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To: Birmingham Chapter
National Defense Transportation Association
Bankhead Hotel
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"SATURN AND THE NASA SPACE PROGRAM"

I am delighted to have this opportunity of meeting with you gentlemen this evening. Actually, you know, we talk the same language, because we at Marshall are also in the Transportation Business - We consider our SATURN vehicle the workhouse in the space program directed by the National Aeronautics and Space Administration. In Government jargon, this is known as N-A-S-A or "NASA." Tonight, I'd like to tell you about the SATURN, which will be responsible for transporting the first men and cargo to the moon. My particular area of endeavor is concerned with propulsion systems that use liquid propellants, and my discussion of the SATURN will center primarily on the various engines that are to be used in this vehicle. Near the end of my talk, I plan to take all of you on a quick trip to the moon - and return.

We have learned a lot about the earth and our solar system during the past five years. The United States has launched a variety of earth satellites and deep space probes, and has shared with the world the information gained about space and man's ability to function in this new environment.

During 1962, for the first time, the United States surpassed the Russian performance in total weight of satellites placed in orbit. At the beginning of this year we had orbited about 50 metric tons of payload, compared with about 41 tons for the Soviet Union, according to public announcements.

But we had to make four times as many launches as the Soviets to get our 50 tons of Satellites into orbit.

During the first years of NASA's program for the peaceful and sceintific exploration of space for the benefit of all mankind, we have, somewhat ironically, had to rely entirely upon rockets that were developed for defense. These have been modified for our missions, and we have been highly pleased with the results. But, as you know, our ballistic missiles for defense do not match the weight-lifting ability of the Soviet intercontinental ballistic missiles. They do not need to, because of our advances in weight reduction of atomic warheads. But we have long needed larger, more powerful rockets for heavier earth satellites, instrumented deep space probes, and manned space travel.

This need will be met by the Saturn family of launch vehicles now under development by NASA's George C. Marshall Space Flight Center at Huntsville.

Now, with the help of a few slides, I would like to describe briefly the Saturn launch vehicles,

Lights Off.

Slide 1 - SATURN Vehicles

The three members of the SATURN family are SATURN I, SATURN IB, and SATURN V. The SATURN I will be able to place a three man spacecraft into an earth orbit, which will be a preliminary step in our plan to go to the moon. Saturn V will launch this spacecraft to the vicinity of the Moon. The SATURN IB will be an intermediate step between the SATURN I and SATURN V.

Slide 2 - Saturn I launch

Furthest along in development of the three is the Saturn I, which was launched for the first time October 27, 1961. Three other launches have been held since that time, each equally as successful as the first. Only the first stage is live during these first four research and development launches. Upper stages are inert, and about 100 tons of water is added to simulate full propellant loading.

Slide 3 - H-1 Engine

The first stage of SATURN I is powered by a cluster of eight engines known as the H-1 model. These engines burn a kerosene fuel and use liquid oxygen for the oxidizer. Since rocket engines usually spend very little time in the Earth's atmosphere, we must carry the oxygen along. In order to conserve space, we use pure oxygen in liquid form, at a temperature of about -285^{o}F. The thrust of each engine is 188,000 pounds to eight of them provide a total of 1.5 million pounds of thrust for the Booster, or first stage.

Since many of you are in the trucking business, perhaps you will get a better feel for the power of this engine if I tell you about its turbopump. This pump pushes the kerosene and liquid oxygen into the combustion chamber somewhat like the fuel pump on an internal combustion engine. The pump is driven by a turbine, and generates 4 thousand horsepower! Remember, this is an accessory on the engine!

Slide 4 - S-1 Stage

Here is a SATURN booster or first stage fabricated at the Marshall Space Flight Center at Huntsville. You can see the eight engines in a cluster. The four inboard engines are mounted in a square pattern at a fixed 3 degree cant from the vertical. The four outboard engines are canted six degrees from the vertical, and can be swivelled ten degrees for controlling the direction of flight. The engines are fed from a cluster of nine propellant tanks - five for oxygen, and four for fuel.

Slide 5- SATURN Static Firing

Each booster undergoes hot performance tests at the Marshall Center. To prevent the fiery exhaust of the eight engines from melting the metal deflector plates at the base of the tower, 40,000 gallons of water per minute must be pumped through them. The flames literally ride on a cushion of steam. During each static test we record some 1,000 channels of information to keep our fingers on the pulse of the intricate machinery. Such close surveillance of the behavior of every component during the stresses and strains of a static firing is one of the main reasons that the development of the S-1 stage progressed as rapidly as it did.

Slide 7- SATURN Barge

Barges take the stages built at Huntsville to Cape Canaveral for flight testing. The barge goes down the Tennessee, Ohio, and Mississippi Rivers to the Gulf of Mexico, circles the tip of the Florida peninsula, then goes up Florida's east coast to the Cape.

Slide 8 - Booster Being Erected

Here we see a Saturn I in the service structure at the Cape. Only the first stage is live. The mission of the first four flight tests of the Saturn I is to test the live first stages only. Inert upper stages are added to complete the external configuration, and water is used as ballast to simulate full propellant loading. Live second stages will be used starting with the fifth launch vehicle.

Slide 9 - Saturn Just After Lift-Off

The Saturn is a marvel of engineering. The countdown for such a complex vehicle is necessarily long --ten hours, to be specific. There was only one hold before each of our first three launches, and none was directly connected with the rocket itself. A hold was called before the first launch because cloud cover would have interfered with satisfactory tracking; before the second launch the countdown was stopped once until a stray ship could be shooed away from the impact area; and before the third launch a single hold was called because of generator difficulty in the ground support equipment.

During the second and third launches we performed an experiment in upper atmospheric physics, known as Project High Water. After booster cutoff, the vehicle was deliberately destroyed. About 100 tons of water carried as ballast in the upper stages were dumped into the ionsphere and the optical and meteorological effects were observed.

During our last firing (March 28, 1963) the engine-out capability of the Saturn was tested as a secondary mission. Its purpose was to examine tail-heating effects and to confirm operation of the propellant feed system under emergency, inflight conditions. The mission was a complete success.

Slide 10 - Saturn I, Block I; Saturn I, Block II; Saturn I-B

The two-stage Block II Saturn will be flight tested during the fifth Saturn launching, scheduled for later this year. The Block II design changes will provide a marked increase in vehicle performance. The booster will have the fully up-rated H-1 engine, developing 188,000 pounds of thrust. Four detachable tail fins will be added for increased vehicle stability during the boosted phase of flight.

The initial flights of Block II Saturns will concentrate on booster and second stage performance characteristics.

On the right you see the Saturn IB, which I will discuss in more detail later.

Slide 11 - Cutaway of Saturn S-IV Stage

The second stage of the Saturn I, shown here in this cutaway, is called the S-IV Stage. It is under development by the Douglas Aircraft Corporation at Sacramento, California. This stage is 18 feet in diameter and about 40 feet in length. It is a self-supporting structure containing two propellant tanks fabricated of aluminum alloy. The oxygen tank is located beneath the hydrogen tank; the two are separated by a common insulated bulkhead made of a fiberglass honeycomb core between aluminum faces.

It has six Pratt & Whitney developed RL10 engines.

The S-IV vehicle is controlled by swiveling the six engines.

Slide 12 - RL10 Engine

The RL10 engine burns liquid hydrogen and liquid oxygen to produce 15,000 pounds of thrust. This is the same engine used in the Centaur vehicle.

When liquid hydrogen enters the cooling jackets around the thrust chamber it not only cools the chamber, but heats the liquid hydrogen and expands it through a turbine, which dirves a two-stage centrifugal pump. The heat absorbed by the liquid hydrogen in the cooling jacket gives enough energy for turbopump drive. The chamber operates under 300 psi pressure conditions and 6,000 degrees F.

Slide 13 - S-IV Stage

Development of the S-IV stage is moving along very well. A number of severe engineering and design problems have been solved -- in particular, development of a satisfactory fuel-tank insulation. Successful development is also continuing on the helium heater for the Lox-tank pressurization system.

Preparations for the first static hot firing of all six engines included comprehensive cold flow and engine chilldown tests at the Sacramento Test Facility of Douglas Aircraft Corporation. Liquid hydrogen, you will remember, boils at -423 degrees Fahrenheit. Cold flow is the transfer of the liquid hydrogen and liquid oxygen from ground storage tanks to a steel "battleship tank," an overstrength, non-flying test vehicle installed in one of the two static test stands at the Sacramento site.

Slide 14 - Instrument Unit

This 154-inch diameter instrument will be pressurized and will contain vehicle guidance instrumentation. It will transmit guidance and sequencing signals to the appropriate stages during powered flight.

These electronic instruments can tell if the vehicle is moving off course--as a result, perhaps, of a wind gust--and send electrical signals to hydraulic pistons to gimbal the engines. Some people don't realize that most of the weight of a vehicle--about 85 per cent--is liquid. Have you ever tried to run with a wash tub half full of water? Then you know how the fuel sloshes about. The vehicle structure is flexible. It bends, sways, swings, and vibrates as it accelerates. The instrument unit must know if the vehicle is really off course, or whether it is only doing a giant version of the twist.

The Saturn I will be used to place into low earth orbit boilerplate versions of the command module and service module of the Apollo spacecraft, which will take men to the moon. Re-entry of the command module from a low earth orbit will also be tested. While the method of re-entry of the Apollo capsule is similar to that used in the Mercury program, the problems are greater. Mercury capsules re-entered from a speed of about 18,000 miles an hour, while the Apollo will re-enter at close to 25,000 miles an hour.

Slide 15 - Saturn IB and Apollo Lunar Spacecraft

The two-stage Saturn IB vehicle will be developed to test the lunar orbit configuration of the Apollo spacecraft. It will be an interim step between the present Saturn I and the advanced Saturn V. The first stage of the Saturn I will be mated with the third stage of the Saturn V to form this vehicle. Thus the first stage will cluster eight H-1 liquid oxygen/RP-1 engines, and the second stage will feature a single J-2 engine, burning the hydrogen/oxygen combination to produce 200,000 pounds of thrust. The Saturn IB will be able to place about 16 tons into low earth orbit compared with ten tons for Saturn I. By the mid -1960's, we will be able to test the Apollo lunar-orbit configuration, in low-earth orbit. These flights will concentrate on crew training and perfection of module maneuvering in orbit.

The Apollo spacecraft, you will note, has three major parts. The command module carries the three-man crew, plus guidance and control instrumentation. This module will weigh about five tons and measure 12 feet high.

Immediately beneath the command module is the service module, containing the primary spacecraft propulsion elements. This propulsion will be used to correct the spacecraft;s flight path as it moves from the earth toward the moon. It will also provide the power to escape from the lunar orbit into an earth trajectory.

Slide 16 -- Saturn I Saturn IB, and Saturn V

After the Saturn IB, our next seven-league step forward in rocket development is the Saturn V.

Measuring more than 350 feet, the three-stage Saturn V with its Apollo spacecraft payload will stand taller than the Statue of Liberty.

The Saturn V will be able to lift 120 tons into an orbit 300 miles above the earth. That is equal to 85 John Glenn capsules.

Or it can hurl 45 tons to the vicinity of the moon. This is the weight of about 25 family automobiles.

And it could probably boost a single Chevrolet clear out of the solar system...probably to the delight of Ford and Chrysler. There's no telling how far it would send a Volkswagon.

Slide 17 --Saturn V Booster

The booster -- or S-IC -- stage for the Saturn V is being developed jointly by Marshall and the Boeing Company. The stage will measure 33 feet in diameter and 138 feet in length. Five F-1 engines, each generating 1.5 million pounds of thrust, provide a total stage thrust of 7 1/2 million pounds. Four of the engines, mounted in a square pattern, will gimbal for control. One F-1 engine will be centrally mounted and rigidly fixed.

Suction lines from the forward liquid oxygen tank will pass through tunnels in the fuel tank to the engines. Dry weight of the stage will be about 280,000 pounds, with a propellant capacity of about 4,400,000 pounds.

Slide 18 -- F-1 Engine

The F-1 engine is now well along in development for NASA by the Rocketdyne Division of North American Aviation.

It is the largest engine under development in the United States. The F-1 is of simplified conventional design, incorporating proven concepts in high thrust conventional propellant rocket technology. It is scheduled for use first in the Saturn V. If two of these engines were operating at one time, they would be gulping oxygen at a rate equal to that of all the people of the United States for breathing purposes! The turbopump on this engine, which you remember is an accessory generates 68,000 horsepower!

Slide 19 -- Static Test of F-1 Engine

The first full-duration, full-thrust static firing of the F-1 was conducted by Rocketdyne in May at Edwards, California. The engine produced over its rated thrust of 1.5 million pounds for two and one-half minutes.

Slide 20 -- S-II Stage Cutaway

The slide shows the current configuration of the second, or S-II Stage of the Saturn V. This stage has five J-2 engines which burn the liquid hydrogen/oxygen combination for a total of 1,000,000 pounds of thrust. The stage will measure about 82 feet long and 33 feet in diameter. An insulated common bulkhead separates the Lox tank and the forward hydrogen tank.

The stage will be controlled by swiveling the four outer engines. The fifth engine is rigidly mounted. Primary guidance and control signals for the S-II will be provided from the vehicle instrumentation unit, located forward of the third stage.

Slide 21 -- J-2 Test Area (S-II-d-1)

The J-2 engine is being developed by Rocketdyne at Canoga Park, California, and is test fired at the Santa Susana facility, shown here. Thrust chamber development has progressed satisfactorily, concurrently with tests of the oxidizer and fuel turbopump assemblies. A number of J-2 engine system tests have been conducted.

Slide 22 -- S-IVB Stage

A single J-2 engine will be used on the S-IVB Stage, the third stage of the Saturn V. Design studies of the stage are now being conducted by the Douglas Aircraft Corporation.

The S-IVB will measure about 58 feet long and 260 inches in diameter. It will have a usable propellant capacity of about 230,000 pounds. The single engine will gimbal for pitch and yaw control. Auxiliary propulsion systems will provide attitude control during coast.

Slide 23 -- Saturn V First Stage Test Facility at MSFC

This artist's concept shows the new static test tower now in the early stages of construction at Marshall for captive firing the Saturn V's first stage booster. The tower, including the crane at the top, will be 405 feet high, and will measure about 160 feet square at the base.

The stand will provide handling equipment and thrust restraint for vehicles up to 178 feet in length, 48 feet in diameter, and with thrust up to 7.5 million pounds.

Slide 24 -- Launch Complex 34

Most of NASA's large space carrier vehicles are launched from the Atlantic Missile Range at Cape Canaveral. We have quite a large investment there in real estate and facilities and we are planning more. The four Saturn vehicles which have already been successfully launched were flight tested from NASA's Vertical Launch Facility 34, which you see on the slide.

Launch Complex 34 is used for launching the R&D Saturn I's. It occupies 45 acres. The word <u>complex</u> is a very good one to describe this facility, for the Saturn launch site is rather complex. The service structure used at the launch site is the tallest structure in the state of Florida and the largest self-propelled, movable structure in the world.

Slide 25 -- Launch Complex 37

Vertical Launch Complex 37 is located about a mile north of Complex 34, but unlike it, will have two pads served by the same support facilities. This arrangement will permit us to launch six vehicles a year rather than four, which is the maximum number of launches permitted by Complex 34.

Principal items at the complex are liquid oxygen, liquid hydrogen, and kerosene storage facilities, two launch pads, and blockhouse. Construction is scheduled for completion in time for the firing there of our first Block II Saturn later this year.

Slide 26 -- Vertical Assembly Building

The Advanced Saturn, including the Apollo spacecraft, will be transported vertically to its launch site after assembly and checkout in a rear area. This assembly and checkout building will be 48 stories high, more than two city blocks long, and 230 feet deep. It will be some 150 feet higher than Florida's tallest building -- the Dade County Courthouse in Miami.

In the assembly building the three-stage Advanced Saturn will be erected, mated to the Apollo spacecraft, and checked out on a launch rack which also supports its 400-foot umbilical tower.

Slide 27 -- Crawler Vehicle

When checkout is complete a crawler vehicle -- some 130 feet long, 115 feed wide, and weighing some 2,500 tons-- will move to the building on eight tank-type treads. It will be driven by electric motors powered by diesel-driven generators.

The crawler will pick up the rack with the Saturn V and spacecraft and the umbilical tower and carry it the two miles over special roadways to the launch pad, with a stop at the arming tower. During the journey, the 33-foot diameter rocket will be kept balanced by four load-leveling hydraulic cylinders. The cylinders -- each four feet in diameter -- are 90 feet apart, like the bases on a baseball diamond. At the pad, the 20-foot high crawler will use the cylinders to lower the rack and vehicle onto support blocks on the launch platform.

Slide 28 -- C-5 Launch

Now let's take a quick trip to the moon via the lunar orbital rendezvous method.

On a moon mission, the three-stage Saturn V will launch the Apollo spacecraft from the Cape in an easterly direction, thereby benefiting from the earth's rotation. The first and second stages of the launch vehicle will drop away after burnout, and the third stage and attached spacecraft will go into an inclined earth orbit.

Slide 29 -- Injection

After orbital checkout, the third stage is ignited at the proper moment, accelerating the 90,000-pound spacecraft to the required 25,000 mile-per-hour escape velocity.

Slide 30 -- Docking in Transit

After injection into the translunar trajectory, fairings are released forward of the third state, freeing the Lunar Excursion Module, or Bug. The Command Module is disconnected and turned 180 degrees, then mated none-to-nose with the Bug. After this maneuver, the third stage of the Advanced Saturn is separated and drops away.

During the journey to the moon, the astronauts must keep close watch on radiation levels. The great radiation area encircling the earth, discovered by America's first satellite, Explorer I, constitutes a severe problem to manned space flight. Radiation from solar flares and meteorites are other hazards. Inside the Spacecraft, pressurized space suits can be discarded for light comfortable coveralls. The crew can talk directly to earth ground crews, reporting scientific observations, and physical and mental condition.

Slide 31 -- Entering Lunar Orbit

Halfway to the moon, the crew makes a navigation check by taking bearings on the earth, moon, and stars, and corrects the spacecraft's course, if necessary. The pull of earth's gravity will slow the spacecraft's speed to about 6,500 miles an hour after one day, and 1,500 miles an hour after two days. As it approaches the moon, the gravitational pull becomes stronger than that of the earth, and the craft begins to fall toward the moon, picking up speed.

At the proper time, the propulsion system of the service module is ignited, slowing the spacecraft so that it goes into a precise, circular orbit, about 60 miles above the lunar surface.

Slide 32 -- Entering Lunar Landing Ellipse

Two astronauts transfer to the Bug, which separates from the Apollo spacecraft. Using its own propulsion system, it goes into a trajectory having the same period as the mother craft, but with a lower perigee. The low perigee, within about 50,000 feet of the lunar surface, permits a close examination of the intended landing site.

Slide 33 -- Lunar Descent

The engine on the Lunar Excursion Module is again fired, and the Bug decelerates from orbit and into trajectory toward the pre-selected landing site.

Slide 34 -- LEM Field of View

A large glass area is provided in the Bug for the astronauts to inspect the touchdown site visually, and to control the landing maneuver.

Slide 35 -- Landing Manuever

With landing legs extended, the vehicle descends to within 100 feet of the lunar surface. It will be able to move laterally for about 1000 feet for choosing the best touchdown point.

The stay on the moon may range from one to four days. Manned exploration of the moon is a logical extension of unmanned lunar exploration; the knowledge gained by unmanned vehicles will raise additional questions which can be answered by manned exploration. Man's physical characteristics, his judgment, and his ability to make unscheduled observations make him a valuable means for gathering scientific information.

Much of the lunar exploration will be geologic in nature. It will include mapping, photography, observation of surface characteristics, core and surface samples, seismic measurements, and radiation measurements.

Slide 36 -- Lunar Liftoff

After the exploratory mission has been accomplished, the two astronauts return to the Bug. The upper portion of the bug is then launched into ascent trajectory, using the burned out landing stage as a launch pad. The orbiting command module will be above the horizon when the Bug is launched. Radar and visual contact are maintained between the two vehicles. A flashing light will aid visual acquisition.

Slide 37 -- Lunar Orbit Rendezvous

Docking will be made under a high degree of manual crew control. At close up docking distances, man becomes the best judge of range, range rate, and orientation. He will be provided, however, with a high degree of automation. After docking, the two astronauts transfer back to the Command Module.

Slide 38 -- Leaving Lunar Orbit

After checkout of the spacecraft, the Service Module propulsion is ignited and the Apollo is accelerated into the return trajectory.

On the return trip to earth, the spacecraft must again fly a very precise trajectory to enter into orbit around the earth. Too shallow an approach and the earth is missed entirely; to steep an approach, and the spacecraft plunges directly into the atmosphere.

Slide 39 -- Re-Entry Corridor

The re-entry corridor is only 40 miles in depth, and yet it must not be missed from a distance of 240,000 miles away. Mid-course corrections are again made for refinement of trajectory. The Service Module is jettisoned, and only the Apollo Command Module re-enters the atmosphere.

Slide 40 Re-Entry

Traveling at 25,000 miles an hour, it encounters heating rates several times higher than those encountered during Project Mercury re-entries.

Slide 41 -- Descent in Atmosphere

Pressure and friction of the atmosphere slow the module, and at 10,000 feet parachutes open to bring it to a safe ground landing.

Slide 42 -- Recovery Teams

Radar and optical instruments track its descent to the pre-designated landing area, and recovery teams proceed immediately to pick up the three crewmen.

<u>LIGHTS ON</u>

The journey which I have just described will take place before the end of this decade. Until just a few years ago, the possibility of such a feat was regarded by most people as harmless fantasy or sheer lunacy. The moon was the exclusive property of astronomers, poets, dreamers, and young lovers. Now two strong nations are trying to set foot on this distant frontier, and to explore the space about us. For the first time in man's history his science, technology, and economy can support his imagination of the past for manned space travel. And because man <u>can</u> go into space, he <u>must</u>.

Man has an insatiable curiosity to learn everything possible about himself and the universe, to explore new regions, to improve the past. His curiosity has often been the measure of his progress. Today we have just crossed the threshold of man's greatest adventure.

During the first five years of the Space Age there has been an epidemic of statements on its meaning for man. These have ranged from vague implications of unforeseen but certain benefits to rash declarations that space exploration is the panacea for all our ills. The truth lies somewhere in between.

The results of scientific inquiry can seldom be foretold with accuracy. But history teaches that it always pays, often in the most unexpected manner, to probe the mysteries of the universe about us.