N64-30333

# MAN'S TRANSPORTATION TO SPACE

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As an introduction, the three launch vehicles of the Saturn class, namely, Saturn I, Saturn IB, and Saturn V, will be described briefly. They are being developed by NASA for extension and increase of the space-flight capability of the United States in general and for the Apollo program in particular. Although the Titan II in its application as a launch vehicle for the Gemini program and the Atlas Centaur for the Surveyor program and other possible scientific uses, can be considered as large-launch vehicles, we will concentrate on the Saturns.

Figure 1 shows all three Saturns in their configurations with payloads for the Apollo program. The following data are rounded to present an idea of the size of the Saturn vehicles.

The Saturn I, on the right in figure 1, is a two-

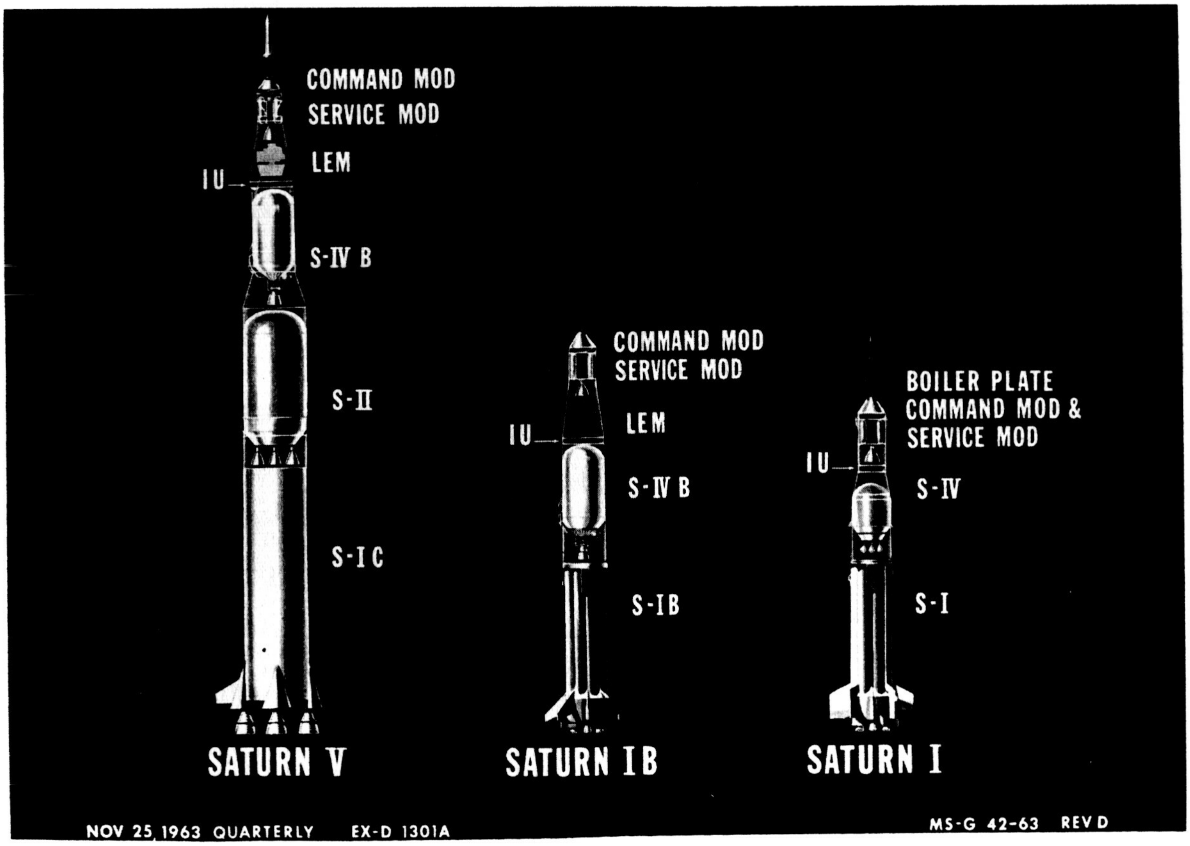

FIGURE 1.—Saturn vehicles for Apollo.

stage vehicle. Its total length, including the payload, is 190 feet. The length of the launch vehicle, itself, including the instrument unit (IU), is 126 feet. The takeoff weight of the launch vehicle is approximately 1,125,000 pounds, of which 950,000 pounds are propellants. The Saturn I is capable of placing a payload of 22,000 pounds in a 100-mile orbit.

The Saturn IB, as depicted here for its Apollo mission, is also a two-stage vehicle with a total length, including payload, of 224 feet. For the launch vehicle, including the IU, the length is 141.6 feet and the takeoff weight is 1,240,000 pounds, of which 1,120,000 pounds is propellants. The Saturn IB is able to place a payload of 32,500 pounds in a 100-mile orbit. For missions other than Apollo we are considering a third stage, which will be discussed later.

The three-stage Saturn V in its present configuration is optimized for the Apollo program. It is capable of injecting a payload of 90,000 pounds into a lunar trajectory. It could also carry approximately 240,000 pounds of payload into a 100-mile Earth orbit. The length of the total vehicle, including payload for the three-man landing on the Moon, is 360 feet. The launch vehicle, with the IU, is 281 feet in length and at takeoff weighs 6 million pounds, which includes 5.5 million pounds of propellants.

As can be seen in figure 1, we adhere to some extent to the building-block concept. The first stage of the Saturn I—that is, the S–I—appears with some small modification as the S–IB first stage of the Saturn IB launch vehicle. Both stages are clusters of eight H–1 engines. These modifications are mainly in the areas of lowering the structural weight and in obtaining higher engine performance. Therefore, the overall performance of the S–IB is better than that of the S–I. We also incorporate into the S–IB as improvements whatever we learn from the S–I development, insofar as the time schedule permits. The S–I and S–IB are being produced under a prime contract with the Chrysler Corporation's Space Division at the Government-owned Michoud Plant in Louisiana. The H–1 engines are produced by the Rocketdyne Division of North American Aviation. The propellants are kerosene and liquid oxygen.

There is somewhat greater difference between the S–IV stage, which is the second stage of the Saturn I, and the S–IVB stage, which is the second stage of Saturn IB. The S–IV has a small diameter, is shorter, and has six Pratt & Whitney RL–10 engines which provide total thrust of 90,000 pounds; whereas the S–IVB is propelled by one J–2 Rocketdyne engine of 200,000 pounds thrust, using liquid hydrogen and liquid oxygen as propellants. However, the principal structural design, the material, the insulation concept of the hydrogen tanks, the manufacturing methods, tooling concepts, and many other features are exactly the same. Again, in the development of S–IVB we are utilizing all the knowledge and experience gained from the S–IV. The prime contractor is Douglas Aircraft. The S–IVB stage also is the third stage of the Saturn V.

The instrument unit, called the IU, contains all equipment to guide and part of the equipment to control the launch vehicle up to insertion point, or in the Saturn V to injection point. It also contains such items as power supply, power distribution, certain telemetry equipment, command receivers, and tracking transponders. This instrument unit on the Saturn IB is quite different in design from the one used on the Saturn I. However, a number of guidance and control devices—for instance, the stabilized platform—are being tried on the Saturn I and then used on the Saturn IB and Saturn V. However, the IU's on the Saturn IB and Saturn V are the same. Of course, settings on instruments are sometimes different from individual launching to launching, depending on the various missions. The prime contractor for the IU is International Business Machines, IBM.

The S–IC first stage of the Saturn V is under development and production by Boeing's Launch Systems Branch at Michoud, La. It is propelled by the largest kerosene/liquid oxygen engine, the F–1, which produces a thrust equal to all eight engines of the Saturn I. In the S–IC, five F–1 engines are used in a cluster to yield a total of 7.5 million pounds of thrust. This engine is a product of the Rocketdyne Division of North American Aviation, NAA.

The S–II second stage of the Saturn V, a liquid hydrogen/liquid oxygen stage, is under contract with the Space and Information Division of NAA at Downey and Seal Beach, Cal. A cluster of five J–2 engines with a total thrust of 1 million pounds propels this stage; thus the J–2, like the H–1, is used as a common engine for two stages.

Figure 2 shows the S–IC stage, mentioned earlier, with the two separate propellant tanks, the engine arrangement, the heat shield, the thrust frame, the propellant lines, and the interstages. The length is 138 feet, and the diameter is 33 feet. During the

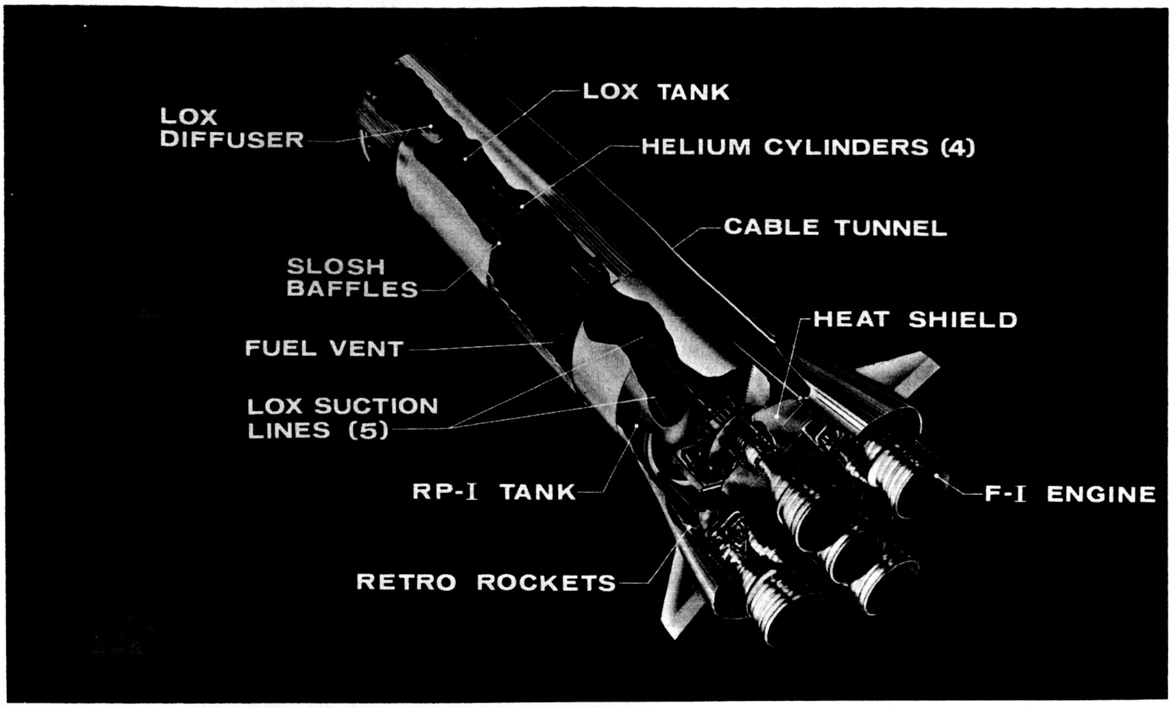

FIGURE 2.—S–IC stage.

burning time of 150 seconds, more than 4 million pounds of propellants are consumed. When this stage cuts off, the Saturn V space vehicle has attained a velocity of approximately 7,000 feet/second—almost 5,000 miles/hour. The stage is then dropped.

The initial static testing for development and for acceptance of the stage will be performed at Huntsville. Later, testing will take place at the large Mississippi Test Facility near Michoud.

Figure 3 depicts the S–II stage. The liquid hydrogen and the liquid oxygen tanks are separated by a common bulkhead. This is a challenging assignment in manufacturing but provides considerable savings in weight. The engines are arranged with the inner engine mounted in fixed position, and the outer four engines can be deflected by hydraulic actuators to control the vehicle in pitch, yaw, and roll as is done on S–IC stage. During the S–II burning time of approximately 390 seconds, about 920,000 pounds of propellants are consumed. When this stage cuts off, the Saturn V vehicle has attained a velocity of approximately 20,000 feet/second, almost 14,000 miles/hour.

The four types of engines utilized in the Saturn launch vehicle program are shown in figure 4. As noted earlier, the F–1 is used in the S–IC first stage of the Saturn V. The J–2 is used in the S–II second stage of the Saturn V and in the S–IVB, which serves as the third stage of the Saturn V and the second stage of the Saturn IB. The H–1 serves in the S–I and S–IB first stages of the Saturn I and the Saturn IB. The RL–10 serves in the second stage of Saturn I and in the upper stage of the Centaur.

A few of the major considerations which guide the current Saturn launch vehicle program are:

1. Building block concept
2. Extensive test and quality assurance program on the ground
3. Systems engineering
4. All-up concept

The building block concept is considered a vital element in the program since it saves time and money, helps build up experience and knowledge, and will contribute considerably to the reliability.

An extensive test and quality assurance program on the ground is necessary because of the extreme technical complexity of each system, subsystem, and

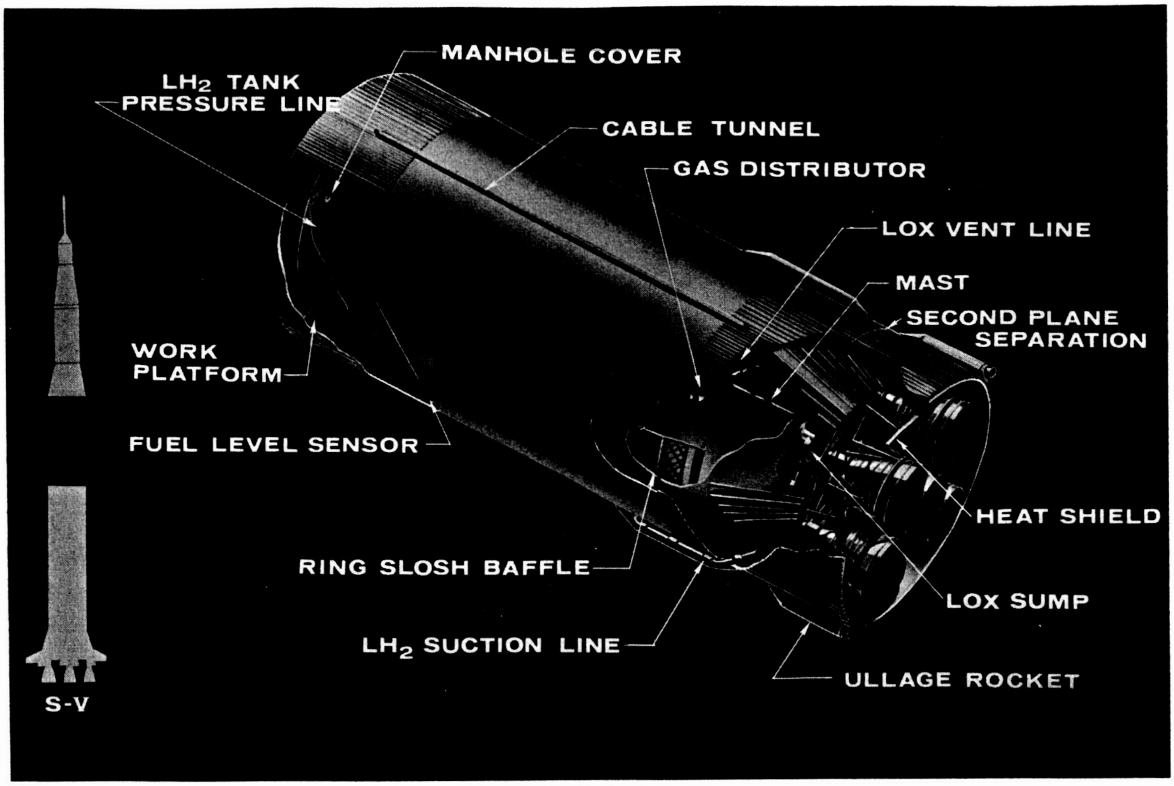

FIGURE 3.—S–II stage.

component—as well as the small number of launch vehicles planned for development. In the development of guided missiles for weapons systems it was found expedient to plan for quite a number of launchings to prove such matters as design, performance, accuracy, and reliability. Only after a launch program of this magnitude had been conducted successfully could the military services feel assured that they could declare the vehicle operational for troop use.

This approach in the Saturn launch-vehicle development is completely impracticable because the conduct of such a program would cost an excessive amount of money and time. NASA must therefore restrict itself to very few launchings for the development of the vehicle. Although the primary mission of these few launchings is the development of the launch vehicle, it is necessary to carry some payload in the early phase of development to get maximum benefits from these expensive undertakings. This is especially true with respect to the Saturn V. Therefore, we must have the highest possible confidence that each and every launching is successful.

This needed assurance can be obtained only by conducting a very thorough test, quality assurance, and reliability program at the NASA Centers, at the prime contractors' plants, and at their subvendors' plants on systems, subsystems, components, and vital parts.

The urgent necessity of such a program is emphasized by the fact that the Saturn IB and V will have to transport astronauts. Man rating requires the highest possible reliability of all systems, and this in turn must be assured by these few launchings. It will not be possible to conduct full-fledged reliability programs conducted prior to the first launchings. This will be accomplished, however, as part of the man-rating programs, which will be carried out by the time manned flights are scheduled. We have also planned the manufacturing of whole nonflying stages for ground testing just prior to the manufacturing of the first stage ready for flight. These stages are:

*Static test stages*—sometimes called battleship stages—for the development of the overall propulsion system. A considerable number of hot firings of these are being conducted.

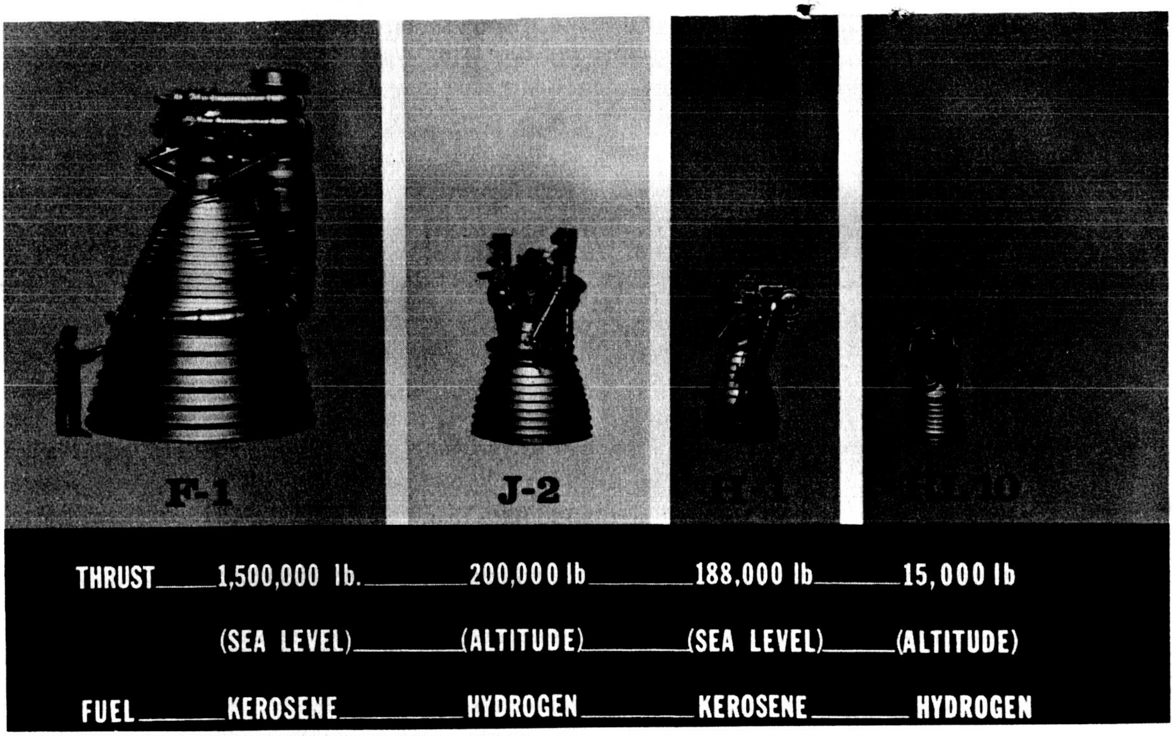

FIGURE 4.—Engines for space flight.

*Structural test stages*—for complete testing of the overall structure to establish safety margins and to obtain the lowest possible structural weights.

*Dynamic test stages*—for checking such matters as dynamic behavior, bending modes, and natural frequencies of the total configuration.

*Facility stages*—for the checkout of launch sites—requiring the use of the whole launch vehicle with its stages as close as possible to the final configuration with respect to such things as fueling systems, compatibility with launch tables and their holddown devices, and the vehicle's compatibility with swing arms, umbilical towers, and their equipment.

*All systems stages*—complete stages with all the features of a final flight stage—used for extensive static testing and a shakedown of all systems and subsystems and sometimes combined with the static propulsion test vehicle.

Many test activities with these nonflight articles must be done concurrently if a reasonable time schedule is to be met. Results and experience gained from the testing of one stage will be applied as far as feasible across the board.

Careful systems engineering is needed to assure that components of large systems for missions like Apollo, which are delivered from all over the country, are extremely well coordinated not only as to their proper delivery dates but especially as to such matters as their technical compatibility with each other and with the necessary ground support equipment and the launching site. We came to the conclusion that systems like the Saturn V, even in the early development stage, can no longer be checked by hand—that is, by the methods usually applied until now. Therefore, we had to develop an entirely automatic checkout system. The design and development of such a system is one of the systems engineering tasks of the first order. This system has to be applied while work is still in progress at the prime contractors' plants to match the final automatic checkout at the launching site.

We switched over to an "all-up" concept for the Saturn IB and Saturn V, in which all stages will be live at the first firing, in contrast to the concept we applied in the development program of the Saturn I launch vehicle, where we tried out first the first stage and later both stages. This causes little trouble in the Saturn IB, because the first stage is already proven in the Saturn I program. It is, however, quite a challenge for the Saturn V program. Again, the third stages will have been tested on the Saturn IB, so we have only two new stages. The reason we changed to this concept is that we are trying to come to a final man-rated configuration as fast as possible. The earlier in the program we find shortcomings, the better.

Figure 5 shows a very crude line-up of the launching schedule. On Saturn I we have planned 10 launchings, of which we accomplished 5, all successful. The next firing is in the immediate future. It carries an Apollo spacecraft in its outside configuration. Numbers 8, 9, and 10 will take payloads into earth orbits for detection of micrometeoroids.

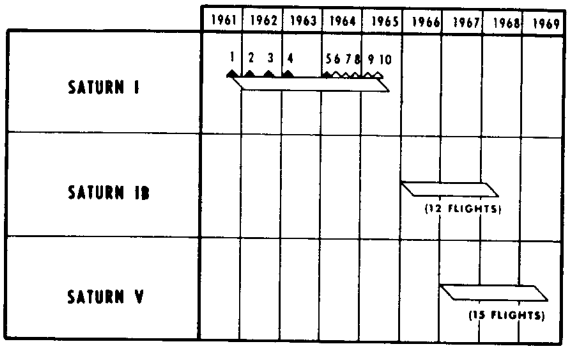

FIGURE 5.—Summary flight schedule for Saturn vehicles.

The first Saturn IB flight is scheduled for approximately early 1966. From flight 3 on, the launch vehicle will have a configuration allowing for manned flight.

The first Saturn V flight is scheduled for early 1967, approximately. We try, also, to have the capability for a manned flight beginning with the third vehicle.

For future large-launch vehicles, we should first exploit to the maximum extent what we have and build up from that platform. The Saturn IB lends itself extremely well to carrying a third stage. If we consider, for instance, the Centaur as such a third stage, we could take 35,000 pounds of payload into an earth orbit, and inject 13,000 pounds on a lunar mission or 7,000 to 8,000 pounds on a planetary mission. There are other third-stage possibilities. Refinement of the present two Saturn IB stages could increase these payloads by approximately 20 percent Similar refinements could be applied to the Saturn V stages, which would improve its performance by approximately 30 percent. Refinements in the area of weight savings and higher engine performance, which is in good reach, will play the largest part in these increases.

A future step will be the application of advanced propulsion systems. Some of these are merely in an exploratory paper stage; others are in research; and, again, others are already under development.