, but they simply did not have the time to do it—or NASA's permission. We had to depend on a random chance photograph of one of the rocks they actually scooped up and brought back. The vital thing in Gene's mind was to find—not only the rock—but to know what side of the rock was up—that is exposed to the micrometeorite flux.

This author and others on the Geology Team jumped at the opportunity to find such an "oriented" rock for Gene—and in the process making him a happy man. Gene had been more than a little grumpy during those first couple of weeks following Apollo 11 because there was so little science to actually talk about in the required NASA reports.

Over and over, we watched the grainy, black and white television videotapes from the stationary camera set up during the mission outside of the LM. We also listened repeatedly to the audiotapes of the conversations between the crew and the CapCom at MSC, starting with the crew's taking of the so-called "contingency sample"—collected just outside of the LM immediately after both crewmembers had stepped onto the lunar surface.

As each of the rock samples returned by Apollo 11 was photographed in the Lunar Receiving Lab (LRL), we obtained copies of these rock mug shots. Using these data, we began the arduous task of comparing the physical characteristics and shapes of rocks in the mug shots with rocks photographed—perhaps by accident—on the lunar surface before they might have been retrieved up by the crew.

Working every day, as well as well into the early morning, for the first few weeks following the mission, I was fortunate enough to come up with several good candidates for rocks seen in the lunar photographs that just might correspond to rocks photographed in the LRL.

The Lunar Geology Team had had the good sense to have Tom Lee, one of Astrogeology's photographers at Flagstaff, drive a portable photolab trailer (made by the Field Support Group at Flagstaff) down to MSC for use by the Geology Experiment Team in their analysis of the mission photographs, and in writing the obligatory NASA reports. The portable photolab was parked adjacent to the Geology Team's trailers at the back of MSC. I had Tom Lee enlarge small rocky areas from the surface photographs, in addition to single 16-mm frames from the onboard camera that documented the taking of the contingency samples.

This procedure finally paid off! One surface photograph discovered included a rounded rock that I thought look suspiciously like one mug shot of a lunar rock designated sample 10046 (Fig. 66). I had the appropriate area of the surface photograph blown up in the portable photolab. The 8 X 10 inch black and white photograph was the proof I was looking for. A small dark area of shadow on the rock visible on the blow up from the surface was in exactly the same location as a depression on one of the mug shots taken of sample 1004. The clincher however, for me was the rounded shape of the rock on both the mug shot and the surface photograph. It was clear to me that because of the pronounced flat bottom and rounded top of the rock, the LRL people had placed the rock on the flat side to photograph it for convenience.

Excited now to the point where I was more or less positive that the two rocks were the same—and thus had found a rock in its proper lunar surface orientation to show Shoemaker, I cautiously approached Gene's office in the trailer with both photographs—one in each hand.

I recall that Gene's door was only partially shut. I knocked, and Gene gruffed come in. All I had to do was hold up both photographs facing Gene from the doorway. At that point Gene jumped up and screamed "That's it, that's it." He grabbed the two photographs out of my hand and ran out of the room with them. I don't know where he went, probably to have Sutton or someone else-from Astrogeology who had access to the LRL, to start immediately counting the tiny micrometeorite craters on rock 10046.

The counting of the micrometeorite craters on rock specimen 1046 proved to be everything that Shoemaker had hoped for. As a result, the Lunar Geology Team was able to include in their 45-day report to NASA—for the first time ever—the size-frequency distribution of impact craters from the many-kilometer size down to the micron size. It was a major breakthrough in Astrogeology for sure.]

The following was taken from the Center of Astrogeology Monthly Report for August 1969 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 29 August 1969:

G.A. Swann in August 1969 briefed the Apollo 11 crew at the manned Spacecraft Center, Houston, Texas, on the geologic results to date from the Apollo 11 mission.

J.C. Nuttall (SPE, Chief, Electronics Support Group), G.E. Ulrich, and J.D. Alderman, conducted TV, videotape, and film tests at Granite Dells, Yavapai County, Arizona, for a comparative analysis of the television and photographic results with those of a facsimile camera test conducted by Philco-Ford at that site in April 1969.

The following was taken from the Center of Astrogeology Monthly Report for September 1969 to Assistant Chief Geologist for Environmental Geology, and to NASA; from Chief, Branch of Surface Planetary Exploration; dated 30 September 1969:
In September 1969, the Apollo Lunar Geology Experiment Team submitted to NASA its 90-day report entitled: "Geologic Setting of the Lunar Samples Returned with Apollo 11." Contributors to the report include: E.M. Shoemaker, N.G. Bailey, R.M. Batson, D.H. Dahlem, M.J. Grolier, M.H. Hait, H.E. Holt, K.B. Larson, G.G. Schaber, D.L. Schleicher, R.L. Sutton, G.A. Swann, M.N. West, U.S. Geological Survey, Flagstaff, Arizona; T.H. Foss, H.H. Schmitt, Manned Spacecraft Center, Houston, Texas; E.N. Goddard, University of Michigan, Ann Arbor, Michigan; J.J. Rennilson, Jet Propulsion Laboratory, Pasadena, California; and A.C. Waters, University of California, Santa Cruz, California.

H.E. Holt [USGS, Flagstaff] attended a bench review of Apollo geologic hand tools, lunar cameras, gnomon, and other items of equipment carried in the ascent stage of the Lunar Module, at Kennedy Space Center, Florida, 9 September 1969, by the Apollo 12 crew. Holt answered questions concerning the use, the status, and operation of equipment in support of the Lunar Geology Experiment

During September 1969, N.L. Langbecker assisted by W.T. Borgeson with the photogrammetric calibration of the two 60-mm focal length electric Hasselblad cameras that will be used on Apollo 12 geologic traverses. The raw calibration data, in the form of photographic plates, were taken at the Branch of Research and Design's calibration facility at McLean, Virginia. The data were reduced in Flagstaff, Arizona.

In September 1969, T.N.V. Karlstrom (SPE Branch, Flagstaff, Arizona) completed compilation of 1:25,000 and 1:100,000 data package operational maps for Apollo 12 from preliminary geologic compilations by P.J. Cannon and H.A Pohn.

The following was taken from the Center of Astrogeology Monthly Report for September 1969 to Assistant Chief Geologist for Environmental Geology, and to NASA, from the Chief, Branch of Surface Planetary Exploration; dated 30 September 1969:
[Astrogeology milestone: On 29-30 September 1969, the Center of Astrogeology, Flagstaff, Arizona, hosted NASA's Science and Technology Advisory Committee and the Lunar Panel of the Lunar and Planetary Mission Planning Board in demonstrations of the Lunar Surveying System (LSS), Lunar Rover Vehicles, and the SPE Branch's Data Facility Operations in East Flagstaff. This demonstration of the Lunar Surveying System, lunar roving vehicles (LRV), and the SPE Data Facility Operations in Flagstaff was attended by Harold James, Chief Geologist of the USGS, Captain Lee Scherer, Director, Apollo Lunar Exploration Office, Office of Manned

Spaceflight, Don Beattie, Program Manager, Plans and Objectives, Apollo Lunar Exploration Office, Office of Manned Spaceflight.

The following was taken from the comprehensive reference material document that was put together by personnel from the SPE Branch for this demonstration on 29-30 September 1969:
The schedule of this important and well organized demonstration by personnel of the Branch of Surface Planetary Exploration included the following:

<u>Monday 29 September 1969:</u>
- Welcoming remarks by Harold James.
- Introduction to briefing on lunar exploration program by Captain Lee Scherer
- Review of Apollo 11 mission science results by Robin Brett (sample analyses), Gary Latham (passive seismic experiment), Carroll O. Alley and Donald H. Eckhardt (Laser ranging experiment, and Gene Shoemaker (Field Geology Experiment).
- Discussion of typical lunar exploration mission (Mission of Apollo17 by Donald Beattie [Apollo 17 at that time was scheduled to be an extended later Apollo-type mission scenario].
- Discussion of combined operations of the Science Support Room (SSR) (or Apollo Data Facility-ADF- as we called our facility), lunar surveying system, and manned lunar rovers by Al Chidester, Branch Chief, Surface Planetary Exploration Branch, U.S. Geological Survey, Flagstaff, Arizona.
- Demonstration of LRV simulators at Apollo 11 site—Cinder Lake Crater Field Number One.
- Demonstration of the Lunar Surveying System (LSS) and Explorer LRV vehicle on geologic traverse.
- Discussion of LSS engineering model and demonstration of distant tracking capability, using corner reflector on one of LRV simulators.
- Demonstration of LRV simulator in remote control
- Demonstration of LRV simulator on "obstacle course"

<u>Tuesday 30 September 1969</u> (Meetings at Flagstaff Elks Lodge)
- Spacecraft influences on lunar surface operations
    - Site accessibility
    - LM performance trade-offs
    - EVA constraints

- Executive session—joint STAC/LPMB Lunar Panel
    - Discussion of lunar exploration program
    - Stellar ATM

The purpose of the field demonstration was to illustrate the combined use of the Lunar Surveying System (LSS) and a roving vehicle in one segment of a 5-km geologic traverse. The test subjects conducted the investigation on outcrops and surface-blanketing deposits within the volcanic maar crater, Spruhl, near Merriam Crater just northeast of Flagstaff. The test subjects supplemented their oral descriptions with the LSS TV and film cameras, which automatically document the spatial position and orientation of geologic features along the traverse. The Lunar

Surveying System, consisting of a laser-operated tracking and ranging device, was also demonstrated in the field along a segment of a geological and geophysical traverse within a volcanic maar crater (Spruhl), using the Branch of Surface Planetary Exploration's Explorer vehicle as an LRV. [Unfortunately, the LSS was later dropped from consideration for use during the Apollo program; See Beattie, 2001, p. 115.]

Two Lunar Rover Vehicle (LRV) simulator prototypes, brought to Flagstaff for this exercise by Grumman Aircraft Engineering Corporation and Bendix Aerospace Systems Division, were demonstrated [actually competed] in a LRV test at Cinder lake Crater Field (Fig. 67).

The principal participants from the SPE Branch in this important demonstration were George Ulrich, John M'Gonigle, Edward Wolfe, John Strobell, Hans Ackermann (In situ Geophysics Group),

Clerk-Typist Darline Johnson entered on duty with the Branch of Surface Planetary Exploration in Flagstaff in September 1969. Darlene would work with the Apollo Lunar Geology Experiment Team down in Houston during Apollo missions 13 through 17 typing verbatim transcripts of the astronaut's verbal communications and inputting relevant geologic data into the team's primitive data base and word-processing software programs, called SEARCH and WYLBUR.

The following was taken from the Center of Astrogeology Monthly Report for September 1969 to Assistant Chief Geologist for Environmental Geology, and to NASA, from the Chief, Branch of Astrogeologic Studies; dated 30 September 1969:
The U.S. Defense Atomic Support Agency and the Canadian Defense Research Establishment detonated a 100-ton hemispherical charge on the ground surface at the CRES test site in Alberta, Canada. D.J. Roddy (BAS Branch, Flagstaff, Arizona), using a U.S. Geological Survey Beaver aircraft, completed air blast, oblique and low altitude black and white and color photography of this cratering experiment. The crater, 46 m in diameter and 9 m deep, had a raised rim, overturned flap, terraced rim crest, and a hummocky ejecta blanket with inverted stratigraphy.

The following was taken from the Center of Astrogeology Monthly Report for October 1969 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 31 October 1969:
In October 1969 M.H. Carr (BAS, Menlo Park) and S.S.C. Wu (BAS, Flagstaff) submitted separate proposals to the National Aeronautics and Space Administration (NASA) to participate in various capacities in the Viking Mars '73 Orbital Science Imaging Team.

Harold Masursky (BAS, Flagstaff), in October 1969, submitted a proposal to NASA to participate as team leader in the development of the imaging system for the Viking Mars '73 lander

E.C. Morris (BAS, Flagstaff) submitted a proposal in October 1969 to participate as a member of the Viking Mars '73 Landing Imaging Team.

H.J. Moore (BAS, Menlo Park) proposed in October 1969 to become a member of a team investigating the "Physical Properties of the Mars Surface Materials for the Viking Lander Data."

The U.S. Defense Atomic Support Agency and Waterways Experimental Station detonated a 100-ton hemispherical surface charge on tonolite near Cedar City, Utah. Dr. J. Roddy (BAS Flagstaff), using a U.S. Geological Survey Beaver aircraft, completed air blast, oblique and low altitude black and while, color, and false-color photography of this cratering experiment. The crater, about 15 m in diameter and 3 m deep had an uplifted rim, locally overturned flap, inverted stratigraphy, and a blocky ejecta blanket. Blocky rays extended for at least 150 feet from the crater.

The following was taken from the Center of Astrogeology Monthly Report for October 1969 to Assistant Chief Geologist for Environmental Geology, and to NASA, from the Chief, Branch of Surface Planetary Exploration; dated 31 October 1969:
A final geologic training exercise was held at the Cinder Lake Crater Field near Flagstaff, Arizona, on 9-10 October 1969 for the Apollo 12 prime (Conrad, Bean) and back-up crews (Scott, Irwin); and for the two Capsule Communicators (Capcoms) (Ed Gibson and Paul Weitz) who were to be in the Mission Control Center, Houston, Texas, during Apollo 12 lunar surface extravehicular activities [the following month] (See Table I) (Fig. 68).

[See Flagstaff's *Arizona Daily Sun* newspaper of 10 and 11 October 1969 for more details on this final Apollo 12 geology exercise in Flagstaff.

October 9 was spent as a familiarization exercise and dry run for the Capcoms, in preparation for the activities with the crewmembers the following day (10 October). The morning of 10 October was spent in training the crews in cratering mechanics, use of craters to solve geologic problems, and in verbal description, photographic, and sampling techniques. During the afternoon, the crews went through a geologic traverse in shirtsleeves that simulated a lunar geologic traverse.

Voice communication was established between the crew members at the crater fields and the Mission Control Center, Houston, Texas, during the traverse, and this portion of the activities was conducted from the control Center in much the same way that the lunar missions are conducted. The Science Support Room Geology Team from Flagstaff, Arizona, supported the simulation from the Mission Control Center, Houston, Texas, as it was done during the Apollo 12 mission.

[Author's Note: T.N.V. Karlstrom (SPE) completed final editing on 19-28 October 1969 of the 1:100,000, 1:25,000, and 1:5,000 scale data package Maps to be flown on Apollo 12. These operational maps which are printed by Topographic Command, Washington, D.C., represented modifications and extensions in detail of the preliminary geologic maps of the prime landing site compiled earlier by H.A. Pohn (1:100,000), P.J. Cannon (1:25,000) and Jerry Harbour (1:5,000) and edited by N.J. Trask. For mission-planning purposes, T.N.V. Karlstrom completed a 1:2,500-scale geologic map of the central part of the Apollo 12 prime-landing site 7 (Apollo 12).

[Author's Note: See story below about the secretive, last minute, hand-colored maps that were taken to the Moon by the crew of Apollo 12 as part of their data Package.)

R.L. DuBois, D.P. Elston, J.D Strobell, and H.D. Ackerman in October 1969 submitted to NASA a proposal for Apollo 16-20 missions entitled "Traverse Magnetometer Staff." If accepted, the experiment would have involved the application of a portable, staff-mounted magnetometer in determining the character of the magnetic properties of the Moon's rocks.

[Author's Note: The above proposal was not accepted by NASA for Apollo 16 or 17, and missions 18-20 were eventually cancelled by NASA].

During October 1969 NASA presented to the U.S. Geological Survey a Certificate of Appreciation for outstanding contributions to the Apollo Program. The citation goes on to state: "The geological training and lunar mapping services provided to the Apollo astronauts were in large part responsible for the successful accomplishment of the scientific objectives of the world's first manned lunar landing mission in July 1969" (Fig. 69).

The following was taken from the Center of Astrogeology monthly report for November 1969 from the Chief, Branch of Surface Planetary Exploration to Assistant Chief Geologist for Environmental Geology; dated 30 November 1969:
Part of the Lunar Geology Experiment Team participated in the final lunar surface simulation that included geologic activities, at the Mission Control Center, Houston, Texas, on 4 November 1969, in preparation for the Apollo 12 mission.

M.H. Hait and G.A. Swann accompanied the Apollo 13 astronauts on a geologic training trip to Kilbourne Hole, New Mexico, 11 November 1969 (see Table I).

5.3-Apollo 12

Apollo 12 was launched 14 November 1969; landing site: Oceanus Procellarum; Astronauts were Charles Conrad Jr., Commander**;** Richard F. Gordon, Command Module Pilot; Alan L. Bean, Lunar Module Pilot.)

T.N.V. Karlstrom, A.H. Chidester, and G.A. Swann (all SPE Branch) conducted four weekend pre-mission briefings of the Apollo 12 astronauts, at Cape Kennedy, on the geology of the prime-landing site 7. Four 1:5,000-scale 8 X 10-inch operational geologic maps were prepared by Center of Astrogeology personnel, Flagstaff, Arizona, less than one week prior to the launch of Apollo 12, for use on board the spacecraft and in the Mission Control Center. The maps and traverse plans were reviewed at Kennedy Space Center by astronauts Charles Conrad, Jr., Alan L. Bean, David R. Scott, James Irwin, Harrison H. Schmitt, and Edward G. Gibson (Capsule Communicator); Gerald D. Griffin (EVA Flight Director); and T.V.N. Karlstrom, A.H. Chidester and G.A. Swann of the U.S. Geological Survey, Flagstaff, Arizona.

Base relief was prepared at Flagstaff and flown to the Kennedy Space Center (Florida) one week before launch. The geology and preplanned traverses were added to the base relief by J.W.

VanDivier and R.E. Sabala of the U.S. Geological Survey Flagstaff, Arizona, checked for final flight qualification, and loaded aboard the Apollo 12 spacecraft about four days prior to launch.

Gordon Swann:
"The Apollo 12 crew wanted their lunar data Package Maps in color. They decided this about two weeks before the mission. At the Cape, we were down there briefing them with these rather new maps, and they said they would like to see the maps colored. They told us about a guy who knew what kind of colored pencils would work okay in the lunar environment—the vacuum and all that. We got the name of these pencils, and we had two draftsmen (Ray Sabala and Jim VanDivier) start on these. They came down to the Cape with us the next weekend, and finished hand-coloring four sets of these maps. It had to be done by, I believe, Monday morning—the launch was going to be the next Friday. Since NASA did not officially approve the colored maps, Pete Conrad more or less had to smuggle his set aboard the spacecraft. And the guy from Houston who was in charge of overseeing our Data Package maps really had a fit when he found out that those colored maps were aboard, because they hadn't gone through him! Well, they wouldn't have "got through him." He would have said NO, and at that late stage, they wouldn't have had them [on the lunar surface for Apollo 12] (Fig. 70).

Well, on the first EVA [of Apollo 12] they spent most of their time setting up the Geophysical Experiments (ALSEP). On the second EVA, they got out the maps and started figuring out where they were on the traverse—and looking at the maps. One said to the other, "these colored maps are the best idea we ever had." From then on, we got Data Package maps onboard without any trouble; well, maybe only a little" (from a filmed interview with Gordon Swann by Harry Ryan in 1966).

The onboard geologic traverse maps for Apollo 12 included test material dry mounted on the back of each map sheet, briefly describing the important geologic features at indicated traverse stations and noting the sampling and observational tasks to be completed. The maps [including the coloring of the maps as described above by Swann] were prepared in response to a last minute request by the Apollo 12 crew, to be used as an aid in traverse planning and feature location after the "Intrepid" (their LM spacecraft) had landed on the lunar surface. A slightly modified version of what was labeled "Traverse #4" was followed during the actual Apollo 12 geology traverse in EVA II. The maps were used by the crew after landing to help locate the landed LM, to plan the modification of preplanned traverse #4 to accommodate the actual landing location of the Lunar Module; and were used at least three times during the actual traverse to help spot the features for which they were looking.

When they [the Apollo 12 crew] landed (next to Surveyor III that had landed about three years earlier), they wanted us to figure out four different traverses from four different landing spots in the vicinity of the [Surveyor] crater. We knew about where they had landed from their descriptions [from the LM windows], but we couldn't pinpoint it. We knew, I would say, within several hundred yards radius—which is significant when you're walking in a spacesuit. But when they got out of the spacecraft [LM], and looked back, they saw the Surveyor III spacecraft down in the crater behind them. They couldn't see it when they landed because they were facing the other way. But once they got out, they knew exactly where they were—and told us exactly where they were.

Then what we did was take their various stations from the various traverses [we had made at their request], and made a new one, and radioed it up to them between the EVAs. And so, we had a nice pre-planned traverse based on these maps, and previous studies of what they could do at each of those stations. We just took some stations from each traverse, and made a new traverse. This worked very well" (taken from a filmed interview with Gordon Swann by Harry Ryan in 1996).

With Shoemaker's formal Lunar Geology Experiment Team (LGET) in the Science Support Room in the Mission Control Center in Houston for the Apollo 12 mission, some of their colleagues in Flagstaff [some who would become part of the LGET for the later Apollo missions] manned SPE's ADF (Apollo Data Facility) on Fourth Street in East Flagstaff to act as sort of an Ad Hoc support group for the prime team in Houston. They also would, at the same time, practice for their own forthcoming participation with the Lunar Geology Experiment Team in the SSR at MSC (Fig. 71).

The following was taken from the Center of Astrogeology Monthly Report for November 1969 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 30 November 1969:
R.L. Sutton and D.H. Dahlem (both with the SPE Branch, Flagstaff) were picked as representatives of the Apollo Lunar Geology Experiment to work behind the Biological Barrier in the Lunar Receiving Laboratory, as science observers of the samples returned by Apollo 12. E.M Shoemaker and G. Swann each gave briefings to Lunar Receiving Laboratory personnel on the geology of the landing site, and the probable geologic significance of the samples, as interpreted from the astronaut verbal transcripts.

The following was taken from the Center of Astrogeology Monthly Report for December 1969 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief Branch Astrogeologic Studies; dated 31 December 1969:
In December 1969, E.C Morris (BAS, Flagstaff, Arizona) was appointed as an investigator on the Imaging Team for the Viking Mars '73 mission. The team consisted of T.A. Mutch, Brown University, Providence, Team Leader; A.B. Binder Illinois Institute of Technological research; F.O. Huck, Langley Research Center; E.C. Levinthal, Stanford University, Carl Sagan, Cornell University; and A.T. Young, Jet Propulsion Laboratory.

Also during December 1969, Harold Masursky and M.H. Carr were appointed members of the Orbital Science Imaging team for Viking Mars '73.

The following was taken from the Center of Astrogeology Monthly Report for December 1969 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 31 December 1969:
The Lunar Geology Experiment team submitted a general report entitled "Geologic Setting of the Apollo 12 Samples" to the Lunar receiving Laboratory, Manned Spacecraft Center; Houston, Texas. The report is part of the "Lunar Sample Data Catalog" that will be distributed to scientists who study the lunar samples. The introductory part of the report and the map of

sample locations were prepared by E.M. Shoemaker, R.L. Sutton, G.G. Schaber, M.H. Hait, G.A. Swann, R.M. Batson, K.B. Larson, A.W. Waters, and .N. Goddard.

On 17-20 December 1969, G.A. Swann and M.H. Hait accompanied the Apollo 13 crew and members of the Manned Spacecraft Center geology group, Houston, to the Kilauea Volcano area, Hawai‘i, for an astronaut training trip. Participating astronauts included Jim Lovell, Fred Haise, John Young, and Charlie Duke.

David Levy:
"The second half of 1969 was almost entirely devoted to the Apollo 11 and Apollo 12 missions, even though the period between these missions was marked by Gene's surprise announcement that he would leave the Apollo program and concentrate on his duties at Caltech" (Levy, 2000, p. 142).

Don Wilhelms:
"Gene Shoemaker had ably chaired the Apollo 11 and 12 geology teams, except that he never got around to writing the expected professional papers summarizing the mission results and he remained as Chief of the Apollo 13 team at least in title" (Wilhelms, 1993, pp. 235-236).

During a talk a Caltech on 8 October 1969, that he considered "informal," not knowing a reporter was present, Gene announced that he was withdrawing the following March from formal status as an Apollo Experimenter and gave the reasons. One was his deep commitment to his proud post as chairman of the Caltech Division of Geological Sciences. The reasons that made the newspaper, however, were his criticisms of the way Apollo was conceived and operated: NASA had never made much of an effort to accommodate science into the lunar program; all they wanted to do was build ever bigger and better hardware; Apollo had become just a transportation system, and its scientific job could have been done earlier and more cheaply by unmanned spacecraft. Shoemaker foresaw that NASA simply wanted to use up its remaining spacecraft as fast as possible without making the major changes needed to exploit Apollo scientifically.

Needless to say, his comments were not well received by NASA. Homer Newell, Shoemaker's early supporter who had struggled himself to insert science into Apollo, never forgave him. Newell complained that NASA had lifted Shoemaker from a young unknown into the leader of a major program—financed by NASA. Now, however, Shoemaker "Seized every opportunity [Newell said]…to castigate NASA."

Shoemaker's point was that the astronauts should be instruments of scientific discovery, not just passengers. A field geologist could get down on his hands and knees and intelligently sample layers of the regolith, which contains a detailed record of solar and galactic as well as lunar history.

Gene felt strongly that NASA had failed to exploit the scientific opportunity presented by Apollo, and he did not feel as beholden to NASA as the agency might have imagined; his great outpouring of lunar discoveries came before it gave him or the USGS a dime.

That his [Gene's] basic approach had some merit is shown by a particularly plaintive note in Newell's list of grievances: "And, anyway, what good was all the criticism going to do?" NASA lacked the funds to continue Apollo landings much longer. Moreover, voices on Capitol Hill were asking why the agency didn't just stop all further lunar missions, since each new flight exposed NASA and the country to a possible catastrophe.

Shoemaker was not alone in his views. Coming from him, however, they struck a particularly tender nerve (with NASA).

The leadership of future geology teams would be established by the usual NASA process of formal proposal and review and was up for grabs. University professors and everyone else could have a crack at the grand adventure, and it was no secret that the acceptance of a Principal Investigator and Co-Investigators from the universities would be greeted by widespread relief. Lee Silver could have done it; but he was deeply committed to his teaching and laboratory work at Caltech" (Wilhelms, 1993, pp. 235-236).

David Levy:
"Gene's 8 October 1969 speech was a shock to NASA but a tremendous relief to Gene and to the geological sciences division at Caltech, which had suffered with a leader, who, until that day, could devote precious little time to his work there. As Gene settled into Caltech, he found that in addition to teaching and Apollo, he had to concentrate on hiring, firing, and all the administrative details his new job required" (Levy, 2000, p. 142).

Don Wilhelms:
"In the month of Shoemaker's infamous talk, one of the stalwarts of the subsequent field program submitted his proposal to be team leader for the remaining H missions (Apollo 14-15) (half of the remaining missions). Gordon Swann had been at the Houston Astrogeology office, and since October 1964 had been with the Manned Investigations Group at Flagstaff that became SPE [in 1967].

The official announcement that Apollo 13 was cleared for [the] Fra Mauro [region of the Moon] came on 10 December 1969. Swann's proposal to lead the H-mission geology teams was accepted about the same time.

The other successful proposer was geologist William Rudolph Muehlberger (b. 1925) of the University of Texas (see Appendices A and B) [proposal submitted to NASA on 3 April 1970]. After Apollo 11, Don Wise, wearing the hat of the Lunar Exploration Office of NASA Headquarters, had called Bill to tell him that the request for proposals was soon to go out and asked him to put together a team from the universities to manage *all* Apollo science. The USGS was becoming too dominant. Bill thought this was too much to do and said no. Next, Gene Simmons, a geophysicist from MIT and Chief Scientist at MSC since late 1969, called with much the same thought except that Bill's scope would be restricted to geology. That sounded better. At the time of the Apollo 11 Lunar Science Conference in January 1970, Bill attended a meeting in a smoke-filled room at the Rice Hotel in Houston that was also attended by the other candidates, some NASA management people, and Arnold Brokaw, who had moved to Washington in July 1969 as Deputy Chief Geologist for Astrogeology. Bill realized that he could not assemble the necessary expertise from the universities, and he proposed hiring USGS people from SPE. That broke up the meeting. Soon, however, Brokaw called with another scaled-down request: would Bill join the team for the J-missions, Apollo 16-20, as a Co-investigator? Later, Brokaw re-escalated the offer [to Bill] to Principal Investigator" (Wilhelms, 1993, pp. 236-237).

5.4-1970

[Author's Note: A total of 26 separate geologic field-training exercises were carried out during 1970 for the NASA astronauts selected for Apollo missions 13-16. These exercises were planned and carried out under the direction of personnel from the Surface Exploration Branch in Flagstaff. Seven of these training exercises took place near Flagstaff or in the Verde Valley south of Flagstaff (See Table 1).

[Note- The people who worked for the Branch of Astrogeology at the Menlo Park office in 1970 included: Mike Carr, Keith Howard, Carol Ann Hodges, Lew Croft, Don Wilhelms, Newell Trask, Maxine Burgess (secretary), John Serbang, Jack McCauley, Howard Wilshire, Henry Moore (now deceased), Chuck Mesa, Charles Meyer, Susan Pratford (who worked for Mike Carr), Jacquelyn Freeberg (librarian), Beth Swartzman (worked for Howard Wilshire), Danny Milton, Evelyn Newman (mathematician), Desire Stewart-Alexander, and Dick Lund (now deceased).

The following was taken from the Center of Astrogeology Monthly Report for January 1970 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 30 January 1970:
G.E. Ulrich and D.H. Dahlem (SPE Branch) submitted statements on the manned science requirements for geology, geochemistry, and geodesy/cartography for the Dual-Mode Lunar Rover Vehicle to the George C. Marshall Space Flight Center, Huntsville, Alabama in January 1970.

Preliminary geologic maps of the Fra Mauro (Apollo 13) landing site were given to T.N.V. Karlstrom (SPE) to use for preparation of the Data Package materials that will be carried by the astronauts on the mission. T.W. Offield and R.E. Eggleton (BAS) compiled the maps—at three scales.

The following was taken from the Center of Astrogeology Monthly Report for January 1970 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 31 January 1970:
Frank Cuttitta (BAS, Washington, D.C.) reported in January 1970 that he and his entire staff were involved in the analysis of 28 Apollo 11 samples from Tranquillity Base. Both major elements and 22 minor elements were determined.

S.S.C. Wu (BAS) reported in January 1970 that two models of the 500mm photography from Apollo 12 magazine U were successfully set up on the AP/C plotter [at Flagstaff]. From the models, G.M. Nakata and Raymond Jordon compiled two contour maps of the Apollo 13 landing area [in Fra Mauro] at a scale of 1:25,000 and a contour interval of 25 meters. The contour maps were compared with a planimetric map at the same scale, which was made earlier from Lunar Orbiter photography. The agreement was excellent. These were reported to be the best maps yet compiled from Apollo photographs. A photograph from magazine U was then rectified in order to prepare a contoured photomap.

[Astrogeology Milestone: In January 1970, the Branch of Astrogeologic Studies submitted its eighth (?) *Annual Astrogeology Progress Report* for research carried out during the period 1 October 1968 to 1 October 1969. This would be the last of the Annual Astrogeology Progress Reports. The report was in five parts: Part A- Luna Investigations, Part B- Crater Investigations, Part C- Cosmic Chemistry and Petrology, Part D- Geologic Support for Planetary Missions; and Part E- Spaceflight Investigations**]**

Don Wilhelms:
"On 4 January 1970, a day before the first lunar Science Conference began, it fell to [George] Low [Acting NASA Administrator at the time] to announce that Apollo 20 had been cancelled. No funds were available to reopen the Saturn 5 production line, and the Saturn 5 that was to have launched Apollo 20 was needed for the launch of the Earth-orbiting space station, Skylab. Skylab and the Apollo-Soyuz joint mission with the USSR in 1975, also gleaming in the eyes of planners in 1970, were the sole survivors of AAP (Apollo Applications Program). The last glimmer of hope for a post-Apollo lunar program had flickered out. Reassuringly, however, Low also observed that cancellation of any more Apollo missions would waste the great investment in the program and diminish its scientific return. The remaining seven missions (Apollo 13-19) would be stretched out to place the Apollo 18 and 19 launches in 1974, after Skylab, a pace that suited mission-support scientists and engineers better than the constant fire drills that they had come to know. Apollo 13 was moved from 12 March to 11 April 1970" (Wilhelms, 1993, pp. 239-240).]

Don Wilhelms:
"I was serving on the Planetology Subcommittee of the Space Science Steering Committee of OSSA that was charged with reviewing space science proposals when it met in February 1970 in the Caltech library to review Muehlberger's proposal. Swann's had already been accepted, and he was also present. Noel Hinners went into a long discourse to the effect: "Dr. Muehlberger, Dr. Urey believes that geologists have no place studying the Moon because it's a simple chemical body not suited to their line of inquiry, etc., and they haven't had enough experience with selenology, etc., and anyway they're not very bright, etc. etc. Bill shifted his bulky frame on the chair and intoned his first words of the day, "Waal, that's bull s—it." His proposal was quickly accepted, and the Apollo field geology experiment acquired another astute geologist, who expertly and effectively led his team and fended off those who were trying to cripple the effort.

I refer to the resumption of the USGS-MSC rivalry that had begun in 1964. The Apollo-era phase of the conflict was a major distraction for the participants. It was personified by space physicist Anthony John Calio (b. 1929), who replaced Wilmot Hess as the director of MSC's Science and Applications Directorate after Hess resigned in September 1969. Hess was intelligent and competent but had proved unable to prevail against the other, anti-science MSC directorates. Calio's name still raises the hackles of the USGS survivors of that era, and I suspect the feeling is mutual. Two problems among others, apparently more personal ones, were that Calio wanted his own people to take over the field geology teams, and he hated the USGS. Calio and his directorate were constant thorns in the sides of Swann and Muehlberger and the entire USGS operation. The real and adopted westerners from Flagstaff on the field teams usually wore string bolo ties, which became known at MSC as "spy ties." However, they had the respect of the astronauts and also of the flight directors and controllers of the Flight Operations Directorate, and this closeness saved many a day.

Shortly after the Apollo 12 mission Calio brought in the respected petrologist Paul Gast to be chief of the Planetary and Earth Science Division and his chief science advisor—a move, I am told, designed to help Calio in his own competition with the other directorates at MSC and the Apollo Program Office at NASA Headquarters. Many geologists (including me) found Gast obnoxious, but he was straightforward (often a positive aspect of obnoxiousness) and an effective manipulator who could get things done. No one doubted that he was an intelligent and dedicated scientist who thoroughly understood the petrology and chemistry of rocks. Swann is positive that Gast helped more than hurt the program, though he does not say the same for Calio" (Wilhelms, 1993, pp. 237-238).

Don Wilhelms:
"Apollo was at the divide between eras at the beginning of 1970. The day on which the Fra Mauro Formation was confirmed as Apollo 12's target, 10 December 1969, was also the effective date of resignation of George Mueller, a major force in the Apollo planning and a supporter of a vigorous space program—including the science. Mueller was one of the Apollo giants who had moved over from private industry long enough to carry out the grand enterprise and now was returning, as had or would most of the others.

NASA had burned too many bridges to permit all ten of the landings that had been foreseen in 1967. The prime driver within NASA for the manned lunar landings had been George Low, the manager of the Apollo Spacecraft Program Office at MSC since the Apollo 1 fire.

But [following the recent cancellations of the Post-Apollo missions 18-20] the budget cutters were just getting warmed up. In February 1969 Nixon had appointed a very-high-level panel with the same name as the Langley group that had designed Project Mercury, and in effect the manned spaceflight program of the United States, Space Task Group. The new STG, chaired by Vice President Spiro Agnew, entertained such money-be-damned options as space stations in lunar orbit, a lunar base, an Earth-orbiting space station capable of supporting 50 to 100 people, and a manned Mars landing in the 80s or 90s. They also realized, however, that the public was balking at great expenditures for manned flight and proposed cheaper alternatives such as a robotic Mars landing possibly followed by human crews by the end of the century.

In March 1970, just before the Apollo 13 launch, Nixon pronounced himself in favor of a middle ground emphasizing the space shuttle. NASA administrator Thomas O. Paine had bucked the growing trend to small thinking and tried to put a good face on the decision. But he had already confirmed publicly that the Saturn 5 production line had been irrevocably shut down. The future road to the Moon was closed" (Wilhelms, 1993, pp. 239-240).

The following was taken from the Center of Astrogeology monthly report for February 1970 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 28 February 1970:
In February 1970, T.N.V. Karlstrom completed final compilation of the operational data Package maps for the Apollo 13 from geologic maps prepared by R.E. Eggleton and T.W. Offield. The geologic maps will be printed by the U.S. Geological Survey prior to the mission. Final editing of the data package versions—drafted by and published by TOPOCOM (Topographic Command, Corps of Engineers) at scales of 1:100,000, 1:25,000, and 1:5,000—was completed in Washington, D.C., on 24 February 1970. 1:2,500 scale traverse map base has been used by the Field Geology Experiment team with consultation with the astronauts J.A. Lovell, F.W. Haise, Jr., and A.W. England, in preparing traverse plans at selected landing points within the Apollo Fra Mauro site.

J.L. Derick in February 1970 reported that he had completed topographic compilation of a stereoscopic model taken with the Apollo 11 Stereo Close-up Camera. The model covers an area of 6.6 cm X 7.6 cm. The compilation scale was 2:1, and the contour interval was 0.5 mm. Pits larger than 0.5 mm in diameter in both solid and fragmental areas were also plotted. This map and others like it will allow the study and mapping of the detailed relationships between rocks and fine-grained material on the lunar surface.

[Incidental Note from Ray Batson (personal Communication, 2002): Tommy Gold [Cornell University] was furious about this! The camera was "his" experiment, and we had no business utilizing data from it without his permission (he said). I'm not sure if his position had merit or not.]

[Astrogeology Milestone: The pre-construction planning stage for the Branch of Surface Planetary Exploration's Black Canyon (also earlier referred to as Black Mesa) Crater Field near the town of Cottonwood, Arizona took place by Red Bailey and his associates between 16 and 26 January 1970. The pre-shot construction phase was from 27 January to 18 February. Test shots were fired on 19-20 February; and final prep took place on 23 February. The blasting of the crater field took place on 24 February 1970 in four shots of 292, 52, 16, and 2 craters, respectively, in order to have overlapping ejecta—and thus craters of different relative ages. The Black Canyon crater field was 1,000 X 1,500-feet in size (Fig. 72).

The following is taken from (personal Communications to this author by Red Bailey between 2001 and 2002):
The Black Canyon crater field in the Verde Valley, Arizona, constructed for the Branch of Surface Planetary Exploration (SPE) has been referred to by several different names. Red Bailey (SPE, Flagstaff), who directed the construction of the crater field, says that he originally called it the "Verde Valley Crater Field." He then referred to it as the" Black Mesa Field" by 14 January 1970 in his work records notebook, and that designation lasted until the construction period [for the field] in early 1970. The reason for the change in name was that the nearest named "physical feature" (or natural feature) is the major drainage southeast of the field that is named Black Canyon (See Cornville 7.5-minute quad; Twp 15 N-Range 3 E; sections 24 and 25). There was also a cattle tank just west of the west corner of the field that was named Black Mesa Tank. Bailey says further that both Al Chidester and Jack Strobell called it the Cottonwood Crater Field

in 1973 memos. However, Bailey recalls, he also referred to it as Black Canyon Crater Field as early as 28 January 1970 and 5 February 1970 when the area was being cleared and surveyed for the shot hole locations. Red Bailey eventually suggested that we use the name Black Canyon Crater Field since that was the post-construction name used when the Apollo 13 and 14 crews trained there.

The 35-acre site, located 60 miles and 90 minutes southwest of Flagstaff, Arizona, contains 380 craters ranging in diameter from 6 to 82 feet. Fourteen of the craters were fired as test shots in early February. The remaining 366 craters were fired in five groups and four single shots 20, 24, and 26 February 1970. A total of 86,880 pounds of ammonium nitrate, 1,172 pounds of TNT, and 50,000 feet of Primacord were used in making the craters. Construction time beginning with land clearing on 28 January totaled four weeks. The Black Canyon crater field was constructed to be used by the Branch of Surface Planetary Exploration personnel for astronaut training in winter when Cinder Lake Crater Fields I and II near Flagstaff were snowed under or too cold for field exercises. The Black Canyon Crater Field was used to train the prime and backup crews of Apollo 13 (Jim Lovell, Fred Haise, John Young and Charles Duke-on 15-17 March 1970) and Apollo 14 (Al Shepard) [on his 47th birthday no less] and Ed Mitchell on 16 November 1970 [see details below).

The following was taken from the Center of Astrogeology Monthly Report for February 1970 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 28 February 1970:
D.W.G. Arthur (BAS) continued during February 1970 his efforts for the Lunar Nomenclature Working Group of the International Astronomical Union (IAU) in preparation for the 14th General Assembly of the IAU in August, 1970.

As a member of the Imaging Sciences Team evaluating instruments and mission plans for the Mariner Mercury-Venus 1973 flyby, N.J. Trask (BAS) participated during February 1970 in the preparation of documents outlining the scientific research objectives of the mission and listing desirable supporting research that should be initiated by NASA, and comparing alternative imaging systems.

M.H. Carr was asked in February 1970 to act as team leader for the Imaging experiment on the Viking Mars 1975 Orbiter. The team members include Harold Masursky (USGS BAS, Flagstaff, Arizona), D.U. Wise, University of Massachusetts, and W.A. Baum, Lowell Observatory, Flagstaff, Arizona.

H.J. Moore and L.T. Youd contributed during February 1970 to the engineering model for the Viking Lander project. Estimates of both surface topographies down to the slope length applicable to the spacecraft base length and soil properties were included in their contributions

The following was taken from the Center of Astrogeology Monthly Report for March 1970 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 31 March 1970:

In March 1970, D.E. Wilhelms (BAS, Menlo Park, California) made a series of short film segments for West German television Channel 2 to be shown during the Apollo 13 mission. D.E. Davis (BAS, Menlo Park), Astrogeology's artist, was also interviewed.

Harold Masursky (BAS, Flagstaff, Arizona) made a film on Apollo 13 for the British Broadcasting Corporation at the Manned Spacecraft Center, Houston, Texas on 13 March 1970.

[<u>Astrogeology Significant Scientific Finding</u>: N.J. Trask reports that the crater count for the Apollo 12 site is only half that of the Apollo 11 site despite the fact that the age of the mare material appears to be at least three-fourths as old! This suggests that the crater production rate was falling during the first two billion years of lunar history.]

J.F. McCauley (BAS Flagstaff, Arizona) was appointed 8 March 1970 to the newly formed Mission Operations Task Group for the Mariner-Mars '71 Television Experiment.

Harold Masursky conducted seminars on orbital science for the Apollo 15 crew on 13 March 1970 and for the Apollo 14 crew on 14 March at the Manned Spacecraft Center, Houston, Texas.

D.J. Roddy and Harold Masursky gave a seminar on base surge deposits at Meteor Crater and stratigraphic relationships at experimental craters to the Apollo 13 crew at Flagstaff, Arizona on 15 March 1970. These deposits may be similar to the deposits on the Moon at the Fra Mauro site.

During March 1970, H.E. Holt (BAS, Flagstaff, Arizona) and T.J. Lee (Branch Photographer, Flagstaff) participated in engineering optic tests of the Surveyor III camera mirror and filters which were returned by the Apollo 12 astronauts [from the Moon]. The optic tests were conducted at the Hughes Aircraft facility at Culver City, California.

The following was taken from the Center of Astrogeology Monthly Report for March 1970 from Chief, Branch of Surface Planetary Exploration to Assistant Chief Geologist for Environmental Geology and for NASA; dated 31 March 1970:
The Apollo 13 cameras, one Command Module and two lunar surface Hasselblads, were calibrated during March 1970 by H.E. Holt, J.J. Rennilson, T.J. Lee, J.A. Jordon, K.J. Dixon, F.S. Anderson, J. Hall, J.W. Langman, and B.L. Burgert.

Three reference walking traverses for the Apollo 13 landing site were completed during March 1970 by G.A. Swann and T.N.V. Karlstrom in conjunction with astronauts J.A. Lovell, F.W. Haise, Jr., and A.W. England (Capcom). Sets of six 8 X 10.5-inch traverse maps (1:5,000 scale), showing the pre-planned traverses, were prepared on Cronopaque by the Center of Astrogeology's technical staff for use by the Apollo 13 mission—both on the Moon, as part of the data Package, and at the Mission Control Center, Houston, Texas, in the Science Support Room (SSR).

[<u>Author's Note</u>: As fate intervened, these Data Package maps would never be used on the lunar surface during Apollo 13, but would instead be used to save their lives after the explosion onboard the spacecraft when they were about halfway to the Moon; See 1970 discussion of the Apollo 13 mission below.]

The Apollo 13 prime (J.A. Lovell, F.W. Haise) and backup (J.C. Young, C.M. Duke, Jr.) crews participated in a mission simulation at the Black Canyon Crater Field southwest of Flagstaff, Arizona, in the Verde Valley on 15-16 March 1970. The simulation was carried out like a lunar mission: the astronaut crews at the crater field reported observations, took pictures, and collected samples while the Lunar Geology Experiment team at Mission Control Center, Houston, Texas, recorded and analyzed the information (Fig. 73).

The crater field exercise included briefings on crater geology and practice in Lunar Module (LM) location, LM-window description, sampling and photography. Following the exercise on 16 March, a 24-foot crater [crater #429 according to Red Bailey] was blasted especially for the crews and the fresh features around the crater were discussed.

People supporting the exercise included: (1) from the Manned Spacecraft Center, Houston, Texas: U. S. Clanton, J.W. Dietrich, R.G. Zedekar; (2) from the Center of Astrogeology, Flagstaff, Arizona, A.H. Chidester, R.L. Sutton, D.J Roddy, H.E. Moore, N.G. Bailey, J.C. Nuttall; (3) from California Institute of Technology, Pasadena, California: L.T. Silver. The Lunar Geology Experiment team was represented at Mission Control Center, Houston, by G.A. Swann, M.H. Hait, D.H. Dahlem, D.L. Schleicher, G.G. Schaber, R.M. Batson, and by court stenographers [from Flagstaff Superior Court] Keith Welch, D.R. Thacker, and B.W. Leesman—Welch and Thacker from Flagstaff and Leesman from Washington, D.C.

Observers of the exercise included: P.F. Sennwald and P.L. Benjamin, Bellcom, Inc, Washington, D.C., and D.A. Beattie, D.F. Senich, and G.P. Chandler, NASA Headquarters, Washington, D.C.

As part of the SPE Branch's Post-Apollo Investigations, a two-week navigation field test was held on 19, 23-24 March 1970 at the Merriam Crater Lunar Rover Test Site (northeast of Flagstaff] in support of the Astrionics Laboratory at George C. Marshall Space Flight Center, Huntsville, Alabama. The equipment tested was a directional gyro and 4-odometer navigation system mounted on a 6-wheel Amphicat all-terrain vehicle. The system was a prototype of that proposed for Lunar Roving Vehicle missions on Apollo 16-19. Initial vehicle heading was determined by a sun-sensor attached to a theodolite that was also mounted on the vehicle. Both digital and X-Y recorder displays provided vehicle location along loop traverses ranging from four to 32 kilometers in length. A fifth-wheel odometer mounted on a small trailer provided measurements for wheel slippage calculations (Fig. 74).

Support provided by the USGS, Center of Astrogeology (Flagstaff) included personnel and vans for the data handling tasks in the field. Calculations of error, slopes, and wheel slippage and plots of traverse data were compiled as the vehicle proceeded. Special scale topographic and photogeologic maps were prepared to accommodate the X-Y recorder and the traverse plotting in the data handling facility. Surveying on the test course, communications, and vehicle and electronic maintenance support in the Center's facilities were all utilized. Photographic documentation of the field test was also provided at the request of NASA Headquarters and George C. Marshall Space Flight Center.

R.M. Batson and V.S. "Steve" Reed performed photogrammetric calibrations on three cameras that would be flown onboard Apollo 13 in early April 1970, although only one of the cameras, as it turned out (see below), was actually used during the aborted Apollo 13 mission. Tests of film flatness and variation of distortion as a function of aperture were made for the first time. The results of these tests would be used to improve and, hopefully, simplify procedures for calibration of cameras to be used on future missions. It would also be applied to the Apollo 11 and 12 camera data, improving by inference at least our knowledge of the optical geometry of those cameras.

Cartographer/illustrator Patricia Marie (Mitchell) Bridges (b. 1933; Fine Arts degree, 1955, University of Washington in Saint Louis, Missouri), who has earned herself a permanent place in the annals of early lunar exploration "lore", by using her artistic airbrushing talents to "secretly" draw the very first shaded relief map of the Moon starting in 1959 while working for the Air Force Aeronautics and Chart Center (ACIC) in St. Louis (see 1959-1960 above; see Appendices A and B). She subsequently moved to Flagstaff, Arizona in September 1961 to work for ACIC at Lowell Observatory on Mars Hill. At the request of Ray Batson, Pat Bridges formally joined the Branch of Surface Planetary Exploration in March 1970. Her first assignment was doing an airbrush map of the Apollo 11 landing site for some NASA report by the Branch for that mission. That work was for Gordon Swann who was in charge of Pat's first project.

She was located in Building-One (Astrogeology's administrative headquarters) on McMillan Mesa in Flagstaff; but after a very short time Pat and her associates were moved down to the 3rh floor of the Arizona Bank Building. Pat started out on the Apollo landing site maps, but she was also doing some mosaicking from the images returned from the Mars [1964]-flyby mission. Pat went out to JPL with USGS colleagues Sue Davis and Jay Inge to make a 1:1-scale model of one of the Surveyor landing sites. She also participated at JPL with the Branch of Astrogeology Science Team during the encounters of the Voyager spacecraft with Jupiter, Saturn, Neptune and Uranus during the late 1970s and 1980s.

Pat Bridges officially retired from the USGS in 1990, but stayed on working part-time for another couple of years finishing up some maps from the Magellan radar mapping mission (1990-1994). Pat Bridges still resides in Flagstaff.

5.4.1-Apollo 13: A Successful Failure

(Crew: James A. Lovell, Commander; John L. Swigert, Command Module Pilot; Fred W. Haise, Jr., Lunar Module Pilot; proposed landing site was Fra Mauro)

Don Wilhelms:
"Fifty-six hours after liftoff of Apollo 13 on 11 April 1970, a loud bang and a drop in voltage elicited the comment first from astronaut Swigert and then from Lovell, "We've have a problem." Indeed they had; one side of the Service Module had blown away when one of its two oxygen tanks exploded, damaging the other one. Apollo 13 had to return to earth after looping once behind the Moon. The crew had to depend on the oxygen, water, electric power, and air-cleaning systems in the Lunar Module (LM) Aquarius and spacesuit backpacks for the fight back to Earth. The problem was that the trip would take something like 90 hours and Aquarius

theoretically had consumables for only half that time. The free-return trajectory having been abandoned after Apollo 11, trajectory corrections would be needed; but because the usual performer of this job, the Service Module engine (the SPS), was thought probably damaged (and in fact was), Aquarius would have to fill in here too.

Good luck and brilliant work by a small army of engineers from NASA and Grumman, the LM's builder, saved the astronauts' lives and, undoubtedly, the future life of the Apollo program itself. Almost 142 hours after launch and 86 hours after the explosion, the lifeboat Aquarius was jettisoned, and one hour later on 17 April 1970, the well-named Command Module Odyssey splashed down" (Wilhelms, 1993, p. 240-241).

5.4.2- A Lunar Map Package from Flagstaff Helps Save the Crew of Apollo 13

This author, and other Branch of Surface Planetary Exploration personnel, found some solace- and irony in the fact that the crew of Apollo 13 did use some part of the Lunar Map Package for Apollo 13 that was produced at the Center of Astrogeology in Flagstaff. As everyone who has seen Tom Hanks' movie *"Apollo 13"* knows, the crew needed to make some sort of adapter contraption that would connect a square hose connector and a round hose connector from the LM lithium hydroxide (LiOH) canisters vital for eliminating CO_2 from the air from the LM. These particular air hoses from the LM and the Command Module were thus incompatible—but no one had ever thought that the crew would have to take up residence in the LM on the way back home in order to save electricity—-and their lives.

The engineers at Grumman, MSC, and elsewhere figured out—and made—a workable patch that the astronauts could make using duct tape and articles that they had on board the two spacecraft (LM and CM). One of the things that they had was Flagstaff's Lunar Data Package Maps that they were supposed to use while on the lunar surface. These maps were made of multiple 8 X 10-inch-sheets of Chronopaque, a very tough, plastic-like material. The Field Geology Team, having left MSC for home, did not actually find out that the crew had indeed used our maps as a major component of the "fix" that saved their lives. It was not until we were all at Jim Lovell's home near MSC following the last Apollo 15 EVA (July 1971) that Gordon Swann asked him whether they did indeed use our Data Package Maps to make the makeshift connector during Apollo 13. He said, yes, they did—and thank you! The USGS, Branch of Surface Planetary Exploration came through once again—even if "indirectly" in this case!

[Author's Note: The Branch's Lunar Data Package Maps would once again be used with duct tape as a "patch" during the Apollo 17 mission in December 1972 to repair the missing (broken off) fender on the Lunar Rover wheel that was kicking up too much lunar dust in the Taurus-Littrow Valley.]

5.4.3-The Pace of USGS Science Support for Apollo Accelerates

Don Wilhelms:
"Starting with Apollo 13 the voice of science was heeded as never before. The pace of lunar exploration accelerated dizzily for the geologic support teams, which were assembled under NASA contract in official NASA science experiments and through Apollo 14 were officially

called the Apollo Lunar Geology Experiment Team. The teams did not work directly with the Moon rocks unless they individually contracted for projects. What they did was oversee the fieldwork during which the rocks were collected [on the Moon]. First, they had to train the astronauts in the geologist's way of extracting information from rocks, a process that Dale Jackson's group in Houston had begun way back in 1964, and now was getting down to cases. Second, they mapped out the EVA traverses, located stations along them deserving of close attention, and worked with MSC, in preparing detailed timelines to guide the astronaut's activities. Third, working with the astronauts during frequent field exercises, they simulated the missions in appropriate localities on Earth. The fourth task came during the missions when the teams oversaw what was happening from the back room at MSC; earlier called the Science Support Room, but as of Apollo 13 officially called the Science Operations Rooms. Last but not least, they prepared reports that ranged from first-reaction judgments about what happened on each EVA to elaborate U.S. Geological Survey professional papers, which are really books. I did not participate directly in this activity and so can say without conceit that is was an all-out exercise of competence and devotion in the finest tradition of cooperative endeavor.

For five years intensive preparations for these tasks had been under way by the Manned Studies Group of geologists, geophysicists, photogrammetrists, electronics specialists, draftsmen, and secretaries headquartered in Flagstaff who, since August 1967, had been collected in the Surface Planetary Exploration Branch (SPE). They knew that the astronauts would be on the moon for a precious short time and that what the geology teams did might make the difference between wasting and exploiting an opportunity that would come only once.

What the SPE personnel could not know was whether they themselves would constitute the field teams [for the J-missions]. NASA was far from accepting their participation as inevitable. The USGS was anathema not only in much of NASA but in much of academia, presumably because the USGS was a little too aware of its leadership in American geology. This feeling has a long history. I quote the following letter, dated May 1966, to D.M. Barringer from J.C. Branner, who had recently resigned from the Survey: "Survey people have a way of knowing it all that is quite convincing to themselves and to a large part of the rest of the world. That you dare call into question the conclusions of a member of the Survey will be looked upon with suspicion and strong disapproval you may be sure. Recent history was also against leadership of the ground support effort. The squabble between Dale Jackson and NASA in 1964 [when the USGS had its astronaut-training group down at MSC in Houston; see above] had left an indelible mark in the collective memories of MSC" (Wilhelms, 1993, pp. 232-233).

The following was taken from the Center of Astrogeology Monthly Report for April 1970 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief Branch of Astrogeologic Studies; dated 30 April 1970:
R.E. Eggleton and T.W. Offield were appointed in April 1970 as Co-Investigators for the Apollo Field Geology Experiment (SO59) for the Apollo 13 mission.

B.K. Lucchitta reported in April 1970 that the West German television "2. Programm" interviewed her and taped a short presentation in German on the planned landing traverses of Apollo 13.

K.B. Larson, R.M. Batson, M.H. Hait, and G.G. Schaber, G.A. Swann, and R.L. Sutton completed in April 1970 the final map of the landing site of Apollo 11. The map shows conspicuous blocks and craters, photo locations and orientations (including surface coverage on 16-mm movies taken during LM descent), 0.5 m contour lines, lineaments (including rose diagrams) in selected areas, crater age relationships and inferred ejecta patterns, astronaut traverse areas, positions of the LM, the flag, the television camera, the solar wind composition experiment, the Laser Ranging Retro Reflector and the Passive Seismic Experiment.

A.H. Chidester, M.H. Hait, and R.M. Batson, along with M.C. McEwen and T.H. Foss of the Manned Spacecraft Center, Houston, Texas, and Dick Jahns (geologic observer) accompanied the Apollo 14 crew (prime and backup) to Hawai‘i for geologic and photo-documentation training. The three days of field exercises (on 2-4 April 1970) in various volcanic areas gave the crews a variety of situations in which to practice the procedures for location, sampling, photography, and verbal description. Each of the exercises was followed by a debriefing session in which the crews and geologists discussed and interpreted the geology of each local area”

[Astrogeology Milestone: In April 1970 Putty Mills, Bill Tinnin and I.L. “Dick” Wiser of the Branch of Astrogeology’s Field Test Support Unit began construction of a brand new, hand-made, Lunar Roving Vehicle (“Grover”) at their vehicle support shop at 1720 East Street in the Sunnyside area of East Flagstaff. The Grover was to be built closely following the blueprints for the actual Apollo LRV design by the Boeing Company, whose winning design had then been selected by NASA.]

Don Beattie and Putty Mills recount below the rather amazing story of how the Geological Survey’s Lunar Roving Vehicle simulator (Grover) came to be built in Flagstaff, Arizona in only ninety days:

Don Beattie:
“When the contract was signed to build the LRV (Lunar Roving vehicle) for the last three missions, Rutledge “Putty” Mills, our vehicle guru at Flagstaff, was charged [by Don Beattie himself—see story below] with building a training vehicle that would approximate the LRV configuration so that we could continue to do mission planning and simulations at Flagstaff. (The flight version of the LRV could not be used in terrestrial simulations because it was designed to operate in lunar gravity. It would have collapsed under the astronaut’s Earth weight.) An LRV simulator that could be used in Earth’s gravity was not due from the contractor for some months, and we wanted to get an early start on our simulations. Putty [along with his talented co-workers Bill Tinnin, Dick Wiser and Walt Fahey] did his usual innovative job of constructing a vehicle from odds and ends and his fertile imagination. We named it “Grover the Rover” for one-G Rover, and it was ready for testing by the end of June 1970, just six months after Boeing was given the final LRV specifications” (Beattie, 2001, p. 185).

[Author’s Note: Don Beattie above is quoted as saying that they [the Branch of Astrogeology] called it Grover—for one G-Rover. Putty Mills stated in his interview with Gerald Schaber that it was nicknamed Grover for “Geologic Rover—not for 1-g Rover. George Ulrich agrees with Putty that the Grover acronym was for Geologic Rover. In fact, George Ulrich told Gerald

Schaber (27 July 2002) that he remembers that we had a contest at the Center of Astrogeology in Flagstaff to name it.]

Putty Mills' personal story about how Don Beattie approached him to build "Grover" goes as follows:
"We were supposed to get one [a one-g rover]—they [Boeing Aerospace] made six vehicles, four for the Moon, a vibration test unit, and then a training one, similar to the one we were supposed to get.

They [Boeing] were having trouble with it [the one-g version of the LRV]. They used some exotic materials for the chassis and they kept breaking the welds. I talked to a guy I used to know from the GM plant. So Boeing wasn't going to deliver it [for a long while] and we wanted it for Dave Scott and Jim Irwin [the Apollo 15 lunar surface crew]. They were starting [serious mission] training about July 1970.

So Don Beattie came to me and said "Putty, we're in a bind—we've got 90 days. Could you get out something together for us?" So, I said "Don (I was kind of brash then because I had already looked into it), we are going to end up where we need an electric vehicle." So I said "have the astronauts put on their calendar—90 days from now to come to Flagstaff to test-drive their simulator" [Rover]. He [Don] said, "Do you really mean that? I said "yeah!" So, he said, "meet me Monday down at Huntsville, Alabama." They had a whole Boeing setup down there—a lot of people were designing the LRV—and he said to bring your Polaroid camera. So I met Don down in Huntsville the following Monday, and he told everyone that we were going to build this thing ourselves. So, I got all the drawings from Boeing—and a lot of pictures. Of course, I had to make a simpler version. There was no way I was going to make an identical vehicle in 90 days" (from an interview with Putty Mills by Gerald G. Schaber on 22 January 2001) (Fig. 75).

[Author's Note: Boeing eventually delivered some sort of one-g version of the LRV to Houston that Putty said was used mostly for Public relations—for Walter Conkrite, etc. However, it could not be used in the field without breaking welds, etc.

NASA had spent $1,250,000 for the Boeing one G version of the field simulator LRV [that never actually worked properly] while the USGS-built version constructed by Putty Mills, Bill Tinnin, Dick Wiser and Walt Fahey cost a grand total of $1,900. When Don Beattie asked Putty how much did this thing cost [i.e. the USGS version of the Lunar Rover]; Putty said "Something like $1,900. Beattie said, oh we couldn't say that to NASA Headquarters—so they multiplied the cost by about ten and claimed that we built it for $20,000—still a great bargain.]

Putty Mills:
"Our Grover has an electric motor in each wheel, which included a gear reduction in that same motor case. So, the actual lunar rover on the Moon had that 80-to-1 reduction. I was hoping to find about a 60-to-1 reduction. I had to settle for a B-26 landing gear motor that had a reduction of 45-to-1. That little motor had about 6 ft-lbs. of torque, and you multiple that by 43-to-1 and you come up with 250 some pounds that was adequate for the vehicle.

I got the B-26 landing gear motors off surplus in Los Angeles for $12.50 apiece. So everything was cheap on that [Grover]. The actual LRV was a torsion bar suspension. I know I can find some already built up because you know we can't do a custom build—in 90 days. So I searched around the wrecking yards in Phoenix. A particular German vehicle had torsion bars, and then a Morris Minor from the 1960s also had torsion bars. I settled on those, and it worked out great. So, here again, those things were really cheap. The rest of the Grover was built out of stock—you know—from our metal racks [at Flagstaff].

The Grover's original navigation system consisted of a regular speedometer that was wheel driven and cost $12.00. We had Jim Crossan [one of Astrogeology's surveyors] chain out and mark a surveyor mark that we put into concrete. Thus, we had a very accurate 1/4-mile course. We also listed the mileage and in kilometers. Then to calibrate it [the navigation system] we'd run back and forward on that marked distance, so as to obtain the exact mileage.

Oh, a funny thing that happened when we were with the Apollo 16 crew [with the Grover]—John Young and Charley Duke during the astronauts' first checkout of the Grover. We were talking about the navigation equipment on the actual Lunar Rover—and the fact that it cost $3,500,000. What it did is—it was an electronic device that took the average speed of the three closest wheel speeds to consider that one wheel was up in the air and was spinning—not driving. That thing costs a lot of money. John Young was joking because the system we had on the Grover was very accurate and only cost $12.00.

Also, we had a gyro system on the control panel. I had a friend at Santa Barbara, Rob Williamson. I told him what I needed, and he came up with an electric-driven gyro out of one of the Frontier Airlines planes. So we modified that to meet our requirements on the Grover. Williamson Aircraft Co provided that gyro. It may have been that we had $800 bucks in it—or something like that" (from an interview with Putty Mills by Gerald G. Schaber on 22 January 2001).

[Author's Note: If the reader wants to know more details about the exceptionally talented mechanics at Flagstaff who built the Explorer and Grover vehicles for the Branch of Astrogeology, see this author's interviews with Putty Mills, Bill Tinnin in Appendix A).

The following was taken from the Center of Astrogeology Monthly Report for May 1970 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 31 May 1970:
G.G. Schaber (SPE Branch, Flagstaff, Arizona) reported in May 1970 that personnel of the Radar Techniques project are currently engaged in geologic study of 25-cm wavelength terrestrial radar data (from Northern Arizona and Death Valley, California) and 70-cm wavelength delay-Doppler lunar radar data. The 25-cm radar image data were acquired (using a jet aircraft) by the Microwave Group at the Jet Propulsion Laboratory, Pasadena, California. Evaluation of these data is considered as a feasibility study in support of a Command Module lunar orbit radar sounding experiment presently scheduled for [then scheduled] Apollo 19. The final proposal for the experiment was submitted to NASA by W.E. Brown, Jr. of the Jet Propulsion Laboratory.

Investigations of the terrestrial 25-cm radar images by Schaber have revealed some interesting relationships between image tonal contrast and known geology and variations in mean, small-scale surface roughness.

Schaber also reported during May 1970 that his research in delay-Doppler lunar radar data at 70-cm wavelength has been centered in the Sinus Iridum and Cassini quadrangles in northern Mare Imbrium. Very low radar backscatter values in Sinus Iridum are characteristic of the youngest mapped mare surfaces in the region, including an extensive sequence succession of lobate volcanic flows. The regions of lowest radar backscatter are also those of lowest visual albedo, reduced crater density and they contain a number of partially mantled craters suggesting post-crater deposition of lava and/or ash materials. This correlation suggests to Schaber a causal relationship between reduced radar backscatter, the geologic processes involved, and the constitution of the materials that buried the craters (See Schaber, G.G., Eggleton, R.E., and Thompson, T.W., 1970, Lunar radar mapping: correlation between radar reflectivity and stratigraphy in northeastern Mare Imbrium: *Nature*, v. 226, P. 1236-1239.)]

Frank Cuttitta (BAS, Washington, D.C.) was appointed in May 1970 a member of the Lunar Sample Working Group (LSWG) at the Apollo Program Office, Washington, D.C. The LSWG will take over the responsibility and functions of the previously existing Planetology Subcommittee, which had made recommendations to the Associate Administrator, Office of Space Science and Applications. In cooperation with the Manned Spacecraft Center, the LSWG will carry out internal reviews of all incoming lunar sample research proposals.

The following was taken from the Center of Astrogeology Monthly Report for April to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 31 May 1970:
Geologic mission-traverse planning reports for Apollo 16-19 site evaluations were prepared in May 1970 for Marius Hills and the central peaks of Copernicus [crater] by E.W. Wolfe, J.P. Shafer, J.D. Strobell, D.P. Elston, G.R. Scott, and G.E. Ulrich. W.R. Muehlberger of the University of Texas, Austin (and the USGS), was briefed on the traverse plans designed to utilize the Lunar Roving Vehicle (LRV) up to 10 km away from the landing sites. These reports are to be working documents for planning activities by the Surface Science Working Panel's sub panel on Traverse Planning coordinated by J.R. Sevier at the Manned Spacecraft Center, Houston, Texas.

[<u>Astrogeology Milestone</u>: In June 1970, geologist Jack Strobell (1917-1990) was made Chief of the Branch of Surface Planetary Exploration by Arnold L. Brokaw (then Deputy Chief Geologist for Astrogeology) (and at the insistence of the Chief Geologist, Hal James). At the same time, Jack McCauley becomes Chief of the Branch of Astrogeologic Studies and Alfred Chidester (then Branch Chief of the Branch of Surface Planetary Exploration), became Deputy Assistant Chief Geologist for Astrogeology.]

Don Wilhelms:
"When Arnold Brokaw moved [from Flagstaff] to Washington in July 1969, Al Chidester had returned temporally as Branch Chief of Surface Planetary Exploration. However, Brokaw and Chief Geologist Hal James, the creator of SPE, had witnessed the straightforward Chidester's

impatience in dealing with Calio and Gast and concluded that relations with NASA would improve if he were replaced. In June 1970 they yanked him as SPE Branch Chief, whereupon he left the lunar program entirely. To make a clean sweep, Brokaw and James canned Hal Masursky as chief of the Astrogeologic Studies Branch because his free-spending and jurisdictional dispute with Chidester had caused them and other survey manager's endless grief.

Thus, a memo from James dated 19 June 1970 greased the skids under Chidester and Masursky with the wording, "Following our policy…of rotating personnel in administrative positions…"Chidester" has agreed to head up our cooperative work in Columbia," and Hal…will act as consultant and advisor to the two Branch Chiefs and [Brokaw]. Further: "In dealing a new administrative hand, we open with a pair of Jacks." Jack McCauley eagerly accepted the chiefdom of Astrogeologic Studies, moving from San Francisco back to Flagstaff, and Jack Strobell became Branch Chief of SPE. McCauley served until he burned out in 1975. Strobell did not work closely with his branch, but the geologists of SPE were so confident of themselves and the value of their mission that they surmounted all obstacles erected by the USGS or NASA. James and Brokaw never did succeed in their efforts to rein in SPE, which continued to function independently of the century-old regulations and customs of the USGS.

Jack Schmitt suggested a visionary program of four spectacular landings to regain public support: Tycho, the Orientale Basin, the North Pole, and the far side. But the Apollo 13-14 interlude was not a happy one for the lunar program. Money was getting ever tighter as the Vietnam War escalated, and Robert Gilruth and others in NASA were also worried that their luck might not hold out and they would lose a crew if flights continued too long. The future belonged to the shuttle.

As both a visionary and a Democrat, Paine felt out of place in the Nixon administration and resigned on 15 September 1970, to be replaced temporarily by George Low as acting Administrator, and then permanently in April 1971 by the unimaginative Utah Republican James Fletcher.

Wernher von Braun had moved from Huntsville to Washington in February 1970, and he watched with increasing dismay as his adopted country's vision shrank from the unlimited vistas of cosmic travel to the cramped perspective of the short-term bottom line" (Wilhelms, 1993, pp. 242-243).

The following was taken from the Center of Astrogeology Monthly Report for June 1970 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 30 June 1970:
In June 1970, D.E. Wilhelms (BAS, Menlo Park, California) briefed the six members of the Apollo 14 prime and backup crews in general lunar geology, stressing the structures and deposits of Orientale, Imbrium, and other multiringed circular basins [on the Moon].

H.A. Pohn and H.W. Radin of Bellcom, Inc., briefed astronauts S.A. Roosa and R.E. Evans [Command Module pilots] at Cape Kennedy, Florida in June 1970, on the lunar photometric function and the geologic implication of albedo. A number of visual experiments were discussed concerning the lunar Heiligenschein [Earthshine lighting of the lunar dark side]

On 4-5 June 1970, D.J Roddy conducted for the Apollo 15 prime and backup crews a field tour of Meteor Crater and the man-made crater field (Cinder Lake # 1) recently constructed just east of Flagstaff by personnel from the USGS Branch of Surface Planetary Exploration. The astronauts participating included the prime crew David Scott and Jim Irwin, and Al Worden, and the backup crew, Jack Schmitt, Dick Gordon and Vance Brand; in addition to Joe Allen, and Robert Parker (Capcoms), and Karl Heinz. Joe Roberts (MSC) also participated. The astronauts studied the basic features associated with impact craters at both sites. Such features as the "overturned flap", ejecta rays, shocked rocks, meteoritic fragments, and ejecta blankets could be seen at one, if not both sites. A special booklet for the field trip was prepared and given to each astronaut. The booklet, which included cross-sections based on the recent drilling on the south rim of Meteor Crater [by the Center of Astrogeology, Flagstaff], proved successful, and would be used in future field tours (Fig. 76).

In early June 1970, H.J. Moore gave a lecture in Flagstaff, Arizona on the use of craters on the lunar surface to collect samples and establish lunar stratigraphy to astronauts Dave Scott, Jack Schmitt, Jim Irwin, Dick Gordon, Al Worden, Vance Brand, Joe Allen, Karl Heinze, and Bob Parker. Joe Roberts (MSC) also participated. The lecture was illustrated by a field tour of craters at the Cinder Lake Crater Field, Flagstaff, Arizona.

The following was taken from the Center of Astrogeology Monthly Report for June 1970 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 30 June 1970:
D.P. Elston, M.H. Hait and Farouk El-Baz (Bellcom, Inc., Washington, D.C.) conducted an exercise 18-19 June 1970 in aerial geological observation over the San Francisco and Hopi Buttes volcanic fields, Arizona, for the prime and back-up Command Module pilots of Apollo mission 14, S.A. Roosa and R.E. Evans. Work consisted of "pre-mission" briefing, a 4.5-hour aerial exercise, and "post-mission" debriefing. Also present were P.K. Chapman and J.P. Allen, Manned Spacecraft Center, Houston, Texas, mission scientist astronauts for Apollo 14 and 15; and M.C. McEwen, Manned Spacecraft Center, Houston.

The following was taken from the Center of Astrogeology Monthly Report for July 1970 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 30 July 1970:
The mission planning Lunar Roving Vehicle simulator Grover for geologic field testing was in the final stages of construction in July 1970 by the Field Test Systems shop at the Branch of Surface Planetary Exploration at 1720 East Street in East Flagstaff, and was expected to be operational in August (See August 1970 for more details on how and why the Grover was built for NASA by Putty Mills, Bill Tinnin and Dick Wiser) (Fig. 77).

J.W. Young, C.M. Duke, F.W. Haise, G.P. Carr. W.R. Pogue and A. W. England accompanied L.T. Silver, California Institute of Technology, Pasadena, California, and M.H. Hait on an astronaut-training trip 8-10 July 1970 into the San Juan Mountains area of southwest Colorado. The two phases of the trip included a fly-around over the major physiographic, volcanic, and structural features of northwest New Mexico and an on-the-ground study of various igneous, metamorphic, and structural relationships and associated sampling problems within the San Juan Mountains.

G.A. Swann and M.H. Hait briefed the Lunar Module and Command Module crews of Apollo 15 during July 1970 on photographic results from Apollo missions 11 and 12.

D.P. Elston and M.H. Hait conducted the prime and backup Command Module Pilots of Apollo mission 15—A.M. Worden and V.D. Brand—on a two-day exercise on 15-17 July 1970 in aerial geologic observation and description over the San Francisco and Hopi Butte volcanic fields, Arizona. The exercise consisted of "pre-mission" briefing and an introduction to volcanic stratigraphy and landforms, a six-hour aerial exercise, and "post-mission" debriefing. Following this, the Command Module Pilots observed the areas studied from high altitude from their jet aircraft.

On 15-17 July, 1970, G.A. Swann, L.T. Silver, and G.E. Ulrich, during July 1970, conducted the Lunar Module crew members—D.R. Scott, J.B. Irwin, R.F. Gordon, and H.H. Schmitt—on a one and one-half day exercise in surface (volcanic) geology in the Crater 160, S.P. Crater, and Merriam Crater areas, near Flagstaff, Arizona. This was followed by a fly-around of the area.

On 22-23 July 22, 1970, Dave Roddy (USGS-BAS Flagstaff) led thirteen astronauts on an observation exercise of a 500-ton TNT experimental explosion (called Dial pack; detonated on 23 July) at the Defense Research Establishment, Suffield, Alberta, Canada, to simulate crater formation. Astronaut participants included: G.P. Carr, C.M. Duke, Jr., R.F. Gordon, Jr., J.B. Irwin, W.R. Pogue, D.R. Scott, A.M. Worden, J.W. Young, J.P. Allen, V.D. Brand, A.W. England, F.W. Haise, Jr., and H.H. Schmitt.

After watching the crater explosion, the participants then went in to examine the crater within 10 minutes of the blast. They saw a crater that was 230 feet in diameter and 15 feet deep with a central mound. They then went down into the crater, saw overturned flaps, backwash and glass beads. They then walked around the crater at the edge of the continuous ejecta blanket; rays, both blocky and powdery were obvious. Everything was gray-black (similar to the lunar surface) from the TNT.

Also during July 1970, M.H. Hait met with the Apollo 15 crew members—D.R. Scott, J.B. Irwin, R.F. Gordon, H.H. Schmitt, A.M. Worden, and V.D. Brand-for a review and discussion of the Apollo 11 and 12 lunar surface panoramas and selected stereo photographs. The purpose was to identify and describe details of lunar surface features that contribute to the understanding of lunar surface processes and that pose situations for sampling, description, and photography.

Don Wilhelms tells us below how Lee Silver (see above) came to work for the USGS, Branch of Surface Planetary Exploration in July 1970:

Don Wilhelms:
"During his undergraduate days at Caltech between 1953 and 1957, Jack Schmitt had been particularly impressed by an enthusiastic and versatile professor of geology and geochemistry by the name of Leon Theodore "Lee" Silver (b. 1925). Actually the connection was older than that:

Harrison Schmitt, Senior, had introduced the 11-year-old Jack to Silver during a visit to the Schmitt home in Silver City, New Mexico, in 1946. Jack had taken as his mission the enlargement of the role of science in Apollo and was trying to activate the interest of the Apollo 13 crew in geologic training. He was sure that Silver was the man to do it and called him in August 1969. Silver was willing but felt that he had to get permission from the department chairman. No obstacle there; the chairman was Gene Shoemaker" (Wilhelms, 1993, p. p. 234).

The following was taken from the Center of Astrogeology Monthly Report for August 1970 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from the Chief, Branch of Astrogeologic Studies; dated 31 August 1970:
D.J. Roddy reported in August 1970 that 13 astronauts participated as part of the U.S. Geological Survey project in the Dial Pack 500-ton TNT crater experiment [detonated 23 August 1970] Roddy and G.H.S. Jones, Maritime Command, Canadian Government, gave a pre-shot technical briefing to the astronauts and conducted the field examination of the crater.

Gerald Schaber:
Geophysicist Laurence A. Soderblom (b. 1944), a gifted and forward-thinking individual (much like Gene Shoemaker) entered on duty in WAE status with the Branch of Astrogeology in August of 1970 after receiving his PhD in geophysics from Caltech (Pasadena, California) in June 1970 (see Appendices A and B). For his Doctorate research at Caltech, Larry had dual advisors, Gene Shoemaker and Bruce Murray. His dissertation work under Gene Shoemaker was on modeling the morphological evolution of small craters under the influence of impact gardening; and under Bruce Murray, studying the chemical and compositional variations of the surface of the Moon using reflectance spectroscopy in the visible from Earth-based telescopes, notably at Mount Wilson, California. As a result, Soderblom's thesis was a union of those two topics, and was entitled: *"Regional Lithologies of the Lunar Maria"*, which involved mapping them based on their self-reflectance properties, and age-dating them by using a crater-erosion model (Larry's widely-heralded DL model).

As a post-doc at Caltech between June and October of 1970, Larry was working closely with Professors Bob Sharpe and Bruce Murray on analysis of the Mariner 6 and Mariner 7-Mars flyby data. Thus, he had already been engaged in Mars (planetary) data even before coming to Flagstaff.

At the advice of Jack McCauley and Hal Masursky, Larry and his wife Barbara moved to Flagstaff, Arizona in October 1970 to work for the Branch of Astrogeologic Studies there. At Flagstaff, Larry worked part time for the Survey (Branch of Astrogeology) and part time for Caltech for about one year. He spent much of this initial period in Flagstaff working on his lunar gardening (DL-mare surface age) model which, after perfecting, he turned over to Joe Boyce and Art Dial. In 1971, Larry went back to Caltech for about a year to work on the Mariner 9 mission and encounter. In the fall of 1971, he wrote a successful proposal to NASA to be a member of the Voyager mission in the fall of 1971. This would only be the beginning of a truly remarkable career for Larry Soderblom; one that continues at full steam with the Branch of Astrogeology in Flagstaff to the present day

The truly outstanding original contributions that Larry Soderblom has made to lunar and planetary science, as well as planetary mission design, unmanned spacecraft scientific instrument design and development, and lunar and planetary data processing are legendary in the domestic and international planetary science community. These achievements are now part of the historical record. Equally important (at least to NASA HQ) has been Larry's long-standing "never-say-no" attitude to NASA when they—on literally hundreds of occasions over the years—have asked him to chair, or participate in, literally hundreds of NASA Committees (see partial list below) that would monitor the progress of current missions or set the ground rules, designs, and objectives for future probes.

Larry became part of the Branch of Astrogeologic Studies in Flagstaff, Arizona at just the right time—as the Apollo missions began—to guide the Branch out of the highly-heralded Apollo Era (1961-1973)—spearheaded by Gene Shoemaker and others—and rekindle the Branch personnel's well-established enthusiasm for hard work and original research by skillfully directing it into the next phase—Planetary Exploration on a grand scale. This included his leadership at Flagstaff in pioneering achievements in data processing of vidicon images and other data returned from planetary probes. As during the Apollo Era, a number of Branch of Astrogeology personnel would be active participants or team leaders on virtually all of NASA's planetary-mission science teams for the three decades that have now followed the Apollo manned lunar landings. Like Gene Shoemaker, Larry is not only brilliant, but perhaps even more importantly, he is an outstanding visionary and motivator of people to achieve things that they themselves would never believe they could do.

[Branch of Surface Planetary Exploration Milestone: Grover, the Lunar Roving Vehicle (LRV) simulator, built by R.A. Mills, B.G. Tinnin, and I.L. Wiser (SPE Branch, Flagstaff, Arizona) as a near-replica of the Lunar Roving Vehicle 1-G simulator for crew training, underwent its in-house maiden traverse (using USGS staff) at the Cinder lake Crater Field No. 1 on 21 August 1970].

[Branch of Astrogeology Milestone-Flagstaff's *Arizona Daily Sun* on 25 August 1970 featured a SUNfeature by Staff Writer Jeff Stone entitled "Astrogeologists Reach 10th Year of Operation." The article goes on to say, in part:

"Nearly ten years have passed since late President John Kennedy promised America that the country would put men on the Moon before the end of the 1960's. The America Space Program made the deadline July 20, 1969, when the Apollo 11 mission carried two men to the Moon's Sea of Tranquility.

Ten years have passed since the National Aeronautics and Space Administration (NASA) granted $200,000 for a project within the U.S. Geological Survey to study the geology of the Moon.

On August 25, 1960 NASA officially funded a small group of men working in the USGS Regional Office at Menlo Park, California, as an "astrogeologic studies unit" to work with the infant space program. From that group of 12, the present day USGS, Branch of Astrogeology grew, and today celebrates its tenth year of existence.

The Branch has seen much growth in those years; employees now number 182, most of them at the Flagstaff Center of Astrogeology. The branch has split into two branches, one of Astrogeologic Studies, and the other of Surface Planetary Exploration. From a few Menlo Park offices, the branches also have several buildings in Flagstaff and a laboratory in Washington, D.C. And this year's budget for the branches is $5 million dollars, a long way from the initial $200,000."

The following was taken from the Center of Astrogeology Monthly Report for August 1970 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from the Chief, Branch of Surface Planetary Exploration; dated 31 August 1970:
On 26-28 August 1970, astronauts D.R. Scott, J.B. Irwin, R.F. Gordon, H.H. Schmitt and J.P. Allen accompanied L.T. Silver, California Institute of Technology, Pasadena, California; G.E. Lofgren, U.S. Clanton, Manned Spacecraft Center, Houston, Texas; and M.H. Hait (SPE, Flagstaff) on an astronaut training trip into the San Juan Mountains area of southwest Colorado (see Table I). The two phases of the trip included a fly-around (from Albuquerque to Durango, Colorado) over the major physiographic, volcanic, and structural features of northwest New Mexico and an on-the-ground study of various igneous, metamorphic, and structural relationships and associated sampling problems within the San Juan Mountains. The ground training consisted of several exercises and one simulated EVA exercise. The general geology included metamorphic and granitic Precambrian rocks and 30 and 5 million year old volcanic rocks. The exercises emphasized contact relationships and the differentiation of igneous and high grade metamorphic rock types.

On 11-13 August 1970, The Apollo 14 prime and backup crews completed three days of geology training in the vicinity of the Ries impact crater structure in Germany (see Table I). The stratigraphic section of the Ries contains a wide variety of rock types, and these were studied both in the undisturbed state and through all stages of shock alteration, including complete melting. The areal and stratigraphic separation of rock types in the ejecta blanket as a function of their original stratigraphic position was observed throughout the trip. Scouring and striations on the upper surface of the "country rock," caused by the radially-outward blast of the material at the time of impact, were observed by the astronauts at several localities. At the Steinheim basin, a smaller impact crater near the Ries, shatter cones were found in the central uplift. Local experts in the area of the Ries were Prof. Wolf von Engelhardt and Dr. Dieter Stoffler from the University of Tubingen, and Dr. Fred Horz from the Lunar Science Institute (MSC-Houston, Texas).

The following was taken from the Center of Astrogeology Monthly Report for September 1970 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from the Chief, Branch of Surface Planetary Exploration; dated 30 September 1970:
Apollo 16 astronauts J.W. Young, C.M. Duke, F.W. Haise, G.P. Carr, and W.R. Pogue, led by T.R. McGetchin, Massachusetts Institute of Technology, Cambridge, Mass., visited sites on 1-2 September 1970 in the Eastern San Francisco Volcanic Field, Hopi Buttes, and Monument Valley areas which contain deep-seated rocks (xenoliths). Frederick Horz and astronaut A.W. England of the Manned spacecraft Center, Houston, Texas; D. R. Wones of MIT; and R. L. Sutton of the U.S. Geological Survey (SPE Branch) assisted with the astronaut training trip. Tom McGetchin gave a briefing to the crew on the regional geology of the area on 31 August.

Geologic sites visited by the Apollo 16 prime and backup crews during the 1-2 September geologic field trip on the southern Colorado Plateau included Hopi Buttes, Arizona, Moses Rock dike, Mexican Hat, Utah, Monument Valley, Utah/Arizona, and finally to the SPE Branch's Cinder Lake Crater Field near Flagstaff.

Following the field trip (on 3 September, 1970), the Apollo 16 crew were the first of the Apollo astronauts given the opportunity to check out the newly-completed Grover vehicle built in Flagstaff.

[Branch of Astrogeology Milestone-Astronauts John Young, Charles Duke, Tony England, Fred Haise, Gerald Carr, along with MSC geologist Bill Phinney, Jack Hanley from MSC, and various engineers from MSC (Houston, Texas), Marshall Spaceflight Center (Huntsville, Alabama) and NASA Headquarters (Washington, D.C.) took part in the initial checkout of the Grover vehicle on 2 September 1970 in a vacant lot adjacent to Putty's shop at 1720 East Street in East Flagstaff (Fig. 78).

Putty had built the Grover to run on electric motors like the real LRV, and he had three battery packs available to recharge so we could have more or less continuous operation. At full throttle the Grover could make seven miles an hour carrying two passengers, similar to what we could expect of the LRV on the lunar surface. Mock-ups of some of the tools were stowed on a pallet on the vehicle, the way we anticipated they would be carried on the Moon, although a final stowage configuration for the LRV had not been decided.

Everyone agreed at the end of the test that the Grover would be a valuable addition to future mission simulation; especially when Putty had a chance to add refinements such as a navigation system and additional mock-ups for the lunar communications relay unit, TV, and other equipment the LRV was scheduled to carry. Eventually, we obtained a fully functional, albeit simulated, LRV for our simulations.

[Author's Note: Page one of The *Arizona Daily Sun (Flagstaff, Arizona)* of 5 September 1970 included the headline "Spacemen Get Moon Preview." The article goes on to say:

"Six of America's astronauts were in Flagstaff this week (1-2 September 1970) to consult with scientists of the U.S. Geological Survey's Center of Astrogeology, to observe geologic features like those they may find on the Moon, and to drive a new version of a Moon vehicle simulator [Grover"-see above]. John Young, Charles Duke, Gerald Carr, Fred Haise, Bill Pogue, and Tony England from NASA's Manned Spacecraft Center at Houston spent Tuesday and Wednesday on a field trip in Northern Arizona and southern Utah. Leading the excursion was Dr. Tom McGetchin accompanied by R.L. Sutton, both geologists. Their first stop was the Hopi Buttes area, about 80 miles northeast of Flagstaff. In this area are several maar-type volcanic craters—about 4 million years old that were formed rather violently, and the material ejected includes rocks brought up from deep beneath the Earth's surface. The craters later filled with water, which in turn, deposited layers of sediments. Fish fossils have been found in some of these beds. The astronauts were also taken to Rattlesnake Crater, nearer Flagstaff, to examine another maar-type crater, one that is much younger than those at Hopi Buttes.

The next day, the field party drove to Moses Rock diatreme near Mexican Hat, Utah, to observe still another type of volcanic feature. On the final day of their visit to Arizona, the astronauts tested a new vehicle, built by the U.S. Geological Survey in Flagstaff. It is similar in many respects to the one being developed for actual use on the Moon. The Moon vehicle, known as LRV (Lunar Roving Vehicle) is being built by Boeing. The Flagstaff LRV simulator, called Grover (Geology Rover) has been built to LRV proportions."

The following was taken from the Center of Astrogeology Monthly Report for September 1970 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 30 September 1970:
G.G. Schaber, R.L. Sutton and H.J. Moore took part in geologic training activities on 11 September 1970 with the prime and backup crews of Apollo 14 at Schooner and Sedan Craters at the Nevada Test Site (NTS) (see Table I). The exercise was organized and directed by M.C. McEwen from the Manned Spacecraft Center, Houston, Texas. Astronaut participants included: A.B. Shepard, E.D. Mitchell, E.A. Cernan, J.H. Engle, P.K. Chapman, C.G. Fullerton, and Bruce McCandless. Nevada Test Site advisors P.A. Orkild and K.A Sargent of the Survey's Special Projects Branch, Denver, Colorado, acted as advisors and liaison on the test site.

A 2.7-km traverse was planned (by this author) around Schooner crater from photogeology alone and was added to a simulated lunar surface data package of the crater area prepared by the support staff at [the Center of Astrogeology] Flagstaff, Arizona. Schooner Crater (300-m diameter) is approximately the same size as Cone Crater, the prime EVA-2 objective of the Apollo 14 mission. Radio communication links were set up between the crews and two (astronaut) Capsule Communicators situated at separate positions on the crater rim. G.G. Schaber and R.L. Sutton (both SPE Branch, Flagstaff, Arizona) worked with the Capsule Communicators as mission control science personnel during the exercise. Schaber and Sutton unfortunately had to wear dosimeters, while sitting on the rim-crest of the highly radioactive nuclear craters in order to allow a line-of-sight with the astronauts [<u>Author's Note</u>: the things we had to do in order to insure good science by the astronauts while on the lunar surface].

[<u>Author's personal account:</u>: The pre-exercise traverse briefing with the Apollo 14 prime and backup crews for the above NTS exercise took place in this author's hotel room at the Sahara Hotel and Casino in Las Vegas late in the evening (about 10:00-11:00 PM) on 10 September—because the crews arrived in Vegas late in their T-38's. The rumors were ripe that they (instigated by Alan Shepard no doubt) had had a "dog fight" over Nevada on the way up from Houston—-unsubstantiated, however) The briefing was also attended by several other USGS and NASA personnel. I recall that upon completing the pre-exercise briefing, we told the crews to get some sleep because they had to be down at breakfast (at the Sahara) at 4:30 AM in order to drive with us up to the NTS (the usual military choppers were unavailable for the crew to take to the NTS on this particular exercise). Anyway, I showed up about 4:15 AM with one or two of my USGS colleagues at breakfast the morning of 11 September. We waited for them—then ate—then waited some more for the crews to come down. Finally, Al Shepard and the rest of the astronauts walked in the front door of the casino dressed in suits and carrying on and laughing—they had been up all night doing God knows what! Then, these were our nation's heroes—and damn it, they were very special human beings. During the exercise, they did their job and never acted, or admitted to, being tired. I also recall driving from Vegas to the NTS in the USGS Carryall with Ed Mitchell (LMP for Apollo 14 who had a PhD in Physics and a PhD in Aeronautical Engineering as I recall]. We had a nice discussion about ESP, and other such esoteric subjects in which both he and I (at that time at least) were interested.]

The following was taken from the Center of Astrogeology Monthly Report for September 1970 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 30 September 1970:
In September 1970, Harold Masursky (BAS, Flagstaff, Arizona) was designated a member of Working Group 7—Space Related Studies of the Moon and Planets, COSPAR, Committee on Space Research, an international committee headquartered in Paris, France, that sponsors cooperation on space-related activities.

H.J. Moore participated in training of the Apollo 14 crew at the Nevada Test Site (NTS) 10-11 September 1970 (see Table I). The training consisted of examination of the Sedan Crater where inverted stratigraphy was illustrated and field examination of shocked and unshocked samples of various rock types were conducted. The astronauts conducted a traverse exercise at the crater Schooner where they described the rocks and shocked products, establishing the stratigraphy beneath the crater by examining both the crater wall and inverted stratigraphy of the ejecta, collected samples representing horizons from the surface down to a depth of 200 feet, and described the crater and ejecta topography. The value of this exercise is that the crater Schooner is about the same size as Cone Crater [at the Apollo 14 landing site] on the Moon. Blocks around Schooner reach 30 feet in length, and are comparable in size with those at Cone Crater.

Don Beattie:
"A memo to my staff in September 1970 lists a schedule for Apollo 14 surface experiment simulations, giving an idea of what these simulations entailed. By this time, simulations were conducted from the Mission Control Center, Houston (same place as MOCR, different name). The memo called for two simulations of the planned first EVA and three simulations of the second, spread over two months rather than the one-month originally planned. It was getting harder to assemble the large cast of characters that was required and more important, to fit the simulation into the astronauts' tight schedules. The simulations would include the prime crew, using either sites at KSC or one designated by Flagstaff. There were also two "canned" simulations at Houston when the astronauts were not part of the exercise and the flight controllers and our SSR staff was tested with contrived problems. Later missions, because of their complexity, added additional simulations. Each simulation would last four hours or more and would be followed by a candid critique, usually leading to new guidelines on how to respond to emergencies during the real missions.

As the PIs and their supporters began to spend more and more time at MSC, the members of the Field Geology Team availed themselves of a rather unusual perk. Jack Schmitt had long since completed his flight training and was now in Houston full time. He had a modest bachelor apartment just a few blocks from the center. His old Flagstaff buddies saw nothing wrong in staying there when they were in town, and if you visited Jack late at night you usually found at least one of them in a sleeping bag on the floor. I don't know how many keys were in circulation, but Jack's hospitality helped the visiting team members stretch their meager government per diem to include extra dinners at the San Jacinto Inn, the Rendezvous, or some other favorite restaurant. Jack was also using the LM and CSM simulators at MSC and KSC when they were not scheduled for designated crew simulations, to become familiar with these complicated spacecraft. When Jack was selected in the first scientist-astronaut class in 1965, some of us who knew him at Flagstaff recommended that he make it clear to Deke Slayton and Al Shepard how seriously he wanted to be looked on as one of the "regular guys," removing any stigma from his hyphenated title [scientist-astronaut.] Whether or not this urging had any influence, Jack spent long hours in the simulators and added to his flight log by flying the astronauts' T-38s around the country, frequently coming to Washington to attend meetings and briefings at headquarters. Did Jack's diligence have any direct effect on Slayton and Shepard? I have to believe it did; and as we know he was selected for the crew of the final Apollo landing mission" (Beattie, 1993, pp. 96-97).

[Spaceflight Milestone-"On 12 September 1970 the Soviet Lunar 16 registered the first unqualified success by an unmanned spacecraft in collecting a sample from the Moon [0.7 Degrees S., 56.3 Degrees E] and returning it to Earth" (Wilhelms, 1993, pp. 243).

The following was taken from the Center of Astrogeology Monthly Report for September 1970 to the Assistant Chief Geologist for Environmental Geology and to NASA, from the Chief, Branch of Surface Planetary Exploration; dated 30 September 1970:
On 17-18 September 1970, the Apollo 15 (prime and backup) crews —D.R. Scott, J.B. Irwin, R.F. Gordon, H.H. Schmitt, J.P. Allen, and R. A. Parker—accompanied M.H. Hait, R.L. Sutton, G.A. Swann, and L.T. Silver on a geology training exercise to the Buell Park kimberlite pipe north of Fort Defiance, Arizona (see Table I). The kimberlite diatreme is exposed 500 to 1000 feet below its original surface. The kimberlite outcrop and intrusive minnette dikes form a circular structure that has been formed by erosion.

The exercise included practice in lunar sampling and photographic procedures carried out along pre-planed traverses. Personnel from the Manned Spacecraft Center, Houston, Texas, participating in the exercise included Gary Lofgren and U.S. Clanton (Science and Applications Division); R.G. Zedekar and J. Olmstead (Flight Crew Support Division); G.S. Lunney, G.D. Griffin, B.L. Sharpe (Flight Operations Division); and J.M. Peacock (Apollo Spacecraft Program Office).

On 30 September -2 October 1970, a three-day field test with the [Center of Astrogeology's] Mission Planning Lunar Rover Vehicle simulator (Grover) was conducted under the direction of George Ulrich and Edward Wolfe (both SPE, Flagstaff) at the [Survey's] Merriam Crater test site [northeast of Flagstaff, Arizona]. The purpose of the test was to evaluate various scales and types of maps for a typical 15-km lunar traverse. A brief report on the test concluded that scales of 1:10,000 or 1:25,000 are best suited to reconnaissance traverses of this length due to the ease of location and reference to geologic features. It was also found that 1:5,000-scale maps provide poorer renditions of relief and surface feature relationships, and require four times the number of 8 X 10 inch map sheets.

A first field test of the 360-degree FOV Hycon Camera was carried out using "Grover" at the Merriam Crater Test Site northeast of Flagstaff during September 1970 (Fig. 79).

Don Wilhelms:
"Another Soviet success during the Apollo 13-14 lull, and the first of a second type of mission, was achieved with Luna 17 in November 1970. Luna 17 landed Lunokhod-I, which continued to function for ten months after its landing. It crawled 10.5 km across the surface of Sinus Iridium far from any other Soviet or U.S. landing site, transmitting television photographs and other data by lunar day and resting by night. It stuck a penetrometer into the lunar soil to measure its density, analyzed the soil chemistry with an X-ray spectrometer, and was tracked by a laser reflector. The spacecraft returned no samples" (Wilhelms, 1993, p. 244).

[Author's Note: The 1:1,000,000-scale geologic map of the Sinus Iridum quadrangle (LAC-24) authored by this author (1969, USGS Misc. Map-Series, I-602) included the spot where Lunokhod-1 would land in November 1970. The map was formally published in 1969 by the USGS as Misc. Series Map I-602.]

The following was taken from the Center of Astrogeology Monthly Report for October 1970 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from the Chief, Branch of Surface Planetary Exploration; dated 31 October 1970:
On 8-9 October 1970, the Apollo 15 crew participated in a geologic field exercise at Ely Minnesota to investigate the gabbroic-to-anorthositic rocks of the Duluth Complex (see Table I). The trip was led by William Phinney (NASA/MSC). (See discussion below for problems investigated at site.)

On 11-14 October 1970, it was the Apollo 16 crew (Charles Duke and John Young) who investigated the Duluth gabbro near Duluth, Minnesota (see Table I). Local guide for the trip was William Phinney (NASA/MSC); other participants included William Muehlberger (USGS and University of Texas at Austin), Tony England (CB/MSC), and Fred Horz (NASA/MSC). Day one (Oct 12) was dedicated to a detailed study of special relationships and time sequence of various gabbroic sub-varieties, hornfels and anorthosite. The planned traverse went across a contact between a gabbroic dike and Anorthosite. The next day (13 October) was designed to familiarize the crew with the description of noncohesive materials (glacial tills in this case at the Embarrass Mine and Iron Mountain). On October 14, the crew was taken to a site about 15 miles south of Ely, Minnesota to investigate an Anorthosite knob (Traverse III) with a horizontal contact line to olivine gabbro (trocolite). The traverse was crossing this contact repeatedly to demonstrate the special relations of trocolite, Anorthosite with olivine aggregates, and Anorthosite.

In October 1970, Gerald G. Schaber (SPE Branch, Flagstaff, Arizona) [and Jim Head, Bellcom, Inc., Washington, D.C.] presented preliminary Apollo 15 (Hadley-Apennine) walking and Lunar Rover Vehicle (LRV) traverses to a special meeting of the Surface Working Panel group (SWP) at the Manned Spacecraft Center, Houston, Texas. Three traverses for both the walking and riding cases were designed for the two landing points presently under consideration for the Hadley-Apennine site.

Fourteen new craters ranging from 9 to 30 feet in diameter were blasted in the Black Canyon Crater Field in Verde Valley on 20 October 1970. This was done because the heavy rains over the Labor Day weekend (1970) seriously eroded the crater field, which will be used 14 November for the full-up training simulation by the Apollo 14 crews.

The mission planning Lunar Roving Vehicle Simulator, Grover, was fitted during October 1970 with mockups of various electronic equipment provided by the Manned Spacecraft Center, Houston, Texas, to permit realistic field exercises with the crews of Apollo 15-17 (Fig. 80). The mockups of equipment provided included:

Lunar communications relay unit
High gain TV antenna
Low gain antenna
Ground controlled TV camera

In October 1970, R.L Sutton completed an Apollo 12 traverse map showing the location of samples in relation to major crater morphologic units. This map resulted from a study of all returned lunar surface photographs, in close conjunction with the transcript and with the samples in the Lunar Receiving Laboratory.

[Space Exploration Milestone: "The last lunar flight of the Soviet Zond spacecraft series to the Moon was by Zond 8 on 20 October 1970. Like its predecessors, Zonds 5, 6, and 7 (September and November 1968, August 1969), Zond 8 looped once from the northern near side to the southern far side before returning to Earth for a braked landing. The Zonds obtained good stereoscopic coverage of strips of the far side, regional coverage of parts of the west limb barely covered by the U.S. Lunar Orbiters, and color photographs (Zond-7)" (Wilhelms, 1993, pp. 244).

The following was taken from the Center of Astrogeology Monthly Report for November 1970 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from the Chief, Branch of Astrogeologic Studies; dated 30 November 1970:
N.J. Trask (BAS, Menlo Park, California) discussed the geology on the ground track of Apollo 14 with Command Module Pilots Stuart Roosa and Ronald Evans at the Kennedy Space Center, Florida on 8 November 1970.

The following was taken from the Center of Astrogeology Monthly Report for November 1970 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from the Chief, Branch of Surface Planetary Exploration; dated 30 November 1970:
Grover, the Mission Planning LRV Simulator, provided field transportation for the Apollo 15 prime and backup crews (Dave Scott, Jim Irwin, Dick Gordon and Jack Schmitt) on a two-day geologic exercise on 2-3 November 1970 at Flagstaff, Arizona that had been postponed from October 1970 (see Table I). This crew would be the first to drive the first [actual] Lunar Roving Vehicle on the Moon in the summer of 1971. The fresh cinder-covered and explosion-cratered surface at the Cinder Lake Crater Field served on the first day for location, sampling, and crater avoidance exercises. On the second day a 5-km traverse was run over the maar, lava flows, and ash-fall deposits at Merriam Crater test site on the eastern edge of the San Francisco volcanic field (Fig. 81). The objective of the exercise was basically the familiarization with the use of Grover by both the prime and backup Apollo 15 crew members. The effects of craters and boulders on course of traverses, photography from Grover, determination of points to stop for

sampling and photography, and other possible problems were evaluated while actually using a Lunar Rover Simulator vehicle.

Evaluation of the crews' surface photography and sampling procedures showed that 1:25,000 and 1:10,000 photomaps were both useful, especially with photogeologic, topographic, and traverse map overlays. Their general comments following the exercise were that the integration of lunar hand tools, cameras, and a roving vehicle with space suits will require continued practice and evaluation prior to the mission. Those participating in the exercise were astronauts D.R. Scott, J.B. Irwin, R.F. Gordon, H.H. Schmitt, J.P. Allen, and R.A. Parker. Instruction was given by L.T. Silver of Caltech, W.C Phinney of the Manned Spacecraft Center, Houston, Texas, in addition to the U.S. Geological Survey staff from the Center of Astrogeology, Flagstaff. Visitors to the test included: P. Bayer and J. Hanley, NASA Headquarters, Washington, D.C.; J. Roberts and K. Thomas, Manned Spacecraft Center, Houston, Texas; G. Barnes and R. Frye, General Electric, Manned Spacecraft Center, Houston, Texas; W. Wiley, TRW, Manned Spacecraft Center, Houston, Texas; K. Zieman, TRW, Redondo Beach, California; J. Head and R. Raymond, Bellcom, Inc. Washington D.C.

D.J. Roddy and G.E. Ulrich conducted a two-day field tour on 12-13 November 1970 for astronauts John Young, Charles Duke and Tony England at the Sedan, Collapse, and Danny Boy craters at the Nevada Test Site. Ken Sargent (USGS Special Projects Branch, Denver, Colorado) was the local guide. An extended six-hour technical traverse was completed at the Schooner nuclear crater. Technical and applied debriefings were conducted during the traverse. The trip was extremely successful in terms of information exchange and acquisition, and in surface cratering exploration techniques, and development of descriptive terminology. Field trip booklets were prepared by D.J. Roddy and Kenneth Sargent.

Following a military helicopter ride from downtown Las Vegas to Danny Boy Crater on 12 November, the crew was briefed on cratering mechanics, and regional geology (Paleozoic sediments, volcanic sequences, structural geology). This was followed by a general description of Sedan Crater (1,300 ft. diameter, 320 feet deep), Collapse Crater, and Danny Boy Crater (280 feet in diameter and 90 feet deep). At each crater, the crew gave descriptions of the crater (LM simulation). While standing on crater rim, the crew members recognized all important details (overturned beds in the rim, faults, slumping, ejecta blanket with secondaries, etc.). Detailed radial traverses were used to recognize and determine various lithologies of ejecta blanket. The crew sampled and classified individual rock types, in terms of progressive shock damage.

On 13 November, the crew once again did their LM simulation description on the rim of Schooner Crater. Detailed traverse was accomplished according to the traverse previously outlined on aerial photographs by the trainers. The crew was completely on its own in this exercise—and did very well.

[<u>Author's Note</u>: Flagstaff's *Arizona Daily Sun* on 13 November 1970 carried the secondary page one headline: "Apollo 14 Astronauts to Arrive for Rehearsal of Lunar Mission"—see below].

[<u>Author's Note</u>: Astronauts Shepard and Mitchell would participate on 16 November 1970 in their final geology training exercise before leaving for the Moon (January 1971) at the Black

Canyon Crater Field in the Verde Valley, Arizona (south of Flagstaff, Arizona). This crater field was constructed as a winter training site by the SPE Branch under the supervision of Norman "Red" Bailey between Jan 1970 and October 1970 (See 1970).]

The following was taken from the Center of Astrogeology Monthly Report for November 1970 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from the Chief, Branch of Surface Planetary Exploration; dated 30 November 1970:
The Apollo 14 Prime-crew astronauts A.B. Shepard and E.D. Mitchell participated in a complete EVA-2 simulation at the Black Canyon Crater Field in Verde Valley, Arizona on 16 November 1970 (see Table I). Audio communication links were complete to the Mission Control Center at MSC in Houston, Texas. The astronauts completed their planned lunar surface sampling, describing, and photographic activities while pulling the two-wheeled modular equipment transporter (MET) to be first used on the Apollo 14 mission to the Fra Mauro region of the Moon. Lunar Geology Experiment team personnel (including G.A. Swann, M.H. Hait, R.L. Sutton, N.G. Bailey, J.S. Loman, and K.B. Larson) were at their duty stations at the Mission Control Center furnishing science support data during the simulation. H.J. Moore and G.G. Schaber (a Co-Investigator on the Apollo 14 Lunar Geology Experiment Team) participated as observers in the simulation at the Black Canyon Crater Field. Visitors to the test included J. Hanley and R. Sheridan, NASA Headquarters, Washington, D.C.; R. Frye, General Electric, Manned Spacecraft Center, Houston, Texas; and D. Toups, Manned Spacecraft Center, Houston, Texas (Fig. 82).

A simulated fan malfunction in a Portable Life Support System (PLSS) near the end of the planned EVA was introduced into the operation to test real-time decision capability of mission control personnel [in Houston].

Henry Moore (BAS, Menlo Park, California), who observed the 16 November Black Canyon Crater Field test, commented after the exercise that the performance of the astronauts was excellent. They demonstrated a complete understanding of the principles of sampling the rims of fresh to young craters of various sizes to obtain materials from various depths. As a result, they collected samples from all the stratigraphic horizons below the surface of the crater field which, when combined with the knowledge of the crater sampled, would permit reconstruction of the pre-crater stratigraphy. The sampling was accompanied by astute and pertinent observations.

[<u>Author's Note</u>: George Ulrich contributed the following comments following his review of the first draft of this work: "I seem to recall pre-briefing the crew with Henry Moore and Jerry Schaber in the motel in Flagstaff the night before [the exercise]. I also remember the crew's Houston geologist trainer Mike McEwen being on the trip.

[See Flagstaff's *Arizona Daily Sun*, 17 November 1970 for more details of this astronaut exercise at the Black Canyon Crater Field in the Verde Valley, Arizona.]

E.W. Wolfe and G.E. Ulrich participated in an Apollo 15 training trip and partial field exercise in the San Gabriel Mountains, southern California, on 19-20 November 1970, led by L.T. Silver (Caltech, Pasadena, California) and W.C. Phinney (MSC, Houston, Texas) (see Table I). The area of deformed anorthosites served as a possible analog for sampling and interpretation problems of the Apennine Front at the upcoming Hadley-Apennine landing site for Apollo 15. The trip included two simulated EVA exercises with the purpose of examining coarse-grained anorthositic rocks which, unlike those in Ely, Minnesota, have undergone considerable tectonic deformation. They would more closely resemble shocked rocks, for example. Astronauts participating in this exercise included D.R. Scott, J.B. Irwin, R.F. Gordon, and H.H. Schmitt.

The exercise included a 3.5 km preplanned traverse (outlined on aerial photographs) in "Anorthosite" (thought to make up much of the lunar highlands) along the "Mill Creek" (i.e. north of Mt. Cristo Ranger Station, Angels Forest Highway). The emphasis was placed on lithological heterogeneity of various Anorthosite and gabbroic scrub varieties including intense deformation of these units due to folding and faulting between the San Andreas and San Gabriel fault systems.

On 21-22 November, 1971, a similar geologic field exercise at the San Gabriel Mountain site was run for the Apollo 16 crew members John Young, Charlie Duke and Fred Haise. Once again, the local guide was Prof. Lee Silver (Caltech/USGS); others participating included Tony England (astronaut office/MSC) and Fred Horz (MSC)

L.A. Soderblom (BAS, Flagstaff) and L.A. Lebofsky, Massachusetts Institute of Technology, completed in November 1970 a significant research manuscript entitled *"A technique for rapid determination of relative ages of areas on the lunar surface from Orbiter photography."* The technique is based on a model that relates the shape of a crater to the integrated flux of debris that has impacted the surface since that crater was formed. Determinations of relative ages of individual mare units requires only a few minutes.

The following was found in the Center of Astrogeology Monthly Report for December 1970 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from the Chief, Branch of Surface Planetary Exploration; dated 31 December 1970:
The Apollo 15 crew, D.R. Scott, J.B. Irwin, R.F. Gordon, H.H. Schmitt, J.P. Allen, R.A. Parker, participated in lunar simulation field training exercises on the Big island of Hawai'i 5-12 December 1970 (Fig. 83; also see Table I). The exercises were led by E.D. Jackson and D.L. Peck. Real-time science support was supplied by G.A. Swann, G.G. Schaber, R.L. Sutton (SPE Branch, Flagstaff), L.T. Silver (Caltech, Pasadena, California), W.C. Phinney and G. Lofgren (Manned Spacecraft Center, Houston, Texas), and J. W. Head III (Bellcom, Inc., Washington, D.C.) This trip included five simulated EVA exercises (compiled by Gerald Schaber, USGS, using stereo-pair aerial photographs) designed to develop an understanding of fresh volcanic features and to present challenging geologic problems to solve.

The exercises provided concentrated practice in photographic and sampling procedures, use of maps, tools, use of a vehicle, and geologic description in conjunction with a real-time science support group.

The field areas studied by the astronauts included:

1. <u>Kapoho area</u>: study of small flow, composite cone and associated post-volcanic structures.
2. Kilauea caldera: study of a smooth "mare" surface underlain by complex pyroclastic deposits: sampling at the base of a steep cliff for samples representative of units exposed in cliff face.
3. <u>Hualalai nodule beds</u>: study of flow structures, stratigraphy and flow mechanics at head of a dual "rille" system.
4. <u>Hale Pohaku</u>: study of age relationships of cones; search for xenoliths; remote description of topographic features.
5. <u>Pohakuloa finger flows</u>: study of surface characteristics and age relationships of flows; age relationships between flows and cones

The group also visited the active vent and flows at Mauna Ulu near Chain-of-Craters Road in Hawai'i Volcanoes National Park.

This author recalls one amusing event that took place during the Apollo 15 geologic field exercise on the Big Island of Hawai'i on 5-12 December 1970 (listed above):

For all of us, including astronauts Schmitt, Scott, Irwin, Parker, Gordon and Allen, were transported by Volcano National Observatory vans to the Mauna Ulu eruption going on within the Hawaiian Volcanoes National park (mentioned above). They took us to a spot where we got a great look at the spectacular fire fountaining of cinders and molten lava violently erupting — hundreds of feet high—from the fissure and the cinder cone that was being created as we watched.

The next evening, we were then taken to where we could look at the active lava flows running over the Pali (fault scarp) to the Pacific from the Mauna Ulu flank eruption that was ongoing at that time. It was close to sunset by the time we parked the vans and trekked over the edge of an active lava flow about 1/4 mile from the vehicles. Some of us had geology-type boots on—but others didn't. As we were led over the alien-like landscape of glassy and steaming pahoehoe lava that was flowing only a few days or weeks earlier, we began to smell something burning—like rubber. It was the soles of our shoes! Several of the astronauts became visibly concerned and sort of suggested that perhaps we should go back. The local geology leaders, including our own people like Swann and Silver, pooh-poohed that idea—maintaining that it was safe.

Then, as the Sun was almost setting, we arrived at the edge of an active aa flow, but we could see a very rapidly-flowing lava flow in the distance only a few hundred meters away. We were told that the flashing, burning things being carried down the Pali (fault scarp) with the lava were burning trees.

Then someone got the bright idea to poke a stick they found into the edge of the nearby aa flow, thus triggering a rapid little pahoehoe lava flow that proceeded to run over USGS geologist Bob Sutton's boot. I remember Bob kicking his foot violently splattering off the glowing lava onto several of the astronauts and geologists standing close by.

If that wasn't bad enough, then astronaut Dick Gordon picked up the stick and said that he was going to take back a cooled sample of this stuff (the molten lava) to his kids. He jammed the stick into the lava and lifted it up hoping that the sticky lava would cool on the end of the stick. Well, as it cooled, it also started the end of his stick on fire. Then someone, I believe it was Gordon himself, had the equally bright idea of pissing on the lava on his stick to cool it more rapidly. After accomplishing this feat, astronaut Joe Allen said Damn it Dick; you're not getting into our car with that stinking stick! About that time, Dick's lava souvenir fell off the stick onto the ground—and he gave up the idea.

I actually thought the idea of bringing back a sample of the lava was a good one. I picked up the stick and took my own sample. Somehow I managed to get it back to the car without peeing on it.

It had become quite dark by the time the group left the lava flow for the vehicles. On the way back it became very obvious that the lava flows we had walked across to get to the flow were glowing bright red only a foot or so below the surface—as indicated by the bright red fractures in the flows. This was very disconcerting to the astronauts—and to this author as well.

[Author's Note: See 1972 below for my personal account of a visit to see the lava lake formed by the same, extended, Mauna Ulu eruption during the geology field-training exercises for the Apollo 17 crew on the Big Island on 22-28 June 1970.]

The following was taken from the Center of Astrogeology Monthly Report for December 1970 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from the Chief, Branch of Surface Planetary Exploration; dated 31 December 1970:
During December 1970, H.E. Holt calibrated (at Cape Kennedy, Florida) flight models of the Gnomon and color chart to be used on the lunar surface by the crew of Apollo 14.

M.H. Hait and E.W. Wolfe participated during December 1970 in an exercise at MSC in Houston, Texas, simulating EVA 2 of the Apollo 14 mission."

The fourth field test of the Branch of Surface Planetary Exploration's Mission Planning LRV Simulator ("Grover"), in December 1970, simulated the fields-of-view from the remote controlled TV camera scheduled to be mounted on the Lunar Roving Vehicle for the last three Apollo missions. A 35-mm film camera with lenses equivalent to the TV camera's maximum and minimum zoom was used. Panorama mosaics illustrated obstruction by various antennae and other hardware. An unanticipated result of the test was that telephoto views permit resolution of detail that is obscured by antenna posts in wide-angle views. Requirements were then currently being defined for use of the TV camera on the J-missions to aid the Apollo Field Geology Investigation team in analyzing the surface geology.

George Ulrich:
"The objectives of this test were (1) to simulate the fields of view of the ground-controlled television camera mounted on the Lunar Roving Vehicle to simulate potential uses and to recommend procedures for increasing the geologic return of J-missions, and (2) to determine the extent of observation to the camera view by presently designed equipment mounted on the

vehicle" (from a USGS Memorandum dated 7 January 1971 from George Ulrich with the subject: Fourth Field Test of Mission Planning LRV Simulation, Grover)

[Author's Note: George Ulrich told this author (personal communication, 27 July, 2002) that he directed this Grover field test with the help of Bob Skinner and Karl Zeller (Astrogeology photographers). George subsequently presented the results of the test to Glen Lunney's Committee on Traverse Planning at NASA/MSC in Houston].

The following was taken from the Center of Astrogeology Monthly Report for December 1970 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from the Chief, Branch of Astrogeologic Studies; dated 31 December 1970:
In December 1970 K.A. Howard (BAS, Menlo Park) discussed the geology of the lunar far side with Apollo 14 Command Module pilots Stuart Roosa and Roland Evans at the Kennedy Space Center, Florida.

Menlo Park-based geologists of the Branch of Astrogeologic Studies in December 1970 provided a two-day briefing on lunar geology with Apollo 15 Command Module pilots A.J. Worden and V.C. Brand, with emphasis on the Hadley-Apennine landing site and the orbital ground track of the Apollo 15 mission.

Harold Masursky (BAS, Flagstaff, Arizona) attended an Apollo Program Office review at the Manned Spacecraft Center, Houston, Texas, to determine the feasibility of carrying a long focal length lens camera to the lunar surface on the Apollo 15 mission to Apennine-Hadley. The system would be used to photograph—at a few centimeters resolution—the west wall and lava flows on the Hadley Rille and possible outcrops along the Apennine Mountain Front. Hal presented the results of testing done by F.J. Shafer, J.D. Crossen, and A.G. Dahl, who had taken pictures of the sequence of lava flows exposed in the cliffs at Wallenda Gap on the Columbia River with a theodolite, and pictures of a canyon on the Colorado River Arizona, with a 1,400 mm Questar, a 700-mm Perkin-Elmer solid catadioptric lens, and a 60 mm lens with an Apollo-type Hasselblad. Topographic and stratigraphic measurements were obtained from the pictures by use of the analytical plotter/computer and the results were compared. On the basis of the tests the recommendation was made at this meeting to carry a Questar and 35-mm Nikon camera or the equivalent on Apollo 15.

[Author's Note: The crew did actually take along a 500 mm lens for the purposes described above. The close-up pictures that they acquired with the 500-mm lens of the west wall of Hadley Rille and other areas, including the North Complex (that they referred to on the surface as "Schaber Hill") turned out to be extremely important because they never got to visit this area as had been planned" [See Apollo 15, 1971].

[Author's Note: During 1970 the Branch of Astrogeologic Studies' 30-inch telescope built in 1964 on Anderson Mesa south of Flagstaff was officially transferred from the U.S. Geological Survey to Lowell Observatory—and is still used by them at the present time.]

The staff at Astrogeology's Menlo Park office in 1970 included the following people:

Dave Scott (now deceased), Keith Howard, Carol Ann Hodges, Lew Croft, Don Wilhelms, Newell Trask, Maxine Burgess, John Serbang. Jack McCauley, Howard Wilshire, Henry Moore (now deceased), Chuck Mesa, Charles Myer, Susan Pratford (worked for Mike Carr), Jacquelyn Freeberg (Librarian), Beth Swartzman (worked for Howard Wilshire, Danny Milton, Evelyn Newman (Mathematician), Desire Stewart-Alexander, and Dick Lung (now deceased).

5.5-1971

[Author's Note: There were a total of 28 geologic field-training exercises were planned and led in 1971 by members of the Branch of Surface Planetary Exploration (Flagstaff) for prime and backup crews designed by NASA for the upcoming Apollo 15, 16 and 17 Apollo missions to the Moon (see Table I).

The Lunar Geology Experiment team (G.A. Swann, M.H. Hait, L.T. Silver, R. M. Batson, R.L. Sutton, G.G. Schaber, Red Bailey, J.D. Loman, K.B. Larson, and the court reporters Keith Welch, Don Thacker and Ben Leesman) participated in an Apollo 14 EVA I simulation (SIM) at Mission Control Center, Houston, Texas on 7-9 January 1971. Voice communication and television pictures were transmitted from the Apollo 14 prime crew (A.B. Shepard and E.D. Mitchell) at Cape Kennedy Space Center, Florida.

The following was taken from the Center of Astrogeology Monthly Report for January 1971 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 1 February 1971:
In January 1971, G.G. Schaber and G.E. Ulrich (SPE Branch, Flagstaff) participated with the Apollo 15 crew in a traverse-planning meeting in Houston, Texas for the Apennine-Hadley landing site.

On 18 January 1971 R.L. Sutton and G.E. Ulrich (USGS SPE Branch -Flagstaff) participated in a geologic traverse exercise for the Apollo 15 prime and backup crews (Dave Scott, Jim Irwin, Jack Schmitt, and Dick Gordon) at Kilbourne Hole, New Mexico (see Table I). They provided "back room" evaluations of the astronauts' verbal descriptions and sampling and photographic procedures. W.R. Muehlberger (University of Texas, Austin and USGS) participated in a similar exercise (18-20 January) for the Apollo 16 prime crew (Charles Duke, John Young and Fred Haise). The cartographic and photographic groups at Flagstaff, as for other training trips, prepared gridded photomaps of the traverse areas to large-and small-scale formats planned for mission use.

On 19 January, 1971 the Apollo 16 crew (John Young, Charles Duke) participated in a similar field exercise at Kilbourne Hole, New Mexico (see Table I). The local guide was Gary Lofgren (MSC); other participants included Carter, Fred Horz, Bill Muehlberger, and Tony England (CapCom). The backroom consisted of Bill Muehlberger and Fred Horz. The exercise consisted of a 4-hour traverse along the eastern rim of the Kilbourne Hole structure: geomorphology, stratification of basalt flows, rim-deposits; i.e., multitude of various ashfalls with delicate crossbedding, erosional features, xenoliths of various lithologies, source of magma flows, and origin of structure. Backup Apollo 16 astronaut Fred Haise and EVA CapCom Tony England participated in geologic training at Kilbourne Hole on 20 January, 1971. Fred Horz was the local guide. They used the same traverse as did the prime crew the day before.

The fifth LRV field test (sans astronauts) using the Mission-planning LRV simulator (Grover) was conducted from the Cottonwood Crater Field (Verde Valley), Arizona on 25-26 January 1971. The combined Apollo 14-15 and Apollo 16-17 Field Geology team members rehearsed their science operation room roles. One exercise used videotapes of the Apollo 11 EVA. A second was run live from the crater field to Flagstaff using a remotely controlled TV camera mounted on Grover and a pre-planned geologic traverse. The electronics capability was provided by the [Electronics Field support] group of the SPE Branch working under J.C. Nuttall. The field test permitted a better understanding of the complexities of data compilation and interpretation.

The following was taken from the Center of Astrogeology Monthly Report for February 1971 from Chief, Branch of Astrogeologic Studies to Assistant Chief Geologist for Environmental Geology, and to NASA; dated 28 February 1971:
On 10-12 February, 1971, Grant Heiken (NASA/MSC), Dave Roddy (USGS-Flagstaff) and Bruce Crowe (affiliation unknown)) led prime and backup Apollo 15 astronauts Dave Scott, Jim Irwin, Dick Gordon, and Jack Schmitt on a geologic training exercise to Ubehebe Crater, California (north of Death Valley, California) (see Table I). Ubehebe Crater is the largest maar volcano of a series of overlapping craters, formed by magmatic and steam (phreatomagmatic) eruptions. The craters are very young and free of vegetation. An overflight preceded the EVA exercises. The exercises emphasized the problems of sampling ejecta from closely-grouped craters. The relative ages of craters and the stratigraphic sequences within crater walls were described and interpreted. Rocks in the ejecta from the pre-volcanic terrain were sampled and described.

N.J. Trask and K.A. Howard (BAS, Menlo Park, California), as part of the Astrogeologic Studies Apollo data-integration effort, worked in concert during February 1971 with the Field Geology Experiment Team on binocular microscopic description of Apollo 14 rocks at the Lunar Receiving Laboratory, Manned Spacecraft Center, Houston, Texas.

The following was taken from the Center of Astrogeology Monthly Report for February 1971 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 28 February 1971:
V.L. Freeman, G.E. Ulrich, E.W. Wolfe, D.J. Roddy, and J.B. Lovelace of the USGS (Flagstaff), accompanied by G. Lofgren and G. Heiken of MSC, Houston, Texas, participated on 10-12 February 1971 in a geologic traverse exercise for the Apollo 15 prime and backup crews (D.R. Scott, J.B. Irwin, J.P. Allen, R.F. Gordon, H.H. Schmitt, and R.A. Parker) at Ubehebe Craters, California (see Table I).

W.R. Muehlberger, M.R. Brock, D.P. Elston, V.L. Freeman, Ivo Lucchitta, R.D. Regan, D.J. Roddy, and J.P. Shafer (all USGS) participated in a geologic traverse exercise for the Apollo 16 prime and backup crews 25-26 February 1971 at Meteor Crater, Arizona (see Table I). Astronauts participating in the exercise included John Young, Charles Duke, Fred Haise, and

Tony England (in an acting capacity). D.J. Roddy, G.W. Colton, V.L. Freeman (SPE Branch), and Fred Horz (NASA/MSC) provided traverse planning and briefings for the Apollo 16 prime and backup crews. Dave Roddy and Fred Horz acted as the prime and backup local field guides; Ivo Lucchitta and Bob Regan acted as the prime and backup CapCom for this test. Prime team participants in the science backroom included Bill Muehlberger, Val Freeman and Bill Colton; the backup CapCom team consisted of Don Elston, Maury Brock and Phil Shafer.

Unfortunately, during the traverses on 25 February with 70-mile per hour winds at the crater, any constructive field work became impossible about three hours into the traverse. The exercises were terminated for the day. Some of the lost exercise was made up by visiting the Meteor Crater museum and discussing the displays.

On 26 February the crews started where they had stopped on 25 February and completed the outlined tasks for this Meteor Crater exercise.

5.5.1-Apollo 14

(Launched 31 January 1971; landing site Fra Mauro; Crew Alan B. Shepard, Commander; Edward D. Mitchell, Lunar Module Pilot; Stuart Roosa, Command Module Pilot)

Members of the Apollo Lunar Geology Surface Experiment (ALGSE) team [called the Lunar Geology Experiment team on earlier missions][4] provided real-time geologic support for the Apollo 14 mission in the Science Operation Room at Mission Control Center, Houston, Texas. This support consisted of location of the Lunar Module landing point, map plots of astronaut traverses and activities, real-time court stenographer transcript, sketches, hard copy and mosaic of television pictures, topical notes, and photographic and sample logs. The information thus collected was used to prepare questions that were radioed to the astronauts on the lunar surface.

Between the two traverses (EVAs), when it was determined that the second or geology traverse would have to be shortened, G.A. Swann and M.H. Hait met with scientists and engineers from the Manned Spacecraft Center and replanned the second EVA to fit within the shortened time schedule.

After the Lunar Module and crew lifted off the lunar surface, the experiment team participated in a debriefing of the crew by submitting questions that were prepared on the basis of information radioed to earth.

The major objective of the Geology Experiment at the Apollo 14 landing site was to collect, describe and photograph materials of the Fra Mauro Formation. The Fra Mauro Formation was believed to be [and turned out to be] ejecta from the Imbrium Basin, which in turn was believed to have been created by a large impact. This material was thought to probably be best exposed in the vicinity of the Apollo 14 landing site where it has been excavated from below the regolith by

[4] G.A. Swann, Principal Investigator; M.H. Hait, sketcher; R.L. Sutton, topical notes; G.G. Schaber, map plot; J.S. Loman, stenographer; R.M. Batson and K.B. Larson, TV and photography; L.T. Silver, sample logs and synthesis; R.H. Jahns, R.E. Eggleton, regional geology; H.E. Holt photometry; N.G. Bailey, L.B. Sowers, transcript revision; D.R. Thacker, K.E. Welch, B.L. Leesman, court stenographers.

the impact that formed Cone crater. The major part of the second EVA traverse, therefore, was designed to sample, describe, and photograph representative materials in the Cone crater ejecta.

Gordon Swann:
"Paul Gast was an excellent scientist—a geochemist—who passed away just after Apollo. Paul got on our case—the ALGSE Team. He didn't think that we were getting reports out fast enough for the sample community during the earlier Apollo missions (Apollo 11 and 12)—about the field geology [surface context of the samples, etc.], location of the samples, and those sorts of things. Paul put together a group of his MSC guys over in their Geophysics Building [Building 226] where they could receive TV and air-to-ground transcript [voice from the lunar surface]. This first occurred during Apollo 14.

I got to thinking, we can beat that! So, I got a guy named Dick Jahns Penn State [and later, Caltech], who is an excellent writer and technical reviewer and editor to head up what we called our "Tiger Team." I asked Gene Kranz (the Flight Director of Apollo 13 fame] if there was anyplace in the Mission Control Center that we could [starting with Apollo 14] get the down link stuff and voice, watch TV, have a typewriter and a place for a draftsman? I said, and then we could make up reports between EVAs to be distributed among the people in the Control Center, summarizing essentially the geology—how much they had gotten done—what were their accomplishments, etc.

Gene Kranz said, sure, in my office! I don't use my office during the missions; I'm in here [the Control room] all the time. I've got the live TV, I got the voice, and there are typewriters. I'll even give you my secretary if you need her.

It turned out great. It was not far from the SOR (Science Operations Room) where the science group was—in the same building. There was a Xerox machine close by where we could make copies. We had reports completed two or three hours "before" the next EVA. We put together written reports—about 50 copies to pass around among the people working on the missions.

Right after that report was finished, we sat down and wrote a report on sample location and sample documentation—an Interim Report—one that was bound with pictures and everything—kind of hastily put together—and with some mistakes in it. That report was given to the people who made the decision as to who got what [lunar] samples.

Paul Gast came to me and said that's exactly the kind of thing I've wanted you to do—and thought you ought to be doing. I don't rally have the facility or the people to really compete with this kind of thing. I'm glad you're doing it. We'll be out of your hair if you just keep doing this kind of thing.

From then on, Paul and I got along just like that! I did know that Paul was a good scientist—no question. His only thing in life was to see that good science was done on the Moon—whoever did it—he did not care. It wasn't a turf battle [at least as far as Gast was concerned], he just wanted to see good science done, and he thought there were some places where he thought we were remiss a bit—and he was right!

We, the ALGSE Team, had been trying too hard [during the earlier Apollo missions-Apollo 11 and 12] to make sure that we didn't have any mistakes in the reports. We suddenly realized (thanks to Paul Gast's pressure) that a few mistakes don't mean too much. They still needed the information [when they need it]. We were just trying to be too conservative-make sure we didn't have a sample mis-located, mis-oriented, or something—and we did have a few!

And then shortly after the rocks were brought back, in order to let the sample community know everything we knew about the samples in their lunar context, there was a third report called the 90-Day Report which was a formally published NASA document. It was called the 90-Day Report because it was supposed to be published within 90 days of the mission. We were required to have the draft in for publication by 45 days. The later missions had gotten to where it was impossible [even for us!]. I think we started getting a deadline of 120 days—but they still called it the 90-day Report. That was a killer, the 90 or 120-day Report. To get that thing done under the deadline and have it in good enough form for formal publication—but we made it [somehow]!

There were of course other short-term kind of quick and dirty reports: the 5-Day Reports and those kinds of things. For the 5-day reports we had only to submit a paragraph summarizing what they did, how many pounds of samples they took, 2,500 photographs, or whatever—and that we thought that they did a good job. But that 90—Day Report was a back breaker" (from a filmed interview with Gordon Swann by Harry Ryan in 1996).

5.5.2-The Apollo 14 Backup Crew's "Bet" with Shepard and Mitchell

Just prior to the Apollo 14 mission, the Apollo 14 backup crew had bet Al Shepard and Ed Mitchell a case of scotch that they wouldn't be able to pull their Mobile Equipment Transporter, or MET (the "Golf Cart" as Al called it) all of the way up to the rim of Cone Crater—the major objective of that mission. Al actually had a lot to do with formulating the idea for building such a "golf cart" for his mission; and of course, he did store his famous lunar golf club on it.

This author remembers that those of us in the Science Support Room at Mission Control in Houston could hear anything from Al Shepard during the actual mission except "huffing and puffing" as he walked up towards Cone crater dragging the MET. This shortness of breath became especially apparent as Al began to climb up onto the rather steep and hummocky ejecta blanket from the crater. Al was 47 years of age and had lived a devil-may-care fighter pilot's life up to that time—and NASA couldn't fly the Lunar Roving Vehicle (LRV) until Apollo 15. The LRV would have made life much easier for Al Shepard on the Moon.

When Shepard and Mitchell reached a large group of "white rocks," which we in the backroom correctly interpreted as the blocky ejecta from Cone crater, the crew was told to stop and sample them—even though they said that they had not yet actually seen the crater. Well, time ran out on that EVA and [with Al's persistence] the crew had to return to the LM without actually seeing into the crater. Gordon Swann, along with the rest of us in the science backroom, thought that the backup crew had won their bet with Shepard and Mitchell.

Gordon Swann:
"Upon their return home, Al and Ed capitulated and sent a case of scotch to the backup crew. A couple of days later, after Ray Batson [and his cartography group from Flagstaff] resected the photographs taken by Shepard and Mitchell, they calculated that the crew had actually made it to within 17 meters of Cone Crater. We decided that for all practical purposes, they had made it to the rim! So I passed the hat among the ALGSE Team, and "we" bought a case of Johnny Walker Red and sent it in to the LRL quarantine area for the prime crew (Al and Ed), to show our appreciation for the hard work and success (as far as we were concerned) in making it—for all practical purposes—to the crater rim!"

In February 1971, G.A. Swann, G.G. Schaber, and J. Head of Bellcom, Inc. briefed the Apollo 15 crew at the Manned Spacecraft Center, Houston, Texas [see below]

Following this author's briefing at the February 1971 meeting (at MSC) with the Apollo 15 crew on the geology of the landing site and the status of the LRV and contingency traverses for their upcoming mission (Apollo 15 in July 1971), Dave Scott took me aside during a break and asked, "Where would you send us if I got you an extra hour on the surface?" I asked Dave, "How in the world are you going to find sixty more minutes out of our already tightly-scheduled traverse?" Dave said, "Don't worry about that; where would you send us?" I didn't have to think about it more than a few seconds, and said—to the "North Complex." Dave responded, "I thought so; work it up and show it to us at our next meeting**" (**Fig. 84; also see Apollo 15—July 1971 below**).** This author had named the North Complex feature earlier during the 1:12,500-scale geologic mapping of the Hadley landing site for use in the Apollo 15 Lunar Surface Data Package maps.

I had intensively studied the stereo coverage of the Hadley landing site in preparing the traverses with my colleague Gordon Swann, and Jim Head from Bellcom, Inc. However, I was especially interested in an area just north of the planned landing site that consisted of some low hills with low albedo similar to the surrounding mare (lava flows). Three fairly large craters, including the largest one, Pluton, dominated these rolling hills. The craters all appeared to be normal impact craters, but I thought that because of the low albedo of the low hills (crater ejecta blanket) making up the North Complex, they may have been mantled (post impact) to some degree by volcanic ash (or lavas) from nearby Hadley Rille—or from some volcanic vent within the hills themselves.

I had in earlier briefings with the Apollo 15 crew brought to the attention of Dave Scott and Jim Irwin the possibility that the area of the North Complex could have some kind of geologically interesting volcanic component in its origin. This possibility of checking this out while they were at the Hadley site obviously fascinated Dave Scott who clearly wanted to do the best job of exploring the Hadley-Apennine landing site area that was possible

Although I was personally unaware of it at the time, Apollo 15 Commander David R. Scott had back on 12 November 1970 sent a Memorandum for the Record to D.K. Slayton (CA), T.P. Stafford, R.F. Gordon, J.W. Young, E.A. Cernan, and F.W. Haise (CB), G.F. Lunney (FC), G.D. Griffin (FC). J.M. Peacock (PD7), J.G. Zarcaro (TM) and R.G. Zedekar (CF7) discussing the Apollo 15 Lunar surface timeline. In this memorandum, Scott was clearly already pushing for an extension of EVA # 1 to the Apennine Front so that a complete rerouting of EVA # 2 and EVA # 3 on Apollo 15 would be available—thus enabling EVA # 3 to reach a possible post-impact volcanic complex to the north which couldn't even be considered in the [then] current work-rest surface plan. Scott states in this earlier Memorandum that investigation of this feature may have extreme geological significance. [It seems that we—the geologists on the Apollo 15 Field Geology Team—had clearly made the case in our earlier traverse briefings that the North Complex area would be of interest to us].

At Scott's request, Jack Sevier, Gordon Swann, Jim Head, and I carefully examined the possibility that the third EVA could be redirected north from the proposed LM landing site to the area of the North Complex. The first objective would be to explore and sample the ejecta from Pluton crater, which clearly would have excavated Apennine Bench material or Imbrium Basin materials from beneath the local, but relatively thin, lava plains at Hadley Rille. A second objective, of course, would be to search for any evidence of any post-impact volcanic activity in the area.

Given the extra hour promised to be found by Dave Scott, Jim Head and I found that such a LRV traverse to the North Complex would be possible—but with barely sufficient time for perhaps only a couple of stations (sample sites).

On 16 February 1971, Jim Head sent a Bellcom, Inc. Memorandum (B71 02026) titled "Status Report on Preliminary Traverse Planning for Apollo 15 Hadley-Apennine-Case 340."

This Memorandum included a copy of the white paper that we had put together (authors: Gerald G. Schaber and James W. Head) titled: "Hadley-Apennine Preliminary Exploration Traverses-Preliminary traverse stations, observations, and activities." In this preliminary traverse report, we detailed the current plans for both LRV and contingency walking traverses for EVAs # 1, 2 and 3. In this document, (as Dave Scott had requested) we included on EVA #3 stops (planned stations 13 and 14) at the base of the rolling hills of the North Complex, north of the landing site.

Jim Head and I presented the new plan for the third EVA to North Complex to the crew at the next traverse planning meeting with them in March 1971. By that time, Dave Scott (as he promised at the February meeting) had somehow successfully managed to cut an hour out of the original lunar surface timeline and agreed to go for the revised EVA-3 to the north. I integrated the revised traverse into the Lunar Map Package that I was overseeing being prepared at Flagstaff.

[See Apollo 15 (July 1971) below (as well as NASA's Apollo Lunar Surface Journal (http://www.hq.nasa.gov/alsj/) for the story of how the North Complex and three other landmarks near the Apollo 15 landing site were unofficially renamed after the four geologists who led in their geologic training and traverse planning for the Apollo 15 mission—Gordon Swann, Lee Silver, Jim Head, and this author.]

The following was taken from the Center of Astrogeology Monthly Report for February 1971 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 28 February 1971:

During February 1971, G.A. Swann, G.G. Schaber, and M.H. Hait participated in a briefing of M.P. Frank, G.D. Griffin, and M.L. Windler of the Flight Control Division on the Hadley-Apennine Apollo 15 site. J. Head of Bellcom, Inc. also participated.

Also during February 1971, G.A. Swann, G.G. Schaber and M.H. Hait participated in a discussion of Apollo 15 TV requirements with E.I. Fendell (aka-"Captain Video") and G.A. Pennington of the Flight Control Operations Group. Representatives were also present from the Manned Spacecraft Center's Experimental Branch, Apollo Spacecraft Program Office, and Bellcom, Inc.

D.P. Elston and R.D. Regan attended a Stage-I planning conference for developing unmanned lunar surface exploration. Elston presented a report titled; "Definition of candidate science sites for Post-Apollo automated lunar exploration," which outlined a strategy for geologic exploration of the lunar surface in light of what was presently known about major lunar map units and structures. It was recommended that any unmanned program should be directed to obtaining samples from about 12 of the major lunar provinces that will not be investigated during Apollo exploration. A suite of samples, it was believed, would allow a broad framework of lunar exploration to be established, and would set the stage for any future detailed investigations of the lunar surface [unfortunately, that never happened].

The following was taken from the Center of Astrogeology Monthly Report for February 1971 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 31 March 1971:
Harold Masursky and J.F. McCauley held a meeting with George Recant of Langley Research Center, at Flagstaff on 3 March 1971 to discuss the possible role to be played by the Center of Astrogeology in Viking landing site studies based on Mariner Mars '71 data. H. J. Moore was tasked with preparing a proposal for LRC describing the scope of the Astrogeologic effort within the next month

The following was found in the Center of Astrogeology Monthly Report for March 1971 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 31 March 1971:
On 10-12 March 1971, the Apollo 15 prime and backup crews (D. Scott, J. Irwin, R. Gordon, H. Schmitt, J. Allen, and R. Parker) were accompanied by Astrogeology personnel (L.T. Silver, W.R. Muehlberger, V.L. Freeman, G.A. Swann and M.H. Hait) to the Rio Grande Gorge near Taos, New Mexico. W. Phinney and G. Lofgren were the geologists from the Manned Spacecraft Center, Houston, Texas who participating in the test. R.A. Mills and W. Tinnin, from the Center of Astrogeology, Flagstaff, provided Grover (LRV Simulator) support. The crews conducted two four-hour traverses—the prime crew on "Grover" and the backup crew in a jeep. Exercises were centered on Rio Grande River gorge as a simulation of many of the problems to be encountered at Hadley Rille on the Moon by the Apollo 15 crew. Both the prime and backup crews received real-time mission support in the compilation of geologic descriptions and other information (Fig. 85).

In March 1971, G.A. Swann and G.G. Schaber presented traverse briefing to the Apollo 15 prime and backup crews and other members of the Astronaut Office at the Kennedy Space Center, Florida. G.A. Swann discussed the results of the Apollo 14 mission with regard to future traverse planning, and G.G. Schaber, assisted by J. Head of Bellcom Inc., Washington, D.C., presented a review of the detailed geologic mapping currently being completed on the Hadley-Apennine (Apollo 15) landing site.

Later that month (March 1971), G.G. Schaber, G.A. Swann, and M.H. Hait (SPE Flagstaff) participated in a briefing with the Apollo 15 prime and backup crews at the Manned Spacecraft Center, Houston, Texas and discussed several possible formats for the Apollo 15 lunar surface Map Packages. Several preliminary scales were selected for further evaluation. It was at this meeting that Schaber presented to Dave Scott and Jim Irwin his (and Jim Head's) revised LRV traverse for EVA III to the area of the "North Complex," as Scott had requested during their earlier meeting at MSC in February 1971; see February 1971 above and Apollo 15 mission, July 1971 below).

W.R. Muehlberger and G.E. Ulrich held a training session in March 1971 with the Apollo 16 crew at the Manned Spacecraft Center, Houston, on geologic description, sampling, and photographic procedures, the Descartes landing site, and a review of the upcoming training trip to the San Francisco volcanic field (Flagstaff, Arizona)—including a data map package and aerial photos for their own study and traverse planning.

On 29-30 March 1971, the Apollo 16 crew was again in Flagstaff for a two-day astronaut-training trip at Merriam Crater and the Cinder Lake Crater Field near Flagstaff, Arizona (see Table I). Reviews of the photogeology and geophysics of the Merriam Crater test site were followed by vehicle traverses designed largely by the astronaut crew, based on their own prior study of the aerial photograph (provided earlier). The eight-kilometer traverses were conducted simultaneously by the prime crew, J. Young and C. Duke, on Grover, and by mission scientist A.W. England, standing in for backup LM pilot E. Mitchell, on the "Explorer" LRV Simulator. A contingent of Surface Planetary Exploration Branch personnel provided "real time" mission support in monitoring, evaluating, and reviewing with the astronauts their accomplishments on the traverses, including the use of the remote controlled TV camera mounted on Grover at one of their geologic stations. George Ulrich and Ed Wolfe were the local guides. Field observers included Fred Horz (MSC), Uel Clanton (MSC), and Ivo Lucchitta (USGS). Acting as Capcom were Bob Regan (USGS) and G.E. Hannish. The backroom participants included Bill Muehlberger, Ed Wolfe, Tim Hait, George Ulrich, Dave Scott (the geologist—not the astronaut), and Val Freeman (all USGS).

The second day's traverse (30 March, 1971) was performed in much the same way at the [nearby] Cinder Lake Crater Fields (just east-northeast of Flagstaff) where crater, block field, and regolith stratigraphy problems were emphasized. F. Horz and Uel S. Clanton were the geologists who participated from the Manned Spacecraft Center, Houston, Texas. R.A. Mills and W. Tinnin (SPE Branch, Flagstaff) provided outstanding support in vehicles and Lunar Module simulators at sites, and J. Nuttall, E. Kelly, and J. Thompson provided the TV and Science Support Room facilities. R. Batson and K. Larson prepared Polaroid mounts of the TV pictures and panoramas. I. Lucchitta contributed to the geologic critique of the training exercise, and H. Ackerman (USGS geophysicist) conducted a geophysical debriefing from surface experiments at the Merriam Crater test site, relating them to recent lunar results.

G.G. Schaber, in late March 1971, attended a final review of the 1:2,000-scale topographic relief model that was currently being completed at the Army Topographic Command, Washington, D.C. Representatives of the U.S. Geological Survey, Kennedy Space Center, Manned Spacecraft Center, and Bellcom, Inc., carefully studied the model and several minor changes suggested were completed on the model during the meeting. The model was scheduled for installation on the Lunar Module (LM) Simulator at the Kennedy Space Center in late April or early May 1971. It was to be used for landmark tracking and LM descent and landing training for the Apollo 15 mission.

The following was taken from the Monthly Report for April 1971 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from the Chief, Branch of Astrogeologic Studies; dated 30 April 1971:
The Apollo 14 Orbital Science Report was submitted to NASA in preliminary form on May 1, 1971. Contributors were J.F. McCauley, D.H. Scott, Harold Masursky, D.E. Wilhelms, D.E. Davis, M.N. West, D.J. Milton, B.K. Lucchitta, C.A. Hodges, H. A. Pohn R.L. Wildey, T.W. Offield, and J.R. McCord.

D.J. Milton (BAS) at the request of the Smithsonian Institution and the Geological Survey of India, left in April for India to assist in field work and the study of drill cores obtained at the Lonar Lake impact structure. This is the worlds only known impact structure occurring in a basaltic terrain and the results of its investigation should be directly applicable to geologic interpretations of the lunar surface.

Two geologic maps of the Apennine-Hadley (Apollo 15 landing site) region of the Moon were approved for publication by the Director, April 22, 1971. A map by M.H. Carr and Farouk El-Baz (scale 1:250,000) shows the landing site in the regional context, and the other map, by K.A. Howard (scale 1:50,000) shows the detailed geology of the immediate vicinity of the landing site.

The following was taken from the Monthly Report for April 1971 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from the Chief, Branch of Surface Planetary Exploration; dated 30 April 1971:
H.E. Holt and J.W. Langman verified the quality of photometric paints on the seven flight gnomons and photometric charts fabricated for the remaining Apollo lunar missions. Special laboratory photometric goniophotometer equipment, built by the U.S. Geological Survey, was taken to the Manned Spacecraft Center (Houston, Texas) to verify the reflectance of the paints.

The lunar surface Hasselblad camera, which was used by astronaut Alan B. Shepard during his lunar traverse, was tested and photometrically measured in Flagstaff the week of April 12.

The Apollo 15 complete prime and backup crews spent two days in field exercises in the Coso volcanic area, located on the Naval Weapons Center north of China Lake, California (see Table I). The purpose of the exercise was to give the crews experience in observing, describing, and sampling a wide variety of geologic features during traverses performed on simulated lunar roving vehicles as well as on foot. Emphasis was placed on defining the geology of inaccessible mountains by selective sampling at the base of slopes and by sampling alluvial debris derived from inaccessible areas. Somewhat similar problems in observation and sampling are expected at the Hadley-Apennine landing site for Apollo 15. The Coso exercise provided practice in communication between the crews and their CapCom, as well as practice in data recoding and synthesis by "back room" geologists providing science support.

Participating Astronauts included D.R. Scott, J.B. Irwin, A.J. Worden, R.F. Gordon, H.H. Schmitt, V.D. Brand, J.P. Allen, R.A. Parker, and K.G. Henize. Command Module pilots Worden and Brand made flights over the Coso area to describe the regional geology.

Geologic support was given by G.A. Swann, L.T. Silver, W.R. Muehlberger, M.H. Hait, G.G. Schaber, R.L. Sutton, G.E. Ulrich, E.W. Wolfe, V.L. Freeman (USGS), W.C. Phinney, G.E. Lofgren (NASA/MSC), and J.W. Head (Bellcom, Inc.). Logistical support in equipment, radios, and traverse vehicles was given by Joe Roberts, Wendell Davis, Earl Quinn (MSC), R.A. Mills, B.G. Tinnin, and I.L. Wiser (USGS).

The Coso exercise was observed by NASA Headquarters directors Dr. R.A. Petrone, Apollo Program Director, C.H. Lee, Apollo Mission Director, L.R. Scherer, Apollo Lunar Exploration Director, and D.A. Beattie, Program Manager, Apollo Surface Experiments.

G.A. Swann briefed the Apollo 15 crew at Kennedy Space Center on April 5, and on April 26 and 27, on results of Apollo missions 11 and 12, and traverse plans for Apollo 15.

D.P. Elston and G.R. Scott, W.R. Muehlberger, University of Texas, and Fred Horz, Manned Spacecraft Center, conducted a pre-traverse photogeologic exercise for the Apollo 16 prime and backup crews (John Young, Charles Duke, Fred Haise, and Tony England) in Houston, on April 23, prior to an astronaut training exercise in volcanic stratigraphy in the Hackberry Mountain volcanic center, central Arizona, on April 26 and 27. The field exercise required the astronauts to carry out reconnaissance geologic mapping while recognizing generic units in the stratigraphy and maintaining their stratigraphic position across faults.

G.G. Schaber participated in Apollo 15 (Hadley-Apennine) base map review at the Army Topographic Command (TOPOCOM), Washington, D.C. on April 15 and 27. The reviews were also attended by representatives from TOPOCOM, NASA Headquarters, and Manned Spacecraft Center (mapping science laboratory), and Bellcom, Inc.

A preliminary topographic map of the Descartes (Apollo 16) landing site was prepared by [USGS photogrammetrists] R. Jordan and G.M. Nakata [from Flagstaff]. The map plus 11 {topographic] profiles were prepared on the AP/C analytical plotter using one pair of Hasselblad photographs (55-mm focal length) taken from orbit on Apollo 14.

[<u>Spaceflight Milestone</u>: The Mariner 8 Mars mission failed during launch on 8 May 1971. The failure of Mariner 8 necessitated a U.S. Geological Survey team-wide effort to help redesign the Mariner 9 mission to achieve its maximum scientific potential. After a number of meetings a maximum data return mission was designed which in most of its characteristics resembles the original Mission A, but with considerably more flexibility and potential polar and variable features return.]

The following was found in the Center of Astrogeology Monthly Report for May 1971 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 31 May 1971:
In May 1971 the Apollo 15 lunar surface cameras were photometrically calibrated by U.S. Geological Survey personnel from Flagstaff at the Manned Spacecraft Center, Houston. Six cameras were measured, and three cameras were recommended for flight on the basis of their overall performance.

A training exercise for the Apollo 15 crew at the Nevada Test site was led 20-21 May 1971 by D.J. Roddy (BAS Branch, Flagstaff, Arizona), and supported by P. Orkild and K. Sargent, Special Projects Branch, and L.T. Silver, G.E. Ulrich, M.H. Hait, R.L. Sutton, E.W. Wolfe (SPE Branch) (see Table I). NASA geologists W. Phinney and G. Lofgren also participated. E. "Gene" Kranz, NASA/MSC Flight Operations, was also present as an observer. The crews examined Sedan and Danny Boy craters from helicopters and on the ground.

Gerald Schaber [and Gordon Swann] participated in a geology briefing of the Apollo 15 prime and backup crews at the Kennedy Space Center, Florida on 25 May 1971. Mare sampling rationale was discussed along with results of the detailed geologic mapping of the Hadley-Apennine landing site at the 1:12,500-scale.

W.R. Muehlberger, D.P. Elston, V.L. Freeman, and J.R. Lovelace accompanied the crew of Apollo 16 (J.W. Young, C.M. Duke and F.W. Haise) to the Capulin Mountain area near Raton, New Mexico, for a geologic training exercise on 24-25 May 1971 (see Table I). Participating geologists from the Manned Spacecraft Center, Houston, Texas, were Fred Horz and G.E. Hanisch. The crew completed two traverses of about 3 1/2 hours each. The problems studied were the lithology and age relations of a series of basalt flows and cones.

In May 1971, D.P. Elston with F. El-Baz, Bellcom, Inc, Washington, D.C., and R.L. Laidley, MSC, Houston, Texas, conducted T.K. Mattingly, Command Module Pilot for Apollo 16, and C.C. Fullerton, on a training exercise for the aerial discrimination of stratigraphy and structure, and the recognition of a variety of volcanic and morphologic features over the Mountain Province of Central Arizona and the San Francisco volcanic field near Flagstaff (see Table I).

Apollo 15 photomosaic negative materials were received in Flagstaff on 8 and 19 May 1971 from the Army Topographic Command (TOPOCOM), St. Louis, Missouri) and compilation of the lunar surface traverse map package was begun. Detailed geologic mapping of this site at 1:12,500 and 1:25,000 scales has been completed by G.G. Schaber and J. Head (Bellcom, Inc., Washington, D.C.), and will appear on all lunar traverse sheets. The map package will consist of both riding (LRV) and walking (contingency) traverses, some with topographic information. A total of thirteen pages with back-to-back maps (26 separate items) will make up the traverse package.

R.M. Batson, K.B. Larson, V.S. Reed, R.L. Tyner, and M.H. Hait (Center of Astrogeology Flagstaff, Arizona) participated in an Apollo 15 TV simulation at the Manned Spacecraft Center, Houston, Texas in May 1971. The purpose was to practice making quick-time Polaroid hand copy mosaics of TV panoramas, and to deliver the mosaics to the Science Operations Room (SOR-previously called Science Support Room, or SSR) for analysis (during the actual mission). Total time from start of TV pan to delivery to the SOR was six minutes!

Branch of Surface Planetary Exploration personnel G.A. Swann, M.H. Hait, R.L. Sutton, G.G. Schaber, G.E. Ulrich, E.W. Wolfe, L.T. Silver, and W.R. Muehlberger visited the Manned Spacecraft Center (Houston) in May 1971 to participate in a series of meetings. The meetings began with a discussion of the arrangement of people in the Science Operations Room (SOR) at the Mission Control Center during the Apollo 15 mission, continued with a traverse planning session, and ended with a simulation of EVA I (for Apollo 15).

It was decided that the arrangement of people in the SOR will consist of an Operations Group that will man the SOR during traverse activities and a Planning Group that will man the SOR between periods of traverse activities. These are roughly 12-14 hour periods with a 1.5 to 2-hour overlap at each end, when one team will "hand over" to the other.

The surface Planetary Exploration TV crew (R.M. Batson, K.B. Larson, V.S. Reed, and R.L Tyner) joined the other SPE personnel in May 1971 for the final session: a simulation of the Apollo 15 planned first EVA. During this simulation the Apollo 15 prime and backup crews carried out science and engineering tasks at Kennedy Space Center, Florida [the "sand pile training site], using pressure suits, science equipment, the lunar rover training vehicle, and the TV camera. The operations and planning teams carried out their mission activities of data compilation and synthesis and used the TV mosaics provided by R.M. Batson and crew for redirecting the TV camera to zoom in on geologic targets of opportunity.

E.W. Wolfe, J.D. Alderman, and R.A. "Putty" Mills, in May 1971, reran the Merriam Crater Apollo 16 training traverse course with a Hycon 307 panoramic camera mounted facing backwards on the rear deck of the USGS Grover LRV Simulator vehicle. Panoramic photos with an angular width of 130 degrees were taken approximately every 50 meters from the moving vehicle and 360 degree panoramas were made at stops. A brief report was prepared summarizing the science potential of this tool on the Apollo Lunar Rover. [The Hycon camera was first tested on the Grover at Merriam Crater in September 1970; see September 1970 and Fig. 79.]

The following was taken from the Center of Astrogeology Monthly Report for June 1970 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 30 June 1970:
On 4 June 1971, D.P. Elston, E.L. Boudette, E.W. Wolfe, and J.B. Lovelace (pilot) conducted Apollo 15 Command Module Pilot, A. Worden and backup CMP, V. Brand, on a fly-over of Central Arizona to help the pilots prepare to recognize and describe lunar geologic features from orbit (see Table I).

E.L. Boudette, E.W. Wolfe (USGS), and T.R. McGetchin (MIT) planned traverses in the field on 5 June 1971 for the Apollo 16 training exercise at Mono Craters, California. E.W. Wolfe and

David Wones (MIT), with Fred Horz and Grant Heiken of MSC briefed the members of the crew on 8 June on the geology of the Mono Craters area. The traverse exercise was run on 10-11 June (see Table I). Working with the crew (both prime and backup) on procedures in the field and as "science operations room" geologists were W.R. Muehlberger, Principal Investigator for the Apollo 16 and 17 Lunar Field Geology Investigations, G.E. Ulrich, E.W. Wolfe, E.L. Boudette (SPE Branch, Flagstaff), who prepared the data package map, and V.L. Freeman (SPE Branch, Flagstaff), F. Horz (MSC) and G. Heiken (MSC). Astronauts Karl G. Henize and A.W. England (MSC) were the science communicators (Capcoms). The traverse afforded the crew an opportunity to study and sample a broad spectrum of volcanic rock textures in the domes and ash of Mono Craters and the ashflows of the Bishop Tuff.

Gerald G. Schaber participated in a briefing of the Apollo 15 prime and backup crews at the Kennedy Space Center, Florida on 7 June 1971. Discussions included the format for the Apollo 15 surface-traverse map package and a general review of mare sampling techniques.

G.A. Swann, Principal Investigator (Field Geology Experiment for Apollo 15), and M.H. Hait held a briefing on the geology of the Apollo 15 mission site at Cape Kennedy 10 June 1971 for the astronauts.

The flight and backup Apollo 15 gnomons and photometric charts were calibrated at the Kennedy Space Center by Center of Astrogeology (Flagstaff) personnel on 13-21 June 1971. The reflectance from each reflective step (20 steps in all) was measured over the view angles planned for lunar surface photography at four illumination angles that spanned the solar incidence angles expected during lunar surface activity. J.A. Jordan, H.E. Holt, J.W. Langman, K.W. Moll, and L.B. Sowers [from the USGS in Flagstaff] carried out the reflectance measurements.

G.A. Swann and G.G. Schaber participated in a briefing of the Apollo 15 prime and backup crews at the Kennedy Space Center on 22 June 1971. The [final] lunar surface traverse data maps prepared at Flagstaff were presented to the crews; this was followed by a discussion of geologic results from the Apollo 14 Field Geology Experiment.

On 29-30 June 1971, Branch of Surface Planetary Exploration personnel organized and directed field exercises using Grover for the Apollo 16 crew at Merriam Crater (day one) and the Cinder Lake Crater Field (day two) near Flagstaff, Arizona (Fig. 86) (see Table I). One of the purposes of this test was to test out the remote TV camera that had been recently rigged up on the Survey's "Grover" LRV vehicle by Johnny Nuttall (Electronics Group leader, Branch of Surface Planetary Exploration) for use during the planned traverses. During these exercises, the Grover was test driven by a NASA technician (unidentified) at Putty Mills' vehicle facility on East Street in East Flagstaff. This engineer also participated with John Young and Charles Duke during the traverses at Merriam Crater and the Cinder Lake Crater Field.

E.W. Wolfe met in June 1971 with F. Horz (MSC) and the Apollo 16 astronauts at MSC to review the effectiveness of the crew's photographic documentation of geologic features in an earlier training traverse at Merriam Crater, near Flagstaff.

In June 1971, D.P. Elston (SPE, Flagstaff), and R.A. Lidless (MSC, Houston), conducted an aerial training exercise in volcanic terraiin north of Salt lake City, Utah, for Kenneth Mattingly, Command Module Pilot for Apollo 16 (see Table I).

During June 1971, arrangements were made to ship two freight-car loads of basaltic cinders and bombs from Arizona (courtesy of V.L. Freeman and T. Weathersby, Center of Astrogeology, Flagstaff), a load of granite and gneiss from Llano uplift, Texas, and a load of anorthosite from the San Gabriel mountains, Pasadena, California (courtesy of L.T. Silver, Caltech, Pasadena, California) to [the so-called sand pile"] Cape Kennedy, Florida. At the small simulated lunar surface constructed near the crew's living quarters at Cape Kennedy, E.W. Wolfe and G.E. Ulrich arranged these imported rocks to tell a geologic story for the Apollo 15 crew to describe and interpret while practicing their traverse simulations for their Hadley-Apennine landing site.

[Author's Note: George Ulrich told this author (personal Communication, 27 July 2002) that when he and Ed Wolfe arrived at the simulated lunar site, or sand pile, an engineer named Rudd, using a Lunar Orbiter photo of the Hadley Rille (at the Apollo 15 landing site) had constructed a replica of the sinuous rille—but in reversed relief (i.e., a sinuous ridge instead of a sinuous valley like Hadley Rille at the Apollo 15 site**)**. It was a winding "ridge" of sand about 4 feet high and 15 feet wide. Mr. Rudd was quite proud of his creation and he pronounced it the Hadley Rille. From then on, we fondly referred to it as Rudd's Rille!]

Gordon Swann:
"A guy named Jack Sevier from the Engineering Office at MSC was very interested in the training and worked with us a lot on it. Jack suggested that they had some money, and asked if we could send some rocks down for the crater field at the Cape. He asked me one day on an airplane, could you send some rocks to the Cape? I said, yeah. If you'll pay for it, we can get rocks!

So, we ended up getting an 80-foot gondola car full of anorthosite rocks from the San Gabriel Mountains near Pasadena, California, that Lee Silver set up. The Santa Fe Railroad has a quarry near Flagstaff in a cinder cone where they can get some road bed material. We got two gondolas full of cinders and a lot of volcanic bombs. Bill Muehlberger got a 16-ton dump truck loaded with plutonic, deep-seated rocks from the Llano Uplift in Texas.

They scattered them around in the sand down there at the Cape so these guys would have some rocks to beat on, identify, and select for samples. Florida is pretty well known for rattlesnakes—and rattlesnakes like rocks. But they didn't have any rocks in Florida until we sent some down! The area attracted every rattlesnake in the county. Every morning, before the astronauts went out and did things at the crater field there, they would send a couple of guys out with shovels to get rid of the rattlesnakes that had found some rocks" (from a filmed interview with Gordon Swann by Harry Ryan in 1996.)

The following was taken from the Center of Astrogeology Monthly Report for June 1971 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 30 June 1971:

G.G. Schaber reported during June 1971 that the Flagstaff Technical Illustrations group completed the Apollo 15 Lunar surface traverse maps of the Hadley-Apennine region. The final version of the surface traverse map package consists of fourteen separate maps depicting both the nominal riding (LRV) and contingency walking traverses. The maps are at both 1:25,000 and 1:12,500 scales and they include a set of topographic surface navigation charts. The three 7-hour, 7-hour, and 6-hour riding traverses are scheduled to be a total of 9km, 16km, and 11.5 km in length, respectively. All maps in the Surface traverse map package include detailed geologic annotations to aid in real-time geologic evaluations.

Ten members of the Branch of Surface Planetary Exploration participated in simulations for the Apollo 15 mission at Houston/MSC on 8 and 21 June 1971 under the leadership of GA Swann, Principal Investigator of the Field Geology Experiment, to practice science support room operations prior to the final simulation.

The final geologic simulation for the prime and backup crews for the Apollo 15 was carried out 25 June 1971 at Coconino Point, Arizona (just south of Grand Canyon north of Flagstaff) on the territory of the Navajo Nation. The exercise area on the north slope of Gray Mountain afforded some morphologic similarities to the Apollo 15 Hadley-Apennine Front, and the Little Colorado River gorge simulated Rima Hadley. Both the USGS Explorer and Grover vehicles were utilized during the exercises (Fig. 87).

Prime crewmembers D.R. Scott and J.B. Irwin conducted the simulated stand-up EVA and EVA II (Apennine Front traverse), using the USGS Explorer test vehicle while the back-up crewmembers, R.F Gordon and H.H Schmitt, observed. The simulated EVA III (Rima Hadley traverse) was conducted by the back-up crew, using the USGS Grover mission training vehicle while the prime crew observed.

The following Branch of Surface Planetary Exploration personnel at Coconino Point supported the test:

<u>Staff Observers</u>: J. Strobell, J. Hanley, and R. Bryson (NASA HQ)

<u>General Logistical Organizer</u>: N.G. Bailey assisted by J.B. Fife

<u>Communications Network</u>: J.C. Nuttall, E. Kelly, J.G. Thompson, J.L. Richards

<u>Test Vehicles</u>: R.A. “Putty” Mills, I.L. Wiser, B.C. Tinnin

<u>Back-up Backroom</u>: V.L. Freeman, R.D. Regan

<u>Field Geology and Briefing</u> (also Houston debriefing): E.L. Boudette

<u>Data Package Preparation</u>: J.W. Vandivier, Ray Sabala, J.L. Remy, W.E. Miller, and H.F. Thomas, G.G. Schaber (photogeology of site and traverse planning of exercises)

<u>Public Relations</u>: R. Wahmann, H.G. Stephens

Meanwhile, back at Mission Control Center Houston, Texas, on the other end of the communications link, the science support teams practiced the data compilation and synthesis in what amounted to the longest session yet—a stint that closely approximated that expected during each EVA of the Apollo 15 mission.

The Coconino Point exercise tested the astronaut's abilities to describe and interpret the geology of the site and taxed the science support teams and the court stenographers to compile data and re-plan the traverses in the face of real-time geologic information. The Geological Survey and NASA people who participated were as follows:

<u>Operations Team</u>

J.A. Lovell (MSC) Leader

Science Thinkers
G.A. Swann, P.I.
L.T. Silver
W. C. Phinney
R. Pepin (U. of Minn.)

R.L. Sutton (note taker)
G.G. Schaber (map plot)
M.H. Hait (sketcher)

G Griffith (MSC) Flight Director

Vehicle Operations
S Law (MSC)
T. Newton (MSC)
J. Cooper (MSC)

Court Stenographers
D. Thacker (Flagstaff)
K. Welch
B. Leesman
L. Williams

<u>Planning Team</u>

J.G. Zarcaro (MSC)

W.R. Muehlberger (U. of Texas, Austin/USGS)
E.D. Jackson (USGS)
D. Strangway (MSC)
N. Hinners (Bellcom, Inc, Washington, D.C.)

G.E. Ulrich (SPE Branch, Flagstaff)
J. Head (Bellcom, Inc.)
E.W. Wolfe (SPE Branch, Flagstaff)

R. Koos (MSC)
B. Sharpe (MSC)

Other NASA attendees included Gary Lofgren, Fred Horz, Joe Roberts, Dave Schultz, and Milton Reim. Other NASA HQ visitors included, Wilson Barber; other observers included Navajo Nation Tribal Chairman Peter McDonald, Bruce Wiley, Al Goldtooth and Paul Blanchard. Other USGS Flagstaff personnel attending included Jack Strobell, Nancy Dietze, Nona Sutton, Eugene Boudette, Darline Johnson, and Fred (Dietz?)

The following was taken from the Center of Astrogeology Monthly Report for July 1971 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 31 July 1971:
Harold Masursky (BAS, Flagstaff) participated in the Science Working Panel meeting as the Apollo Orbital Science Team representative at the Lunar Science Institute in Houston, Texas on 1-2 June, and attended the Apollo 15 Orbital Science Mission simulation at the Manned Spacecraft Center, Houston, Texas on 7-8 and 21 June

Harold Masursky gave a briefing session I Orbital Science for the Apollo 15 crew at Cape Kennedy, Florida, on 7 July 1971, and an astronaut training lecture on Orbital Science to the Apollo 15 crew at Cape Kennedy, Florida on 19 July.

D.P. Elston and E.L. Boudette (SPE Branch, Flagstaff, Arizona) in July 1971 were mapping the geology of the Descartes landing site (Apollo 16) in detail at a scale of 1:12,500 using the AP/C analytical stereoplotter at the Center of Astrogeology, Flagstaff. Film positives of 500-mm Hasselblad photographs of the Apollo 16 site obtained during Apollo 14 have provided the stereo model. The plotter permits geologic details to be resolved to a much finer degree than use of stereo pairs of positive prints.

A geological training exercise for the Apollo 16 prime and backup crew was held on 7-9 July 1971 at Sudbury, Ontario, Canada (see Table I). Good examples were available there of the shock effects on the rocks resulting from meteorite impact and of the post-shock sequence of both melted and internally-derived igneous rocks. The International Nickel Company (INCO) liberally cooperated. Astronauts Young, Duke, Haise, and England participated with the INCO geologists, Bevan French of NASA-Goddard, Fred Horz and Gary Hanisch of NASA-MSC, and W.R. Muehlberger, E.L. Boudette, V.L. Freeman, Ivo Lucchitta, G.E. Ulrich, and E.W. Wolfe of the U.S. Geological Survey (Fig. 88).

Members of the Apollo Lunar Geology Investigation team participated in two Apollo 15 simulations at the Manned Spacecraft Center in early July 1971. The first simulation used as "astronauts," J.W. Head (Bellcom, Inc.) and J.R. Sevier (MSC, Houston). They prepared an exercise that combined geological surprises and engineering problems—enough of both to give a good test to the Geology Team which was practicing duties in the Science Operations Room at the nearby Mission Control Center.

In the second simulation, Apollo 15 crew members Scott, Irwin, Gordon, and Schmitt practiced their lunar tasks at the Kennedy Space Center "rock pile" (formerly "sand pile") while the Geology Team participated at the Mission Control Center.

G.G. Schaber and G.A. Swann participated in the final pre-launch geology briefing with the prime and backup crews of the Apollo 15 mission at their crew quarters at the Kennedy Space Center, Florida on 22 July 1971. The briefing was the last of a series dealing with the detailed geology and traverse activities planned at the Hadley-Apennine landing site. Other participants in the briefing were L.T. Silver (Caltech), J.R. Sevier (Apollo Surface Planning and Operations, Manned Spacecraft Center, Houston, Texas), and J.W. Head (Bellcom, Inc., Washington, D.C.)

Chapter 6

The J-Series Apollo Moon Landings with Lunar Rover Vehicles (LRVs) to Explore More Scientifically Interesting Sites

6.1-Apollo 15

(Launched 26 July 1971; landing site at Apennine-Hadley; crew David R. Scott, Commander; Alfred M. Worden, Lunar Module Pilot; James B. Irwin, Lunar Module Pilot)

[Author's Note: For a detailed description of the astronaut's activities on the lunar surface during Apollo 15, the reader is referred to NASA's web address for the Apollo Lunar Surface Journal (http://www.hq.nasa.gov/alsj/), as well as the books by Wilhelms (1993), and Chaikin (1994)].

The Apollo 15 mission was extremely successful and the landing crew (Scott and Irwin) showed the world what good geologic observers military, pilot/astronauts can be if they are well-trained and extremely interested in doing top notch geologic exploration on the Moon—as Scott and Irwin truly were (Fig. 89).

For the Apollo 15 mission, the Apollo Lunar Geology Investigation team was organized into three groups, which operated at the manned Spacecraft Center. During the EVAs, G.A. Swann, Principal Investigator, was assisted by R.L. Sutton, G.G. Schaber, M.H. Hait, and L.T. Silver (Caltech, Pasadena, California) in following and recording the observations reported by astronauts Dave Scott and Jim Irwin on the lunar surface. Their data were summarized in a short report to accompany a map of the traverse showing photo and sample points, both of which were the responsibility of R.H. Jahns (Stanford University), K.A Howard, H.G. Wilshire, and V. Freeman, R. Sabala, J. Loman and R. Madden. This quick report was distributed prior to succeeding EVA for planning purposes. The third group included W.R. Muehlberger, .D. Jackson, G.E. Ulrich, and E.W. Wolfe, who evaluated the results and assisted in planning the succeeding EVA within the changed framework imposed by revised time schedules.

Gordon Swann:
"Well, I think Apollo 15 was my favorite landing site. Maybe because I'm a little prejudiced that way, but it had such a variety of things. It had Mt. Hadley, which is the highest point on the Moon. It had Hadley Rille, which is the longest, largest, sinuous rille on the Moon. It had both mare material and lunar highland material, and just a tremendous variety of things. We thought that they [the Apollo 15 crew] might find anorthosite in the highlands because we'd found anorthosite in earlier samples, so they were taught to look for anorthosite—and they found some!"

Anorthosite is an important building block in the development of a planet such as Earth. Where you have a lot of volcanism, you have what's called a magmatic differentiation from melting stuff—and then recombining it. Anorthosite is one of the more primitive kinds of rocks that come out of this process. Finding anorthosite tells quite a bit about the thermal evolution and thermal history of the moon. It was an important thing. We thought they'd find it because we found little bits of it in the soil, but they [the Apollo 15 crew] found some good-sized rock samples [of anorthosite].

We had taught them to look across canyons and describe the opposite walls. We did that at the Colorado River gorge near Flagstaff. We also taught them this technique at the Taos Gorge in New Mexico—because they were going to be on the edge of the big canyon on the Moon called Hadley Rille. Here, they almost certainly would be seeing actual [basalt] outcrops in the [upper] walls on the far side of the rille, which was about a mile away from them. They took some good telephoto pictures of them [the basalt layers], and described it in quite a bit of detail. It's probably the best evidence of real bedrock on the Moon that we've got from any Apollo mission.

We had good cooperation with the Capcom and the flight directors. In fact, several of the flight directors got pretty interested in geology. The astronaut/Capcoms went on most of the geology field trips so that they would understand what we were trying to do in those areas.

The Science Support Room [SSR] activities, especially for the later parts of the training [Apollo 15-17] would emphasize more and more of the mission aspects, and the actual back room personnel and the Capcoms got pretty directly involved with the training. In fact, in some areas we would set up a tent and play like it was the SSR at MSC, and the Capcom would be in that tent—the guy who was actually going to be the Capcom during the mission—talking to the astronauts out in the field through radios. We would try to put together their story [what the astronauts were describing], in an attempt to simulate the real thing.

So the Capcoms and the flight directors got pretty involved with geology, and they were quite interested in it, and quite supportive. In fact, on the J-series missions [Apollo 15-17], the Capcom for the EVAs were all three scientist-astronauts. Joe Allen, who is a physicist form Yale was Capcom on Apollo 15, Tony England, an MIT geophysicist, was Capcom on Apollo 16, and Bob Parker, an astronomer from Caltech, was Capcom for Apollo 17. So these guys were also scientists" (from a 1996 filmed interview with Gordon Swann by Kirk Wolfinger from Lone Wolf Productions preparing for the NOVA documentary "*To the Moon*" first aired in 1999).

Don Beattie:
"In terms of science training, the crew of Apollo 15 was the best prepared yet. Based on my observations, Dave Scott, James Irwin, and Alfred Worden showed the greatest interest of any of the crews to date in understanding the science objectives for their landing site (the Apennine Mountains and nearby Hadley Rille) and the new suite of experiments housed in the Lunar Module (LM) and CSM" (Beattie, 2001, p. 229).

[Author's Note: The astute geologic training, and the Apollo 15 crew's attention to geologic detail was brought home to this author when I later wrote a paper with the Apollo 15 crew detailing (once and for all) the origin of the glass in the bottom of small lunar craters, whose origin had puzzled everyone starting with Neil and Buzz's observations of such glassy-bottomed craters during Apollo 11 (Schaber, G.G., Scott, D.R, and Irwin, J.B., 1972, Glass in the bottom of small lunar craters: An observation from Apollo 15: *Geologic Society of America Bulletin, v. 83*, pp. 1573-1578).

[Author's Note: Gordon Swann gave Commander Dave Scott (Apollo 15) his own personal geologist's hand lens to take to the lunar surface during the Apollo 15 mission. Dave returned the hand lens to Gordon upon his return to Earth; and today, this very special hand lens is one of Swann's most cherished possessions.]

Gerald Schaber:
As one of the Co-Investigators on the Apollo 15 Apollo Lunar Geology Investigation team, my job in the Science Backroom during that mission (as it was earlier during Apollo 11 and 14) was to keep track of the astronaut's exact location at their landing site. This was accomplished using a large-scale landing site map and astronaut and Lunar Rover cutouts that could be moved along the map to the appropriate sampling station or unplanned stop. The map was situated on a lighted plotting table with an overhead television camera in the Geophysical Experiments (ALSEP) readout room adjoining the room where the remainder of Swann's ALGI Team was gathered around several large tables (See Fig. 61e).

The TV camera above my plotting table enabled the flight controllers in the next room to call up their display of astronaut positions, whenever they so desired. This was the first mission to utilize the Lunar Rover (first J-mission) with its navigation system and color television camera; both located onboard the Rover. This made it much easier to keep accurate track of the crew; during the previous early-Apollo missions I had to depend solely on the field of view of the stationary TV camera set up by the LM, and the crew's verbal commentary.

I recall having just removed my head set at the end of Apollo 15 EVA 2 (146:49:02 mission elapsed time—hours: minutes: seconds from launch) when I heard over the speakers in the Science Operation Room (SOR) something that sounded like "my last name" coming from the voice link from the lunar surface. Jim Head shouted across the room, " Jerry did you hear that?" I said that he thought I heard my name on the lunar voice link. Jim said you did; they just referred to the "North Complex" as "Schaber Hill."

The story of the North Complex/Schaber Hill and my role in planning a LRV traverse up to it for the third EVA on Apollo 15 (which unfortunately never took place) goes back a month or so before the mission during a February 1971 meeting with the crew at MSC in Houston, Texas [see story above about February 1971 briefing of the Apollo 15 crew at MSC.]

It turns out that during the mission, Dave Scott and Jim Irwin had to spend an extra sixty frustrating minutes trying to remove the stuck 3-m drill bit from the lunar surface near the LM. As a result, EVA-3 to the North Complex/Schaber Hill had to be aborted in lieu of the contingency traverse to Hadley Rille just west of the LM. However, instead of a walking traverse, the contingency traverses for Apollo 15 were designed to be, they used the LRV. The contingency EVA-3 traverse over to Hadley Rille worked out very well. However, Dave Scott, Jim Irwin, Head and I, along with the entire USGS Geology Team at MSC, were disappointed that the drill had caused them to lose what might have turned out to be an even more geologically rewarding traverse to the North Complex. Of course, the lunar sample people who desperately wanted to retrieve that drill core were equally as insistent in the Science Backroom on bringing back home that admittedly valuable 3-m sample of the regolith.

Gordon Swann:
The biggest argument I had with the ten-meter drill on Apollo 15 was that they left the "drill string" in the hole overnight, which you never do if unavoidable in uncertain ground. Dave gave it a couple of tugs, but didn't get it out. If they had both (Dave and Jim) been given a few minutes to work on it, which they still had in their backpacks (oxygen wise), they might have got it.

This author recalls that there was a crazy splashdown party [they all were] at Jack Schmitt's apartment in Nassau Bay [near MSC] following the end of lunar activity during the Apollo 15 mission in late July 1971. The party took place at the pool right below Jack's apartment. In fact, Jack had arranged earlier with the landlady to have a party there.

People were getting thrown into the pool with their clothes on—billfold, watches and all. Gordon Swann got a gang of people together to throw in Bill Muehlberger. But, as Gordon's group turned around to do it- here comes Muehlberger with his own gang after him! Gordon says that Mully [Bill's nickname] didn't need a gang, as Bill is a very big and imposing fellow.

Gordon Swann:
Mully wrapped his arms around me, but fortunately I got my arms up in the air, so I got my wallet out and threw it [onto the side of the pool]. And poor Jerry Griffin, the Apollo 15 mission Flight Director, was standing right by the pool, and Gordon said I just gathered him up. Jerry [Griffin] and I went arching out across the pool belly first with him [Jerry] under me—so Jerry technically was the first guy in the pool—and I was second. Then all of my guys hit Muehlberger—and he was in.

I helped to throw Tony Calio [from MSC] in the pool with a suit on. Then he helped throw Tony's wife in. She had a long dress on! He had a suit on.

Dick Gordon [the Command Module Pilot from Apollo 12] was standing chin deep in water, and he had on his white buck shoes, white-and pink-checkered pants, and a sport coat and a white turtle neck sweater—and he had two girls in each hand dunking them. And his (then) wife, Barbara walked up to the edge of the pool and said, Dick, you're just ruining your clothes, and that's when Swann grabbed Barbara [to throw her in the pool]. Dick turned loose of both girls and grabbed hold of Barbara, and started dunking her" (from an interview with Jody and Gordon Swann by Gerald G. Schaber on 16 March 2001).

Jody Swann recalled during that same 16 March 2001 interview "Then, the four of them went over to Sally Muehlberger (Bill's wife) who was sitting in a recliner by the side of the pool. We picked her up—chair and all—and dropped her in the pool!"

About at that time, this author quietly snuck away from the party and went across the street to avoid getting thrown in the pool. There he ran into my Apollo 15 colleague and fellow coward—Jim Head (from Bellcom, Inc.)—who also was also hiding out, trying to avoid the somewhat out-of-control violence at Schmitt's pool party.

Putty Mills:
"Soon after Dave Scott and Jim Irwin returned from the Moon [from Apollo 15] they came down to my shop in Flagstaff. They said "Hey Putty, the first thing we noticed is when we got on this thing [the LRV] in 1/6 gravity is we set up much higher than we did on your Grover in the field here on Earth. The view from the Rover while you were siting in it [on the lunar surface] was totally different because we were sitting—like a foot higher. So then Dave suggested that I make some thicker seats for Astro's Grover-to more or less simulate the lunar surface case. So, we made the seats a lot thicker to raise the astronauts in the seated position" (from an interview with Putty Mills by Gerald G. Schaber on 22 January 2001).

David Levy:
"In 1971 Gene's schedule [while at Caltech] included time, once again, with the Apollo Program. This time it was with the BBC: for Apollo 14 in February and Apollo 15 in July, he served on a panel that provided background to the British coverage of the missions. This was an exciting time in geology, but the demands of teaching and research often conflicted with Gene's need to keep Caltech's geological sciences division running smoothly" (Levy, 2000, p. 150).

"Although the students loved Gene as an inspiring teacher, neither Gene nor some of his colleagues were happy with his performance as head of the division. The minutiae of administration were not something he particularly enjoyed. Where his attention to detail was food for science, it slowed him down quite a bit when it came to running the department. The problem, as Caltech colleague Robert Sharp put it, was that Gene was very good at working with tremendous focus on a particular endeavor, often to the exclusion of everything else. However, if he began to lose interest in a project, he would spend so much less time on it that it would not get completed.

If Gene's performance as chairman was questionable from the point of view of some of his colleagues, it was given the highest ratings from his students. Gene was one of the most successful teachers we have ever had in our division, remembers Lee Silver. His immense enthusiasm and confidence inspired other people. Gene was not a controlling person with his students" (Levy, 2000, pp. 148-149).

Andy Chaikin:
"In August 1971, NASA was on a high. With Apollo 15, the agency had scored its biggest success since the first lunar landing. Within the scientific community, even skeptics applauded the mission. Gerry Wasserburg, a Caltech geochemist who had voiced his share of opposition to Lee Silver's astronaut training efforts, publicly named it "One of the most brilliant missions in space science even flown." For Dave Scott, there was an unaccustomed gesture of praise from a fellow astronaut; a note from Alan Bean congratulating him on a superb performance. And throughout the space center there was the new realization that Apollo had reached maturity. Almost every one of Apollo 15's innovations, from the Rover to the upgraded Lunar Module to the training and planning efforts, had come through with barely a hitch. The way was clear for the final two missions to be even more ambitious.

And for six men, August was the moment of truth. The crew of Apollo 17, as yet unnamed, was about to be announced. Six men eyed three seats on the final Moon-bound command module. So did the scientific community. All through 1971 they had been turning up the heat on NASA, decrying the fact that NASA had a fully qualified scientist and wasn't sending him to the Moon. Word of this filtered down to the Astronaut Office, where Dick Gordon had been making a hard run to snare Apollo 17 for his own. He knew very well that by Slayton's rotation it was Gene Cernan, who had backed up Shepard on Apollo 14, who was in line for the mission. When Cernan crashed his helicopter in the Banana River during training, Gordon had hoped Cernan had taken himself out of the running, but that little episode had just slid off Cernan's back. Now, as the decision neared, Gordon was betting that Schmitt would be his edge. And he had no qualms about politicking for the flight; he went to Shepard and Slayton and asked them to keep his crew together.

From the sidelines, the other astronauts watched and waited with great interest. There were two ways this could go, they realized. Even if Gordon didn't get the mission, Slayton could still take Schmitt and put him on Cernan's crew—in which case things were looking very bad for Cernan's lunar module pilot, Joe Engle. He was one of the most experienced test pilots among the Original 19, and in Cernan's mind, one of the best pilots he'd ever flown with.

But in truth, Deke Slayton wasn't especially concerned. In his mind, only one thing mattered; it would have been unthinkable for NASA to have a geologist-astronaut and not send him to the Moon" (Chaikin, 1994, pp.448-450).

This author contributes a personal story below that took place during a hot Houston evening in August 1971. James Head and I were at Jack Schmitt's apartment in Nassau Bay [near MSC] when Jack received the official phone call from the Director of NASA, James Fletcher, who told him that he had been selected to go to the Moon as Gene Cernan's LM Pilot on Apollo 17. This author also contributed a version of the following story for Andy Chaikin's book *Man on the Moon* (Chaikin, 1994, pp.450-451):

It was during this time that Jim Head (Bellcom, Inc., Washington, D.C.) and I were sharing a room at the Kings Inn Motel on NASA Road One across from MSC during the Apollo 15 mission. Jim and I had been discussing the pending decision by NASA as to the makeup of the Apollo 17 crew. Although strongly agreeing of course that Jack should be on the crew of Apollo

17, I did not believe that NASA would be convinced by the scientist-lobby to add Jack, especially if it meant bumping Joe Engle, one of NASA's most experienced and best-liked test-pilot astronauts, from the mission.

I had just bet Jim Head five dollars that Schmitt probably wouldn't receive the nod from NASA for the Apollo 17 mission. Jim accepted my bet. Shortly after we shook on it, Jim went into the bathroom in our motel room, and I switched on the TV. The set had no sooner warmed up when I heard Walter Conkrite say something to the effect that Harrison Schmitt, geologist-astronaut, will be going to the Moon on Apollo 17! I was surprised, but very excited.

I took out my billfold and without a word slipped a five-dollar bill under the bathroom door. Jim, being no dummy, —that you have been designated LM Pilot for Apollo 17. Jack said it's not true because I haven't yet got the official word directly from James Fletcher, NASA Administrator.

So Jim said "well, do you mind if Schaber and I come over and wait with you?" Jack said I don't care what you do. Jim opened his large leather briefcase and took out four little bottles of whiskey and other assorted liquors that he had gotten free (in those days) on the airplane. He said "these are just in case a celebration is in order."

Jim and I drove the short distance from the Kings Inn to the Nassau Bay Apartment complex where Jack had his small bachelor pad. We went in and Jack was sitting at his desk studying impressive cardboard mockups of the complex control panels for the LM.

When Jim took out the four little bottles of booze from his briefcase and placed them on Schmitt's little kitchen bar window, Jack scowled and said "what are those for?" Jim said "those are just in case we need to celebrate anything." Schmitt got his usual dumb look of disgust on his face and went back to studying his LM control panel mockups.

The three of us just basically sat there and said very little. I remember I was so bored and tense that I started reading a National Geographic that was lying on Jack's coffee table. Then the phone rang. We all three quickly became alert. Jack answered it. It was his sister who also had just heard the news about the Apollo 17 crew selection on TV. Jack told her the same thing he had told us—"it's not true, I haven't heard from NASA Headquarters." He told her that he needs to keep the phone free, and hung up. After another seemingly endless amount of time—probably only a half an hour or so, he got "the call." It was James Fletcher.

I remember Jack's side of the very brief phone conversation with NASA Director Fletcher going something like the following: Yes sir, no sir, I will do my best sir. Thank you for calling. With that, saying nothing to us, Jack went over to his kitchen bar area and picked up all four little bottles of booze, opened them, and put all four in his mouth at once and drank them.

After that, we congratulated him and chatted for a while. I can't remember what we talked about. I only remember that nobody else called him during that period of time—no one from the Astronaut Office, for example, to offer their congratulations. I remember actually feeling sorry for him in some strange way—and on this, one the most remarkable days in his life—knowing that he also was well aware that his success meant that Joe Engle would <u>not</u> be going to the Moon!

One of us asked Jack if he had eaten dinner yet. He said no, so we drove down toward Kemah and stopped at the Pizza Hut [no longer there]. We ordered a pitcher of beer and two large pizzas. The conversation at the restaurant, as I recall, was mindless (and somehow purposely) on subjects other than Apollo 17. There was nothing near the level of excitement one would expect—even from generally reserved Jack—on such a momentous occasion. We ate quietly, and then drove Jack back to his apartment. He did not encourage us to stay. He obviously wanted to think about what had just happened to him. I cannot imagine what was going through his mind that night.

When we arrived back at our motel, my mind was on Jack's pending adventure, as well as poor Joe Engle who had just lost his trip to the Moon. I also pondered the fact that here was Jack Schmitt—who had interviewed me for my job with the Branch of Astrogeology, and to whom I was supposed to report as my immediate supervisor when I arrived at Flagstaff in July 1965. Now, he was a good friend who was <u>going to the damn Moon for God's sake</u>! It was like living in a science fiction movie from the 1950s (and I saw them all!)

Andy Chaikin:
"The next day, Jack Schmitt said to Dick Gordon, "Why don't you let me talk to Deke [Slayton]?" No, I've had my shot, Gordon said [on Apollo 12]. "The decision's been made." Schmitt went to Slayton anyway and asked him not to break up the crew. He and Gordon had worked very well together, he said, they made a great team. But his effort was in vain: Slayton wasn't going to change his decision. In the days that followed, Schmitt also spoke with Joe Engle. It was an awkward time; Engle was visibly upset and Schmitt could tell he was bitter. But Engle handled himself as well as could be expected. He told a reporter that the toughest thing he could remember doing in a long time was explaining to his kids that he wasn't going to the Moon" (Chaikin, 1994, p. 451).

The following was taken from the Center of Astrogeology Monthly Report for August 1971 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 31 August 1971:
H.G. Wilshire (BAS, Menlo Park, California) participated in the Apollo 15 mission by assisting in the sample description and location during the EVAs. In August 1971 he was engaged in the description of returned samples as an observer for the Apollo Lunar Geology Experiment team on the Lunar Sample Preliminary Examination Team (LSPET).

Harold Masursky (BAS, Flagstaff, Arizona) spent 1-4 August 1971 at Mission Operations, Manned Spacecraft Center, Houston, Texas, and took part in an Apollo 15 post-mission press briefing on the orbital science results. Hal also attended a photographic and science debriefing of the Apollo 15 crew at MSC on 16-17 August 1971.

In August 1971 astronomer Gerard de Vaucouleurs, as a guest observer, completed a three-month series of Mars opposition observations at the U.S. Geological Survey 30-inch telescope that is located on Anderson Mesa south of Flagstaff, Arizona. He distributed preliminary results in the form of two reports prepared at the USGS cartographic facility [in Flagstaff].

The following was taken from the Center of Astrogeology Monthly Report for August 1971 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 31 August 1971:
During August 1971, three large rooms and one office area were being renovated in the Center of Astrogeology's Headquarters building (Building One) on McMillan Mesa in Flagstaff to house the new Data Facility. One room will store Apollo surface and orbiter photography and will also serve as a mapping and compilation area for project scientists. The adjoining room to the east will contain Lunar Orbiter photography and related reference material. The large room at the east end will be for planetary data and storage of large panel mosaics of both lunar and planetary photography; it would also contain the files of Mars photographic data.

A preliminary summary by G.A. Swann, (Principal Investigator) and the Lunar Geology Experiment team of the geology and field petrology at the Apollo 15 landing site (*Open-File USGS Interagency Report 32*, dated 5 August 1971) was given to the astronauts by the Director of the Manned Spacecraft Center, Houston while they were STILL on the recovery ship!]

H. G. Wilshire, L.T. Silver, and E.D. Jackson served on the Preliminary Examination team in the Lunar Receiving laboratory, participating in the initial look at the samples returned by Apollo 15. Documentation of the samples was begun by studying the voice transcript (provided by the USGS), the photos taken on the surface, and the samples themselves as they were unpacked, and the first results were issued in Interagency Report 34 (USGS *Open-File Report*) on 26 August 1971.

In addition to the summaries of each EVA during the Apollo 15 mission, which were mentioned in the monthly report for July 1971, the voice transcript was corrected and key-worded for quick cross-reference and entered into computer storage in August 1971. The key words provided a ready means of accessing the voice record by geologic subjects in the course of compiling and analyzing the mission data. A printout of the corrected and key-worded transcript was distributed to the Science and Applications (SA&D) Office at MSC and to the Apollo 15 crew after their return.

In addition to the reports mentioned above, the Geology Experiment team contributed to the "5-day" and "45-day" reports on the Apollo 15 mission prepared by ASPO-MSC, and began a detailed study of the geologic environments of the individual samples returned by the astronauts. Some results of this latter study were then informally transmitted to PET and LSAPT.

The following was taken from the Center of Astrogeology Monthly Report for September 1971 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 30 September 1971:
C.A. Hodges (BAS, Menlo Park, California) reported in September 1971 that her pre-mission map of the Apollo 16 Descartes landing site (scale 1:50,000) was in technical review. It was planned that this map and a smaller scale (1:250,000) companion map of the general region by D.J. Milton will be formerly published in the I-map series before the launch date [for Apollo 16].

K.A. Howard (BAS, Menlo Park, California) reported during September 1971 that a "pseudo" lunar grid might indeed exist. K.A. Howard and K.R. Larsen performed experiments to simulate lunar lighting conditions on random piles of powder. Visually, and in photographs, these showed definite linear patterns developed in conjugate sets at acute angles to the direction of lighting. The distances from which the linear patterns are best seen, and their orientations, are variables that depend respectively on the size of individual hummocks, and the slopes angles and "sun angle." The patterns are strikingly reminiscent of lineament patterns measured at all scales on the Moon [including those at footprint scale by the astronauts mapped by yours truly after Apollo 11 and 12], suggesting that caution should be exercised in mapping and interpreting lunar grid patterns.

[Author's Note: Keith Howard from Astrogeology's Menlo Park contingent would be the first to question the validity of the, by then, well known and omnipresent northeast-, north-, and northwest-trending lunar lineaments that were originally recognized and reported from early telescopic observations by scientists at the U. of Arizona. The Apollo 15 crew strongly agreed that these striking lineaments were definitely real and commented on them at length during their lunar traverses. Howard was puzzled by the remarkable variation in the scale of these "lineaments" from regional scale all the way down to footprint scale in the lunar dust. He wisely advised the Lunar Geology Team to hold off releasing their press release announcing the recognition of striking lineaments or dipping stratigraphic beds in the mountains surrounding the Apennine-Hadley site until he could perform some simple experiments. Keith set up an experiment at home using a 35-mm projector as a light source and used piled powdered material with similar photometric properties as lunar dust. The results confirmed his suspicions. The well-known lunar lineaments were nothing more than an illusion of the lunar illumination under certain grazing conditions and the physical properties of the pervasive lunar regolith (for more experiments by Branch of Surface Planetary Geology personnel on the pseudo-lineaments at the Apollo 15 site, see November just below).

[Author's Note: Keith Howard, in his interview with Gerald Schaber for this document on 1 February 2002, stated that he believed that his experimentation and analysis of the very likely "pseudo" lunar grid was perhaps his most important single contribution to the Apollo program. I agree!]

Keith Howard published his findings in a little note in the *Apollo 15 Preliminary Science Report*. "It never got beyond that, but he always felt that that was one of the biggest contributions he made to the Apollo Program" (from an interview with Keith Howard by Gerald G. Schaber on 1 February 2002).

The following was taken from the Center of Astrogeology Monthly Report for September 1971 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 30 September 1971:
A review of the geology of the Apollo 16 exploration site, Descartes, was held [at the Center of Astrogeology] in Flagstaff in September 1971. Its purpose was to provide the basis for traverse planning and sampling strategy for the mission that was to fly in March 1972. Results of current geologic mapping by D.J. Milton, C.A. Hodges, D.P. Elston, E.L. Boudette, and J.P. Shafer were

augmented by discussions of relative ages and possible origins [including, as it turned out, an incorrectly predicted volcanic origin] of the upland plains units (Cayley Formation) and adjacent mountains of the Descartes Formation.

Other participants at the Flagstaff meeting (described above) were the Apollo 16 crew, J.W. Young, C.M. Duke, and mission scientist A.W. England; W.W. Jaderlund (MSC), J.B. Hanley (NASA HQ), J.W. Head (Bellcom, Inc.), S.R. Titley (University of Arizona), T.R. McGetchin (MIT), and from the USGS: N.J. Trask, J.D. Strobell, H. Masursky, J.F. McCauley, L.R. Page, H.J. Moore, D.H. Scott, E.W. Wolfe, V.L. Freeman, and G.E. Ulrich.

An Apollo 16 crew training exercise was held near Taos, New Mexico on 9-10 September 1971 (Fig 90; also see Table I). Attending was the prime crew, J.W. Young and C.M. Duke; the backup crew, F.W. Haise and E.D. Mitchell; acting Capcoms, A.W. England and G.E. Hanisch; geologists from MSC, W.C. Phinney and F. Horz; and the USGS geologists, L.T. Silver, W.R. Muehlberger, G.E. Ulrich, R.M. Batson, V.L. Freeman, and E.W. Wolfe. Support personnel from NASA were E. Quinn, R. Kane, and R. Zedekar; and from the USGS were R.A. Mills, I.L. Wiser, B.G Tinnin, and J.R. Lovelace.

The second ground exercise was preceded by a flyover exercise with L.T. Silver (USGS-Caltech) and R.A. Laidley (MSC) training T.K. Mattingly. The area at Taos provided an opportunity to study and describe a layered sequence of volcanic rocks and the age relations of two series of volcanics with associated geomorphic forms and debris deposits

The following was found in the Center of Astrogeology Monthly Report for October 1971 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 31 October 1971:
On 27 October 1971, an Apollo 16 astronaut training exercise trip took place on the Nevada Test Site using Schooner Crater as an analogue of North Ray Crater at the Descartes lunar landing site (see Table I). The second traverse, including a variety of crater sizes and associated stratigraphic problems on Buckboard Mesa, was snowed out, but an informal conference on geologic interpretations from craters in general and the Descartes site in particular, led by William R. Muehlberger, H.J. Moore, and E.L. Boudette proved to be a productive substitute.

Participating in the exercise were the surface crews, astronauts J.W. Young, C.M. Duke, and F.W. Haise, mission scientist and capsule communicator A.W. England, backup capsule communicator D.E. Peterson, and the Command Module pilot T.K. Mattingly who observed the regional features of the exercise area from an altitude simulating the low-altitude lunar orbit of 10 miles. Assisting Mattingly were astronaut H.W. Hartsfield, orbital capsule communicator, R.A. Laidley, geologist, Manned Spacecraft Center, Houston, Texas, D.J. Roddy (USGS, BAS, Flagstaff) and K.A. Sargent, Special Projects, USGS, Denver. The “backroom” geologists for the two surface crews were W.R. Muehlberger, E.D. Jackson, E.W. Wolfe, R.L. Sutton, E.L. Boudette, V.L. Freeman, and J.W. Head (Bellcom, Inc.). Field evaluation was by H.J. Moore, G.E. Ulrich, R. Horz (MSC) and W.C. Phinney (MSC). Field observers on the first day’s exercise were G.A. Swann and, from NASA Headquarters, Washington, D.C., R. Petrone, C. Lee, W.T. O’Bryant, and D.A. Beattie.

The success of the training trip required, in addition to the usual collaboration of NASA and USGS/Astrogeology, the outstanding hospitality of the Atomic Energy Commission, helicopter support from the Air Force at Indian Springs, Nevada, and the Army at Edwards Air Force Base, and the generous help of Paul Orkild and Ken Sargent of Special Projects Branch (USGS) and Mrs. Lynn Bessent of the USGS office in Mercury, Nevada.

On 13-15 October 1971 W.R. Muehlberger participated in a 2-day flyover exercise with T.K. Mattingly, CSM Pilot for Apollo 16, and R.A. Laidley, MSC, from Mt. Lassen, California, to Bend, Oregon (see Table I). Such training and experience in geologic observation increased the capability of the CSM pilot to report his interpretations of features of the lunar surface,

On 19-22 October 1971 The Apollo 17 astronauts, E.A. Cernan and H.H. Schmitt joined Principal Investigator of the Apollo 17 Field Geology Experiment, William Muehlberger, in a three-day field examination of geologic features in the Big Bend area of Texas, to increase overall geologic proficiency and initiate the period of final preparation for the geologic tasks of their mission [to Taurus-Littrow] (see Table I).

E.L. Boudette, J.W. Vandivier, and G.G. Schaber reviewed the progress on the photomosaic base map for the Apollo 16 mission at TOPOCOM in Washington, D.C. during October 1971.

Starting on 1 November 1971, geologist Ed Wolfe (Branch of Surface Planetary Exploration in Flagstaff) wanted to pursue Keith Howard's earlier idea (see September 1971 above) questioning the "reality' of the so-called "lunar grid" and perhaps try to prove that it might be an artifact of the unique lunar solar illumination. With significant help from Red Bailey they traced the lineaments on surface photographs taken both from orbit (Apollo 15 Metric Camera) and from the lunar surface near Mt. Hadley by the Apollo 15 crew (Scott and Irwin). They decided to make a model of Mt. Hadley using cement powder (best material they could find at the time with similar photometric properties of the lunar soil). They photographed the model in black and white at different low-lighting angles. They then decided to model Mt. Hadley in 3-D and to photograph that model, eventually using collimated light (like lunar Sunlight).

The resulting "cement" Mt. Hadley created quite a stir (Fig. 91). When the proper "solar illumination angle' was used, there appeared the almost identical "layers" that were observed and photographed by the crew of Apollo 15. Figure 91 compares the cement Mt. Hadley (inserted into an actual Apollo 15 surface photograph) with the original photograph of Mt. Hadley. Both show remarkably similar "layers" sloping from the upper right to the lower left. This comparison convinced nearly everyone who says that the "layers" were in fact lighting artifacts, perhaps unique to the lunar surface.

To this author's knowledge, Apollo 15 Commander Dave Scott, who was convinced (while on the lunar surface) that these were in fact rock layers (stratigraphy) within Mt. Hadley proper, has still not been totally convinced by the Geological Survey's cement modeling experiment that these linears are artifacts of the solar illumination. Dave (and Jim Irwin) agreed that "they looked so real from the lunar surface"].

The following was found in the Center of Astrogeology Monthly Report for November 1971 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeology Studies; dated 30 November 1971:
K.A. Howard (BAS Menlo Park California) briefed Apollo 16 Command Module Pilot, K. Mattingly, and his backup, S. Roosa, during November 1971 on geologic problems in the central highlands of the Moon. D.J. Milton spoke to the Apollo 16 Command Module Pilot on targets for orbital observation near the Descartes landing site.

NASA Headquarters appointed G.G. Schaber (SPE Flagstaff) and R.E. Eggleton (BAS, Flagstaff) as Co-Investigators on the Apollo Lunar Sounder Experiment (ALSE) team during November 1971. The experiment objectives were (1) to study the subsurface geology to depths of perhaps 1.3 km along the orbital paths and (2) to develop continuous surface profiles. The experiment will operate at radar wavelengths of 2-m, 20 m and 60 m; it was scheduled to fly [and did] on the Apollo 17 Service Module in December 1972. The experiment also includes personnel from the Jet Propulsion Laboratory, the University of Utah, and the University of Michigan.

[Spaceflight Milestone: Mariner 9 was inserted into orbit around Mars on 13 November 1971 and the orbit successfully trimmed on 15 November. Surface obscuration problems produced by the Great Dust Storm necessitated an early change in mapping plans and the development of several planetary reconnaissance plans in an attempt to obtain pictures of those few areas that appeared relatively clear. Pictures of Nix Olympica (Olympus Mons), North and South Spots showed craters unlike any seen on the Moon [that is because they were large volcanic caldera]. USGS participants in Mariner 9 mission operations included Harold Masursky, J.F. McCauley, M.H. Carr, D.J. Milton, Larry Soderblom, D.E. Wilhelms, R.M. Batson, R.L. Tyner, V.S. Reed, R.S. Madden, and J.M. Boyce (starting in December). A preliminary draft of the 30-day Mission Report was completed prior to 1 December and circulated to the other TV Team members and outside reviewers.]

[Author's Note: For additional details on how the Branch got involved in and participated in Mariner 9, see the biographic narrative for John F. "Jack" McCauley in 1963, and Appendix A.]

The following was taken from the Center of Astrogeology Monthly Report for November 1971 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 30 November 1971:
A total of 15 man days at the end of November 1971 were spent by Center of Astrogeology personnel in the initial calibration measurements on the gnomon and photometric chart for the Apollo 16 mission. The work was done at MSC Houston and would continue into early December 1971.

On 17-18 November 1971, the Apollo 16 crews (prime and backup) used a full complement of lunar hand tools, cameras, and geophysical traverse experiments aboard the Grover and Explorer LRV-simulator vehicles in the Coso Hills area (Naval ordnance Test Range) near China Lake, California (see Table I). Two EVA traverses were conducted with the "backroom geologists" of the Apollo Lunar Field Geology Investigation Team participating in the McCloud Flat and Volcanic Peak areas. The variety of volcanic, plutonic, and metamorphic rocks and their erosional products provided a challenging array of problems for the crews to observe, photograph, and sample and for the geologists to interpret from their remote locations inside closed tents. The Apollo 17 crew, Gene Cernan and Jack Schmitt, observed the second day's traverse in preparation for their geologic training (Fig. 92).

Participants at the Coso Hills exercise included:

Astronauts: E.A. Cernan (Apollo 17 CDR); C.M. Duke (Apollo 16 LMP); A.W. England (Apollo 16 mission scientist); F.W. Haise (Apollo 16 backup CDR); E.D. Mitchell (Apollo 14 LMP and Apollo 16 backup LMP); R.A. Parker (Apollo 17 mission scientist); H.H. Schmitt (Apollo 17 LMP); J.W. Young (Apollo 16 CDR)

Science personnel from USGS (Flagstaff): E.L. Boudette, V.L Freeman, M.H. Hait, E.D. Jackson; W.R Muehlberger, R.L. Sutton, and G.E. Ulrich

Support personnel from USGS (Flagstaff): J.R. Lovelace, R.A. Mills, and I.L. Wiser

Science and other personnel from MSC: G.P. Barnes (MSC), J.H. Cooper, F. Horz, R.R. Kain, T.O. Montgomery, A.B. Patneski (NASA Photographer), J.M. Peacock, D.H. Peterson, W.C. Phinney, E. Quin, M.E. Reim, G.B. Scott.

The following was found in the Center of Astrogeology Monthly Report for December 1971 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 31 December 1971:
The December training trip for the Apollo 16 crew was held on the Big Island of Hawai'i (7-13 December 1971) and led by E.D. Jackson (USGS) (see Table I). A mostly walking traverse at Kapoho crossed a recent flow, ash fall deposits, and cones formed from splatter and cinders. The second traverse, a rover exercise at Kilauea, crossed large areas of ejecta that served as an analogue of a regolith surface. On a walking traverse at Hualalai, flow vents, flow structures, and channels were studied. The fourth traverse, at Pohakuloa, was a rover traverse in an area where age relationships between flow fingers and between flows and cones would be examined and described.

A final traverse on Big Island of Hawai'i used rovers at Hale Pohaku, where several cones and several ejecta blankets provide a complex lesson in age relations and regolith distinction. The training trip finale was a "show and tell" at Salt Lake on the island of Oahu, where the crew was shown a dissected tuff ring.

Participating in the exercise were the crews J.W. Young and C.M. Duke, Prime; F.W. Haise and E. Mitchell, backup; Capcom A.W. England; geologists from MSC/Houston, W.C. Phinney and F. Horz; G. Barnes of SA&D, MSC; MSC equipment personnel R. Montgomery, R. Kain, and E. Quinn; Bellcom geologist, J.W. Head; and USGS geologists W.R. Muehlberger, E.D. Jackson, D.L. Peck, E.L. Boudette, V.L. Freeman, J.P. Shafer, G.E. Ulrich, and E.W. Wolfe. Helpful cooperation was received from the Hawaiian Volcano Observatory and the National Park Service.

On 20-21 December 1971 E.W. Wolfe and R.L. Sutton attended an Apollo 17 crew-training trip in the Kilbourne Hole area in west Texas (see Table I). Other attendees included astronauts E. Cernan, H. Schmitt, and R. Parker; G. Lofgren, D. Morrison and D. Bland from MSC/Houston; and J. Hoffer from the University of Texas at El Paso.

6.2-1972

[Author's Note: A total of thirteen geologic field-training exercises were planned and led in 1972 by personnel from the Branch of Surface Planetary Exploration for astronauts assigned by NASA as crew members on the Apollo 16 and 17 missions (see Table I).

David Levy:
"By 1972, Carolyn [Shoemaker] notes, "Gene was not satisfied with the job he did as chairman [of the geology division at Caltech]; administration was not something he enjoyed." Gene decided to resign the chairmanship and looked forward to the free time he would have to continue his teaching, especially his field excursions, and his research. At this time, Gene rejoined the USGS and worked full-time with both Caltech and the Survey, and on alternating leaves from each for half the year. This essentially meant that Gene had two major positions bidding for his time. By 1985, Gene left Caltech entirely, although he returned two years later as a visiting associate" (Levy, 2000, p. 150).

The following was taken from the Branch of Astrogeologic Studies Monthly Report for January 1972 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 31 January 1972:
The 1800 color (35-mm) and 1100 black and white (70-mm) aerial photographs taken of the eolian, erosional, and depositional features in the coastal deserts of Peru by J.F. McCauley, M.J. Grolier, E.C. Morris, and G.E. Ericksen have been processed, catalogues, and screened. Over 100 of these photographs have been selected for an atlas that will be used to aid in interpreting the Mariner 9-Mars images.

R.M. Batson, A.W. Hall, R.S. Madden, V.S. Reed, and R.L. Tyner made mosaics and other cartographic displays in support of Mariner 9 mission operations throughout the month of January at the Jet Propulsion Laboratory, Pasadena, California.

The following was taken from the Branch of Surface Planetary Exploration Monthly Report for January 1972 to Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 31 January 1972:

On 5-6 January, G.E. Ulrich, J.P. Schafer, N.G. Bailey, R.A. Mills, and J.C. Nuttall visited McCullough Mountains near Boulder City, Nevada, to prepare for the upcoming Apollo 16 simulation and Apollo 17 training trip.

On 24-25 January 1972, W.R. Muehlberger, R.L. Sutton, E.W. Wolfe, G.E. Ulrich, and N.G. Bailey provided the "science backroom" for the Apollo 17 crew on a geology traverse in the McCullough Mountains, Nevada. The exercise utilized the [Survey's] Explorer and Grover roving vehicles and lunar hand tools and cameras for the crew's familiarization with present equipment. The exercise stressed procedures for observation, photogeology, and collection of samples from andesite flow breccias, basalts, intrusive rocks, and alluvium. The test was designed originally to simulate traverses 2 and 3 of the Descartes mission for Apollo 16, but the latter exercise was postponed until February due to a slip in the Apollo 16 schedule.

The exercise was evaluated in the field by R.E. Anderson (Special Projects Branch) and E.D. Jackson (Menlo Park). The preceding day was spent with the Apollo 17 prime crew in Cleopatra Wash north of Lake Mead on an informal training trip to study geology.

Other persons attending the training exercises included the following:

E.A. Cernan, A-17 Commander
H.H. Schmitt, A-17 LM Pilot
R.A. Parker, AP-17 Mission Scientist
R. Laidley, NASA, Houston
R. E. Evans, AP-16 Command Module Pilot
E. David, the President's Science Advisor (and his wife)
J.B. Hanley, NASA Headquarters
J.P. Allen, Mission Scientist on Apollo 15
D .Morrison, NASA, Houston
D. Bland, NASA, Houston

Flyovers of both exercise areas were made by R.A. Laidley, R.E. Evans, W.R. Muehlberger, and R.E. Anderson to review the regional geology in association with the surface traverses. This is part of the geologic training for the Command Module Pilot who, during the mission, will remain in orbit while the Commander and LM Pilot explore the lunar surface.

Preparations for the Apollo 16 geology simulation near Boulder City, Nevada (McCullough Mountains) continued. Plans and field tests of the communications links were made by J.C. Nuttall, E. Kelley, and J. Thompson. Arrangements made by N.G. Bailey included NASA Public Affairs Office requirement, room reservations, vehicles and logistics, sheriff's support, and conference rooms. Geologic maps for the data packages were prepared for two EVAs, drafted, and reproduced, along with cuff check-lists.

The following was taken from the Branch of Surface Planetary Exploration Monthly Report for February 1972 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 29 February 1972:
The geologic maps for the Apollo 16 lunar surface data package were completed-except for one more change to accommodate the crew's desires. Geologic maps at three scales for the orbital data package were also completed and transmitted to MSC. The drafting and photographic work on all these maps was under the direction of James W. VanDivier at Flagstaff.

Photogeologic mapping and study of the Apollo 17 site (Taurus-Littrow) was begun by E.W. Wolfe and V. L. Freeman, using stereoscopic pan camera photos taken on the Apollo 15 mission. Preliminary planning of traverses [for Apollo 17] was also begun on the basis of this initial work.

The prime and backup surface crews for Apollo 16 participated in a one-day geologic field exercise in Cleopatra Wash, north of Henderson, Nevada, where a dissected volcano can be readily examined. Most of the same people who participated in the EVA simulations on the following day were also on duty at Cleopatra Wash (see below), with the addition here of Donald P. Elston.

W.R. Muehlberger, Principal Investigator of the Apollo 16 Lunar Geology Experiment, conducted briefings on lunar geologic interpretations with the prime and backup crews of Apollo 16 at the Kennedy Space Center.

The crew of the Apollo 17 mission participated in a geologic field exercise (22-25 February) in the Little Chuckwalla Mountains, California, conducted by Prof. Leon T. Silver of Caltech, and G.A. Swann of the Survey (Flagstaff). This location was substituted for the Baja, California site when the Mexican Government cancelled its permits.

Members of the Lunar Geology Experiment Team supported one "paper" simulation and one "math model" simulation at MSC-Houston, and also planned and executed a simulation of two EVAs in the field near Boulder City, Nevada for the Apollo 16 prime and backup crews (Fig. 93). Arrangements in Nevada were completed by N.G. Bailey and coordinated between the field and Houston by G.E. Ulrich. The geologic data packages for this exercise were prepared by Bailey, Ulrich, and J.P. Schafer. A standby science operations room was staffed by G.G. Schaber, J.P. Schafer, V.L. Freeman, and C.A. Hodges. The Survey's simulated lunar rover vehicles Explorer and Grover were provided by R.A. "Putty" Mills and his assistants, I.L. Wiser and B.C. Tinnin, and the communications were designed and operated by J.C. Nuttall, E. Kelley, and J.G. Thompson. Geologic observers with the crews on the traverse included E.D. Jackson, H. Moore, and Ernest Anderson (local geologic expert).

The following was taken from the Branch of Astrogeologic Studies Monthly Report for February 1972 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 29 February 1972:
Mosaicking in support of the Mariner-9 Mars mission operations is continuing at the Jet Propulsion Laboratory, Pasadena, California. This effort is part of the MM '71 team responsibility, and is being supervised by V.S. Reed and R.L. Tyner under the general direction of R.M. Batson. In addition to variable-scale mosaicking and general data cataloguing, two spherical mosaics are being made, each at a scale of 1:5,570,000. One of the mosaics is being made up of pictures that show enhanced topographic details, and the other contains pictures that emphasize albedo variations [on the lunar surface].

[Space Exploration Milestone: On 18 February 1972, the Soviet spacecraft Luna-20 landed on the flank of the Crisium Basin on the Moon, at 3.5 Degrees N, 56.5 Degrees E., and returned to Earth a core sample from the lunar regolith.

The following was taken from the Branch of Astrogeologic Studies Monthly Report for March 1972 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 31 March 1972:

J.P. Schafer and Raymond Jordan have completed the manuscript version of a contour map of the southern half of Hadley Rille [later the landing site area for Apollo 15]. According to K.A. Howard, these topographic maps and Apollo photography shows that in numerous places the Hadley mare subsided differentially while still partly molten. The differential subsidence can be explained if Hadley Rille is a lava conduit that drained the mare lavas. This conclusion is contained in a manuscript submitted to the *Third Lunar Science Conference Proceedings*, titled "Geology of Hadley Rille" by members of the of the Apollo 16 Lunar Geology Experiment Team.

R.J. Pike has compiled five surface measurements of more than 300 lunar and terrestrial craters fro an experiment in the numerical taxonomy of craters.

The following was taken from the Branch of Surface Planetary Exploration Monthly Report for March 1972 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 31 March 1972:
H.E. Holt and J.J. Rennilson (California Institute of Technology) conducted photometric verification tests on the prime and backup lunar surface 500-mm Hasselblads to be used on the Apollo 16 mission. These tests consisted of spatial distribution of irradiance at the film plane, iris repeatability, and polarization filter transmission axis for each detent position.

On 8 March, the Field Geology Investigation Team for Apollo 16 met in Flagstaff to bring everyone up to date on the mission objectives, procedures, and mission assignments for Apollo 16. Final pre-mission geologic maps of the Descartes region and traverse area were completed for distribution to appropriate offices before the mission. A synopsis, by D.P. Elston, E.L. Boudette, J.P. Schafer, W.R. Muehlberger, and J.R. Sevier, of the regional and local geology and planned traverse appeared in the March issue of *Geotimes*, which was distributed to the scientific public before the mission. A geologic map was printed in the centerfold, and a large-scale map of North Ray crater was used on the cover.

[Author's Comment: It is rather unfortunate that the first Apollo landing site geologic map that was released to the scientific community (through *Geotimes* or any other publication) prior to an Apollo landing was that for Apollo 16, given that the prime scientific objectives of the Apollo 16 mission to observe and sample highland volcanic rocks (that had been proposed to exist –and mapped—at the Descartes site by members of the Apollo 16 Lunar Geology Experiment Team, was not met. Much to the surprise (and with considerable embarrassment) of the Apollo 16 Field Geology Experiment Team in Houston, the proposed highland volcanic rocks turned out to be shocked melted (fluidized) impact breccia, not volcanic rocks—as immediately recognized by the well-trained and astute geologic observers on Apollo 16, Commander John Young and Lunar Module Pilot Charles Duke]

On 14 and 15 March, a field exercise for the Apollo 17 crew was held at Sierra Madeira, Texas, under the direction of E.D. Jackson and H. Wilshire. Prime crew members E.A. Cernan and H.H. Schmitt participated in one rover traverse and one walking [contingency] traverse. The two traverses started on a remnant of the crater rim and proceeded into the central peaks of this eroded impact structure. [Astronaut] R.A. Parker, Manned Spacecraft Center, served as Capcom, and J.B. Irwin [Apollo 15 Lunar Module Pilot] helped in the "backroom." Also attending were

D.A. Morrison and W.C Phinney, geologists from the Manned Spacecraft Center, Houston; E. Quinn and R. Blevin; V.L. Freeman, R.L. Sutton, and G.E. Ulrich, USGS; and R.A. Mills, B.G. Tinnin, and I.L. Wiser, USGS.

W.R. Muehlberger prepared a flyover exercise for the Apollo 17 crew in West Texas, which was conducted on 29 March, 1971. He also reviewed a possible area for Apollo 17 crew training in New Mexico.

On 16-17 March 1972 there was a geologic training exercise for the Apollo 16 crew at the Nevada Test Site using the USGS "Explorer" vehicle (Fig. 94). No other documentation could be found regarding this NTS geologic-training exercise.

On 9-10, 21, and 28 March, many members of the Apollo 17 Lunar Geology Experiment Team attended paper SIMS [simulations], math models SIMS, or EVA Cape SIMS. Preparations for team operations in real time during the mission were undertaken in order to assure efficient data acquisition and real-time interpretation.

The revised report on Apollo 15 samples was completed and issued during April as Interagency Report: *Astrogeology 47,* "Documentation of Apollo 15 Samples."

The following was taken from the Branch of Astrogeologic Studies Monthly Report for April 1972 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeology Studies; dated 30 April 1972:
The U.S. Geological Survey's Center of Astrogeology hosted a quarterly meeting of the full Apollo Lunar Sounder Experiment Investigator Team at Flagstaff, Arizona on 4 and 5 April. Members of the team from the Jet Propulsion Laboratory, University of Utah, University of Michigan, the Center of Astrogeology (R.E. Eggleton and G.G. Schaber), and NASA's Manned Spacecraft Center (Houston, Texas) attended. In addition, Floyd Roberson (Apollo Orbital Science Program), NASA Headquarters; Richard Diller (Apollo Orbital Science Hardware), NASA Headquarters, and Spencer Gardner (Apollo Timeline Planning), NASA Manned Spacecraft Center, were present.

R.E. Eggleton and G.G. Schaber prepared a document entitled "Science Evaluation of Apollo 17 Lunar Sounder Timeline Options. They made a presentation at the Flagstaff Lunar Sounder Team meeting based on the document and on an updated version of their map showing the distribution of selected extensive lunar deposits expected to constitute informative Lunar Sounder targets. Subsequently at the meeting, the Team Leader pointed R.E. Eggleton as chairman of an intra-team Ad Hoc Working Group for the Lunar Sounder Timeline to include Schaber and representatives of the three other team institutions.

While in Flagstaff, the Lunar Sounder Team also met jointly with the Apollo 16 and 17 Lunar Geology Investigation Team for discussions of the Taurus-Littrow Apollo 17 landing site and the Lunar Sounder Experiment. At this second meeting, R.E. Eggleton and G.G. Schaber prepared a document entitled "Figure of Merit Definitions and Values for ALSE [Lunar Sounder] Target Types."

R.E. Eggleton, as chairman, called a meeting of the Apollo Lunar Sounder Team's Ad Hoc Working Group for the Timeline. The meeting, held 18-19 April at NASA Manned Spacecraft Center, Houston, Texas, was also attended by G.G. Schaber, USGS; Walter E. Brown, Jr., JPL; William R. Sill, University of Utah; Phillip L. Jackson, University of Michigan and Vernon M. Dauphin, MSC. Recommendations of specific resolutions for the Lunar Sounder's principal block of observations (FTO's land 2) and two alternate lists of individual special targets (FT0-5) were developed and conveyed to the Team Leader.

The following was taken from the Branch of Surface Planetary Exploration Monthly Report for April 1972 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 30 April 1972:
On 4 April, W.R. Muehlberger met with Survey geologists in Menlo Park to review the traverse plans for the Apollo 16 mission.

D.P. Elston reviewed the geologic objectives of the Apollo 16 mission for engineers of the Mission Planning and Analysis Division, Manned Spacecraft Center, Houston. Three maps by D.P. Elston, E.L. Boudette and J.P. Schafer, were issued in the U. S. Geological Survey Open-File: one is entitled "Engineering geology of the Apollo 16 (Descartes) traverse areas, the second was the large-scale map of the Descartes region. In addition, a "road log" was prepared describing the ground to be crossed by the LRV on the three EVAs.

6.2.1-Apollo 16

(Launched 16 April 1972, Lunar Landing in Descartes Highlands 21 April 1972; crew John W. Young, Commander; Thomas K. Mattingly, Command Module Pilot; Charles M. Duke, Lunar Module Pilot)

The following was taken from the Branch of Surface Planetary Exploration Monthly Report for April 1972 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 30 April 1972:
Members of the Apollo 16 Field Geology Investigation team converged on the Manned Spacecraft Center, Houston, beginning 18 April, to participate in mission operations during the landing in the Descartes region of the Moon. Four operating groups were formed: (1) a science-operations-room group, which helped direct geologic decision-making activities during the three EVAs; (2) a backup group, which summarized the results of the verbal and television data received during each EVA and distributed a brief report and traverse map prior to the next EVA; and (4) the AS-11 plotter team, which followed the traverse on a stereo model and also recorded orbital observations of the Command Module Pilot as he passed over the landing area. Participants in Houston included the following people:

N.G. Bailey, R.B. Batson, F.E. Beeson, E.L. Boudette, D.P. Elston, V.J. Fischer, V.L. Freeman, M.H. Hait, C.A. Hodges, H.E. Holt, E.D. Jackson, R.H. Jahns, D.E. Johnson, K.B. Larson, J.S. Loman, R,S. Madden, T.R. McGetchin, D.A. Milton, W.R. Muehlberger, J.C. Nuttall, D.L. Peck, V.S, Reed, J.J. Rennilson, R.E. Sabala, G.G. Schaber, J.P. Schafer, G.R. Scott, L.T. Silver, R.B. Skinner, L.B. Sowers, D. Stewart-Alexander, R.L. Sutton, G.A. Swann, R.L. Tyner, G.E. Ulrich, J.W. VanDivier, H. Wilshire and E.W. Wolfe

The EVA reports and traverse maps were sent to the crew upon their recovery in the Pacific. A more detailed summary was completed on the morning of the splashdown (27 April) and distributed as Interagency Report: *Astrogeology 48*, "Preliminary report on the geology and field petrology of the Apollo 16 landing site."

The Moon-to-Earth comments of the astronauts were recorded in real time by a team of court reporters [from Flagstaff] during the EVAs. This transcript served as an immediate record. Later, the official NASA transcript was condensed into a geologic transcript which was stored in the N.I.H. computer system using the WYLBUR text-editing program [developed by the Branch of Surface Planetary Geology in Flagstaff]. This condensed transcript totaled 7,737 lines which was far larger than in the case of previous missions. This operation was carried out under the direction of N.G. "Red" Bailey.

The lunar roving vehicle (LRV) permitted the [Apollo 16] crew to travel a total of 24 km. The duration of the three EVAs taken together was slightly over 20 hours. A total weight of 97 kg (213 pounds) of lunar rocks was returned. More than 1,800 exposures of black and white and color film were taken by the astronauts (Fig. 95).

Flagstaff's *Arizona Daily Sun* newspaper dated Saturday April 15, 1972 carried an extensive story and photographs describing how Flagstaff men and women helped ready this latest Apollo mission [Apollo 16].

Gordon Swann:
"The Apollo 16 mission went to the Descartes area of the Moon, and the astronaut's primary function was to sample what we called old lunar highlands called the Descartes Formation, and to sample some of the highland-like plains material called the Cayley Formation. The first interpretation of the geologists who studied that area was that the Cayley Formation there was probably old highland volcanics; their second choice was that it was the result of impact (impact breccia). There was some criticism that perhaps some people oversold the idea of highland volcanics there, but the folks that had really studied it weren't really sure that it was volcanic. That's what they wanted to find out; and it turned out it wasn't volcanics—so the first choice interpretation was wrong. Well, if we hadn't made any mistakes, maybe there'd have been no reason to go the Moon. That would have meant that we had all the answers!

By the time of Apollo 16 and 17 we had worked into three [separate] science support teams. One was the [usual SSR] EVA team that sat and worked during the EVAs. The second was the planning team that worked up some suggestions for the next EVA. The third group was what we called the "Tiger Team," that sat down and wrote a quick and dirty report of what happened on the last EVA that could be circulated around the through the Mission control Center.

I was on the planning team for the last two missions (AP 16 and 17). One of the questions we were asked to consider was since they had such a short time at Shorty crater with the orange soil—and it would have very adversely impacted the third EVA and what we had planned to have them do, and what they wanted to do—would we recommend that they go back. Our decision as a planning team was to recommend that they not go back. The EVA team in the SSR concurred with that decision, and sent it up to the astronauts, who also concurred" (from a filmed interview with Gordon Swann by Kirk Wolfinger from Lonewolf Productions in preparation for the NOVA documentary "*To the Moon*" first aired in 1999).

Tim Hait:
"One of the Apollo 16 crew—maybe both of them—John Young and Charley Duke—told me at one party we were having pre-mission I think—that if I had it to do over again, I'd become a geologist! They really liked geology. I think it was John Young" (from an interview with Tim Hait by Gerald G. Schaber on 16 April 2001).

Gordon and Jody Swann tell the story [to this author] about the time that the two of them, plus George Ulrich, Ed Wolfe, Steve Reed, Jean Fischer, and perhaps one or two others played the ultimate revenge game on jokester Apollo 16 Geology Team Principal Investigator Bill Muehlberger in Houston. The story goes something like the following: went something like the following:

Gordon and Jody Swann:
"The six of them went over to Bill Muehlberger's apartment near MSC. George had a key to his apartment. Bill had gone home to Austin, Texas for the weekend. He was coming back Sunday night. Sunday afternoon, the six of them went over there and spent hours taking that apartment apart. They took every pin out of every door hinge. They disabled his bed and put it back together with butcher's string—and short-sheeted it of course! They stretched Saran Wrap over the toilet and filled his toothpaste tube with shaving cream. They dumped out his gin—they didn't throw it away but replaced it with water! They put coffee grounds in his ice cubes, replaced all the cushions in his couch with Styrofoam, Kryloned his bars of soap, replaced every bulb in the place with 15-watt bulbs, turned all the light switches upside down, and sewed the towels to the towel rack.

Bill's wife Sally said the next day that it was hilarious when they got back to the apartment that [Sunday] night. Bill was fumbling with the key to get into the doorknob—and the door fell down. He said everything was going wrong! She said Bill stepped in the room—flipped on the light switch—and there was this dim glow. Finally Bill said, I'm going to have a Martini—that had been watered of course! He went in and plopped down on the couch, and about broke his back [on the hard Styrofoam]. He was really hacked!

But Jody recalls that Bill did NOT think it was funny! He didn't say one word. Gordon says that Bill's wife Sally just followed him around and laughed at him, and probably had to put the apartment back together that night" (from interviews with Gordon and Jody Swann by Gerald G. Schaber on 1 January 2001 and 2 February 2001, respectively).

Don Beattie:
"A site selected for the simulations conducted towards the end of crew training for the final Apollo 17 mission was again the island of Hawai'i on 22-29 June 1972 (see Table I). Despite the prevailing view that most of the lunar features were the result of impact processes, all the astronauts had visited Hawai'i earlier in their geologic training to study the wealth of lunar-like features created by the many active or semi-active volcanoes. Simulations for specific missions

were a different matter. More like a final exam. We chose several locations on the island to represent geological situations similar to those the crew might encounter on the Moon. Typifying the Hawaiian simulations, the Apollo 17 crew spent the first four days (22-26 June 1972) visiting these sites, then had a day of rest.

Dallas Peck, a noted volcanologist who had spent a number of years on Hawaiʻi studying the island's geology, acted as coordinator and principal lecturer. The final three days (27-29 June 1972) were spent at Kahuhu, Hualalai, and the volcanic ash wastelands at the crest [actually on the slope] of Mauna Kea (elevation 13,796 feet), chosen to represent what astronauts Gene Cernan and Jack Schmitt might find at their designated lunar landing site, the Taurus-Littrow Valley" (Beattie, 2001, 186).

[Author's Note: These simulations on Hawaiʻi (as was the case for all of our geologic field-training sites) were not so much promoted to the crews as actually representing the geologic conditions they would find at their specific lunar landing sites as they were to familiarize the crews with volcanic processes—and more importantly—to finely hone their interpretative and descriptive skills in geologic field work, to accomplish a pre-determined specific schedule of activities at each geologic station, and to use their own discretion with regard to what additional geologic activities they feel should be carried out based on their observations.]

Don Beattie:
"At Mauna Kea the [USGS] staff had prepared a series of traverses around the volcano's summit that would approximate those the crew would follow on the lunar surface. Sampling and description stations had been designated at intervals replicating as closely as possible the Taurus-Littrow timeline that had already been carefully plotted by the Field Geology team for the actual mission. All the surface equipment the crew would deploy or operate, except for the ALSEP, was transported to the Mauna Kea training site, including a simulated LRV. Putty Mills (USGS-Astrogeology-Flagstaff) had modified a local jeep to use as a simulated LRV, a cheaper and less sophisticated version of the Grover and other LRV training vehicles. It also avoided the expense of transporting one of these trainers from the mainland to Hawaii. He had removed most of the jeep's body and engine so that the astronauts were sitting on open seats on the frame and could climb on and off easily. He [Putty Mills] had also added racks for their tools and sample bags and a mount for their communication antenna, similar to the stowage on the real LRV.

During this training exercise most of us lived in motels on the coast, either in Hilo or in Kailua-Kona, commuting the thirty to forty-five miles a day to the training sites. Some of the USGS staffers lived closer in an army base [Pahaloa Army base] and kept most of the equipment we would use each day there.

Cernan and Schmitt wore street clothes for these simulations. It would have been too costly and time consuming to try to conduct them in pressure suits this far from Houston. To add some mission reality they wore backpacks similar to the portable life-support system, but with battery power only for voice communications back to our simulated Science Support Room out of sight of the traverses.

Bill Muehlberger, the Field Geology Team PI appointed for Apollo 16 and Apollo 17, was in charge of this trip. He brought several members of his team including George Ulrich, Gerald "Jerry" Schaber, and Dale Jackson. [Jim Head was also present.] Scientist/Astronaut Robert Parker was also on hand, since he had been designated capsule communicator (Capcom)**.**

During the period of extravehicular activity [for Apollo 17], Muehlberger and his team would man the rudimentary SSR, connected to the astronauts only by radio, plotting their progress as they drove around the summit and communicating through Parker as they would during the actual mission. The Field Geology Team, through trial and error on earlier missions, had devised procedures to assist the astronauts if something unexpected happened or to respond to any questions they might have, and these procedures were also practiced.

Those of us not directly involved in the backroom simulation would follow Cernan and Schmitt from a distance as they drove from station to station, making note of how everything fit together—or didn't, as the case may be. At the end of the exercise, Muehlberger and his team retraced the traverse with Cernan and Schmitt, reviewing how they interpreted their voice reports, correcting their map, and then suggesting ways to improve the crew's descriptions to produce a better interpretation of what they actually saw.

With the first scientist-astronaut geologist in the crew [Apollo 17] and a highly-motivated and well-trained Commander [Gene Cernan], we didn't expect there would be much need for this type of support, but with all things NASA, we were going to be prepared. All in all, this Hawai'i simulation was about as good as we could get in obtaining a high-fidelity rehearsal before the real mission was under way.

We conducted one week of intensive, almost uninterrupted training for both the crew and the Field Geology team. Apollo 17 would be the last mission, and Muehlberger was determined that it would be the best if he had anything to do with the training and simulations. In just five months it would be the real thing.

A final reward for our efforts had become a tradition. On the last night of these trips [to the Big Island], a dinner was held at Teshima's, a lovely Japanese restaurant high on a hill overlooking the Ocean [in Kona], with Mrs. Teshima providing a royal welcome and a special menus. It was a night of storytelling, practical jokes, and reminiscing; a dinner that all who attended will long remember" (Beattie, 2001, pp. 186-188).

This author recalls the practical jokes that Jim Head [Bellcom, Inc.] and I played on the lovely, young, and painfully shy Japanese waitresses wearing Kimonos at Madame Teshima's that night:

As is typical of any authentic Japanese restaurant, there was a sort of bottom platter with many different-shaped small bowls for each of the food items that fit into similar-shaped holes in the platter. Jim or I had noticed that when someone at our table moved one of these particular small bowls out of its proper place on the platter, one of the shy Japanese girls would scurry up to the table and rearrange the bowls back into their proper slot.

So we both purposely moved every one of the little bowls on our plates into an improper hole. Immediately, two of the girls came up and, in a flash, set things right again. I believe that Madame Teshima told them in Japanese (as they could not speak English) what we had done was a joke on them. All of the girls giggled with their hands over their mouths, and scurried out of the room—visibly embarrassed.

I also recall the many pitchers of warm sake that Madame Teshima keeps refilling for us during the meal as her "thank you" gift to us. It is a wonder that any of us could find our way back to the motel that night!]

At the end of the meal, I remember that Madame Teshima's staff, including the cooks and the girls who served us so magnificently, wanted to get the astronaut's autographs. Given that they didn't know who was who, they asked us all for an autograph—including Jim Head and me. I believe that Jim Head signed as [astronaut] Jim Lovell. I can't recall whom I signed as.

[Author's Note: In Red Bailey's daily log of activities during the Apollo Era, he says that on 2 August 1972, he talked to Russ Wahmann and George Ulrich about a proposal to preserve the Branch of Surface Planetary Exploration's Cinder lake Crater Fields in Flagstaff for posterity. Cinder Lake #2 had already been fenced off back on 19-20 June 1968. The fencing was later broken through by dune buggies and reported (July 1) to the Branch. Unfortunately, the proposed preservation of historic Cinder Lake Crater Field, where the Apollo 15, 16 and 17 prime and backup astronaut crews trained has now been all but eliminated by the persistent dune buggy enthusiasts, and erosion since it was built in the late 1960s.]

Astrogeology Milestone: On 5 September 5 1972, Flagstaff Astrogeologist Harold Masursky received the national Aeronautics and Space Administrations Medal for outstanding scientific achievement for his work in the Mariner 9 project.

On 6-7 September 1972 was the second to last geologic training trip for the Apollo 17 prime crew at Lunar Crater near Tonopah, Nevada (see Table I). John Young and Charles Duke from Apollo 16 were also in attendance. Both the Explorer and Grover vehicles were used for the exercise (Fig. 96).

The following was taken from the Branch of Surface Planetary Exploration Monthly Report for September 1972 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 30 September 1972:
The first quarterly meeting of NASA's Mars Geologic Mapping Program was held in Menlo Park, California 20-21 September. The meeting was attended by 18 USGS geologists and 16 geologists from other institutions. In attendance were H.J. Moore, M.H. Carr, C.A. Hodges, K.A. Howard, D.J. Milton, D.E. Stewart-Alexander, D.E. Wilhelms, Fred Wahl, J.W. Allingham, G.W. Colton, Rene Dehon, S.E. Dwornik, D.E. Elston, Henry Faul, Mack Gibson, Ronald Greeley, M.J. Grolier, Hatten Howard III, E.A. King, J.S. King, B.K. Lucchitta, Harold Masursky, J.F. McCauley, G.E. McGill, J.D. Meyer, E.C. Morris, T.A. Mutch, J.F. Peterson, S.E. Saunders, G.G. Schaber, D.H. Scott, L.A. Soderblom, H.G. Stephens, N.J. Trask, M.N. West, and Don Wise. Quadrangle assignments were made and photographs and base map materials were distributed to all mappers. Over half of the 30 Mars quadrangles were assigned to USGS

geologists and the remainder to geologists from 13 other institutions, mostly universities located in the east, south, and southwestern part of the United States.

P.M. Bridges and J.L. Inge have completed a shaded-relief map of Mars. This map covers 100% of the planet, and was drawn on a Mercator projection in the region between 65 degrees N. and 65 degrees S., and polar stereographic projections in the regions from the north and south poles to 65 degrees N. and S., respectively

D. H. Scott [Branch of Astrogeology-Flagstaff] discussed the geology of the Lunar Crater Volcanic Field, Nye County, Nevada with the Apollo 17 prime and backup landing crews, and participated in the two-day exercise there [see SPE Monthly Report for September 1972 below].

D.H. Scott conducted briefings of the regional geology of the Taurus-Littrow area with the Apollo 17 orbital prime and backup crews at the Manned Spacecraft Center, Houston, Texas.

On 13 September, at Cape Kennedy, Florida, B.K. Lucchitta [Branch of Astrogeology-Flagstaff] briefed the Apollo 17 Command Module crew and the surface backup crew on the geology of the Taurus-Littrow area of the Moon.

The following was taken from the Branch of Surface Planetary Exploration Monthly Report for September 1972 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 30 September 1972:
On 1 September, details of special sampling plans were discussed at the Manned Spacecraft Center by W.R. Muehlberger, L.T. Silver, and E.W. Wolfe with the Apollo 17 crews and MSC personnel.

On 6-7 September, a geologic field exercise for the Apollo 17 crews [prime and backup] was held at Lunar Crater near Tonopah, Nevada. Two simulated EVAs were run with the Survey's training vehicles "Grover" and "Explorer," complete with data-package maps and cuff checklists to give the astronauts an understanding of relatively young, little-eroded volcanic features analogous to some of the features [expected] in the Taurus-Littrow area of the Moon.

On 18-19 September, members of the Apollo 17 Field Geology Investigations Team participated in a "paper" SIM on 18 September, and a "math model" SIM in the Mission Control Center at the Manned Spacecraft Center, Houston.

The following was taken from the Branch of Astrogeologic Studies Monthly Report for October 1972 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 31 October 1972:
B.K. Lucchitta briefed the Apollo 17 Commander, Gene Cernan, and the Lunar Module Pilot, H.H. Schmitt, on the dark mantling deposits in the Littrow area on October 11 at Cape Kennedy, Florida.

R.E. Eggleton and G.G. Schaber attended an Apollo Lunar Sounder Experiment (ALSE) team meeting at the University of Utah. Prototype test data were studied, and Apollo 17 ALSE data processing and a catalogue of predicted characteristics of the Apollo 17 ALSE targets were discussed. The team perused fully-focused, 2-meter wavelength radar imagery from a test flight of the ALSE prototype hardware. The test was flown over the margins and interior of the Greenland continental glacier and southeastern Canada. Then samples, constituting a few percent of the data, were selected for continued intensive study. Finally, these samples were prioritized by R.E., Eggleton, P.L, Jackson (University of Michigan, Ann Arbor) G.G. Schaber, and S.H. Ward (University of Utah-ALSE-PI). Near-real-time data processing of the Apollo 17 telemetry from the ALSE specular power monitor to an apparent specular reflectivity was discussed. Format for a catalogue of predicted characteristics of Apollo 17 ALSE targets, and some details of the characteristics, were discussed.

R.E. Eggleton and G.G, Schaber participated in the first Apollo 17 orbital science mission simulation. In preparation for the simulation, U. S. Geological Survey personnel brought to 50% completion the final drafting of the lunar equatorial photogeologic map for ALSE planning and targeting. Copies obtained from these reproducibles will be used during the Apollo 17 mission in making decisions about any necessary real-time changes in the ALSE observations included in the Flight Plan. Preliminary versions were used during the simulation. During data reduction and analysis, the map will aid in locating and interpreting the lunar features observed by ALSE.

R.E. Eggleton began geologic analysis of samples of the ALSE prototype test images from Greenland. The samples consist of a surface profile and in the order of 100 meters of subsurface profiling showing several reflecting material interfaces in the stratigraphic sequence of snow and ice. The analysis involved visual study and preparation of overlay diagrams for the purpose of seeking identification of reflections, correlations of discontinuous reflections or reflectors, and documentation of, and distinction between, real and noise contributions to vertical relief structure of the reflector images.

G.G. Schaber prepared a draft of a geologic map and a brief description of the lunar Euler Hills area I southeastern Mare Imbrium and a statement of the objectives of the ALSE sounding target in that area.

Harold Masursky gave a presentation on planetological reasons for the exploration of Venus at a briefing for Dr. James Fletcher at NASA Headquarters by the Venus-Pioneer Science Steering Group.

E.C. Morris [Branch of Astrogeologic Studies—Flagstaff] conferred with S.E. Dwornik and John Allingham, Planetary Programs Office, NASA Headquarters, Washington D.C., to coordinate geologic mapping of Mars. Most Mars quadrangles (scale 1:5,000,000) will be compiled under the sponsorship of the above office by a group of University and Survey geologists. Some quadrangles, however, will be compiled in preliminary form solely by Branch members under the sponsorship of the Viking Project Office, Langley, Virginia.

The following was taken from the Branch of Surface Planetary Exploration Monthly Report for October 1972 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 31 October 1972:

H.E. Holt and assistants spent 18 days at Kennedy Space Center during October to calibrate the Apollo 17 gnomon and photometric chart, and also mission Hasselblad cameras and their polarization filters.

On 10 October, W.R. Muehlberger, E.W. Wolfe, and V.L. Freeman participated in a briefing on the Apollo 17 EVA-2 traverse for the crews at the Kennedy Space Center. On the 11th, they attended a crew briefing on the geology of the dark mantling material held at the Cape by B. Lucchitta

On 17 October, E.W. Wolfe discussed Apollo 17 data-package requirements at the Kennedy Space Center, Florida with Apollo 17 astronauts Eugene Cernan, Harrison Schmitt, and Dave Parker (CapCom). On 23 October, E.W. Wolfe and V.L. Freeman reviewed EVA-3 traverse activities with the Apollo 17 crew at the Manned Spacecraft Center, Houston.

On 30 October, W.R. Muehlberger, E.W. Wolfe and V.L. Freeman held a briefing with the Apollo 17 crew concerning EVA-1 and EVA-2 traverse plans at Ellington AFB, Houston.

The Apollo 17 surface geologic maps and data package maps were competed, and master negatives were delivered to the Manned Spacecraft Center for printing.

A field geology exercise was held at the Blackhawk slide near Victorville, California on 6 October to give the Apollo 17 astronauts experience in interpreting landslide features in preparation for the Taurus-Littrow landing, where one of the prominent features is interpreted as a possible landslide from the South Massif. Many USGS people participated in the EVA exercise, which was run in a realistic way with vehicles and traverse-science experiments in addition to geology (see Table I).

On 26 October, the Principal Investigator, W.R. Muehlberger, and scientists of his geology Experiment Team for Apollo 17 attended a paper SIM in the Mission Control Center, Manned Spacecraft Center, Houston, Texas. The same group participated in a math-model SIM the next day.

The following was taken from the Branch of Surface Astrogeologic Studies Monthly Report for November 1972 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 30 November 1972:
During November, two-pre-mission geologic maps of the Apollo 17 landing site were published and released by the U.S. Geological Survey. They appeared as Miscellaneous Geologic Investigations Map I-800. Map scales are 1: 250,000 and 1:50,000. The smaller scale map was compiled by D.H. Scott and M.H. Carr; the larger-scale map by B.K. Lucchitta. Taking full advantage of the excellent panoramic camera and metric camera photographs available as a result of the Apollo 16 mission, an unusually large amount of well-substantiated detail is shown. Deserving credit are R.D. Carroll and others in the Cartographic and Illustrations Unit, Center of Astrogeology, Flagstaff, who, in order that the maps would be published and ready for distribution prior to the Apollo 17 mission, spent many hours, day and night, to prepare the maps for the press run.

Mappers involved with preparing geologic maps of the candidate Viking "75 Mars landing sites met in Flagstaff, 28-29 November. The geologic merits of each site were presented by the individual mappers. Safety, engineering, and orbital constraints were discussed and remote sensing data (radar, UVS, IRIS, CO_2) available for each area, which had been previously evaluated by H.J. Moore, J.T. O'Connor, and R.J. Pike, were considered. Consideration of the above and of maximum geologic return (both orbital and surface) resulted in the following consensus:

First Choice
Prime A-mission site: Chryse, 19.5 Degrees N., 34 Degrees W.
Back-up A-mission site: Eumenides, 21 Degrees N., 157 Degrees W.
Prime B-mission site: Memnonia, 9 Degrees S., 141 Degrees W.
Backup B- mission site: Aquae Apollinares, 9 Degrees S., 181 Degrees W.

Second Choice
Prime A-mission site: Candor, 10 Degrees N., 80 Degrees W.
Backup A-mission site: Uraniae, 8 Degrees N., 163 Degrees W. (If this site is landed upon, Memnonia becomes prime B-mission site).
Prime B-mission site: Amazonis, 2 Degrees S., 142 Degrees W.
Backup B-mission site: Zephyria, 2 Degrees S., 144 Degrees W.

The following was taken from the Branch of Surface Planetary Exploration Monthly Report for November 1972 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 31 November 1972:
Owing to difficulties encountered with a polarizing filter for one Apollo 17 Flight Hasselblad camera, H.E. Holt retuned to Kennedy Space Center to recheck the orientation of this filter.

Drafting and reproduction of three Apollo 17 mission maps (detailed geologic, topographic, and traverse) were completed. The detailed geologic map was submitted for Open-Filing by the USGS. These maps will be used by many investigators and the Manned Spacecraft Center's mission operations staff during the mission, and by the Geology Experiment Team for recording and analyzing the data returned by the astronauts.

[Astrogeology and Project Apollo Milestone: The final geologic training exercise for the prime and backup crews of Apollo 17 (and for the entire Apollo Project) was carried out 2-3 November 1972 at Sunset Crater and the Cinder Lake Crater Field just northeast of Flagstaff, Arizona. This was the most comprehensive geologic field exercise that the crew had participated in prior to their launch toward the Moon the next month (7 December 1972) (see Table I). About twenty USGS participants in the Apollo 17 Lunar Geology Experiment Team were on hand at Houston Mission Control while the astronauts ran through two simulated EVAs at Sunset Crater and Cinder Lake Crater Field in the San Francisco Volcanic Field (Fig. 97).]

[Author's Note: Red Bailey reminded this author that the final pre-exercise astronaut briefing (1 November 1972) for the final Apollo 17 geologic training exercise (full up SIM)—described just above—was led by "he, and this author "over drinks" (as he recalls it), while lying on the living room rug at his home in East Flagstaff, Arizona (personal communication; 24 May 2004).]

[See Flagstaff's *Arizona Daily Sun* of 2 November 1972 for brief article on page: "Astronauts Use Cinder Fields for Trail Run."]

The following was taken from the Branch of Surface Planetary Exploration Monthly Report for November 1972 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 31 November 1972:
A briefing with the Apollo 17 crew focusing on EVA-3 was held by W.R. Muehlberger and V.L. Freeman on 13 November at the Kennedy Space Center. On 22 November, a crew-briefing session was held by W.R. Muehlberger.

On 28 November, a final geological briefing of the prime and backup Apollo 17 crew members at Kennedy Space Center was attended by W.R. Muehlberger, G.A. Swann, E.W. Wolfe, and V.L. Freeman of the USGS-Flagstaff.

Additional paper and math-model SIMS attended by members of the Apollo 17 Geology Experiment Team were held at the Manned Spacecraft Center, Houston, on 8-9, 16-17, and 27-29 November.

6.2.2-Apollo 17—The End of an Amazing Era

6.2.2.1-One of the Branch of Astrogeology's Own, Harrison H. "Jack" Schmitt Walks on the Moon

(Launched 7 December 1972; the crew aboard Apollo 17 included Eugene A. Cernan, Commander; Ronald E. Evans, Command Module Pilot; Harrison H. Schmitt, Lunar Module Pilot)

[Author's Note: My colleague Red Bailey (personal communication-29 May 2004) reminded this author that about 20 or 25 of us from Flagstaff were at Cape Canaveral on the night of 6 December 1972 waiting for the launch the next night to the Moon of our friend and former USGS colleague Jack Schmitt aboard Apollo 17. Of course, we were all celebrating (perhaps a little too much in those heady days) at the local hangout along the strip at the Cape at that time, the bar at the Holiday Inn. As it got later, I (Red reminded me) got the bright idea to call up Jack on a special unlisted phone at the astronaut crew quarters down the road at the Kennedy Space Center. It seems I was the only one at the bar who actually had the phone number (from previous trips to the crew quarters to brief the Apollo 15 crew during 1971). I recall thinking that it was only right that I call Jack because (1) he followed Jack McCauley in interviewing me for my job with the Branch of Astrogeology in Flagstaff in April 1965, and (2) I was with Jack (along with Jim Head, then of Bellcom, Inc) at his apartment at Nassau Bay (near the Manned Spacecraft Center in Texas) on 12 August 1971, the evening that Jack received the formal phone call from the NASA Administrator that he would be replacing astronaut Joe Engle and going to the Moon on Apollo 17 as the first (and only to date) geologist-astronaut. The call, as I recall, was loud (because of my many "very happy" friends standing beside me at the bar) but cordial—and greatly appreciated by Jack. He truly had a great adventure ahead of him the next day.]

The following was taken from the Branch of Surface Planetary Exploration Monthly Report for December 1972 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 31 December 1972:
During the Apollo 17 mission, the Field Geology Investigations Team under [PI] W.R. Muehlberger participated at the Mission Control Center (Science Support Rooms, and elsewhere) at the Manned Spacecraft Center, Houston, observing the TV photos transmitted to Earth and recording and analyzing the information relayed by Astronauts Cernan and Schmitt as they explored the Taurus-Littrow landing area. The Experiment Team issued a preliminary summary of the geologic observations in Interagency Report: *Astrogeology 69* on 17 December "prior" to the return of the astronauts to Earth.

The Apollo 17 crew visited, observed, photographed, and sampled each of the diverse, major geologic features of the Taurus-Littrow Valley (Fig. 98). The remarkable performance of the crew thoroughly exploited the potential at the landing site and met the highest standards for scientific exploration. The two massifs were sampled at different levels ranging from the upper 15 to 20 percent (blue-gray layer) on the South Massif to near-horizontal boulder lines about one-third of the way up the North Massif. The samples could conceivably include the oldest materials returned from the moon. These samples may include ejecta not only from Serenitatis, but also from Tranquillitatis, Crisium, Fecunditatis and Imbrium Basins. Profoundly shocked and recrystallized materials suitable for determining the ages of these great impact events appear to have been collected.

The floor unit is composed of mare-type basalts, possibly an extension of the mare flooding of the Serenitatis region. If so, another major mare has been sampled. The discovery of bright reddish and orange materials at the crater Shorty lends credence to previous suggestions that Shorty and some nearby dark, sharp-rimmed craters, may be "relatively young" volcanic features [Author's Note- Not found to be the case, after subsequent dating of these materials).

Panoramas were prepared from the TV pictures during the mission; maps showing the EVA traverses as actually accomplished and preliminary geologic interpretations; and initial inventories, locations, and descriptions of samples were included in Interagency Report: *Astrogeology 69*.

Gordon Swann:
"Apollo 17 went to the Valley of Taurus-Littrow, which was interpreted as possibly being very young volcanics—or at least relatively young. Well, there were volcanics there a little younger than other volcanics on the Moon—but it was still pretty old. Everybody got very excited about the orange soil, of course. Jack [Schmitt] found it-and it was some interesting stuff, and was expertly sampled by Jack.

The orange soil was important because it's about the first color anyone saw on the Moon. Everything on the Moon is gray except for an occasional individual mineral here and there. But now, all at once, here's something that's got some color on the Moon.

Jack's [geologic] descriptions were a bit better than anyone else's, but then they should have been, he had a PhD in geology. He was a very enthusiastic guy when he got up there; in fact, medics started to worry that his heart rate was getting too high.

Everyone in the Science Support Room in Houston was tickled to death. We laughed at Jack quite a bit. There was this little crater that's become known as the Ballet crater on the Moon. It's a little crater, oh, a couple of meters in diameter, and kind of shallow. Jack went to take a sample near it and he took a couple of pictures of a rock with the crater in it [the background], and when he went for the rock [to sample it], he lost his balance and he started spinning around and fell on his back. He bounced up and went round and round—and back and forth——and we were all laughing as it was on television. It was wonderful! When he finally regained his balance, and got stopped, there wasn't any sign of that crater—he had completely demolished it, so it is known as Ballet crater" (from a 1996 interview with Gordon Swann by Kirk Wolfinger from Lone Wolf Productions in preparation for the NOVA documentary "*To the Moon*", first aired in 1999.)

Jack Schmitt:
"Gene [Cernan] and I through the training cycle had worked out a very good arrangement for how we could conduct the exploration of Taurus-Littrow. And it was not really one of leadership, and a subordinate; it was more one of the allocation of responsibilities. Gene took care of a great deal of the more mechanical aspects that were required at each station; cleaning surfaces on the Rover, deploying experiments at various times off the Rover—things like that—as well as being another set of eyes. One pair of eyes is never going to be enough in a challenging and diverse environment like that. And even though I had the [geologic] experience on Gene and was able to look around and plan our set of activities—where was this sample going to be taken? Where was this core tube going to be driven? That was my job. Still, another pair of eyes often picked out something that I might have scanned over and missed—and would force me to explain very quickly why we didn't go there and why we went here instead. Thus, sometimes, then, we would change the plan. So it was a very important relationship between the two of us. Outside the spacecraft we worked together as a team; one in which the allocation of responsibilities, as well as the allocation of observations, was very important and very well done" (from an interview of Jack Schmitt by Kirk Wolfinger of Lone Wolf Productions in preparation for the NOVA documentary "*To the Moon*").

When Kirk Wolfinger (Director of the NOVA Documentary "To the Moon") NOVA asked Jack Schmitt to describe what it was like when he first landed in the Valley of Taurus Littrow on the Moon? Jack responded as follows:
"We knew a great deal about Taurus-Littrow. We had pre-mission photographs; we had 3-dimensional models, and we had the information that came from the other missions about other parts of the Moon. So, one would have thought that once you landed, you would know pretty much what you were going to see. Well, like any meaningful event in anyone's life, it always turns out to be far more than you ever expected. And to actually be sitting on the Moon and looking out the window at these immense mountains that are surrounding us—mountains 6,000 to 7,000 feet high. We were in a valley deeper than the Grand Canyon; one of extraordinary geological variability. One that we know we're finally going to have a chance to explore! The whole thing caused me to say almost immediately; well this is a geologist's paradise if I ever saw

one." And that indeed is what it looked like to me. It was brand new country, no geologists; nobody had ever been there before. It was far more than I ever expected to see once we got down inside of it; even though I had studied and planned along with Gene and others what we were going to do. The whole thing became an extraordinary experience. And now, when we got out of the spacecraft, then you could put this into an even broader context. You could see this brilliant blue Earth of ours up over the southwestern mountains. It just gives you a setting that will be imprinted on my mind, and I think on the minds of many others for the rest of their lives'" (from a 1999 interview with Jack Schmitt by Kirk Wolfinger. Director of the NOVA Documentary "*To the Moon").*

When Kirk Wolfinger also asked Jack Schmitt, what Apollo meant to Harrison Schmitt, Jack responded as follows:
"Apollo for me was an accident. I happened to be at the right place [Shoemaker's Branch of Astrogeology in Flagstaff] at the right time [1964] with the right attitude to volunteer to enter the program. After the fact, it has been very important to my future life. It gave me an opportunity, as it did many of the other astronauts, to expand their horizons in terms of careers. I had always thought about going into politics. After I was out of Apollo, I began to look at that as a possibility again. And indeed, the fact that I could go into communities in New Mexico and talk about Apollo and space gave me an opportunity to compete with a very strong incumbent—and ultimately to win a seat in the United States Senate. Since the end of my Senate career, I've been able to continue to work in large part in areas related to space—but not entirely. It was a very important opening for me to continue to do things that I think are important to the future of Mankind on this planet, as well as in space" (from an interview of Jack Schmitt by Kirk Wolfinger of Lone Wolf Productions in preparation for a NOVA documentary "*To the Moon*").

Tim Hait recollects:
"By the time of Apollo 17 the Apollo Lunar Geology Team had figured out how to make our television panoramas. The guy at Mission Control who controlled the television cameras on the Lunar Rovers for missions 15-17 [E.I. Fendell] called and gave me the acronym of TIM—Television Instructions Monitor. We were out in our own little backroom. Let's see, Kay Edwards was there, and I would imagine that Ray Batson was there.

The television would stop at a particular place, and we would have our Polaroid camera there and take a picture. Then, it [the Rover camera] would move on and take another picture. We had people taking pictures and gluing the pictures down so that after a panorama, we would have our own Polaroid panorama. We would rush that up to the Science backroom where Gordon [Swann], [Bill] Muehlberger, and the others were. That was really neat!

The way we designed that particular panorama system was when we were over in our trailers [in back of MSC]. All we had was a Polaroid camera, and we pretended that this was the camera on the lunar surface. We'd take a picture—rotate it a little bit—take another picture. In the meantime, Kay and whomever else she was working with pasted them together. And we timed it. I think you were there Jerry doing the timing. [Yes, I recall that I was]. We found that it took X minutes to make a complete panorama, and have it pasted or taped all together. So we could then tell NASA that heck—we'll get you a lunar-surface panorama in one and a half minutes—or whatever the time was" (from an interview with Tim Hait by Gerald G. Schaber on 16 April 2001).

Flagstaff's *Arizona Daily Sun newspaper* of Thursday December 14, 1972 carried a photograph of the USGS Branch of Astrogeology's Grover Lunar Rover training vehicle of the front page in addition to a front page byline entitled "Footprints on the Moon Tell of Peace, Hope." The article (Byline Space Center, Houston, Texas) begins as follows:

Eugene A. Cernan stepped off of the Moon today, leaving in lunar sand perhaps the last footprints of the generation which first challenged space. Exploration by the Apollo's ended as it began, "with peace and hope for all mankind."

"As I take these last steps from the surface for some time into the future to come, I'd just like to record that America's challenge of today has forged man's destiny of tomorrow," Cernan said moments before entering the Apollo 17 landing ship.

Then he added, "And as we leave the Moon and Taurus-Littrow, we leave as we came, and, God willing, we shall return, with peace and hope for all mankind."

Turning, Cernan then followed his crewmate, Harrison H. Schmitt up the ladder into the cabin of their craft Challenger.

The following was taken from the Branch of Astrogeologic Studies Monthly Report for December 1972 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 31 December 1972:
[Author's Note—The following was truly a space exploration Milestone; the MSJ mission would eventually become the remarkable Voyager I and 2 missions, launched on 5 September 1977 and 20 August 1977, respectively]

The NASA selection on investigators for the Mariner-Jupiter-Saturn (MJS) Imaging Science Team was completed during the first week of December. The Imaging Team members include: B.A. Smith (Team Leader), New Mexico State University; A.F. Cook, Smithsonian Astrophysical Observatory; G.E. Hunt, Meteorological Office, Bracknell, Berkshire, England; Tobias Owen, State University of New York, Stony Brook; Carl Sagan, Cornell University; L.A. Soderblom, USGS (Flagstaff); and V.E. Some, University of Wisconsin. Soderblom's involvement was the result of his proposal to study the geology of the satellites, particularly polar geology; his mission is to optimize an imaging experiment to best photograph the satellites, to maximum resolution and surface coverage and to define an image processing scheme for use with such a mission with so many targets.

The first team meeting for the MSJ Imaging Science Team was held 19-20 December 1972 at the Jet Propulsion Laboratory in Pasadena, California. Two task groups were set up—one to study imaging hardware, and a second for mission analysis of sequences and trajectories. Larry Soderblom (Branch of Astrogeologic Studies- Flagstaff) is a member of both.

Personnel arriving at the Branch of Astrogeology in 1972 included among others:

Ginny Hall (Clerk-Typist)
Mary Ann Bauer

Pauline Spady
Anna Diaz
Jimmy Diaz
Abra Watkins
Angel Marcias
Ron Carlson
John Hallinan (pilot) (see Appendices A and B)

6.3-1973

The following was taken from the Branch of Astrogeologic Studies Monthly Report for January 1973 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 31 January 1973:
Harold Masursky (Masursky met with K.P. Florensky and his associates at the Moscow Space Science Institute and discussed the panoramic photographs just received from Lunokhod 2, the unmanned Soviet lunar rover that landed in the crater Le Monnier on the east side of Mare Serenitatis. A quick study of the Soviet landing area will be made from the photographs acquired by Apollo 15 and 17, and will be published in the Apollo 17 Preliminary Science Report.

[Author's Note: This would be the start of a long and scientifically productive scientific collaboration between scientists with the Soviet Space agency (most notably, the Vernadsky Institute in Moscow) and the USGS in Flagstaff—thanks to the foresight of the Branch of Astrogeology's greatest Ambassador in those early years—Harold Masursky)

The following was taken from the Branch of Surface Planetary Exploration Monthly Report for January 1973 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 31 January 1973:
The Apollo 17 Lunar Geology Experiment Team under W.R. Muehlberger, Principal Investigator, participated in science de-briefing with the Apollo 17 astronauts, and proceeded with analysis of the voice transcript, lunar surface photos, available sample data, and albedo maps of the site. This analysis led to completion of a preliminary catalogue of Apollo 17 surface pictures and a preliminary sample-documentation report.

[Limited-distribution] Apollo 17 reports prepared by the USGS for NASA during January 1973:

Apollo Lunar Geology Investigation Team, Preliminary Report on the Geology and Field Petrology at the Apollo 17 Landing Site: U.S. Geological Survey Interagency Report: Astrogeology 69, December 17, 1973.
Kay Larson, Ray Batson, Steve Reed and Ed Wolfe, Preliminary Catalog of Pictures Taken on the Lunar Surface during the Apollo 17 Mission: U.S. Geological Survey Interagency Report: *Astrogeology 70*, January 19, 1973.
Apollo Lunar Geology Investigation Team, Documentation and Environment of the Apollo 17 Samples: A preliminary Report: U.S. Geological Survey Interagency Report: *Astrogeology 71*, January 21, 1973)

[Astrogeology Milestone: In April 1973, Flagstaff's Surface Planetary Exploration (SPE) Branch Chief, John D. Strobell, accepted the NASA Group Achievement Award on behalf of the Branch of Surface Planetary Exploration, and Harold "Hal" Masursky received his second NASA medal for Exceptional Scientific Achievement. This time Hal's award was based on his contributions to the successful conduct of the Orbital Science Program on Apollo missions 15-17.]

[Space Exploration Milestone: In January 1973 the Soviet spacecraft Luna 21 landed Lunokhod-2 in the crater Le Monnier, north of the Apollo 17 landing site. "This Lunokhod was equipped with the same instruments as Lunokhod-1, plus another camera, a magnetometer, an ultraviolet sensor, and an astrophotometer" (Wilhelms, 1993, p. 244).]

The following was taken from the Branch of Surface Planetary Exploration Monthly Report for February 1973 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Surface Planetary Exploration; dated 28 February 1973:
Apollo 17 astronaut Jack Schmitt's first return to the Center of Astrogeology in Flagstaff following his return from the Moon [in December 1972] was in February 1973 (see 1973). The City of Flagstaff threw a big party that evening for Jack, and mayor Sylvan Harenberg proclaimed 6 February 1973 as Apollo 17 day in Flagstaff. Jack Strobell (Branch Chief of the Branch Surface Planetary Exploration) presented Jack with a silver bolo tie. On 6 February 1973, Flagstaff Mayor Sylvan Harenberg proclaimed that day as Apollo 17-USGS Day**)**.

6.3.1-The End of a Remarkable First Decade for the Branch of Astrogeology

[Astrogeology and Flagstaff Milestone: During March 1973 Apollo astronaut Harrison H. "Jack" Schmitt made a triumphant return to Flagstaff and the Center of Astrogeology three months after being the first "geologist" to explore the surface of the Moon during the final Apollo 17 lunar mission to the Taurus-Littrow Valley (December 1972). Jack was of course an active member of the Branch of Astrogeologic Studies between July 1964 and June 1965. Jack was anxious to find out what geologic insights his colleagues at the USGS had learned thus far from his and Gene Cernan's exploration and sampling in the Taurus-Littrow Valley (Fig. 99).

This final Apollo mission debriefing in Flagstaff with one of Astrogeology's "own geologists," who had just returned from a very successful final exploration of an important lunar science site, could now be conceived perhaps as a kind of finale for the Branch of Astrogeology with regard to its formal participation in Project Apollo. It had been about 25 years earlier when Gene Shoemaker, as a teenager with the USGS on the Colorado Plateau, began to envision the unthinkable—geologically mapping the lunar surface and eventually sending a geologist there to do geologic science in situ—preferably Gene Shoemaker of course.

Jack Schmitt's visit to the Flagstaff Center of Astrogeology in March 1973 came 13 years after Shoemaker first set his lunar dream into motion by starting up a small Astrogeologic Studies Unit within the Geological Survey at Menlo Park, California (which, as a formal Branch, would move its Headquarters to Flagstaff, Arizona in 1963).

[Astrogeology and Apollo Milestone-With Jack Schmitt's post-Apollo 17 mission debriefing in Flagstaff during March 1973, the Branch of Surface Planetary Exploration's formal role in astronaut training, mission planning, and mission operations, and mission debriefing of the Apollo crews would essentially come to and end, and the Branch was formally terminated on 13 October 1974 [see below], leaving once again, only a single Branch of Astrogeology. Of course, the long task of researching and formally documenting for NASA exactly what new geologic/geophysical information all six Apollo expeditions returned about the Moon would continue for a number of years following Apollo 17.

Work continued under the direction of W.R. Muehlberger, Principal Investigator, in analyzing the data returned by the Apollo 17 crew for inclusion in the preliminary science report, which was being written. This included intensive work with the Lunar Sample Preliminary Examination Team (LSPET) on sample identification, location, and orientation [on the lunar surface before sampling]. Recommendations were transmitted to the Lunar Sample Analysis Planning Team (LSAPT) concerning early distribution of some of the returned samples.

The following was taken from the Branch of Astrogeologic Studies Monthly Report for April 1973 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 31 April 1973:
G.G. Schaber presented a paper entitled "Lava Flows in Mare Imbrium: Geologic Evaluation from Apollo Orbital Photography" at the 4th Lunar Science Conference. He showed that virtually all of the Eratosthenian-age mare mapped in the Imbrium Basin were derived from a single volcanic source region south of the crater Euler in southwestern Imbrium, and was erupted in at least three major episodes during the 3.0 +/- 0.4 b.y. to 2.5 +/- 0.3 b.y. time period. Flows from the three periods exceeded 1,200 km, 600 km, and 400 km, respectively, from their vent source region. Schaber also discussed evidence that such flow lengths are feasible on 1:1,000 slopes and are controlled primarily by small changes in mean flow thickness associated with increased rates of lava extrusion at the vent. The reduced viscosity of lunar lavas is assumed to have only a secondary effect on maximum flow length. Schaber has traced the youngest Imbrium lava flows to their actual source fissure just west-southwest of the crater Euler. Rectified Apollo 15 metric, oblique, photographs of the flow lobes were used in mapping the details of the volcanic units. This work was published in the Proceedings of the 4th Lunar Science Conference (Schaber, 1973, Lava flows in Mare Imbrium: Geologic evaluation from Apollo orbital photography, in Lunar Science Conference, 4th, Houston, March 5-8, 1973, Proceedings: *Geochimica et Cosmochimica Acta, vol. 1, supplement 4*; pp. 73-92.) A second paper dealing with the Earth-based radar response of the Imbrium flows was published by G.G. Schaber and others in 1975 (G.G. Schaber, T.W. Thompson and S.H. Zisk, 1975, Lava Flows in Mare Imbrium: An evaluation of anomalously low Earth-based radar reflectivity: *The Moon*, v. 13, pp. 395-423).

D.J. Milton, while on annual leave, revisited Lonar crater in India and consulted on a Geological Survey of India project. Danny also, with the hospitality of the Geological Survey of Iran, visited Qaleh Hasan Ali craters near Kerman, which were recently discovered and described as impact craters. These craters turned out to be maar volcanic craters, as proven especially by the excellent bedding in the ejecta.

The following was taken from the Branch of Astrogeologic Studies Monthly Report for June 1973 to the Assistant Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 30 June 1973:
D.H. Scott reports that the recently acquired photographs from the Russian lunar orbiter—Zond 8—have contributed to geologic mapping around the Orientale basin—particularly in distinguishing between mare and plains material, and in the identification of Copernican-age craters.

[Astrogeology Milestone: For the past year there has been a continuing effort at the Flagstaff U.S. Geological Survey Computer Center Facility to develop a capability for computerized processing of digital imagery. Because of the involvement of the Branch of Astrogeologic Studies in ERTS, Mariner-Mars, Mariner-Venus/Mercury, Mariner Jupiter-Saturn, Viking '75, and other NASA Planetology Programs, it was realized several years ago that the U.S. Geological Survey should start building an in-house image processing facility for selective handling of those data that are essential to the cartographic and geologic work of the Branch.

During the last six months, the following programs have been completed and applied to ERTS and Mariner-9 data: histogram and data list, table stretch, linear stretch, auto-stretch, high-pass filter, picture ratio, multi-color cluster analysis, multi-color cluster map, and sun angle removal. Additionally, the following programs are in various states of completion: Ultra-violet Spectrometer (UVS) noise removal, generalized geometric transformation, reseau finding and removal, and generalized cartographic transformation (orthographic Mercator conformal, Lambert-conformal, polar stereographic, traverse Mercator). Also, an interactive display is being interfaced with the computer which will display on a TV monitor the image at any point in the processing. Also, this has a "light Pen" (interfaced between the monitor and the computer) which, when pointed at a particular spot in a picture on a TV screen, will automatically supply the computer with the coordinates of that point so that special cosmetic or geologic notations can be made at the desired place of places within the picture.

[Author's Note: The two paragraphs above describe one of the most forward-thinking and necessary changes in direction made by the Branch of Astrogeology immediately following the end of the Apollo Era. The move by the Branch move to the, then still infant, world of digital image processing can be mostly credited to Lawrence "Larry" Soderblom who is widely considered to be one of the most brilliant and innovative minds in the field of lunar and planetary science since Gene Shoemaker (one of Larry's professors at Caltech) coined the new science of astrogeology in the early 1960's. Larry and a number of equally creative, willing, and eager young mathematicians and cartographers at the Branch of Astrogeology, and at the Flagstaff Field Center's Computer Group, led the Branch of Astrogeology out of the "slide rule" world of the pre-Apollo and Apollo Era into the fledgling world of digital image processing starting in the late 1970s. Larry Soderblom and his colleagues rapidly developed (by the 1980's) a world-renowned capability for innovation and high quality digital image processing—long before it had become commonplace. Many of the digital image processing methodologies and techniques developed under Soderblom's leadership at the USGS in Flagstaff have become the standard by which many subsequent digital image processing operations around the world have been based.

[Spaceflight milestone: The Mariner 10 Venus/Mercury spacecraft was launched from Cape Kennedy on 3 November 1973. Encounter with Venus occurred on 5 February 1974 (see below), and encounter with Mercury occurred on 29 march 1974 (see below).]

Cartographer/Illustrator Jay Inge (b. 1943), another of Flagstaff's heralded lunar and planetary airbrush artists (along with Pat Bridges), began working WAE (part time) with the USGS Branch of Astrogeology in 1973 (on the 5th Floor of the old Arizona Bank Building) with the encouragement of Hal Masursky. At that time Jay was actually still employed for Lowell Observatory in Flagstaff. Jay had worked for Lowell several times, starting back in 1965 when he was working with Pat Bridges [then at ACIC on the Lowell Observatory campus in Flagstaff] and others producing the early LAC lunar charts in support of Project Apollo. Jay Inge became a fulltime employee with the Branch of Astrogeology in 1974 and resigned from Lowell Observatory.

The following was taken from the Branch of Astrogeologic Studies Monthly Report for December 1973 to the Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 11 February 1974:

L.A. Soderblom and G.A. Swann met with the Chief Geologist, Office Chiefs, and others in Washington, D.C. to discuss recent advances in image processing techniques that have been developed in Flagstaff. It is anticipated that these new techniques will result in increased use of ERTS imagery in the Geological Survey's mapping program.

6.4-1974

The following was taken from the Branch of Astrogeologic Studies Monthly Report for January 1974 to the Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 20 May 1974:

J.M. Boyce and A.L. Dial, in conjunction with L.A. Soderblom, have extended the results of estimates of surface ages using the Soderblom-Lebofsky technique (DL method). The results indicate that the light plains deposits (i.e., Cayley Formation) pre-date the emplacement of the maria. In general, the mare basalts increase in age westward. The oldest lunar mare is Mare Tranquillitatis and the southern dark edges of Serenitatis are also old. Mare Imbrium, Serenitatis and Humorum have lavas in them like the Apollo 15 basalts that formed during the period between 3.3 to 3.5 b.y. ago. A series of young flows (~2.5 b.y. ago) invaded the western maria (Oceanus Procellarum); and a few patches were superposed on southwestern Mare Imbrium, northern Mare Humorum, and northwestern Mare Serenitatis. Some of these younger units may have crystallized as recently as 2.0 b.y. ago. The pattern of surface ages in Serenitatis bears some resemblance to the remote sensing units reported in the Apollo 17 Preliminary Science Report by [T.W.] Thompson and other.

R.J. Pike reports that the transition from 100 percent absence to 100 percent presence of (1) rim terraces, (2) textured flat floors, (3) central peaks in all lunar craters occur characteristically with a rather restricted size range. The data on which this conclusion is based comes from a paper by E.I. Smith and A.G. Sanchez. Respectively, the 50 percent frequency of occurrence of each of these three features lies at 25 km, at 10 km, and at 15 km-diameter. The average of these three transition diameters, 16.7 km, indicates a characteristic size at which a fundamental change in crater shape occurs. This average value, 16.7 km, agrees too well with the 10-20 km-diameter range containing inflection of the lunar crater depth/diameter, rim height/diameter, and rim slope/diameter relations to be accidental. All six differences in crater shape probably have a common, size-related origin.

G.G. Schaber reports that a comparison of the photogeology with Earth-based mapping of color and radar reflectivity in the western two-thirds of Mare Imbrium shows a general correlation between very weak 70-cm wavelength, depolarized, radar echoes and "blue" mare deposits of Erathosthenian and Imbrian age in the Imbrium basin. A similar but weaker correlation of 3.8-cm wavelength depolarized echoes and "blue" mare exists. Anomalously low backscatter of depolarized echoes may result from (1) low surface roughness, and slope of various scales, (2) regolith and basalt substrate chemistry leading to high attenuation, (3) low crater and rock-frequency distributions, and (4) a thick attenuating regolith. The present investigations, when combined with the results that indicate the "blue" maria have high $T1O_2$ contents, suggests that the chemistry of the materials may contribute to the low depolarized radar echoes.

[Author's Note: The relationship between Titanium and blue mare I predicted based on Earth-based radar reflectivity (see above) was confirmed following analyses of the returned Apollo mare samples in the laboratory by Williams Sills and others from the University of Utah. My paper (co-authored with T.W. Thompson, JPL), "Lava flows in Mare Imbrium: An evaluation of anomalously low Earth-based radar reflectivity" was published in 1975 in the journal *The Moon*, vol. 13, pp. 395-423).]

The following was taken from the Branch of Astrogeologic Studies Monthly Report for February 1974 to the Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 20 May 1974:
Mariner 10 flew past Venus on 5 February. The TV system performed flawlessly and nearly 4,000 pictures of Venus have been transmitted to Earth. R.M Batson, V.S. Reed, and S.P. Messer participated in mosaicking some of the real-time frames in order to obtain a global picture of the Venus cloud system [covering 100% of the planet; Mariner 10 would now fly on to Mercury and begin taking close-up images of that mysterious planet for the first time.]

The following was taken from the Branch of Astrogeologic Studies Monthly Report for March-April 1974 to the Chief Geologist for Environmental Geology, and to NASA, from Chief, Branch of Astrogeologic Studies; dated 29 July 1974:
G.G. Schaber was selected by NASA to participate in a working group for utilization of active microwave systems in future applications programs being organized by personnel at the Johnson Space Center (formerly the Manned Spacecraft Center), Houston, Texas. The working group will include approximately 67 individuals from University, Industry, and Government, and will have as its major objective to define the uses and anticipated advantages of active microwave systems in providing data in the areas of Earth, Ocean and Atmosphere.

G.G. Schaber (USGS) and G.L. Berlin (Northern Arizona University, Department of Geography; Flagstaff, Arizona) made a two-day field trip to the Death Valley National Monument area for the purpose of photographing and collecting selected fan gravels and saltpan samples to be used in a surface roughness calibration of the backscattered radar power levels. This type of "ground truth" calibration was necessary to confirm the validity of the "Rayleigh Criterion" at the longer imaging radar wavelengths. The Rayleigh relationship defines the theoretical transition between radar "rough" (diffuse backscatter) and radar "smooth" (specular reflectivity) as:

$h < \lambda/8 \sin \gamma$, where h = the height of surface irregularities; λ is the wavelength, and γ is the radar grazing angle or antenna depression angle.

[Author's Note: The above radar research in Death Valley would result in a formal Journal publication in 1976 (Schaber, G.G., Berlin, G.L., and Brown, W.E., Jr., 1976, Variations in surface roughness within Death Valley, California: Geologic evaluation of 25-cm wavelength radar images, *Geological Society of America Bulletin*, v. 87, pp. 29-41.)

An almost 30-year interest by this author in terrestrial (airborne and space borne) and planetary (Earth-based and spacecraft-borne) synthetic aperture Radar (SAR) imaging research actually started with my participation in the first USGS/NASA remote sensing project in 1966 (soon after my arrival in Flagstaff to work for the USGS Branch of Astrogeology in July 1965). My participation in radar-related research (with regard to its geologic applications), eventually grew to include radar backscatter and terrain micro roughness studies in Death Valley (1970-1985), radar penetration studies in southern Egypt and northwestern Sudan (1982-1997); and Northern Arizona (1966-1995). [5].

My experience in the investigation of the geologic potential of synthetic aperture radar-mapping sensors led to my being selected, along with Larry Soderblom, to participate on the Radar Science Team for NASA's Magellan mission that radar-mapped 98 percent of the cloud-covered surface of the planet Venus (1990-1994). However, these are stories for post-Apollo chapters in the history of the USGS Branch of Astrogeology].

[Astrogeology Milestone-Mike Carr from Astrogeology's Menlo Park office became Chief of the Branch of Astrogeologic Studies in May 1974. With the end of Project Apollo and manned lunar exploration for the foreseeable future, the Surface Planetary Exploration (SPE) Branch was terminated on 13 October 1974. The two Branches merge once again into a single entity renamed the Branch of Astrogeology. Starting on 24 October 1974, many personnel that had been with the Branch of Surface Planetary Exploration personnel moved their offices from the Arizona Bank building to the USGS, Flagstaff Field Center on McMillan Mesa (including this author). A large number of the geologists soon left Flagstaff to return to what they were originally trained for—field geology on planet Earth.

Chapter 7

Gene Shoemaker the "Father of Astrogeology," finally Reaches the Lunar Surface following His Tragic Death in 1997

In the years prior to and during the Apollo Era, Eugene M. Shoemaker was the recipient of numerous awards including: Honorary Doctorate of Science from Arizona State College,

[5] This author was a NASA Co-Investigators on SIR-A (1981); a Principal Investigator on SIR-B (1984) and SIR-C (1994), and a Co-Investigator on the Magellan Radar-Mapper mission to Venus (1990-1994).

Flagstaff, 1965; Wetherill Medal of the Franklin Institute, co-recipient with E.C.T. Chao, 1965; Arthur S. Flemming Award, 1966; Honorary Doctorate of Science, Temple University, 1967; NASA Medal for Scientific Achievement, 1967; U.S. Department of the Interior Honor Award for Meritorious Service, 1973.

In the Post-Apollo Era, Gene Shoemaker would receive the following additional honors and awards:

Member, U.S. National Academy of Sciences, 1980; U.S. Department of the Interior Distinguished Service Award, 1980; Arthur L. Day Medal of the Geological Society of America, 1982; G.K. Gilbert Award of the Geological Society of America, 1983; Reiser Kulturpreis, co-recipient with E.C.T. Chao and Richard Dehm, 1983; Honorary Doctorate of Science, University of Arizona, 1984; Barringer Award of the Meteoritical Society, 1984; Kuiper Prize of the American Astronomical Society, Division for Planetary Sciences, 1984; Leonard Medal of the Meteoritical Society 1985; Distinguished Alumni Award of the California Institute of Technology, 1986; Rittenhouse Medal of the Rittenhouse Astronomical Society, co-recipient with C.S. Shoemaker, 1988; U.S. National Medal of Science (in Rose Garden from President George W. Bush), 1992; Whipple Award, American Geophysical Union, 1993; Fellow, American Academy of Arts and Sciences, 1993; AIAA Space Science Award, 1996; NASA Exceptional Scientific Achievement Medal, 1996; Bowie Medal, American Geophysical Union, 1996; Special Award, American Association of Petroleum Geologists, 1997.

Following the Apollo era, Gene and Carolyn Shoemaker mainly focused their considerable energies on jointly locating and geologically mapping impact craters in Australia, and on their own systematic search of the night sky for unrecognized asteroids and comets (Fig. 100a). With the latter research effort, Gene and Carolyn hoped to add significantly to the then somewhat meager database of these bodies. Together, they are credited with the discovery of many hundreds of asteroids and numerous comets. Carolyn would in a relatively short period of time become the leading comet finder of all time with 32 comets to her name. Together, along with David H. Levy, Gene and Carolyn would become household names throughout the world—as a couple—with their discovery (along with David Levy) of the Shoemaker-Levy 9 comet on 25 March 1993. Fragments of this "string of pearls" comet, disrupted by the massive gravity of Jupiter on 7 July 1992, impacted the atmosphere of Jupiter (releasing unimaginable energies) with the Hubble Space Telescope, and the entire world, watching two years later. Some 21 large fragments of the disrupted Shoemaker-Levy 9 comet impacted Jupiter's atmosphere between 16 and 22 July 1994 in one of the greatest space science media events since the Apollo 11 mission to the Moon almost 25 years earlier (see Levy, 2000, Chapters 1 and 20) (Fig. 100b-f).

[Author's Note: See the National Geographic Society's film-documentary "Asteroids: Deadly Impact."]

Sadly, Gene Shoemaker died at the age of 69 in a head-on car crash in the Australian Outback on 18 July 1997 while on a combined holiday and trip researching impact craters with his wife Carolyn. The accident occurred on a dirt road near the border of the Northern Territory and Western Australia State, about 500-km (300 miles) northwest of Alice Springs. Carolyn survived the accident, but sustained various serious injuries. She has fully recovered and still resides in Flagstaff, Arizona where she still has offices both in the New "Shoemaker building" on McMillan Mesa, and at Lowell Observatory.

Many tributes from around the world were paid to Gene Shoemaker following his untimely death in 1997. This author has chosen to include the following tributes which I believe aptly describe the man, his dreams, his accomplishments, and the esteem in which he is held by his colleagues.

7.1-Lunar Prospector

The following passages are from the touching tribute to Eugene M. Shoemaker by Carolyn C. Porco at the Lunar and Planetary Laboratory, University of Arizona, Tucson.

Carolyn C. Porco:
"Only two years before he died, he [Gene Shoemaker] said, not going to the Moon and banging on it with my hammer has been the biggest disappointment in my life."

Shoemaker was finally, in death, granted his wish. On 6 January 1998, a small polycarbonate capsule carrying an ounce of his cremains traveled to the Moon aboard NASA's Lunar Prospector spacecraft. Wrapped around the capsule was a 1.5 inch (3.8-cm) square piece of brass foil, laser-inscribed with a composite image designed to commemorate Shoemaker's scientific legacy (Fig. 101). The top of the inscription features an image of Hale-Bopp, the comet that graced the spring skies of Earth in the year that Shoemaker died, and the last comet that the Shoemakers observed together. This image, taken on 14 April, 1997 from Tucson, Arizona, dramatically displays the details in both the comet's ion and diffuse dust trails. In the lower left corner [of Fig. 101] is Shoemaker's favorite photo of Meteor Crater, the 4,000 ft. (1.2 km) wide and 750 ft. (230 m) deep bowl-shaped depression in northern Arizona where he trained the Apollo astronauts. In 1960, it was Shoemaker who provided convincing evidence that the crater was formed by an impact event. Later, he and his colleagues demonstrated that the impact occurred about 50,000 years ago, shortly before humans permanently inhabited this part of the Colorado Plateau.

And at the inscription's center is a passage from William Shakespeare's enduring love story, "Romeo and Juliet," chosen for its apt expression of the warmth and admiration bestowed on Shoemaker by his friends, colleagues and fellow explorers all over the world.

On 31 July 1999, after eighteen months of successful orbital scientific operations, Lunar Prospector was commanded to crash into the surface of the Moon. The fulfillment of one man's dream, and the final episode of his inspirational life, met on impact. At his journey's end, thirty years to the month after humans first set foot on the Moon, Eugene M. Shoemaker became the first inhabitant of Earth to be sent to rest on another celestial body."

Flagstaff's *Arizona Daily Sun* of 31 July 1999 carried an article by Chris Fletcher (Associated Press Writer) entitled: "Man on the Moon." With the subheading: "Shoemaker's ashes headed for lunar resting place." This article reports on the fact that NASA's Lunar Prospector spacecraft, carrying one ounce of Gene Shoemaker's ashes, slammed into a lunar crater at 3,800 mph before dawn this morning. Gene always wanted to go to the Moon but was sidetracked by his contraction of Addison's disease, and it's diagnosis in the summer of 1963. It is the ultimate and most fitting tribute to Gene Shoemaker—a man who just knew back in the late 1940's that he would someday get to the Moon. He finally did—and we are all happy for him.

7.2-NEAR-Shoemaker

The Near Earth Asteroid Rendezvous (NEAR) mission was the first of NASA's Discovery missions and the first mission ever to go into orbit around an asteroid. The spacecraft was equipped with an X-ray/gamma ray spectrometer, a near-infrared imaging spectrograph, a multispectral camera fitted with a CCD imaging detector, a laser altimeter, and a magnetometer. A radio science experiment was also performed using the NESAR tracking system to estimate the gravity field of the asteroid. The ultimate goal of the mission was to rendezvous with and achieve orbit around the near Earth asteroid 433 EROS in January 1999, and study the asteroid for approximately one year.

NEAR was launched on 17 February 1996 atop a Delta II launch vehicle. On 27 June 1997, NEAR flew within 1200 km of the C-class main-belt asteroid Mathilde, and included high resolution and color (seven filters) imaging. An abort of the first encounter burn and the mission had to be rescoped for a 23 December 1998 flyby of EROS and a later encounter and orbit on 14 February 2000.

On Valentines Day, 2000 the thruster burn to put the NEAR spacecraft into orbit around Asteroid Eros went as close to perfect. The NASA satellite conducted the first-ever close-up study of an asteroid. The images of Eros sent back to Earth by the spacecraft show a surface covered with craters.

In a very bold and innovative move NASA successfully attempted to land the NEAR spacecraft (an orbiter—not a lander) actually on the surface of EROS. NEAR touched down on the surface of EROS on 12 February and contact was maintained. The spacecraft impacted at a velocity of about 1.5 to 1.8 meters/second (3.4 to 4.0 mph). The spacecraft, remarkably, obtained 69 high-resolution images before touchdown, the final image showing an area 6 meters across. NEAR was not designed as a lander, but survived the low-velocity, low-gravity impact, a signal continued after the "landing" using the omni-directional low-gain antenna as a beacon.

During the Lunar and Planetary Science Conference in Houston (14 March 2000), Carl B. Pilcher, Director of Solar System Exploration at NASA Headquarters, announced that the spacecraft, currently orbiting asteroid 433 Eros more than 145 million miles from Earth, will now be known as NEAR Shoemaker, to posthumously honor Eugene M. Shoemaker and his ground breaking work with NASA, the Moon, other planets, and asteroids. Carolyn Shoemaker accepted in Gene's behalf (the above was taken from: the NASA website http://nssdc.gsfc.nasa.gov/planetary/near.html, and the USGS, Branch of Astrogeology website http://astrogeology.usgs.gov/].

[Author's Note: Knowing how strongly Gene Shoemaker really wanted to not only to personally explore the surface of the Moon, but to land on and explore an asteroid, he would be delighted with the honor accorded him with the successes of both the Lunar Prospector and NEAR

Shoemaker spacecraft. Carolyn Shoemaker still carries on "their" work of publishing the results of Gene and her geologic mapping of impact craters in Australia (some of which they first identified), and continuing the search for asteroids and comets. She is still very active with both Lowell Observatory (Flagstaff) and the USGS Astrogeology Team—founded by Gene)]

[Author's Note: For additional tributes to Gene Shoemaker, the reader is encouraged to visit the Branch of Astrogeology website (http://astrogeology.usgs.gov/).]

Concluding Remarks

In a letter to William Phinney (NASA/MSC) dated 15 April, 1974, Dale Jackson (USGS) reported the following:
"NASA had awarded us [the USGS] a contract (not a very lucrative one, I'm afraid) to write up a history of the astronaut training program in the geological sciences. As you know, the program started in 1962, and was passed from hand to hand until 1973. During that period all sorts of help was called for, and, under the extreme pressure of the missions, few coherent records were kept. We do hope to heaven we have a complete list of people who were involved, and we'd like two things: 1) to be sure of factually crediting everybody; and 2) to get copies of photos or relics or anecdotes or whatever, that might be considered for publication in a Survey Professional Paper on this subject. I'm enclosing a form, which you may or may not find useful, but we could deeply appreciate some kind of response. It would be hell to have the thing full of "we think we went to Katmai, but we are unable to document when, where, or why."

On 8 August, 1974, Dale Jackson (who was by then at the National Center for Earthquake Research-Earthquake Tectonics Program, at Menlo Park, California) wrote a more detailed Dear Colleague white paper or outline for the Survey professional Paper on the geologic training of the Apollo astronauts. Unfortunately Dale passed way suddenly in 1978 before the USGS Professional Paper on the geologic training of the Apollo astronauts was in any sort of draft form.

William Phinney, who worked with the geology group at the Manned Spacecraft Center in Houston (now, the Johnson Space Center), took up the challenge many years later. He presently (at this writing) has completed an account of the scientific training of the astronauts from the perspective of the geology group at JSC, titled "Scientific Training History of the Apollo Astronauts" (William C. Phinney, submitted). Bill has been kind enough to allow me to quote liberally here from his work.

My effort in the present work is focused on the role of the USGS, especially the efforts of personnel with the USGS's Manned Lunar Exploration Group, leading up to Project Apollo. For that reason, I believe that it nicely meshes with those earlier published works, or in progress works, of Wilhelms (1993), Levy (2000), Beattie (2001), and Bill Phinney.

In Dale Jackson's letter to his colleagues on 8 August, 1974 (see above), he said the following:

"The purpose of the [USGS] Professional Paper [that he was going to write, but passed away before he actually got started] is to attempt to express why so many of us spent so much time in an effort to cooperate as scientists, engineers, and crews to make the Apollo program the success that it came to be, and to document why so many of us considered that important."

This author could not agree more. This was also my goal in compiling the present document, using the words of others as well as my own. I hope that I have succeeded in some small way.

It is well known that the amazingly successful and daring Apollo program was just the auspicious beginning of the role that the U.S. Geological Survey would play in supporting mankind's exploration of the other planets and satellites in the Solar System. Having already begun with the early Mars flybys and Orbiters (e.g., Mariners 6, 7, and 9) during the Apollo Era—would blossom exponentially during the following decades up to the present time. It is widely known within the lunar and planetary science community that scientists and image processing staff from the Branch of Astrogeology have played crucial roles in the design, planning, mission operations and data analysis phases for nearly all of NASA's many unmanned planetary missions starting with the first flyby of Mars by Mariner 4 in November 1964. During the hectic Apollo Era, Branch personnel from both Flagstaff, Arizona, and Menlo Park, California, were also actively engaged in the instrument design, mission planning, mission operations and data analysis phases for the Mariner 6 (February 1969), and Mariner 7 (March 1969) flybys of Mars, in addition to the Mariner 9 orbital mapping mission of Mars (1971) (see 1969 and 1971 above).

In the summer of 1968 the Branch of Astrogeology's proposal for a two-camera Television system for the 1971 Mars-orbiter (subsequently called Mariner 9) was selected by NASA. Hal Masursky (Branch of Astrogeology,-Flagstaff) was listed as the Principal Investigator for the Television Experiment, and Jack McCauley (Branch of Astrogeology, Flagstaff) would head up the Geology Team.

In 1971, Branch of Astrogeology geophysicist Lawrence A. "Larry" Soderblom was selected as one of the few original team members for the Voyager Mission Imaging Science Experiment. He became Deputy Team Leader of the experiment with responsibility for conducting that part of the scientific experiment focused on the satellites of Jupiter, Saturn, Uranus, and Neptune, with the additional responsibility of technical leadership of the Teams' digital image processing and data processing activities. Larry twice received NASA's medal for Exceptional Scientific Achievement for his contributions to Voyager (see Appendices A and B).

During NASA's rapidly-accelerating unmanned planetary program following the Apollo Era, Larry Soderblom, Hal Masursky, Mike Carr and others USGS scientists would brilliantly spearhead the effort to keep the U.S. Geological Survey's Branch of Astrogeology as one of NASA's most dependable group of scientists and support personnel for getting the job done with regard to instrument design, mission planning, mission operations, and post-mission data analysis. Scientists with the Branch of Astrogeology (both in Flagstaff, Arizona, and Menlo Park, California) have been actively involved in virtually every NASA manned and unmanned lunar and planetary mission since shortly after NASA was founded in 1958 [as Gene Shoemaker, the Founder of the Branch of Astrogeology, was just completing his pioneering geologic investigations at Meteor Crater, Arizona.]

Again, the scope of the present document detailing the role of the U.S. Geological Survey in Project Apollo was not intended to extend beyond the Apollo Era. It is sincerely hoped, however, that someone within the Branch of Astrogeology will take on the daunting task of documenting the equally exciting, and perhaps even more significant, role that the U.S. Geological Survey Branch of Astrogeology personnel (both in Menlo Park, California and Flagstaff, Arizona) continued to play in the post-Apollo Era, with regard to basic planetary geologic research, comparative planetology, and in supporting the planning, mission operation, and data analysis for NASA's growing list of terrestrial, lunar and planetary missions.

We have here attempted to communicate to the reader how extraordinary dedication, hard work, and creative thinking by a number of enthusiastic young professionals and supporting staff in the U.S. Geological Survey's Branch of Astrogeology and Branch of Surface Planetary Exploration were inspired by the visionary geologist Eugene M. Shoemaker at what turned out to be one of the most astonishing ten years in U.S. history.

Given that a complete chronological documentation of these events has not been previously available to the media, much of the U.S. Geological Survey's role in Man's Greatest Adventure—Project Apollo—has either been overlooked, or substantially (in our opinion) altered or understated in various post-Apollo media documentary films, TV mini-series, etc. The author sincerely hopes that this chronological accounting of the U.S. Geological Survey's activities leading up to these historic events will help prevent any future unintentional revisions of Apollo-science history.

As mentioned at the beginning of this document, most of the U.S. Geological Survey's critical lunar geologic mapping –and its masterful coordination by Don Wilhelms—was carried out at the Branch of Astrogeology's original office in Menlo Park, California. These geologic mapping activities, in addition to the Branch's wide variety of pure lunar research activities—and participation in unmanned lunar mission—activities are well-documented in Don Wilhelm's book *"To a Rocky Moon"* (Wilhelms, 1993, 477 pages).

For that reason, these activities carried out by Branch of Astrogeology personnel located in Menlo Park, and are only touched on in the present work. This work was instead focused on the activities of the Survey's "Manned Lunar Exploration Studies (MLES) group and, subsequently, the Branch of Surface Planetary Exploration (SPE) (between 1967 and 1973) that were carried out in support of NASA in Flagstaff, Arizona following Gene Shoemaker's decision to move the headquarters of his Branch of Astrogeology there in 1963. In that effort, the timely and comprehensive first-hand account of the Manned Lunar Science activities from the perspective of NASA Headquarters during the Apollo Era provided by Don Beattie in his excellent book, "Taking Science to the Moon" (Beattie, 2001, 301 pages) was invaluable—and heavily quoted in this work.

The significance to the geologic training of the astronauts of Flagstaff, Arizona, and the great variety of geologic landmarks surrounding that mountain city cannot be overstated. As described in this work, much of the development of Apollo lunar surface geologic techniques and procedures, and the field geologic training of the NASA astronauts by scientists from the USGS Branch of Astrogeologic Studies and Branch of Surface Planetary Exploration took place either inside the city limits of Flagstaff, or less than an hour or so from downtown Flagstaff at Sunset Crater National Monument, Merriam Crater, Cinder Lake Crater Field—south of Sunset Crater, Meteor Crater, and at various sites within the Hopi Buttes Volcanic Field east of Flagstaff. This author here would like to thank the Navajo Nation for their excellent cooperation during the pre-Apollo and Apollo era, and allowing us to develop and test lunar geologic procedures on their beautiful lands.

The 1960's and early 1970's were dominated by two major events. One was very distressing and frustrating, the other very exhilarating—the Viet Nam War and the "Race to the Moon." For those persons involved in the war, whether fighting to win it or protesting strongly against it, the 1960's and early 1970's was a time of pain, anguish and despair. For those of us in the United States actively engaged in the race to beat the Soviets to the Moon, that period was a "can do" era like no other since WW II. The secret appears to be for our nation to set lofty, seemingly impossible—but positive—goals that bring out the very best resolve and hidden talents in everyone—whether it be manned missions to the planet Mars and beyond—or saving humanity from our many growing problems right here on planet earth.

<u>And finally</u>—Gene Shoemaker strongly believed that most people don't realize anywhere near their full potential—and he would relish in challenging his own colleagues at the USGS to reach for it and accomplish things they never thought possible—and we did!

Acknowledgments

Many current (*) or former personnel with the Survey's Branch of Astrogeology and/or the Branch of Surface Planetary Exploration (between 1967 and 1973) made significant contributions to this document through taped or personal phone interviews with this compiler (G. Schaber) between 2000 and 2002[6]

Special acknowledgment and appreciation is given to colleague Gordon A. Swann (Principal Investigator of the Lunar Geology Field Team for Apollo missions 14, and 15) for his review of earlier drafts of this manuscript, and for sharing his first-hand knowledge and insights on the myriad of activities carried out by personnel with the Branch's Manned Lunar Exploration Studies (MLES) Group (later the Branch of Surface Planetary Exploration) and the various Apollo Lunar Geology Experiment Team(s) in support of Project Apollo between 1964 and 1973.

Special thanks also goes to Norman G. "Red" Bailey for his review of drafts of this manuscript, and for his foresight—during an unbelievably hectic period of time (1964-1973)—to have kept a

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[6] Paula Ables; Des Stewart-Alexander; Betty Bachstein; Norman "Red" Bailey; Ray Batson; Fern Beeson; Lynda (Sowers) Bellisime; Ramona Boudreau; Michael Joseph Boyce; Pat Bridges; Joe Bullmore; Mike Carr; Roger Carroll; Bill Colton; Jim Crossan; David Dahlem; Krista (Kenna) Edmonds; Kay Edwards; Richard "Dick" Eggleton; Donald (and Shirley) Elston; Walt Fahey; Richard 'Dick" Godson; Tim Hait; John Hallinan; Rae (Schaul) Harvey; John Hendricks; Henry Holt; Jay Inge; Ray Jordan; Marty Kane; Ginny (Hall) Keiper; Keith Howard; Baerbel Lucchitta; Ivo Lucchitta; Jack McCauley; John M'Gonigle; Putty Mills; Danny Milton; Elliot Morris; Betty Nuttall; Joe O'Connor; Dick Pike; Howard Pohn; Carl Roach; David Roddy; Larry Rowan; John Running; Ray Sabala; David Schleicher; Larry Soderblom; Hal Stephens; Ken Stice; Mimi Strobell; Gordon Swann; Jody Swann; Hugh Thomas; Bill Tinnin; Rich Tyner George Ulrich; Joel Watkins; Ken Watson; Howard Wilshire; Edward Wolf; Sherman S.C. Wu and Karl Zeller

detailed personal log of his own activities for the Branch of Astrogeology. Red's activity log has been a major source of dates and other important details about Branch of Astrogeology and Branch of Surface Planetary Exploration activities, especially with regard to the numerous field tests carried out in Hopi Buttes, Meteor Crater, Sunset Crater, the Cinder Lake Crater Field, Merriam Crater, and elsewhere during this time period.

Appreciation is given to Derrick Hirsch, Jane Ciener and Mike Diggles of the U.S. Geological Survey for their individual efforts in editing this extensive work, and to Wes Ward for his encouragement in 1999 for me to actually take on this work, as well as his assistance in seeing it through to final completion. Thanks also to Lisa Gaddis for her support and encouragement, and to Adrienne Wasserman for her help in locating and accessing historical photographs used in the compilation of this document.

Much information used in this work (as referenced in the text) has been quoted (with permission of the copyright owners) from books or memoirs that have been published in recent years, or are in progress. The books include: (1) *To a Rocky Moon* (Wilhelms, 1993), (2*), A Man on the Moon-The Voyages of the Apollo Astronauts* (Chaikin, 1994), (3) Shoemaker -*The Man Who Made an Impact* (Levy, 2000), (4) *Taking Science to the Moon—Lunar Experiments and Project Apollo* (Beattie, 2001), and (5) *Science Training History of the Apollo Astronauts* (William C. Phinney, submitted to NASA/JSC in 2005). Additional information has been taken from audio taped or filmed interviews conducted by Gerald G. Schaber (USGS, Branch of Astrogeology-Emeritus), Harry Ryan (formally under contract to USGS, Branch of Astrogeology in Flagstaff, Arizona), and Kirk D. Wolfinger, Director of the 1999 NOVA two-hour documentary "*To the Moon.*" This documentary first aired on PBS in summer 1999; however, the second hour of the film was substantially revised for NOVA in 2001 by Lonewolf Productions to reflect more accurately the important roles of Gene Shoemaker and his USGS Branch of Astrogeology in project Apollo[7].]

For a more detailed account of the history of lunar geologic mapping, and other research carried out early in the history of the Branch of Astrogeology (especially at Menlo Park, California), the reader is referred to the excellent book by Donald E. Wilhelms: *"To a Rocky Moon"* (Wilhelms, 1993, 477 pages).

[7] The second hour of the two-hour NOVA-documentary "*To the Moon*" was revised considerably by NOVA in 2000 and 2001 in response to letters and phone calls of protest from several Apollo-era staff members of the Branch of Astrogeology (including Harrison H. Schmitt, Apollo 17 astronaut), and others. They were protesting the fact that the original version of the film did not even mention the significant efforts of the USGS Branch of Astrogeology, or even the name of Gene Shoemaker—to whom the documentary film was actually dedicated. The revised and more historically correct version of this NOVA documentary "*To the Moon*" was aired on 25 June 2002 on PBS stations around the country. The U.S. Geological Survey, Branch of Astrogeology thanks Paula Apsell (Production Manager for NOVA, Boston, Massachusetts.), Kirk Wolfinger (owner of Lone Wolf Productions, South Portland ME), and Rushmore DeNoyer (Writer-Producer, Lonewolf Productions) for re-examining the content of their original (1999) NOVA documentary *"To the Moon,* and their joint decision to revise the film with the laudable intention of more accurately portraying facts and historical events.

References

[Some references cited in text at appropriate location only)

Published Sources Cited in Text:

Beattie, Donald A., 2001, *Taking Science to the Moon- Lunar Experiments and the Apollo Program*, The John Hopkins University Press, Baltimore, Maryland, 301 pages.

Chaikin, Andrew, 1994, *A Man on the Moon- The Voyages of the Apollo Astronauts*, Viking Press, Penguin Group, New York, New York, 670 pages.

Levy, David H., 2000, *Shoemaker by Levy-The Man Who Made an Impact,* Princeton University Press, Princeton, New Jersey, 303 pages.

Stephens, Hal G., and Shoemaker, Eugene M., 1987, *In the Footsteps of John Wesley Powell: An Album of Comparative Photographs of the Green and Colorado Rivers, 1871-72*; Boulder, Colorado.; Johnson Books, 286 pages.

Wilhelms, Don E., 1993, *To a Rocky Moon- A Geologist's History of Lunar Exploration*, The University of Arizona Press, Tucson, Arizona, 477 pages.

Miscellaneous Sources Cited in Text

(1) Interviews by Gerald G. Schaber with sixty-six current and past employees of the U.S. Geological Survey's Branch of Astrogeology and Branch of Surface Planetary Exploration (the latter, in existence from 1967 to 1973) (see Appendix A)[8].

(2) Branch of Astrogeology and *Center of Astrogeology Monthly Reports* to the USGS and NASA (1961-1974).

(3) The personal daily logs of Branch of Astrogeology and Branch of Surface Planetary Geology activities during the Pre-Apollo through the Apollo era (1965-1973) by geologist/driller Norman "Red" Bailey

(3) The unpublished memoirs of Branch of Astrogeology geologist John F. "Jack" McCauley.

(4) Transcripts of the audio tracks from Beta-format video tape interviews of key Branch of Astrogeology personnel (active and retired) by Flagstaff amateur historian Harry Ryan in 1996 and 1997 while under contract with the USGS Branch of Astrogeology in Flagstaff to document early Branch history (never completed).

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[8] Paula Ables; Des Stewart-Alexander; Betty Bachstein; Norman "Red" Bailey; Ray Batson; Fern Beeson; Lynda (Sowers) Bellisime; Ramona Boudreau; Michael Joseph Boyce; Pat Bridges; Joe Bullmore; Mike Carr; Roger Carroll; Bill Colton; Jim Crossan; David Dahlem; Krista (Kenna) Edmonds; Kay Edwards; Richard "Dick" Eggleton; Donald (and Shirley) Elston; Walt Fahey; Richard 'Dick" Godson; Tim Hait; John Hallinan; Rae (Schaul) Harvey; John Hendricks; Henry Holt; Jay Inge; Ray Jordan; Marty Kane; Ginny (Hall) Keiper; Keith Howard; Baerbel Lucchitta; Ivo Lucchitta; Jack McCauley; John M'Gonigle; Putty Mills; Danny Milton; Elliot Morris; Betty Nuttall; Joe O'Connor; Dick Pike; Howard Pohn; Carl Roach; David Roddy; Larry Rowan; John Running; Ray Sabala; David Schleicher; Larry Soderblom; Hal Stephens; Ken Stice; Mimi Strobell; Gordon Swann; Jody Swann; Hugh Thomas; Bill Tinnin; Rich Tyner George Ulrich; Joel Watkins; Ken Watson; Howard Wilshire; Edward Wolf; Sherman S.C. Wu and Karl Zeller

(5) Transcripts of interviews and film audio tracks with key Branch of Astrogeology personnel (active and retired) by Kirk Wolfinger from Lone Wolf Productions in preparation for the NOVA documentary *"To the Moon."* [Author's Note: The above NOVA documentary first aired on PBS in summer 1999. However, the second hour of the film was substantially revised for NOVA in 2001 by Lonewolf Productions to reflect more accurately the important roles of Gene Shoemaker and his USGS Branch of Astrogeology in project Apollo.]

(6) William C. Phinney, book entitled *"Science Training History of the Apollo Astronauts"* submitted to NASA/JSC in 2005; form of publication unknown at the time of this writting.

(6) The NASA Apollo Journal web site (http://www.hq.nasa.gov/alsj/) (excellent resource)

Recommended Additional Resources:

Wilhelms, Donald B., 1987, The Geologic History of the Moon, *U.S. Geological Survey Professional Paper-1348*, 302 pages; 24 plates.