FOOTSTEPS ON THE MOON

By Col. Edwin E. Aldrin, Jr.

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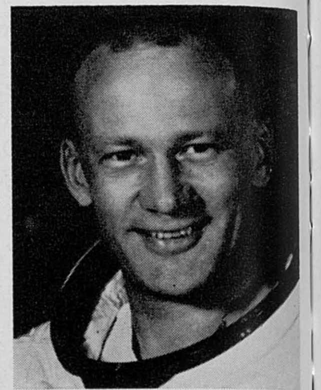


A tremendous amount was learned about the surface of the moon, information that will lead to a better understanding of the origin of the solar system and the origin of the earth. In order to provide the fuel and space stations in lunar orbit, consideration is being given to the development of a shuttle back and forth from earth to moon. Pinpoint landings in more rugged areas will be made on future missions.

WHETHER you realize it or not, today is the fifth anniversary of the first EVA in space performed by Ed White. We have had some heartaches since that time, but in the short period of five years, it is amazing to me to see just how far we have come. I would like to walk you through some of our experiences during a portion of our flight where we were on the surface. I'd like to do this through the medium of pictures, of slides. I'd like to follow this by a brief discussion of some of the reasons why we are going to the moon. These may seem a little technical, but I am trying to get this as understandable as possible, and I will follow this with a short film clip which will show some of our ventures that we will be seeing in the future.

Cast of Players

Now, we have to deal with the players in this expedition—Neil Armstrong, in Russia now, and yours truly. One of the reasons why we went there was to put a footprint on the moon. We did that and we learned not only that we could do that safely, but we learned a tremendous amount about the surface of the moon, information that will lead us to a better understanding of the origin of the solar system, the origin of the earth.

Where we landed is relatively flat. We did that on purpose because we didn't know exactly where we would be landing, where the guidance system would be taking us. On our future missions we will be going to much more rugged areas now that we have learned how to make pinpoint landings.

Neil and I both looked out the forward windows shortly after we touched down on the surface. A shadow was cast by the American Eagle on the lunar surface. As we looked down-sun, most of the features seemed to blend away and were very hard to discern. As we looked out to the side, out the left window, we could see the attitude control thruster in the foreground, and with the sun's rays coming from behind us, we could see a wide variety of lunar features, rocks varying in size from the smallest that we could see up to those perhaps four, five feet across.

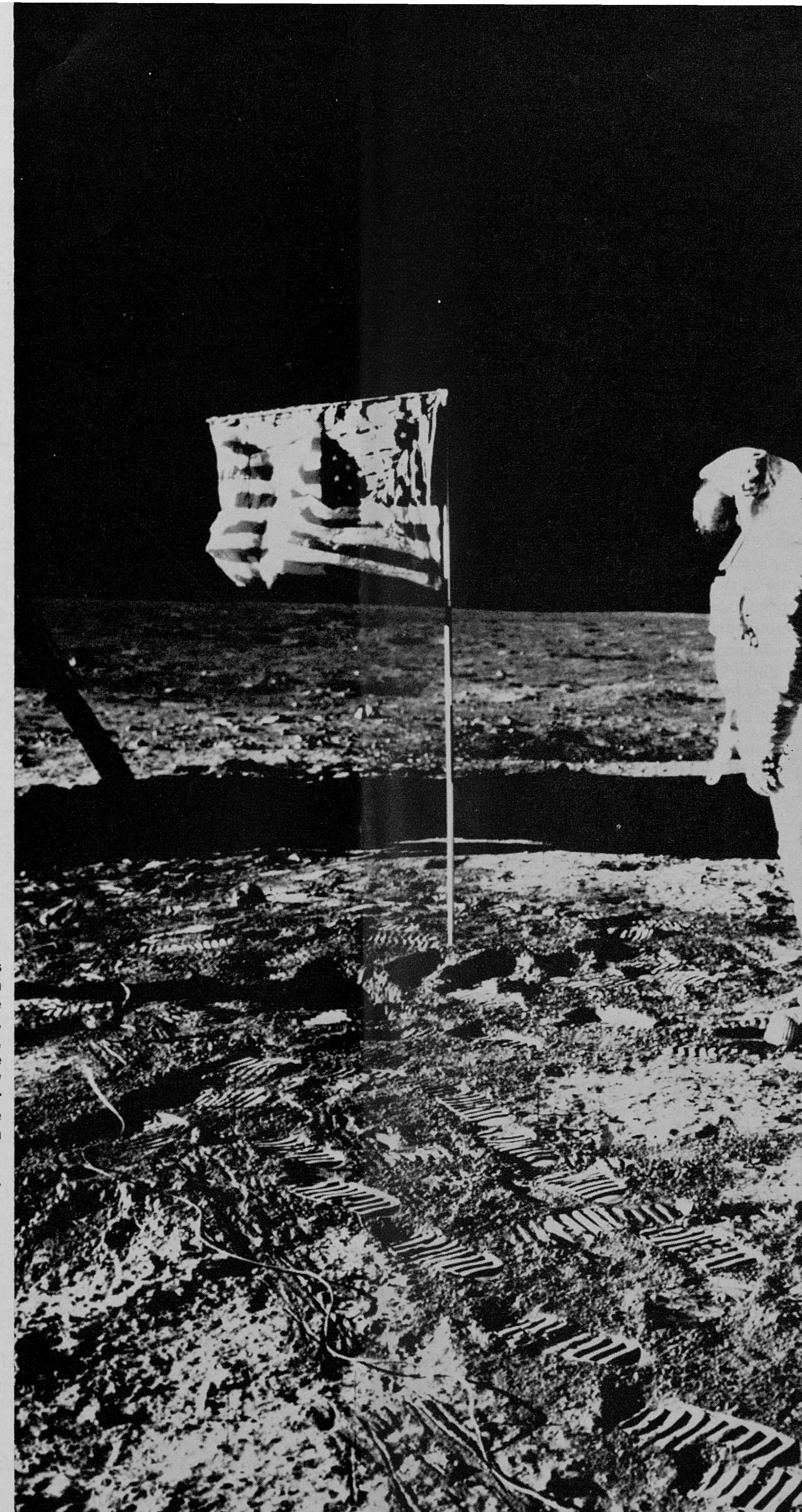
Looking a little bit forward from this position, we saw this series of double craters. Most of them were very well rounded, indicating that these were very, very old features and had been on the surface for quite some while. Out the right window we noticed that the terrain was a little bit more rugged. In the background we saw a boulder field that was probably produced by the crater that, in the last moments of our descent, we had to extend our landing profile to land past that crater because of the many rugged rocks that were in the area.

We spent about two hours checking our spacecraft out after we had landed on the surface, and then after a brief meal, we took about another three hours to prepare ourselves for our excursion on the surface. Then Neil and I descended the ladder. Of course, you all remember seeing the television pictures of Neil and his descent.

Foot Pad Didn't Sink Far

The foot pad, of course, didn't sink in the surface very far at all, so we are frequently asked the question: "Weren't you concerned when you first put your foot on the surface?" Well, we weren't at all. We had sent unmanned spacecraft that had landed on the moon and we knew what the surface features were generally like, and since our landing craft did not sink in we, of course, weren't concerned at all either.

Mounted on the landing gear—the front landing gear—between several of the rungs, was the plaque that we felt very proud to leave on the surface. It says: "Here men from the planet earth first set foot upon the moon, July, 1969, AD. We came in peace for all mankind."



he Stars and Stripes is anted on the moon on ly 20, 1969 by the pollo 11 astronauts. ol. Edwin E. Aldrin, Jr., shown by the flag. The hoto was taken by pollo 11 commander eil A. Armstrong, the st man to set foot on the moon.

Photo courtesy NASA

An address before the 38th Annual Convention of Edison Electric Institute, Boston, Mass., June 3, 1970.

One of our early tasks, of course, was to raise the Stars and Stripes on the surface of the moon, and to me this just has to have been the proudest moment of my life.

Dance Around the Moon

While Neil was filling the first rock box, I was doing my little dance around on the surface, which was really completely planned ahead of time. The task that I was doing at that time was to demonstrate just how well a person could move around on the surface.

And, of course, we weighed about 350 pounds if we were to get on scales on the earth, with all the backpack and everything we had, but on the moon we only weighed 50 pounds. But you still have this mass that you have to move around and it took a while to get moving and, likewise, it took a while to get stopped. And we had to anticipate our movements. We found that we could control our balance very well on the surface of the moon.

In general, we had to lean forward a little bit more than perhaps might seem natural, but this, of course, was due to the large mass of the backpack that was on our back. Interestingly, we found it very difficult to determine just when we were standing completely upright—without reference to the horizon, which sometimes slopes a little bit, and, of course, the curvature of the moon was also very noticeable to us even at a height of only five feet above the surface.

We found it very difficult to tell when we were standing perfectly upright. The reason for this was, naturally, that we only weighed 50 pounds, so that the physical cues that came from our feet to tell us when we were nearing the point of imbalance were very, very small. We have been asked many times: "Did you worry about falling over?" Well, since you weigh so little on the moon and the force of attraction is so small, if you do start to fall over, you fall very, very slowly and there is plenty of time to just take your foot and move it off to the side and get it underneath you.

If you were to fall down on your stomach, again it is very easy to just reach out and push against the surface and swing yourself up on your knees and on your feet. If you were to get on your back, and we practiced this many times in our one-sixth G trainers, the best one really to simulate one-sixth G is the aircraft that does a parabola, and for about 30 seconds in doing this parabola it is able to reduce the weight. We use the same thing for simulating zero gravity, and we found that was very high fidelity reproduction of what it was really like on the surface of the moon.

Armed with many hours of training in this, we felt quite confident that we could move around quite well on the surface and, if anything, we found it a good bit easier to move around than our training had indicated. After we collected our first samples, our task was to move around and inspect the lunar module very closely. A probe, about five feet long, when it first touches the surface lights a light in the cockpit and tells us we are just about to touch down. Of course, we did have a small amount of sideways motion moving in that direction and that caused the probe, as the landing gear came down, to bend.

We were only impacting into the surface by about maybe one or two inches at the most. The footprints in general sank in about half an inch. Now, we had hoped to get a very dramatic picture of one of us standing behind the LM with the LM in the background and the earth in the field of view. Our landing site was fairly close to the center of the moon, as we look at it, and as a result the earth was fairly close to the zenith, so we had to get close up to the LM to take the picture.

You could see the very stark nature of the coloring of the LM, and I will have to admit as we walked a little bit away from it, it didn't look very natural standing there in front of all this desolation. But I think man does belong on the moon, but not for very long at a time. As we moved around the back of the spacecraft after inspecting it, it was my task to open up the scientific equipment bay panel that exposed two experiments that we deployed on the surface of the moon.

One was a passive seismic experiment powered by the sun's rays. In my right hand I carried a radar reflector. I walked along the edge of the crater off to our left front. This was a double crater. The first foot print didn't penetrate the surface very much, but as I walked across the edge of the crater, I penetrated here about two or three inches.

Seismometer on the Moon

We found this to be quite consistent. Near the rounded edges of the craters, the material, the soil of the moon seemed to be a good bit less compacted and gave us this increased penetration. We left a seismometer on the moon. It continued to function for about 13 days before it went into darkness. It was powered up again the next day period and some of the components began to overheat a bit, so it is no longer operating.

Another seismometer that was powered by a nuclear generator—radio isotope thermal generator to generate the electricity—was left on Apollo-12, and I will have a few more things to say a little later on about some of the very interesting results from that. The other experiment was the radar reflector which enable laser beams to be beamed toward the moon and be reflected back from the array of 100 small corner reflectors, and send the laser beam back to the earth.

By measuring the change in frequency in this, we are able to determine very accurately, down to the order of six centimeters, the distance from a transmitting station here on earth to this experiment on the moon. Now, this means that by monitoring this over periods of time, we can detect continental drift, we can test the theories of relativity, and there are many other interesting results.

You may wonder why the flag looked like it is waving. Of course, there isn't any wind on the surface of the moon, so we had them arrange a telescoping rod through the top part of the flag and then when this was raised to the 90 degree position, it would lock into position there.

Telescoping Rod Freezes

The telescoping rod was supposed to extend another four, five inches, or maybe six inches, from its stowed position. Evidently the thermal conditions prior to the deployment of this were such that the telescoping rod was frozen in its position and I don't think you back here on earth saw it, but Neil and I were conducting a nice tug of war trying to extend this. In a way it is perhaps fortunate we didn't get it extended because it let us ruffle the flag up a little and give it that appearance of waving in the breeze.

I'd like to discuss some of the questions that will be answered by our trips to the moon. Before we sent out Apollo flights, our detailed knowledge of the moon was quite sketchy. Everything was based upon information that we had from telescopes and, of course, the Surveyor spacecraft. Estimates of the age of the moon varied from three or four billions of years to perhaps only several hundreds of years. We didn't really know the origin of the mare areas we find strangely enough just on the earth side of the moon. We didn't know whether most of the craters were really formed by impacts of meteorites or whether they were formed by volcanic activity.

Very interesting mass concentrations that you may have heard about, these little pockets of higher density in the moon, that seemed to appear in these mare areas and cause the spacecraft as they are in orbit around the moon to wobble somewhat. Their orbital parameters change, of course. We didn't know very much about these.

As we look at the areas that we have interest in our exploration, the first, of course, is we'd like to visit some of the special features on the moon, and the special features that we are interested in looking at are some of the meandering rills. Many people thought these meandering rills were created by flows of water. Of course, we didn't find any water on the moon, but we still don't know the exact reason for these features.

There are some dark, very interesting halo craters that we don't understand. There are domes that many of the geologists have various explanations for—strange dome-like features. Of course, on Apollo-12 they discovered another feature that we hadn't seen because it was a good bit smaller, and this was the mounds that were about 15 feet long and about five feet high, very strange looking features.

In order to understand many of the activities that have been taking place on the moon, we need to visit these special areas. Of course, we couldn't go to see these on our first several missions because we wanted to pick the flattest, the most uninteresting place to go to guarantee our success until we became convinced a little bit more of our exact capabilities to make pinpoint landings. Of course, we demonstrated this remarkably on Apollo-12, as they landed within several hundred feet of the Surveyor spacecraft that had been landed there two years previously.

Another area, of course, we are interested in looking at are the highland areas. Now, the reason that we'd like to visit these areas is because we think these highland areas form the original crust of the moon. Apollo-13 was scheduled to land in one of the lower area highland areas, and we are going to be sending Apollo-14 to that area. We expect that the rocks we bring back from there would be a good bit different.

You may have read in the paper recently that one of the rocks brought back on Apollo-12 was considerably older than all the rest of them that we brought back. And it had an age of about 4.3 billion years. We think that perhaps, or at least I think, that this may have come from the highland area. It may have been thrown out into this mare area because of an impact by a meteorite.

About the Sea Area

We can say a good bit more about the mare—or sea—area because we have been there. And what has been taking place in these areas can be categorized in two processes, a continuous one, one that's been taking place all throughout the origin, since the origin of the solar system. What I mean by this continuous process is the bombardment by a wide variety of size of meteorites that come from some unknown place, perhaps the asteroid belt in the solar system, but this is taking place constantly today and has been for millions of years.

The other process is a discrete one, and it is characterized by volcanic activity, and we see different evidence from these discrete processes. So let's start with the first process that's been taking place in the mare areas. We find when we look at some of the lunar rocks that they are round. Some of the other ones are not round. They are more angular.

Now, why is this? Well, on the earth we know what makes rocks round: they are in stream beds, and they get tumbled over each other and they grind each other down. But there aren't any stream beds on the moon. The meteorites impact on these rocks when they are exposed to the surface and causes them to be rounded and worn away.

Now, what else to the meteorite impacts do? They put holes in rocks. There are pits in some rock created by the impact of a very small meteorite. Some of the pits are lined with glass. Why did they get lined with glass? It is because the impact created enough temperature to melt the rock and when you melt rock and then cool it rapidly, as, of course, it would following an impact because it is not way down deep in the surface of the moon. When you cook rock rapidly you produce glass, and we found a tremendous quantity of glass, far more than anybody had ever anticipated we would find, in the dust and also spattered around the rocks.

Impacts not only put holes in rocks, but it puts holes in the moon also. There was a crater about 150 feet behind us and we landed just past another. Neil went back while I was collecting some core samples and took a picture of one crater. It was about 10 feet deep, perhaps 80 feet across. Now, this continual bombardment that creates craters, that breaks rocks apart, rounds them, and creates a vast amount of dust, continually churns up what was at one time, we think, a lava bed. It churns this up and creates a vast amount of rubble to a depth of about 10 to 15 feet, just about the depth of one crater. We think that some of the rocks in the bottom of a crater were the bedrock or the underlying lava flow that was the original surface before it started being impacted by all the meteorites.

I took a core tube that had an extension rod on it and drove this as far as I could into the surface of the moon. It was hollow, and by doing so, we drove the lunar material up into it and we'd get a sample down as deep as I could drive the tube. Surprisingly, as powdery as the surface appeared to be, as I started to hammer this thing in I could only get it about four or five inches down, and at the same time it wouldn't stay upright and it started to lean over.

So I had to hold it a little while until I got it in a little further. It doesn't tend to support anything at all, very interesting characteristics of this very dusty lunar surface. I think the reason why it increases its resistance so rapidly and so discretely is that all of this was formed in a vacuum and there is no lubrication by the air molecules to provide the cushioning effect. And, of course, it is continually being stressed with changes in temperature from a +270 F in a day to about a —270 F. This temperature change, of course, causes it to move back and forth and it just settles into a very, very compact mass.

As we take some of the surface material and run it through a strainer, we find we have a wide variety of little pebbles and rocks, some of them rounded, some of them angular, depending on whether they have been on the surface or beneath the surface for a good bit of their lifetime. Let's talk about this dust for a moment. As I said, we found surprisingly large amounts of glass. Most of the glass was in the form of spheres.

Small Spheres

These spheres are very small, about the size of the head or the point of a pin. And most of them are round, and very glassy appearing.

Let's take one of those surfaces and magnify it 800 times with an electron microscope, and see what we find: very spectacular feature of this glassy surface, it has a little wave going across it, and another impact. It is a very, very small one, but it is very obviously high-energy and it melted and spattered some glass. You couldn't even see the crater with your naked eye if you looked at it. Very surprisingly, we have never seen anything like this in any of the surface material that we looked at around the earth.

Breccia Rock

Another rock shows some of the glass that is spattered on it. Obviously it was a larger impact, melted a good bit more rock and threw it out on the surface and the rock happened to be in the way and got spattered. In addition to breaking rocks apart, rounding them, creating all this dust, and making glass, making big holes in the moon, we find that this continuous process of impact actually makes rocks. This it does by the increase in temperature in the close vicinity of where the impact takes place. It takes all the rubble that is on the surface and with its increase in temperature, forms a solid mass and it is a rock that we call a breccia rock. Of the solid rocks that are brought back, this is one type.

The other type of rock is the volcanic rock. When viewed closely, the breccia rock shows some of the angular fragments that are in all of this mass that's been welded together by this increase in temperature. The geologists can look at a thin section of breccia rock and tell many, many interesting characteristics of what they see. They can identify the different minerals, and can see the different spheres of glass and all the dusty material. They can use this to analyze this type of breccia rock.

Contrast this with the second type rock that we found on the moon that is produced deep down, due to volcanic activity or deep melting and then a slow cooling. This is an igneous rock, volcanic type. We see many of them around the earth. If we look at that in a thin section, we see the various crystals, all of them intertwined together in this structure.

These igneous rocks have holes in them, also, but these holes were created by pits. They were created by cooling very close to the surface of this rock and the crystals, of course, are very small because the cooling took place rapidly, producing tunnels that the geologists call vesicules. We see rocks like this in many places of the earth—Hawaii, Iceland. Most places that have volcanic activity produce rocks like this.

One of the igneous rocks brought back had been sitting upright on the surface for quite a while. Its upper surface had been rounded and had a coated appearance. The lower portion of it was angular and it had been sitting on the surface or perhaps buried a half-inch or so, and it hadn't been worn down as much. So the rock was thrown out by an impact that reached the bedrock. It landed like that and then started getting peppered by all those meteorites.

A thin section of a rock brought back on Apollo-12 had crystals much larger, indicating that it formed at a much greater depth and cooled slower. This tells us that heating has taken place in many different areas and because of the age difference of the rocks that we brought back and they brought back, why they know the moon has been heated up and has cooled over a period of at least a billion years.

The rocks that we brought back generally were 3.5 billion years old, and Apollo-12 rocks were for the most part—except for one—2.8 billion years old. The solar system, of course, has been known for many years to have an age of approximately 4.6 billion years.

The first three minerals brought back on the two flights agree in their percentage pretty much with what we find here on the earth. But it was very surprising to find that the iron titanium oxide, called ilmenite, was in a very high concentration in the areas where we found it, much higher than where we could find it naturally here on the earth. I am not sure it means it would be profitable to mine titanium on the moon, but the thing it does indicate is that the chemistry is apparently different between these two bodies, and this has something to say about the origin of the two.

Evolution of Moon

When we look to the evolution of the moon we are interested in the time span of activities. As we look to this category, the large-scale evolution of the moon, what we are interested in are questions like this: "Did the moon ever totally melt—the whole body, itself?" "Does it have any internal structure the way that the earth does with its crust and the mantle and then an inner core of iron?" "And what are the differences between these highland areas that we haven't visited yet and the mare areas?"

In order to get this subject, we need to establish different seismic chains of stations which would be in different places which will enable us to look at the vibrations that come back from the moon that are created by impacts. So in order to do this we have to go and visit different places. One interesting thing came up on Apollo-12. They had a magnetometer, which was to detect the presence or absence of a magnetic field. They found a magnetic field and it was about 10 times what we expected it to be.

As we take these experiments to different places on the moon, and we find perhaps the same orientation of the magnetic field, then we can draw some conclusions about the evolution of the moon. By looking at the rocks that are near the surface, we can also tell a good bit about the evolution of the solar system. Because the sun, itself, emanates all these particles continuously, called the solar wind. By looking at their composition in rocks of different ages, we can tell what has been taking place in this solar wind or these particles that have been emanating from the sun.

As I said, the experiment that we left was a seismometer. It worked for about a month. Apollo-12 left a seismometer on the moon also and gave us some very fantastic and unexpected results. The upper line shows a trace of a seismometer for an event like an impact or a landslide that would occur on the earth. It would cause a rapid build-up in the vibration and it would die off quite rapidly in terms of four, five minutes. It doesn't happen that way on the moon.

This result was produced by the impact of the ascent stage of the lunar module after the guys lifted off from the surface and they joined together. They intentionally caused the ascent stage to impact the moon some 75 miles away from where the seismometer was. I tell you, the scientists that saw this result after this impact thought there was something wrong with their machine back here on earth, and they started looking at it, and couldn't figure out what possibly could have caused this. They are coming up with various theories.

One guy is saying that perhaps the moon is hollow and there is a big gong inside and when it gets hit, it vibrates. It looks like water on the earth has a significant effect on the damping of these vibrations and, of course, there is no water on the moon. The cohesive nature of the surface of the moon, as I have indicated, tends to cause these waves to go round and round and to not diminish as much as they do here on the earth. But this was a very surprising result.

And, of course, they are building theories about this. Why does it last for 57 minutes, something like that. They had them all set up, and then on Apollo-13, the upper stage of the rocket was intentionally impacted on the moon again and it landed, I think, about some 100 miles away from this same seismometer. Well, what happened then? It lasted for four hours. So they are going back and revising all their theories now.

As we look to the question of the origin of the moon, there are three theories that come to mind. The first is that the moon at some time was captured by the earth. It was a wandering body going through the heavens and happened to come by our solar system and come close enough to the earth and initially had a very large orbit and then this orbit slowly went to a circular one. The chances of this happening are very, very infinitesimal. Of course, there's been a long time for things like this to take place, but it is a very low probability one and there are a lot of moons orbiting the various planets of our solar system. To expect that each one of them was captured in the same way and in the same very similar orbits requires a good bit of building up your case to convince people.

Second Theory

The second theory for the formation of the moon is that it broke apart, and this is called the fission, or separating, theory. If the moon did break apart at some time after the original formation of the earth, we would expect to see the chemistry to be about the same. But we find in certain characteristic minerals that this is really not the case and it tends to make the people think now that perhaps the moon did not break away.

The third theory is that at the time that the earth formed by condensing the gases into rocks the moon was also formed. And there are variations of all three of these theories. I guess we have to continue to gain more information about the internal structure before we will really be able to say what the origin of the moon is. So these are the things that we have been talking about, the unusual features, the ones that we haven't seen too much of up close, the highland areas that we expect to visit on the next trip, the mare areas. We have been there twice and we know a good bit about continuous processes of bombardment that wears rocks down, that creates glass. It churns up the surface. We know that the other process is volcanic. It produces the rocks deeper down underneath the surface. Perhaps the origin of this vulcanism may be the impacts of larger meteorites. The evolution of the moon, we know a little bit about that, but we need to get more stations around at various places before we can really tie this together. The origin of the moon, we are very interested in because it tells us a good bit more about the origin of the solar system.

(Col. Aldrin then showed a film.)

On Apollo-16, we hope to extend our range of moving around on the surface with the use of a roving vehicle, battery powered. It has four wheels, will enable us to move to about a five-mile radius from where we land. Of course, we always have to consider that the batteries may go out or something may happen to it and we may have to walk home. So this generally limits our total radius of action, even though we do have a wheeled vehicle.

As we look further to the future after we complete our landing program on the moon, we will be making use of the equipment that has been developed for Apollo in a program called Skylab. The upper stage of the Saturn V will be converted into a very preliminary or very initial space station. From this, we will be able to study much more about the surface of the earth, looking at things like pollution in Galveston Bay and so forth.

Following this, our hope for the future is called a space shuttle. It is a two-stage rocket. Both stages have wings and as the first stage burns out, it comes back and re-enters the atmosphere and lands on a runway, is serviced, and is used again in about two weeks. Probably we won't have a man in that first stage. The upper stage, of course, will have a crew of two and carry up to 12 passengers, up to about 50,000 pounds, will rotate men and equipment up to space stations that look like cylindrical objects, with electricity provided by solar panels for the station.

As we look a little further, we will see things like space tugs that will be used to move space stations to different orbits, to synchronize orbits, perhaps. Another use of the space tug is to equip it with landing gear and take it to the vicinity of the moon and have it conduct a landing. Here again the key to this economy in operation is reusability. We would reuse these space tugs. Both stages—it is a one-stage vehicle—takes off, goes back into orbit, and is reserviced.

In order to provide the fuel and space stations in lunar orbit, we are looking toward the development of a shuttle back and forth from the earth to the moon. And we are looking very favorably toward nuclear propulsion to do this. Now, all these little building blocks hopefully will give us the capability to put together a program that may one day see man on Mars.

Shearon Harris Elected Vice President

(Continued from page 201)

1941 and 1943, Mr. Harris served as principal clerk in the North Carolina House of Representatives. He was the representative from Stanly County in 1955.

He was elected vice president of Carolina Power & Light in 1960 and a member of the board of directors in 1961. In 1962 he became general counsel and was elected president of the company in 1963. Mr. Harris was named chief executive officer in 1969 and chairman of the board this year.

Mr. Harris is a director and member of the Executive Committee of the Institute, a former chairman of the board of directors of the National Association of Electric Companies, and chairman of the Southeast Regional Advisory Committee of the Federal Power Commission.

A prominent Baptist layman, he is a deacon and Sunday School teacher at Hayes Barton Baptist Church in Raleigh. He is a director of the North Carolina Foundation of Church-Related Colleges. During 1966 he served as president of the North Carolina Educational Council on National Purposes, Inc., and is presently a director. He is chairman of the board of trustees of Meredith College and former chairman of the College's Board of Associates, a fund-raising group. He is a member of the National Resources Committee of the United States Chamber of Commerce, and is also president of the North Carolina Citizens Association, and director of Wachovia Bank and Trust Co. and the Durham Life Insurance Co.

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