Project Gemini design philosophy

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First of the second-generation manned spacecraft, just emerged from design, Gemini introduces major departures from Mercury— a new level of systems integration and operational potential

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Project Gemini, which introduces the second generation of NASA's manned spacecraft, has completed the design stage. Many individual pieces and components, moreover, have been fabricated, and the long and complicated process of assembling and checking out the parts—first as modules, then as major systems, and finally as a completed integrated spacecraft—has begun.

To understand the Gemini design philosophy, we should look first at the primary project objectives:

1. With a minimum of expense and time, to provide a logical follow-up to Project Mercury.
2. To subject two men and their supporting equipment to long-duration flights in space, a requirement for lunar trips and beyond.
3. To rendezvous and dock with another orbiting vehicle.
4. To maneuver a spacecraft in space after docking to a new propulsion system.
5. To experiment with men climbing out of the spacecraft for short periods while in orbit.
6. To perfect methods for returning and landing the spacecraft on a small preselected land site.

The first objective—providing a follow-up to Project Mercury—imposes many limitations on the design of the Gemini spacecraft. Although the objective resulted in following in the footsteps of Mercury in many ways, it also necessitated departures from the Mercury program to remove many of the limitations of the Mercury design, some of which were inherent in its objectives and some of which were revealed as the program progressed.

Mercury was designed with the sole purpose of placing a man in orbit in a minimum time. The main emphasis was put on solving problems—re-entry aerodynamics and thermodynamics, human tolerance to both high accelerations and zero gravity, etc.—which had never been encountered before. Consequently, great attention was not directed to the serviceability of the spacecraft. Hence, when guide lines were established for a follow-on program, it was assumed that solutions to all the basic problems had been obtained in Mercury and that the emphasis could be placed on serviceability and flexibility of detail design. The Gemini spacecraft would reduce flight itself to a relatively routine performance and put the emphasis on experiments in orbit, rather than just attaining orbit.

In Project Mercury, most system components were in the pilot's cabin; and often, to pack them in this very confined space, they had to be stacked like a layer cake and components of one system had to be scattered about the craft to use all available space (see page 37). This generated a maze of interconnecting wires, tubing, and mechanical linkages. To repair one malfunctioning system, other systems had to be disturbed; and then, after the trouble had been corrected, the systems that had been disturbed as well as the malfunctioning systems had to be checked out again. Only one technician could work inside the Mercury cabin at any one time.

In the Gemini craft, systems are modularized, all pieces of each system being in compact packages. Spare packages can be kept completely checked and ready for rapid replacement. The packages are so arranged that any system can be removed without tampering with any other system, and most of the packages ride on the outside walls of the pressurized cabin for easy access. This arrangement allows many technicians to work on different systems simultaneously. The illustration on page 37 shows clearly only one of several walls used in this way. The modular concept applies even to wire bundles, which are fabricated on special fixtures and then merely clipped in place.

Only the visual instruments, controls, and survival ingredients such as the food, water, waste-handling equipment, rescue aids, and breathing apparatus ride inside the pressure vessel.

Placing units outside the pressure compartment causes other problems. For example, cabin atmosphere can not convectively cool the units, and each must therefore be mounted on a cold plate to carry away heat electrically generated. The elimination of convective cooling has the effect of modularizing the systems thermodynamically. A space radiator has therefore been designed to unload system heat. Since the outer covering of the spacecraft re-entry section does not lend itself to radiator construction, the transition, or adapter section between spacecraft and launch vehicle has been made to serve this purpose.

Besides radiating heat into space, the adapter stores mission supplies. These supplies include breathing oxygen in supercritical form, fuels and thrusters for orbital maneuvering, communications equipment needed only in orbit, and the fuel cells and associated supercritical hydrogen and oxygen used to generate electric power and drinking water. The adapter, being unprotected against high heating, must be jettisoned before re-entry.

The second objective—a two-man crew and long-duration flights—introduced basic departures from Mercury. The first was the *two-man* crew. It was believed that, for really extended periods, it was most desirable to be able to alternate rest periods and generally to lighten the load on one man. It was obvious, moreover, that providing supplies and facilities for living in space for a long period represented a major step. The basic problems to be faced were made much more difficult by the small space available in the cabin.

In many cases, even the equipment that performed the same function in Mercury required considerable modification for Gemini to boost the mean time to failure to a level consistent with long-duration flights. Many provisions had to be incorporated in the circuit design and selection of electronic components to secure the required life. For instance, although there are not many vacuum tubes in Mercury, none could be tolerated in the Gemini spacecraft. In the mechanical area, gear drives on fans and horizon scanners had to be eliminated for Gemini. Special inverters were installed so that the correct fan speed could be obtained directly. Here the policy of separating systems, which resulted in modular power supplies within the individual system packages, proved a necessity, not just a virtue.

The long-duration flights planned necessitated special attention to the meteorite problem, particularly in the space radiator. The design evolved circulates fluid in a hollow bulb along the inner edge of the stiffener extrusions, as shown in the illustration below right, and hence secures a high degree of inherent mechanical protection. This design combined with the redundant paths gives acceptable reliability.

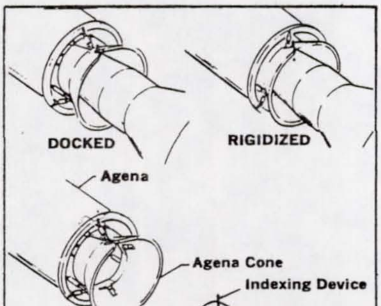
In general, a great deal of attention has been directed in all aspects of design to reliability. But the goals are so high that really meaningful demonstration testing is virtually impossible in the time available. The dilemma involved in this situation suggests that some new approaches to reliability testing must be devised.

The third objective—to effect rendezvous and docking with another vehicle—introduces new systems such as radar units, on-board computers, and propulsion systems for making small accurate changes in flight position. These systems will include the following new equipment: radar, Westinghouse; digital computer, IBM; paraglider, North American; space radiator, McDonnell; fuel cells, GE; docking mechanism, McDonnell; landing skids, McDonnell; inertial-guidance platform, Minneapolis-Honeywell; incremental velocity measuring unit, IBM; and supercritical oxygen and hydrogen systems, AiResearch.

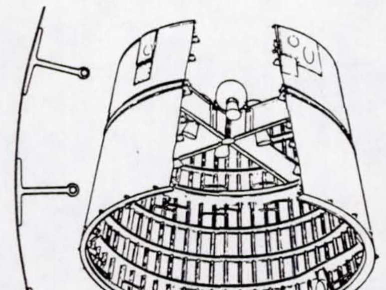
The third objective also requires launches to be performed within narrow periods of time, which means that holds on the launch pad and flight cancellations have to be minimized; this is where the benefits are realized from the emphasis on serviceability throughout the design. It introduces, moreover, the mating hardware on the spacecraft and target vehicle for docking, as illustrated below left. The Gemini spacecraft will rendezvous and dock with an Agena, initial contact being made with a floating cone supported on the front end of Agena by oleos. This cone absorbs energy when hit in any reasonable way, and will not cause a rebound, but will guide the Gemini in toward springloaded latches. After engagement, a mechanism snubs the whole cone to the Agena, making the combination rigid for space maneuvers.

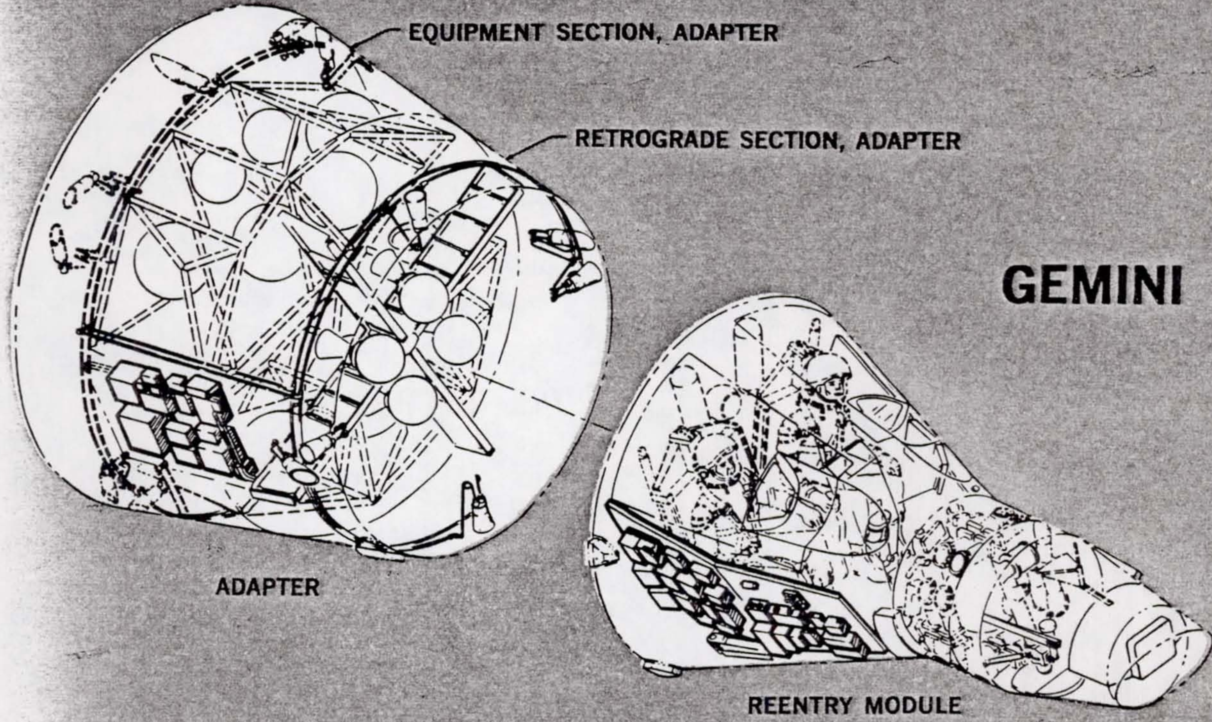
The fourth objective—maneuvering the docked assembly in space—is almost implicit in the choice of target vehicle. It was considered necessary to indicate the "health" of the various target-vehicle systems to the pilots before doing any maneuvering. Accordingly, a series of parameters were chosen which could be used to activate lights and provide indications on gages as to the condition of the Agena systems. At first it was thought that these should be displayed on the pilot's instrument panel. After due reflection, however, it was considered that a much better and vastly simpler method, as to hardware, would be to display them on a panel on the outside of the *target* where either pilot could see them both before and after docking. This scheme eliminates a major requirement for hardline connections between vehicles. Much the same type of reasoning was applied to the command system. Since the system must operate by a microwave link before docking, this link might as well be used after docking. Hardline connections are retained for engine shutdown in parallel with the radio command.

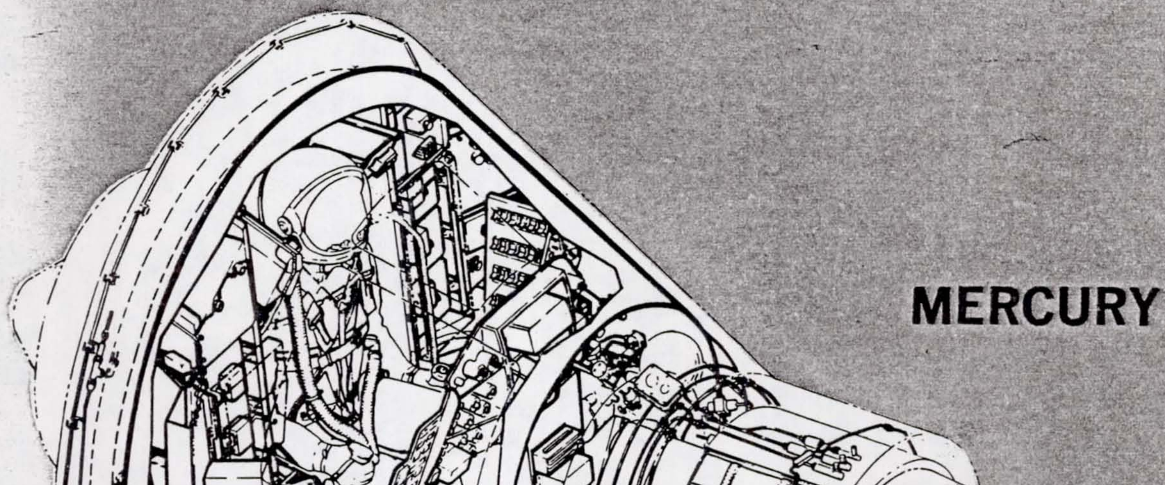
The fifth objective—extra-vehicu-



MECHANISM for docking and making rigid connection.


GEMINI ADAPTER STRUCTURE used as space radiator.





SIGNIFICANT DEPARTURES of Gemini from Mercury are illustrated in these cutaway drawings. In the Mercury spacecraft, the exigencies of the moment made it necessary to stow most systems in the cabin with the astronaut. The Gemini design moves most systems out of the pressure vessel and consolidates system components in easily accessible modules, an example of which is shown on the Gemini spacecraft.

lar experiments—also requires only minor changes to the spacecraft configuration. The hatch, instead of being bolted in place, is hinged and locks by mechanical linkages. Suitable personnel equipment is under development for the extra-vehicular experiments.

The sixth objective involves re-entry control and a paraglider for spacecraft recovery.[1,2] Re-entry control is obtained by using the lift generated by offsetting the center of gravity of the spacecraft and then modulating the roll during re-entry. An on-board inertial system and computer generates the required commands. The paraglider stows in the spacecraft's small cylindrical section. The sketches on page 39 show how it deploys by inflation to become a full-fledged wing. This can be flown by the astronauts much as a conventional light aircraft. The craft will have landing skids.

One of the most important differences in design philosophy between Mercury and Gemini has been greater reliance on the astronauts to control the Gemini spacecraft. This has been made possible not only by having redundancy in equipment (a common practice in Mercury) but also by having two pilots. Manual control, as opposed to complete automatic control, was selected to increase reliability by simplifying sequencing. The automatic abort modes in Mercury, for example, are very complicated and have caused the loss of complete spacecraft in the early developmental unmanned flights. In each instance, had a man been on board, he could have manually salvaged the situation. The Atlas is so instrumented that it will automatically abort the Mercury spacecraft if any one of a number of malfunctions is sensed in the launch vehicle. If a malfunction occurs, the propellants used in Atlas would react rapidly, causing a violent explosion. The storable propellants of the Gemini launch vehicle react more slowly and allow more time for pilot action.

In Gemini, a launch-vehicle malfunction activates lights and gages on the instrument panel and the astronauts exercise judgment as to the seriousness of the situation and the best procedure to follow during any special circumstances. With this sort of system, more than one cue can be used to verify an abort situation. Simulations reveal that, in many cases, much reliance is placed on the audio-kinesthetic cues for this purpose. These cues are not only very reliable but instill confidence in the pilots in the validity of the systems when they are checked by this means. Manual-control is used in many other mission phases, see table on page 39.

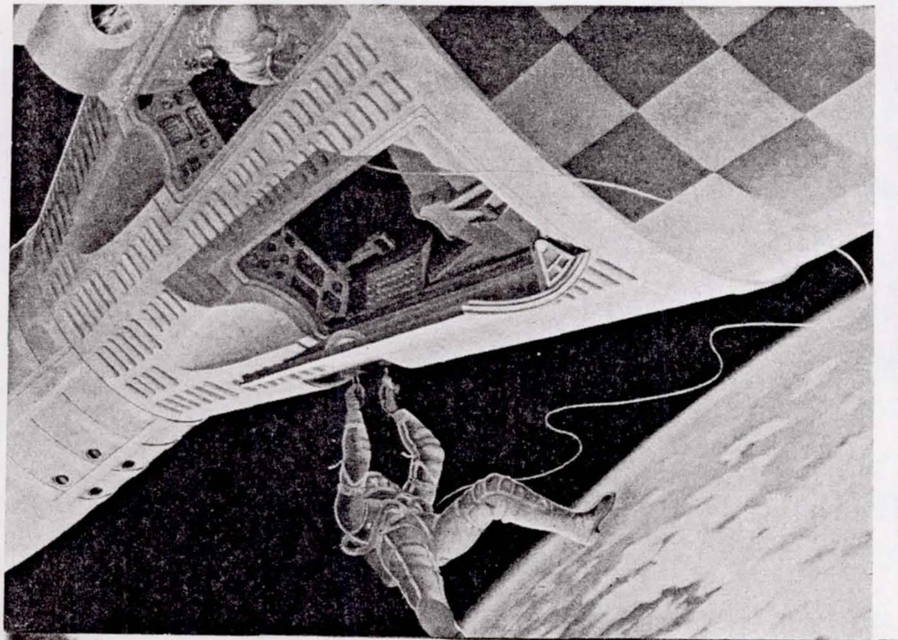
There are a few other differences in the design concepts of the two current manned space programs. Mercury uses an escape rocket that lifts the entire spacecraft, whereas Gemini uses ejection seats. There are advantages and disadvantages to both systems. The escape tower is only available up to staging. The ejection seats not only provide a substitute for a reserve parachute but also provide an escape mode both early in the flight and on landing. Ejection seats were favored because they are consistent with the modular concept, but they were really only made possible by the fact that there is no problem from blast pressures in the event of deflagration of the propellant used in the Gemini launch vehicle.

Another important design concept being pursued in the Gemini program is to retain a flexible universal spacecraft configuration. This effort is greatly facilitated by the modular design for the systems. In the Mercury program, much effort and money were spent in changing among unmanned (heavily instrumented), simulated-man, chimpanzee, manned, three- and six-orbit, and one-day configurations. In the Gemini program, mission variations are accommodated simply by replacing specialized modules.

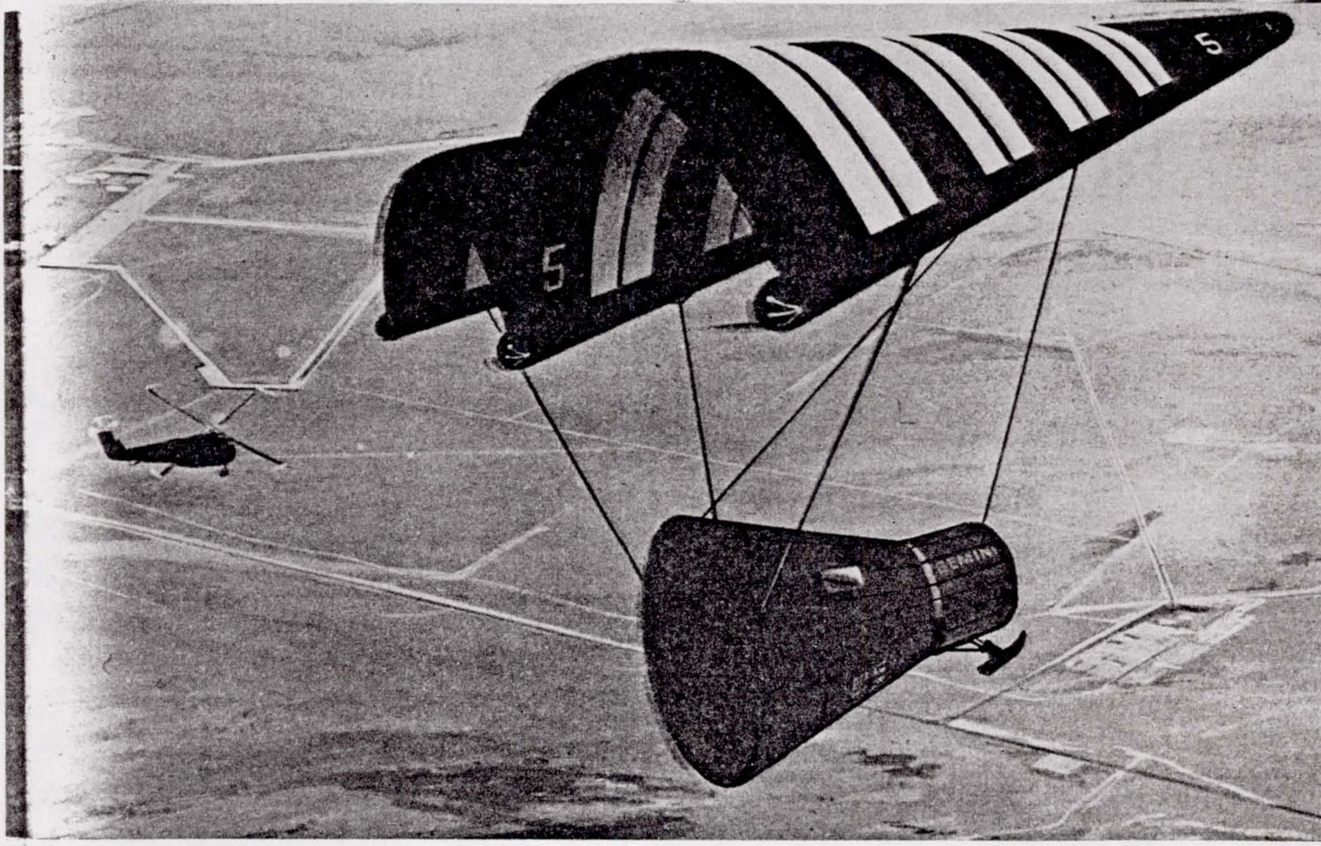
Finally, some hardware familiar from Mercury has been dropped. The periscope was eliminated because the benefits derived from it did not warrant the weight or the complications introduced by the need to extend and retract the main lens body. The landing bag is no longer a necessity when a paraglider and landing skids are used, or even if a large parachute should prove necessary instead of the paraglider. When a parachute is used, the spacecraft has been designed to land in water on the edge of the heat shield to attenuate the impact forces. Finally, the large reserve parachute has been omitted because the ejection seats allow emergency escape.

The objective behind all these changes and innovations has been to produce a spacecraft that will make manned orbital flight commonplace. Project Gemini is well on the way toward this goal.

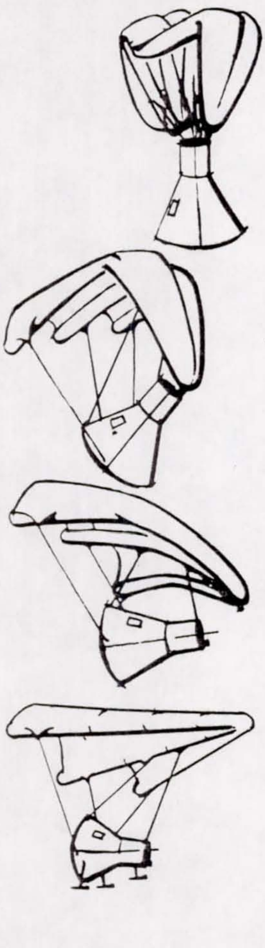
REFERENCES: 1. Rogallo, Francis M., "Paraglider Recovery Systems," presented at the IAS Meeting on Man's Progress in the Conquest of Space (St. Louis, Mo.), April 30–May 1–2 1962. 2. Rogallo, Francis M. and Lowry, John G., "Flexible Re-entry Gliders," Preprint No. 175C, SAE Meeting (New York, N.Y.), April 4–8, 1960.



HUMAN-FACTORS STUDIES such as the one illustrated here, involving egress and tools, will be possible with Gemini.



PARAGLIDER SYSTEM, being developed by NAA, will be used as the primary Gemini landing system.



PARAGLIDER DEPLOYMENT follows the sequence indicated by the sketches at left.

GEMINI AND MERCURY FLIGHT OPERATIONS COMPARED

SEQUENCE		
Booster separation from spacecraft.	Automatic with manual backup.	Astronaut fires separation system.
Capsule turnaround to retro or orbit attitude.	Automatic with manual backup.	Astronaut turns spacecraft manually to proper attitude by watching attitude indicator.
Retro attitude before re-entry.	Automatic when signal is received by spacecraft.	Astronaut turns spacecraft manually to retro attitude, as displayed on attitude indicator.
Aborts, all levels.	Automatic with manual backup.	Ground-command lights, spacecraft-abort light, and astronaut control sequences manually.
Drogue-parachute deployment.	Automatic by 21,000 ft., barostat with manual backup.	Astronaut deploys drogue parachute manually at 60,000 ft.; automatic backup at 21,000 ft.
Landing.	Automatic from 21,000 ft. by parachute.	Manual control of paraglider by control stick.