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Manned Space Flight: Projects Mercury and Gemini

MANNED SPACE FLIGHT

A major goal of the United States space program is manned flight to the moon and safe return to earth before the end of this decade.

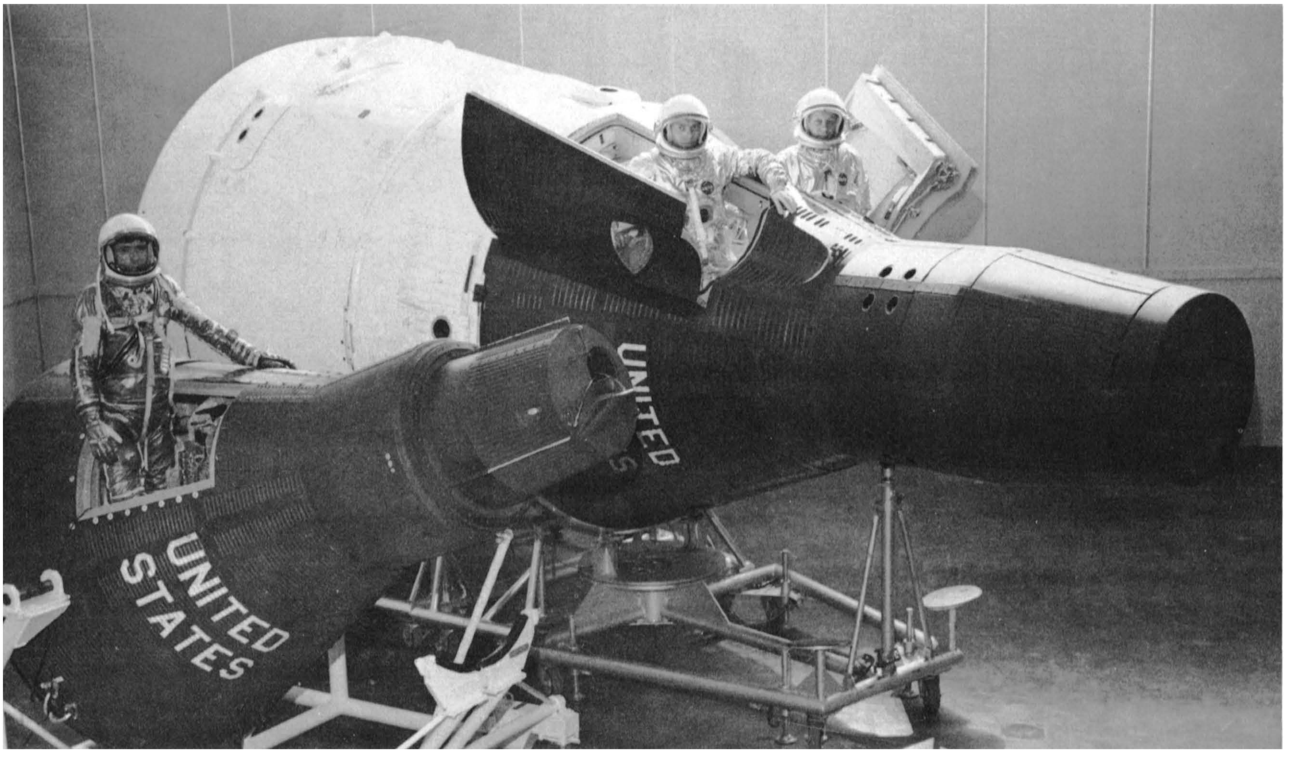
NASA's manned space flight program has been divided into three steps or projects — Mercury, Gemini, and Apollo.

Project Mercury put manned spacecraft into a controlled earth orbit to investigate man's performance capabilities and his capacity to withstand the environment of space and to test and successfully recover the vehicle.

Project Gemini has fulfilled its original objectives; among them, extending orbital missions up to two weeks at a time and developing the techniques for orbital rendezvous and docking, in which two space vehicles are maneuvered close together and finally joined.

That same technique of orbital rendezvous — but around the moon instead of earth — will enable astronauts in the three-man Apollo spacecraft to achieve lunar landings.

One-man Mercury spacecraft (foreground) alongside two-man Gemini spacecraft.



PROJECT MERCURY

Project Mercury became an official program of NASA on November 26, 1958. A Space Task Group (the forerunner of today's Manned Spacecraft Center, Houston, Texas) was formed at the Langley Research Center, Hampton, Virginia. Seven astronauts were chosen in April 1959 after a nationwide call for jet pilot volunteers.

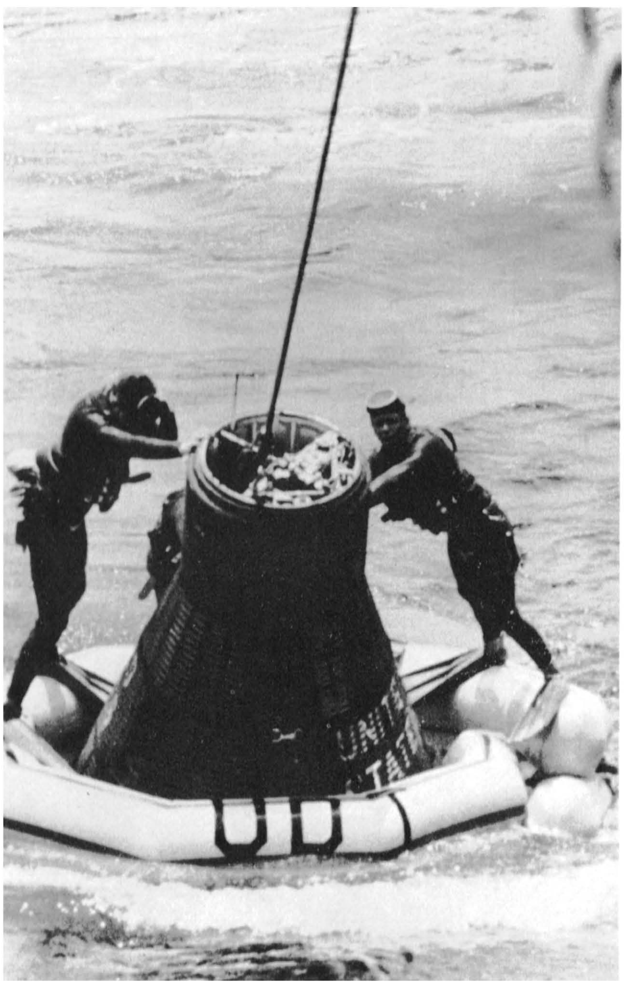
The one-man Mercury spacecraft was designed and built with a maximum orbiting weight of about 3,200 pounds. Shaped somewhat like a bell (truncated cone), the craft was 74.5 inches wide across the bottom and about 9 feet tall. The astronaut escape tower on top added another 17 feet for an overall length of approximately 26 feet at launch. Two boosters were chosen – the Army's Redstone (78,000 lbs. thrust) and Air Force's Atlas (360,000 lbs. thrust) – for suborbital and orbital flights, respectively. Before the manned flights began, Ham, the chimp, successfully achieved a suborbital Mercury-Redstone 2 (MR–2) flight on January 31, 1961.

Then all was ready for the historic MR–3 flight of May 5, 1961, as Astronaut Alan B. Shepard, Jr., made the first U.S. manned space flight. His suborbital mission of 15 minutes took his Freedom 7 spacecraft 116 miles high into space.

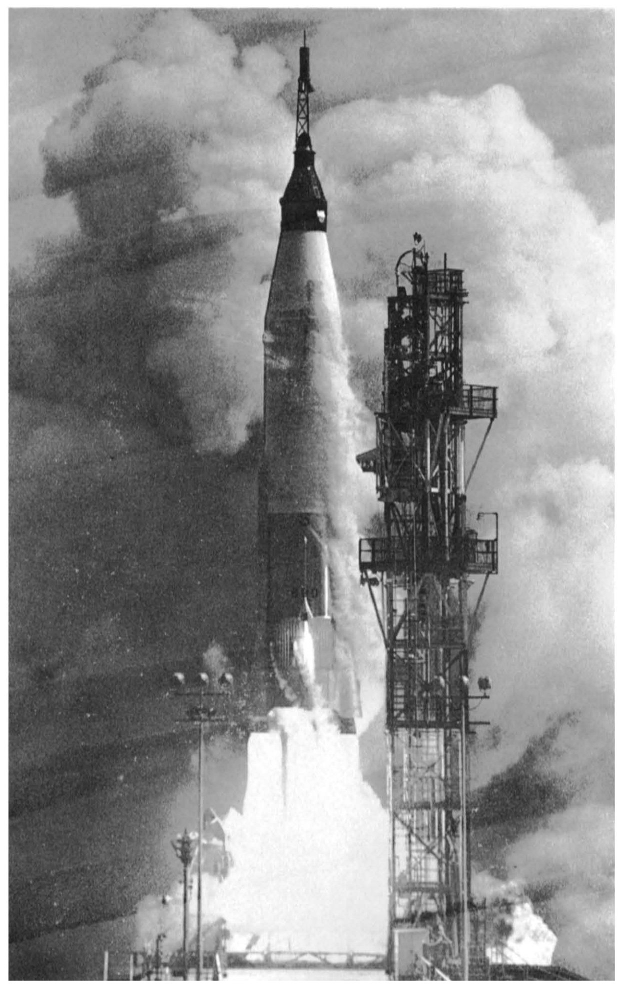
After another countdown for MR–4 on July 21, 1961, the Redstone booster hurled Astronaut Virgil I. "Gus" Grissom through the second ballistic (suborbital) flight in the Liberty Bell 7.

This ended the Redstone suborbital tests as the Mercury-Atlas series of flights advanced to orbital missions. Before the first manned attempt another chimp, Enos, made an orbital flight (MA–5) on November 29, 1961.

An MA–6 space milestone, on February 20,



Frogmen fit a flotation collar to Mercury spacecraft after its completion of an orbital flight mission.



Atlas launches Mercury spacecraft.

1962, made Astronaut John H. Glenn, Jr., the first American in orbit, completing three circuits in Friendship 7.

On the MA–7 mission of May 24, 1962, Astronaut M. Scott Carpenter in Aurora 7 completed another three-orbit flight.

MA–8 of October 3, 1962, doubled the flight time in space as Astronaut Walter M. Schirra, Jr., orbited six times, landing Sigma 7 in the Pacific recovery area, instead of the Atlantic.

Finally, on May 15-16, 1963, Astronaut L. Gordon Cooper, Jr.'s, Faith 7 completed a 22-orbit mission of 34½ hours, triumphantly concluding the flight phase of Project Mercury.

Originally, Project Mercury was assigned only two broad missions by NASA—first, to investigate man's ability to survive and perform in the space environment; and second, to develop the basic space technology and hardware for manned space flight programs to come.

Among the significant aerospace medical information derived from Mercury were:

- Consumption of food and beverages and sleeping during space flight were proved possible.
- Radiation dose received by the astronauts was considered medically insignificant.
- All measured physiological functions remained within anticipated ranges throughout all flights. There was no significant degradation of pilot function attributable to space flight.
- There was no evidence of abnormal sensory, psychiatric, or psychological responses to space flight.

The following were also accomplished in Project Mercury:

- Development of a NASA management system that could carry out more advanced manned space flight ventures.
- Exploration of the fundamentals of spacecraft reentry.
- Starting a family of launch vehicles from existing rockets that led to new booster designs.
- Setting up of an earth-girdling space tracking system that was later modified for the Gemini and Apollo projects.
- Training of a pool of astronauts that could be augmented to meet the requirements of future space exploration programs.

PROJECT GEMINI

Project Gemini was named after the constellation Gemini (Twins).

NASA decided to follow the Mercury's basic "capsule" design for Gemini spacecraft, saving time and engineering efforts. But the two-man craft was wider (10 feet), taller (19 feet), and more than twice as heavy (8300 lbs.). These dimensions provided 50 percent more cabin space, making room for much new equipment and with it far greater performance flexibility.

Since Mercury's Redstone and Atlas boosters lacked the power to orbit the heavier two-man craft, a modified version of the military Titan II became the Gemini Launch Vehicle (GLV), with a total thrust of 530,000 pounds (first stage, 430,000 pounds). The hypergolic (self-igniting) propellants used were non-explosive, an astronaut safety factor.

Chosen for Gemini's prime mission of orbital rendezvous and docking was the Agena-D target vehicle, a modified version of the reliable Agena-B second stage that, with Thor or Atlas boosters, had orbited many satellites and launched Mariner and Ranger probes. Agena's "stop-and-restart" rocket engine, capable of cutoff and reignition at least four times, was important for maneuvers with Gemini. The hypergolic propellants are UDMH (unsymmetrical dimethylhydrazine) and IRFNA (inhibited red fuming nitric acid).

Agena-D is 32 feet long and 5 feet in diameter and shaped like a cylinder.

GEMINI FLIGHT STATISTICS

From the first Gemini unmanned flight on April 8, 1964, to the final manned flight ending November 15, 1966, Gemini flight time totaled 974 hours, 37 minutes, and 42 seconds. Of this, 969 hours, 51 minutes, and 26 seconds were manned.

The highest altitude reached by the manned Gemini spacecraft was 853 miles during the Gemini XI mission. This set a world's record.

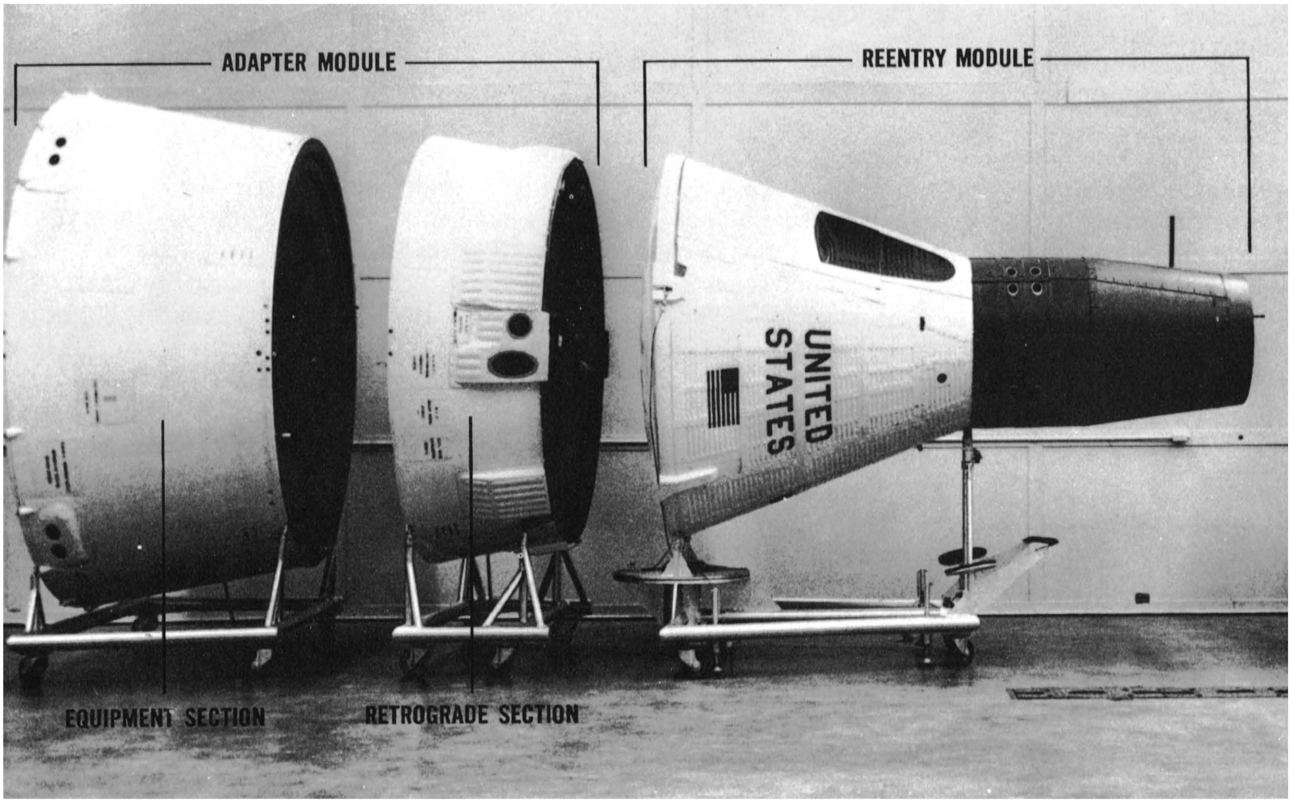
Orbital rendezvous was accomplished 10 times; docking, 9 times. Docking, first accomplished March 16, 1966, in the Gemini 8 experiment, is another Gemini first in space.

Gemini astronauts spent a total of 12 hours 12 minutes without the protection of their spacecraft in "space-walk" and other activities. In a gravity gradient experiment (See Gemini Experiments."), Gemini and Agena, linked by a taut tether, orbited earth for over 4 hours in a station-keeping exercise aimed at saving maneuvering fuel.

GEMINI SPACECRAFT

The Gemini craft was designed to be piloted by

Gemini astronaut floats high above earth outside of his orbiting spacecraft.



Separated segments of Gemini mock-up.

its two-man crew. After an automated launch, the Gemini spacemen took over: turning, changing speed, even shifting orbits.

The spacecraft consists of two major portions—the reentry module and the adapter module. The latter, in turn, also has two separate sections, so that Gemini, as launched, is actually a three-part structure.

Only the reentry module returned to earth. This module contains the "living" quarters where the two astronauts ride.

The life-supporting cabin is double-walled with an inner shell around the crew's pressurized compartment and an outer shell as the craft's external hull.

Between these shells is a storage space for electronic gear and other apparatus—a technological improvement over the Mercury craft, whose components (parts) were "stacked" upon one another inside the crowded pilot's compartment. In contrast, much Gemini equipment was in the double-walled storage area, where it could be easily checked, adjusted, replaced, even when Gemini was in place atop Titan on the launch pad.

The aft (rear) section contained more equipment, including the ablative (melting and evaporating) heat shield that protected the reentry module from air-friction heat on earth return.

One purpose of the two-part adapter module, which flares out from 7½ feet to 10 feet in diameter, was to "adapt" (fit) the narrow Gemini to the Titan booster's broad top. Secondly, the adapter's 90-inch deep volume was another housing area for equipment.

The adapter retrograde section, adjacent to the crew's reentry module, includes two sets of engines—retrorockets (for reducing speed) and space-maneuvering thrusters.

The adapter's equipment section holds fuel cells, attitude controls, propellant tanks, oxygen supplies, electrical components, and a liquid-coolant radiator to dissipate internal spacecraft heat away into open space.

The lower end of this two-part adapter is mated, by means of a metal collar, to the top of the Titan launch rocket.

EJECTION SEAT

Based on a jetplane technique, Gemini's lightweight ejection seats could, in emergency, catapult the astronauts out of two large hinged hatches that opened mechanically.

Unlike Mercury's automatic ejection sensors, Gemini's system relied upon the astronaut crew's quick reflexes, because Titan's non-explosive propellants merely burn and allow time for human reactions.

COMPUTER

Among Gemini innovations was a "shoebox" computer, weighing only 57.6 lbs. and occupying a mere cubic foot of cabin space, yet able to make the computations for the intricate rendezvous and docking maneuvers with the orbiting Agena-D.

FUEL CELL

Another "space first" was Gemini's fuel cell generating electrical power by chemical reaction. Much lighter than the equivalent batteries they replace, two groups of fuel cells could provide 1,000 watts each, supplying the spacecraft's total electrical needs.

GUIDANCE SYSTEM

Aboard Gemini was an inertial guidance system which records and totals every bit of progress forward, backward, and sideways, from the earth-launched starting point to the space destination. Linked into the guidance system during orbital maneuvers were other units—computer, radar, electronic controls, attitude thrusters, propulsion units—so that the astronauts' master controls could accurately achieve rendezvous and docking with Agena.

RENDEZVOUS RADAR

Gemini's high-definition radar gave the range (distance), bearing (direction and angle of approach), and closing speeds of the chase and target vehicles, with data starting when they were 250 miles apart.

Later, the high-intensity flashes of Agena's light beacon became visible to the astronauts, at a maximum range of 50 miles. These optical observations, plus radar tracking, were then combined, as the astronauts manually guided Gemini toward rendezvous with Agena.

COMMUNICATIONS SYSTEMS

Gemini missions employed three major communications systems: voice, which included an intercom connection between the astronauts; the receiver of command signals and updated orbit information from Mission Control Center; data collection tapes and their relay transmitters for automatic transmission of reports to earth.

ENVIRONMENTAL CONTROL SYSTEM (ECS)

The Gemini environmental control system provided oxygen for astronaut breathing; eliminated waste such as exhaled carbon dioxide; cooled the spacecraft, its equipment, and the astronauts' space suits; and provided drinking water.

Though the Gemini life-support system was similar to the Mercury ECS, major engineering changes were made. Each astronaut had two parallel suit circuits for oxygen, plus the option of using the cabin's habitable (purified) atmosphere while being partially unsuited for more freedom of action.

Mercury's bottled gas was replaced in Gemini by a liquid oxygen supply, requiring less storage volume for the maximum 14-day supply.

The third major ECS change was an improved method of dissipating unwanted heat into space.

FOOD AND WATER

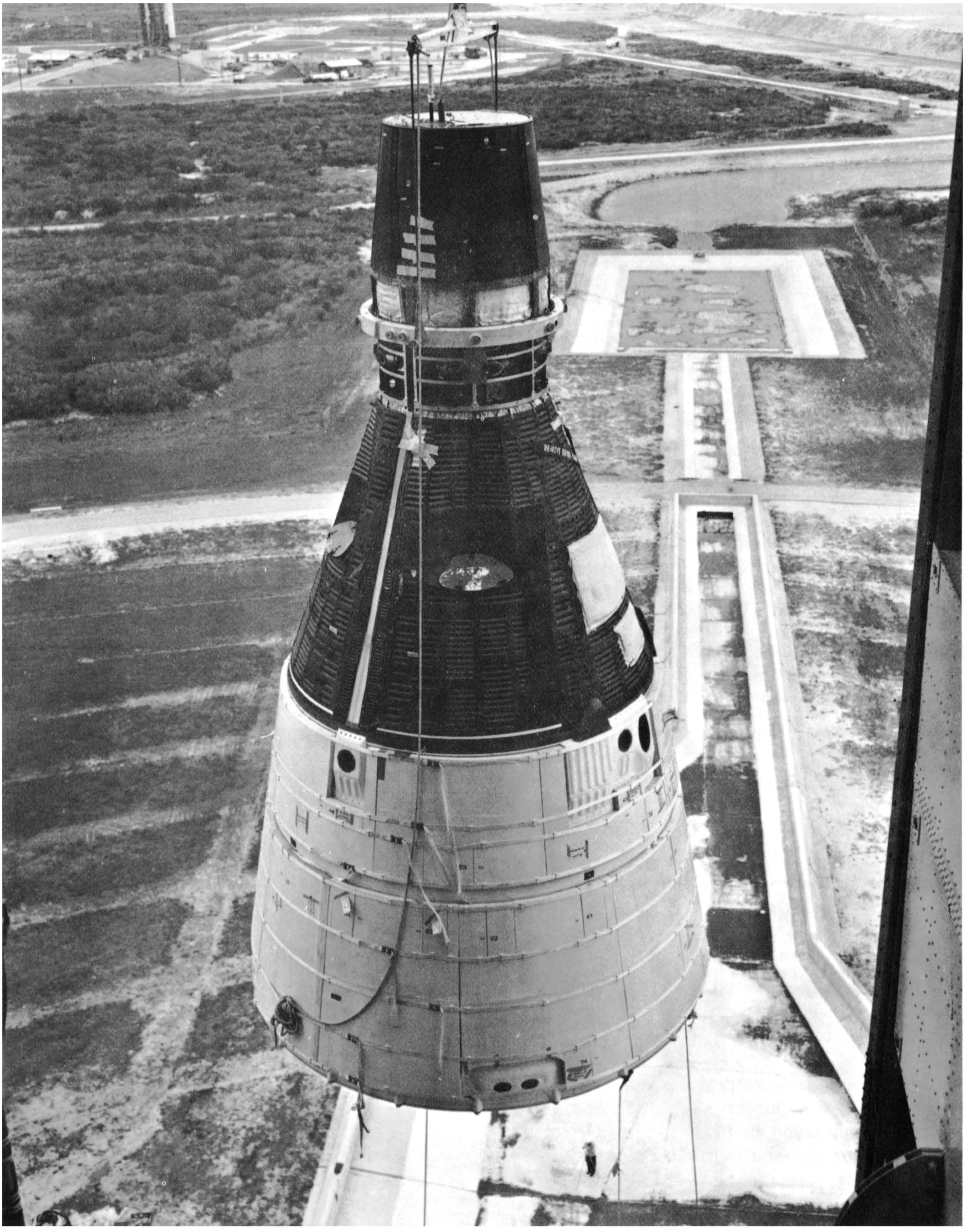
Besides being a body fuel, food is important to man as a psychological "uplift."

A basic diet of 2,550 calories per man was fulfilled by freeze-dried foods including meats, soups, desserts, and fruits. Water restored the food to its original form.

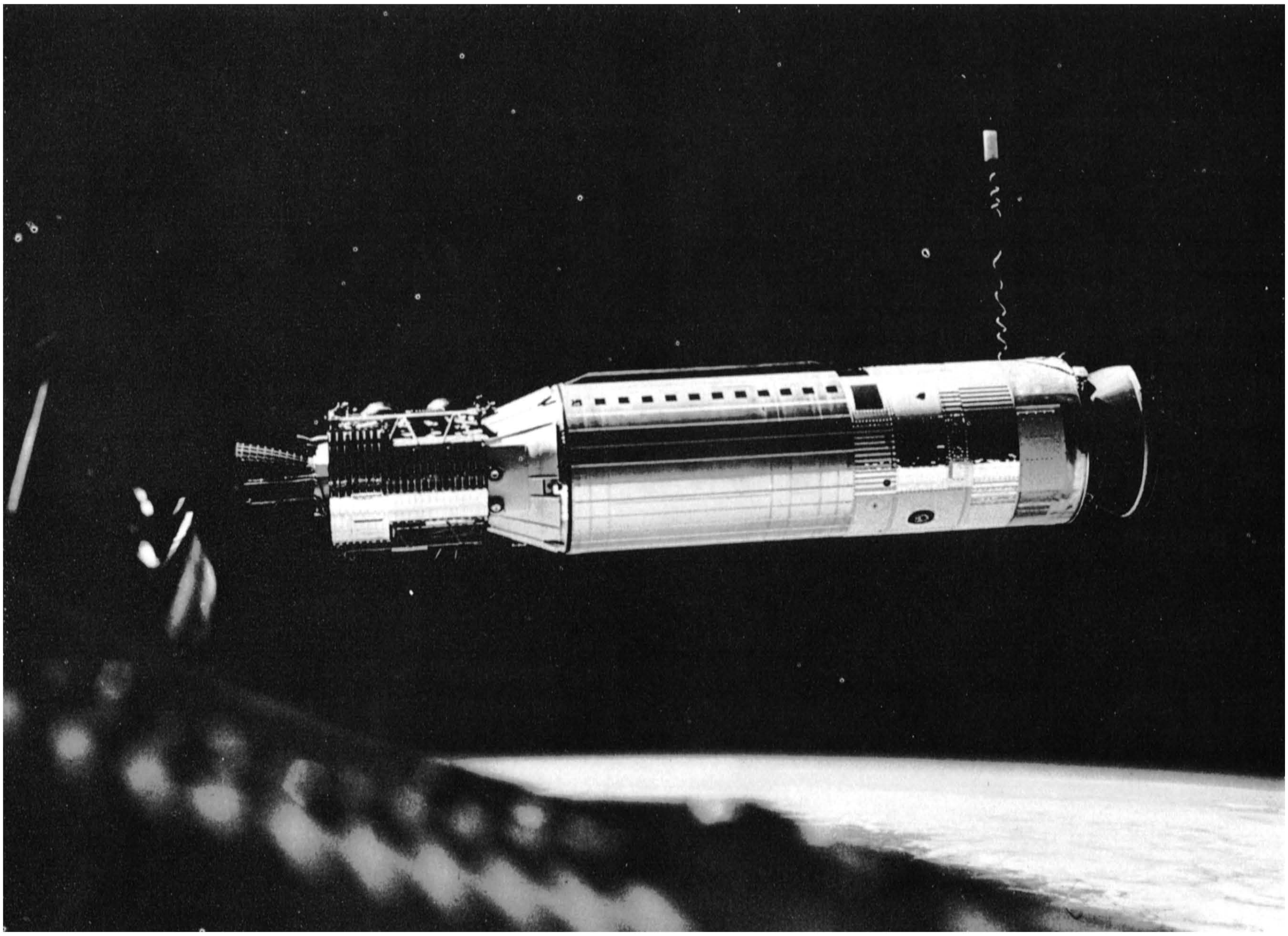
GEMINI LAUNCH VEHICLE

The Gemini launch vehicle was a modification of the military Titan II. Fueled with stable and storable propellants, it was 10 feet wide and 89 feet long (first stage booster 70 feet). The combined Gemini-Titan stood 108 feet high.

An important Gemini launch vehicle system was the Malfunction Detection System, whose electronic monitors watched the vehicle's performance during launch for possible booster trouble. Warning signals allowed ample time for the astronauts to abort (cut short) the mission, if necessary, by using their ejection seats.



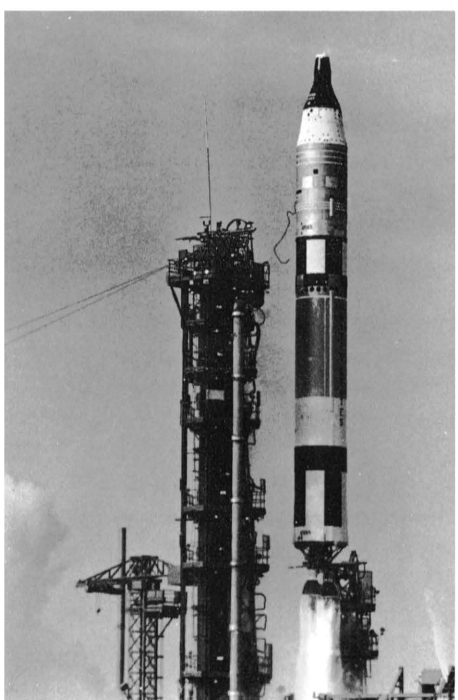
Gemini spacecraft is raised to top of gantry for mating with launch vehicle.

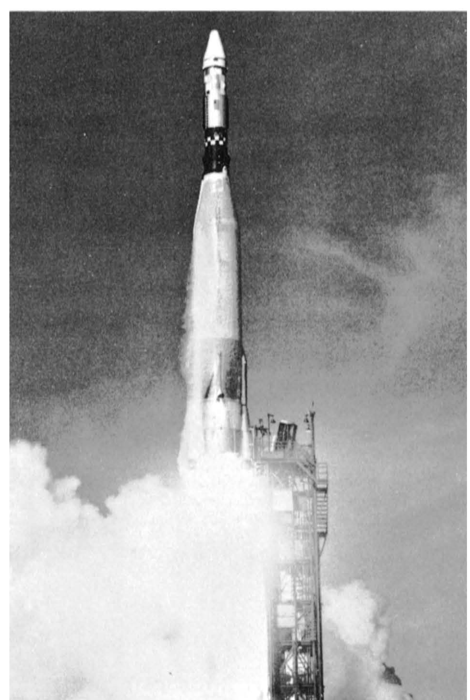


The Agena D target vehicle as seen in space during approach of the Gemini spacecraft. *(above).*

Gemini launch vehicle rockets Gemini spacecraft from Cape Kennedy, Fla. *(right).*

Atlas launches Agena target vehicle from Cape Kennedy, Fla. *(far right).*





AGENA-D TARGET VEHICLE

In the docking of Agena-D and Gemini, the two spacecraft were joined nose to nose. Hence, after first being orbited, the Agena was turned around so that its fore-end faced the nose of the upcoming Gemini.

At the Agena's forward end, the target docking adapter (TDA) is a cylindrical collar, within which is a docking cone illuminated by two approach lights. Self-adjusting mechanisms locked firmly to the inserted nose of Gemini and moored the two vehicles.

STANDARDIZED SPACE LAUNCH VEHICLE

Historically famous as the booster for highly successful Mercury space flights, the Atlas also served as the Agena launch rocket in Gemini's rendezvous experiments.

Known as the Standardized Space Launch Vehicle (SSLV), this 72-foot Atlas booster was powered by conventional liquid rocket engines. Atlas power alone cannot orbit the Agena, and at booster burnout, pyrotechnic devices (explosive bolts) at the SLV-adapter's forward end released the Agena, whose own engine fired to gain orbital velocity.

PRE-LAUNCH CHECKOUTS

All the major vehicles arrived at Cape Kennedy broken down into modules and sections. After dozens of checkouts, all modules were mated into full vehicles. The final tests included radio and radar circuits; stimulated flight via computer; simulated launch with the two astronauts aboard the spacecraft; servicing and fueling of Titan with checkout of engine systems; complete check of total Gemini Titan equipment; 300-minute dress rehearsal countdown; final 2-day servicing and checkout.

Only after this long parade of cross-check checkouts did the real countdown start.

Sharing in all main tests, the two Gemini astronauts gained confidence that the Titan booster and Gemini spacecraft would bear them into orbit, and safely return them to earth.

The Mission Control Center at Cape Kennedy monitored the early Gemini flights. In later missions, the flight phase was monitored by the new Mission Control Center at the Manned Spacecraft Center, Houston, Texas, the launch phase still being conducted by the Cape Kennedy team.

TRACKING NETWORK

Expanded from the former Mercury network, the Gemini tracking system comprised 13 land stations and two tracking ships, the latter filling landless gaps in the Pacific Ocean.

Besides tracking equipment, all stations had two-way communications with the Gemini spacecraft. Some had additional telemetry equipment or command signal transmitters.

GEMINI RENDEZVOUS MISSION

A Gemini rendezvous mission generally called for sending up the Agena target vehicle from Cape Kennedy's launch Complex 14 prior to the Gemini chase vehicle's lift-off from Launch Complex 19.

The Agena was propelled into a circular orbit 185 miles up, after which precise velocity and trajectory elements were calculated. Later Gemini blasted off, within the specified "launch window" —the time interval during which launch will produce an orbit permitting the two craft to meet.

Gemini's orbit had to be in the same plane (slant toward equator) as Agena's. This restricted the Gemini launch window to about 2 hours in each 24-hour day during the 5-day period the target vehicle could wait for rendezvous and docking. Certain orbit-correcting maneuvers by the Agena, before Gemini launch, expanded the launch window.

The basic plan was to maneuver the Gemini into a circular orbit whose altitude was less than the Agena. The Gemini, traveling a shorter distance, would catch up with the Agena.

TARGET CAPTURE

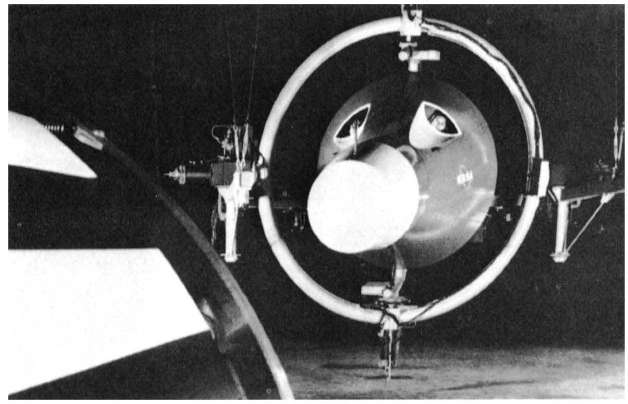
When the distance between vehicles was 250 miles radar was switched on. As the gap closed to 50 miles, the Gemini astronauts picked up the Agena's flashing beacon and took over control of Gemini.

Aiding the astronauts was the status display panel outwardly mounted on the Agena-D, giving visual data on Agena fuel reserves, electrical power, and attitude position.

During rendezvous maneuvers the relative speed between the vehicles was cut to less than 2 mph, so that when docking, their noses touched gently.

On contact, the Gemini's narrow end entered the Agena's target docking adapter, whose latches clamped shut to prevent the two vehicles from slipping apart. Then a motorized Agena unit pulled the Gemini inward.

Photograph of Red Sea and Gulf of Aden area snapped from Gemini XI spacecraft about 540 miles above earth.



Gemini astronauts practiced docking with the Agena in this simulator at Langley Research Center, Hampton, Va.

Once the two craft were tightly moored, matching electrical contacts met and gave the Gemini astronauts direct control of Agena's onboard equipment—guidance, propulsion, attitude control, relay switches, and the rest.

Union of the two vehicles results in a Gemini/Agena spacecraft almost 50 feet long and much more versatile. The rocket power provided by Agena allowed for flights to higher altitudes or to change orbital plane.

REENTRY AND RECOVERY

Their maneuvers completed, the astronauts unhooked their Gemini craft from the Agena (left in orbit) and prepared for earth-return. The Gemini returned to earth under guidance of the spacecraft computer, or under astronaut control.

Because of Gemini's slight "lift" (gliding ability), there is a capability for guiding the spacecraft toward the desired landing site.

Gemini spacecraft also had large parachutes for water landings, as did Mercury.

ASTRONAUT SELECTION

High physical, mental, and academic standards are among the criteria for selection of astronauts. As of March 1967, NASA had selected a total of 55 astronauts, of which 47 were still active. Another group is to be added later in 1967.

Astronauts are chosen on two bases: as pilot-astronauts and scientist-astronauts. The pilot-astronaut must have at least 1000 hours of jet flying experience. The scientist-astronaut has to have a doctorate or the equivalent in experience in the natural sciences, medicine, or engineering He must meet the physical and psychological standards required of pilots. After appointment, the scientist-astronaut is trained to fly high-performance helicopters and jet planes.

ASTRONAUT TRAINING

All astronauts are trained to reach peak mental and physical efficiency for Gemini flights. Basic science studies were expanded to include such courses as computer fundamentals, guidance technology, and astrogation (space navigation).

To prepare for space missions, astronauts practiced earth-simulated flights in trainers. Through the use of such simulators, astronauts learned the elements of rendezvous and docking by means of electronic dials and dummy controls.

One Gemini mission simulator was located at the Manned Spacecraft Center's Clear Lake site at Houston, Texas, where the Mission Control Center is also located. Another simulator installation was at Cape Kennedy, Florida.

Centrifuges at Johnsville, Pennsylvania, and at Ames Research Center in California provided high-g loads to match the stresses of powered launches, training astronauts to handle controls despite acceleration strains.

GEMINI EXPERIMENTS

Gemini astronauts carried out a large number of scientific, technical, and engineering experiments. The information derived from these experiments adds up to a considerable increase in space knowledge.

Astronauts took photographs from their orbiting spacecraft of the zodiacal light—a disk of light around the sun which cannot be seen from earth.

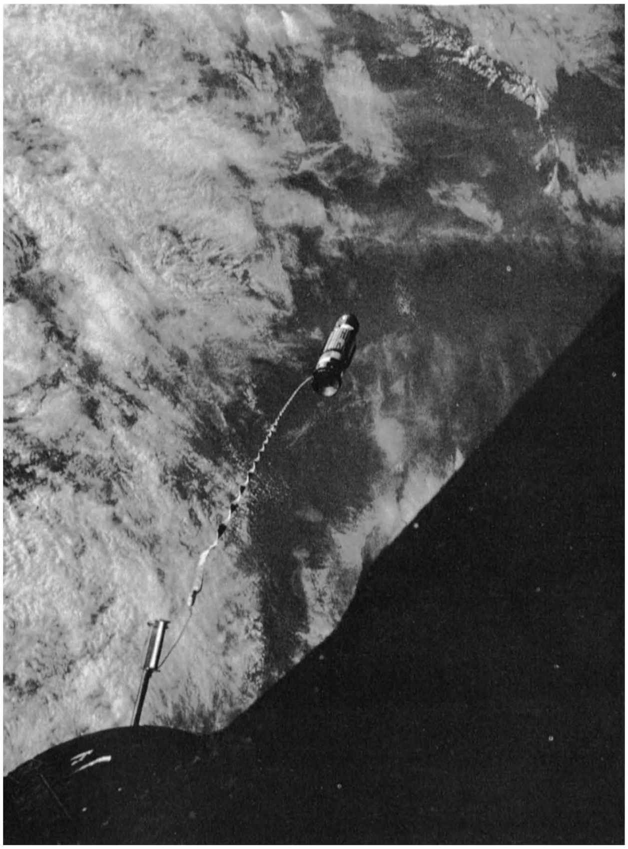
They took ultra-violet pictures of stars. Ultra-violet radiation from stars tells much about their physical and chemical compositions. Such radiation is cut off from earth observatories by the atmosphere.

They took photographs of earth and its cloud cover, providing a new wealth of information for geographers, meteorologists, and oceanographers. Their photographs indicated that sensing from orbit may be a good way to locate and observe earth's resources: water, minerals, oil, and others. A new atlas is based on photographs of earth taken by the astronauts during Gemini flights.

Micrometeoroid and radiation experiments carried out during Gemini flights have increased understanding of what to expect from these space phenomena.

The gravity-gradient experiment, in which Gemini and Agena were stabilized at opposite ends of a 100-foot-long tether, has important implications for operation of future manned stations in earth orbit.

The performance and physical conditions of the astronauts have shown that, in periods of at least two weeks, there are no deterioration of an astronaut's visual acuity, no noticeable changes in behavior, and no abnormality in vestibular, metabolic, digestive, or respiratory functions.



The Agena target vehicle secured by a tether to the Gemini XII spacecraft, part of which can be seen in foreground.

Gemini experiments validated life-support techniques, equipment, and concepts for future space missions. They suggested that man can safely conduct operations in space for as long as 30 days.

DEFINITIONS

APOGEE: In an orbit about the earth, the point at which the satellite is farthest from the earth; the highest altitude reached.

ASTRONAUTICS: The art, skill, or activity of operating space vehicles. In a broader sense, the science of space flight.

ATTITUDE: The position or orientation of an aircraft, spacecraft, etc., either in motion or at rest, as determined by the relationship between its axes and some reference line or plane such as the horizon.

BALLISTIC TRAJECTORY: The trajectory followed by a body being acted upon only by gravitational forces and the resistance of the medium through which it passes.

BOOSTER ROCKET: A rocket engine, either solid or liquid fuel, that assists the normal propulsive system or sustainer engine of a rocket or aeronautical vehicle in some phase of its flight. A rocket used to set a missile vehicle in motion before another engine takes over.

DOCKING: The process of bringing two spacecraft together while in space.

EVA (Extra-Vehicular Activity): Any activity performed by astronauts outside of the protective confines of their spacecraft.

HYPERGOLIC: Propellants, fuel and oxidizer, which ignite spontaneously upon contact. Hydrazine and nitrogen tetroxide are examples.

MODULE: A self-contained unit of a launch vehicle or spacecraft which serves as a building block for the overall structure. The module is usually designated by its primary function as command module lunar module, etc. A one-package assembly of functionally associated electronic parts, usually a plug-in unit.

PERIGEE: That orbital point nearest the earth when the earth is the center of attraction.

PITCH: The movement of an aircraft or spacecraft about its lateral (nose going up or down) axis.

PROPELLANT: Any agent used for consumption or combustion in a rocket and from which the rocket derives its thrust, such as a fuel, oxidizer, additive, catalyst, or any compound or mixture of these.

REACTION ENGINE: An engine that develops thrust by its reaction to ejection of a substance from it; specifically, such an engine that ejects a jet or stream of gases created by the burning of fuel within the engine.

REENTRY: The event occurring when a spacecraft or other object comes back into the sensible atmosphere after being rocketed to altitudes above the sensible atmosphere; the action involved in this event.

RETROROCKET: A rocket fitted on or in a spacecraft, satellite, or the like to produce thrust opposed to forward motion.

ROLL: The rotational or oscillatory movement of an aircraft or similar body which takes place about a longitudinal axis through the body—called "roll" for any amount of such rotation.

SENSOR: The component of an instrument that converts an input signal into a quantity which is measured by another part of the instrument. Also called "sensing element."

SUBORBITAL: Non-orbiting or ballistic flight trajectory from launch point to target point.

TRAJECTORY: In general, the path traced by any body, as a rocket, moving as a result of externally applied forces.

WEIGHTLESSNESS: A condition in which no acceleration, whether of gravity or other force, can be detected by an observer within the system in question. A condition in which gravitational and other external forces acting on a body produce no stress, either external or internal, in the body.

YAW: The lateral rotational or oscillatory movement of an aircraft, rocket, or the like about a transverse axis. The amount of this movement, i.e., the angle of yaw.

GEMINI MISSION BOX SCORE

Mission	Crew	Dates	Duration (Hrs:min:sec)	Revolutions	Objectives Accomplished
Gemini I		Apr. 8-12, 1964	Tracked for three orbits only.		Check spacecraft/launch vehicle structural compatibility and aerodynamic performance.
Gemini II		Jan. 19, 1965	18:16	suborbital	Systems performance and heat shield reentry test.
Gemini III	Grissom-Young	Mar. 23, 1965	4:52:31	3	Spacecraft systems and crew compatibility.
Gemini IV	McDivitt-White	June 3-7, 1965	97:56:12	62	Demonstrate spacecraft systems and crew capability for four days; EVA for 20 minutes.
Gemini V	Cooper-Conrad	Aug. 21-29, 1965	190:55:14	120	Demonstrate long-duration flight, rendezvous radar and rendezvous maneuvers.
Gemini VII	Borman-Lovell	Dec. 4-18, 1965	330:35:01	206	2-week duration, shirt-sleeve environment, rendezvous vehicle for Gemini VI, controlled reentry.
Gemini VI	Schirra-Stafford	Dec. 15-16, 1965	25:51:24	16	On-time launch procedures, closed-loop rendezvous, station keeping with Gemini VII.
Gemini VIII	Armstrong-Scott	Mar. 16, 1966	10:41:26	6.6	Demonstrated rendezvous and docking with Agena, multiple Agena restart in orbit, controlled landing, emergency recovery (mission terminated early because of control system electrical short).
Gemini IX	Stafford-Cernan	June 3-6, 1966	72:20:50	45	Demonstrate three rendezvous techniques, EVA (2 hrs., 7 min.), with detailed work tasks, precision landing (0.38 nm from planned landing point).
Gemini X	Young-Collins	July 18-21, 1966	70:46:39	43	Dual rendezvous using Agena propulsion for docked maneuvers, retrieval of experiment package from Agena during 92 minutes of EVA; demonstrated feasibility of using onboard navigation for rendezvous.
Gemini XI	Conrad-Gordon	Sept. 12-15, 1966	71:17:08	44	First-orbit rendezvous and docking with Agena, 853 statute miles apogee using Agena propulsion, 167 minutes total EVA, tether exercise, automatic reentry.
Gemini XII	Lovell-Aldrin	Nov. 11-15, 1966	94:34:31	59	Three EVA's total of 5 hours, 26 minutes, gravity-gradient tether exercise, rendezvous and docking with Agena, rendezvous with solar eclipse.

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