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March 8, 1961

CENTAUR FACT SHEET

The Centaur is being developed as the nation's first high-energy space vehicle. Designed to open the entire inner solar system to research, the system is under the technical direction of the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration.

Centaur, which is scheduled to begin flight tests in the second quarter of 1961, will be used in the launching of interplanetary probes planned in 1962, and "soft" landings on the moon (Project Surveyor) in 1963.

The Centaur space vehicles (exclusive of engines) and ground support equipment are being developed for NASA by Convair (Astronautics) Division of General Dynamics Corporation. The engines, the first to burn liquid hydrogen, are under development by Pratt & Whitney Aircraft, a Division of United Aircraft Corporation.

The two-stage rocket consists of a modified Series D Atlas rocket topped by a short, high-energy stage of Atlas-type construction. It will be capable of placing 4 1/4 ton payloads in 300-mile earth orbits, and of sending large, instrumented probes deep into space.

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The Centaur second stage will be used as the final stage of the Saturn heavy space vehicle, currently under development at the Marshall Center's Huntsville, Ala., facility.

VEHICLE: Centaur's first stage is powered by three main rocket engines -- built by North American Aviation's Rocketdyne division -- developing 360,000 pounds of thrust. Two small vernier rockets provide acceleration at the end of the first-stage propulsion period.

The second Centaur stage is powered by two hydrogen-oxygen rocket engines of 15,000 pounds thrust each. Ten smaller rockets, four of which are "ullage" rockets and six are verniers, are used for stabilization and attitude control, respectively. The combined Centaur vehicle is 10 feet in diameter and 105 feet in length.

Both stages are built of thin-gage, lightweight stainless steel. Each is free of internal framework and is pressurized to maintain its shape.

OBJECTIVES: The importance of the Centaur to NASA is more far-reaching than the capability of the vehicle itself. This is because of its relationship to Saturn, which will begin flight tests in 1961. In addition to being a final stage for the massive Saturn, basic Centaur engines in a different arrangement will power the Saturn's second stage.

Further use of Centaur in manned space mission is under study by NASA.

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HISTORY: The Centaur vehicle evolved from studies of strategic high-altitude satellites for early missile warning, global survelliance, communications and weather reconnaissance work. With the realization that such satellites would require a high-energy upper stage for Atlas, the hydrogen-oxygen combination was selected.

In the fall of 1958, the Advanced Research Projects Agency selected Convair's proposal to develop a modified Atlas and a 30,000-pound hydrogen-oxygen engine. Pratt & Whitney, which had developed a liquid hydrogen pump, was designated associate contractor for propulsion. Thus it was possible to abandon the pressure-fed propulsion system considered up to that time and develop instead the pump-fed, twin-engine hydrogen-oxygen stage.

LIQUID HYDROGEN: Because liquid hydrogen offers a maximum amount of energy per pound, it becomes possible to lift -- with a two-stage vehicle -- payloads which would require three or more stages using earlier fuels.

It is estimated that Centaur's hydrogen-oxygen engines will produce a specific impulse (amount of thrust per pound of propellant during each second of engine operation) 40% greater than high-altitude rocket engines that burn kerosene-type fuels.

The reason given for the slow development of hydrogen-oxygen engines is that prior to 1956 there were few suppliers. Since then, however, several large liquid hydrogen plants have gone into operation.

ENGINE PERFORMANCE: Efficient performance of these engines depends on propellants being received by the propellant pumps at precise

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pressures. This is accomplished by special boost pumps developed by Pesco Products Divison of Borg-Warner Corporation. In this pump-fed system, the initial high propellant pressurization designed to force the propellants into the main fuel and oxidizer pumps is avoided.

The hydrogen reaches the main fuel pumps as a liquid, then flows through a cooling jacket which surrounds the combustion chamber. This process cools the engine and simultaneously heats the hydrogen. The "hot" hydrogen (the temperature of which is still more than 100 degrees below zero) operates a turbine which, in turn, drives the fuel and oxidizer pumps. These pumps force the hydrogen and oxygen into the combustion chamber.

GUIDANCE: The Centaur second stage is controlled in flight by an inertial (self-contained) guidance system developed by the Minneapolis Honeywell Regulator Company. A general-purpose computer is contained in the guidance system. It stores information on the vehicle's position and velocity, received from accelerometers mounted on a gyro-stabilized platform. If changes in position or velocity are required, the guidance system sends an electronic message to the autopilot, which transmits corrective information to the engines.

FLIGHT SEQUENCE: In a typical flight operation, the three Centaur first stage engines and two verniers are all ignited before launch. After several minutes of flight, the booster section, with two of the main engines, is jettisoned.

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Thrust is then provided solely by the remaining sustainer engine. At sustainer cutoff, the vehicle is traveling at approximately 10,000 miles per hour. The upper stage is unlatched and driven out by the four ullage rockets, while small retrorockets aid in the separation and prevent the first stage from bumping the second stage. Moments later, the second-stage engines ignite.

Most missions will require the Centaur engines to stop at a pre-determined time to allow for a "coast"period. Thus, the vehicle can wait until its "target" is in the most advantageous position before the engines continue flight. Current planning provides for two restarts during a mission.

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Public Information Office
NASA Lewis Research Center
Cleveland, Ohio 44135
252-7700, ext. 415

Centaur, the nation's first space vehicle to use the highly powerful liquid hydrogen as fuel, completed its initial flight success with this launch from Cape Kennedy, Fla., on Nov. 27, 1963.

Development of the vehicle is under technical direction of the National Aeronautics and Space Administration's Lewis Research Center, Cleveland, Ohio.

This flight--termed AC-2--was the second of eight planned to make Centaur operational by 1965.

The 300,000 pound, 109-foot high Atlas-Centaur combination was launched from Pad 36-A at 2:03 p.m. Some 235 seconds later the Atlas booster was separated from the second-stage Centaur. Centaur's twin hydrogen engines, developing a total of 30,000 pounds of thrust, then fired for about 380 seconds.

Completing a near-perfect trajectory, the second stage was injected into an earth orbit with an apogee of 1,039.5 statute miles and a perigee of 354.8 statute miles. Centaur is now circling the earth every 107.7 minutes with a speed of 17,553 miles per hour at perigee. It is expected to remain in orbit for approximately 200 years.

With the high-energy capability provided by its hydrogen fuel, Centaur will play a key role in launching medium-weight scientific payloads. Its first scheduled task is lofting to the moon a Surveyor instrumented spacecraft--forerunner of manned lunar landings.

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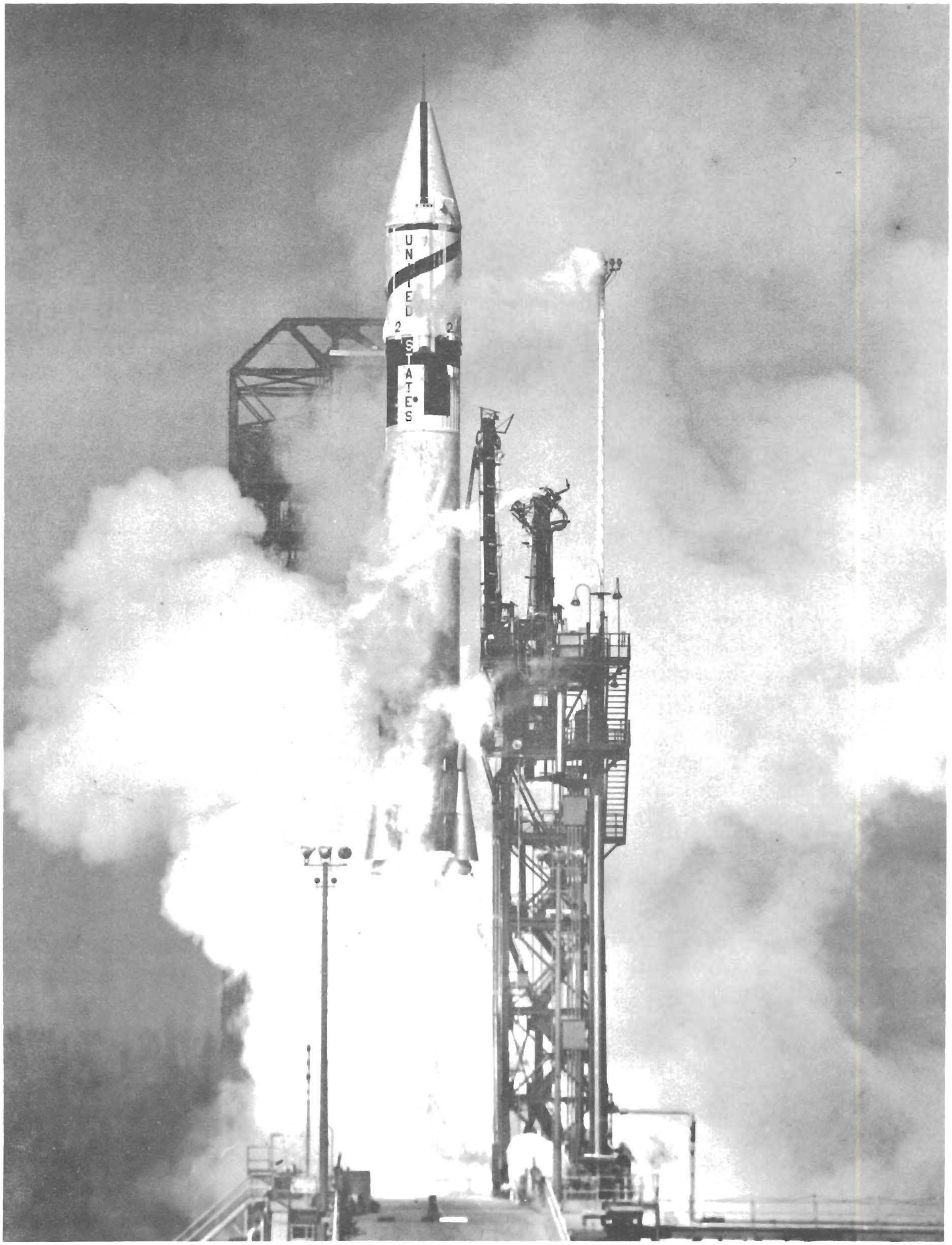

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Public Information Office
NASA Lewis Research Center
Cleveland, Ohio 44135
252-7700, ext. 415

December 13, 1963

CENTAUR

Centaur, an upper-stage, hydrogen-fueled space vehicle, is being developed for lunar and planetary missions. It is the first space vehicle developed by the U.S. employing high-energy liquid hydrogen as fuel.

The Centaur project is under the technical direction of the National Aeronautics and Space Administration's Lewis Research Center, Cleveland, Ohio. General Dynamics/Astronautics, San Diego, Calif., is the prime contractor for Centaur. More than 300 other contractors throughout the U.S. are participating in the program.

Now in the research and development stage, Centaur completed its first successful R&D launch from Cape Kennedy on Nov. 27, 1963. After initial boost by an Atlas launch vehicle, the Centaur second stage hydrogen engines, developed by Pratt and Whitney Aircraft Division of United Aircraft Corp., were ignited and burned for full duration. This was the first known instance of hydrogen engines being ignited in space.

Following second stage ignition, the 28-foot long Centaur vehicle was injected into an elliptical earth orbit with an apogee of 1039 statute miles and a perigee of 354 miles.

The Nov. 27 flight was the second of eight planned R&D missions to qualify the Centaur space launch vehicle. Once it attains operational status, Centaur's primary mission will be to soft-land the Surveyor spacecraft on the moon. Surveyor is an unmanned, instrumented spacecraft designed to make lunar surface studies prior to Apollo manned missions to the moon. Surveyor missions will begin in 1965.

Centaur also may be used to power Mariner B spacecraft to Mars and Venus.

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Fully developed, Centaur will have the capability of sending 2,300-pound payloads to the moon or 1,300 pounds to Mars or Venus.

Since it is pioneering liquid hydrogen technology in flight, Centaur has broad applications in other major NASA programs. Hydrogen is the fuel for upper stages of the Saturn I, I-B and V vehicles and NERVA--nuclear engine for rocket vehicle applications.

VEHICLE DESCRIPTION

The Centaur first stage is a modified Series D Atlas space booster similar to that used for Mercury and Agena projects, except that the tapered nose has been widened to a constant 10-foot diameter to accommodate the second stage. An interstage adapter connects the two stages.

The entire vehicle is about 110 feet high. Its fueled weight is about 300,000 pounds.

Two booster engines and one sustainer engine are powered by liquid oxygen and RP-1, a type of kerosene fuel. The engines are produced by Rocketdyne Division of North American Aviation. Two small vernier engines provide directional control. A total of 367,000 pounds of thrust is produced in the first stage.

The second stage, 28.5 feet in length, weighs about 38,500 pounds fully fueled, plus several hundred pounds of insulation around the hydrogen tank to prevent excessive boiloff.

The second stage is powered by two Pratt and Whitney RL-10 engines of 15,000 pounds thrust each. They are capable of being shut down and re-started during flight. These engines burn the high-energy combination of liquid hydrogen and liquid oxygen.

Small hydrogen peroxide rockets mounted on the periphery of the second stage provide additional thrust for propellant ullage control as well as attitude control during coast periods.

The payload, guidance and electronic equipment are mounted on the forward bulkhead of the liquid hydrogen tank and are protected by a plastic fiberglass nose fairing which is jettisoned after the vehicle leaves the atmosphere.

Centaur is controlled in flight by an inertial (self-contained) guidance system which determines its instantaneous position and velocity and generates steering and sequence commands.

The guidance system was originally designed for the precision task of launching 24-hour synchronous communications satellites but has been adapted to the current Surveyor soft-landing lunar mission and Mariner planetary fly-bys.

HYDROGEN TECHNOLOGY

Hydrogen in its natural gaseous state has been known as a major element of our atmosphere for almost four centuries. Men have been trying to use hydrogen to fly for almost half that time--since 1766 when the English chemist Henry Cavendish announced that hydrogen was lighter than air.

Now, as a liquid fuel for Centaur, hydrogen has entered the rocket propulsion scene. But this time research and development has preceeded its use. An entire new technology has been evolved for handling, controlling and utilizing hydrogen is its liquid form.

Supercooled to 423 degrees below zero, this colorless, odorless liquid is powerful--and temperamental. It must be kept at its cryogenic temperature of -423 degrees or it will vaporize. It is very lightweight--only one-fourteenth as heavy as air.

Mixed with liquid oxygen in a rocket engine, hydrogen will provide about 35 per cent more thrust for each pound of propellant than conventional kerosene-type fuels. In short, it is the best liquid rocket fuel currently usable.

NASA's Lewis Research Center did much pioneering work in developing liquid hydrogen technology. In 1953, the center was far enough along in liquid hydrogen work to fire an experimental hydrogen/oxygen engine producing 5,000 pounds of thrust.

Behavior of liquid hydrogen under weightlessness is another unknown and vital question. Project engineers hope to learn more about this problem during flights late in the Centaur research and development program. Zero gravity problems can be studied for brief periods on the ground, but most questions can be answered only in actual flight.

Lightweight hydrogen has been called the ultimate fuel. The Sun itself "burns" hydrogen in its internal thermonuclear reactions that provide light and heat to our solar system. Fusion rockets duplicating the energetic reactions of the Sun are in the infancy stages of research, but hydrogen will find more immediate use in nuclear rockets.

TEST PROGRAM

Prior to its first successful flight on Nov. 27, the Centaur space launch vehicle was subjected to one of the most strenuous ground test programs in the history of U.S. rocketry. Many of these tests will continue throughout the development program.

Test facilities are used at General Dynamics/Astronautics in California, Lewis Research Center, Pratt and Whitney in Florida and at subcontractor facilities located throughout the country.

At Lewis' Plum Brook Station near Sandusky, Ohio, an Atlas booster is undergoing a series of structural tests designed to determine if the Atlas can carry the Centaur second stage--by far, the heaviest weight ever lifted by the booster.

Several of the tests at Plum Brook--all completed successfully--were necessary prior to the Nov. 27 launch.

Engineers are now readying a Centaur test vehicle for combined structural testing with Atlas. To this combination will be added a dynamic model of the Surveyor spacecraft so that engineers can simulate on the ground conditions the vehicle will encounter during flight through the earth's atmosphere.

At Lewis, Centaur engineers have modified an altitude wind tunnel, now called a space power chamber, to accommodate a Centaur vehicle for extensive environmental testing. Engine and electrical systems will be tested up to engine ignition in a simulated space environment. The hot and cold temperatures of outer space will be duplicated using liquid nitrogen and solar simulators.

Another major program at Lewis involved testing a new system designed to separate Atlas and Centaur during flight. These tests were conducted at a simulated altitude of 97,000 feet and successfully demonstrated the separation system prior to the Nov. 27 mission.

TYPICAL FLIGHT SEQUENCE

During a typical Centaur flight, with the objective of placing the Surveyor spacecraft on the moon, the Atlas booster's three main engines and two verniers are ignited on the pad.

After more than two minutes of powered flight, the two main engines are jettisoned. The sustainer engine continues to provide thrust with first stage power ending after about four minutes of flight.

As Atlas power ends, a shaped charge cuts through the interstage adapter, separating the two stages. At the same time, retrorockets mounted on the aft end of Atlas are fired to pull the booster away from Centaur.

Within a very few seconds, the two hydrogen-fueled engines are ignited and the Centaur vehicle attains sufficient velocity to escape the earth's gravitational pull.

Centaur and its Surveyor payload are now on a direct trajectory toward the moon. Once outside the earth's gravity, Surveyor separates from Centaur and continues toward the moon.

This type of mission is termed "direct ascent." It provides far less problems since the space launch vehicle is under power until it escapes the earth's gravity, thus eliminating prolonged periods of coasting under weightless conditions.

One disadvantage to this type of mission is what flight planners call the "launch window." This is a calculated period during which a vehicle must be launched from earth to intercept the moon.

Another method of reaching the moon is called a "parking orbit." This involves placing Centaur and Surveyor into a low earth orbit, about 100 miles high. Centaur then coasts until it is in the proper position relative to the moon. The Centaur engines are re-started and Surveyor begins its flight to the moon.

The hydrogen engines used on Centaur are designed to be stopped and re-started in space. During later missions in the development program, Centaur will fly into earth orbit, coast briefly, then re-start its engines to accelerate the vehicle to escape velocity.

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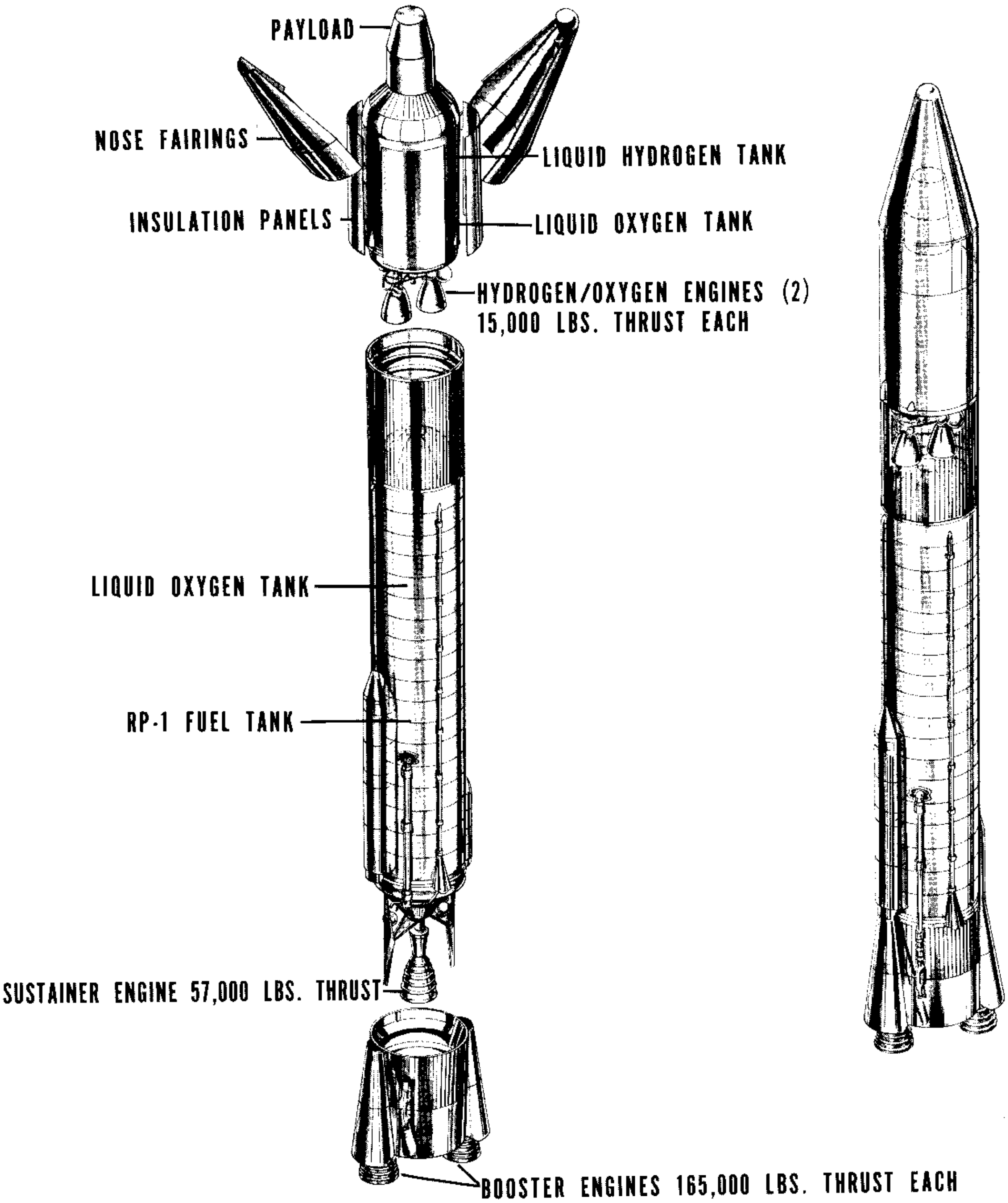
CENTAUR VEHICLE DESCRIPTION



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NASA Lewis Research Center • 21000 Brookpark Rd. Cleveland, Ohio 44135 • AC 216/433-4000 Ext. 415

HISTORY OF CENTAUR

In 1957, almost one year before Congress created NASA, the Air Force studied an exhaustive proposal from General Dynamics/Astronautics Corp. to develop a new space booster that could give the U.S., in the shortest possible time, a means of orbiting heavy payloads.

That vehicle was to become the Centaur, a high-energy second stage with a new propulsion system using liquid hydrogen. Mixed with liquid oxygen, this new fuel afforded the promise of boosting payloads as great as 8,500 pounds.

By August of 1958, the government's Advanced Research Products Agency accepted from the Air Force a more elaborate proposal for the Centaur and assigned authority for its development to the Air Force.

Centaur promised new muscle in space. The U.S. needed it. Russia had taken the lead with the very first space flight: Sputnik I launched into earth orbit on Oct. 4, 1957, its "Bleep, Bleep" being heard around the world.

Centaur became an official hardware development program the same year NASA was established, in 1958. At that time the heaviest Russian satellite orbiting the earth was the 3,000-pound Sputnik III.

Reflecting long-range U.S. space strategy, on July 1, 1959, NASA took over jurisdiction of Centaur from the Department of Defense. Soon after, the first Centaur flight test was set for January, 1961.

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(Distributed May 1984)

Centaur was not to be just another booster, but "the" rocket by which NASA would conduct extensive earth orbit missions, lunar investigations and planetary studies. Aside from military satellite missions assigned to Centaur, which were to be considerable, NASA planned to launch one operational Centaur every month for a period extending well into the 1970's and beyond.

That schedule became hopelessly over-optimistic, dogged by an avalanche of problems, failures, test-stand explosions and other delays. On May 8, 1962, the first Centaur rose, a perfect launch for 54 seconds. Then the Centaur upper stage exploded. DOD officials became convinced that operational Centaurs would not be available until 1966.

NASA rescheduled another first test flight for October, 1962. Now Dr. Abe Silverstein stepped forward and convinced the hard-pressed NASA organization that his Lewis Research Center could de-bug and manage the problem-ridden Centaur. Full responsibility for the ailing rocket was assigned to Lewis under Dr. Silverstein, its second director.

Engineers at Lewis were familiar with Centaur's liquid-hydrogen/liquid-oxygen cryogenic fuels, having developed the technology for safe handling of the -400 degrees F. propellants.

Finally on Nov. 27, 1963, it happened. Centaur made its first successful flight. No payload was carried but the powerful rocket scored a significant milestone: first in-flight burn of a liquid-hydrogen/liquid-oxygen engine. Major successes followed rapidly.

Coupled with already proven Atlas first stages, Centaur vehicles sent seven Surveyor spacecraft to probe the surface of the Moon between May 30, 1966 and Jan. 7, 1968, furnishing valuable data for the first manned landing on the Moon in July, 1969.

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Other important Atlas/Centaur missions followed, including boosting the Orbiting Astronomical Observatory to scan the stars from above the Earth's atmosphere . . . sending two Mariner spacecraft to chart the planet Mars . . . launching two Pioneers to Jupiter on a solar system escape trajectory and a Mariner to Venus and Mercury.

The Centaur stage combined with the Air Force Titan III booster provided a capability to launch larger spacecraft like Helios A and B around the Sun, two Vikings to Mars, and two Voyagers to Jupiter, Saturn and beyond.

Centaur has flown not only exploratory scientific missions but also those with terrestrial benefits such as Applications Technology Satellites and the Intelsat, Comstar and Fltsatcom communication satellites. Centaur has delivered these domestic and military communication satellites into geosynchronous orbit.

Centaur today is a mature, high-energy, still-viable upper stage with an overall operational reliability record of 96% . . . 100% since 1971.

As Centaur begins its third decade, it is being modified to fit into the Space Shuttle as a high-energy upper stage and will launch the Galileo spacecraft for further study of Jupiter and its moons as well as send the International Solar Polar spacecraft over the poles of the Sun, both launch events scheduled to take place in 1986.

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