GEMINI: MERCURY EXPERIENCE APPLIED

By Jerome B. Hammack and Walter J. Kapryan

NASA - Manned Spacecraft Center

INTRODUCTION

It is the intent of this paper to show how the Gemini program has attempted to draw upon and profit from Mercury experience.

The Gemini Project has evolved as a NASA space program with its prime mission of providing a flexible space system that will enable us to gain proficiency in manned space flight and to develop new techniques for advanced flights, including rendezvous. To achieve these objectives, we must have a space vehicle with substantially greater capability than the Mercury spacecraft. This increased capability will include provisions for two men, instead of one, as in the Mercury spacecraft and for space missions of up to two weeks' duration. It is the intent of the Gemini Project to build upon the experience gained from Mercury so that most of the energies of the new program can be devoted to the solution of the problems associated with achieving its primary mission objectives and not have to fight its way through a swelter of old problems.

DESCRIPTION OF GEMINI

The Gemini flight program is shown in figure 1. The first flight is a ballistic sub-orbital qualification flight. It is presently planned for manned flights to begin with the second flight. Rendezvous flights should begin with about the fifth flight.

The Gemini spacecraft is shown in figure 2. It is made up of two major sections, the reentry module and the adapter module. The adapter module, see figure 3, contains equipment and systems required to sustain the spacecraft in orbit. The adapter consists of two sections; the equipment section that contains the main oxygen supply, the primary electrical system, a propulsion system for orbital attitude control and maneuvers; and a section which contains a retrograde system. The adapter will be jettisoned in two stages prior to reentry. The reentry module contains the cabin which will house the two astronauts, the reentry control system module and the rendezvous and radar module. A front-end view of the spacecraft is shown in figure 4. The crew station or "cock-pit" is shown in figure 5.

The Gemini launch vehicle is a modified Titan II which represents a second-generation vehicle evolved from the Titan I. The primary modifications for the GLV are the incorporation of a redundant flight control system and the addition of a Malfunction Detection System (MDS) for pilot safety.

The target vehicle is a modified Agena-D. The primary modifications to the Agena are the incorporation of a multiple restart system, the addition of a secondary propulsion system, and a command and control system that is compatible with the spacecraft.

The Agena launch vehicle is the Atlas standard space launch vehicle. This vehicle is a refined Atlas-D and is planned as a "work-horse" vehicle for many space projects.

EXAMPLES OF APPLIED MERCURY EXPERIENCE

The authors have selected four areas to illustrate how Mercury experience influenced Gemini. These areas are; integration of man into system, design, checkout, and launch vehicle integration. There follows a discussion of each area.

Integration of Man Into System

The first example of applying Mercury experience to Gemini is the integration of man into the flight system. Since the Mercury program was America's first manned space venture, its design constraints were in some ways more restrictive than those of the Gemini program. First, since we had never before put man into space, it was necessary to develop a vehicle that could and would operate through all phases of flight completely independently of man. This requirement has been successfully met with the Mercury spacecraft. To achieve such a vehicle for Gemini, with its added systems for fulfilling the more ambitious mission objectives and within the time framework allotted, would have been an almost impossible task. The design concept behind Gemini, therefore, is different than it was for Mercury. Actually it is Mercury experience itself that makes this possible. Man as a positive factor contributing to mission success in space environment has proven himself during the course of Project Mercury. All of the manned Mercury flights have been well documented (see Bibliography). Two examples of man's contribution to mission success will be cited here. During the MA-6 flight (John Glenn's mission), malfunctions in the automatic control system prompted the astronaut to assume manual control. Had this flight continued in the automatic control mode, there would have been insufficient fuel to complete the three-orbit mission. During MA-8 (Schirra's flight) a change in flow characteristics of a valve in the environmental control system caused pressure-suit temperatures to reach uncomfortable levels, but systematic and effective adjustment of the control valve by the pilot corrected the overtemperature. Had the pilot been unable to exercise this control, the flight would have been terminated much earlier than was planned. Other examples could be cited but these should be sufficient to make the point.

To state that man in space has proven himself in Mercury does not imply that there are not still many many unknowns in the area of human factors in space flight. However, there is now concrete evidence that man can materially improve chances of mission success. In Gemini, man therefore is being integrated into much of systems operation. This approach enables use of simplified circuitry, minimization of automatic equipment, and since man is to be heavily relied on, more will be learned with regard to man's capabilities in space than would be the case if he were only required to play a passive role during the course of a mission.

Design

The Gemini program has drawn heavily upon Mercury experience in the design of the spacecraft. There follows a discussion of three major systems to illustrate this fact.

Landing System. - Considerable effort was expended to develop a suitable landing system for Mercury. In fact, the first flight tests of the Mercury spacecraft were performed primarily to develop the landing system. These tests involved dropping boiler plate capsules from high-flying cargo airplanes with various parachute configurations.

Due to vigorous in-house efforts within the NASA as well as extensive effort by the contractor, a reliable landing system was developed which is presently being utilized in the Mercury program.

There are several disadvantages to the Mercury system, however. These are: (1) high landing dispersion, (2) necessity for water landing, (3) need for a landing shock attenuator (Landing Bag).

For item 1, the Gemini spacecraft incorporates an offset center of gravity so as to trim at some definite value of lift. The direction of the lift vector can be controlled by rolling the spacecraft through use of the reentry control system. This, coupled with information provided by an onboard computer, will make possible landings within smaller areas of dispersion.

A paraglider development program is being diligently pursued by the NASA to provide the capability of land landings on prepared sites. A typical paraglider configuration illustrating the deployment sequence is shown as figure 6. With the paraglider, the pilot will be able to maneuver, to avoid local obstructions and land in much the same manner as with an airplane. Use of a paraglider will eliminate the need for a landing bag as was used on Mercury.

Since the paraglider is a new development, a parachute landing system similar to the Mercury system is being developed for interim use until the paraglider system is qualified (see figure 7). However, the spacecraft is suspended in such a manner as to provide reduced landing impact loads. When the spacecraft enters the water in the manner shown, the onset g rate is greatly reduced. The parachute utilized for this system evolved from Mercury experience. It is an 84 ft. diameter version of the ring-sail chute used on the Mercury capsule.

Electrical power system. - The Gemini spacecraft utilizes fuel cells as the major source of electrical power during orbiting flight. This is because of the extensive load requirements for both the long duration and rendezvous missions. A system of silver zinc batteries similar to those used in Mercury will supply electrical power during reentry, post landing and for emergency operation during orbit. All squibs and pyrotechnics, the high transient voltage devices, will be powered by an independent dual zinc-battery supply similar to that used for reentry. During the Mercury program upon a number of occasions relays and timers malfunctioned as a result of the occurrence of high transient voltages or "glitches." A completely independent isolated squib bus such as is being designed into Gemini should minimize, if not eliminate, the "glitch" problem.

A radiator has been provided for fuel cell cooling and to supply coolant to cold plates which are installed under critical heat generating devices aboard the spacecraft. At times during the course of Mercury missions problems arose due to the overheating of electrical equipment. In Gemini most of the equipment will be exposed to the space environment rather than to cabin atmosphere. This, of course, magnifies the heating problem. The use of the cold plates for positive cooling during both ground checkout and flight should minimize our heat balance problems.

Control System. - Attitude control of the Mercury spacecraft is achieved by means of a Reaction Control System utilizing hydrogen peroxide as the propellant. Weight limitations necessitated the use of aluminum tubing throughout this system. The combination of hydrogen peroxide and aluminum is not particularly compatible. Proper passivation of the tubing has been extremely difficult to achieve. System contamination, therefore, is an ever-present problem. Furthermore, design considerations dictated the use of flared tubing. The use of flared tubing has posed a constant leakage threat.

Control of the Gemini spacecraft is achieved by means of the Orbit Attitude and Maneuvering System while in orbit and by means of the Reentry Control System during retrograde and reentry. Both systems utilize hypergolic propellants. The fuel is monomethyl hydrazene, and the oxidizer is nitrogen tetroxide.

Hypergolic propellants were selected primarily due to their higher specific impulse. Furthermore, with hypergolics there is not the ever-present danger of explosive decomposition that is attendant with the use of a peroxide system. The payload saving achieved by Gemini through the use of hypergolics rather than hydrogen peroxide is on the order of 700 pounds. Stainless steel tubing will be used throughout the system which should minimize "passivation" problems. The system will be an all brazed system to minimize leakage. Squib controlled diaphragm type isolation valves have been incorporated just shortly downstream of the pressure and propellant supplies to further minimize leakage. A series of two to ten-micron filters will be used throughout the AGE and the airborne system to minimize the possibility of contaminants restricting injector orifices. Although this control system represents a more advanced state-of-the-art system than Mercury, we feel that the major trouble areas experienced by Mercury are being minimized in the Gemini design.

However, it is well known that hypergolic propellants are extremely toxic and must be handled with great care. At this time, though there is not much experience to use as a guide in handling hypergolics, additional experience is being gained daily as for example in the Titan II and Agena programs.

Checkout

The third and possibly most significant area of the application of Mercury experience is the one of checkout.

When the Mercury program was first conceived, primary attention was paid to defining a vehicle that within severe payload constraints could best withstand the exit and reentry heating environments and the aerodynamic loads associated with manned earth orbiting missions. Much less attention was paid during design to ease of checkout. As a result, the Mercury spacecraft did not lend itself to expeditious checkout. In retrospect we now know that a stronger effort should have been exerted in this direction. Systems were literally piled on top of systems.

Needless to say, removal and replacement of malfunctioning equipment coupled with revalidation of many systems which were disrupted to get at the defective equipment were at times excruciating. Preflight checkout of the Gemini spacecraft is expected to benefit significantly from the lessons learned as a result of this Mercury experience.

As was pointed out in the paper by D. M. Corcoran and J. J. Williams, ref. 1, NASA's Manned Spacecraft Center is an advocate of a rigorous checkout program. The checkout philosophy is to develop the highest possible degree of confidence in the capability of the spacecraft to perform its mission by means of a series of thorough end to end functional tests of each of the systems within the spacecraft, first individually and then on an integrated basis. This philosophy evolved during the course of Project Mercury. This philosophy will be maintained throughout the Gemini program. Though the Mercury program to date has been very successful, the Mercury spacecraft, as previously stated, is very difficult to checkout. It is recognized that if Gemini is ever to achieve a reasonable launch schedule, a vehicle is required that is much more amenable to preflight checkout. Gemini should provide such a spacecraft. Figure 8 shows three of the more significant factors that should contribute to improved checkout over that of Mercury.

The first item on the figure is the modular design concept. This has a two-fold implication. The spacecraft itself is designed in structural modular form and the systems within these structural modules are modular. This gives the capability of separating the spacecraft into its various structural modules for parallel and concurrent testing. Modular systems enable the removal and replacement of subsystems and components with a minimum of disturbance to other systems. This could not be done in Mercury. AGE test points enable the connecting of checkout equipment without disrupting flight connections. This too could not be done in Mercury. Fabrication quality control, a problem in Mercury, is being improved by having more resident quality control engineers and inspectors.

The checkout plan for the Gemini spacecraft is based on manual testing. However, one of the major goals of Gemini is to develop improved checkout techniques. Therefore, a system of automatic checkout is being developed which it is hoped will become fully operational during the latter stages of the Gemini program. Until such time, however, manual hardline checkout will be the primary means of testing the spacecraft.

The use of identical checkout procedures and checkout equipment is being implemented at both the McDonnell plant in St. Louis and at the Cape. This will enable test personnel to better evaluate differences in test results that may occur between tests performed at St. Louis and the Cape. Needless to say, lack of such identical equipment and procedures was a source of continuous irritation and confusion throughout Mercury.

Facilities within which to checkout the Mercury spacecraft at the launch site were woefully inadequate in the early phases of Mercury. The lack of proper AGE was also a handicap. These problems, we feel, are being circumvented in our planning for not only Gemini but future space programs as well. Construction of facilities on Merritt Island in support of both Gemini and Apollo has already begun. It is not to be implied that there will be no problems in this area; however, relative to Mercury, considerably more planning and implementation will be achieved much earlier in the program. There will be an Operations and Checkout Building wherein the master test stations will be installed and wherein most of the modular and integrated tests will be performed. A Liquid Test facility will be provided for testing of hypergolic and cryogenic systems. New altitude chambers will be available for manned and unmanned simulations in a space environment. A radar range will be built for radar boresight and alignment checks and for performing mated Gemini/Agena RF and functional compatibility tests, and so on. In a number of instances, facilities for the performance of similar tasks in Mercury were not available until well after the beginning of the operational phase of the program.

Launch Vehicle Integration

The last area to be discussed which has profited from Mercury experience is the area of launch vehicle/spacecraft integration. It was apparent early in the Mercury program that the launch vehicle and spacecraft must be regarded as a composite vehicle in the critical powered portion of the flight. Therefore, compatibility criteria was defined early in the program. The need for a thorough study and understanding of the structural carry-through loads of the combined vehicle was also recognized during the Mercury program. In Gemini, therefore, a great deal of emphasis is being placed upon interface loads criteria. The influence of cutouts, discontinuities and protruberances in the spacecraft is being thoroughly analyzed. Design of the forward-skirt portion of the launch vehicle is taking these effects into consideration. A combined spacecraft adapter and booster forward section test is being conducted so that detailed knowledge of resultant stresses are known.

The same detailed attention paid the design, fabrication and checkout of the Mercury launch vehicle as outlined in reference 2 will be paid the Gemini launch vehicle. The Martin/Baltimore assembly area will be exclusively devoted to the assembly, integration, and factory checkout of the launch vehicle; therefore, the whole effort at Martin/Baltimore will be directed towards producing man-rated vehicles. The weapon system Titan II is provided at Martin/Denver. The technical teams of the Martin/Baltimore plant have personally visited the General Dynamics/Astronautics plant to inspect Mercury procedures. Teams of NASA/SSD and Aerospace engineers will monitor the more significant tests conducted at Martin/Baltimore. Also, as on Mercury there will be engineering reviews, roll-out inspections and acceptance reviews by NASA/SSD and Aerospace. The same concept will be applied at the Cape during checkout.

Essentially the same management structure is in effect for the Gemini launch vehicle as for Mercury. Directly responsible to the NASA for the launch vehicle is an Air Force Program Office which has the technical assistance of an Aerospace systems office. This AF/Aerospace Program Office implements NASA direction to Martin and associate contractors.

CONCLUSION

It has been the purpose of this paper to describe, without getting into extreme detail, how Mercury experience is being applied to Gemini. A few examples have been given to demonstrate the application of this experience in the areas of integration of man into the system, design, checkout and launch vehicle integration. The examples presented are by no means all inclusive. They were intended primarily to convey the thinking behind Gemini. There is no question but that we must take considerable advantage of Mercury experience if we are to successfully achieve the goals of the Gemini program. Time alone will show how well we have done the job.

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FLIGHT 1 - UNMANNED BALLISTIC QUALIFICATION

FLIGHT 2 - MANNED QUALIFICATION

FLIGHTS 3 & 4 - LONG DURATION

FLIGHTS 5 THRU 12 - RENDEZVOUS

Figure 1.- Gemini flight program.

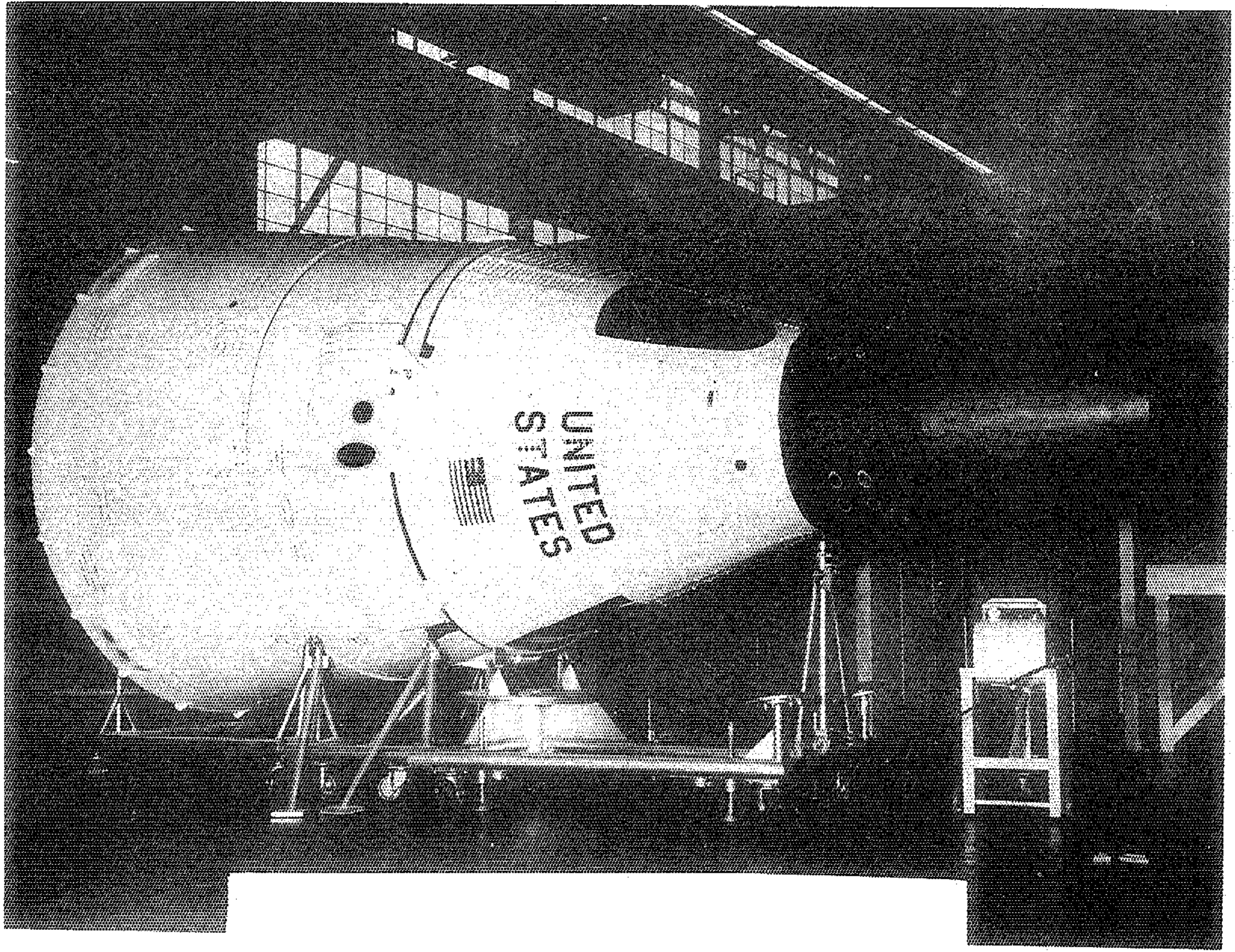

Figure 2.- Gemini spacecraft.

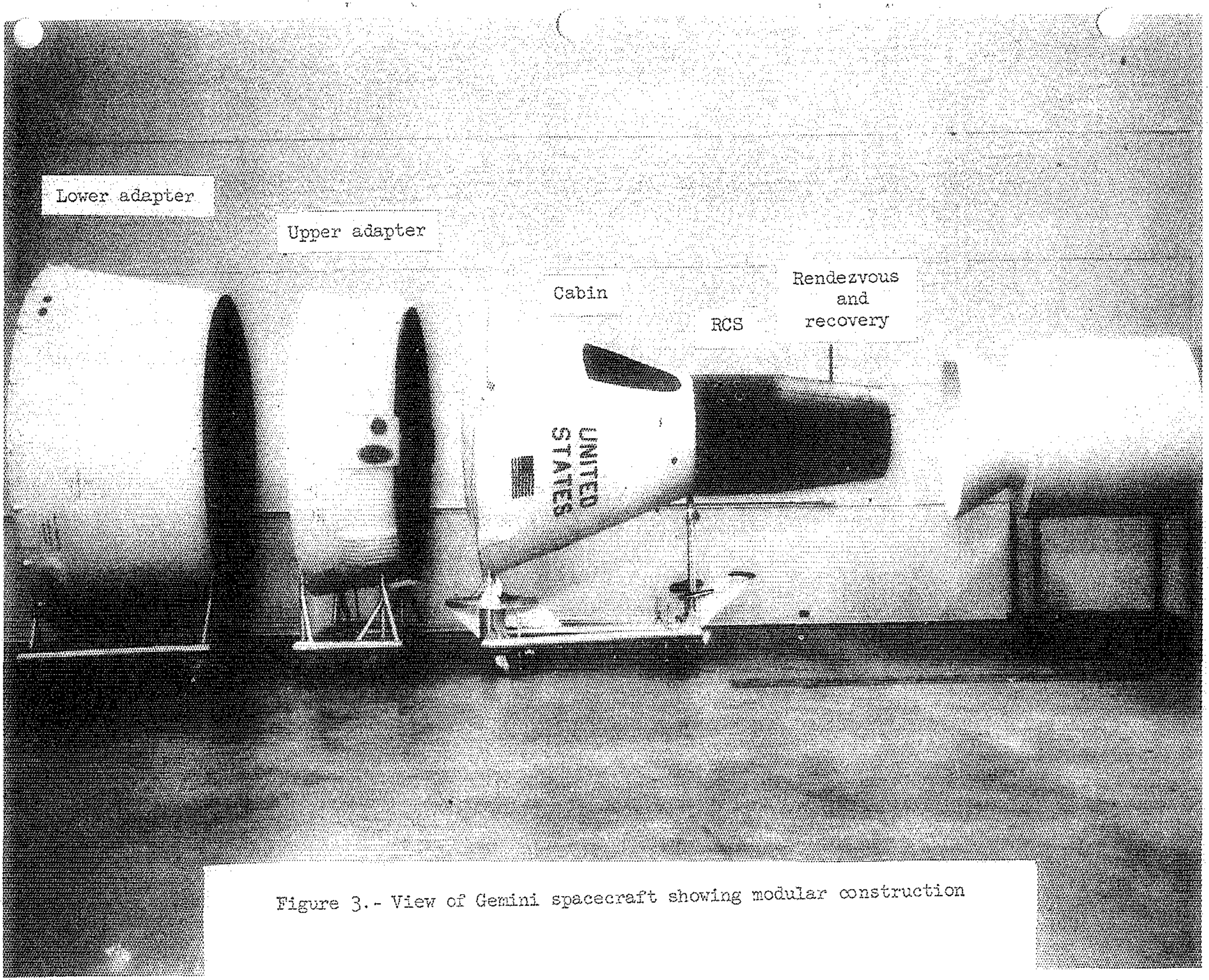

Figure 3.- View of Gemini spacecraft showing modular construction

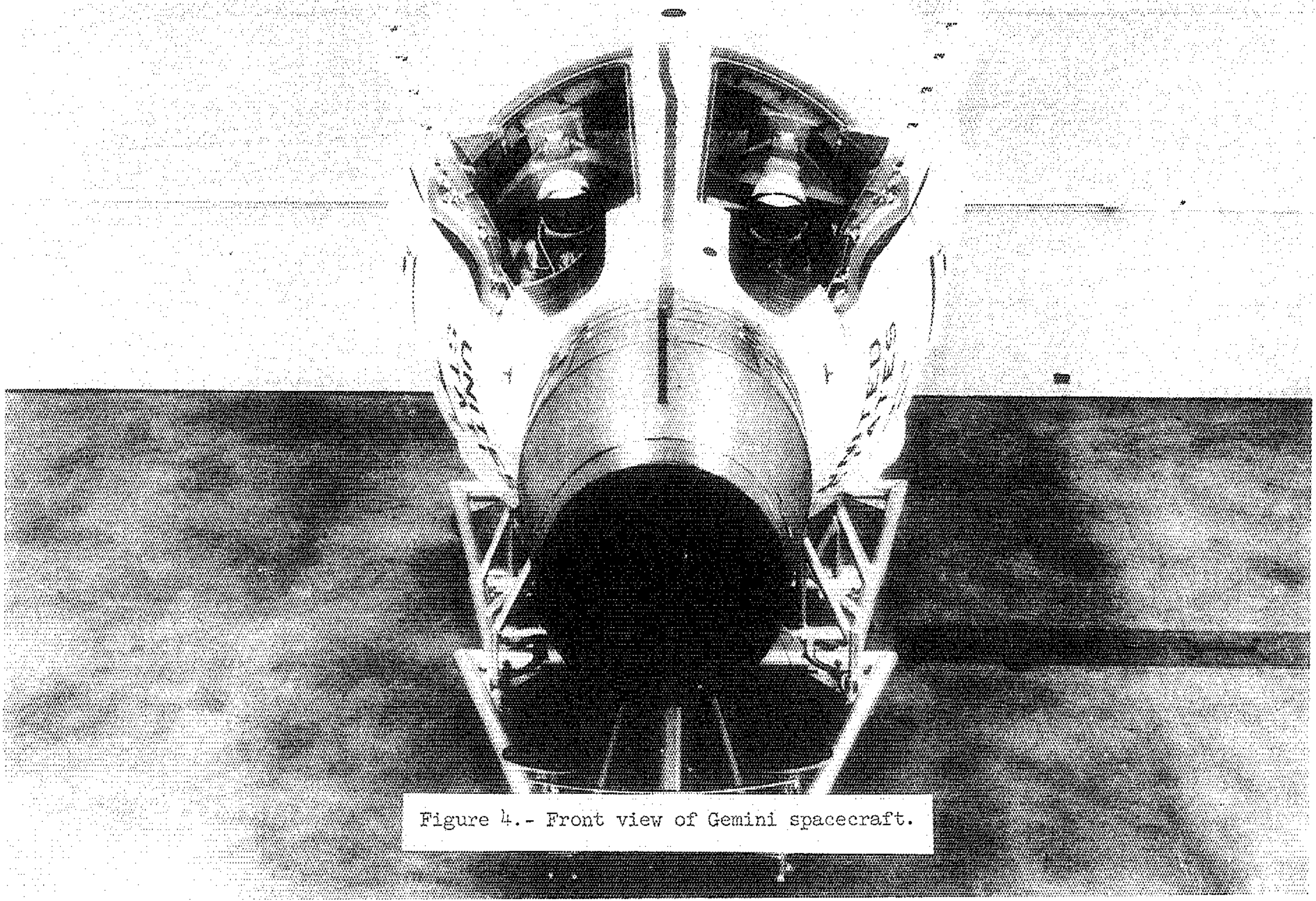

Figure 4.- Front view of Gemini spacecraft.

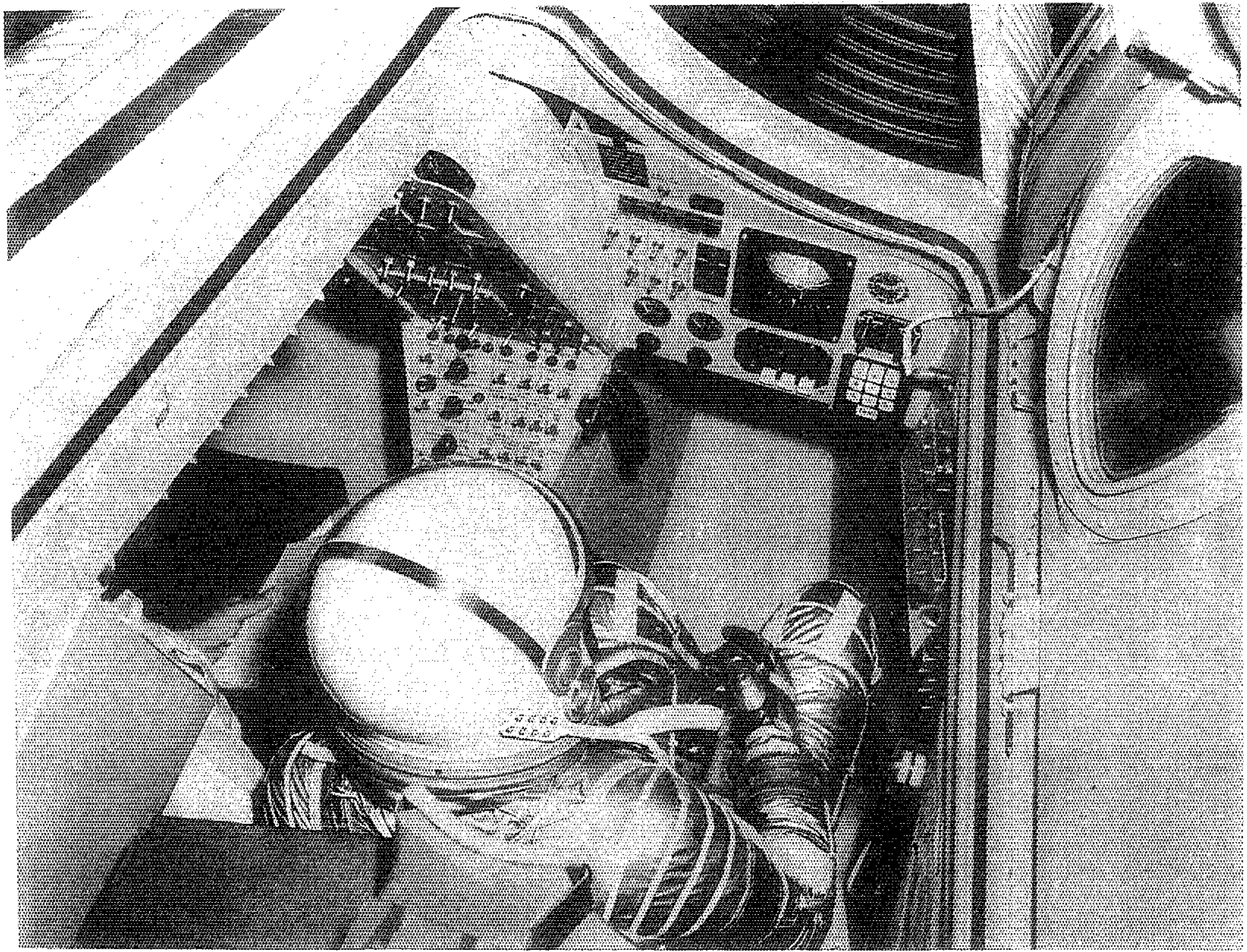

Figure 5.- View of Gemini spacecraft showing crew station.

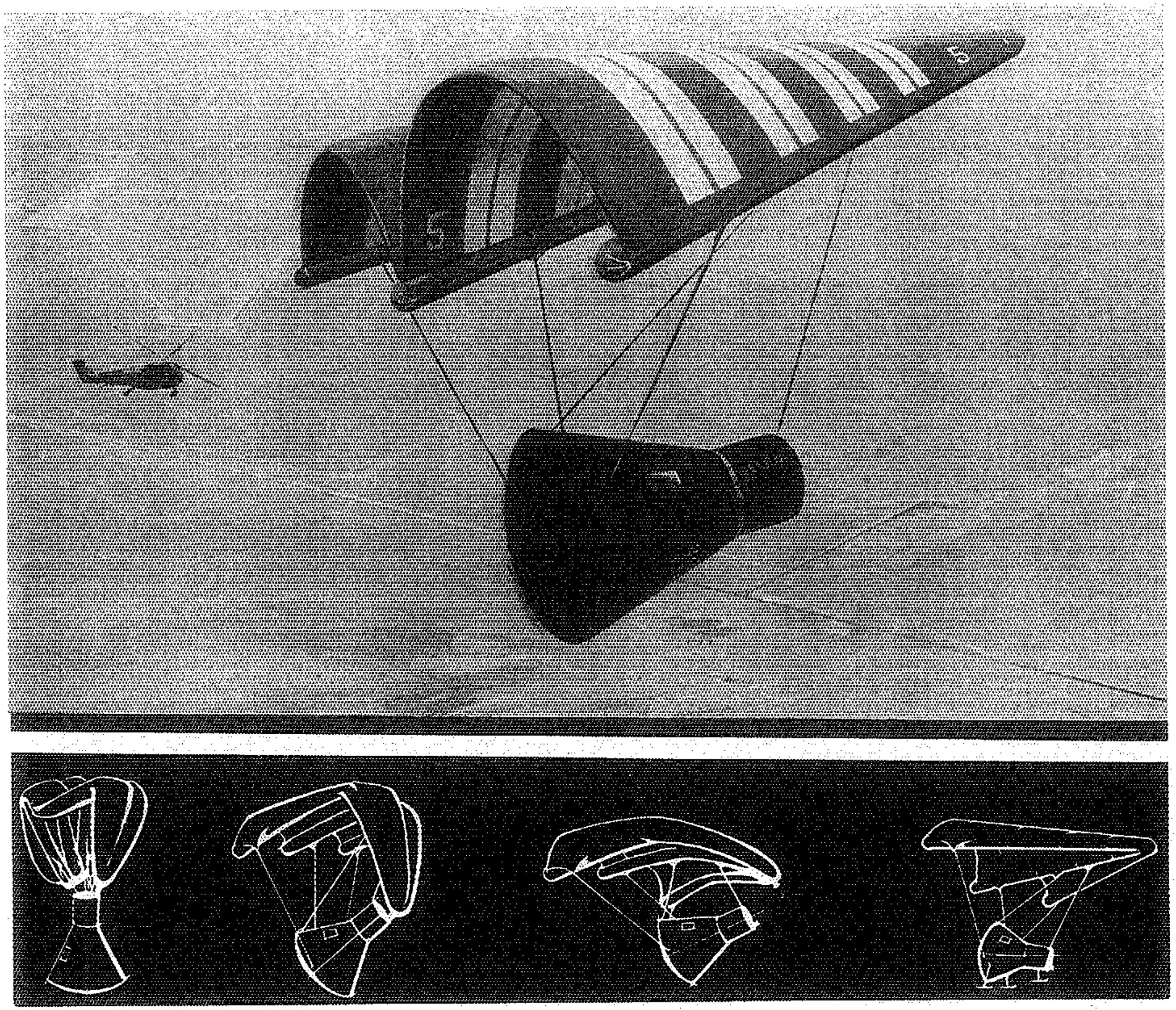

Figure 6.- Gemini spacecraft and paraglider.

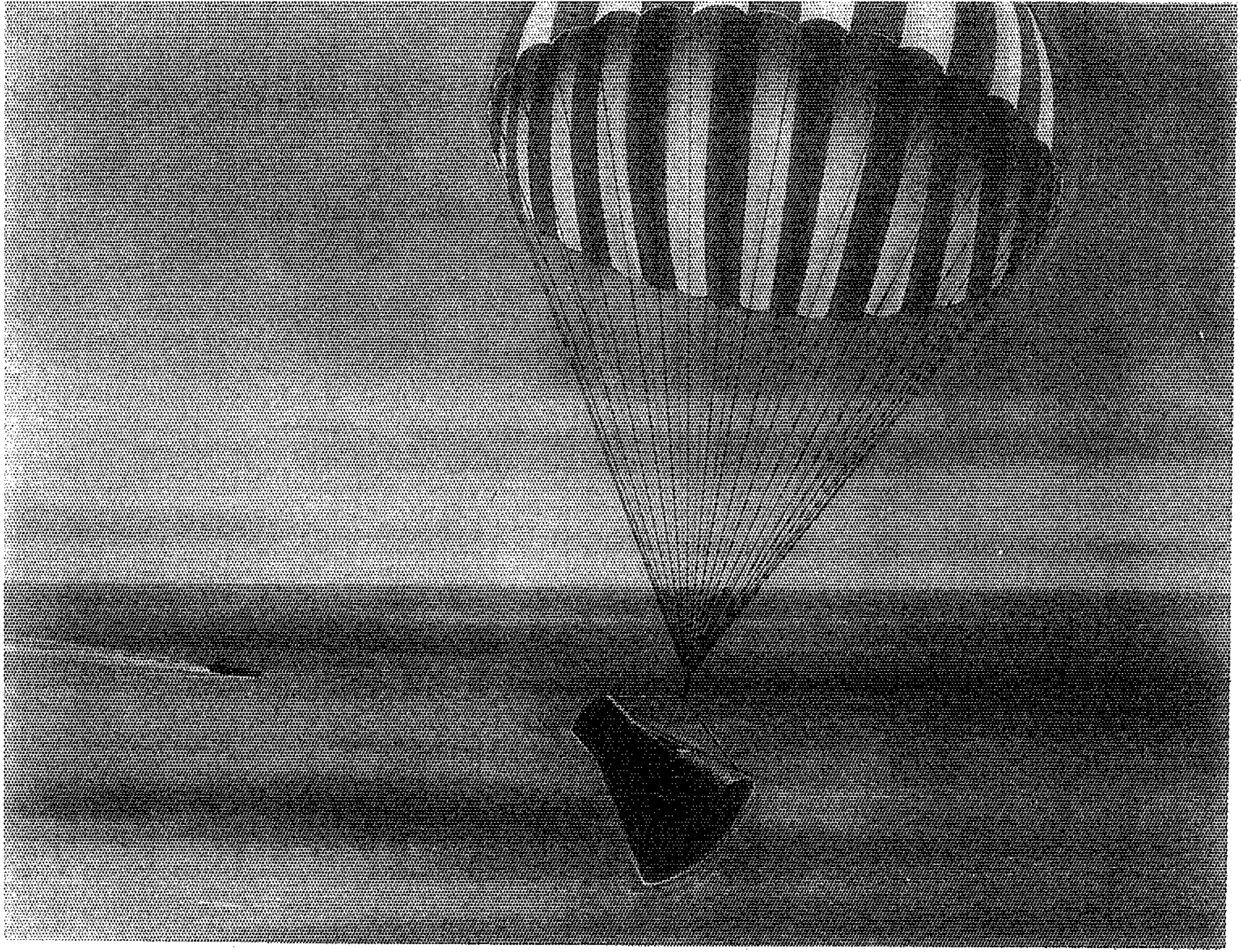

Figure 7.- Gemini spacecraft and parachute landing system.

1. MODULAR DESIGN CONCEPT
    a. PARALLEL AND CONCURRENT TESTING
2. AGE TEST POINTS
3. QUALITY CONTROL

Figure 8.- Factors contributing to expeditious checkout.