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Saturn V Launch Vehicle Program

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For a brief glimpse of the Saturn V Program, I will discuss the following areas: (1) the background of the Saturn V, (2) the vehicle characteristics, (3) the ground test program, (4) the flight test program, and (5) a general program status.

Background

The Saturn V launch vehicle emerged from a series of studies conducted at Marshall Space Flight Center during 1961 and consistent with the NASA overall manned lunar landing program definitions. The NASA requirement for the launch-vehicle portion of the manned lunar landing task was studied in three principal modes of operation: (1) earth orbit rendezvous, (2) lunar orbit rendezvous, and (3) direct ascent.

The selection of the Saturn V configuration was made in early 1962 on the basis of the following performance capabilities for the three modes of operation: (1) earth orbit rendezvous - 125 tons - to near earth orbit, (2) lunar orbit rendezvous - 45 tons - to the 72-hour translunar injection point, and (3) direct ascent - 20 tons soft landed on the lunar surface.

In mid-1962, NASA selected lunar orbit rendezvous as the operational mode for accomplishing the lunar landing mission. All development efforts for the Saturn V launch vehicle are directed toward supporting the LOR mode of operation.

Our present project authorization is based upon a ten-vehicle R&D flight development program; however, our planning is extended to include five follow-on operational vehicles, and our long-range plan is based upon a sustained manufacturing, testing, and launching capability of one vehicle per month. A few of the major accomplishments and milestones are listed in the following chart (Figure 1).

Vehicle Characteristics

The characteristics of the Saturn V launch vehicle are illustrated in Figure 2. Of the 6 million pounds launch weight of the vehicle, 5.56 million pounds are propellants. These weights are broken down as follows: 4.4 million pounds of liquid oxygen/JP fuel in the first stage, .93 million pounds of hydrogen/oxygen in the second stage, and .23 million pounds hydrogen/oxygen in the third stage. I have not included the propellants contained in the spacecraft.

The first stage (S-IC) is propelled by five F-1 engines, each developing a thrust of $1\frac{1}{2}$ million pounds, for a combined liftoff thrust of $7\frac{1}{2}$ million pounds. The second stage (S-II) is propelled by five J-2 engines, each developing 200,000 pounds, for a total thrust of 1-million pounds. The third stage (S-IVB) is propelled by a single J-2 engine, providing a thrust of 200,000 pounds.

An Instrument Unit rides atop the third propulsive stage and aft of the spacecraft. This unit contains the guidance and control instrumentation for the three propulsive stages. The first and second stages have a four-outer-engine-gimbal capability to provide roll, pitch, and yaw control. Auxiliary attitude control is provided to the third stage by attitude control modules.

Operating times for the stages are essentially as follows: (1) first stage, approximately 150 seconds, (2) second stage, approximately 400 seconds, and (3) the first burn of the third stage is approximately 165 seconds into a low-earth waiting orbit. After a waiting orbit of up to $4\frac{1}{2}$ hours, the second burn of the third stage is initiated; this burn time, expected to be in the order of 310 seconds, injects the payload into the 72-hour earth-moon transit.

Ground Test Program

The principal elements of the Saturn V ground test program are illustrated in Figure 3. A major emphasis is placed on an adequate ground test program. Since the expense of each flight test vehicle is quite large, the number of flight tests is kept to a minimum, consistent, of course, with a reasonable number to provide correlation between ground and flight environments.

The ground test program for component selection and qualification is underway, at this time, in many areas of piece parts and what we call "speciality" items, such as valves, bellows, seals, flanges, switches, electrical boxes, etc. These items are not only under continuous design review of a theoretical nature involving "criticality" evaluations, but are also under strenuous testing to reveal short-comings that can be corrected before the stage systems development tests get underway.

Development test capability is provided in close proximity to the design and engineering activities. For example, in first stage (S-IC) activities, MSFC, with the assistance of Boeing, is fabricating and assembling the first ground test stage and the first flight test stage. The static test and development stage will be test fired at Huntsville on the test stand which is now well along in construction. Stage structural testing will be accomplished in the laboratories of the Marshall Center.

The development test area for the second stage, S-II, is located in Santa Susana at the North American Aviation propulsion development site. Two test stands are being prepared for early battleship and all-systems testing.

For the S-IVB, the Douglas Aircraft test area in Sacramento will be utilized for development testing.

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The S-IVB stage is a common item for both the Saturn V and Saturn IB programs.

Vehicle systems development testing will be conducted at Marshall Space Flight Center, where all combinations of flight configuration will be subjected to dynamic analyses.

At the Launch Operations Center, in Merritt Island Launch Area, a functional launch vehicle system will be provided for facilities checkout. The degree of automation and the complexity of operation involved in a multi-stage vehicle of this type have prompted a very thorough operational development program for the NASA launch complex 39. The respective stages will be assembled into a functional configuration, so that, generally, the entire operational procedure can be developed prior to the receipt of the first flight vehicle. This step is taken to assure that the flight stages are not exposed to the initial activities of the Integrated-Test-Launch concept.

Flight Test Program

The flight test program (Figure 4) will start in early 1966. The first three flights are established to test, progressively, the flight stages. For the initial Saturn V flight a live first stage is to be used with inert upper stages. On the second flight, both the first and second stages are planned to be live, with the third stage inert. All three stages are to be live on the third flight. The fourth flight is backup and will provide development confidence and reliability. The fifth and sixth flights are considered to be preliminary launch vehicle qualification flights; that is, these vehicles should be capable of demonstrating full performance capability. Launch vehicles seven through ten are termed "developmental - manned qualification." This series of flights will commence in mid-1967. The operational program begins with vehicle number 511, scheduled for early 1968.

General Status

The final comments of my presentation deal with program status as of this time.

We are in the sixteenth month of the configured and approved program. The decision as to the operational mode was made nine months ago and a further refinement of the launch vehicle criteria, involving structural definitions based upon mission profile, began at that time.

The manpower presently engaged in the development effort totals in excess of 12,000 direct personnel in the major contract areas of: (1) Boeing Aircraft Company - S-IC stage, (2) Space and Information Systems Division (NAA) - S-II stage, (3) Douglas Aircraft Company - S-IVB stage, and (4) Rocketdyne (NAA) - F-1/J-2 engines.

Peak manpower estimates for the four major contract elements noted above are forecast at some 15,500 direct personnel in the 1964/1965. This increase will be in the test, operation, and manufacturing buildup since most areas of engineering are at near peak at this time.

Let me again emphasize that these figures are for the first-tier development contracting only.

At Marshall Space Flight Center, 1,000 direct civil

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service personnel are engaged in the management, systems integration and the design, manufacturing, test and quality control of the Saturn V project. This number is expected to increase to 1,800 in fifteen months as the phase-over from Saturn I to Saturn V continues.

With regard to the longest leadtime item, that is, facilities (authorization and construction), we are now at the estimated 85% point with regard to approvals, authorizations, etc. and about 60% in the construction phase. Many items are being activated and placed into operation; for example, S-IC tooling installation which is going on in the Huntsville shops at this time. Other examples are the static test facility at Huntsville and the structural test facility, also at Huntsville. In the Michoud area, facility modification has been completed in many areas, and the Vertical Assembly Building is under construction. These facilities deal solely with the first stage.

Concerning the second stage, the entire Seal Beach construction program is underway, and the first building was completed to the status of joint occupancy in January 1963. Tooling is being installed for structural fabrication. Stage development test facilities are under construction at Santa Susana, California.

With regard to the S-IVB stage, facility modification in the Douglas Aircraft Company's plant at Santa Monica is underway. Components will be fabricated in this plant. The final assembly of S-IVB will be performed by Douglas in the Huntington Beach area, a new location being developed by Douglas. Occupancy of the major buildings will be phased-in by October 1963.

The static test facility at Sacramento is presently in a site-preparation phase. Construction awards were made in March 1963.

We estimate that we have completed approximately 45% of the detail design and engineering for the Saturn V vehicle and released about 15%.

By the end of this year our schedules require the release of the major portion of all engineering.

Tooling designs are complete for all major structural elements, and tooling fabrication is approximately 75% complete. As you have already seen, some of this tooling is in operation.

With regard to structural components, Boeing has delivered, out of the Michoud Plant, two Y-Rings which involve a major machining operation. These rings are fabricated from three 120-degree segments welded together to give a 33-foot-diameter ring. The first Y-Ring has been delivered to Huntsville for final welding operation into the early structural test tanks.

In Wichita, gore segments are being fabricated for S-IC tanks. First delivery of F-1 engines for stage assembly will be accomplished by the end of this year.

The same general status exists for the two upper stages. J-2 engines will be delivered by the end of this year to start the first preparation for stage mating. These early engines are scheduled for use with heavy-wall, battleship-type tankage.

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Structural components are being fabricated at this time.

In conclusion, the Saturn V Project is proceeding at a rapid pace. Our schedules are tight but are within bounds of our capability, assuming timely and adequate funding. We have a highly competent industrial team already functioning in the development of major vehicle elements. We have a real sense of urgency toward the task we have undertaken. I am confident we can provide a launch to meet the President's stated requirement for "a manned lunar landing in this decade."

<u>1961</u>	
May	Engineering studies of Advanced Saturn Rocketdyne selected to develop upper stage engine
July	First firing of F-1 engine system
September	Michoud Plant selected for NASA use Douglas Aircraft selected to develop S-IVB stage S&ID selected to develop S-II stage
October	Test location selected - MTF
December	Boeing Aircraft Company selected to develop S-IC
<u>1962</u>	
January	<u>Saturn V configuration selected by NASA</u> First firing of J-2 engine
March	Sverdrup parcel selected to plan and design - MTF
April	DX priority established for program
May	Full thrust/full duration firing of F-1 engine
July	<u>LOR mode selected to accomplish first manned lunar landing</u>
October	Full thrust/long duration firing of J-2 engine
November	First major tooling for S-IC delivered
<u>1963</u>	
January	First increment of Seal Beach (S-II) fabrication facility readied
February	Delivery of first S-IC structural components from Michoud Plant
March	First S-IC bulkhead gore segment welded

Figure 1.- Saturn V milestone chronology.

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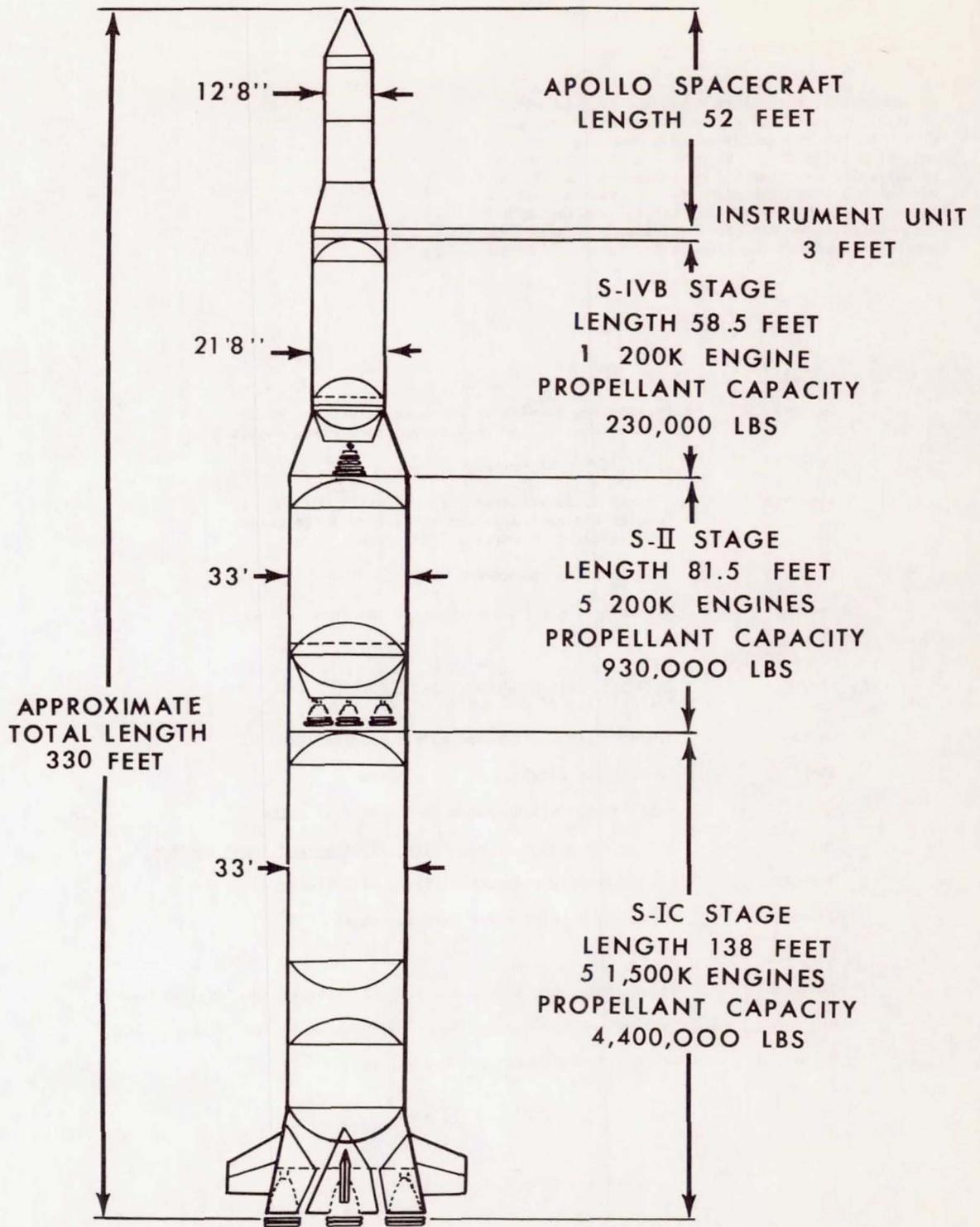


FIG 2 SATURN C-5 LAUNCH VEHICLE

Figure 2.- Saturn V launch vehicle.

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<u>Designation</u>	<u>Configuration</u>	<u>Mission</u>
SA-500-S	<u>Structural Stage</u> non-functional	Certify structural integrity of each complete stage structure under simulated critical load conditions.
SA-500-T	<u>Battleship Stage</u> functional systems	Captive testing to develop functional, operational, design, proof, performance, reliability of stage system
	<u>All System Stage</u> all flight systems	
SA-500-D	<u>Dynamic Vehicle</u> Flight Configuration, functional systems	Determine under various flight configurations the dynamic response, structural flexure, etc.
SA-500-F	<u>Facilities Vehicle</u> Flight Configuration functional systems	Complete checkout LC 39 determine functional compatibility of vehicle with instrumentation system, automatic GSE, facilities support system, etc. before arrival at first flight vehicle

Figure 3.- Saturn V ground-test program.

<u>Designation</u>	<u>Configuration</u>	<u>Mission</u>
SA-501	S-IC - Active S-II - Inert S-IVB - Inert	Structural Integrity, Flight Environment, First Stage Flight Performance
SA-502	S-IC - Active S-II - Active S-IVB - Inert	Structural Integrity, Flight Environment, Separation and Control First and Second Stage Flight Performance
SA-503 SA-504	All Stages Active All Stages Active	Structural Integrity, Flight Environment, Vehicle Performance, Separation and Control
SA-505 SA-506	All Stages Active All Stages Active	Preliminary qualification, Performance and Control accuracies Vehicle capability and reliability
SA-507 SA-508 SA-509 SA-510	All Stages Active All Stages Active All Stages Active All Stages Active	Developmental-Manned qualification
SA-511 & Subs.	All Stages Active	Operational

Figure 4.- Saturn V flight-test program.

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