GEMINI

SPACECRAFT

NASA-MCDONNELL

AUTOMATIC SEAM WELDER

Approximately 85% (by weight) of the Gemini pressure vessel consists of complex welded titanium assemblies. The large pressure bulkhead contains inside wall panels of .010 in. beaded skin titanium and outside wall panels of .010 in. smooth skin titanium seam welded to the mating structure.

INERT GAS WELD CHAMBER

On the cabin assembly alone there are approximately 250 feet of automatic and hand welding, about 6,117 spot welds, and 1,546 feet of seam welding. Mating the thirteen pieces of each hatch requires 285 inches of hand fusion welding.

SPACECRAFT IN CLEAN ROOM

Flight rated Gemini spacecraft are readied for the installation of mechanical and electrical systems in this 32,000 square foot clean room. It has a filtration system which removes dust particles approximately two hundred thousandths of an inch in size.

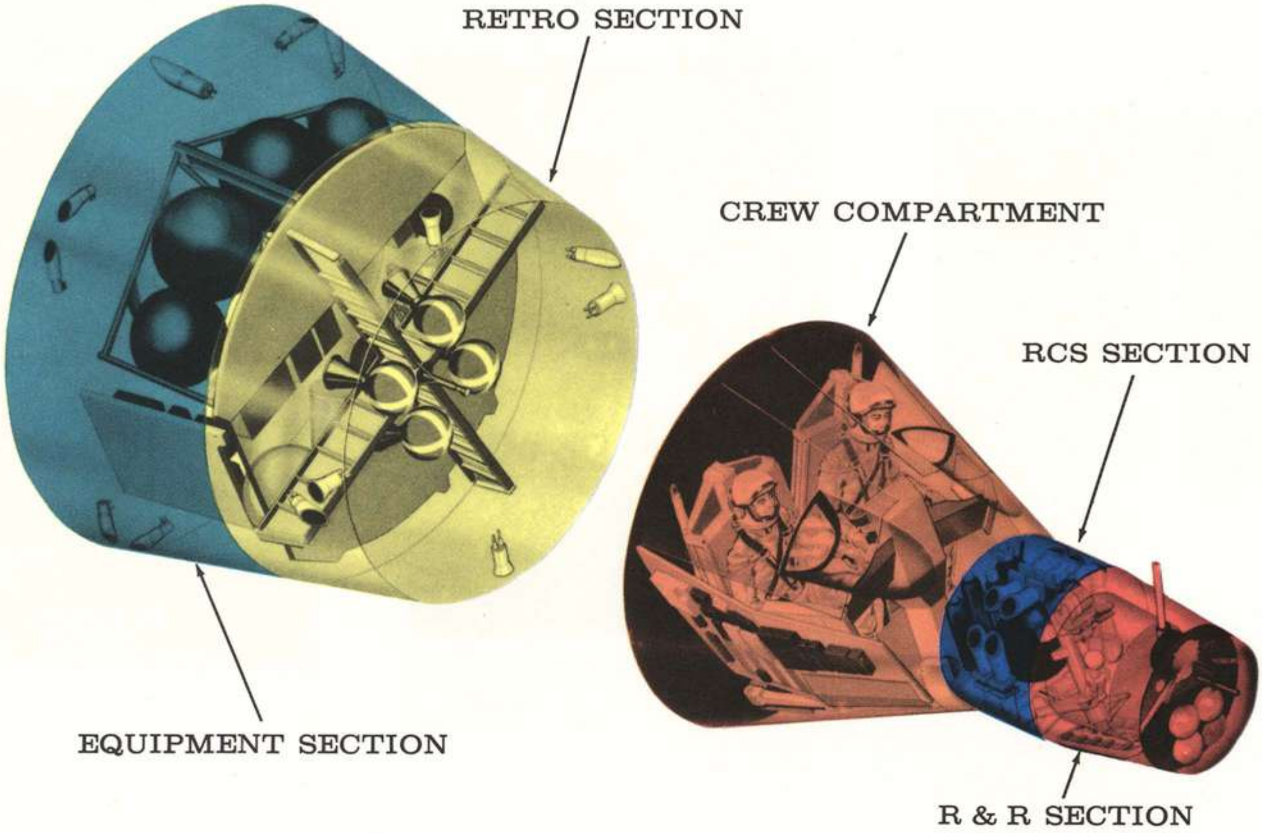
Manned space flight in the Free World had its beginning early in 1959 when the National Aeronautics and Space Administration, now more familiarly known as NASA, selected McDonnell as the prime contractor for the design, development, and construction of Project Mercury Spacecraft. The successful testing and orbiting of Mercury provided NASA and McDonnell with the basic knowledge on which America's future manned space programs are being built.

PROJECT GEMINI

On 7 December 1961, NASA named McDonnell as prime contractor for the design, development, and construction of a two-man spacecraft, called Gemini, after the constellation containing the twin stars—Castor and Pollux. The Gemini program is under the direction of the Manned Spacecraft Center in Houston, Texas.

The Gemini flight program comprises a series of missions beginning with an unmanned, unrecovered orbital flight to check the structural compatibility of the spacecraft and the Titan II launch vehicle. This is followed by an unmanned ballistic shot to evaluate the performance of the spacecraft and all of its systems under zero G and exacting reentry conditions, then by a relatively short manned orbital flight, and then by longer missions for which the spacecraft was developed. These missions will demonstrate the ability of the astronauts and their spacecraft to maneuver in outer space, using manual modes of operation, the feasibility and perfection of techniques for rendezvous and docking, the suitability of such spacecraft systems as the environmental control and electrical power systems, and the demonstration of a maneuvering reentry.

Gemini missions will involve much more than simply orbiting the Earth. The Gemini astronauts will have full control of their spacecraft



and will guide it from one orbital path to another. This maneuvering capability is one of the reasons why the Gemini is recognized as a new generation operational spacecraft.

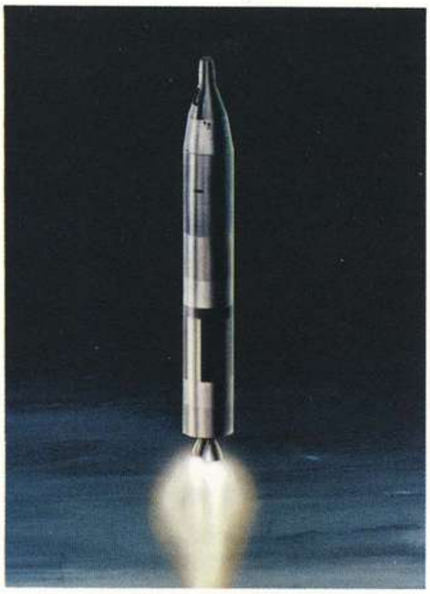
The complete spacecraft is made up of two major units: an *adapter module,* consisting of an equipment compartment and a retrograde compartment which are carried into orbit but are jettisoned just prior to reentry; and a *reentry module,* consisting of a rendezvous and radar section, a reaction control system section, the crew compartment section, and the heat shield.

The spacecraft is of semimonocoque construction, conical in configuration and utilizing titanium as the primary structural material. It is designed to shield its two-man crew from the environment of space, and to provide an operational vehicle that can be maintained easily. Access to system components is provided through easily removed external panels. Major components are arranged in modular packages which can be replaced without opening the crew compartment or affecting systems already checked out, thus reducing maintenance and checkout periods prior to launch.

The Gemini cabin is a pressurized vessel surrounded by an unpressurized volume in which various systems are installed and fuel is stored.

Unlike Mercury, Gemini has no escape tower. Emergency escape is provided by ejection seats functionally similar to those used in contemporary jet aircraft. The crew can eject safely at any time from on-the-pad to more than 60,000 feet above the Earth, both during the launch phase and after reentry. There are two large hatches, one for each astronaut, which may be opened and locked open for escape, even under maximum dynamic pressures.

The first three Gemini flights will be directed from the Mission Control Center at Cape Kennedy. The advanced flight program, directed from the Manned Spacecraft Control Center in Houston, will assume control of the mission at liftoff. The principal member of this team, the Flight Director, is responsible for all flight control operations, including systems and medical monitoring, trajectory assessment, and flight support to the crew during such critical mission phases as rendezvous and reentry. He also has charge of the Global Manned Space Flight Network, which provides tracking, data acquisition, and voice communications during the missions. Another important team member is the Recovery Director, who directs the Department of Defense forces temporarily assigned to the program to provide spacecraft recovery following reentry and landing.



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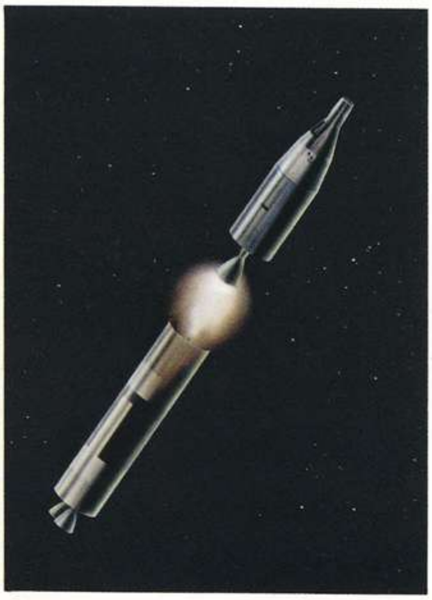

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MISSION PROFILE

A typical Gemini flight includes prelaunch, launch, orbit, retrograde, reentry, and landing phases. In rendezvous missions, there are also catch-up, rendezvous, and docking phases.

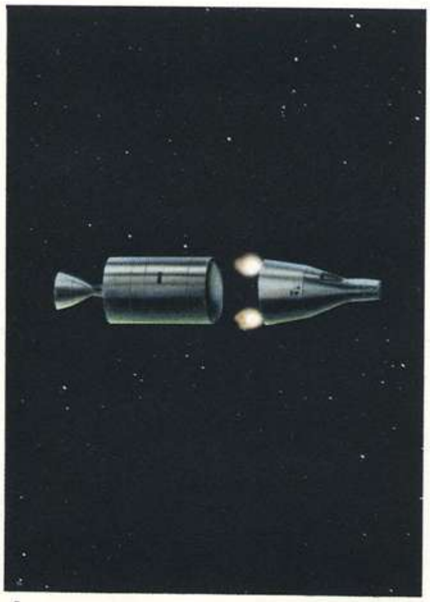
Prelaunch begins when launch vehicle and spacecraft arrive at the launch site. The Gemini launch vehicle, a modified Air Force Titan II, consists of two stages, each 10 feet in diameter; the first stage is 70 feet long and the second stage 20 feet. The combined Titan-Gemini stands 108 feet high, and the lift-off weight is approximately 150 tons. The Titan II uses storable hypergolic fuel, with a high specific impulse or thrust per pound of propellant. Ignition occurs automatically when the fuel and an oxidizer are brought together in the propulsion chamber. Hypergolic fuel can be stored for several days within the missile.

The launch phase begins at the start of the launch countdown and ends when the spacecraft and the launch vehicle separate. At launch, the Titan II
1 first stage produces over 430,000 pounds of thrust, but emits only a relatively small white flame and a rosy cloud rather than the burst of orange flame and billowing smoke familiar to viewers of Mercury launches. During launch, the astronauts monitor instruments and display panels which reveal trajectory and launch vehicle conditions.

Approximately 200,000 feet above the Earth and 2
2½ minutes after lift-off, the first stage falls away and the second stage boost begins. When 3
orbital insertion is approached, second stage cut-off occurs. The astronauts fire explosive charges which release the spacecraft from the launch 4
vehicle.

When Gemini reaches the apogee, or highest point of its elliptical orbit, thrust from its maneuvering rocket system pushes it into a 90-minute circular orbit of the Earth. The astronauts then begin to perform any special tasks assigned to the mission.

The Manned Space Flight Network, which consists of strategically located remote stations around the world, including two tracking ships, records tracking and telemetry data, and provides command, control, and communication to the spacecraft. Throughout much of each orbital period, the astronauts have two-way voice and telemetry communication with the network.



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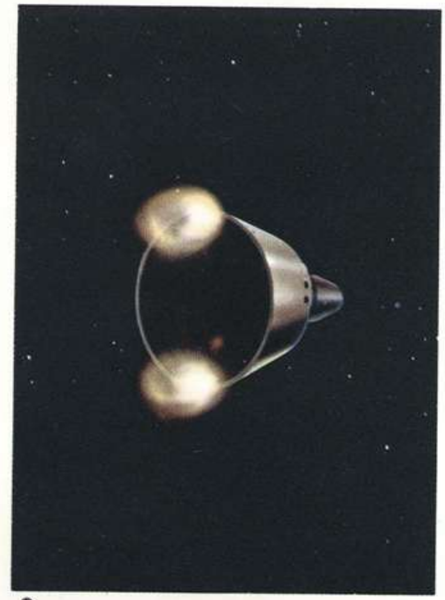

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Equipment aboard the Gemini records and transmits to the network data pertaining to such scientific observations as the crew's physiological reactions to prolonged weightlessness and internal and external environmental conditions.

For the first time in U. S. space flights, man will be exposed to long work-rest cycles, which will present the first opportunity to study the systems of the human body as they make long-term adjustments to the space environment. There will also be concern for personal hygiene and biological and physiological effects on the astronauts. Both NASA and the Air Force have carefully planned experiments to be conducted during the Gemini flights.

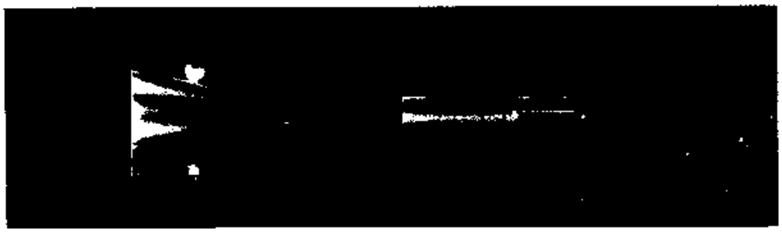
During the advanced stages of the Gemini program, an astronaut may unlatch the hatch above his head, open it, and carefully float out into space.
5 While outside the spacecraft, he will be protected by the life supporting atmosphere within his pressurized suit, augmented by an umbilical line supplying oxygen from the spacecraft.

Food and emergency water are provided for the duration of each mission plus a 36-hour post-landing period. During the relatively short-duration Mercury flights, provisioning and waste disposal for the astronaut were not difficult. As space flights become longer, providing crew comfort and personal hygiene has entailed extensive design consideration.

RENDEZVOUS AND DOCKING

Preparations for rendezvous and docking begin during the launch phase, when the orbital plane can be adjusted slightly by varying the launch azimuth. After launch and prior to rendezvous, 6
orbital-track plane-and-phase maneuvers are made. The spacecraft then meets and mates with an orbiting target vehicle.

The rendezvous target is a modified Agena D version of the rocket used in the Ranger, Mariner, and other space projects. Agena is about 32 feet long and 60 inches in diameter, with a rocket engine on one end and a McDonnell-designed docking adapter on the other.



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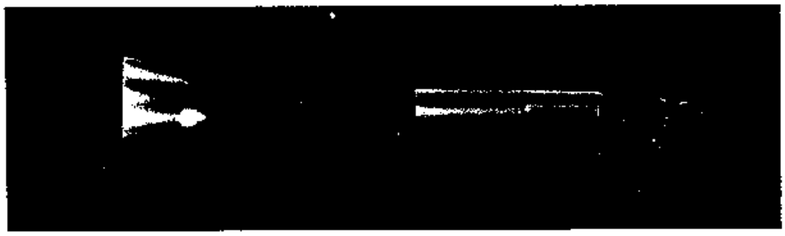

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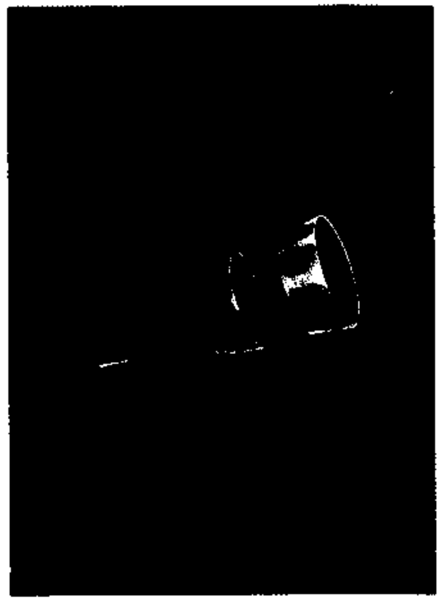

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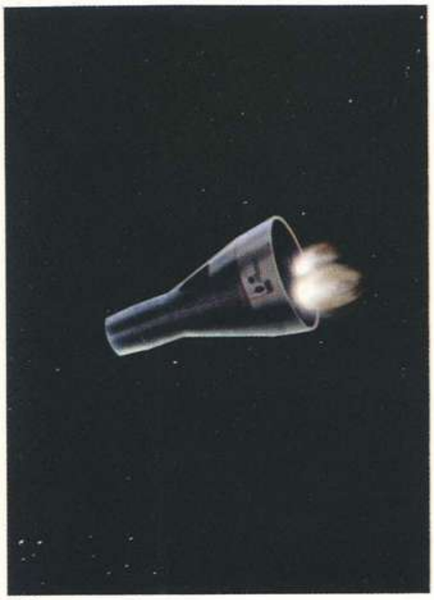
Rendezvous missions require two launchings. First, an Atlas launch vehicle boosts the Agena D toward a nearly circular, 160 mile high orbit, the same altitude as the planned apogee of the Gemini orbit. After ground tracking stations have determined that the Agena has reached the proper orbit, its engines are shut down by ground command to conserve fuel. About 90 minutes later, when the Agena's orbital path again carries it over the Cape Kennedy launch point, a manned Gemini is launched into a 90 to 160 nautical mile elliptical orbit. The Gemini must be launched during a brief period called a "launch window", when all factors for a successful rendezvous are most suitable and the spacecraft can be launched to orbit in close proximity to the Agena. If necessary, the Gemini launch window can be extended to approximately four hours by firing up the Agena's engine on command from the ground to match more closely the planned orbit of the Gemini.

Since the time to complete the shorter elliptical orbit of the Gemini is less than that of the nearly circular orbit of the Agena, Gemini circles the Earth more quickly and gradually catches up. When Gemini is within 250 miles of the Agena, and near the apogee of its elliptical orbit, the astronauts use their maneuvering engines to circularize their orbit.

The Gemini radar acquires the Agena and an on-board digital computer begins to provide the astronauts with bearing, range, closing rate, and other maneuvering information. This small, lightweight, electronic computer, a key component in the complex inertial guidance system, is one of the major subsystems added for rendezvous and docking missions, and reentry. From the computer-provided information displayed on his instrument panel, confirmed by ground tracking stations, the Gemini pilot determines the direction and thrust timing necessary to control his approach to the target. Adjustments in the Agena's path can be made from either ground control stations or from the spacecraft. Even in the absence of radar data, rendezvous can be accomplished by instructions and commands from ground stations.

When within 20 miles, the astronauts will probably be able to see a high intensity flashing light on the target to help guide them in their rendezvous procedure. Although rushing through space at approximately 17,500 miles per hour, the two vehicles dock at very low relative speeds (about 1 mph). Using 100 pound-thrust maneuvering rockets, the astronauts visually and manually guide their spacecraft into final docking position, directing the index bar on the Gemini into a V notch in the McDonnell-



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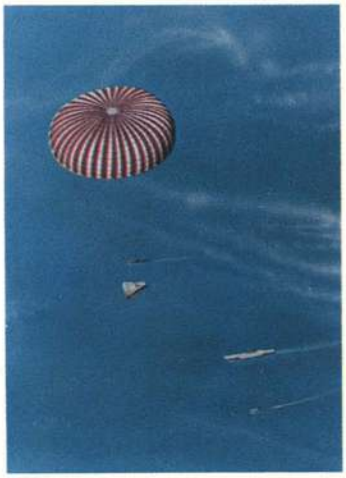

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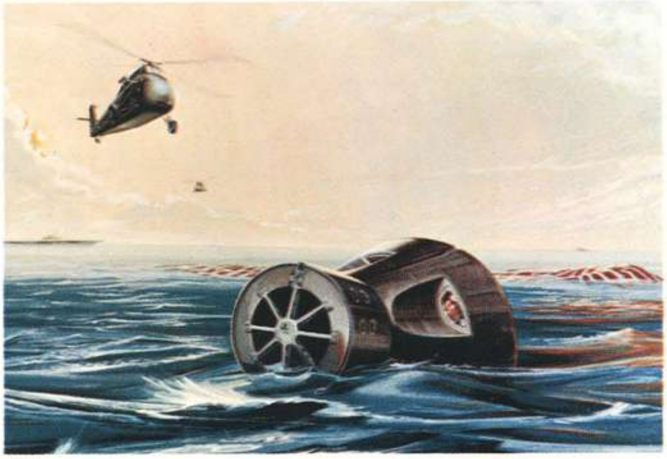

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designed docking collar of the target. Clamps inside the docking collar firmly lock the two vehicles together, and the electrical connectors
8 mate, providing the astronauts with full control of their combined Agena-Gemini spacecraft. The astronauts can then assess the operational condition of Agena and may ignite the Agena engine to make orbital plane and altitude changes.

When this phase of the mission has been com-
9 pleted, the astronauts unlatch their spacecraft and back away from the target by firing the reverse thrust maneuvering rockets. Once more alone in orbit, the astronauts prepare for retrograde, reentry, and landing operations.

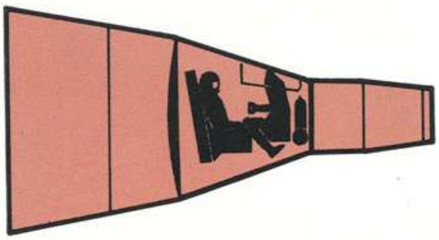
First, the astronauts position their spacecraft so that the large end is headed in the direction of the flight path. Then the equipment compartment
10 of the adapter module is jettisoned to expose the four retrograde rockets. Meanwhile, ground tracking stations transmit data concerning orbital position and track, which the astronauts insert manually into the on-board computer. The computer determines when the desired landing point on Earth is within reach of the spacecraft, and indicates when the astronauts should fire the
11 retro-rockets to reach that point. These sufficiently slow the spacecraft's orbital velocity to cause it to drop gradually from orbit. The retrograde compartment is then jettisoned and the astronauts position Gemini for reentry.

The computer continues to assess the flight path, directing the crew to roll the spacecraft with roll (attitude) control jets, positioning the lift to fly
right or left or to lengthen or shorten the descent 12
as necessary to fly to the selected landing point. The Gemini spacecraft can be "flown" in this manner to any point within a 28,000 square mile area (more than three times the area of the State of Massachusetts). When the spacecraft reaches a point where a ballistic or non-lifting trajectory will carry it to the landing site, the computer directs the crew to establish a continuous roll to negate the effect of lift on the path of the spacecraft. Aerodynamic drag ultimately slows the Gemini to near sonic speed.

At approximately 60,000 feet, the astronauts deploy a small drogue chute which further slows
and stabilizes their descent. At approximately 13
10,000 feet, a large, ring-sail parachute is de-
ployed, and the Gemini makes a conventional 14
water landing.

CREW COMPARTMENT

The crew compartment section, or internal pressure vessel which houses the two astronauts, seated side by side, contains only those systems directly connected with the crew, such as the ejection seats, the environmental control system, food supplies, the waste equipment system, microphones and speakers, the three main instrument and control panels, and guidance controls. The space between the pressurized cabin and the external surface of the spacecraft houses instrument packages and electronics gear. The ablative heat shield is attached to the large end of the module.



Above the astronauts are two hatch openings, large enough to permit normal ingress, egress, and emergency ejection of the two crew members. Each hatch incorporates a glass heat-resistant window, consisting of three specially coated panes.

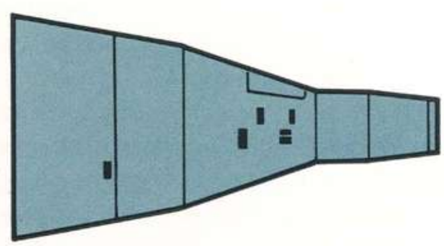
The escape system consists of two ejection seats which operate simultaneously when either astronaut's D ring is pulled. This escape mode is used from ground level up to an altitude of more than 60,000 feet. Above this altitude, spacecraft retro-rockets are utilized to separate the spacecraft from the launch vehicle, and landing is accomplished using the spacecraft parachute system; the ejection seats and the astronauts' personal chutes serve as a back-up system. Escape at near orbital speeds is accomplished by normal launch vehicle-spacecraft separation, followed by standard retrograde and reentry techniques.

COMMUNICATION, TELEMETRY, & RECORDING SYSTEMS

The Gemini communication, telemetry, and recording systems consist of redundant UHF and HF systems for voice communication, a digital command subsystem, two coded tracking beacons, an acquisition aid beacon, a coded recovery beacon, three telemetry transmitters, and associated antennas and matching devices located throughout the spacecraft.

During launch countdown, each astronaut has an independent inter-communication channel to the ground complex through the umbilical cable. Voice controls allow intercommunication between the astronauts. During launch, ground communication is restricted to the UHF mode. Once in orbit, the HF whip antenna is extended, providing a choice of HF communication. Prior to beginning the retrograde phase, the HF antenna is retracted, the UHF mode of voice communication is utilized, the digital command function and the acquisition aid beacon cease operation, and telemetry transmission is reduced. During reentry, communication is limited to UHF voice, a C band radar beacon, and limited telemetry transmission. These will be lost entirely for a short time due to plasma effects.

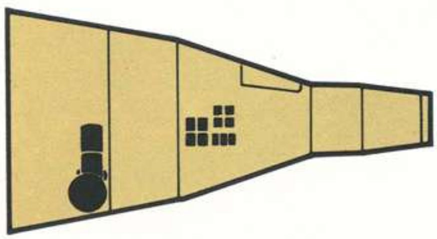
Following deployment of the parachute, the UHF recovery beacon antenna is extended. The C band radar beacon is switched off during this phase. After touch down, the HF antenna is again extended, allowing the astronauts to employ either UHF or HF receiving and transmitting units.



Ground network communication equipment includes two-way HF and UHF radios for voice communication, transmitters for command from the ground, telemetry equipment for command and receiving data transmitted from the spacecraft to ground recording stations, radar beacon tracking equipment, and means for communicating between the spacecraft and the orbiting target vehicle during rendezvous and docking missions. The instrumentation and recording systems on board as well as on the ground provide for collecting and recording all data generated in the spacecraft pertaining to scientific observations and the rendezvous and docking operations. Equipment is included to monitor physiological parameters and to measure and monitor internal and external environmental conditions.

ELECTRICAL SYSTEM

The major components of the primary electrical power system consist of two fuel cells and their reactant supply (located in the equipment compartment of the adapter module), five silver zinc batteries (located in the crew compartment equipment bay), provisions for utilizing ground power prior to launch, and the necessary switches and controls for the proper distribution of A-C and D-C power. In addition, three squib batteries located in the reentry module provide power for firing pyrotechnique separation devices and for energizing relays or other devices which would cause abnormal voltage on the main power electrical supply.



Gemini is the first space vehicle to use fuel cells as a primary source of electrical power. From launch, through orbit, until the equipment section is jettisoned, the fuel cells are the primary source of electrical power. Through the chemical reaction of oxygen and hydrogen, each cell also produces a pint of pure drinking water for the crew as a by-product for each kilowatt hour of operation. Since the adapter module is jettisoned prior to reentry, the silver zinc batteries in the reentry module provide electrical power for the reentry, landing, and post-landing phases of a mission. These batteries also serve as a source of emergency power when the spacecraft is in orbit.

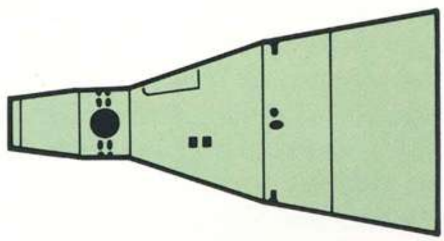
ENVIROMENTAL CONTROL SYSTEM

The cabin environmental control system provides a 100% oxygen environment for breathing and ventilation, controls pressurization and humidity, and removes unpleasant odors and toxic material. It is divided into two packages, one in the adapter module and the other in the reentry module.

Although the crew compartment is pressure sealed and contains the gaseous environment necessary for sustaining life, each astronaut wears a pressure suit which protects him against loss of cabin pressure. The oxygen supply, purification, and suit cooling are all on a single circuit. The suits are connected in parallel to this circuit and fitted with individual regulators so that each man can select the oxygen flow rate he desires. Oxygen enters the suit just below the chest and is routed directly to the face area, the arm areas, and the leg areas, then out an exhaust line to be purified for reuse. The astronauts may remove parts of their flight suits for more freedom of movement when in orbit or remain sealed in their suits, as the mission or emergency conditions require.

ORBIT ATTITUDE & REENTRY SYSTEMS

Spacecraft attitude and maneuvering during orbital phases is accomplished by firing thrusters located in the equipment and retrograde sections. During retrograde and reentry, attitude is maintained by redundant rings of small rocket thrusters located on the nose or small end of the spacecraft. During reentry, the attitude may be controlled manually, or automatically by the computer, as the astronaut desires.



A digital computer provides the necessary launch, insertion, rendezvous, retrograde, and reentry panel displays, computations, and trajectory information by processing stored programs as well as utilizing on-board radar, inertial measuring unit, ground transmitted, or astronaut inserted data.

An infrared-detecting horizon scanner, which senses spacecraft roll and pitch attitudes with reference to the Earth's horizon, provides attitude information. When switched to automatic control, this system operates almost like an aircraft automatic pilot, leaving the astronauts free to direct their attention to other programs.

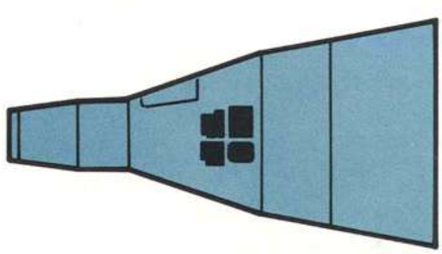
The attitude display indicators on each astronaut's panel indicate roll, pitch, and yaw rates, attitude, and flight direction. The horizon sensor system provides pitch and roll attitude reference during the orbital phase of the mission through observation of the infrared radiation gradient of the Earth's horizon.

INERTIAL GUIDANCE SYSTEM

The inertial guidance system, which provides inertial measurements, computations, digital processing, and the command functions necessary for spacecraft guidance and control, consists of a digital computer, the inertial platform electronics package, and a power supply.

The computer is a general-purpose, binary, digital type unit capable of performing high speed integrations, input-output conversions, arithmetic computations, and rendezvous timing functions. It has a non-destructive memory and automatically indicates any computer malfunction to the astronauts. A manual data insertion unit provides a means for manual insertion of up to 100 messages into the computer, and serves as a backup system for the digital command system. Three push buttons on the control and display panel allow the astronaut to enter, cancel, or read out the displayed data.

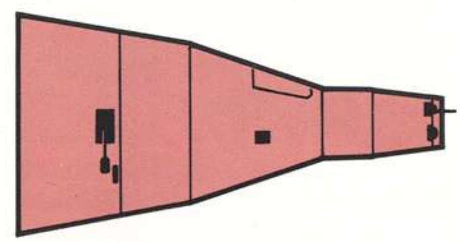
Throughout orbital flight, the computer constantly determines the latitude and longitude of the spacecraft and predicts future path so that at all times the astronauts will know what landing sites are available. If they are interested in a particular site, they can enter the site coordinates into the computer, which then determines whether it is within reach and whether the spacecraft must be maneuvered to a new track to reach the site. The computer indicates the vectors of the maneuver and gives the time for firing the retro-rockets.



The inertial measuring unit, operating in conjunction with the computer, measures all accelerations applied to the spacecraft. The system consists primarily of a stabilized platform, and serves as both an attitude reference and a navigation reference during rendezvous, reentry, and landing. The measurement unit consists of a stabilized inertial platform, a separate platform electronics package, and a power supply. The inertial platform is a four-gimbal assembly, containing three miniature integrating gyros and three pendulous accelerometers.

RENDEZVOUS RADAR SYSTEM

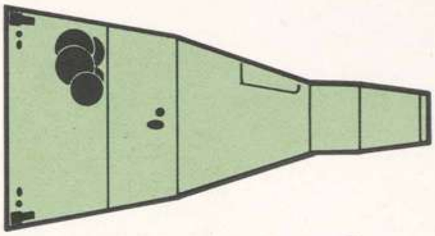
The Gemini rendezvous radar system consists of an interrogator, the radar, and a beacon transponder located in the Agena. Prior to the start of rendezvous operations, the transponder in the Agena, which is capable of accepting the interrogating pulse from the Gemini radar when the astronaut begins transmission, is activated.



When ground control notifies the astronaut the range to rendezvous is within the acquisition capabilities of the radar (about 250 nautical miles), the radar commences sending range, range rate, and bearing information to the computer, which is in turn read out on the instrument panels. When the range closes to 150 miles, an additional output is provided for the range scale on the instrument panel. The astronaut maneuvers the spacecraft to the Agena using tracking data, consisting of range, range rate, elevation, and azimuth or line of sight angle to the target. Radar information is supplied until a range of less than 50 feet is obtained. At approximately 100 feet to rendezvous, however, the radar can no longer make accurate angular measurements and the astronaut will assume full manual control and visually complete the docking procedure.

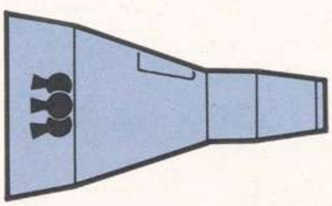
ATTITUDE & MANEUVERING PROPULSION SYSTEM

The Gemini propulsion systems consist of an orbit attitude and maneuver system, a retrograde rocket system, and a reentry control system. The orbital attitude and maneuvering propulsion system functions from launch vehicle separation until retrograde. It also provides thrust for spacecraft separation from the launch vehicle or for high altitude aborts.



This system is a bi-propellant rocket engine system, consisting of sixteen, fixed-mount, thrust chamber assemblies which operate on storable hypergolic propellants supplied by a cold gas, pressurized, positive-expulsion feed system. Pitch, roll, and yaw torques are obtained by firing pairs of the eight 25 pound thrust chamber assemblies. Maneuver ability in six directions (up, down, forward, backward, left, and right) is achieved by firing the appropriate 100 pound thrusters.

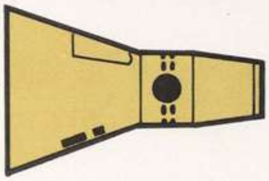
RETROGRADE ROCKET SYSTEM



The retrograde rocket system consists of four, 2500 pound thrust, solid-propellant rockets mounted in the retrograde section of the adapter and symetrically located about the longitudinal axis of the spacecraft. They are ripple fired; their burning times overlap. The resulting velocity decrement permits reentry into the Earth's atmosphere. If necessary to abort a mission at high altitude during launch, this system may be fired in salvo to separate the Gemini from the Titan II launch vehicle. The system consists primarily of the four retro-rockets, two initiators for each retro-rocket, and the associated wiring necessary for rocket ignition, either automatically upon signal from the time reference system, after arming by the astronaut, or manually when the astronaut depresses the retrofire switch for each rocket.

REENTRY CONTROL SYSTEM

The reentry and attitude control is accomplished with a liquid, bi-propellant, rocket engine propulsion system. The reentry module carries two identical but separate systems, each of which consists of eight fixed-mount thrust chamber assemblies operating on storable hypergolic propellants supplied by a positive-expulsion feed system. The two systems are normally used to provide attitude control of the reentry module from retrograde to deployment of the parachute. The two systems respond to electrical signals from the attitude control electronics, which is a part of the attitude control and maneuvering electronics, or from the attitude hand controller. In response to electrical signals, the systems produce rocket thrust forces to control the attitude of the vehicle. If one system should fail, the remaining system can provide attitude control during retrograde, reentry, and post reentry stabilization.



Attitude can be controlled automatically by the attitude control system during reentry, or normally by the crew, either directly or through the attitude control electronics system. The crew controls pitch, yaw, and roll with the three axis hand controller. Pitch, roll, and yaw torques are obtained by selectively firing pairs of thrust chamber assemblies, each of which has a nominal thrust output of 25 pounds.

Before the end of the century, man will have made many flights of discovery in space. Certainly he will have begun exploration of the Moon; probably he will have ventured deeper into the universe.

GEMINI is being prepared to serve as the "Workhorse of Space", bringing closer the time when man can use space to better life on Earth, to study space and learn its secrets, and to begin manned journeys to the planets and the stars.

In addition to 13 flight-rated Gemini spacecraft, McDonnell is providing NASA with two mission simulator trainers. The Gemini mission simulator provides Gemini astronauts, ground crews, and operations personnel with intensive, realistic mission training prior to actual launch of the spacecraft. It not only operates as a flight trainer, but can also be linked to NASA's world-wide control and ground tracking station network for the realistic training of network crews. It accepts commands and responds with appropriate signals, as would an actual spacecraft, and thus provides an integrated training program for both ground operations personnel and the astronauts.

McDonnell is also providing NASA with one docking simulator trainer for docking maneuver practice. In this full-scale, electro-mechanical, computer-controlled Translation and Docking Trainer, Gemini astronauts master the techniques of joining their spacecraft with a target vehicle. The air-bearing supported trainer actually moves through the final 100 feet to a realistic docking operation in which all forces except zero gravity are faithfully represented.

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Cover Photo Courtesy Of The McDonnell Planetarium, St. Louis, Missouri.