Rocket Science

?

Maybe a Little

Experiences In The Space Trade

Norm Walker

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INTRODUCTION

The following pages provide an account of experiences working for various military and space program contractors. The account essentially covers the years of the Cold War between the launch of Sputnik in 1957 and the collapse of the Soviet Union in 1991.

The Cold War actually began in 1945 as action in the European Theater of WW2 wound down. The Soviet Union was not content with surviving WW2 (with help from the USA)) but was intent on spreading their influence and Communist ideology as far as possible throughout the world. USSR did not demobilize their huge army after WW2 as we did but was using it to force Communist rule on East Europe and any other bordering countries. They were also developing a nuclear arsenal and means for delivering intercontinental warheads. Their conventional military forces were being upgraded with superior jet fighters and an advanced technology submarine fleet.

In response to these threats, the U.S began a decades long upgrading of our naval, air and ground military forces. We also built and maintained a nuclear weapon and delivery capability to always stay ahead of the Soviets. Much of this activity involved development of hundreds of rocket designs s of various sizes from shoulder fired to the mammoth Saturn V, 400 feet tall. The Space Program although dubbed non-military was actually a large part of the competition with the Russians and played a part in the eventually economic collapse of the Soviet empire.

My involvement with rocket programs was almost an accident. As a farmer, belatedly armed with an engineering education, I expected to try for a career at an agriculture related industry like John Deere. A glance at a newspaper adds for a free interview trip to California lead instead to a 35 year career in military and space programs.

Background

U.S. Missile and Space Programs

Post WW2

HISTORICAL PERSPECTIVE

The Cold War and the Missiles and Space Race

The U. S. emerged from WW2 victorious and as a super power with the strongest military establishment in the world. We had accomplished this with military, industrial and economic strength; and with a unified population.

Unfortunately, the shooting war called WW2, blended immediately into another conflict called the "cold war" that would last for over 40 years.

While we largely disarmed after the Japanese surrender in August 1945, the Soviets did not. Their massive armies threatened the still recovering western democracies, which now included West Germany. Our containment policy, initially backed by our monopoly on the atomic bomb kept the Soviets from mounting a land attack on Western Europe. During the 50's we developed a number of tactical and strategic ballistic missile delivered atomic weapons to supplement our B-52 fleet.

The Soviets after their surprisingly fast acquisition of the A bomb were building a fleet of Bear bombers capable of reaching the U.S. over the Pole. The loss of nuclear monopoly and the rapid Soviet development of nuclear weapons and delivery capability led to an aggressive and sustained American response

The bomber threat was dealt with by construction of a radar warning network, by jet interceptor fleets and by anti-aircraft missiles such as the Nike Hercules.

The Soviet's atomic weapons were thought to be too heavy for use in long range ballistic missiles. The Soviets surprised us by overcoming that problem by building larger rockets. For a time they had rockets much larger than ours. They demonstrated this very unpleasant reality with the injection of Sputnik in Earth orbit in 1957. Obviously if they could do that they could deliver nuclear warheads to our cities. We had no defense against ballistic missiles. Also by now the Soviets had developed the hydrogen bomb.

Our response was to engage in a doctrine known as "Mutually Assured Destruction" (MAD). This meant that we had to have the capability to massively destroy our adversary even after a receiving a first strike. Thus, we lived for decades with our cities targeted by nuclear tipped Soviet ballistic missiles.

The MAD deterrence strategy required the development and building of multiple strategic delivery systems including advanced aircraft, silo protected Minuteman missiles and submarine based Polaris missiles. We used our industrial strength to always keep ahead of the Soviets in quantity and quality of our weaponry.

The Soviets were also anxious to overtake our technology advantage by besting us in space exploration, which also had the alarming potential for space based weapons. For a time they were succeeding. They followed their Sputnik coup with successfully orbiting and recovering Yuri Gagarin. Another "first".

The American public of the 1960 time frame were not willing to let the Soviet advantage in Space capability stand. They readily supported President Kennedy's wild scheme to dwarf the Soviet's Earth orbit games by LANDING A MAN ON THE MOON !!!! And by the end of the decade!

NASA had already been founded and had been developing and building interim heavy launch vehicles. Also we were belatedly matching the Soviets Earth orbit exploits with our Mercury and Gemini programs. However the moon mission would demand booster capability and spacecraft complexity far beyond previous experience. Thus, NASA formulated the plan for design and construction of Saturn/Apollo, a stack of boosters and spacecraft almost 400 feet tall.

Along the way to final success, there were serious set-backs, agonizing delays, test failures and the fatal Apollo fire. After continuous work by NASA, and their contractors; and with support by the American Public, the goal was achieved with the moon landing of Apollo 11 crew on July 21, 1969. The party NASA threw in Huntsville for government and contractor personnel after the safe crew return was memorable. Several more missions were sent to the moon to demonstrate that Saturn/Apollo was no fluke.

The follow-up program was the Space Shuttle. The development of this system would take another decade. Unlike the Saturn/ Apollo, the Shuttle was mostly reusable. However it had only low Earth orbit capability with only modest payload. The Shuttle has been our space work horse for the last quarter century. The program was marred by the loss of two of our orbiters and their crews. The Shuttle now supports the Space Station.

The Soviets could not match our manned trips to the moon and they finally gave up. They also tried and abandoned the development of a space shuttle similar to ours. The cost of the space race and military weapon competition with the U.S. finally forced the economic collapse and dissolution of the Soviet Union in 1991.

The American space program, although non-military, did have an important role in our winning the cold war and mitigating the nuclear annihilation threat. Without the Soviet challenge and associated fear component, we may never have attempted such and ambitious and risky program as the moon landing.

During the years of the missile and space race with the Soviet Union, equipment models quickly became obsolete and replaced with later versions. Many of this long succession of military and space program products are on display at the U. S. Space and Rocket Center in Huntsville, Alabama.

One of the three remaining Saturn V vehicles is now housed in a new enclosure. There is also a standing Saturn V mock-up (shown on the cover). The complete Saturn V. Apollo stack is almost 400 feet high.

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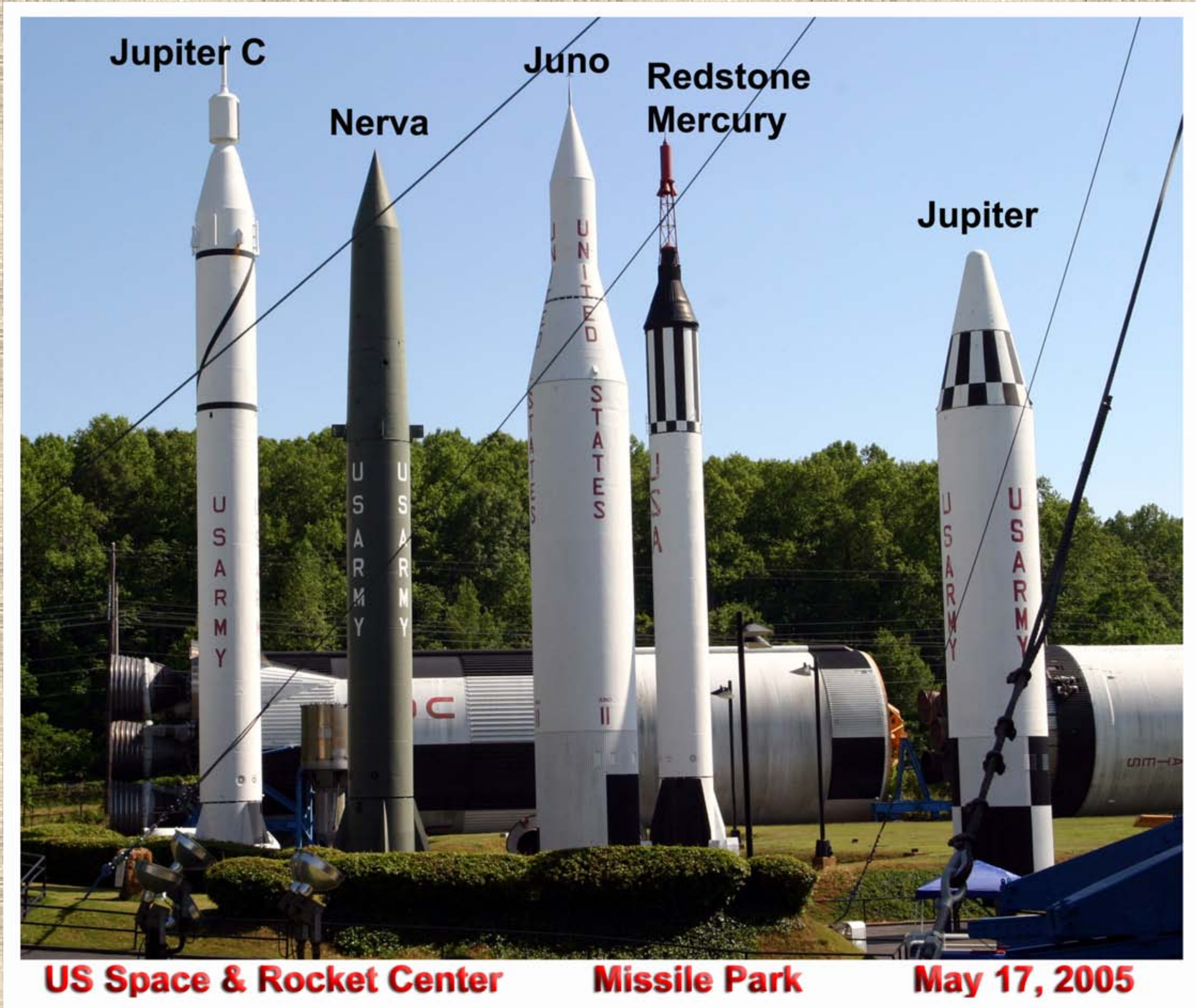


Note the size of the horizontal Saturn V in the background relative to the standing missile arsenal

U.S. Naval Gun Factory

Entry Into The Rocket Business

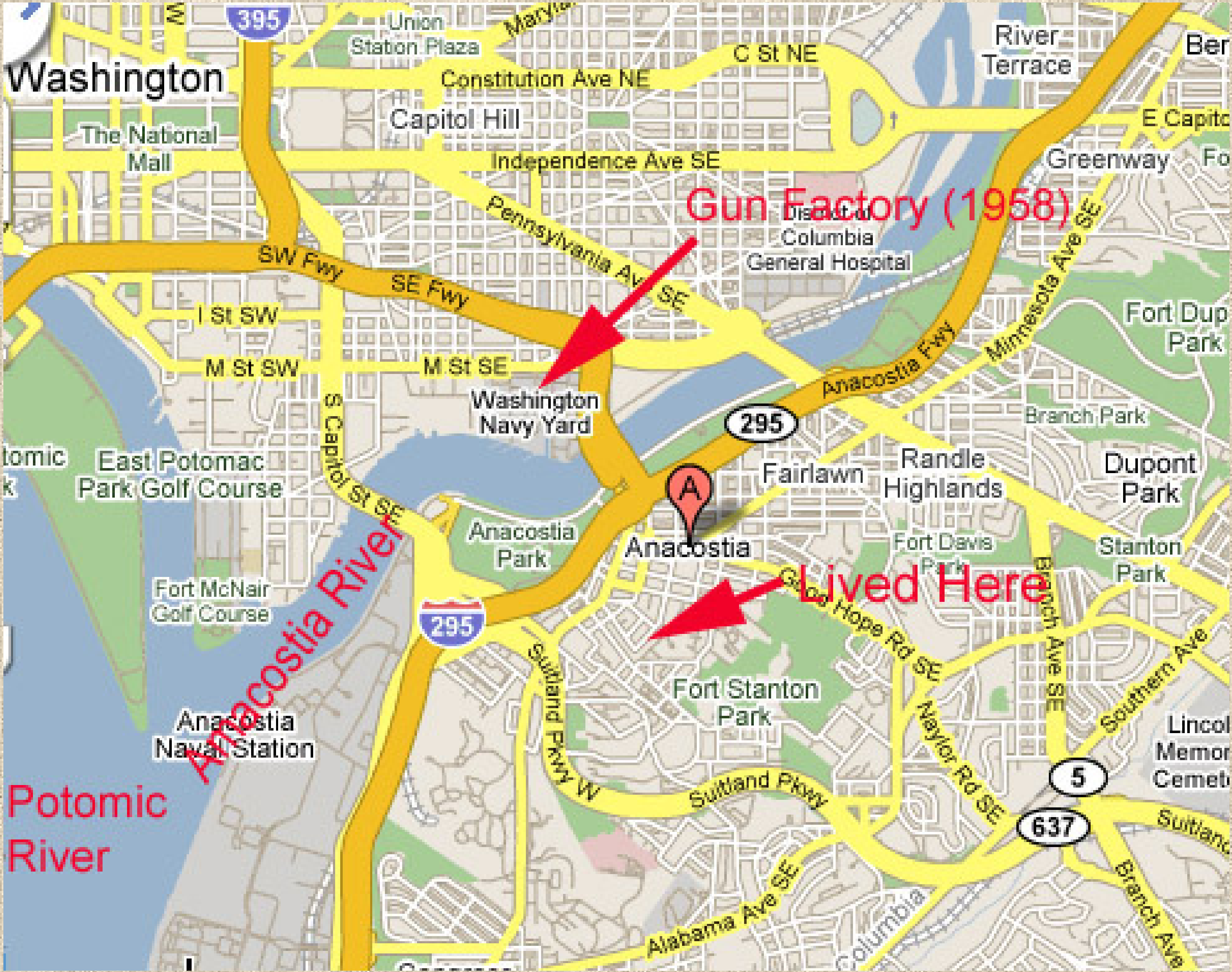
The last two engineering courses at the University of Nebraska were completed in the summer of 1958. The resulting BSME ticket enabled the escape from the family farm scene and opened up the darndest new opportunities. Sputnik really got things going for engineering job applicants. Original expectations were to try for a job at an agricultural related industry like John Deere. However there was an offer on the bulletin board for a job at the U.S. Naval Gun Factory in Washington D.C. No interview or anything necessary, just come !!!! That looked kind of exciting. The 1954 Chevy was loaded up and headed east.

The civil service environment at the Gun Factory turned out to be very slow and reserved compared to the pace at the University. Also large naval guns were definitely going out of style. There was a short but fateful assignment to design a small part for the Sparrow missile. Mention of that miniscule experience at a later interview at Douglas led to a long term specialty.

The papers were full of adds from aerospace companies for engineers They were funding interview trips to their plants. As soon as a few days vacation were earned, I responded to an add placed by Douglas Aircraft who was located in Santa Monica, California.

The interview trip to California was by air. Capital Airlines was flying turboprop Vickers Viscounts out of National (now Reagan) Airport in 1959. Dulles did not exist at this time. National Airport in Washington D.C. was too small for jet airliners that were just coming into use.

An offer from Douglas at a substantial raise was soon in hand. That and the promise of interesting work made the decision easy. Leaving employers in Washington was not easy however. They had been very good and tried to interest me in staying. .



Naval Gun Factory—Washington D.C.

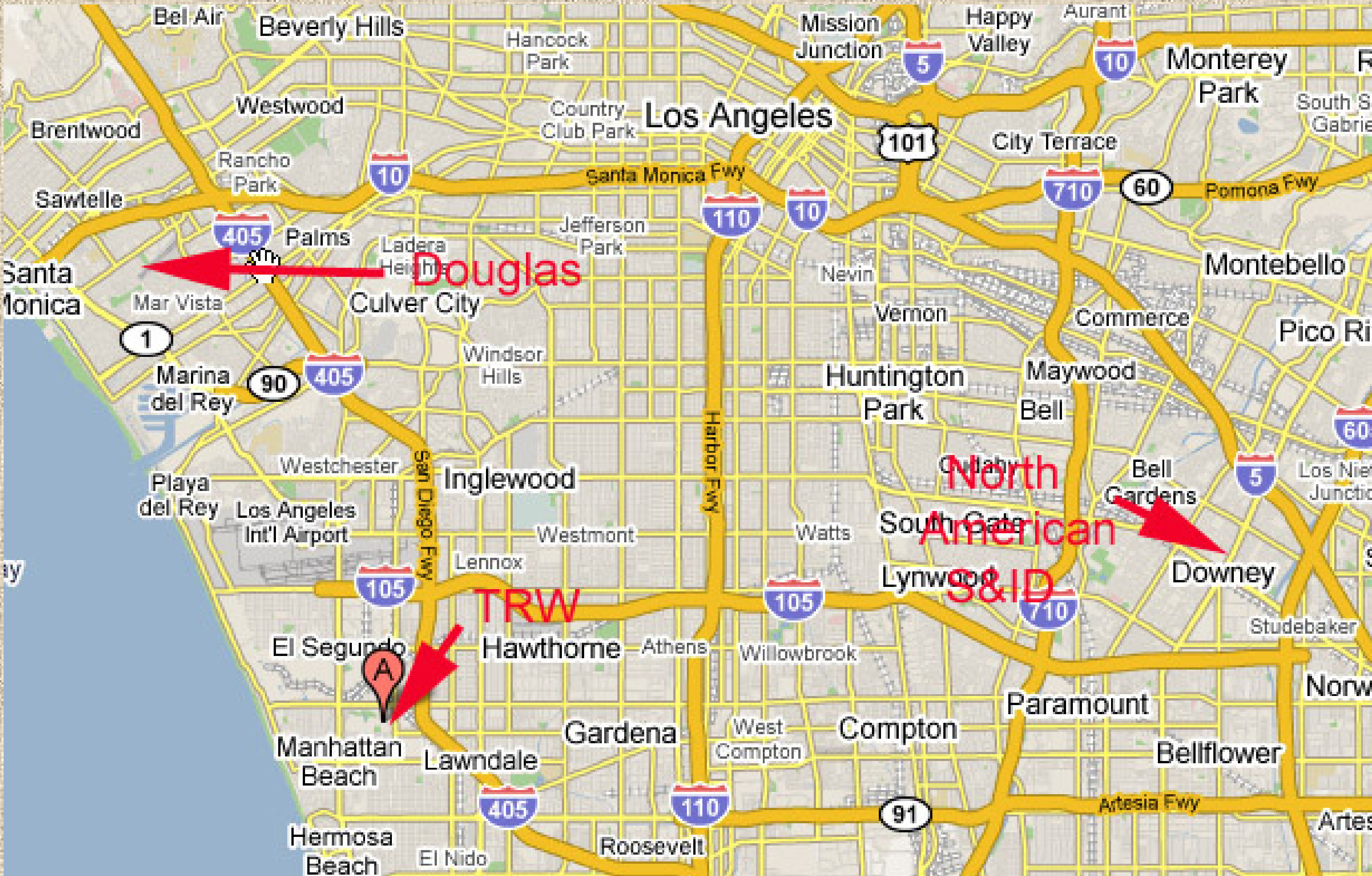
Norman Walker Washinton DC 1958

Not a Congressman, just an entry level grunt at the Naval Gun Factory

Douglas Aircraft Company

Missiles Division

After a short stay at the U.S. Naval Gun Factory in Washington D.C. it was off to California



First Stop —- Douglas Aircraft Corporation - Santa Monica, California

Worries, concerns, failures, luck, close calls, amazement's and occasional success
Douglas Aircraft Corporation, Missiles Division (1959-1962),

Hiring in was a quick process. Queried about experience, mention of the trivial task with the Sparrow Missile in Washington was enough to get assigned to the Armament Group of the Missiles Division.

At the Douglas armament group, engineers designed systems and components on drafting boards. Metal parts were fabricated in Douglas shops and sent to an outside ordnance facility for loading with live materials, usually primacord and sheet explosive. The parts produced were primitive by later standards and had little in the way of environmental protection or quality assurance provisions.

Douglas at that time was functionally organized. All armament engineers worked in the same area regardless of project. This was great place for new hires to quickly pick up knowledge of the trade and to be aware of success and failures of a large variety of components and systems. Some were trying to find ways to use Dave Andrew's new invention "mild detonating fuse" and its early confined adaptation. Others were experimenting with through-bulkhead explosive propagation. Jim Roberts was working on one of the first frangible nut designs. This idea grew to the 3.5 inch ID monsters later used on the Shuttle hold-down bolts. Tom Tersigni was working on an ordnance manifold for an Air Force program. The experience he had was useful later in establishing the configuration for the CDF manifold used for Sat V and Shuttle. Everyone was aware that the sensitive initiators and detonators of the day were far too dangerous. Douglas was working on filtering devices to reduce the chance of accidental activation. After getting the S-4 Saturn contract, Douglas developed the EBW system for MSFC. Work on the early Saturn 1 program and Air Force Skybolt programs began a transition to higher levels of QA and environmental testing.

The Douglas engineers working on the Thor worked at the old aircraft plant in Santa Monica. The rest of us worked at a nearby facility called "A2". A2 was swamped with work and new hires were given design responsibility immediately. The Nike Zeus destruct system that I worked on was mostly based on 100 gr/ft Ensign Bickford PETN primacord. Our working bible was the Blaster's Handbook. The old hands warned about non-simultaneous detonation of redundant primacord lines. Internal time delay variation of the hot wire detonators then in use would result in one branch starting before the other. Thus the first branch to go could disable or blow away the redundant branch before it was initiated, "cut-off" they called it. This problem was easily solved by taping

US Space & Rocket Center Nike Hercules

together. 100 gr/ft primacord had the ability to cross initiate. The redundancy concerns, though easily solvable in this case, was a good exercise in thinking through the issue as much as possible. In some cases, on other programs, lack of thinking through the redundancy issue on a complete system basis, resulted in unwanted results. As examples, the Apollo program proceeded for a year with a "redundant" system that required full functioning of both branches of a separation system. Reliability engineers altered the timing of firing signals for the S-II separation system (for the Skylab launch), defeating the intended redundancy capability. Timing issues on the SRB hold down bolts were encountered as late as 2008.

Douglas Surface To Air Missile Programs

Soon after WW2, the United States and Soviet union began development of intercontinental bombers. USA led the way with the B-36, successor to the B-29 and then with the turbojet powered B-47 and B-52. When the Soviets perfected the A bomb in 1949, there was great concern that the newly developed Soviet Tu-95 "Bear" bomber could launch a nuclear attack anyplace in the United States. The altitude, speed and potential numbers of the bombers would make complete interception by fighter aircraft of that time improbable. More capable interceptor aircraft, known as the Century Series were being designed and tested. However the Army was interested in a surface to air missile approach (SAM).

The Army air defense system against nuclear bombers, to be known as the Nike Project began in the late 1940's when the Army Ordnance Corps assigned responsibility for its development to Western Electric/ Bell Telephone Labs (BTL). This system involved interception of enemy bombers with a ground based missile with a high explosive warhead. Ground based radar tracked both target and missile and after computer processing, provided commands to the missile guidance system for intercept.

The US Space & Rocket Center Nike Zeus

BTL contracted with Douglas Aircraft Corp (DAC) in Santa Monica, CA to build the missile and propulsion components for the system. The first model called the Ajax utilized a single solid propulsion 1st stage and a liquid propellant 2nd stage. This system could effectively intercept aircraft delivered threats up to a range of 25 miles. Many Ajax launch sites were built.

In 1953 the Army contracted with Bell Labs to work with Douglas in exploring the possibility of adding a larger missile capable of carrying a nuclear warhead and extending the range of the system from 25 to 50 miles. The new missile called the Hercules had a booster consisting of a cluster of four Ajax boosters and a new solid propellant 2nd stage. This larger missile ended up with a range of 100 miles. The kill radius of the nuclear warhead would force any enemy to space its attackers to avoid multiple losses. The Hercules was designed to use existing Ajax launch sites. Nike Hercules first entered service on June 30, 1958, at batteries located near New York. Philadelphia, and Chicago. The missiles remained deployed around strategically important areas within the continental United States until 1974. The effectiveness of ground to air missile defenses against aircraft were confirmed in 1960 when a US U2 spy plane was destroyed by a Russian SAM.

Although continuous improvements were made in the radar detection and control systems, Hercules could not defend against the new ballistic missile threat. The hope of an effective anti-ballistic missile defense rested with development of the next Nike, the Zeus. Unfortunately the Soviets could expanded the number of nuclear ICBMs more easily than we could build defensive systems. The Zeus was never extensively deployed.

The Spartan is a development of the Zeus. It is longer and heavier. The 2nd stage is the same diameter as the booster. It has a greater range and altitude capability. During the 60's There was a series of ideas on how to use the Zeus/Spartan missile system. There was another short range missile, called the Sprint added to the mix. However, growth in numbers and sophistication of the Soviet threat always outpaced the ability of defensive systems to cope. For a very short while a few Spartans were deployed around Minuteman Launch sites. Thus we came to rely on the "massive retaliation" doctrine for our safety. Fortunately the Soviets were not suicidal. The extensive system of Ajax and Hercules sites was deactivated by the end of the 80's .

North American Aviation

Space & Information Division

After three wonderful years of training at Douglas, it was off to a larger project. North American S&ID Division had just won major contracts for the Saturn S-II and Apollo Spacecraft This division was located at Downey, California..

North American Aviation (NAA),
Space & Information Division (S&ID) 1962-

North American later became Rockwell International and still later a part of Boeing. The old Downey, California facility that built the Navaho, Hound Dog, Apollo and Saturn S-II is long gone, the land devoted to other purposes. .

S&ID, located in Downey, CA was split off the main NAA Aircraft operation, located in Englewood, in the years after WW2. S&ID had a major role in the Navajo program which although abruptly canceled in the late 50's, produced major advancements in rocket propulsion, guidance and other technologies. These advancements were applicable to future military and space programs. The growth of propulsion and electronic disciplines at S&ID led to the spawning of other major NAA divisions, including Rocketdyne, Autonetics, and Atomics International.

By the spring of 1962, S&ID had two back to back contracts for the Apollo spacecraft (from NASA JSC) and for the Saturn V second stage (from NASA MSFC). They likely anticipated wining only one but not both programs. Handling the huge Apollo task alone would have taxed the relatively small company.

Having the booster program as well, stretched human resources very thin. Middle management engineering positions were often filled with former shop personnel. The S-II was the most challenging of the Saturn V stages. The S-IC, although huge, was built on older and well tried technology. The Douglas third stage S -IVb used liquid hydrogen propulsion, but a similar stage had already been built for the previous Saturn 1.

The S-II, 80 feet long, used five liquid hydrogen engines. A propellant tankage system had to be built utilizing a common bulkhead to separate liquid hydrogen and liquid oxygen. New aluminum welding techniques had to be developed. The S-II proved to be a troubled program and was perpetually behind schedule, driving the Germans at NASA MSFC berserk. Frequent management changes (customer driven massacres) were endured. Two major test stages were destroyed by misadventure, precluding attainment of needed data.

There was momentary relief when the NSA JSC program across the street in Downey suffered a greater disaster, the Apollo fire. The fire caused a break in the over demanding S-II schedule that allowed S-II systems engineers to correct the most vexing problems. With the drop dead date for the first Sat V launch at hand, the S-II finally arrived at KSC, available for stacking. The subsequent launch went perfectly including the lately delivered S-II (complete with CDF connected ordnance systems).

Although thinned out by too much business at once, the S-II project did have some experienced people in traditional disciplines, but not ordnance. The S-II program required the development of several ordnance systems. So, S&ID had to have an Ordnance Group but didn't know where to put it. By chance they decided on the Electrical Section.

I joined NAA in April 1962, not knowing where I would end up. It was to be on the S-II project, Electrical Section, Ordnance group. The group consisted of a supervisor with only electrical experience and Jerry, a recently hired fellow with rocket engine experience, but with NASA contacts. My experience was blowing up Zeus missiles with primacord. Our task was to design the systems for dual plane separation, ignition of the 8 ullage rockets and destruction of the whole thing if it went astray. And then of course, handle all the tasks associated with sub-contracting the building of the various ordnance components. This was a lot to be expected from this meager assortment.

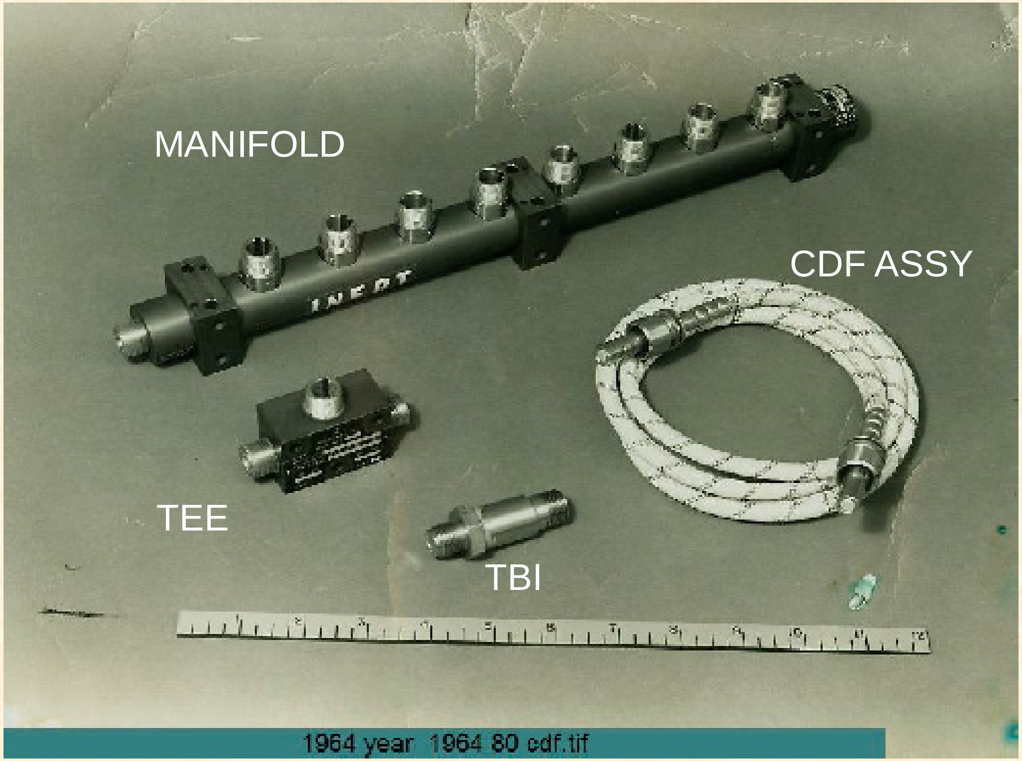
Fortunately Dan Donahey agreed to leave Douglas and join our group and a little later Lloyd Corwin came. Others drifted in but were often more hindrance than help. At first we resisted our aggressive rocketeer associate, Jerry, who had assumed the role as lead man. He knew about the EBW system used on Saturn I. It required a large firing unit, the size and weight of a brick for each rocket motor initiator, two for each motor.

These small motors were used for Ullage and Retro functions on staged launch vehicles. For the S-II there were 8 ullage motors. Considering redundancy, 16 firing units would be required. Jerry also knew about Confined Detonating Fuse CDF and also the unproven concept of the non-electric, thru-bulkhead initiator (TBI) that had been floating around.

To our amazement Jerry talked the NASA Germans in Huntsville into approving a new method for igniting our 8 ullage motors with only two firing units, and two EBW detonators. The detonators would output to ordnance manifolds, with 8 connecting CDF lines led to the motors. The CDF lines would initiate the TBI's, resulting in ignition of the motors.

This system, if it worked, would save a lot of weight, electrical power and money. Although eager to work on the system, Dan and I thought Jerry had oversold it in his discussions with MSFC.

We knew that our friend Bob Sullivan at Douglas had a rough time with the Germans when inevitable trouble and delays were incurred in developing the EBW system for Saturn 1. Instead of cautioning our customer that time and effort would be required to develop and qualify the new system and that failure was possible, Jerry told them that it was such a slam dunk that our system should be used for all three Saturn V stages. There were 22 total small motors on the Sat V stack, so the total saving would really be significant, 44 heavy and expensive EBW sets reduced to a handful.



This is only part of the ordnance devises and systems Dan and I were working on at North American. We also had separation and Range Safety (destruct) systems to deal with.

S-II Separation System

The S-II separation system turned out to be troublesome with a number of problems, some unexpected. The structures people had been working for some time on the basic S -II, for proposal purposes. Now with the contract in hand they were finalizing the design. The dual plane separation concept, probably MSFC directed, was in place. The reason for dual plane separation was to lessen the chance of collision of the departing lower stage from the J-2 engines on the S-II. First separation would occur at the base of the S-II engines. The 2nd separation 30 seconds later, removed the interstage structure, getting rid of 11,000 pounds of unneeded weight. Loads through the separation interfaces were to be carried by 216 hat stringers. The Structures Group had given no realistic thought on how available ordnance could be used for the required stage separation.

The separation joint structure design was well along by the time I came aboard in April 1962. The structures people were receptive to my suggestions that their planned heavy “one directional” inside mounted LSC was not a practical idea. LSC is “one directional” in its cutting ability but not in its blast effects. Their concept amounted to a mini destruct system. They agreed to use butt fittings at each stringer to carry the compressive loads. A thin band would bridge the stringers on the outside to carry the minor tension loads. Thus we only needed to sever .080” 7075 T6 aluminum straps instead of half inch structure. Outside installation would avoid most of the debris problem.

Since all ordnance systems on the Saturn were required to be redundant, this issue had to be addressed. Something other than taping two round charges together had to be used because of orientation and standoff constraints of LSC which has a V cross-section. The V has to be open toward target and positioned at a very specific stand-off. With the initial concept of a continuous tension band around the S-II, side by side installation of LSC would result in a left-over band (or bits with the eventual strap design) flying off in uncontrolled directions. This might have been acceptable for first plane separation but definitely not for the second separation which was above the main engines and many systems. So, it was concluded that redundancy requirements had to be met with a single cut for each separation plane. Thus, the idea of the "piggy back" arrangement of two LSC lines supplemented by initiation from each end of the assembly.

Before writing the procurement specification for the LSC assembly, feasibility tests were conducted at the North American test lab at Downey. A test plan was written calling for segments of a candidate LSC main charge positioned on a plate, the gaps being bridged by a smaller LSC segments nested on top. The LSC readily cross- propagated both ways. Fortunately, the presence of the upper charge did not affect the cutting ability of the lower charge.

The procurement specification was written around piggyback LSC, grain size TBD appropriate for the specified target material. Explosive Technology won the contract. I do not remember if they repeated any piggyback cross-propagation tests during development. If remembered right, they selected 15 gr/foot RDX, topped by 10 Gr/ft RDX to cut a .080 thick strap of 7075 T6 aluminum.

In the pre-spec feasibility testing at North American, various materials were introduced in the stand-off region of LSC. This did not seem to affect cutting ability.

Our organization's responsibility for the S-II separation system officially ended with producing the LSC Assembly. Structures was responsible for mounting it on the S-II. They designed a fiberglass clip to hold the Teflon encased LSC down on each of the 216 tension plates. An aerodynamic shaped foam cover was placed over the LSC and clip installation. Their intent was to use soft retaining and covering materials to minimize the effects of debris generated by detonation of the LSC.

We had known about the extreme temperature changes the mounted LSC and support structure would encounter from mild Florida when installed to frigid cold after loading of nearby cryogenic propellants. Thermal contraction would tend to lift the LSC away from the tension plate. Later we found out that the separation structure expanded during launch loading. That would stretch the LSC and possibly cause it to break. At SI-C thrust tail-off, the separation structure would again contract, putting the LSC in compression and causing it to lift off the tension plates. LSC like all shaped charge products is sensitive to stand-off from its target. A shaped charge needs a specific space to form the stream of hyper-velocity metal particles that penetrate the target. The shaped charge can not be too far away either to be effective.

For the S-II separation System application the desired stand-off and orientation was designed into the Teflon backing material. This backing held the LSC in the correct orientation and also provides the stand-off. To preserve this essential stand-off, the S-II installation design had to assure that LSC Assembly be securely in contact with the tension plates. All of our test history, including qualification was done with the LSC at the correct stand-off. We had not tested for lifted or adverse mounting on the tension plates.

The fiberglass hold-down clips that Structures intended to use were worrisome for two reasons. They were inherently weak and also the fiberglass construction is subject to processing variations. A much stronger and dependable steel clip was needed. The obstinate resistance to this change jeopardized the success of the separation system. It had taken three years of work to overcome many problems. This included stellar dedication and cooperation by Explosive Technology to deliver a viable product. Now that effort was to be negated by petty organizational rivalry at North American.

This issue became contentious and resulted in a departmental meeting including the managers of the affected Electrical and Structures organizations. All the material brought to support the case for more appropriate clips was rejected. Organizational tranquility trumped technical merit. The troublemaker engineer was put in a well deserved management doghouse. That issue was settled as far as local management was concerned.

After a gloomy few months another meeting with Structures was called. A folder of material was carried along in hopes that there would be a safe chance to change some minds. The folder did not even need to be opened. The meeting was very short. No explanation was given for a reversal of plans.

Structures management announced that they were proceeding with design and installation of robust steel clips on both dual plane separation joints. This decision would require rework of some interstage structures already fitted with fiberglass clips. I do not know what happened to cause this turn-around or who intervened. It must have been someone in higher authority who understood the problem. It could have been NASA MSFC, our customer. If so, that would be another example of their superb oversight and management performance in those days.

Since both the most critical ordnance hardware were now on their way to success, it seemed prudent to think about moving on. The fight over the LSC Assembly clips had further damaged an already fragile relationship with local management.

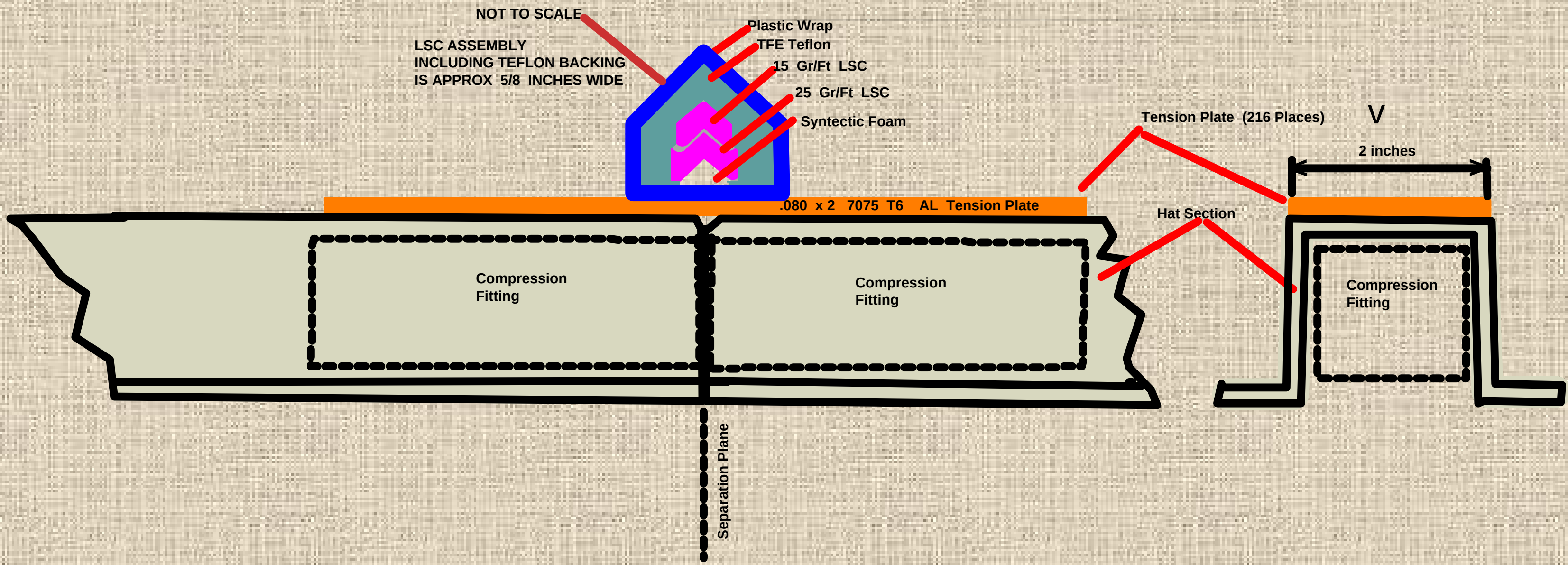
Our work load was mostly dictated by program requirements and very little by regular inputs by the local bosses. Our communication lines were with our customer in Huntsville, S-II subcontractor procurement, and sub-contractors. We should have tried harder to include our boss in our work.

TRW Systems would be the next stop.

SATURN V S-11/SIC DUAL PLANE SEPARATION

1ST Separation at exit plane of S-2 J-2 Engine Nozzels

2nd Separation above J-2 engines, below tankage



NOTE: Not shown are the steel spring clips that hold down the teflon backed LSC firmly at each tension plate.

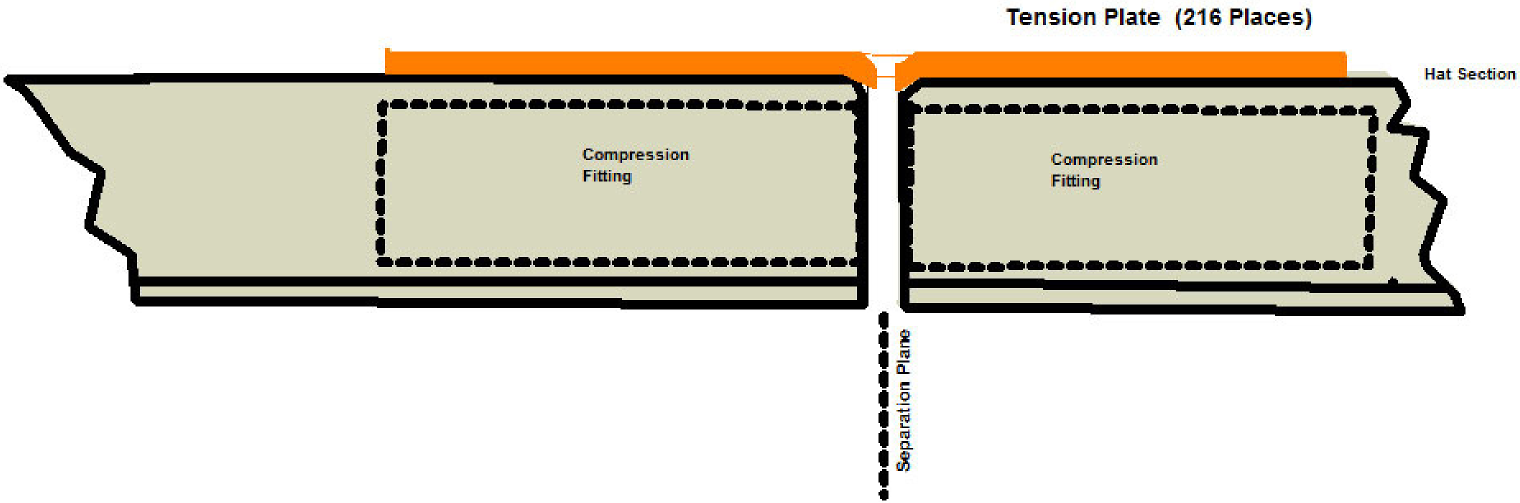
Also not shown is the frangible fairing that covers the externally mounted assembly.

SEVERED JOINT

SATURN V S-11/SIC DUAL PLANE SEPARATION

1ST Separation at exit plane of S-2 J-2 Engine Nozzels

2nd Separation above J-2 engines, below tankage



S-2 FULL SCALE SEPARATION TEST (Photo From Private File)`

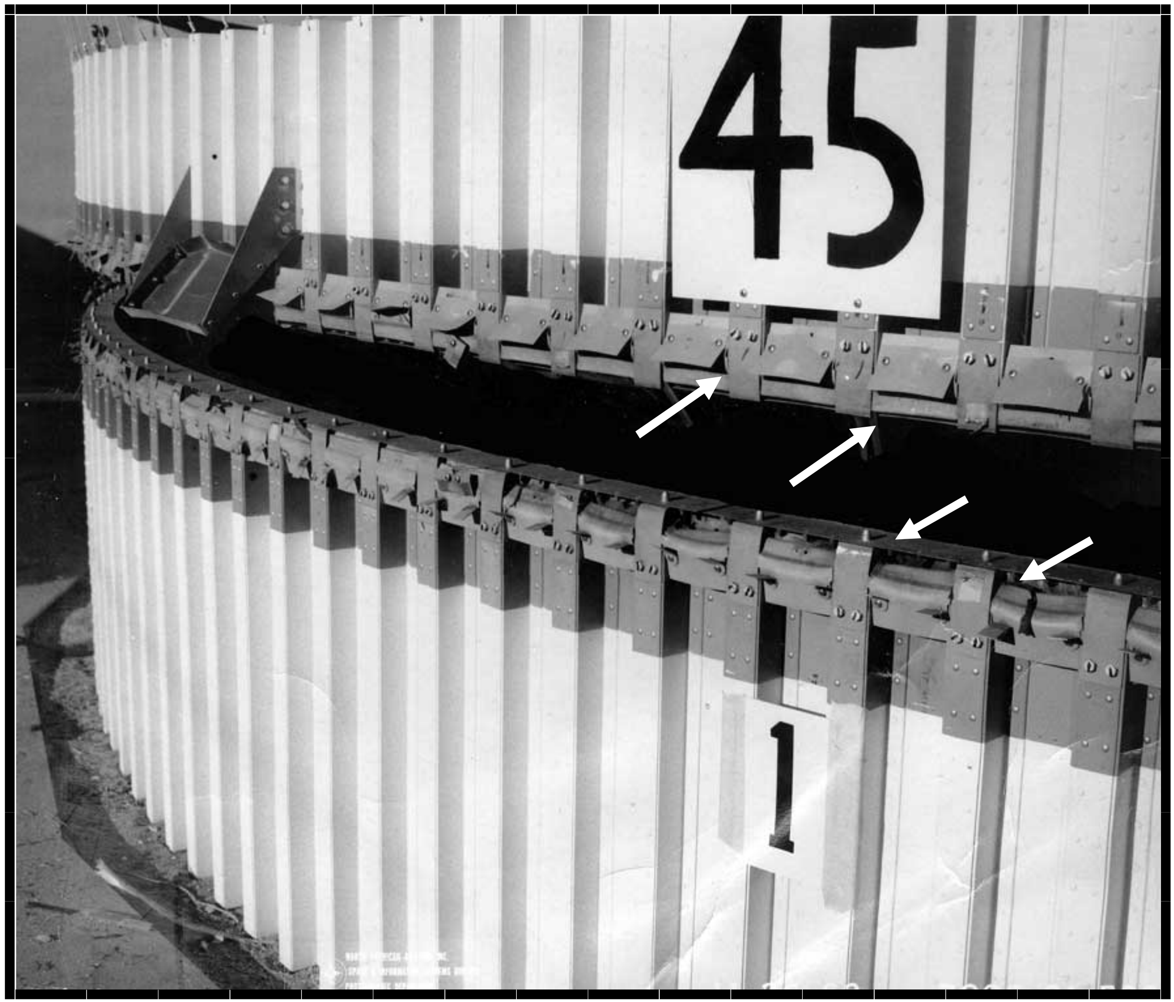
This is a pre test photo of a full scale separation test conducted at El Toro, CA in November, 1963. The photo shows the installation of a preliminary design Linear Shaped Charge Assembly on a test fixture. The fixture simulates the structure of the two separation planes on the Saturn 2nd stage.

The LSC Assembly was later redesigned several times and tested extensively in environmental conditioned test set-ups, but in a straight line. One of the objectives of this test was to evaluate the feasibility of installing the LSC assembly in the manner shown in the photo*. The reel of LSC was mounted on a wheeled cart and rolled around the simulated interstage, completing attachments along the way. This same basic method was later used at the VAB (Kennedy Space Center) for LSC installing on flight vehicles.

Inspection of the tension plates after flights was of course impossible since the stages were dropped in the ocean.

*Tape was substituted for LSC hold-down clips which were not yet available for the test. The mirror was used to examine the fragile LSC element inside the Teflon backing for damage.

This is a post test photo of a full scale separation test conducted at El Toro, CA in November, 1963. All 216 tension plates were severed by the Linear Shaped Charge Assembly (LSC). The test article is not a flight interstage but simulates structure important for purposes of the test. The LSC assembly consisted of stacked 10 and 15 gr/ft RDX linear shaped charge mounted in a Teflon holder. The assembly was over 100 feet long. Note the clean cut in the tension plates obtained with this product. The LSC assembly is normally held snugly against the tension plates by spring clips.



The Assembly then is covered with a frangible aerodynamic fairing. The fairing has been blown away by back blast from the LSC, as expected. The next full scale test of the separation system would be for all the marbles, the first launch of the Saturn V on November 9, 1967. This launch and stage separation (see next page) was the most anxious moment of my life.

Flight Photo of SII 2nd Plane Separation

This is a photo of the real thing. First plane separation had occurred 30 seconds earlier, (detaching the 1st stage). 2nd plane separation occurred just a moment before this photo frame was registered. The photo shows the 11 K Lb. interstage dropping away from the S-II (thankfully without wrecking the mission). Whew!! What a relief !

An early Saturn V launch had cameras installed in the aft portion of the S-II stage. The above still is from the movie film taken of interstage separation. The film package was jettisoned and recovered via parachute. There were 13 total Saturn V launches, the last one for Skylab having only two propulsive stages. On this launch, debris from failed Skylab components disabled the 2nd plane separation LSC. This resulted in unplanned retention of the interstage on the S-II, but caused no problem to the Skylab mission.

CDF ASSEMBLY

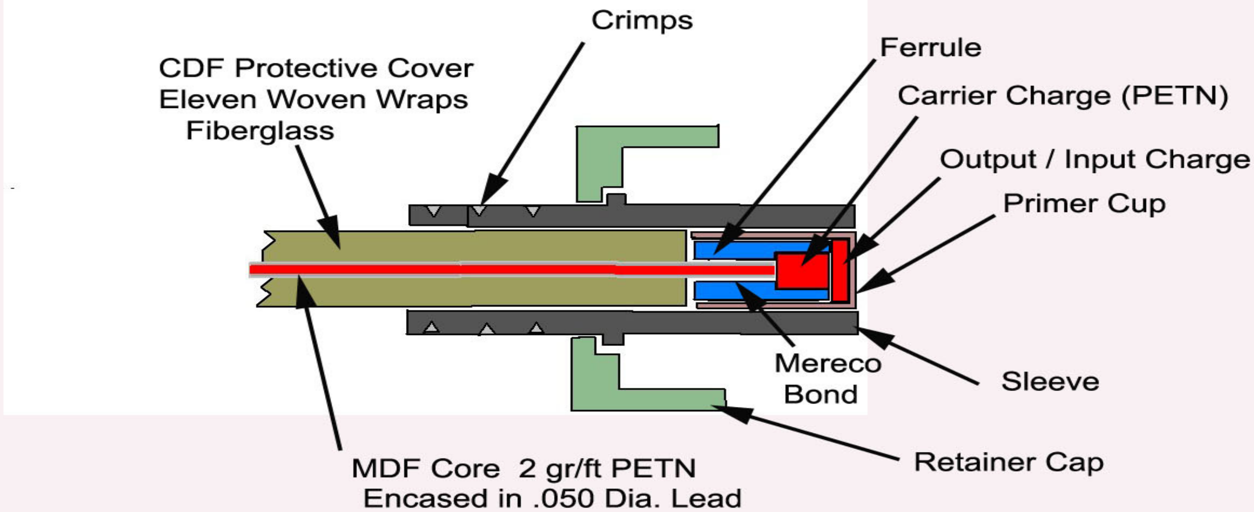
Dan Donahey had a big task in upgrading the original Confine Detonating Fuse (CDF) used at Douglas on the Zeus program. CDF is used to convey a detonation from one component to another without causing any damage in between. CDF is composed of the .050 diameter active core wrapped with concentric layers of fiberglass and plastic. The object is to confine the explosive within the protective wraps. This rope-like component with a ¼ inch diameter is capped at both ends with end fittings. The original CDF would puff out when exposed to Saturn level temperatures. That had to be corrected by Ensign Bickford, the CDF supplier. Revised fiberglass wrapping corrected the problem

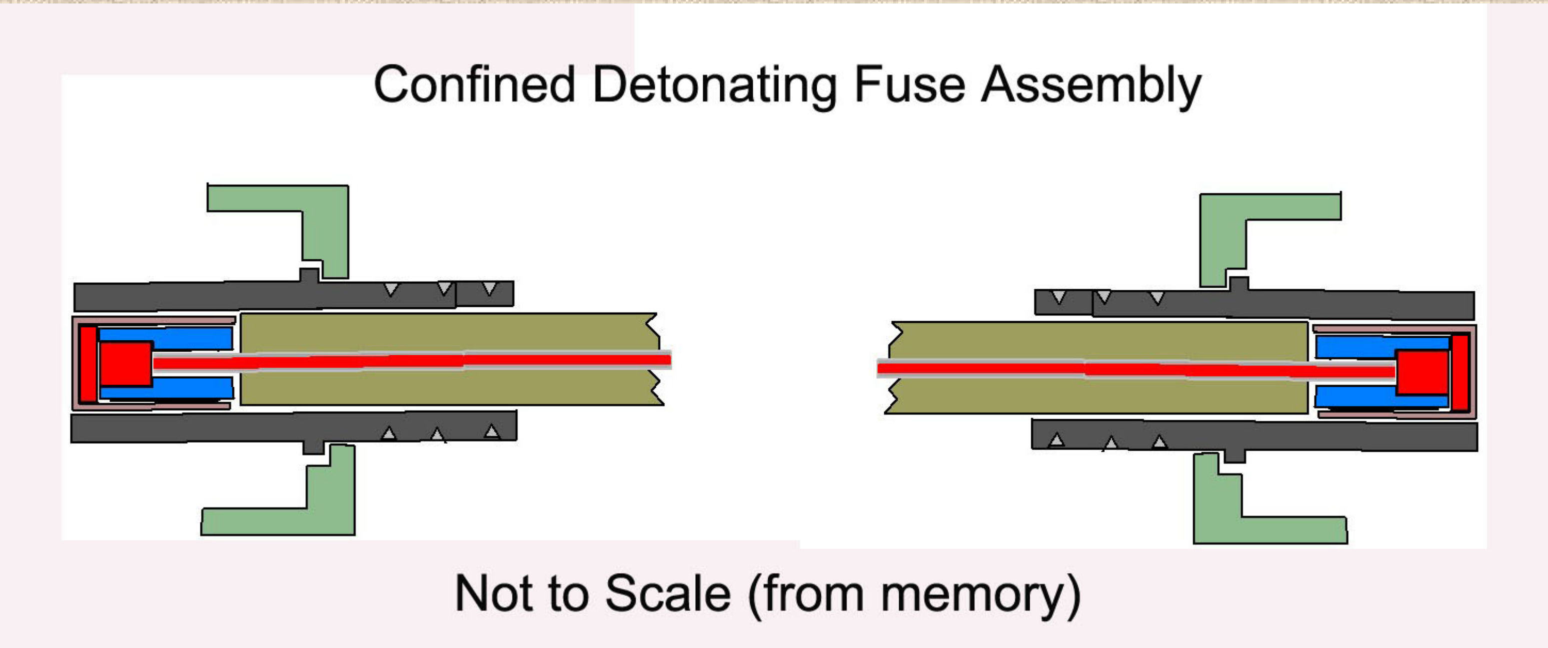
The old Douglas design had end fittings with screw threads that had torque and lock wire requirements. Electrical cable bayonet fasteners were tried to simplify field installation. This neat idea almost worked. Unfortunately the end fittings would back just a little bit out of their receptacle when fired. So back to a threaded nut to hold the end fitting in place, but with a gimmick. A ratchet device borrowed from hydraulic line hardware was fitted to the CDF. It worked. The assembly could be installed without tools, torque checking or lock wire!!!!

We remembered that a Douglas CDF Assembly had accidentally detonated as a result of static electricity. A locally made CDF assembly was to be tested at Special Devices in the desert north of LA. It was a frosty morning when a worker dragged the assembly across the plastic seat cushion. It popped. Even though this unit used a more sensitive material than the PETN used for the Saturn CDF variety, it was better to be on the safe side. Therefore the requirement was put in the CDF procurement specification to provide internal electrical bonding to preclude any sparks near sensitive materials. The electrical bonding feature also permitted the inclusion of a continuity check to final inspection procedures. Positive continuity indicated that the MDF core was not broken.

Another concern left over from Douglas experience is the fear of improper connection of CDF lines with ordnance components. The nightmare is having a motor ignition CDF connected to the destruct system. Requirement for very robust indexing lugs were incorporated in the specification to prevent wrong connections.

When Ensign Bickford won the contract for the CDF Assembly, Dan pursued the program for two years before it could withstand the very severe Saturn environments. Three qualification attempts were necessary before success. Dan also had to develop massive charges that would blast open the liquid oxygen and hydrogen tanks in event it was necessary to terminate a mission. One day when testing the 400 gr/ft Hydrogen Tank LSC, a premature explosion severely injured a technician. Dan had left the test cell only a moment before.


Crimps
Ferrule
CDF Protective Cover
Eleven Woven Wraps
Fiberglass
Carrier Charge (PETN)
Output / Input Charge
Primer Cup
Mereco
Bond
Sleeve
Retainer Cap
MDF Core 2 gr/ft PETN
Encased in .050 Dia. Lead



CDF ASSY

CDF TEE

CDF Initiator (TBI)

The TBI is a device used to initiate solid rocket motors with the input of a detonating cord like the Saturn CDF Assembly. The steel TBI body has two sections divided by an integral bulkhead. A small PETN charge is loaded on both sides of the bulkhead. Detonation of the charge on the input side by CDF will send a shock wave through the bulkhead with sufficient intensity to detonate the charge on the other (output) side of the bulkhead. This must be accomplished with destroying the mechanical integrity of the bulkhead. The output PETN charge must then initiate an adjacent pyrotechnic (flame) charge that is the ignition source for the solid propellant motor. The latter action is called "detonation to deflagration transfer".

When the solid propellant motor ignites, the bulkhead of the spent TBI must contain the pressure without leaking. We were confident that exploratory testing Dan and Tom had done at Douglas proved that the TBI idea was workable. The device just had to be refined into a flight-worthy component. The contract was awarded to Link Ordnance at Sunnyvale, California.

Trouble with two nonsense requirements made development of the TBI difficult and drained time and attention away from a far more important design problem (detonation to deflagration). There are 22 small solid rocket motors on the Saturn V. Only two of these had very fragile igniter baskets. Those two motors were responsible for putting very low and hard to achieve output pressure requirements on the TBI.

The low pressure requirement precluding the use of a conventional pyrotechnic output charge. A more difficult metal oxidant system had to be used for the pyrotechnic output. It was a mixture of magnesium powder, and cupric oxide. When ignited, the magnesium exchanges places with the copper with a lot of heat and ejection of molten copper. That thermite type reaction ought to ignite any motor, or so everyone thought.

The other problem was meeting the over stringent post fire leakage requirement. This test was hard to pass. The tiny bulkhead separating the donor and receptor charges takes a beating when the part functions. Tiny openings can develop in the microstructure of the stainless steel. The test is very severe. 2200 psi nitrogen is applied to the spent unit. If more than 10 cc of water is displaced by the leakage bubbles, the whole lot flunks. None of the units ever leaked more that a few cc's above ten but by the rules an entire Lot of parts had to be rejected. A change from 303 CRES to 321 helped this problem but passing qualification was still worrisome.

To help our struggling subcontractor I attempted to justify a relief in the leakage requirement. The subcontractor for the S-II Ullage Motors was a Rocketdyne Division located at McGregor, Texas. They offered to help with a small test program free of charge. Their contribution would the use of their test facility the use of propellant testers to expose artificial specimens to rocket motor burn. Our Rockwell office pin money was used to have the leak specimens machined at a local Huntsville machine shop. The test specimen was a cylinder with a tapered hole and one end threaded like the TBI. Tapered plugs were also machined to fit the tapered hole.

So, off to Texas with a supply of leak test specimens. The first task was to modify the leak specimens to have know leak rates. The tapered plugs were scored on one side to produce a leak path. The pins were then installed tightly in the leak test body and then hooked up to a nitrogen bottle with the regulator set at 2200 psi. The resulted leakage was then measured by collecting the gas in an inverted graduated receptacle filled with water. Then the calibrated leak test specimen was then installed in the propellant tester and exposed to solid rocket burn environment. Then back to the nitrogen bottle test to check if the leak had increased. Not surprisingly the calibrated leakers no longer leaked. The products from the burning solid propellant was an effective sealant for small leaks.

More test specimens were prepared with leak rates many times higher than our 10cc per minute requirement. The graduated test tube had to be replaced by large containers. Our leak rates were now in the gallons per minute. The propellant tester still plugged them up.

I wrote a report to NASA detailing our experience at Texas and requesting a waiver on the TBI leak test. It was rejected. 25 years later NASA was willing to fly Shuttle SRMs with absolutely humongous leaks. in the field joints. (Challenger disaster).

As 1963 and 1964 wore on Link Ordnance, our CDF Initiator (TBI) contractor was still having trouble.

By this time, our NASA customer at Huntsville was very worried. It was getting late in 1964. Time was running out. The whole common ordnance idea was in real jeopardy. They sent a propellant specialist to Sunnyvale to witness TBI qualification testing. It flunked big time. Our precious little device could not effectively ignite a special solid propellant motor simulator that Art, our friend in Quality Assurance had devised. Big trouble.

Without the TBI, the stage contractors would have to belatedly rebuild their stages with the originally intended electrical and EBW systems. (before Jerry talked them out of it).

EBW detonators would have to be replaced by Saturn 1 type EBW initiators. The contractual costs for MSFC would be immense. The stage contractors relished major changes as a means to get well financially. Our chances of succeeding with the CDF/TBI system had about run out by late 1964.

Redesign efforts at Link Ordnance were not been promising. An emergency meeting at Huntsville was scheduled for December 7, 1964; an ominous anniversary. It would be more like Waterloo for me. Jerry was not around to face the Germans.

However, a break-through only a few days before the meeting saved things. Mas Nakono, at Link Ordnance, was desperately trying to find a way to get the thermite type output mix to ignite effectively before being expelled from the TBI by the PETN receptor charge. He even postponed his wedding to work on our project.

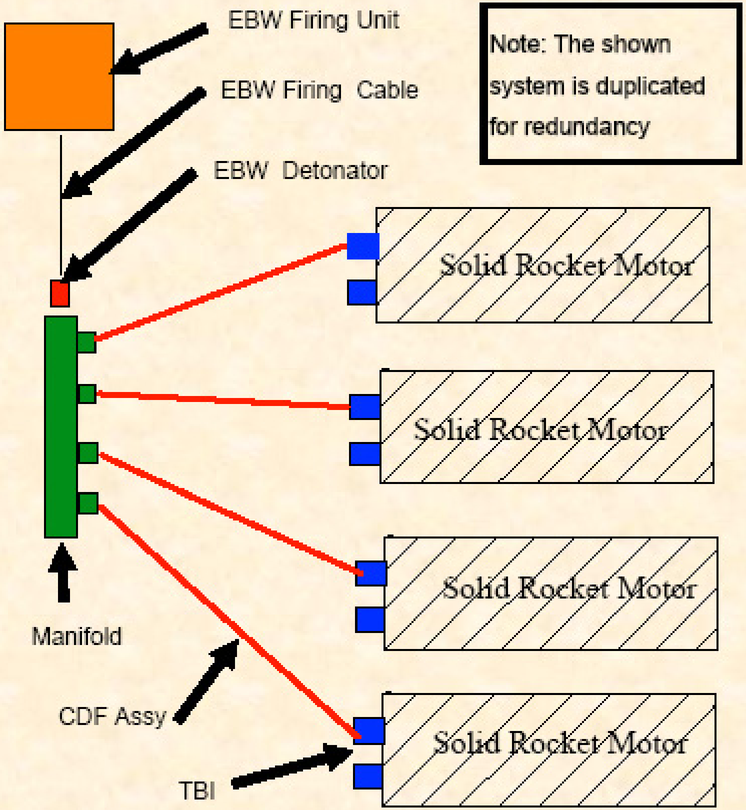
He finally achieved success by placing an empty priming cup between the high explosive receptor charge and the output mix; a design feature dubbed "air gap attenuator". With the good news, the meeting in Huntsville went well. Pearl Harbor or Waterloo did not re-occur.

As a bonus, the trip provided a look-see of Huntsville, the city of residence only 3 years later. Jerry soon saw his CDF/TBI solid motor ignition system qualified and operational, just as he sold it. It is even being used to this day on Shuttle, 40 years later.

Typical 4-motor system. Some systems used 8 motors. There were 22 total solid rocket motors on the Sat V. For redundancy purposed 44 ignition points were required.

Exploding Bridgewire (EBW) was used in lieu of convention initiation devises for all Sat V systems for safety reasons. However the required EBW firing units and detonators were heavy and expensive. For Saturn I, a EBW firing unit and mating initiator was required for each initiation point.

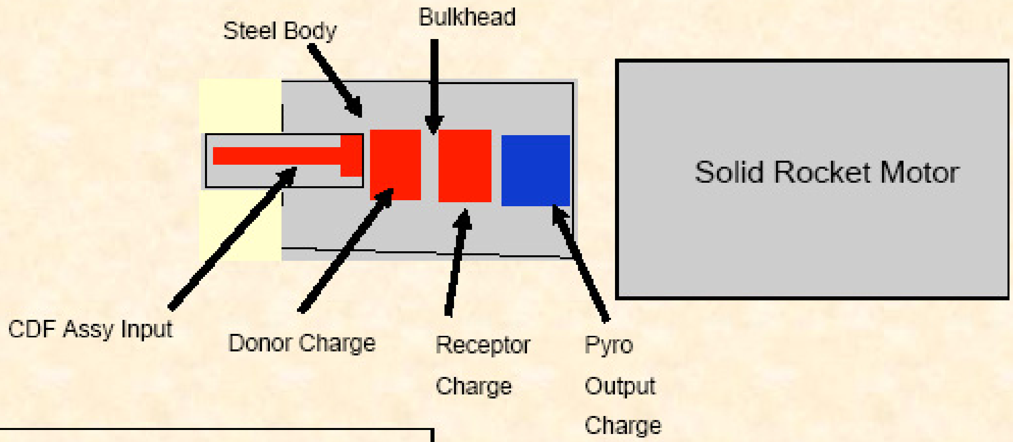
For Saturn V, The number these devices could be reduced by using the relatively cheap and light CDF distribution system and thereby achieve large cost and weight advantages. It would also simplify pre launch checkout at KSC.



That was why the success of the TBI was such an urgent issue.

65

Concept for the non-electric through bulkhead solid rocket motor initiator (TBI)

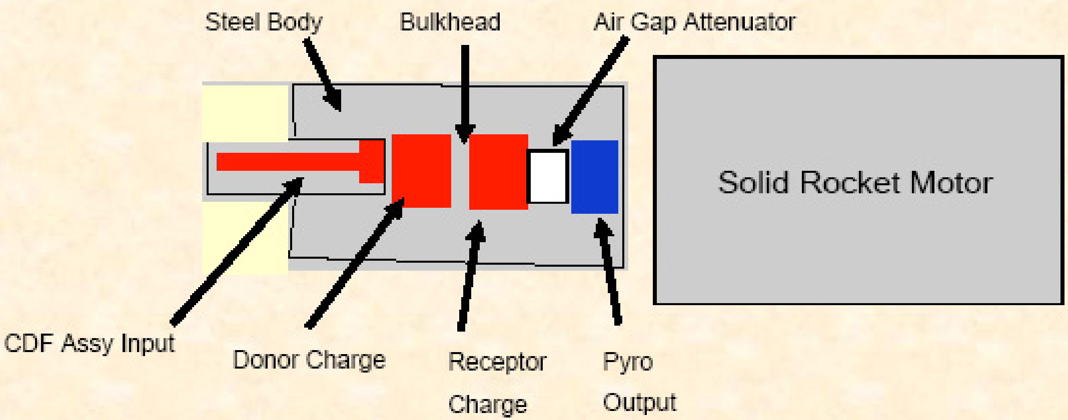


The elements shaded red are PETN
A high explosive material immune
from accidental initiation

The output PETN charge in the CDF Assembly detonates the TBI donor charge. The donor charges sends a shock wave through the bulkhead without rupturing it. The emerging shock wave detonates the TBI receptor charge. The receptor charge ignites the pyro (flame, not detonation) TBI output charge. This flame output is directed to the chain of elements in the solid rocket motor . The TBI body which is mounted to the motor via screw threads remains intact and prevents back leakage from the pressurized motor.

64

Re-design of—solid rocket motor initiator (TBI) Late 1964



The failure of the original design to reliably ignite a simulated test motor was thought to be caused by receptor charge expelling the pyro mix before it was thoroughly ignited . Mos Nakano the engineer at Link Ordnance, the subcontractor, tried inserting an empty primer cup between the receptor charge and the pyro output charge. It worked !!!! To give the design change some credibility, the innocent little empty cup was dubbed "air gap attenuator ". Now, 44 years later this same TBI with "air gap attenuator" still ignites 16 booster separation motors on every Space Shuttle launch. . During my work span we never did have the time or opportunity to find out how and why the little experiment by Mos Nakano worked. He saved our program and we hope that his bride forgave him for delaying their wedding

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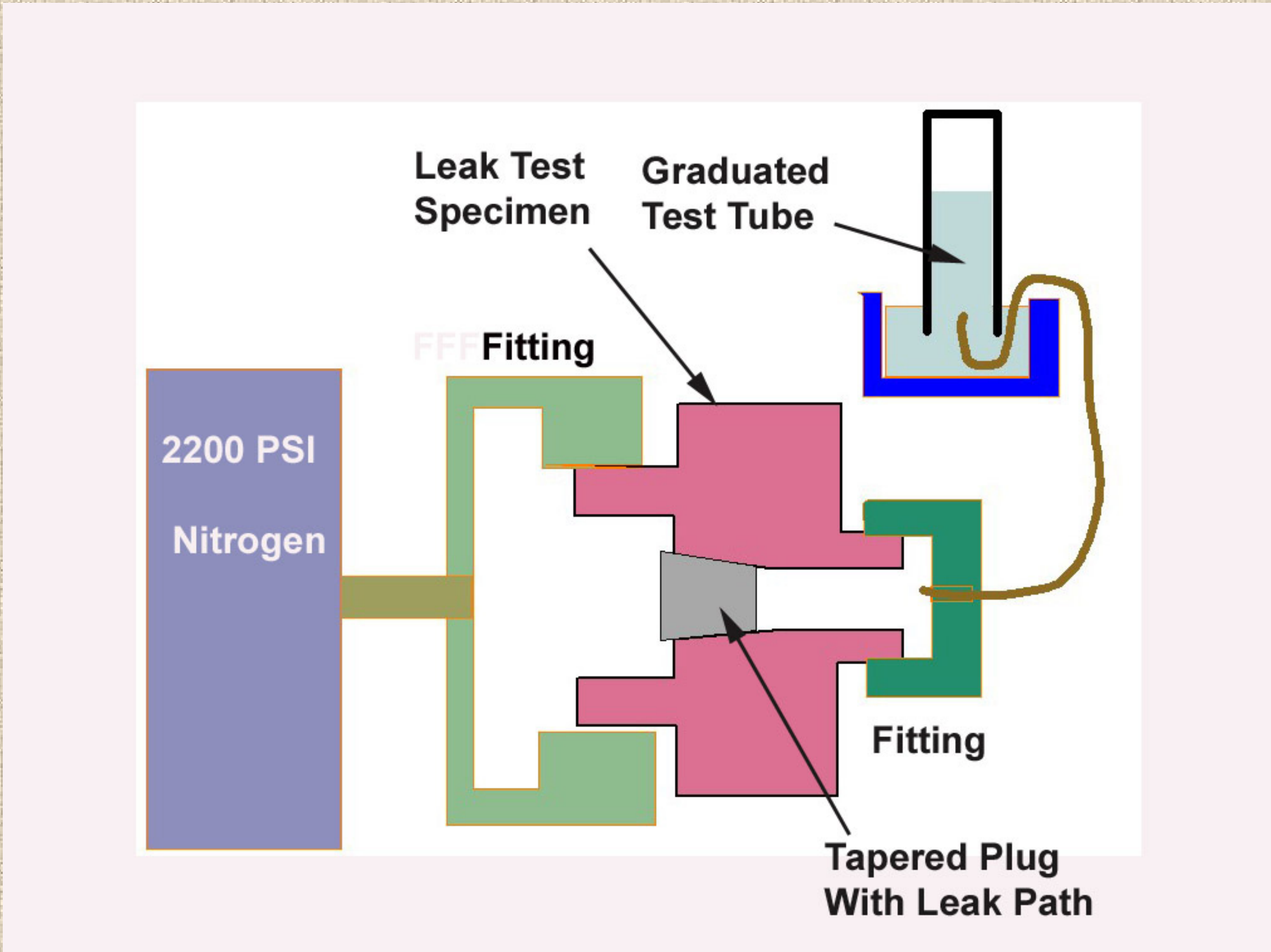
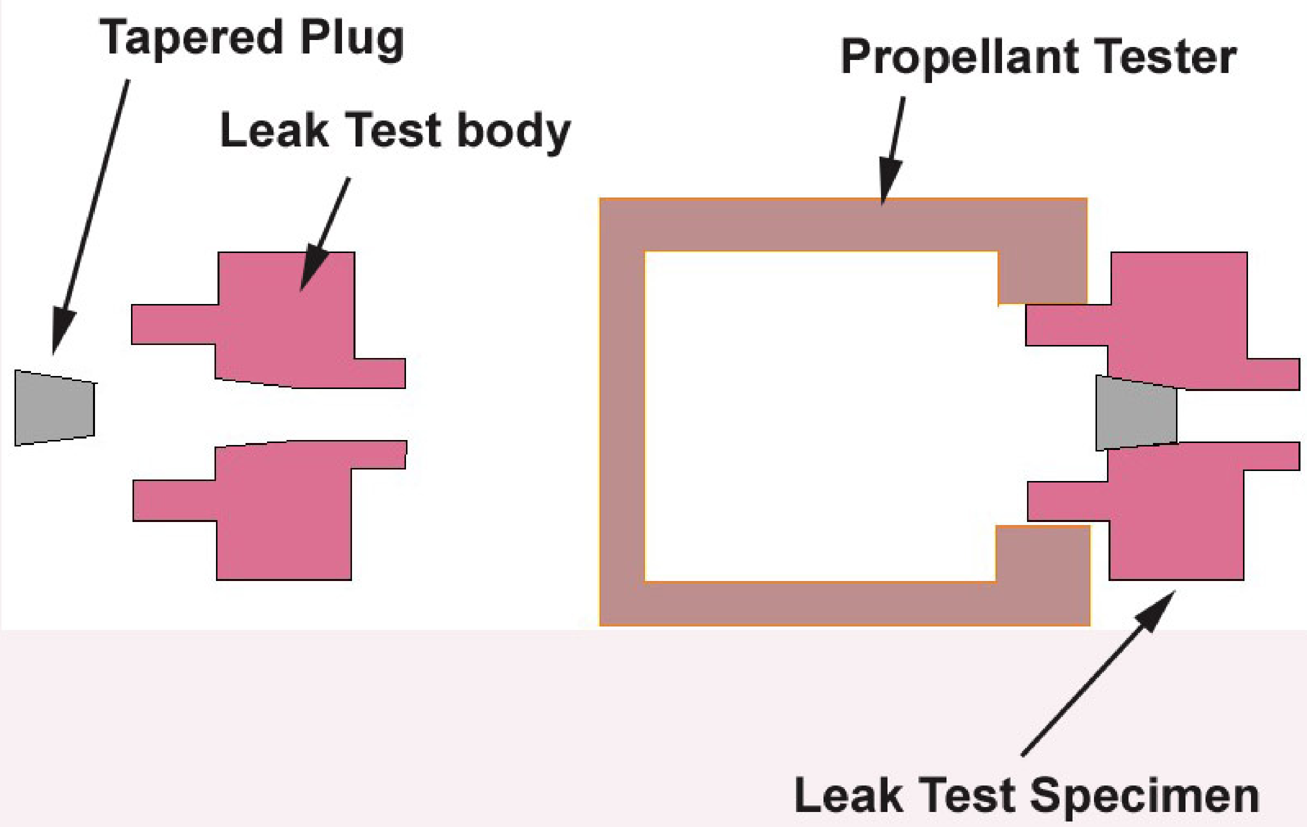


TBI LEAK TEST INVESTIGATION

Set-up for Calibration and Post Fire leak Check



TBI LEAK TEST INVESTIGATION

Set-up for Exposure to Solid Propellant Motor Burn

US Space & Rocket Cent[redacted]RB

Left

The standing Saturn V near I-595 is a mock-up, not an actual vehicle with flight parts. The height of the Saturn V, including escape tower is almost 400 feet.

Next Page

Aft end of giant Saturn V 1st stage showing the five F1 engines. The 1st stage propulsion system uses less demanding RP (refined kerosene) rather than liquid hydrogen as used by the upper stages. Ultra high performance is not as important for lower stages. Lift capacity can be obtained more economically for lower stages by building larger engines.


US Space & Rocket Center
Saturn V
SI-C Stage
May 17, 2005

Next Page

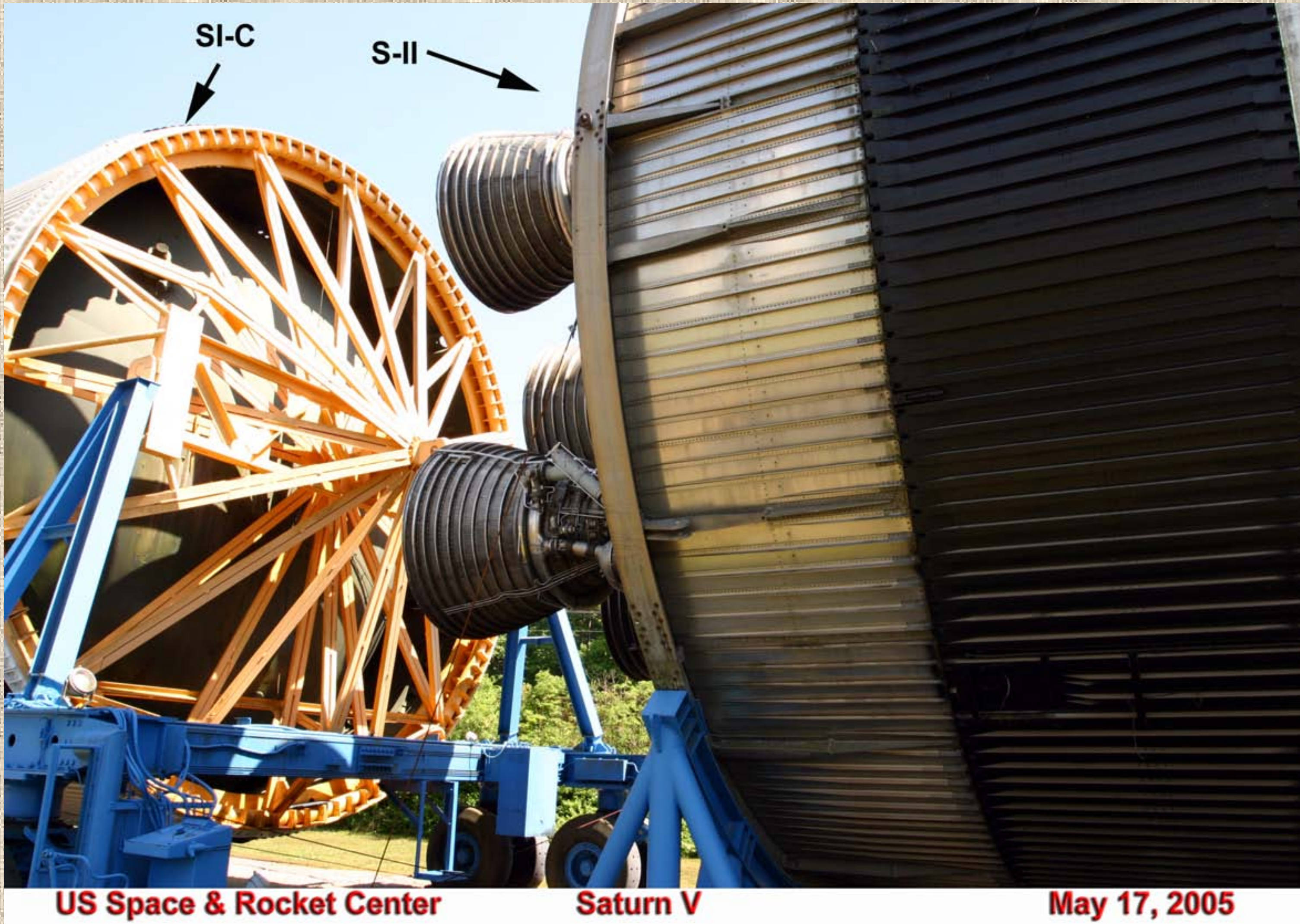
1ST STAGE/2ND STAGE INTERFACE

View of the first and second stage interface, without the interstage. The actual Saturn flight vehicle had a 11,000 pound interstage ring structure to connect the two stages. The interstage was tall enough to house the five 2nd stage engines showing in the photo. At the end of 1st stage burn, the spent stage was separated just below the 2nd stage engines. To have separated any higher would have risked damage or destruction of the engines during the separation process. Eight retro motors mounted aft on the departing 1st stage helped to achieve clean separation. startup of the five J2 2nd stage engines was aided by the firing of eight ullage motors mounted on the interstage. The purpose of this was to settle the 2nd stage propellants for trouble free propellant feed into the turbo pumps. After 30 seconds of 2nd Stage burn, the interstage was separated just above the engines and below the S-II propellant tankage. This got rid of unneeded weight and also avoided overheating equipment mounted in the 2nd stage aft section. The total separation process was called "dual plane separation". The main load across the separation interfaces was compressive so the joints were designed with butted compression fittings and only individual .080 inch thick aluminum straps (218 of them) provided tensile strength. This enabled the relatively small linear shaped charge (LSC) device to cut the straps at the appointed time. The LSC was small in cross section but was over 100 feet in length to reach around the 33 foot diameter of the separation plane. For the dual plane separation two LSC assemblies were needed, the second activated 30 seconds after the first.

The missing interstage for the Center's Saturn V is reputed to have ended up as a concession stand.

Two other left over Saturn Vs exist, one at NASA JSC in Houston and the other at NASA KSC in Florida.

The US Space & Rocket Center Saturn V 5/17/05



The yellow truss work on the S1-C is part of the handling ring, not part of flight structure.

The US Space & Rocket Center   Saturn V   5/17/05

TRW


1960
1965 TRW

TRW SYSTEMS

Workplace Style

The Douglas and North American companies were known as “tin benders’. That name stemmed from their years as aircraft builders. Engineers and draftsmen were treated and housed like production tools. They usually worked in former aircraft hangers in large bays with very utilitarian desks and drafting tables. Only the top level managers had offices. Floors were cheap tile or maybe just painted concrete.

Engineers still tried to be “professional”. Their California uniform was a crew haircut, short sleeved white shirt with button down collar, and narrow tie. Of course we had to have the obligatory plastic pocket protector stuffed with pens and pencils. We also were proud to wear the company badge. Before the days of small electronic calculators, we still used slide rules but got over the college habit of wearing them on our belts. We did not need to punch a clock but sign-out was required when leaving the facility. You were expected to be on the job during working hours.

TRW was different. Engineers and other workers were housed in beautiful buildings in a college campus-like setting. Offices and furnishings were upscale. We worked in a three man office with a big picture window and a nice view. We had a secretary for only the three of us. Work rules were very casual. The work was totally different from recent experience. It was still ordnance related but on Air Force programs, mainly the Minuteman ICBM. Each large organization has its own “culture” The Air Force has different ways of doing things than NASA.

Minuteman Support

We did not make or procure hardware and deliver it to the user. We merely “advised” others who did that. We would review and criticize their paperwork and forward our comments to Air Force. people responsible for Minuteman contractors.

Rapid Fire Guns

We also were involved with studies on new weapon systems for the Air Force. Strangely enough these new weapon ideas were based on guns. The Viet Nam war was still going on. In the process, I learned more than one would ever expect on gun design, large and small. Of particular interest of the Air Force at the time was multiple barrel guns with a very high rate of fire. The Vulcan 20mm and the 30 caliber Minigun were already in existence but the AF wanted something even faster. We proceeded to produce some grandiose but impractical designs. Fortunately no one tried to build and test them.

Rod Penetrator Weapons

Another interesting thing we worked on was penetrator projectiles. When high density slugs are fired at very high velocities, they will penetrate armor plating. They just “burn” their way through and create a shower of molten metal inside the target. Depleted uranium is the favored material for this application. Some tests were actually run to evaluate the effect of this phenomenon on Soviet T-34 tank armor. To get the high velocities, large bore guns with large propellant charges were use to fire small and relatively light projectiles. The projectiles were much smaller than the gun barrel so therefore could not be spin stabilized. Thus, tests were at very short range.

We worked on ideas for keeping these solid rod projectiles stable enough to produce desired accuracy at longer ranges. Mass stabilization was studied. This idea involved a two part rod with lighter material in the back. The other concept simply used the old Indian trick of putting fins (feathers) on the back of their projectiles. We also worked on putting clusters of small rod penetrators in a single warhead. These needle like penetrators were called fleshettes. I did not stay long enough to know if any of the TRW ideas became reality. However during the first Gulf War (1991), our Abrams tanks were routinely using rod penetrator rounds. These weapons decimated the latest and greatest Soviet supplied tanks.

Solid Rocket Propellant Detonation

Another project I worked on at TRW was a study to determine which solid rocket propellants could be detonated. A government agency called Advanced Research Projects Agency (ARPA) was concerned if rockets launched from Vandenberg AFB on polar orbit would threaten populated California coastal areas to the south. Rockets fired from Western as well as Eastern Test Ranges were required to have destruct systems in case anything went wrong. It was feared that deliberate activation of destruct systems would also detonate the huge quantity of solid propellant, causing dispersion of case fragments many miles. We were asked to come up with some answers, but with no real contract or funding. TRW had a very strange old test area in a very unlikely place. It was just off the San Diego Freeway not far southeast from LAX. They had a batch of solid propellant samples and a primitive ordnance test cell.

I actually went out to this place, conducted some tests and wrote a definitive report. For this I had no technician help or instrumentation. Farmers have to do with what they got !!! This irregular activity with dangerous materials should never have been permitted. Some pin money was available to order some Comp C4 and some blasting caps with a manual exploder. Some quarter inch thick mild steel plates about 4x4 inches square were also ordered from our manufacturing shop. A length of half inch aluminum tubing was cut and sharpened on one end. This became a tool to cut core samples from various propellant samples available in storage.

There are two basic types of solid rocket propellants, composite and double base. The composite uses separate fuel and oxidizer fractions. The fuel is usually various types of rubber and the oxidizer is typically ammonium, perchlorate. These basic ingredients are mixed with other enhancers like aluminum and some times even a smidgen of high explosive to perk up performance. Double base propellants use a mixture of nitro cellulose and nitro glycerin. These molecules contain oxygen so no added oxidizer is needed. Double base propellants as used in rocket applications is more energetic than composite types but are more unstable and dangerous. Granulated double base propellants are safely used a “gun powder” in small arms ammunition.

The production of the core specimens went OK except that cutting the double base samples without breathing protection produced the famous ”nitro” headache.
These test specimens were a half inch in diameter and about 2 inches long. A small piece of Comp C4 was molded on top of the propellant specimen. The electric blasting cap went on top of that. Comp C4 is a plastic material containing the high explosive RDX. It is a commonly use military explosive that is reliably detonated with blasting caps.

This stack was positioned on one of the 4x4 steel plates. The bottom of the propellant sample cylinders in contact with the plate. The set-up was detonated by cranking the exploder from a position just around the corner of the open ended test cell. This is as far as the lead wire would reach and too close. Although safe from fragments, the explosion hurts, stinks and with no ear protection, hard on hearing.   Not pleasant at all. I had to do a dozen or so repeats.

The tests were very successful. The double base samples produced a neat half inch diameter depression in the steel plate, just the shape of the sample. The composite propellants left no depression at all, just a black smudge.   The depression in the plate indicated for certain that the sample had detonated.

Propellant Detonation II

The preceding adventure led to another exercise. The Air Force was understandably interested in intercepting enemy nuclear warheads coming our way. It was thought that the effectiveness of defensive missiles sent up to intercept would be enhanced by supplementing the warhead effect by detonating residual propellant in the carrier rocket. Since the intercept would occur in space, the blast would not have the benefit of ambient air to project its damage potential. The AF wanted to evaluate how far the fireball of a given weight of explosive would reach in space.

A kid analyst designed the test. It was set up in a walk-in vacuum chamber about 6 feet in diameter. I was to prepare a large ball of comp C4 to be suspended at the center of the chamber. Remembering the accident at North American I made sure there was no connection between the ball of Comp C I was mounting right in front of my face with the firing controls in the block house. As the supposed "explosive expert" I was responsible for safety and was very leery of setting off a large charge inside a closed metal container. It seemed that a bomb like this could throw fragments of the chamber as far as the nearby San Diego freeway and apartment houses. The kid analyst maintained that setting off our charge would not even raise the pressure in the chamber to ambient. Even so I insisted that the door to the chamber be left unlatched.

The kid analyst was right. The big charge just went plink. The vacuum toned down the sound. We had to let more air in the chamber to get the door open.

California Exit

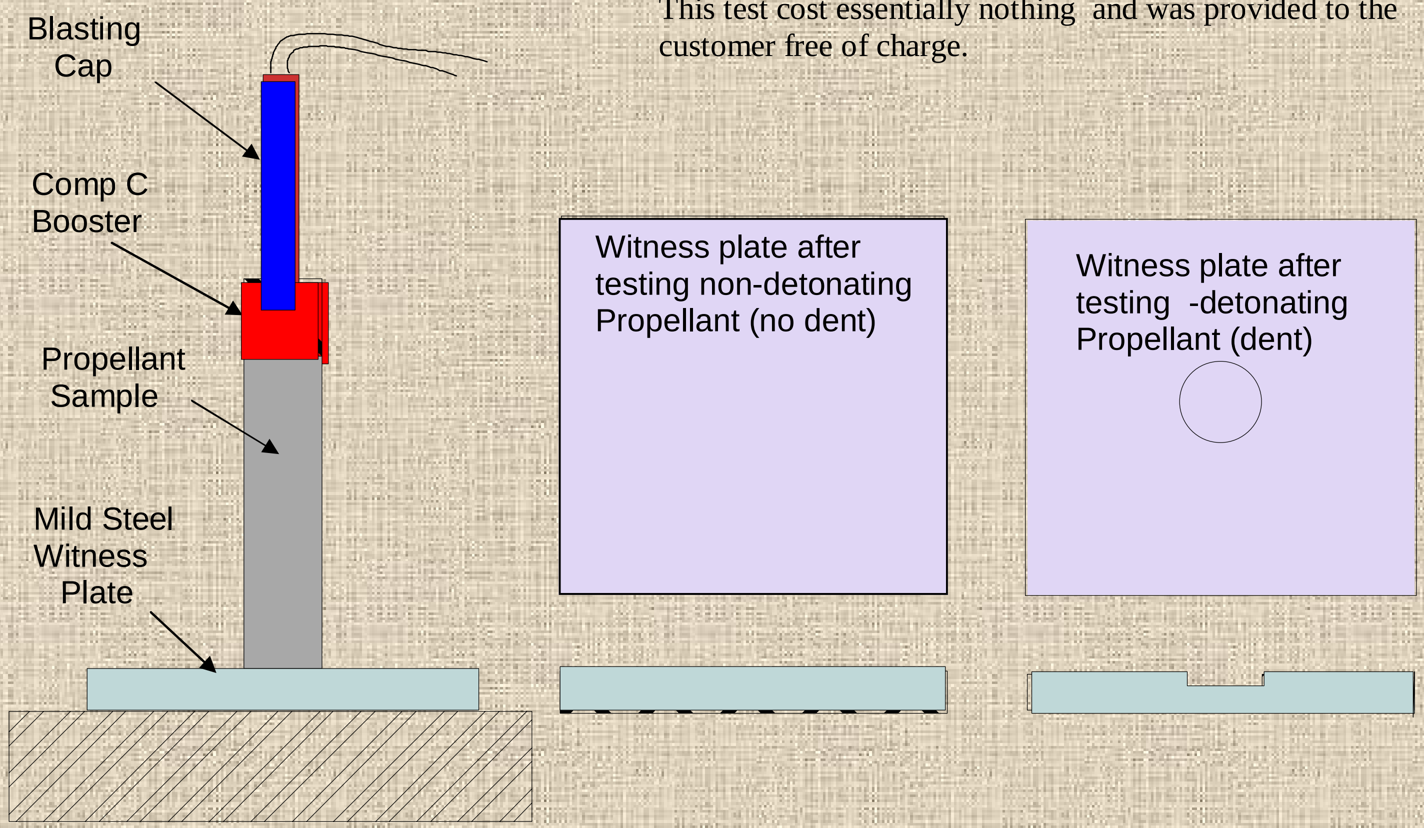
TRW was an enjoyable place to work. I would have been happy to have stayed there longer. However two factors prompted consideration of other options. The one-way commute between TRW and One Space Park near LAX and our home in Orange County was an hour's drive on the San Diego Freeway. This required driving bumper to bumper at 60 mph during rush hours. This mode of living seemed to be standard for most Californians. Doing this twice a day was not appealing.

The other factor was the reluctance to live indefinitely in the middle of ten million people. We frequently went out on weekends to visit the numerous nice places in California. However it was an ordeal to contend with the heavy traffic on the few highways out of the crowded Los Angeles bowl. Other people were trying to escape on weekends also. The same problem occurred coming back on Sunday evenings. (continued on page 56)

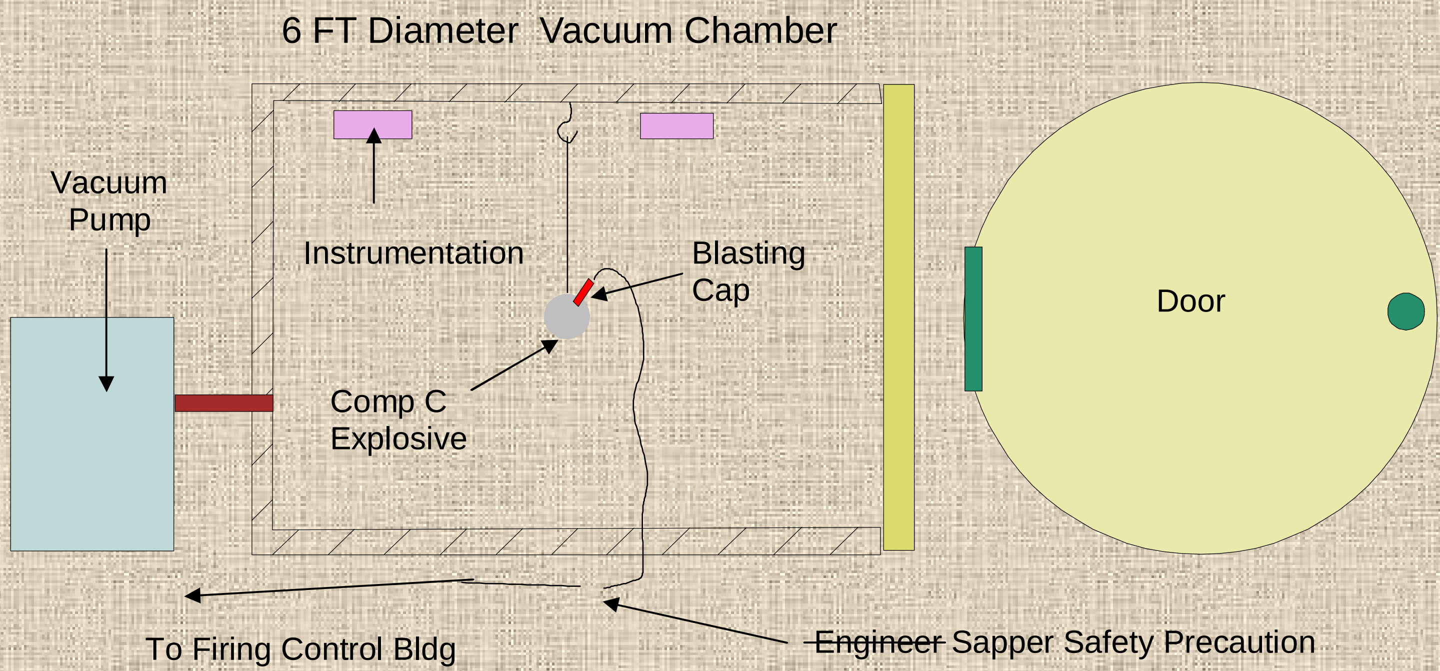
TRW PROPELLANT TEST (1966)

This is a diagram of the previously described test to determine which common solid rocket propellants could be made to detonate. It is not surprising that Double Base Propellants which are made from high explosive materials would detonate when hit with a substantial booster like Comp C4. It was reassuring that Composite Propellants like those used on manned space vehicles would consistently not detonate even when interfaced with the powerful booster charge. The Comp C booster was too far away to damage the plate. The only effect on the plates exposed to the non-detonating propellant tests was a black smudge.

This test cost essentially nothing and was provided to the customer free of charge.



TRW VACUUM TEST



I did not design this test and can not interpret the merits of the results. The vacuum chamber and ourselves did survive. I only played the role of a lab technician which I was not qualified or authorized to do. BAD.

Believe the weight of the Comp C was about 2 pounds which is quite a bit for government work. We pumped for about a day to get most of the air out. The guy who ordered the test was right about the output. We had to let air in to get the door open. Also, without air to transmit sound we could barely hear the charge detonate. We feared that we had a dud until we got the door open. The test was conducted just off the San Diego Freeway, near LAX.

Thus the notion of living in a smaller, less crowded city with space around it (maybe even farm land) became appealing. This idea would only be viable in a locale where interesting and challenging engineering jobs were available. Marilyn was trained in library science. Libraries and schools with libraries are everywhere so that was not a problem.

We had been living in California for several years by now and had become used to the nice year round weather. We always lived close to ocean breezes so never needed air conditioning. Professional sports were at hand, the baseball Angels were only minutes away from our home. Evening classes were available at UCLA and many community colleges. Moving cross country would likely sever connections with a large circle of friends and co-workers. All this was mulled over during the summer of 1966. Moving away would probably not have happened except for an unexpected development back on the Saturn V program.

My reputation was not all bad. I was sought out to rejoin my old company, now named Rockwell International to help with a much expanded Common Ordnance task to be located near our NASA customer in Huntsville Alabama. I had been to Huntsville for a meeting back in 1964. Although there only briefly, the city seemed like a very nice place to live. It was not a small town, but not a large city either.

The job fit my background perfectly. It would be dealing with the same hardware that Dan and I had originated and developed back in the early Saturn V days. Mr. Wayne Andreason was to head the operation at Huntsville. He was well suited for overall management of the job which require keeping the peace with jealous rivals back at Downey, CA and also keeping the project on good terms with our NASA customer. However, Wayne knew nothing about the product or the complicated tasks involved with procurement and sub-contractor relations. That is why I was needed.

Alabama Here We Come

In the fall of 1966 I was offered an opportunity to return to Rockwell, but at Huntsville Alabama. Rockwell had obtained a contract to supply Common Ordnance to all Saturn V Stage Contractors. That task was to be managed from the Huntsville office. After leaving TRW in I worked at the Rockwell Downey plant for a month before the transfer to Huntsville in December 1966..

HUNTSVILLE COMMON ORDNANCE

As mentioned in the account of the early Saturn S-II days, we had developed and qualified several ordnance items that were to be used by all Saturn V stage contractors. However, there was confusion in several contractors all competing for production time at relatively small sources. Mr. Rod Kolyer at North American proposed that one organization pool all Saturn V common ordnance requirements and place coherent orders with appropriate sub-contractors.

That organization would also monitor production and acceptance testing. The finished hardware would then be distributed to users on a schedule supporting Saturn V launch dates. The idea was accepted by NASA MSFC and the basic North American S-II contract was amended to authorize and fund the effort. A Saturn V Common Ordnance office was to be established in Huntsville Alabama. It would be headed by Mr. Wayne Andreasen, who would transfer from California to Huntsville.

Procurement of Common Ordnance For The Saturn V Program

I was initially Wayne's only assistant. Eventually Wendell Garton came in to help. Wendell was an ex military pilot and a veteran of the Apollo Program at North American in Downey. He also had a master's degree from Stanford University. What ever the rest of us lacked in brain power, Wendell could provide. Ed came on board to handle our inventory management task. That was it, we never had more people. The four of us were housed in an office at the Holiday Office Center on Memorial Parkway. We were somewhat isolated from other Company employees. The rest of local Rockwell management and employees interfaced with NASA on the S-II program. Our little section operated independently and were the only group that had actual hardware responsibility.

The items to deal with were the CDF Assembly, CDF Initiator, CDF Tee, and CDF Manifold. We first had to collect the requirements from Boeing S1c, North American S-II and Douglas SIVb for the first block of Saturn V launches. Appropriate military specifications were consulted to determine the required number of destructive test samples to be added to each lot (batch) of like parts to be delivered for flight use. Then purchase documentation including appropriate specifications and numeric quantities was then submitted to our procurement associate in Downey. He in turn obtained cost proposals from the involved ordnance subcontractors.

The tabulation of quantities was somewhat involved. The parts had connector indexing lugs that prevented improper CDF Assembly connections at the launch site. This meant that parts for motor ignition systems had 45 degree end fitting indexing, while others for Destruct systems had 135 degree indexing. In addition CDF Assemblies were needed at varying lengths. All these variations have unique dash numbers. All this had to be kept straight in the orders and subsequent production. Then of course, the right parts and quantities had to be delivered to KSC for use by each of the stage contractors. For each launch cycle there came a time at KSC to install ordnance. Each Stage Contractor had to find the right parts in the storage bunker. It is a wonder that we did not mess up. there was a scare on the final Saturn V launch, which was to inject the Skylab in orbit.

I made frequent trips during those years to our ordnance subcontractors in California and Connecticut; and also to their test labs in New Jersey and Virginia. These were not fun trips. Test labs usually worked around the clock in shifts. I was by myself and had to listen to droning and screeching vibration machines day and night. If anything happened to any of the parts through fault of the testing I had to witness it. This was crucial to protecting the flight worthiness of large quantities of production parts in case of a test induced failure.

Inventory Management

We did not start out as professional bean counters but Ed our 4th man at the Common Ordnance Office became one and took over the Common Ordnance Inventory Management function. Each individual part produced had a unique serial number that was included in quality organization's inspection documentation and also inscribed on the parts. Ed kept listings of the serial numbers associated with each individual part delivered to users. He kept communicating with the users as to the disposition of those parts. That would include KSC storage and also installation on launch vehicles. After each Saturn V launch Ed would mark each of our parts on that launch as expended. Ed even kept track of test parts we sent to Stage contractors for ground test purposes. He would not depend on them to report expenditure of these parts but would periodically call them. This was before the days when every office had a computer. Ed kept his records on thousands of parts on an old fashioned index card file system that filled several drawers. Call Ed about a particular serial number and he could quickly report the status and location of the part, whether still in existence or expended. Parts that ran out of shelf life and not longer available for flight use were identified and made available for alternate uses, such as ground test. This reduced the quantities needed for new ground test buys .

Discrepancy Analysis

"Discrepancy" was the term use for any type of anomaly of a part. It could be actual failure to function or just things like thread damage or corrosion. It was not popular to use the word "failure" even when appropriate. Whenever there was a discrepancy or issue with any of these parts we were required to investigate and report to our customer. If remedial action was required we were tasked to do that. There were no flight failures that we know of. The Saturn stages ended up in the ocean and safe from prying eyes. However CDF test leads were sent to stage contractors and their test lab subs that needed them to test their CDF mating ordnance components. These parts were not in controlled storage or use. They sometimes sustained heat damage from unknown sources. The damaged part would be sent back to the company that made it for detailed study. In the end we had to submit a close-out report to our NASA customer. Verification had to be made that the damaged part did not reflect on the quality of flight parts from the same lot. NASA MSFC was very careful. They had to be in order to have success with the Saturn V with its gazillion parts, any one that could wreck a mission.

Contract Add On, Shelf Life Extension

Eventually Wayne won an add-on tasks with lucrative monetary reward to our company. Our ordnance parts were considered to be perishable and had only a three year shelf life. The parts had to be ordered in time to support original flight schedules. When schedules inevitably slipped, parts would run out of shelf life before they could be used. Wayne convinced our customer that we could expose test parts to accelerated aging. We could then dissect the parts and examine them for evidence of deterioration. The idea was accepted and we were authorized to fund our subcontractors for this program.

Exotic analytic techniques were employed to analyze the artificially aged explosive material. Inspections like “X-ray Diffraction "and “Gas Chromatography” were used. Absence of age related effects were reported to our customer and approval was granted to extend shelf life to 5 years. This was a big savings to the Saturn V program.

Contract Add On, Neutron Radiograph

Another add-on was for evaluation of a new non-destructive testing technique. All of our parts are 100% x-rayed using the traditional procedure The resulting images are important and useful in detecting many flaws in higher density materials. However they can not detect the presence of less dense materials such as explosives. Thus, once a device is finished and sealed we could no longer verify that it had been loaded.

A strange wild looking fellow who worked at North American’s Atomic Energy Division was at that time going around the country trying to sell people on the idea of using neutron rays in a manner like X-rays to produce images of internal parts. The difference was that neutrons are scattered by particles of similar mass. The hydrogen proton is the same mass as a neutron. The neutrons sail through non-hydrogen bearing materials like metals. Hydrocarbons and explosives are chock full of hydrogen and will scatter (partially block) the neutrons. Thus the presence or absence of hydrogen bearing material will show up on the resulting radiograph plate.

The salesman presented neutron radiographs of guns and even of a motorcycle. You could see images of the cartridges in a gun magazine. You could see the powder level in each cartridge (They were not full). In the motorcycle you could see the amount of gasoline left in the tank.

We were quite impressed by the presentation even though it was overly dramatic. It would be great to be able to make one last check to make sure some unloaded explosive parts did not slip through inspection. There was one problem. The parts had to be transported to an active nuclear reactor, the only adequate source for a neutron beam.

Wayne won another add-on to investigate the practicality of this dream. In due time our subs did the required investigation and confirmed that the process was doable and useful. We then added neutron radiograph requirements (now called N-Ray) to all our common ordnance programs. N-Ray inspection subsequently became widely used in industry. We may have been one of the first to put this technique into practical usage.

Incentive Awards

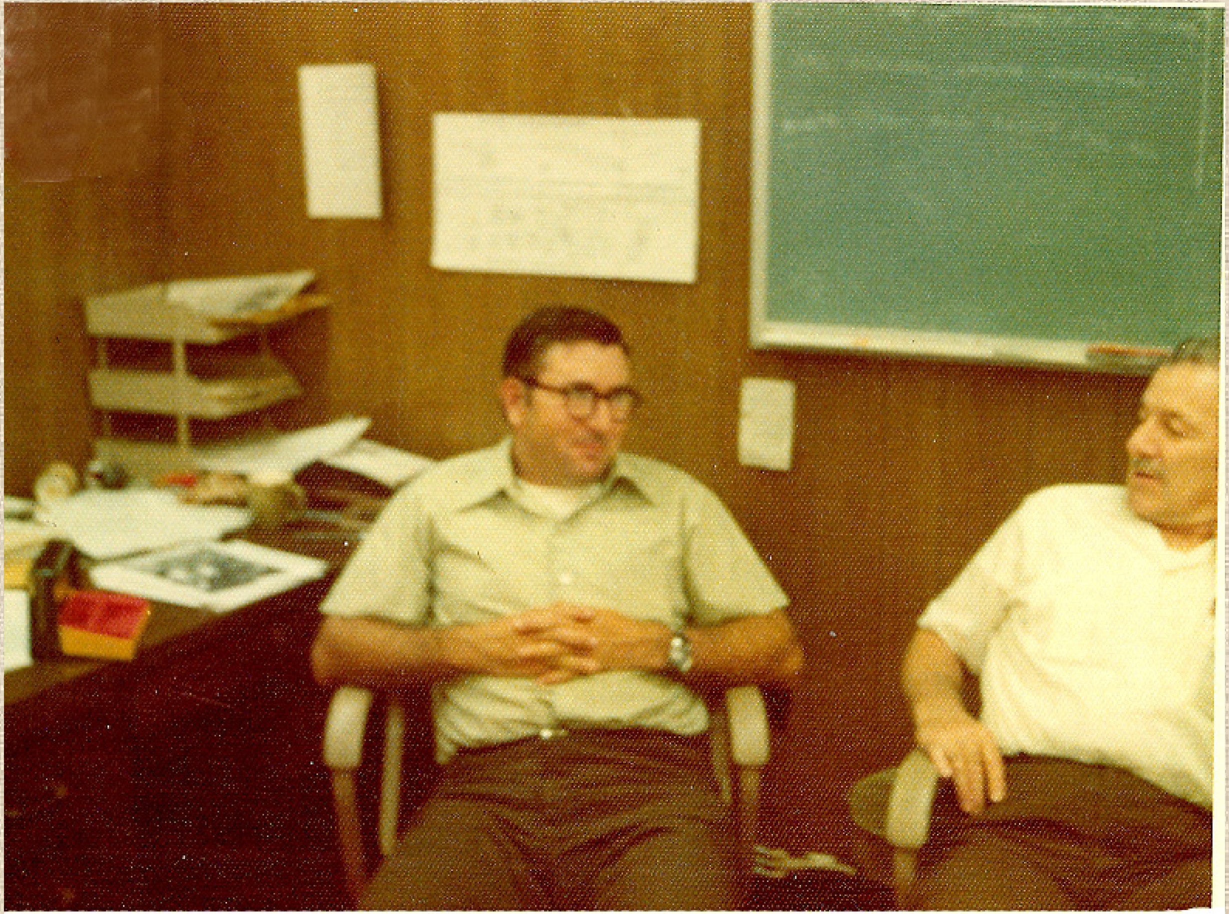
The North American S-II contract included a provision for incentive awards. Every report period included a list of individual projects that were considered meritorious and contributed to justification for awarding our company extra money. Our Common Ordnance operation was sometimes cited. This was amazing because most entries on the list involved large departments or groups of people. We were only a tiny cell of four people. We would like to think it was recognition of how wonderful we were, but more likely it was due to the fast friends Wayne made with influential people at NASA.

End of Saturn V

The last moon mission was launched December 7, 1972. We had only one more Saturn launch to support. The unmanned Skylab 1 was launched May 14, 1973 to place the original Space Station in orbit. Subsequent trips to Skylab were made with the older and smaller Saturn 1b. Two Saturn V vehicles were left over. As a cost saving measure, the government elected to send them to museums. With no more Saturn V's to launch our Common Ordnance work at Rockwell was finished. The Space Shuttle program was about to start.

There is a popular saying; “If we can put a man on the moon, why can’t we do this”. Whatever “this” is at the time. The truth is: we haven’t been able to put a man on the moon ever since the Saturn/Apollo capability was discarded in the early 1970’s. It is unlikely that we will regain that ability in our own or our children’s lifetimes.


North American
Downey
North American Huntsvi
NASA MSFC
NASA JSC
NASA KSC



At Work, Holiday Office Center 1972

Getting good advise from Wendell Garton

1972 CDF Vibration Testing

One of the components we furnished for the Saturn program was an ordnance item called the CDF Assembly. One of our tasks was to monitor production acceptance testing. This required frequent traveling to test labs around the country. The CDF Assemblies were manufactured in Connecticut . Environmental testing , including vibration shown here was conducted in New Jersey, near the present day NY Giants football stadium. Only a small batch of specimens can be tested at a time. It takes hours to work through a typical batch of samples from a production run. . Shock testing must be done also. Temperature Humidity testing takes 2 weeks but once the parts are put in the champer, everything is automatic.

1972 CDF Testing

After enduring 4 weeks of torture, half of the randomly selected parts from each lot were subjected high temperature and the other half to low temperature (-300). Then the parts were functioned (detonated). If all worked, the lot they came from was certified as flight worthy. If even one failed the companion lot was trash. These final function tests were conducted at the Connecticut plant. A tense time. To simplify testing all specimens are hooked together in a "daisy chain". Note the white tube at the end of the chain that encloses the bared CDF core . The bared core is inserted in a small aluminum witness tube. When the 30 minute high temperature exposure is completed the chain is detonated at the head of the chain. Disintegration of the witness sleeve at the end of the chain verifies that all individual assemblies successfully functioned.

SKYLAB EMERGENCY

In the early 70's, it was decided to end the Saturn program and develop a new reusable launch system. Three left over Saturn V's would head for museums. The last Saturn V mission was to use the two lower stages to launch Skylab. This would place the Orbital Workshop (OWS) and the Apollo Telescope Mount (ATM) in earth orbit. The normal S-IVb third stage structure was made into a non-propulsive OWS. This unmanned launch was to be followed by crew carrying Saturn 1b launches to rotate workshop crews. Both the OWS and the ATM had systems requiring the use of Saturn V developed Common Ordnance components. Thus we received a large order to supply CDF assemblies for the Skylab 1 launch. The order would include parts for the two lower Saturn V stages as well as for the OWS and ATM.

CDF Assembly Acceptance Test Failure

Delays in getting numeric quantities settled resulted in a late start for production of the CDF assemblies. Delays were necessary to accommodate new systems being designed for the Orbital Workshop and for the Apollo Telescope Mount.

After fabrication was complete, this group of parts, called a "Lot" began a month long quality assurance process. First the parts are subjected to a series of non-destructive inspection and tests. Then a sample is randomly selected. These parts are subjected to Temperature/humidity exposure, and then to various vibration and shock exposures. Finally, the sample parts are divided into two groups for high and low temperature exposure. After exposure to these temperature extremes the parts are functioned (detonated). All of these destructive tests of the sample must be successful for the rest of the Lot to be accepted for flight use. We had gone through numerous production runs for previous flights so concern for this batch was not great. The high temperature test was the most worrisome because PETN, the active explosive material would not stand much longer than the 30 minute 250 degree test exposure. The cold exposure was –300 degrees F. Liquid Nitrogen (-320 F) was used to cool test parts. The flight parts got cold because of proximity to cryogenic propellants. Liquid hydrogen is -400 F. The liquid nitrogen supply container for test labs is heavily insulated but still must be vented. Otherwise pressure would build up from heat soaking in and blow the container.

For testing a valve would be opened to allow the gas boiling off the liquid nitrogen to circulate through the cooling coils of the container holding the test parts. Thermocouples indicated when the parts were down to -300 F. Then the parts would be soaked at that temperature for 30 minutes and then functioned. This test had never been a problem. The CDF Assemblies just didn't mind being cold. This would be the last batch of parts we were building for the Saturn Program and we had confidence in continued success.

It is usually about noon at Simsbury Connecticut when the parts are detonated. Because everything was all frosted up and stiff it was the custom to go to lunch before checking test success, giving the parts a chance to thaw out. Being the last batch for the Saturn Program the big wigs of the company came out to lunch with us, sort of a celebration of several years of solid success in supporting the moon program. Spirits were high and we took too long returning from lunch. The test crew became impatient and took a look at the parts. When we got back from our premature celebration we were informed by the sorrowful test crew that the test had failed. Many, not just one of the parts had pulled apart internally in the cold soak. They had already x-rayed them.

These parts were a representative sample of a Lot (batch) of parts already installed on the two Saturn stages at the Cape plus the Skylab on top. All these parts (a hundred at least) were suddenly no good and had to be replaced. That would take at least 3 months even if we knew what caused the problem.

I stalled for a couple of hours before calling Wayne Andreason back in Huntsville so he could call the disaster in to our customer at Huntsville NASA. I had hoped to get some clue as to the cause of the problem and a schedule projection for rebuild before calling. No hopeful prognosis was forthcoming; I had to tell Mr. Andreason that our parts were kaput. We knew what failed but had no idea of why.

By the time I got back to my motel in Simsbury the phone was ringing off the hook. It was lots of panicky Rockwell managers in California that had never heard of me or Common Ordnance before. Our previous success had kept our project below radar level. The California managers were thinking that those lowly grunts in Huntsville were jeopardizing their careers. The NASA Germans were ruthless. Nobody wanted to be tagged with delaying the Skylab launch. The Rockwell Saturn program had already gone through 3 sets of top level managers because of program delays.

Ensign Bickford immediately turned their place upside down trying to find the reason for the bond failure. All imagined sources of contamination were investigated. Various possible contaminates, even grease, were deliberately applied to bond surfaces. The bond could not be defeated. The Mereco epoxy held like death.

We desperately needed to get replacement parts in production but it seemed that we first had to find the cause of the bond failure. Then someone came up with a work-around. (It might have been Wendell Garton). Wendell was one of the three peons working for Andreason at Huntsville. Wendell had a master’s degree from Stanford so no wonder he was so smart. His idea would be to bond the parts as usual but then subject each of the sub assemblies to a pull test before installing in the steel housing and completing the assembly. If the mysterious bonding problem showed up we would know it before completing very many assemblies. At this point we would have a better chance of isolating the cause. If the pull test was successful for each sub-assembly we could be confident in completing the production.

None of the new parts exhibited the bond problem. They were hurried through the rest of the process, successfully tested and delivered once again to KSC. As it often turns out there were other delays to the Skylab program that prevented our problem from taking the blame.

Years later, working on the Shuttle program I became aware of Thiokol's ban on silicones in their solid rocket motor plant. This material had proven to be poison to bonding processes. Silicones were probably not included in our failure investigations on our CDF problem. Watch out for silicones when you glue things. (see page 72 for diagram of the bond failure)

Skylab Launch Trouble

All the Skylab troubles were not over. On launch day May 14, 1973, I was at a Space Shuttle meeting at MSFC. The meeting stopped long enough for us to watch the Skylab launch on TV. Everything looked great, perfect launch. The last one, we won't have to worry about the S-II separation system any more. School was still out on all of the Skylab deployment in orbit, which depended on our CDF Assemblies and Manifolds, but we were not worried.

About three hours later, I got called out of the meeting and told to get over to the HOSC. The HOSC is a replica of the Launch Control room at KSC. Representatives of all MSFC responsible systems were huddled around displays of instrumentation data streaming in. Things were gloomy, they knew by now that Skylab was partially wrecked. Bob White and other MSFC ordnance people were there and told me that the Skylab was badly crippled and that the Common Ordnance we had supplied was the primary suspect. Our parts were used in the deployment system for the OWS solar panels. These panels were apparently not deployed and were not producing electrical power. Without their power production, the Skylab mission was a failure. My past association with Common Ordnance was the reason I was ordered to the HOSC on that troubled day. It was like a recall of a paroled prisoner.

People were pouring over telemetry strips trying to verify commands to the various systems. We had a recent management change at our Rockwell company office at Huntsville and our new head boss had not realized before that some of his people had their fingers in actual flight hardware. He thought all of his people had only support functions.

There were only four of us working in the Huntsville office on Common Ordnance and we worked in a separate part of the building. Dick Swartz, the demanding S-II chief engineer at Rockwell Downey, was alarmed by the Skylab trouble and by the possibility of a very negative company impact. He was all over his new Huntsville Saturn S-II support manager for "losing" Skylab and couldn't understand the Huntsville manager's seeming ignorance on what his troops had been up to. Finally about midnight there was confirmation that the meteoroid shield on the OWS had broken loose and caused all the damage. Common Ordnance was not to blame, whew !!!

I went home thinking that our precious ordnance had well supported the mission once again and it would be safe to go to work the next morning.

A Saturn 1b with Apollo Command Module was quickly sent up on a rescue mission. A space walking astronaut was able to release one of the two solar panels with tree pruning shears. The panel deployed and produced enough electricity to supply the OWS throughout the Skylab service life. The other panel was gone but fortunately not needed.

Separation System Failure

For the Skylab mission the S-II stage, being that last propulsive stage had to go into orbit. USAF space watchers, with their supper optics claimed that they could see the S-II in orbit and that it **still had the interstage attached**. No way, said Rockwell in Downey. All indications show that the umbilical at the S-II/ Interstage interface pulled at the proper time. Also the first and second stages could not have delivered Skylab to orbit carrying the 11,000 pound interstage the whole way. Even further, base heating would have burned systems in the S-II aft skirt. The USAF still insisted the interstage is up there and allowed Rockwell people view it for themselv**es.** Golly Moses, it was there and not in the ocean where it belonged.

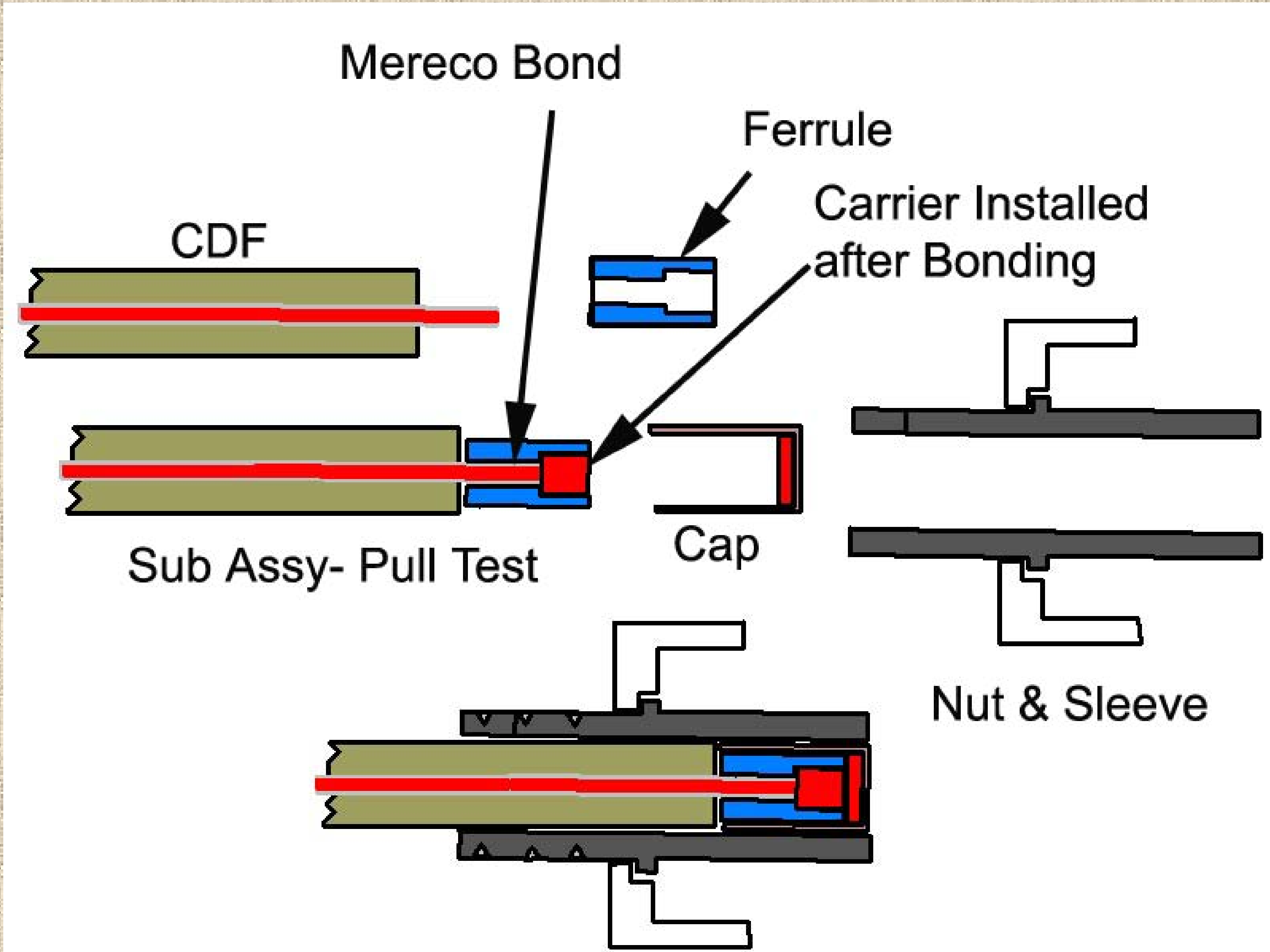
All attention was directed to the successful salvage of the Skylab so there was no concern about the interstage anomaly. The Saturn V was not to be flown again and remaining stages were to end up in museums. The incident should be of interest to future system designers. I did unofficially conger up a scenario

I found out that prior to the Skylab launch, one of the two signals to the separation EBW firing units was moved to an adjacent switch selector tap to remove a "single point failure mode" and "improve reliability". This put a 100 millisecond delay between firing inputs to the two ends of the separation assembly. In the high explosive world, 100 milliseconds is a long time. It could just as well have been the next day. This effectively defeated the redundancy intent of the ordnance design. I believe that debris from the meteoroid shield severed the 2nd plane separation LSC at a special (and lucky) place. When the first EBW firing unit initiated the first LSC end, the charge propagated to the severed place and stopped. Enough of the perimeter of the interstage was severed to allow a sag sufficient to pull the umbilical, which among other things may have carried the trigger to the second EBW firing unit. That is why I think the interstage went along for the ride.

One wonders what have happened had the reliability people not messed with the system. More of the tension plates might have been severed but not all in the damaged LSC area. This could have allowed the interstage hang on momentarily by a few plates to cause the interstage to hinge down on the S-II engines and ended the mission right there. The switch selector mischief might have saved Skylab.

There is not very much clearance between the 5 J-2 engines and the interstage with equipment lining the inside wall. The interstage must come off completely and cleanly to avoid collision with engines and equipment not designed to resist train wrecks. On this launch, it must have been a delicate balance; interstage freed enough to sag but not enough to break loose in some disastrous manner.

Analysts at Rockwell finally conceded that first two stages had enough oomph to put everything in orbit after all. Credit the Germans for being a conservative bunch when they sized the Saturn V and propulsion requirements.



Mereco Bond
Ferrule
Carrier Installed
after Bonding
CDF
Sub Assy- Pull Test
Cap
Nut & Sleeve

Teledyne Brown

Teledyne Brown

With the end of the Saturn program in the early 1970's there was not much to do at the Rockwell office in Huntsville. Teledyne Brown had an active support contract with NASA MSFC for the Space Shuttle program. I joined a propulsion group at Brown in a section that worked mainly on the Solid Rocket Booster (SRB) of the Space Shuttle.

The work dealt with various systems on the SRB, particularly the Trust Vector Control system. This hydraulically powered system vectors the SRM nozzles to assist the main engines in providing flight control for the Shuttle.
Of particular concern was the possibility of the nozzle extension cone hitting structure or components in the aft skirt of the SRB On solid rocket motors the flexible nozzle design results in an imprecise pivot point and complicates analysis of nozzle/structure clearances.

Our work included extensive graphic and computer program modeling of the nozzle positions during vectoring at various directions and chamber pressures. Other studies were made to determine the adequacy of flexible sealing boots used for the SRB. This analysis was used by NASA to encourage Thiokol to redesign the SRM sealing boot. The work at Brown also led to familiarity with the SRM segment joints.

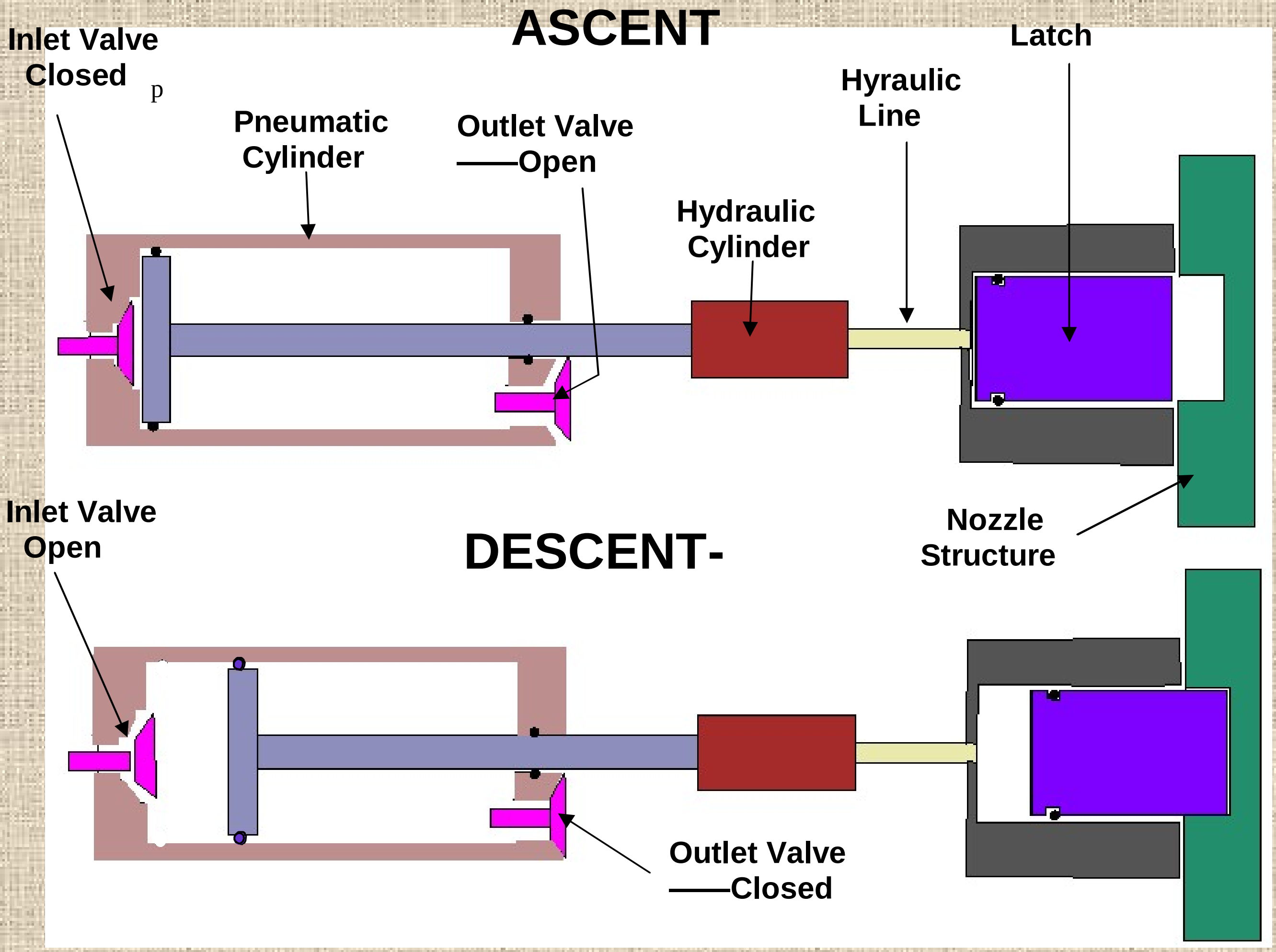
Special tasks were sometimes assigned. After burnout the empty SRM's are parachuted down to the ocean for recovery. The impact with the water is likely to damage the flexible nozzle seal, requiring expensive replacement. The nozzle seal is designed to withstand motor pressure but not the reverse forces from water impact.

One of the special tasks was to come up with an design that would mechanically lock the nozzle after SRM burn-out but before impact with the water. The joke was that this locking system was to do its thing <u>without</u> providing power and <u>without</u> a command signal. Those two constrains at first seemed like an unreasonable obstacle in devising a system to accomplish the task. gain farm experience helped. : If you don't have everything you need so you find ways to make do. I hit upon an idea to steal free power and timing from the trajectory of the SRB. The SRB goes from ambient ground air pressure up to the rarified pressure at 220,000 feet and then back down again.

A design was conceived that would employ a pneumatic cylinder with appropriate automatic relief valves. The cylinder would be evacuated on the way up. On the way down the increasing air pressure admitted to the cylinder would act on the piston, producing a power stroke. The power stroke would actuate a hydraulic cylinder which would in turn hydraulically force the spring loaded latches to their nozzle locking position. The latches would need to be spring loaded in the safe (unlocked) position until SRM burn-out.
The idea was good enough to be patented by NASA. It was called "Nozlock". However Thiokol, builder of the SRB elected to use a different design approach to save the nozzle flex seal from excessive abuse on water impact.

SRM NOZZEL LOCK

This is the idea I turned in as a solution to the problem of damage to the SRM nozzle when impacting the ocean on parachute recovery. Since no power or signal input was available, the action had to be inherently automatic. The action takes advantage of the trajectory from ambient air pressure to rarified then back again.



United Space Booster Inc

USBI

About 1976, NASA MSFC decided not to renew support contracts with Teledyne Brown. They wanted to divert the work back in house. Brown gave us six months to find other work.

Fortunately at this very time NASA was developing the Space Shuttle. The Shuttle consisted of the fly-back spacecraft called the “Orbiter” and two Solid Rocket Boosters (SRB‘s). The liquid propellants for the Orbiter was carried by a huge External Tank. The NASA MSFC share of the Shuttle was the SRB’s and the External Tank.

NASA MSFC was seeking a contractor to assemble the various parts of the Solid Rocket Booster (SRB). The core of the SRB was the Solid Rocket Motor (SRM) being built by Thiokol. Other pieces of the SRB included forward and aft skirts, thrust vector control system, parachute deployment system and best of all, ordnance systems.

A new company, called United Space Booster Inc USBI was selected by MSFC to manage and assemble the Solid Rocket Booster part of the program. They were called the Booster Assembly Contractor (BAC). One of their functions was to procure production ordnance for the SRB. I hired on as a Sub-system manager. This would be my third tour with the hardware we had developed and used on Saturn. This hardware was carried over by NASA for the Shuttle.

The USBI core management came from parent company United Technology. They had experience with Air Force Programs, mainly Titan. They were not used to working with NASA MSFC who had their own way of doing things. In addition USBI had an unusual management structure. There was a head man but the company was run by a subordinate. This subordinate had a group under his direction called sub-system managers. Each of these sub-system managers was responsible for a part of the SRB, such as structures, electrical, hydraulics and ordnance. Our job was to prepare and authorize procurement packages for our respective hardware. The procurement packages would be based on specifications released by NASA. Some of these specifications were essentially copies of Rockwell specification we had used on Saturn. Our procurement counterparts (buyers) would get cost proposals from the various sole source suppliers. We would then evaluate the proposals for technical compliance. After award we would monitor production and testing.

The ordnance subsystem management hardware responsibility job included other components besides the carried-over Saturn Common Items. Those included Booster Separation Motors, Forward and Aft

Separation Bolts, Hold-Down Bolts, LH2 tank destruct charge and the Range Safety S&A. The items had been qualified by NASA. NASA had also ordered the parts for the first few Shuttle launches. We were to provide parts for subsequent launches.

USBI also had Engineering and Quality Departments. Engineering would have normally done most of the tasks described above. That is what I did when I was in Engineering. As it turned out the ordnance guys in in the USBI engineering department were mostly sidelined with no important role to play The main action was with us in Sub System management. I would use our friends in the engineering department only to monitor testing at subcontractors. To make matters worse, our boss sometimes used his subsystem managers as his attack dogs in keeping control of the company for himself and other departments marginalized. This created a resentment that caused trouble after our California protectors went back home after about three years. The revengeful wolves came after us.

I had a large advantage for this job, having had several years of prior experience in ordnance procurement. In addition I knew key ordnance people at NASA and most of the management and workers at the ordnance sub-contractors. Some of the other subsystem managers did not have prior experience and had a very rough time. There was one odd relationship. The parent company of USBI was Chemical Systems Division (Of United Technology) however Chemical Systems Division was also my subcontractor for the SRB Separation motors. How are we going to lean on them when necessary? I had a very good buyer to work with, Larry Tanner. We made many trips to the subcontractors on the course of our duties. Larry was an Alabama native and really dug the opportunity to see California and even New York City. He liked John Wayne and wanted his picture taken standing in Wayne's foot steps at Chinese Theater in Hollywood. Larry was very disappointed in the small size of his hero's foot prints. He didn't realize that old John wore cowboy boots.

Most of the programs went smoothly. Problems did surface in the S&A, Booster Separation Motor and the large Nut for the hold-down posts. The later two were caused by the age old mistake of designing parts with size envelopes to match that necessary for <u>original</u> launch weights. Launch weights always grow during development. When they do, the parts can not be fit into surrounding structure. That forces the use of more exotic alloys to get the required strength in the same sized package.

The S&A device was designed by Douglas for the original Saturn I Launch Vehicle. It was intended for very temporary use. It was made up of pinball machine solenoids and refrigerator door switches. It required a lot of man hours to assemble and was erratic in test. I tried but failed to get a more suitable device substituted for this sorry model.

Through all the years working with ordnance subcontractors it was always evident that they wanted to do their best in support of the Space Program. This was the case from top to bottom. They understood the critical nature of the parts they were supplying. In cases of qualification or acceptance test failures they always quickly started the rebuild and retest cycle. Our contracts were fixed price so the cost of the recycle was borne by the subcontractor. In my position at USBI I had the opportunity to arrange for trips by subcontractor personnel to view Shuttle launches at KSC from the VIP stand. They really appreciated that favor.

After about three years of this fun, I finally started thinking about the retirement pension situation. During the years at USBI Rockwell had expanded and was needing more people. If I went back to Rockwell, I could hook up my remaining work years with previous service and come out with a decent pension. Rockwell also had a nice savings program that they contributed to. I decided to do this even though that would be the end of active dealing with hardware and having my own private office with a window. USBI was getting to be unstable with a lot of in-fighting for position and was becoming a very unpleasant place to work.

Old friends who stayed on told me that eventually a good top manager was brought in. The bad apples were kicked out and things got better. One of these friends wrote a novel based on experiences at USBI. Fake names were used for the company and characters but the locale and people in the book were very recognizable to anyone who had been at USBI. The book version portrays the fictitious USBI even worse than I remember the actual place..

Space Shuttle, Solid Rocket Booster Ordnance

USBI Pyro Sub System Manager

Former Saturn V Common Ordnance items

CDF Assemblies -	Ensign Bickford	Simsbury, CN
CDF Manifolds -	Explosive Technology	Fairfield, CA
Pyrogen Initiators	Space Ordnance Systems	Canyon Country, CA
Safety and Arming Devices	McCormick Selph	Hollister, CA

Unique Shuttle Ordnance

Separation Motors	Chemical Systems Div	Sunnyvale, CA
Forward Attach Bolts	Hi Shear	Torrance, CA
Aft Attach Bolts	Hi Shear	Torrance, CA
Hold Down Nut	Space Ordnance Systems	Canyon Country, CA
Range Safety Linear Shaped Charge	Explosive Technology	Fairfield, CA

This was a big load for one person. Prior experience with ordnance devices and the procurement system helped. I also had a good relationship with Larry Tanner, our Purchasing guy for ordnance. We made frequent trips to the suppliers listed above. Larry was always keen to do some sight seeing when the opportunity presented itself.

When I resigned this pyro subsystem manager position, the job was split up and assigned to more people.


Chemical Systems Div (BSM)
Explosive Tech (Manifold, Tee, LH2 LSC)
Space Ordnance (TBI, Hold Down Bolt)
McCormick Self, (S&A)
High Shear, (Aft Sep Bolt
Fwd Sep Bolt)
Ensign Bickford
CDF Assy
NAA Common
Ordance Office

Job at United Space Booster Incorporated (USBI). Subsystem manager for the Solid Rocket Booster for the Space Shuttle.

This job required occasional trips to Kennedy Space Center (KSC).

Pictured is the massive Vertical Assembly Building (VAB) at KSC.

The VAB had become shabby during the years of disuse after the end of the Saturn Apollo program. It is now once again spruced up.

The job at USBI involved some of the same ord-nance hardware that I helped develop for the Saturn Program.

Also some of the same subcontractors were in-volved. Knowing the companies and people helped in getting con-tracts out for supply of Space Shuttle hardware.

These fellows are the en-gineer and contracts ad-ministrator for Explosive Technology in Fairfield California

Explosive Technolgy   1977

Visit to High Shear, located in Torrance California. The beach is nearby.

Business Trip to California 1977

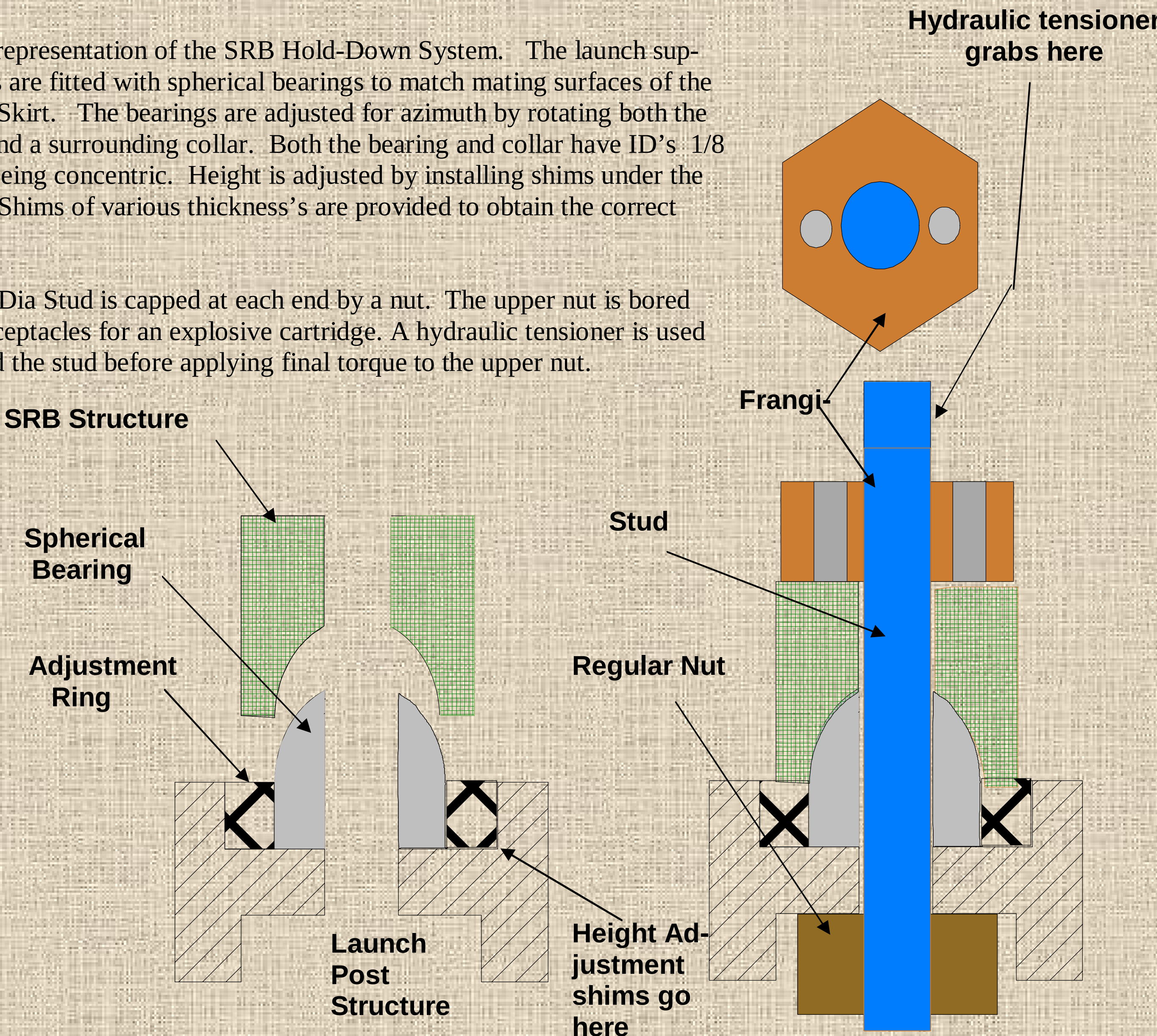
Visit to Space Ordnance Systems located in the boon docks north of LA.

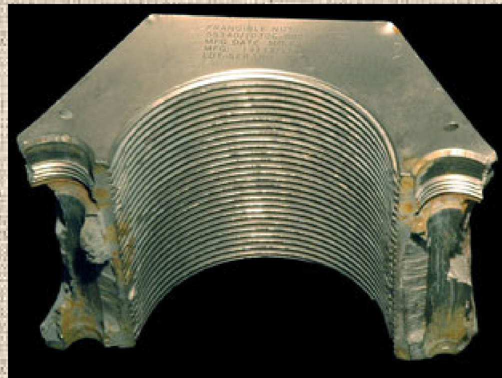
According to Google this place is now "haunted". The company apparently had a bad accident in later years and the ghosts of those killed are still around ??

Business Trip to California 1977

This is a representation of the SRB Hold-Down System. The launch support posts are fitted with spherical bearings to match mating surfaces of the SRB Aft Skirt. The bearings are adjusted for azimuth by rotating both the bearing and a surrounding collar. Both the bearing and collar have ID's 1/8 inch off being concentric. Height is adjusted by installing shims under the bearing. Shims of various thickness's are provided to obtain the correct height.

The 3.5" Dia Stud is capped at each end by a nut. The upper nut is bored with 2 receptacles for an explosive cartridge. A hydraulic tensioner is used to preload the stud before applying final torque to the upper nut.



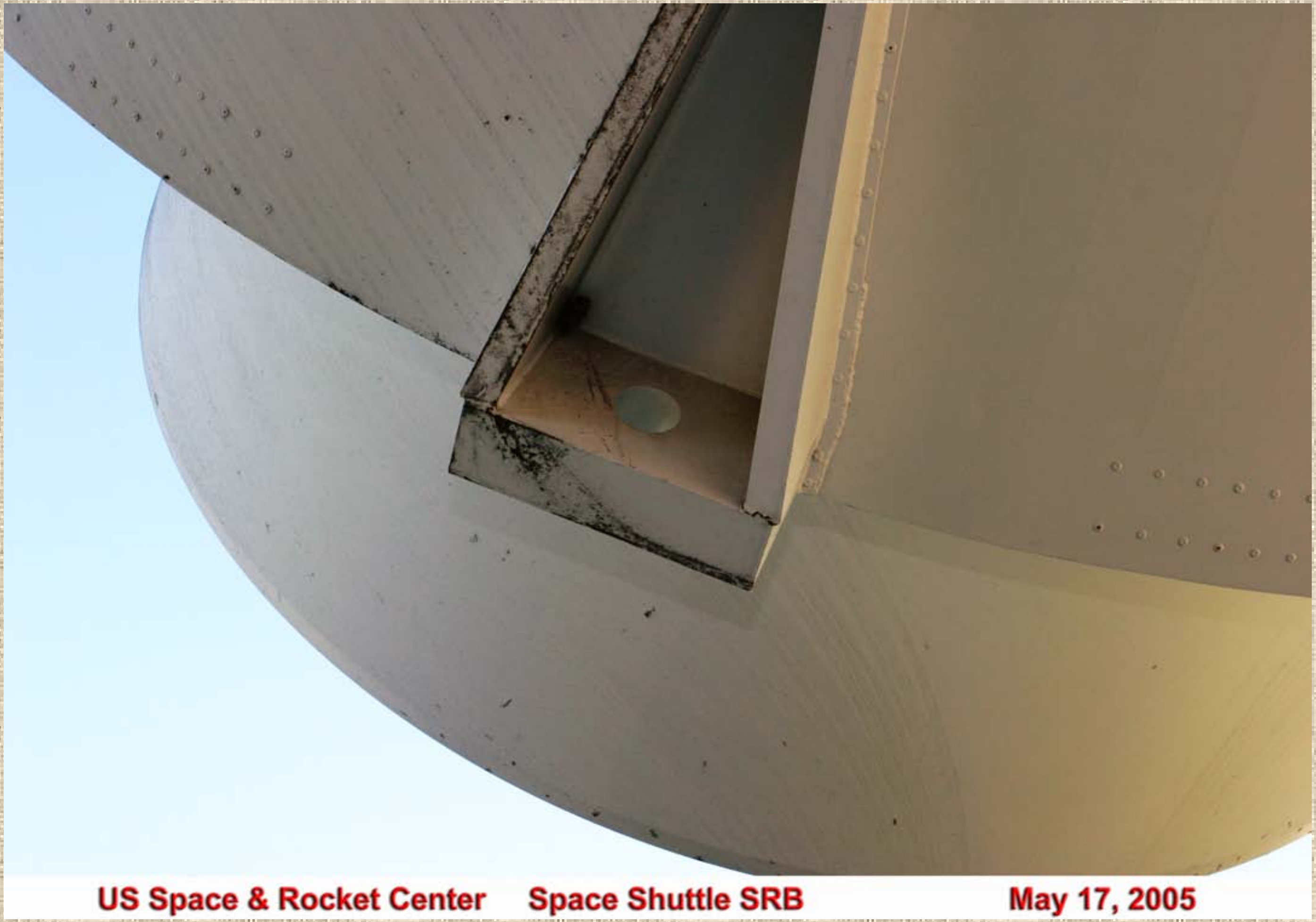


The “Bolt” part of the system is actually a 3.5 inch diameter stud threaded at both ends. The lower end is fitted with a massive hex nut.   A Frangible Nut with the explosive charge receptacles is threaded on the top end. Two charges are installed in each frangible nut for redundancy.

Four of these devices are used for each SRB. They attach the whole Shuttle stack to the mobile launch platform (MLP). This type of device is needed to assure spontaneous release of all hold-down attachments at a timing sequence with tight tolerances. The Orbiter main engines are ignited several seconds before lift-off. The off-set position of the orbiter causes the whole stack to lean over. The SRM’s need to be ignited on the rebound just before the stack reaches vertical. The hold-down system is activated simultaneously with SRM ignition. The three Orbiter Main Engines are already at full thrust

The Stud and both Nuts are made from Inconel 718 steel alloy. This material requires an exacting .heat treat process. This characteristic makes production expensive and difficult. Heat Treat facilities do not like to guarantee that every batch of parts will come out right. This gave us a lot of trouble.

The two nut fragments are captured in a lead enclosure installed on the SRB. Unfortunately these heavy pieces need to be carried along. This frangible nut is a very grown up version of the invention Jim Roberts was working with back at Douglas in 1959.



This shot of the SRB aft skirt shows the structure for attachment of the SRBs to the Mobile Launch Platform (MLP). This structure (1 of 4 for each SRB) mates with a spherical bearing on the MLP. The two elements are held together by a massive 3.5 inch dia. Bolt (stud). Eight of these (4 for each SRB) need to be released simultaneously at launch by explosive elements. .

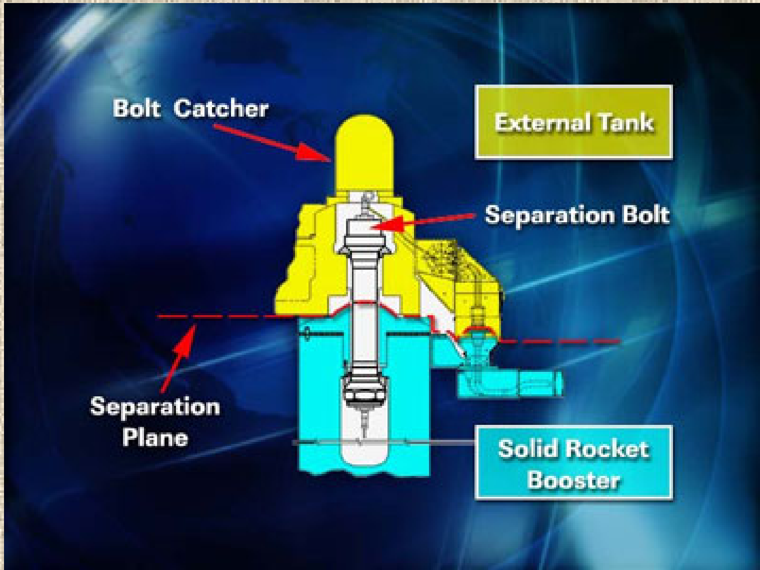
BOOSTER SEPARATION MOTOR

The photo shows a cut-a-way of the case for this small motor used to push the spent SRB's away from the external tank after burn-out. A set of 4 BSM's are used at the forward end of each SRB and another set of 4 at the aft end. The motors are ignited simultaneously with the activation of the Forward and Aft Separation Bolts.
NASA MSFC contracted with Chemical Systems Division, (CSD), parent of USBI for qualification and production of several ship sets of production BSM's. USBI assumed responsibility for ordering subsequent production. That task fell to the Pyro Subsystem Manager. Orders were placed with the same documentation and requirements that NASA had successfully used previously. This time the heat treat facility refused to guarantee the mechanical properties of the aluminum BSM cases. We could not grant waivers without NASA approval.

CSD had originally sized the motor to early SRM requirements. When the SRB got heavier, the BSM no longer had enough propellant. The outer envelope of the case was by then constrained by other structure. So, CSD hollowed out the case (made it thinner) to make more room for propellant. Another required property was Corrosion Resistance. In the heat treat process, strength and corrosion resistance conflicted. Favoring one of these factors hurt the other. Some batches of cases would end up meeting requirements and other batches would not. The problem was not resolved at the time I left USBI in 1981. The program did go on, apparently successfully. NASA probably finally agreed to relax the corrosion resistance requirements to let production continue.

The BSM's are initiated with the Common Ordnance system: Manifolds, CDF and TBI's.

FORWARD & AFT SEPARATION BOLTS



The External Tank and Orbiter are attached to each SRB by a single elongated Forward Separation Bolt at the top and 3 Aft Separation Bolts situated in 3 struts at the lower end of the SRB. The Aft Separation Bolt is shown at lower left. These bolts are an advanced design by the Hi-Shear company. . They do not utilize high explosive. Instead they use a fast burning propellant like that used in guns. The propellant neatly breaks the bolt at a precisely located groove. Avoiding the use of explosives the eliminates most of the problem of blast and fragment damage to the adjacent External Tank However the Bolt ends are ejected at high velocity and must be arrested.

At the end of SRM burn, The Separation Bolts are activated to release the SRB's from the External Tank and Orbiter. At the same time 4 small solid propellant motors and the top of the SRB and 4 more at the bottom are ignited. The motors only burn for a brief time but that is enough to move the SRB's a safe distance away from the still functioning External Tank and Orbiter combo.

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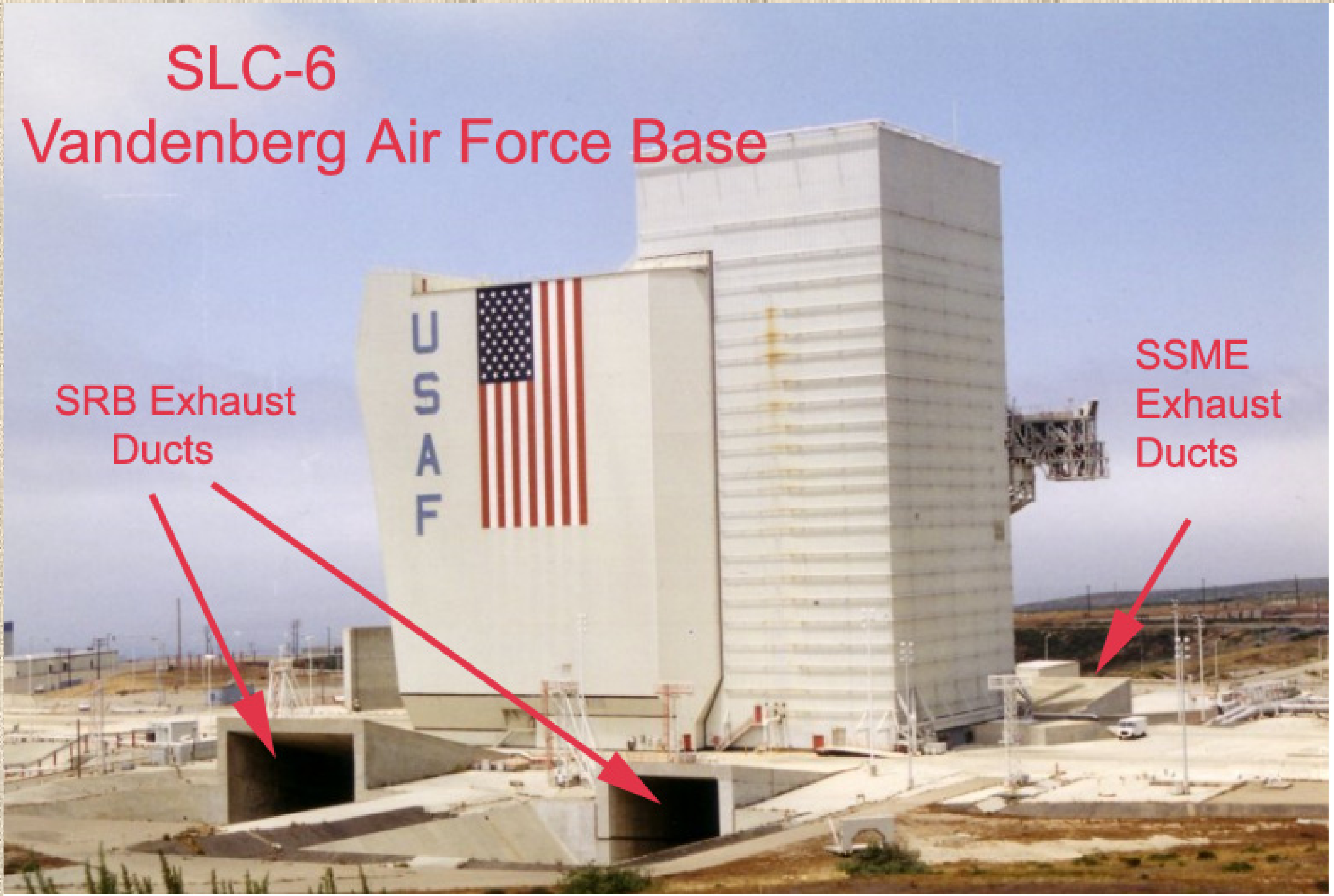

SLC-6
Vandenberg Air Force Base
USAF
SRB Exhaust
Ducts
SSME
Exhaust
Ducts

Vandenberg Support - Ground Equipment

The first job at Rockwell after returning about 1981 was in a section that had a support task with NASA MSFC SSME Engine Office. At this time the Air Force wanted to use their version of the NASA Shuttle to fly polar orbit missions from Vandenberg Air Force Base (VAFB) in California. They were preparing a launch site at SLC-6 on the VAFB property. SLC-6 was usually referred to as "slick six". To process Shuttle components at this site, the Air Force needed all of the Ground Support Equipment (GSE) currently used at Kennedy Space Center in Florida. Since NASA MSFC had all the procurement documentation, they would obtain this gear for the USAF. The fellow I was to work for had the task of holding the hand of the NASA guy who was buying the GSE for the Shuttle Orbiter main engine. This was about three steps down from the USBI position I had just left, but it was what was bargained for. On the plus side it was easy and stress free, better pay and most important of all, had a generous Rockwell savings plan and the opportunity to build on a retirement pension.

When we finally went out to visit one of the GSE suppliers in the Huntsville area we found that this company had been proceeding for the last number of months with the wrong drawings. Our NASA guy messed up and had not even been checking on his supplier since awarding the contract. He only belatedly sent us. We had essentially been waiting around for direction. This was a wild departure from the way we managed procurement at Rockwell and USBI. We kept up contact with our suppliers constantly. Government agencies need contractors to actually get work done. This coasting period eventually led to work in another section with another task also related to the Shuttle Vandenberg support.

Vandenberg Shuttle Launch Site Support

For a while work here was mostly document review. Most of the people in the section were not engineers and seemed happy with their lot. One exception was Harry Beasley.

When we were given mundane tasks, usually document review for a NASA counterpart, we would start picking at it and raising a fuss over discovered flaws. That was not very popular. We once became aware of a possible conceptual mistake in adding a spring complication to the Shuttle hold-down provisions at VAFB. We were shocked that nobody cared. The same was true for other gaps and omissions that we became aware of.

SRB with Filament Wound Case

In an effort to gain more launch energy for intended VAFB launches, NASA contracted with Aerojet to produce a SRM with a filament wound case in lieu of steel. The saved case weight would permit more propellant to be used. The first SRB with this light weight SRM was to be trial stacked at VAFB. Harry and I went out to observe the support post preparation and also stacking/destacking. Since the SLC-6 launch facility was fixed as opposed to the mobile launcher at KSC, bellville springs were installed in some of the support posts. The purpose of the springs was supposedly to simulate the flexibility of the mobile launch platform (MLP) used at KSC. I had doubts that the springs had any affect on dynamic characteristics associated with the "Twang" leaning of the Shuttle after start of the main engines.

Harry and I were sent out to VAFB to witness adjustment of the structural posts that would support the Shuttle. We spent one crazy night actually giving direction to the technicians. We had no business doing this. The contractor in charge and the Air Force representative were not properly prepared. Harry and I had previously studied and worked with documentation prescribing the required shimming and positioning requirements of the bearings on the hold-down posts. Although we were unofficial "invaders" the working personnel gladly accepted our assistance. The filament wound case project was eventually terminated.

Vandenberg Visits

More visits to Vandenberg followed. Harry like to make the most out of these trips. Evenings he sought out the best restaurants in the area. Once we were stuck out there over Labor Day week-end. We took the opportunity to drive up the coast and take in Hearst Castle. When on Vandenberg duty we over-nighted at the small town of Lompoc a few miles outside of Vandenberg. We stayed at the Raffles Motel which was named for a famous hotel of that name in Singapore. On the drive in to SLC-6 we would pass fields owned by the Burpee Company. They would be harvesting the familiar flower seed that is packages and sold about everywhere. The country is pretty and bright until getting near SLC-6 which is at notorious Conception Point on the California coast. Here the weather changes abruptly because of the convergence of nearby cold and warm ocean currents. SLC-6 is a spooky place at night. It was usually foggy and there was a moaning sound beacon just off shore. It was supposed to warn any approaching ships of danger. During the 1930's a string of Navy Destroyers ran aground here. The first ship made a navigation error and the rest of the string followed the leader to their destruction. Nearby points of interest are marked on the small map. They include Solvang, Purismo Mission and the city of Santa Maria.

Hard Times at SLC-6

A smart Rockwell engineer from Downey made an inspection trip to Vandenberg after construction of the launch facility was mostly completed. He filed a report stating that the exhaust tunnels for the main engines were way too long and could not be used. In start-up, the SSME orbiter engines burn fuel rich and dump quantities of liquid hydrogen down into the tunnel. If that hydrogen flashes into gas and mixes with oxygen in the ambient air a destructive explosion could result. This is a concern at KSC with a much shorter tunnel that minimizes the possibility of explosion. Even at KSC , radially outward flame igniters (ROFI) aka (sparklers) are activated prior engine start to burn excess hydrogen before it can build up to dangerous quantities. It is truly disappointing that planning and construction had been going on for years at VAFB without anyone questioning this devastating goof. The Air Force denied the danger for a year before agreeing to try to do something about it. The last plan before the whole VAFB shuttle program was canceled was to use a large aircraft jet engine to continuously purge the tunnel during launch. Many questioned the effectiveness of this idea.

Harry and I were on a trip to Vandenberg again in January of 28, 1986. I was watching practice exercises for moving hydrazine propellant from a delivery tanker to storage tanks at various levels of the launch support tower. Hydrazine is hazardous and the handlers manning the supply lines were decked out in cumbersome protective suits. (SCAPE Suits) We were watching via TV. A guy would call for a wrench he did not have. Before someone could bring him the wrench they also had to put on the SCAPE suit. By this time the first guy had used up his allowable time in SCAPE suit and had to call for a replacement. And so it went, hour after hour. Lockheed engineers I was with were under severe schedule pressure and unfortunate delays were causing them to continue the exercise through the night. They apparently had to do this frequently. I overheard phone calls involving wives begging that their man come home for supper for a change. I heard promises made but the guys would still be around at midnight. Things were really not going well at Vandenberg. Work buildings and offices were all temporary buildings and trailers. They were scattered around within a quarter of a mile from the launcher. When I asked what would happen to these structures during launch. (At KSC there are no ordinary structures within 2 miles.) The answer was, oh they just get blown away.

Disaster Day

On January 28, 1986 Harry and I drove in to the SLC-6 area as usual. At the security gate we greeted the guard with a good morning. He looked a little surprised and informed us that it was not a good morning. California is a few hours behind EST and we had not heard that the Shuttle launch at KSC in Florida had failed. The orbiter Challenger was destroyed with all the crew. It was grim day, normal tasks pretty much stopped. Everyone was huddled around news sources trying to get the latest word and trying to figure out what happened. I could not believe that it was the SRB that had caused the disaster. But it was.

A short time later the Air Force decided that they did not need to launch manned polar orbits after all. So plans for completing the launch site at SLC-6 were dropped. They probably realized that trying to launch shuttles from their facility would likely not be successful. 25 Years earlier another Air Force space vehicle called the Dyna-Soar had been planned for launch at this same site. It too had been abruptly canceled. The place is a jinx.

SPACE SHUTTLE PROGRAM

CHALLENGER DISASTER

The first 25 years of NASA had produced a string of successes. The reputation of NASA was at its zenith. Although there had been some ground test fatalities, there had been none on actual missions. Things looked great for continued NASA prosperity.

However Trouble Was Looming

The repeated success of launches resulted public boredom. Thus, the media started cutting coverage. Political support was weakening.

The Shuttle turned out to be very expensive to operate, and was limited in its capability.

Although not widely known at the time the reusable Shuttle Solid Rocket Boosters had a major problem that was growing with each use cycle.

SRM JOINT FAILURE AND RECOVERY

Trouble

A series of design changes in its early proposal stages were driven by cost reduction mandates. This resulted in a Shuttle with limited performance. Also the promise of cost savings by a reusable design was not realized. The Shuttle never had a chance of being cost competitive with non-reusable designs at any conceivable launch rate. The man-rated requirement also made the Shuttle an expensive way to deliver cargo to space that did not need human accompaniment.

Although not widely known at the time the reusable Shuttle Solid Rocket Boosters had a major problem that was growing with each use cycle. These operational problems were not known to most of us but Program Managers should have been aware of them. They should not, in the face of these obstacles to existing flight safety, start insisting on increased launch rates. They did in fact do this. At Rockwell, as well as other contractors, we were tasked to come up with ideas that could speed up launch processing. Instead of speeding up, the program needed to stop for at least a year. A year break in the program was needed to correct the SRM problems and to cure many other problems with the launch flow. If manned space program was to continue indefinitely, there should also have been a movement to develop a new more cost efficient Shuttle replacement. The emphasis in the teacher in space idea looks like a lame attempt by NASA publicity advisors to gain public and thereby political support.

If there were not already enough red flags flying, delays were steering 51L, the designation for the next mission, into a very cold launch day. Not only did the SRM's have distorted clevis joints, but the rubber O rings would have lost a lot of the elasticity necessary for their sealing function. Various people in NASA and Thiokol were worried and tried unsuccessfully to stop the launch of 51L.

The Space Shuttle launch failure of January 28, 1986 shut down the program indefinitely, pending redesign of the Solid Rocket Motor cases. The previously known defects of the field joints were now public. The long delay in building new boosters and the ongoing difficulties with preparing SLC-6 at Vandenberg caused the USAF to reconsider continuing their plans for manned shuttle launches.

Disaster History

There are many accounts of the Shuttle Challenger Disaster on the web. Many are distorted, inaccurate or incomplete. The joint was essentially copied from the 120" diameter clevis joint used for the strap-on boosters for the Air Force Titan. That program had a successful history, at least up to that date.

The 146” diameter man rated Shuttle booster used the same type of clevis joint but incorporated two O rings rather than the Titan single O ring design. During ground testing and early flights the joint worked fine. However the structural configuration carried launch loads in a way that caused the joint to distort “rotate”. After several reuse cycles the joints became permanently distorted. This increased the gaps that had to be sealed by the O-rings. The distortion also led to difficulties in stacking the SRM segments at KSC.

This problem was known and steps were taken to produce new cases with an extra lip “capture feature” on the joint that would hopefully control the “rotation”. Unfortunately the program would not wait for the new cases and continued using the defective ones. If launches in cold weather would have been canceled, the existing cases may have survived until the new cases arrived, but the risk would have been excessive. Eventually the old cases would have failed, even in warm weather.

After the disaster, several initiatives were started to get the Shuttle program back on track. One was building a totally new booster called the Advanced Solid Rocket Motor. It would have a larger diameter to provide performance the original Shuttle was lacking.

Another was to improve the joint in the existing SRM. It was to have a more upgraded design change than the capture feature configuration under construction. The new design would increase the size of the capture feature, install a third O-Ring and also incorporate an internal sealing flap. This redesigned booster was dubbed RSRM. There was another booster design being developed that was filament wound rather than using a steel case. The object was to save weight.

Recovery

Lockheed was awarded the contract to design and build the totally new Advanced Solid Rocket Motor (ASRM). In addition to having more reliable joints, it was to have increased lift capacity. Instead of starting on the project, Lockheed chose to litigate the terms of their contract for a year. In the meantime the Redesigned booster made rapid progress and reduced the need for the ASRM. After spending a horde of money on the ASRM and filament wound approaches NASA cancelled both.

Eventually the Shuttle flew again. The new joint worked fine. Managers and workers were careful and efficient again. A new Orbiter was built to replace Challenger. A lesson was learned. Or so it seemed.

OMI Review

During the extensive time for redesign and rebuild of the Booster segments, NASA also underwent an exhaustive review of all Shuttle production and launch flow documentation. The principal document used for launch flow is called Operations and Maintenance Instruction (OMI). A OMI is prepared for each launch processing task for each mission. The OMI consists of step by step instructions with sign-off spaces for several level of quality inspections. There was a sizable stack of these OMI's that had to be approved for each Shuttle launch. The intent of the review was to correct and update the OMI's for future flights and to account for design changes made on the RSRM. The review task was apportioned out to many of the contractors that had been participating in the space program. Rockwell Huntsville received a share of this action. This provided a two year extension for our services. It was more paperwork but it did include some visits to KSC and some views of the stacking area in the VAB

Wind Down

After the RSRM came back on line and proved to be successful, our tasks relating to return to flight faded. Then several of us received an opportunity to move out to MSFC and work directly with NASA engineers in the SRB project office.

I came along too early for the computer age and never received company training in this sport. However that did not prevent playing with computers at home. At the NASA office we were given computers to use and fortunately I could use important software like spread sheets and simple data base management applications.

With the computer tool in hand, I was able to provide some marginal assistance to the NASA personnel I was tasked to support. My boss had me go to monthly review meetings to relate to our customer the wonderful things we were doing for them and why they should continue to keep us on. It was very difficult coming up with reasons. It is still difficult, I can't remember a single thing they were told. Fortunately the clock ran out and I had stayed long enough to retire. Rockwell hooked up all years I worked for them in three different periods for pension calculation.

Thereafter information on the Space Program had to come from the public media and a few inside tips from friends. Time was long past for Shuttle replacement but never seriously implemented. Money was spent on re-inventing previously developed programs and in chasing other futureless projects.

The aging shuttle had to be used to support the international Space Station. For this to work we had to depend on the Russians and their launch vehicles. As time went on complacency set in again. Serious problems with the external insulation on the External Tank developed. Pieces were dropping off and impacting Orbiter tiles.

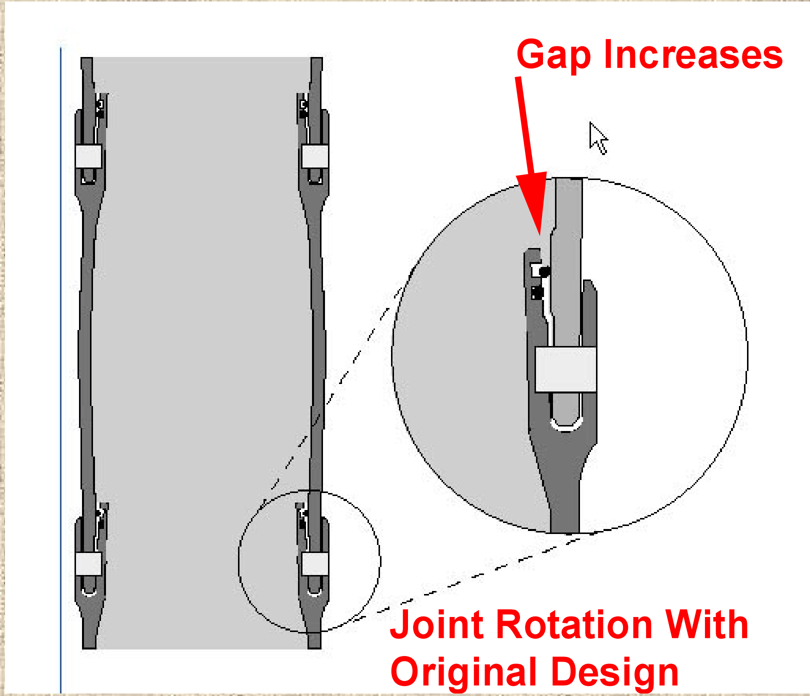
The orbiter heat shield tiles are remarkable in their ability to withstand reentry heating and still remain reusable. However they are very vulnerable to mechanical impact. Dropping an eraser on a tile will ding a tile. This was well known since the start of the Shuttle Program in the early 1970's.

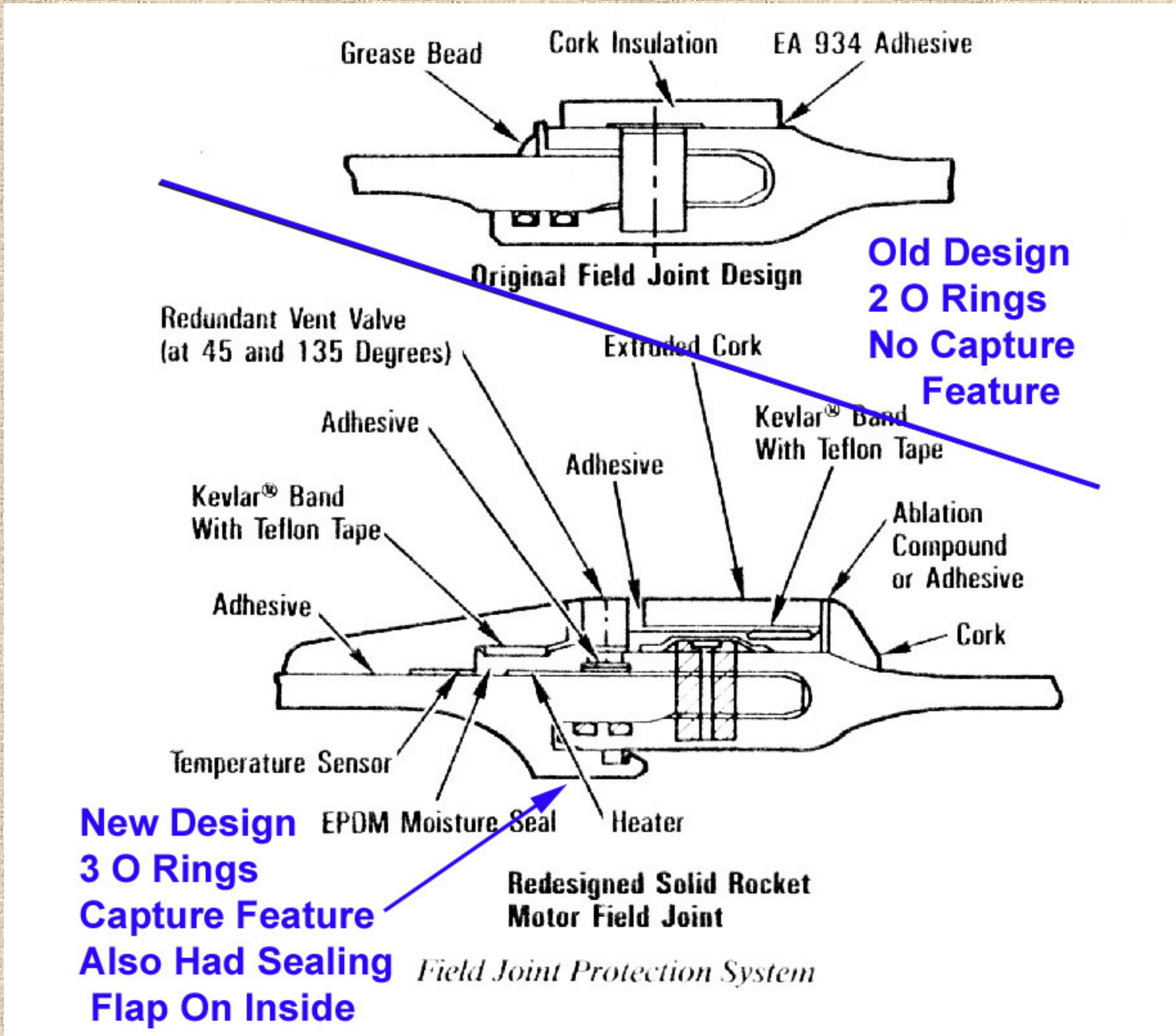
Program vigilance restored after the Challenger disaster could only last for a decade. Ineffective resolution of the External Tank insulation shedding issue led to another disaster. On February 1, 2003 the orbiter Columbia was entering the atmosphere with damaged tiles. A burn through resulted in the loss of another orbiter and its crew.

The problem was belatedly fixed and Shuttle launches resumed after a lengthy delay. There would not be a replacement for the lost orbiter this time. Work finally was started on a Shuttle replacement. However schedule and other difficulties have arisen. As a result of the economy downturn in 2008, there is fear that the program might be canceled. Without a shuttle replacement and with final grounding of the shuttle fleet expected in a few years, we would be out of the manned space business. National pride is not what it used to be.

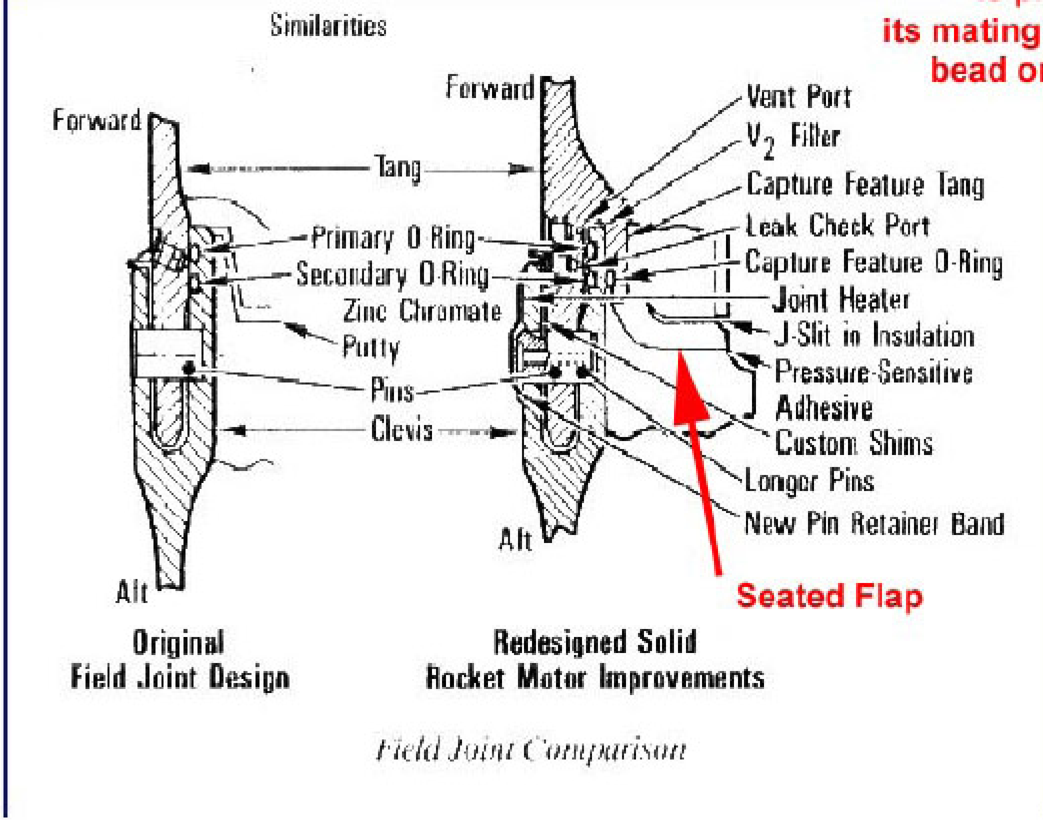
In the meantime, the Shuttle continues to fly. The first launch was April 12, 1981. That makes a 27 year flight history, so far.

SOLID ROCKET MOTOR CLEVIS JOINT

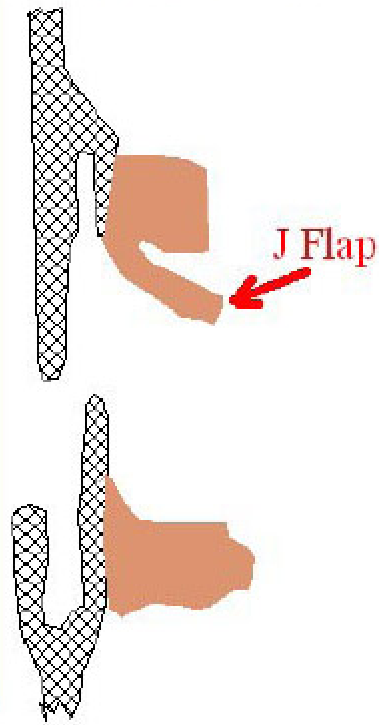



Grease Bead
Cork Insulation
EA 934 Adhesive
Original Field Joint Design
Old Design
2 O Rings
No Capture
Feature
Redundant Vent Valve
(at 45 and 135 Degrees)
Extruded Cork
Adhesive
Adhesive
Kevlar® Band
With Teflon Tape
Kevlar® Band
With Teflon Tape
Ablation
Compound
or Adhesive
Adhesive
Cork
Temperature Sensor
New Design
3 O Rings
Capture Feature
Also Had Sealing
Flap On Inside
EPDM Moisture Seal
Heater
Redesigned Solid Rocket
Motor Field Joint
Field Joint Protection System

The J Flap was added to the redesigned SRB field Joint in addition to the 3rd O Ring which is called a "barrier" rather than a seal. The J Flap hangs down slightly and forms a tight seal with its mating surface then the two SRM segments are brought together. Also adhesive is applied to the lower surface before mating. On ignition and case presurization, the flap is pressed more tightly to its mating surface -- like the bead on a tubless car tire. s



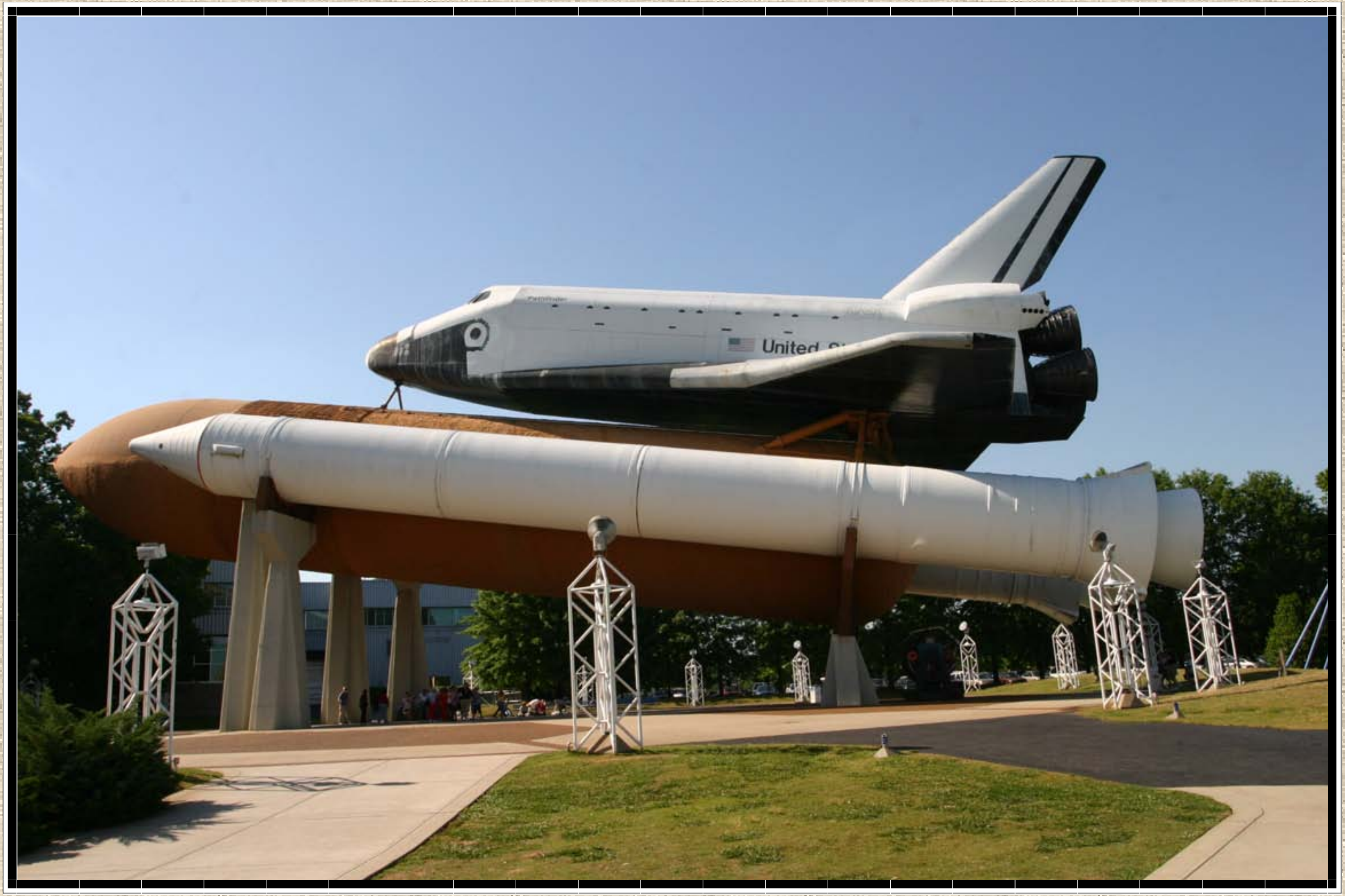
Field Joint Comparison



SHUTTLE PHOTOS FROM THE SPACE & ROCKET CENTER

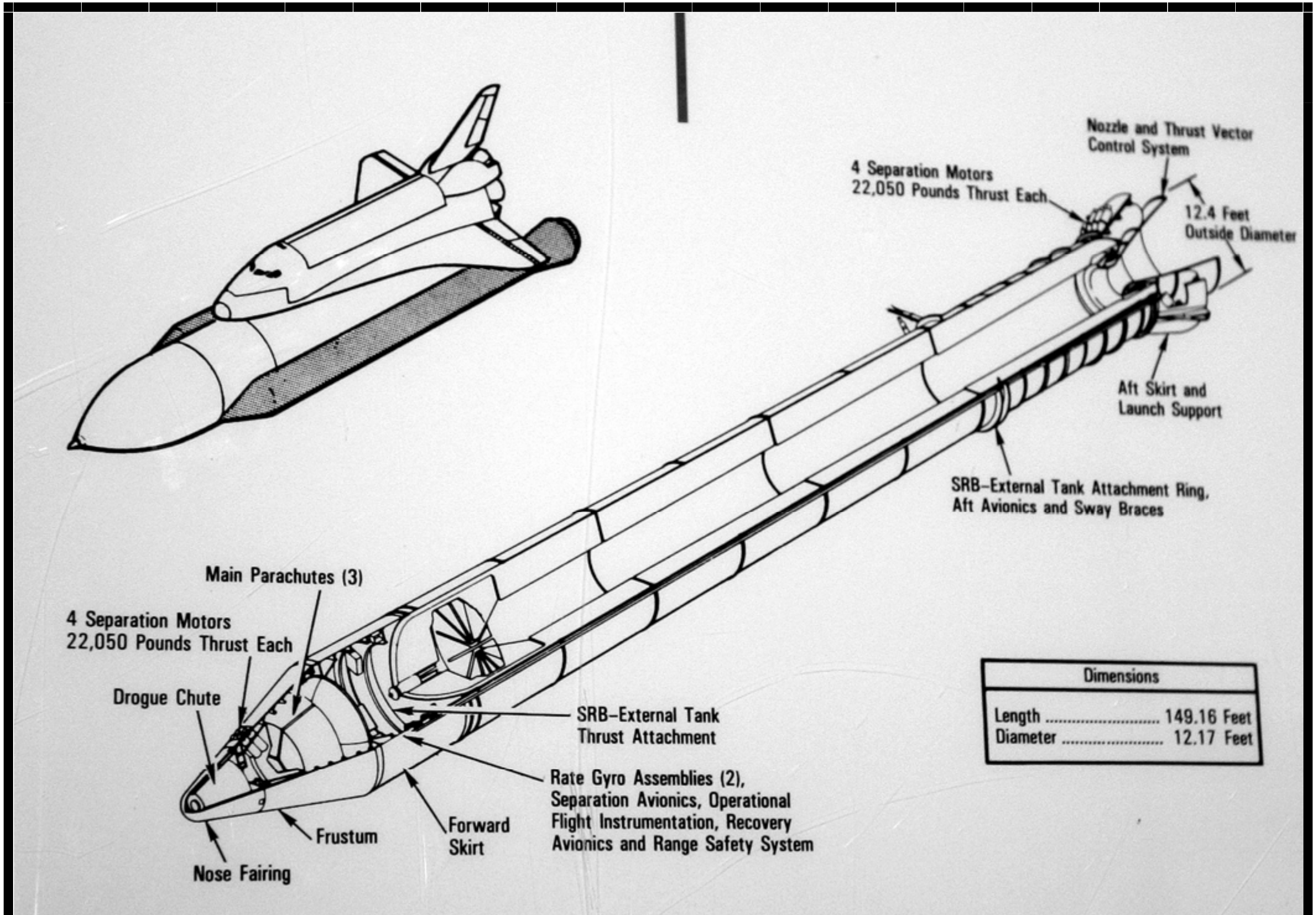
The US Space & Rocket Center   Space Shuttle 5/17/05

US Space & Rocket Center   Space Shuttle SRB

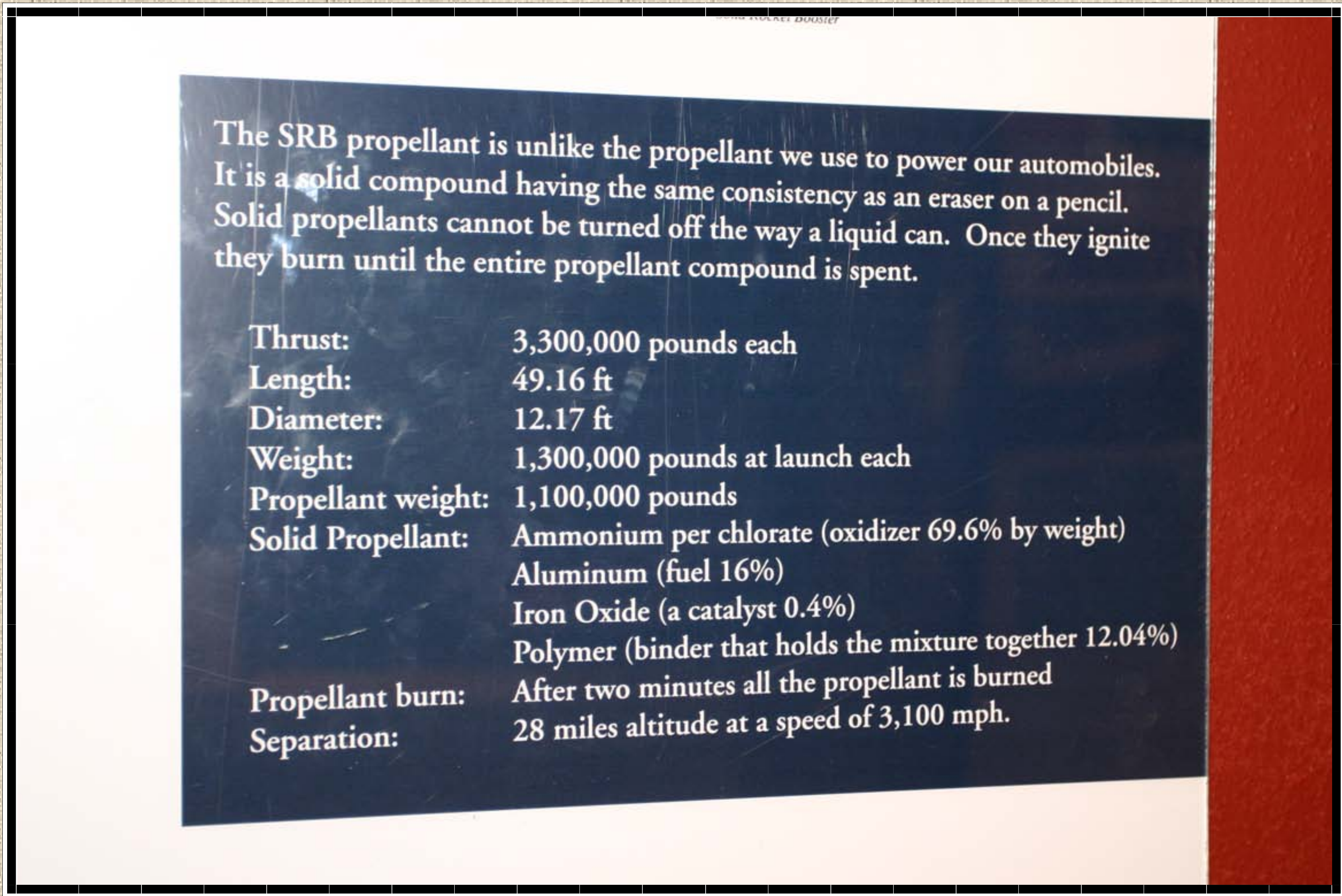


Space Shuttle mock-up at the U.S. Space and Rocket Center in Huntsville, Alabama

US Space & Rocket Center Space Shuttle SRB May 17, 2005



Solid Rocket Booster


The SRB propellant is unlike the propellant we use to power our automobiles. It is a solid compound having the same consistency as an eraser on a pencil. Solid propellants cannot be turned off the way a liquid can. Once they ignite they burn until the entire propellant compound is spent.
Thrust: 3,300,000 pounds each
Length: 49.16 ft
Diameter: 12.17 ft
Weight: 1,300,000 pounds at launch each
Propellant weight: 1,100,000 pounds
Solid Propellant: Ammonium per chlorate (oxidizer 69.6% by weight)
Aluminum (fuel 16%)
Iron Oxide (a catalyst 0.4%)
Polymer (binder that holds the mixture together 12.04%)
Propellant burn: After two minutes all the propellant is burned
Separation: 28 miles altitude at a speed of 3,100 mph.