W. A. Mrazek
Aerospace Workshop
University of Hawaii

Section B VII.1 June 66

THE SATURN LAUNCH VEHICLE FAMILY

It was in October 1957 that the world was shocked out of its lethargy by the announcement of the Russian firing of the first satellite. We had to admit that our planned 2-pound grapefruit-size attempts were weightwise not at all impressive. You may remember that before our contribution to the Geophysical Year, the Vanguard Project, succeeded with its first beeping 2-pound satellite, we were able to match the Russian feat with a small but scientifically successful Explorer I. This Explorer was developed and launched by the Development Operations Division of the Army Ballistic Missile Agency under Dr. von Braun's technical direction. In 1960 this group was transferred to the National Aeronautics and Space Administration and is now known as the George C. Marshall Space Flight Center.

Back to the Russian Sputniks--the size of Sputnik 3 was about 2,000 pounds; Sputnik 8 was 14,000 pounds. The long-nourished suspicion that the Russians were working on a missile considerably larger than any of ours was confirmed by their first launch. It came as no surprise. This high-weight-lifing orbital capability of the Russian missile was incidental. The reason was very simple. The nuclear technology of the Russians was behind ours; they just could not build small efficient nuclear devices; therefore, they had to go the other way and build large delivery systems. None of our Atlas or Titan missiles have this weight-carrying capability. Remember that the Atlas missile was successfully used in our Mercury firing with a one-man capability. The Titan is presently used with the Gemini two-man capability. In 1958-1959 we succeeded in launching several Explorer and Pioneer satellites on Jupiter C and Juno boosters.

At that time the Department of Defense created a small agency "Advanced Research Projects Agency" (ARPA) which had as one of its assigned responsibilities the task of countering the Russian superiority in payload delivery capability. The von Braun team was approached with a query as to whether some shortcut could be found to quickly remedy the disadvantage of the United States.

Appraising the situation, we knew that there were no engines developed larger than those used in the Atlas, Thor, Jupiter, and Titan. One engine, only twice as large as the Atlas engine, was in an early stage of design. A capability which would surpass that of the Russians and gain an advantage could only be achieved by clustering or bundling several of the available engines. Luckily some development work was under way to simplify and modify the Atlas/Thor/Jupiter engine and also to look at a slight improvement and uprating within the capability of the hardware.

The direct question to us was, "With this money, can you demonstrate on a test stand the firing of a multiple-engine cluster in 18 months?" Naturally, we said "yes" and went to work. It was not easy. First, we called in the engine manufacturer and asked him the same question, "Can you deliver?" He said "yes" but he did not think the funding was sufficient for rebuilding, testing, and delivering enough engines and spares for our cluster. With some "arm twisting" and permission to clean the stockrooms of leftovers from previous programs, he agreed; now half of the funds given to us by ARPA were gone. With the rest we had to finance our portion of the job. First we had to modify a test stand in our back yard. The stand had only been used for firing of small missiles with 165,000 pounds thrust and 105' in diameter but now must take a monster 240" in diameter, 80 ft. high, and with a thrust of 1.5 million pounds. Furthermore, we had to build tooling for propellant containers and for the thrust structure to support the engines. We also needed large assembly fixtures to hold all pieces in place for the final assembly and checkout. Finally, we had to build the hardware itself. We also went through our stockrooms to "moonlight requisition" whatever could be made to fit the new projects. Fortunately, from our previous projects we found 70" tanks which were incomplete, partial rejects, and some 105" diameter hardware. These were from successfully terminated missile programs, the Redstone and the Jupiter. The dire need made us more inventive and we bundled the containers to be loaded with propellants for eight engines to burn a total of 2 1/2 minutes. The need became a virtue and the clustered tank arrangement is still with us in the Saturn IB--but more about this later.

Now the design progressed nicely until the "worms began to crawl in." ARPA representatives visited us frequently to observe our progress and finally stated "We really think you will succeed with this demonstration on the test stand. Now we have changed our minds, we would like for you to make this stage fly. We do not know yet the place from which it will be launched. You should build it in such a way that it can be taken apart and quickly reassembled on the launch pad--something like a tinker toy."

We said that we would build into the first flight birds the capability to be taken apart. Thank goodness we never had to disassemble the first flight vehicle. We finally were allowed to launch from Cape Canaveral, and we mobilized our first NASA Navy of barges which could float wholly assembled Saturn I stages of 20-ft diameter, and 80-ft length, down the Tennessee, Ohio, and Mississippi Rivers, through the Gulf of Mexico, and around Florida to the Cape.

The costs of such large stages were, of course, higher than our friends in Washington had experienced before. The head scratching began to work out a solution. The obvious one was "just to fish the spent stages out of the ocean after reentry, give them a "once over' polish, and reuse them." "Yes, we will even try this," we said. Naturally, nobody is willing to work without pay and the development of a parachute system for 100,000 pounds required "some doing" and also some financial support. We had capable companies on hand, were progressing nicely, and were ready to perform the first drop test when, after second thoughts (nourished by fears of too high costs), our financing agency cancelled the recovery plans. The designers had already made all the provisions on the vehicle to accomodate the parachute and all other necessary gear to deploy the large triple chutes.

It was clear from the onset that we could not reach an orbit with the first stage of the Saturn alone--we needed another stage on top. The question of the upper or second stage gave us another round of anxiety. The first direction was to use anything available in the guided missile arsenal as a second stage. The choice was narrow. On hand, there were only the Atlas and the Titan, both 10-ft diameter with low-performance kerosene-oxygen propulsion systems. In comparison, this was like considering the purchase of a 5-ton truck for hauling a heavy load and finally deciding to merely load a wheelbarrow full of dirt.

After numerous iterations, it looked as if the only way to really cash in on the lifting power of the first stage, to reach into the newly developed hydrogen technology with the specific impulse almost 30 percent higher, was to use one engine which was under advanced development with Pratt and Whitney for the Centaur vehicle. There was a big meeting in Washington with all faces red--looking for a good solution. I remember the time of that meeting--it was just before Christmas 1959.

The telephone rang and Dr. von Braun, a member of that hatching committee, called me. I was responsible for the engineering of the stages was Wernher's design chief. His conversation ran somewhat as follows: You know that we just cannot use as upper stage what is laying around; we need a new upper stage. Let us go all out and use the new hydrogen technology and the Centaur engine. Of course we will need six of these engines, but you should not worry. I was just told that the official schedule calls for 12 Centaur firings before we have to launch the first time. I think I can commit us to do it." I looked at the official schedule--there it was 12 firings. I had the justified expectation that I would learn enough from these Centaur firings so that we would not duplicate errors which might slip by the Centaur people. So, I agreed and Wernher committed us and Marshall to use the RL-10 engine and hydrogen.

The ironic part of this story is that we had the first successful launch of a stage and full-duration burning of all-hydrogen six engines ahead of the first successful full-duration Centaur firing; we terminated our Saturn I program with six successful firings of six engines each--a total of 36 engines last summer; and we are still waiting for a successful Centaur firing.

Let me continue my historical resume. That time frame coincided with the birth of our lunar exploration program which was proclaimed by our late President John F. Kennedy.

The Apollo idea crystallized: the size of the capsule was defined for a three-man crew. The mode of doing this job was analyzed over and over and finally changed from an earth orbital rendezvous (EOR) mode to a lunar orbital rendezvous (LOR) mode. In my next lecture I will thoroughly discuss the present lunar program. The vehicles to do this job had to be optimized for this particular mode of operation.

We were able to somewhat clean up Saturn I. Remember all the nonsense we had to consider in the first design such as disassembly for transportation, recovery gear, parachute attachments, the requirement to be able to accept any upper stage decided upon at a later date, etc. Now, we were able to clean the design, to plan for a manrated vehicle to fly the first Apollo mission, and to consider flight safety of the astronauts.

About that time (it just could not be different), a new little twist was added--another pinch of sand thrown into the gears. You may remember the Dynasoar Project which was later cancelled. This was a vehicle for return from orbit. It had lifting surfaces, that is wings, for landing on solid ground instead of in the water as the astronauts do today. We were asked to consider this fixed-shape payload to be boosted to orbital velocities. Because of this possible payload, and in case of booster failure to provide time necessary for the pilot to get away from the holocaust of a failing vehicle, we had to add fins to the end of the first stage booster. We had considered even for the smooth round Apollo capsule some small fins the size of a "one-car garage door." With a lifting body like the Dynasoar on top of the launch vehicle, we had to add fins the size of a barn door. So--back to the drawing board. All load-carrying members in the tail of the first stage were reinforced, redesigned, and released for manufacture. I can assure you it requires a lot of documentation and sweat to define all details of such a complicated structure.

To nobody's surprise, we had just finished when a change of mind somewhere above relieved us from this latest requirement. We had already built up for manufacture, contracts sh ad been let, material in required thicknesses had been ordered and partly machined. The time schedule of course did not change. The only thing we could do was to reduce the fin size from "barn door" to "garage door." This was done by virtually cutting off the oversize.

There we were again settled with the second best solution--to strongly build for a mission we did not fly--with a payload capability down to about 22,000 pounds for injection into a normal 100-mile orbit.

Let me go back and elaborate somewhat on the difference between the Earth Orbital Rendezvous mode "EOR" and the Lunar Orbital Rendezvous mode "LOR." In the first mode, the EOR, it would be necessary to fire two vehicles from the earth in close succession; one smaller one the size of our Saturn IB and the second almost the size of our present Saturn V. In our first designs, the Saturn V was labeled C-4 (configuration 4). In this configuration the first stage had only four engines while the first stage of the Saturn V vehicle has five. The second stage had only two engines instead of the present five engines.

The main feature of the EOR was that the astronauts had to rendezvous in earth orbit with the propellant-carrying vehicle, transfer the propellant into their own spacecraft with quite large propellant containers of a propulsion stage which had a threefold task: to take the astronauts out of the earth orbit into a transfer trajectory to the moon; to break the velocity to zero arriving at the lunar surface; and to take off again from the moon. Imagine the vehicle which would have been required.

It would have been the height of a water tower but with short stilts and a longer cylindrical container. On top of this there would have been the crew compartment. The little astronauts would of necessity have been in a reclining position looking away from the lunar surface into the sky and using a rear-view mirror or a T.V. system for the final approach. I think you would not like this situation and position. Neither did the astronauts.

The first mode, the EOR, was finally dropped in favor of the so-called LOR which I will describe briefly.

The crew compartment, the Command Module (CM), was equipped with a relatively small propulsive stage which had to work less than the propulsive stage in the Eor. This propulsive stage called Service Module (SM) packs beside the electric power and oxygen relocated from the CM into the SM enough propellants to take the less-propellant-consuming braking mission of CM plus SM plus Lunar Excursion Module (LEM) into a lunar, near-circular orbit. Then it must take only the CM out of the lunar orbit, again this being a much smaller vehicle. Finally, it must reduce the velocity of the CM for an earth return and landing before its own disposal. Really the task was subdivided and decreased in magnitude and energy requirement.

The lunar landing is performed out of the circular orbit after transfer of two of the three astronauts from the command module to the LEM by a specially designed small descent stage of the LEM. This LEM will deliver the two astronauts in standing position not more than 10 feet above ground, looking downward so they can see where they are going.

After the astronauts have performed the assigned task, they will dispose of the unit which brought them down by using it as a launch platform for the LEM ascent stage. They will leave it behind on the moon. The ascent stage will propel the LEM into a matching lunar orbit for a rendezvous with the waiting astronaut in the command module. There they transfer and leave the LEM in lunar orbit. Totally the energy requirements are decreased and optimized. The whole adventure can be performed now with only one launch vehicle, somewhat bigger than the second vehicle I described as C-4. Thus the Saturn V was chosen as the launch vehicle for the lunar landing.

Soon the training requirement for the astronauts was established and orbital long-duration flight of the three-man Apollo capsule, exercise of the Service Module propulsion, exercise of the Lunar landing and ascent stage, and finally, the rendezvous were made mandatory.

This necessitated a launch vehicle almost twice as large as that we had in manufacture and already in launch tests, the Saturn I.

A building block approach and quick thinking resulted in an improved Saturn I which we labeled Saturn IB. It consists of the first stage of the Saturn I with the engines another notch "tweeted up" and a second stage which was already under development as a third stage for Saturn V. Thus we even cashed in on early demonstration of the S-IVB stage which is the most important stage of the Saturn V.

This is the factual history of the Saturn family. I have not added to it but rather have shortened it a great deal. Now, with a few slides I would like to bring to you a clearer understanding of the technical features and the realization of the technological progress in space transportation in general.

SLIDE #1

The first slide shows the relative size of the vehicles of the Saturn family. The Saturn V measures 381 feet in height; this is almost 2/3 the height of the Washington Monument.

The improved Saturn I, or Saturn IB, is about 225 feet high.

For completeness sake, I would like to mention that we had other preliminary plans between Saturn I and Saturn V: there were the C-II, C-III, and C-IV configuration, already mentioned. The third stage is called S-IVB because of its historical development. We studied S-III stages and we also flew an S-IV stage.

The next slide shows the prime or main contractor structure and responsibilities.

SLIDE #2

Here I want to emphasize that the Apollo program is the biggest technological task ever undertaken by mankind. It outranks the building of the pyramids in the past and it even overshadows the Manhatten Project of World War II (development of the atom bomb). It is directed by the three Centers of NASA: Kennedy Space Center, the moon port located on Meritt Island close to Cape Kennedy; the Manned Spacecraft Center at Houston, Texas; and the George C. Marshall Space Flight Center located at Huntsville, Alabama, under the baton of Dr. George Mueller, head of the Manned Space Flight Office of the National Aeronautics and Space Administration.

The total manpower actively participating in this program is over 300,000 located in 48 of the 50 states with a system of 17 main contractors and their facilities and about 20,000 subcontractors. The launch vehicle program requires at the present 1 1/2 percent of the national budget, another 1 1/2 percent goes to the spacecraft program. A total of 12,000 government employeees participate actively, working and managing this complex contractor structure with the final management goal of synchronizing all elements of the Apollo program to culminate in a successful launch on schedule.

The task is a difficult one. Just imagine all elements including the astronauts themselves who must be trained and the numerous necessary tests that must be performed if one day, within this decade, a vehicle can be launched to lpursue this nation's biggest human technological achievement--to reach the moon and return safely.

SLIDE #3

Here are the geographical locations of the elements of this program. You see the Centers and the prime contractors.

SLIDE #4

To impress you with just one other necessary aspect of the program, I want to mention the ground transportation for these large subassemblies. You see air transportation routes, river and gulf transportation routes and west-east routes through the Panama Canal. In the left corner you see transportation times and distances.

SLIDE #5

Here is the way our Super Guppy looks during various phases of loading. The Super Guppy is presently the biggest airplane built and flown. I know that I am speaking in superlatives but that is truly the only way to describe the space program.

SLIDE #6

This is a typical river barge.

SLIDE #7

This is a seaworthy military craft adapted to stage transportation. Can you imagine how much planning is required to effect the most economical means of transportation?

Let us get back to the Saturn family. The first of the family, Saturn I

SLIDE #8

This slide shows the characteristics: (read from slide)

SLIDE #9

This is a description of the missions assigned to this vehicle.

I can proudly report that we have concluded the first step of the large launch vehicle development. With an unprecedented success of 10 successful launches out of 10 attempts, we achieved a reliability of .932 at a confidence level of 50 percent, which is pretty good.

We have mastered the clustering of large engines and in tests, on the launch pad and in the air, we have also learned to handle liquid hydrogen as fuel with liquid oxygen as oxidizer, a most potent combination.

As a very important contribution to the Apollo program, three successful "Pegasus" satellites are still circling the earth reporting steadily the frequency and size of small meteoroids populating the higher regions of useful earth orbits.

We can say today, based on the Pegasus measurements, that with the design of our spacecraft we are safe from the most frequent small meteoroids which nevertheless carry a great deal of energy and are able to penetrate certain metal thicknesses. We have successfully launched the first two of the Saturn IB series, the improved Saturn I. This increased the reliability to .994 with a 50% confidence level.

SLIDE #10

Shown here are the characteristics of the improved Saturn I, or S-IB. (DISCUSS)

SLIDE #11

This, again, is a description of the mission. (DISCUSS)

SLIDE #12

This slide shows data of a typical Saturn IB trajectory.

For better clarity, both scales used are different. The altitude of the trajectory in this presentation is shown increased by a factor of 5.

SLIDE #13

This is the majestic liftoff of the first improved Saturn (S-IB) #201 which carried a well-instrumented command module down-range to simulate a steep reentry trajectory from earth orbit.

SLIDE #14

Let me describe briefly the stages of the improved Saturn I.

The S-IB stage is built by the Chrysler Corporation Space Division and is 80 feet long; it has eight 70" containers around a 105" container in the center, with eight engines in the rear. There are eight fins for better flight stability and for the support of the whole vehicle on the launch pad.

SLIDE #15

Here is a view of the assembly line at the Michoud Assembly Facility.

SLIDE #16

A stage is being lifted into the static firing facility.

SLIDE #17

This is how the inferno of a static test looks. Static firings are being conducted in the development phase of the vehicles in order to establish the flight worthiness of the stages.

SLIDE #18

The second stage of the improved Saturn I is the S-IVB stage, 54 feet long, manufactured by Douglas Aircraft Corporation at their Huntington Beach, California facilities. You see the subsystem of the stage depicted on this slide.

SLIDE #19

As are all stages, the S-IVB is also test fired for flight worthiness demonstration.

The next major stage or unit of the launch vehicle is a 3-ft. high slice crammed with instrumentation, actually the brains of the vehicle.

SLIDE #20

Here you see a simplified overall schematic of the electronic intelligence contained in a launch vehicle. This slice,as you see here, carries most of the electronic instruments.

There is a systematic approach which is recognizable in the repetition of the same type of subsystems through all of the stages.

SLIDE #21

This picture shows the physical arrangement of black boxes. All instruments are bolted to cooling plates so they can be properly temperature-controlled during long hot days in the Florida sunshine, and in the hour-long coast time in earth orbit.

SLIDE #22

Here you see the start of assembly of such an instrument unit in the IBM Huntsville facility.

The Saturn V instrument unit is more impressive.

SLIDE #23

Proposed and possible missions are shown here.

SLIDE #24

The most important support data are contained in the characteristics.

SLIDE #25

This diagram explains the payload capabilities of the Saturn V launch vehicle.

SLIDE #26

The first stage is built by The Boeing Co. in the Michoud Assembly Facility. It stands 138 feet high and is 33 feet in diameter.

SLIDE #27

Early static firings were conducted at our Huntsville facility. After completion of a totally new acceptance firing complex in Mississippi, all stages except the S-IVB will be test fired there.

SLIDE #28

The S-II stage, the second stage of the Saturn V stack, is 81.5 feet long.

It is being manufactured at a new North American Aviation, Inc., facility in Seal Beach, California. Basically, the systems look similar to the S-IVB. We use five engines instead of one.

SLIDE #29

In order to appreciate the size, here are the bulkheads of the LOX containers. Please notice the two men working in the center.

In conclusion, I would like to emphasize the new technologies introduced in these advance launch vehicles tax our engineers and managers to the utmost. Sizes never before handled require new tooling approaches, new assembly procedures, and new facilities. Materials in these alloys and thicknesses of materials never before joined demand the highest skills of our welders and welding engineers. Inspection methods must assure prime quality. There have been occasions when we have lost hardware because of incomplete evaluation or misinterpretation of x-ray films of weldments!

The use of hydrogen as fuel in these giant stages imposes further elements of risk in the test and launch areas. In most cases, leakages are critical because of the danger of ignition of hydrogen in air. A pipe connection absolutely tight for use with air or nitrogen may leak considerably if used with hydrogen.

The proper functioning of all electronic equipment is dependent upon selection of dependable components and the skill of craftsmen who assemble these components to systems. Thousands of soldering units have to be produced and inspected.

We just do not have a second chance with a launch vehicle failure--there is no pilot on board to act in emergencies.

The hardware price is high due to its special handling in manufacturing, testing, and inspection. It has to be perfect. Just one imperfection, a little soldering point failure, could nullify the efforts of thousands of workers who went all the way to ensure the highest degree of quality.

By the end of this decade, the United States will have established itself as the first nation in Space. We will be able to launch 1,500,000 pounds of payload yearly into a low-earth orbit of 200-300 miles. We will be able to send probes into the interplanetary sphere with a total yearly payload weight of 500,000 pounds.

With the maintained production of six Saturn I vehicles, we will be able to launch 18 astronauts into orbit every year.

We must master the technologies to stage a Mars mission, a fly-by or a Mars landing, within the next decade.

I hope that we will all live to see man's biggest achievement. Men are now able to defy earth's gravity long enough to be able to travel to the closer heavenly bodies, in fulfillment of mankind's dream through centuries past.

Our nation will be first in Space.