NASA FACTS

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LAUNCH VEHICLES

Whatever space exploration or investigation is planned, the instruments package or the astronauts, or both, must first be put into space. This is the job of the launch vehicle.

A launch vehicle is any device that propels and guides a spacecraft into space, whether for a probe (from which it falls back directly to earth), into orbit about the earth, or into a trajectory to another celestial body.

The launch vehicle must apply a thrust large enough, and long enough, to lift the entire rocket, which also includes the control system and the payload. As the fuel burns in the chamber, the gases expand through a nozzle at high velocity, creating reaction in the opposite direction.

This is in accordance with Newton's third law of motion, which says that for every force acting upon a body there exists a corresponding force of the same magnitude exerted by the body in the opposite direction.

For energy, every rocket in use today burns a chemical fuel, either solid or liquid.

The main advantage of a solid fuel is simplicity. It requires no separate tanks, injectors, pumps, plumbing, cooling, or complex sequencing systems. It is easy to store and handle: it is stored in the launch vehicle. The disadvantages of solid-fuel, or solid-propellant, rockets are lower performance and the difficulty of controlling and stopping the thrust, which cannot repeatedly be turned on or off on command. Solid-propellant rockets are sensitive to temperature change, and their firing time is limited. Moreover, manufacturing them is involved and costly.

Fuels used in solid propellants are asphalts, waxes, oils, plastics, metals, rubber, and resins. Their oxidizers are often the common nitrates and perchlorates.

The main advantages of a liquid fuel are a longer firing time, higher energy, and controllability. Some liquid propellants cannot be stored in the launch vehicle, which therefore must be fueled just before take-off.

Most liquid-propellant rocket engines now in use have a liquid oxidizer and a liquid fuel, which are injected separately into the combustion chamber. The choice of appropriate fuels will sometimes allow the mixing process to ignite the fuel (hypergolic propellants), but if not, an ignition device is necessary.

Examples of liquid rocket fuels are alcohol, liquid hydrogen, kerosene, and aviation gasoline. A common liquid oxidizer is liquid oxygen; among others are nitric acid and fluorine.

A second class of liquid propellants, called monopropellants, do not need oxygen to release their energy. Of this limited class hydrogen peroxide is the best known.

Since the earth's gravity exerts the greatest pull at ground level, the greatest thrust is needed at take-off. Because of the immense fuel weight needed to launch a rocket with a single fuel container, there is a limit to its velocity and hence to its usefulness. To overcome this difficulty, most rockets are now built in stages. The first stage, or booster, gives the initial velocity and overcomes the greatest gravitational effect. This stage is then jettisoned. As the pull of gravity diminishes with distance from the earth, the other stage or stages (sustainer engines) fire, burn out, and drop off, until only the speeding payload remains.

Aside from the basic problem of getting enough thrust for a long enough time to counteract gravity for a particular weight, the rocket engineer must also control the rocket flight and give it only enough velocity for the chosen flight path. The nearer the planned orbit of the satellite is to the earth, the stronger the gravitational pull, and therefore the greater the velocity needed to keep the satellite in orbit. At 200 miles from the earth, a satellite needs a velocity of nearly 18,000 m.p.h. to stay in orbit. At 250,000 miles from the earth—approximately the distance of the moon—it needs 2,000 m.p.h. When a satellite reaches a velocity of 25,000 m.p.h. it completely overcomes the earth's gravitational pull and escapes. Unless its speed can be reduced, it will travel out into space.

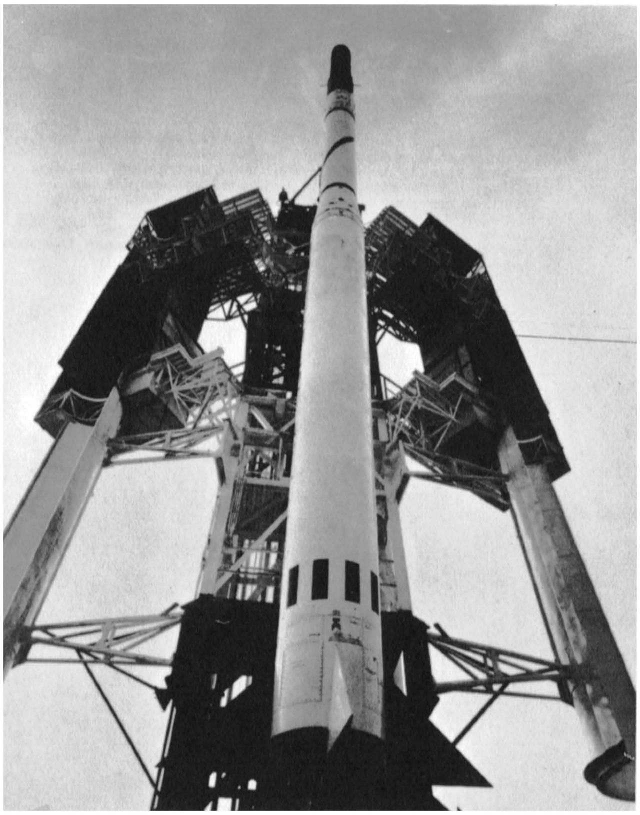
A satellite's path around the earth generally is elliptical rather than circular. With exceedingly precise guidance and velocity control, a spacecraft *can* be put into circular orbit, but the slightest deviation in velocity will produce an ellipse.[1] Earth satellites may be put into elliptical orbits deliberately, so as to produce a variety of altitudes and data.[2]

If an escaping spacecraft has been given a greater velocity than the earth's orbital velocity around the sun, it may achieve an orbit with a greater mean distance from the sun. With the correct velocity and guidance, it can be made to reach an "outer" planet (i.e. farther from the sun than the earth) such as Mars. But if the spacecraft is launched against the earth's rotation around the sun, it falls toward the sun and maintains a smaller orbit. With guidance, it could now reach Venus or Mercury.

The flight path chosen for a payload will thus determine what capabilities are required of the particular launch vehicle. Obviously, it would not make sense to use a moving van to deliver a few parcels. Similarly, it would be impractical to use a Saturn vehicle to orbit a small, lightweight group of scientific instruments. That is why this country is developing a family of reliable launch vehicles of various sizes, shapes, and capabilities. First, this policy is economical. Second, the more experience we have with a few particular kinds of vehicles, the more reliable they become. The aim is to develop the smallest number of vehicles consistent with the full scope of space missions now foreseen.

For each member of the "stable" of launch vehicles, missions have been assigned. The missions range from scientific research and exploration to projects vital for national defense.

At present, NASA manages six vehicles under the National Launch Vehicle Program. They are Scout, Delta, Atlas-Centaur, Saturn I, Saturn IB, and Saturn V. Development of Thor-Agena B, Atlas-Agena B, and Titan in the national program is managed by the U.S. Air Force as agent for the Department of Defense. NASA uses these vehicles also in its programs.



SCOUT

Scout, the smallest of the basic launch vehicles, was designed to provide a reliable and relatively inexpensive launch vehicle for smaller payloads and small satellite missions, high-altitude probes, and re-entry experiments.

It has four stages, is 72 feet high (less the spacecraft), and has a maximum diameter of 3.3 feet at its widest cross section.

Guidance is provided by a strapped-down gyro system, and the vehicle is controlled by a combination of aerodynamic surfaces, jet vanes, and hydrogen peroxide jets.

The only U.S. launch vehicle with solid propellants exclusively, it has a total thrust of 176,000 pounds and can put a 400-pound payload into the lower levels of space, or can put 240 pounds into a 300-nautical mile orbit or of carrying a 100-pound scientific probe about 7,000 miles away from the earth.

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[1] Orbits for the Project Mercury manned spacecraft flights were approximately circular, actually elliptical. For example, Faith 7, with Astronaut Gordon Cooper, had an orbit with a perigee (nearest to the earth) of 100 miles, an apogee (farthest from the earth) of 166 miles.

[2] Explorer XVIII, launched November 27, 1963, achieved an orbit with a perigee of 120 miles and an apogee of 23,000 miles.

DELTA

Delta has two liquid-fuel stages topped by a solid-fuel stage. Ninety feet high and 8 feet in diameter at the base (excluding fins), it can boost 800 pounds into a 300-nautical-mile orbit around the earth. Its gross weight is 112,000 pounds, and the total thrust of the first stage is 170,000 pounds.

It is a workhorse NASA vehicle for a wide range of small-payload satellite missions and space probes. It has launched the first Orbiting Solar Observatory, some of the Tiros weather satellites, and has been used in the communications-satellite Echo I, Telstar, Relay, and Syncom programs.

First launched by NASA in May 1960, Delta was originally intended as an interim vehicle for medium payload satellites and small space probes until newer vehicles such as Scout and Thor-Agena B became fully operational. However, Delta proved to be one of the most reliable launch vehicles the United States has, with a long list of successful firings to its credit.

Its first stage is a modified Thor, its second a modified and improved stage from the Vanguard and Thor-Able programs, and its third stage is the spin-stabilized, solid-propellant Altair. The Altair also derived from the earlier Vanguard and Thor-Able vehicles. Delta thus utilizes proven engines, modified to gain high reliability and perform a variety of missions.

DELTA MISSIONS
(23 successes out of 25 attempts)

COMMUNICATIONS		
Echo	1	1960
Telstar (AT&T)	2	1962, 63
Relay	2	1962, 64
Syncom	3	1963, 64
METEOROLOGY		
Tiros	7	1960, 61, 62, 63
SCIENTIFIC SATELLITES		
Explorer	6	1961, 62, 63
Orbiting Solar Observatory	1	1962
INTERNATIONAL SATELLITE		
Ariel (U.K. No. 1)	1	

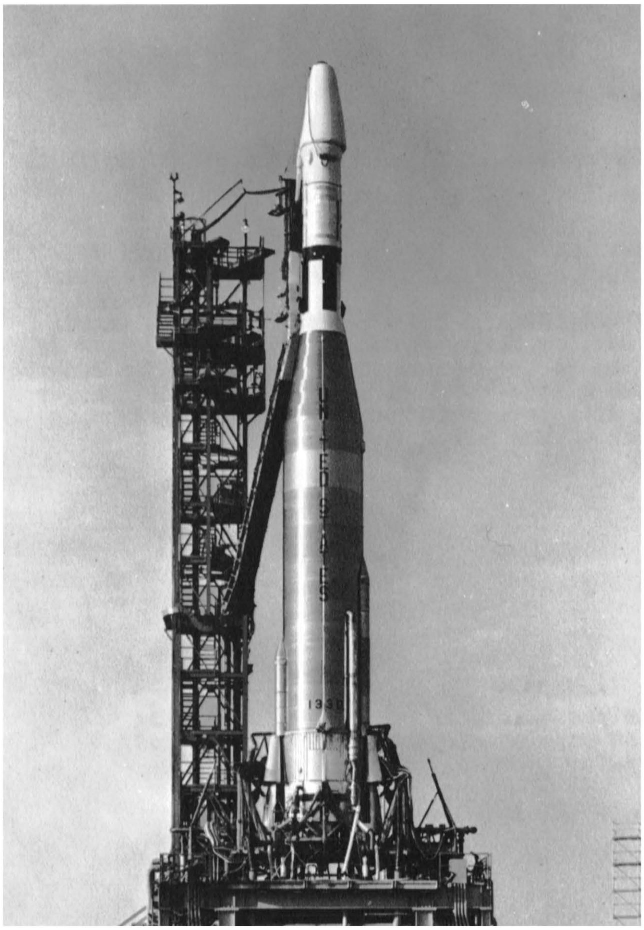
THOR-AGENA B

Thor-Agena B is a two-stage vehicle that can send 1,600 pounds into earth orbit (300 nautical miles) or 600 pounds into a 1,200-mile orbit.

Both stages burn liquid propellants, and the total thrust is 186,000 pounds. The vehicle is 76 feet high (without spacecraft) and 8 feet wide (without the fins). NASA launched its first Thor-Agena B in September 1962.

The second stage is the restartable Agena, which permits great precision in selecting an orbit. Agena was developed by the Air Force as a second stage for use in its own programs. Early in 1960 NASA decided to use it in combination with Thor and Atlas rather than develop a similar vehicle. The NASA version of Agena B is modified so that various types of payloads can be bolted to the front end.

Thor-Agena B is being used by NASA for meteorological, communications, and scientific satellites, including the Orbiting Geophysical Observatory and the Echo II communications satellite. It is also used in the Air Force Discoverer program.



ATLAS-AGENA B

The Atlas-Agena B is a two-stage all-liquid-propellant vehicle regarded as being capable of putting 5,000 pounds in earth orbit and of sending instrumented payloads of 750 pounds to the moon and 400 pounds to Mars or Venus. It is 91 feet high (less the spacecraft) and 10 feet in diameter. The thrust is 405,000 pounds.

The Atlas booster, developed from the Atlas ICBM (intercontinental ballistic missile), won fame in the Mercury manned space program. The first NASA launch was in August 1961 (Ranger I).

The vehicle is used to launch a variety of military, military-support, and scientific payloads. It can orbit large earth satellites and place in departure trajectories lunar probes and interplanetary and planetary exploration craft. When used as the launching vehicle for a satellite, the entire Agena B stage, after separation of the spacecraft, also becomes a satellite.

This vehicle consists of an Atlas D first stage and an Agena B second stage. With its standard three-engine propulsion system plus two small vernier[3] rockets, the Atlas D weighs about 260,000 pounds. The second, or Agena B, stage has a 15,000-pound-thrust engine that can be stopped and started in space.

Components of the guidance system are the inertial reference system, timing devices, a velocity meter, and an infrared horizon sensor. During powered flight, pitch and yaw control is maintained by gimbaling the rocket motor. During coast periods, high-pressure jets are used.

In a lunar application (for example, the Ranger VII launched in July 1964) the Atlas D five engines burn for about 2½ minutes before the outer engines cut off and drop away. The smaller center engine and vernier engines continue firing for another 2 minutes, taking the vehicle to an altitude of 80 miles. The two small 1,000-pound-thrust vernier engines continue firing after center engine cutoff long enough to trim velocity. An on-board computer commands the Atlas airborne guidance system to start the timer on the Agena B stage.

After the verniers cut off, the Atlas-Agena B coasts for a few seconds. Then the spring-loaded aerodynamic shroud protecting the Ranger payload is discarded. Explosive charges separate the Agena B from the Atlas first stage. The Agena B goes through a pitch maneuver to bring it into horizontal alinement with the earth's surface. Then the timer signals the propulsion system and ignition occurs.

During the 2½ minutes of powered flight, the Agena B is controlled by the hydraulic control system. When the engine cuts off, the payload is in a circular parking orbit approximately 100 miles above the earth. After a 14-minute coast period, the Agena B engine re-lights and powers the payload for another 1½ minutes, placing it in the lunar trajectory. Some 2½ minutes after engine cutoff the Agena B and the payload separate, and the Ranger continues alone.

On the whole, this vehicle has proved reliable and is expected to continue as a workhorse of the National Launch Vehicle Program for a number of years. Until Centaur and Saturn become operational, the Atlas-Agena will perform NASA's heavy-duty missions.

The vehicle with which the Gemini will rendezvous in space is the Agena D, a 1,700-pound Air Force upper stage modified to fit the requirements of Project Gemini. The changes include addition of a secondary propulsion system, modifications to the primary propulsion system to provide restart capability, electronics modifications for command and docking, a systems status panel which tells the astronauts the status of the Agena D systems, and an adapter for docking operations.

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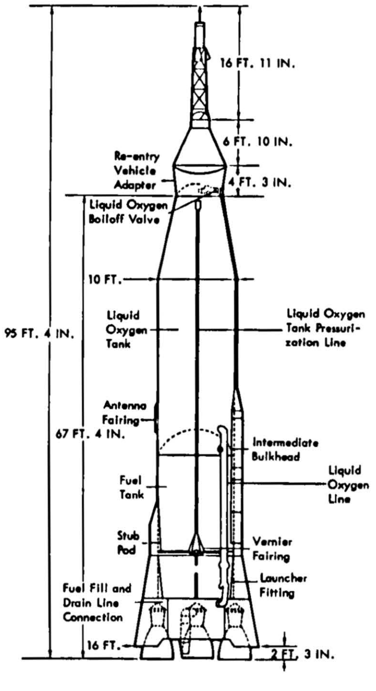
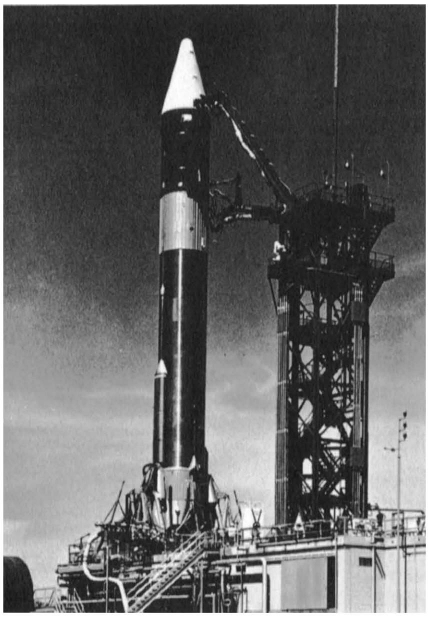
[3] **Verniers are small rocket engines used primarily to obtain a fine adjustment in the velocity and trajectory of a space vehicle or missile.**

MERCURY-ATLAS

Mercury-Atlas was the combination of spacecraft and launch vehicle used for earth-orbital flights by John Glenn, Scott Carpenter, Walter Schirra, and Gordon Cooper. For the suborbital flights of Alan Shepard and Virgil Grissom the launch vehicle was Redstone.





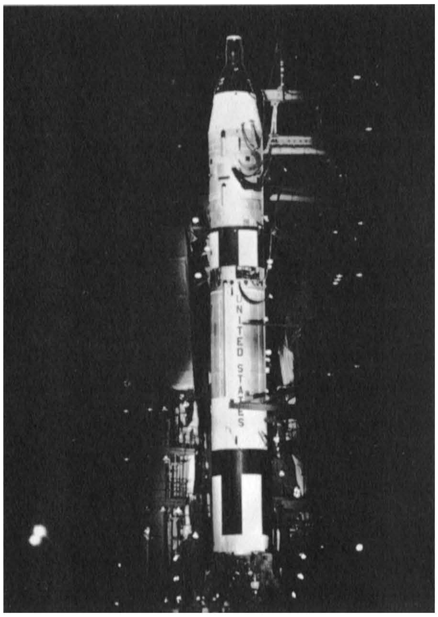
ATLAS-CENTAUR

Atlas-Centaur, with an Atlas D first stage and a Centaur second stage, is the most advanced of the Atlas-based series of launch vehicles. When it becomes operational, this 115-foot-long, 300,000-pound vehicle will be capable of sending approximately 8,500 pounds into low earth orbit, 2,300 pounds to the moon, and 1,300 pounds to Venus and Mars.

The liquid-propelled vehicle will have an estimated thrust of 377,000 pounds.

Atlas-Centaur is expected to be a high-performance, general-purpose launch vehicle for use by NASA and the Department of Defense. It takes a pioneer research effort to develop a rocket vehicle that can utilize high-energy liquid hydrogen as fuel. The Centaur program is such an effort and will provide much of the basic high energy knowledge required for the design of the upper stages of future vehicles and propulsion systems, which will use the same fuel.

Atlas-Centaur is called a "true space vehicle" because its engines can be started, shut down, and restarted to accomplish changes in direction and velocity in space. When fully operational, Atlas-Centaur will fly unmanned lunar and planetary spacecraft beyond the present capabilities of the Atlas-Agena B launch vehicles. In preparation for this future, the first successful launch occurred in November 1963.



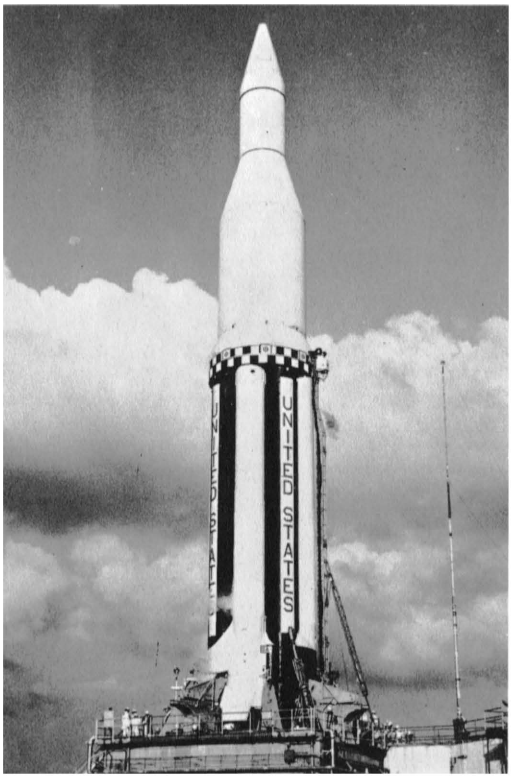
GEMINI-TITAN

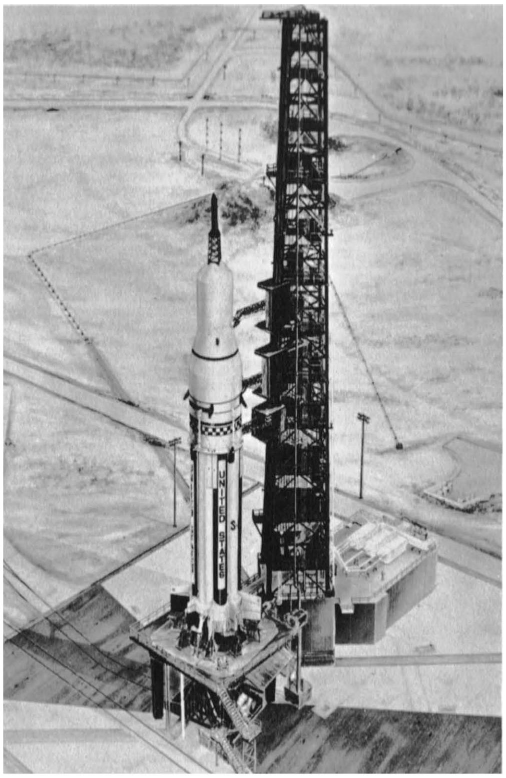
Titan, like the Atlas D, is a U.S. Air Force intercontinental missile that has been adapted by NASA for a specific mission. A modified Titan II, selected for Project Gemini, to boost into orbit the Gemini two-man spacecraft, was first used successfully in the unmanned flight of Gemini on April 8, 1964.

It was chosen for the Gemini mission because its propellants are nonexplosive—a feature permitting use of an ejection-seat escape system instead of the escape tower of Mercury. All engines operate on a mixture in which the fuel is a blend of unsymmetrical dimethylhydrazine (referred to as UDMH) and hydrazine, and the oxidizer is nitrogen tetroxide. The mixture is hypergolic, meaning that when the fuel and oxidizer are brought together the fuel ignites spontaneously, without need for an ignition system.

The propellants can be stored indefinitely in Titan's fuel tanks. The launch vehicle can be readied for use on short notice and need not be drained of fuel if a launch is postponed. Its use with the manned Gemini spacecraft will permit practice of rendezvous maneuvers in orbit, and is expected to pave the way toward success in the Apollo program of landing men on the moon.

Titan II has a 430,000-pound-thrust first stage and a 100,000-pound-thrust second stage. It is 90 feet high and 10 feet in diameter at the base.





SATURN I

Saturn I (formerly called Saturn C–1) was conceived in 1958 to provide early capability for large payloads. Existing components were used wherever possible. The decision to arrange the engines and tanks in clusters allowed the use of equipment developed for U.S. ballistic missile programs. Thus, the first stage of the two-stage Saturn I is a cluster of eight H–I engines, each capable of generating 188,000 pounds of thrust. The second stage has six liquid-oxygen, liquid-hydrogen RL–10 A–3 engines, each generating 15,000 pounds of thrust.

Saturn I is part of a family of three Saturn launch vehicles NASA is developing for its Apollo program. In Apollo, Saturn I will launch boilerplates (engineering test models) of the command and service modules on earth-orbital flights.

Saturn I is 125 feet tall and, excluding fins, has a base diameter of 21.6 feet. The first stage was launched successfully in October 1961. In May 1964 the sixth successfully fired Saturn lofted 37,300 pounds.

Saturn I's first-stage total thrust of 1½ million pounds compares with the 360,000 pounds of thrust of the Atlas missiles that launched our first spacemen into earth orbital flights.

The second stage is a cluster of six engines burning high-energy liquid hydrogen and liquid oxygen, and producing a thrust of 90,000 pounds. Saturn I is capable of placing an 11-ton spacecraft in earth orbit.

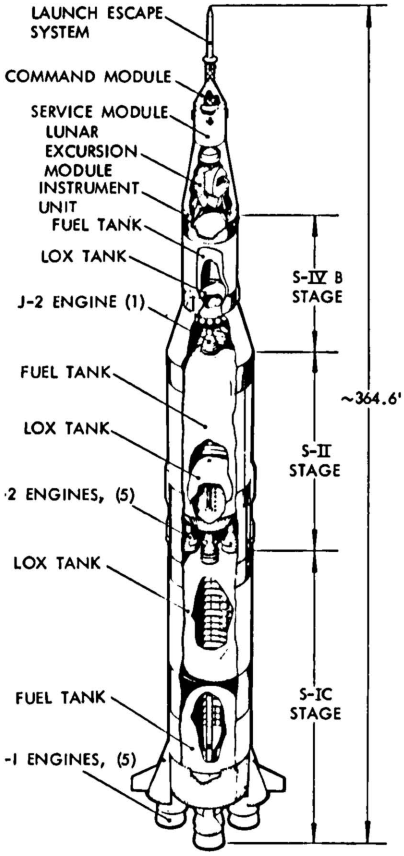
Ten Saturn I launchings are planned. Three Saturn I vehicles are to launch Apollo boilerplates carrying micrometeorite experiments.

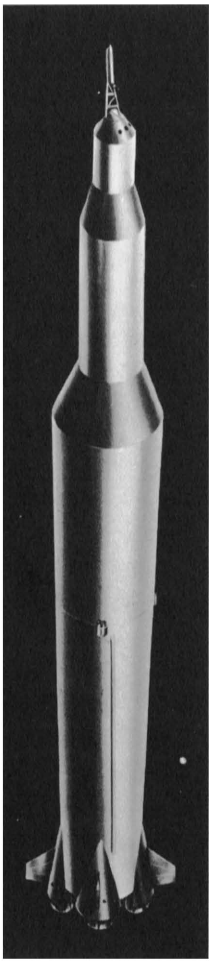
SATURN IB

Saturn IB (previously termed Saturn C–IB) will launch all three modules of the Apollo spacecraft into earth orbit. This vehicle will be used for manned flights of up to 2 weeks duration and rendezvous and docking of the command module and lunar excursion module.

The first stage has the same eight liquid H–I engines as Saturn I, generating a total of 1,600,000 pounds of thrust. The second stage will have a single 200,000-pound-thrust liquid-hydrogen, liquid-oxygen J–2 engine.

The vehicle will stand 141 feet high and be able to orbit a spacecraft weighing 18 tons. It will be used to launch a complete Apollo craft with crew aboard in earth orbit. First vehicle test is slated for 1966.





SATURN V

Saturn V will stand almost twice as high as Saturn IB and have a lift-off weight with payload of more than 6 million pounds. The first stage will be powered by five F–1 engines yielding a total of 7.5 million pounds of thrust. The second stage will be powered by five J–2 engines, each producing 200,000 pounds of thrust at altitude. The third stage will have a single J–2 engine. This combination will enable Saturn V to launch more than 125 tons into low orbit, 47½ tons on lunar missions, or 35 tons on planetary missions.

The vehicle's tremendous lift-off force will be produced by the five F–1 engines, each having the same thrust—1.5 million pounds—as all eight of the H–1 engines in the first stage of Saturn I.

Saturn V will be capable of sending the three-man Apollo spacecraft into orbit around the moon. The lunar landing will be made with the two-man Lunar Excursion Module (LEM), which will be detached from the Apollo. After the landing mission is completed, the LEM will take off from the moon to make rendezvous with the Apollo spacecraft in lunar orbit for the return journey to the earth.

Without the Apollo capsule, Saturn V will stand 280 feet high.

LAUNCH VEHICLES IN THE NASA SPACE PROGRAM

VEHICLE	PURPOSE
Scout	For small satellite missions, high-altitude probes, and re-entry experiments.
Delta	For a wide range of small-payload satellite missions.
Thor-Agena B	Used with Orbiting Geophysical Observatory (OGO) and the Echo II communications satellite.
Atlas-Agena B	For large earth satellites, lunar probes, and interplanetary and planetary exploration craft.

VEHICLE	PURPOSE
Titan	The vehicle for the Gemini program.
Atlas-Centaur	Will launch unmanned lunar and planetary missions and has capabilities suitable for high-velocity interplanetary probes.
Saturn I	Will launch unmanned Apollo spacecraft on earth-orbital test flights.
Saturn IB	Same booster as Saturn I, but more thrust in second stage.
Saturn V	The vehicle for the manned lunar landing mission.

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