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PROJECT MERCURY

THE PROGRAM AND ITS OBJECTIVES

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SUMMARY

Project Mercury is reviewed in the light of experience gained thus far in the technical implementation of this Nation's initial program for manned orbital flight. Initial guidelines formulated for the Mercury program are reviewed together with some of the technical considerations that have influenced the design of the capsule and the operational plan for the booster-capsule vehicle.

The role of the astronaut in the Mercury program is discussed and some observations are made concerning the impact of the Mercury program on future manned space ventures.

PROGRAM CONCEPTS

Project Mercury received official status on October 5, 1958, when it became an active NASA program, although a good deal of the preliminary planning in research activity extended back 12 to 18 months preceding this date. At that time, certain guidelines were adopted by NASA for the implementation of this project. These original guidelines are listed in figure 1 and they still constitute the basic program concepts for Project Mercury.

Objectives

The main objectives of Project Mercury are (1) to insure safe orbital flight and recovery of a man in the space capsule and (2) to study man's capabilities in a space environment. In the initial manned orbital flight of Project Mercury, the first objective will undoubtedly receive much popular emphasis. However, the more far-reaching and scientific objective of the Mercury program is to study man in a space environment. This study may well influence the next generation of spacecraft. This objective will be discussed more fully subsequently.

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Basic Principles

In regard to the basic principles, the approach taken was to use the simplest and most reliable methods known and to minimize new developments. Also, systems reliability was to be demonstrated by a progressive buildup of tests. In this way, the primary objectives could be attained in the most reliable manner in the least amount of time.

Method

The method used to carry out the program is also outlined in figure 1. A high-drag ballistic reentry shape was selected for the basic design. In the present state of technology, this decision still appears to be a sound one. By modifying the adapter section of the Atlas ICBM booster to receive the capsule, this booster can be used to put the capsule in orbit. A cluster of solid-propellant retrorockets were adapted for positive reentry. After the high reentry velocity is reduced because of aerodynamic drag on the blunt shape, a parachute recovery system will lower the capsule to earth. In order to provide the astronaut with a positive means of escape from a malfunctioning rocket, an escape system was provided. Recent tests of this system simulating an off-the-pad abort, an abort at maximum dynamic pressure on exit, and an abort at a very high altitude and velocity have all been successful. The parachute recovery system is also being extensively tested to assure high reliability. Nevertheless, the astronaut is provided with a backup reserve parachute in case malfunction of the primary parachute occurs.

CAPSULE AND ESCAPE SYSTEM CONFIGURATION

Figure 2 shows the capsule with and without its escape system. The retrorocket package and heat shield can be seen on the bottom of the capsule. The heat shield is of the ablative type and is made of a phenolic resin. Three retrorockets are used to initiate the descent from orbit. The metal shingles on the afterbody are made of cobalt alloy which dissipates the reentry heat by radiation. This type of construction allows full expansion in all directions. The parachute recovery system is contained in the upper cylinder. The maximum diameter of the capsule is about 74 inches. The launch configuration shown on the left of figure 2 is approximately 25 feet in height. The tower escape system allows the capsule to be pulled away from the immediate vicinity of the booster at any time. To date, there have been no booster malfunctions that would have prevented a safe escape of the capsule from the scene of immediate danger.

Figure 3 has been prepared to show the relative position of the astronaut, the window, and the emergency egress hatch. The astronaut is shown in a semisupine position with his back toward the heat shield. The window and egress hatch are two modifications that have been made to the capsule since its initial design. The window, directly above the astronaut's head, has been added to allow him to make observations independent of the periscope. The hatch, on the astronaut's right, has been developed so the astronaut could, in case of some unforeseen emergency after landing, exit from the capsule quickly. As the astronaut turns the hatch handle, primacord is exploded in such a manner as to cause the hatch structure to fail and thus fall free.

When all the many systems and subsystems are consolidated and integrated within the capsule structure, the Mercury capsule interior arrangement would be similar to the sketch presented in figure 4. The capsule is complicated by the redundant systems which have been added for increased safety. Starting from the small end of this sketch (from right to left), one can distinguish the antenna can, the two horizon scanners, the parachute package, the pitch and yaw jets and associated plumbing, the periscope housing, the astronaut's instrument panel, the side-arm controller, and sundry electronic and power packages. The environmental-control system is mainly below the astronaut's couch. The capsule is completely automatic, but provisions have also been made for piloted operation. Each system has a backup, and in the area of communications, there are several backups. There are two telemetry systems for sending back capsule data and pilot data. Also, there are onboard recorders which collect the same information sent by telemetry.

The astronaut may take over completely and perform all the functions of the automatic control system. Because of the parallel manual system, he will also be able to fly any mode that might fail on the automatic system.

MAJOR CAPSULE SYSTEMS

All the major Mercury capsule systems have been described in reference 1. Some facts on a few of the systems of special interest are discussed briefly in the following sections.

Instrument Panel

The instrument panel is shown in figure 5. The controls and displays on this panel are grouped as to function. The group on the left side has various pilot controls such as those concerned with the attitude control system and the retrorockets. The two large handles are for decompression and repressurization. Decompression would be the method used for extinguishing a fire.

The next group is a sequencing display. This consists of a series of lights arranged in sequence and designed so as to indicate whether the various functions occurred, or did not occur, at the proper time. A green light comes on when the function does indeed occur and a red light comes on when there is some failure in the automatic functioning. The handle just to the left of each light is the pilot's control to override and correct the failure of any particular function. The light at the very top of this group is the abort light which comes on in the event an abort is initiated. If the abort does not occur, the pilot can abort by using his left-hand grip. The switch immediately under the abort light is the pilot's "ready" switch. This switch is used prior to launch to light up a "ready" light on the test conductor's panel in the blockhouse.

The next series of dials are flight instrumentation. The dials indicate acceleration, rate of descent, altitude, and the fuel supply in the hydrogen peroxide tanks. The top center of the panel is the attitude display. This combination display shows rate and attitude in pitch, roll, and yaw. The rate display is in the center, surrounded by the attitude displays consisting of three dials. This particular display for attitude control was arrived at after a number of simulation flights were made with various types of displays. The astronaut control of attitude will be aided by the periscope, which is located in the center and below the instrument panel, and a window, which is located directly above the panel. The astronaut will be able to see the horizon in back of the capsule through this window in the normal orbital attitude of 14° as well as in the retrofiring attitude of 34°. The periscope provides the astronaut with a view of the earth beneath the capsule. He can control the attitude by location of the earth's image in the periscope.

The instrument in the left center is a dead-reckoning type of device which consists of a small model of the earth, clock-driven to rotate in time with the orbit. In the right center is the satellite clock, which, in addition to firing the retrorockets, indicates time of day, the lapsed time since launch, and time-to-go for retrorocket firing. The astronaut is provided with an additional time-to-go dial which he may set for any desired event and also a separate stop watch.

The environmental-control-system instrumentation is grouped in the upper right-hand corner of the instrument panel. This group indicates the following environmental-control-system instrumentation: cabin pressure, temperature, relative humidity, and oxygen partial pressure; primary and emergency oxygen supply pressure; and carbon-dioxide partial pressure downstream of the lithium hydroxide canister in the pressure-suit control system. Controls for the cabin-pressure-system fans are provided on this panel. A warning-light panel is installed adjacent to the environmental-control-system instrumentation. This panel gives the astronaut visual warning of major systems failures. At the same time, an auditory warning system is actuated when failure occurs. The astronaut would turn off the auditory warning signal by actuating a switch located by the light and then take corrective action. Warning lights are provided for loss in cabin pressurization, depletion of primary oxygen supply, emergency-rate mode of operation, decrease in cabin oxygen partial pressure below 3 psi, increase of carbon-dioxide partial pressure to 3 percent in the pressure-suit circuit, and excessive cooling water to the suit and cabin heat exchangers. A telelight panel is located on the left console to give the astronaut indication of flight-event sequential operation. On this panel the launch oxygen supply and snorkel operation are presented. Manual backup controls are installed adjacent to the lights. A green light indicates that the event has occurred; a red light indicates the event has not occurred. Heat-exchanger water-flow controls and the emergency-rate valve control are located on the right console which is not shown in this figure.

The instrument panel and astronaut will be photographed in flight. In addition, the data from the system instrumentation will be telemetered and recorded by onboard recorders. Continuous physiological data on the astronaut's condition in flight will be made with electrocardiogram, body temperature, and respiration rate and depth measurements. These data will be recorded by onboard recorders and will be telemetered.

Environmental Control System

The Mercury environmental control system (fig. 6) maintains the environment for the astronaut at a temperature between 50° and 90° F. (See ref. 2.) The astronaut may manually select the temperature in this range that makes him most comfortable. During reentry, when the cabin air temperature may approach 180° F, the suit environmental-control systems will still maintain the air in the pressure suit within the desired temperature range. The system is capable of operating for about 32 hours. Body odor is removed by use of activated charcoal, and carbon dioxide is removed by the use of lithium hydroxide. Fresh oxygen enters the suit at the torso and exits at the helmet. As the oxygen leaves the helmet, it enters a debris trap where small particles are removed and then it moves through the odor absorber and carbon dioxide absorber. A filter is provided downstream of the carbon dioxide absorber in order to prevent lithium hydroxide dust from contaminating the suit oxygen. The temperature of the gas is lowered in the heat exchanger and water is removed in the water absorber. The resulting drop in pressure is counteracted by an increased supply of gas from the oxygen bottle. Ten cubic feet per minute is the flow rate through the suit at approximately

5 psi. Considering the fact that this system only weighs about 130 pounds it represents indeed a noteworthy engineering accomplishment.

Automatic Stabilization and Control System

One of the more complex systems in the capsule is the automatic stabilization and control system. Figure 7 shows the normal operation of this system. The Atlas and capsule configuration at lift-off is shown in the left-hand part of this figure. When the Atlas drops its booster engines, an event known as staging, the capsule removes the escape rocket by firing a special jettison rocket. The Atlas booster then follows a tilt program which yields an orbital altitude of approximately 105 nautical miles at the time of insertion. At booster cutoff, the capsule's posigrade rockets fire, separating the capsule from the booster as shown in position B in figure 7. The stabilization system maintains capsule rate damping for 5 seconds until all oscillations of the capsule have been stopped. The capsule then is oriented to the retrorocket firing attitude as shown in position C. The capsule is maintained in this attitude for 5 minutes. In this time period, ground tracking stations can determine if capsule orbital velocities and insertion angles are correct enough to allow the capsule to maintain itself in orbit. The capsule is then oriented into the normal orbital attitude as shown in position D. The capsule is maintained in a $14\frac{1}{2}^{\circ}$ blunt-end-up position. This permits the astronaut, with the aid of the periscope, to see past the larger heat shield end. Also the retrorockets are in the right position for reentering immediately, in case of emergency. The automatic stabilization and control system next orients the capsule into the retrofiring attitude as shown in position F. After retrofiring, the capsule is oriented to the reentry attitude as shown in position G, and the retropackage is jettisoned. As the capsule enters the atmosphere the control system introduces a roll rate of 10 to 12 degrees per second and also maintains rate damping, which prevents large capsule oscillation from building up. At about 42,000 feet, the drogue parachute is deployed and its action gives stability to the capsule prior to deploying the main parachute at 10,000 feet. Upon impact into the water, a small balloon is released carrying an antenna aloft to aid in capsule recovery.

ACCELERATION AND IMPACT ATTENUATION

One of the major concerns in the design of the Mercury capsule is to protect the pilot from excessive accelerations during flight and in landing. The escape rocket, if fired in an off-the-pad abort or at high altitude where the drag forces are low, would place upon the astronaut an acceleration level of 20g for a period of almost 1 second. Impact on the water would give acceleration levels as high as 40g for a few milliseconds. A contoured couch which evenly distributes a man's weight was developed and tested. Normal exit G profiles were run, and the subjects demonstrated ability to control and do tasks which are necessary for normal capsule functions. Tests in which accelerations reached values as high as 25g were also conducted and demonstrated the validity of this support system in case of the escape-rocket firing. However, a major problem still existed for the case of land impact or impact on the water with a high horizontal wind profile. It is believed that a satisfactory solution to this problem has been accomplished by the accordion-like air cushion design shown in figure 8. The air cushion consists of a 4-foot skirt made of rubberized Fiberglas that connects the heat shield to the rest of the capsule. After the main parachute is deployed, the heat shield is released from the capsule and the bag fills with air. Upon impact, the airtrap between the heat shield in the capsule is vented through holes in the skirt as well as through portions of the capsule which are not completely airtight. Thus the desired cushioning effect is provided.

MERCURY FLIGHT TEST VEHICLES

In the preceding sections the capsule and its features have been discussed. In this section the booster for the Mercury capsule and the steps taken to assure its reliability are discussed.

Figure 9 shows the three rocket flight test vehicles used in Project Mercury. The Little Joe System shown at the left is a cluster of solid-propellant rocket motors used in the research and development program. No manned flights are contemplated with this booster although successful flights with small primates aboard the capsule have been made. The Redstone Booster shown in the center of figure 9 will be used for training flights for the astronauts. Before the astronauts' training program begins, an animal will be sent aloft in one of the earlier flights to demonstrate the system. The Mercury-Atlas combination is shown at the right. In the Atlas program, animals will also be sent aloft before a man is put in orbit.

The reliability of each of these systems is of obvious importance in this program. Figure 10 outlines a quality assurance program being followed in the booster programs. Standard booster hardware is being used to take advantage of all the experience gained in conducting the weapons system program of which the basic boosters are a part. The reliability of each system will be based upon the nominal performance of each individual component and subsystem. Also, as these systems are assembled in the various industrial plants, each part is being marked or tagged with a Project Mercury label. Although the assembly-line technique has been established for these boosters, 100-percent inspection of all parts will take place to assure the highest quality control possible. Upon assembly of a booster system, a comprehensive rollout inspection will be made. The history of all parts going into a particular booster will be carefully documented and reviewed. In this manner, the operational proficiency of all systems and their individual components are made known. After the capsule has been mated to the booster and the mechanical and electrical integration is completed, a flight safety review board will be held. This review board reports on the overall expected reliability of the two systems - that of the capsule and booster together. Only after the capsule-booster combination meets the requirements of the flight safety review board will approval for flight be given.

MERCURY ORBIT, TRACKING, AND RECOVERY

Orbit Selection Criteria

Selection of the firing azimuth is very important in the overall Mercury operation. Figure 11 presents the orbit selection criteria used. It was most advantageous to use the existing tracking stations established for other National programs. (See ref. 3.) This resulted in the minimum number of additional stations which had to be implemented. A total of 17 stations, including the control center at Cape Canaveral, will be active while the Mercury capsule is in orbit. Of these 17, two of the stations will be located onboard ship in the mid-Atlantic and Indian Oceans. At each tracking station, there will be telemetry readout giving the personnel real-time indication of the pilot's condition and the capsule systems. Prior to each flight, aeromedical and capsule systems specialists will be sent to each of the monitoring stations facilities. After each flight, these specialists will aid in evaluating the pilot and capsule systems' performance. The down-range tracking facilities of the Atlantic Missile Range will be used for the normal reentry tracking. In this way, the capsule may be followed on radar from the time it begins its reentry until impact. Constant communication by voice will be possible during this time. In order to determine the exact altitude and velocity of the capsule, the tracking facilities in the continental United States will be used extensively for determining the correct time of retrofiring so that the capsule will land in the predicted impact area. In the United States, there are six such tracking installations. Another requirement for the orbit selection is that the capsule should pass over friendly territory and maintain itself in a temperate zone. It is of interest to review the philosophy used in establishing the ground-station requirements.

Ground Stations

Figure 12 presents the ground-station selection criteria. Continuous tracking is required from Hawaii to Bermuda. During each orbit, the retrotiming device must be capable of being reset along with other ground command capabilities. Continuous contact during launch and through insertion is required to determine the orbit characteristics and pilot's well-being. Frequent voice and telemetry contact must be maintained throughout the orbit. There must exist sufficient tracking information to provide continuous impact prediction; that is, at any time during the flight, the recovery forces should know exactly where the capsule would impact if the retrorockets were fired at that time.

Recovery

It is not feasible to provide world-wide recovery forces; therefore, certain areas have been designated as primary recovery areas (fig. 13). A long recovery area is provided (from Cape Canaveral toward the Bermuda Islands) to include all impact points which might occur due to an early abort. Between the Bermuda Islands and the Canary Islands are other primary recovery areas. These areas are so located that if orbital velocity or insertion angle is not correct, firing of the retrorockets would cause the capsule to impact in these designated areas. If the initial orbit is not correct and conditions were to prevent the capsule from making three orbits, a second impact area is established at the end of the second orbit, as shown. The impact area from a nominal flight, however, occurs at the end of the third orbit down the Atlantic Missile Range, designated here as area 3. As mentioned previously, this would mean continuous tracking of the capsule during entry from Hawaii until impact.

THE ASTRONAUT AND HIS TASK

The flight of a Mercury capsule into orbit and return, fundamentally, is an extension of the flight envelope of aircraft. The majority of sensations and demands on the astronaut are similar to those imposed on the pilot of any highly maneuverable, high-performance aircraft. For this reason, the prime technical qualification for the Mercury astronaut was that he should be an experienced pilot, trained in objective flying; i.e., test flying. His presence in the Mercury capsule can be expected to increase the chances of a completely successful mission because he has the capability and ability to take control of the capsule in the event of a malfunction of many of the automatic systems.

The astronaut in Project Mercury will furnish other important milestones in man's conquest of space. Some examples of the kind of scientific information that this first venture of man-into-space makes possible are listed in figure 14.

The Mercury orbital missions will permit the study of the effects of prolonged weightlessness on the physiological reactions, the subjective psychological reactions, and the performance of the astronaut. Of particular interest will be the effects of weightlessness on the function of the respiratory and circulatory systems. Telemetered electrocardiogram and breathing rates will make it possible to determine not only the effects of prolonged weightlessness itself, but the effects of transition from high accelerations to 0g and back to the high accelerations associated with launch and reentry. Problems associated with eating and drinking in prolonged weightless flight can also be studied. Stress hormone studies, together with pre- and post-physical examinations, will allow assessment of the body's physiological reaction to the total envelope of flight stresses.

Subjective psychological phenomenon likely to be effected by the weightless environment can be studied through voice reports and capsule instrumentation. The ability of the astronaut to orient himself in space can be determined. The effects of the reduction in proprioceptive cues in time estimation can also be determined. The extent of the occulogyric and autokinesis and occulogyric illusions in a weightless environment should also be of interest.

Of utmost practical importance to future manned space flight efforts will be the quality of the astronaut's performance in space. Accuracy of manual attitude control should provide a good test of psychomotor performance capability. Monitoring of the capsule orbital systems should provide an indication of the vigilance and perceptual accuracy. Navigation will test reasoning and visual discrimination of earth terrain features and heavenly bodies outside the capsule.

In reference 4, the following statement is made in regard to the importance of Project Mercury. "It has become increasingly evident that the full utilization of space flight for scientific and exploration purposes will depend on man's ability to participate in the flight mission. While, in principle, it is possible to devise increasingly complex instruments and automatic systems, in practice, the availability in the vehicle of human intelligence and decision-making capacity will prove to be essential for successful accomplishment of many advanced space missions."

It is believed that Project Mercury will provide the baselines by which the future space vehicles will be built around the most valuable and useful machine - man himself.

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OBJECTIVES

1. ORBITAL FLIGHT AND RECOVERY
2. MAN'S CAPABILITIES IN SPACE ENVIRONMENT

BASIC PRINCIPLES

1. SIMPLEST AND MOST RELIABLE APPROACH
2. MINIMUM OF NEW DEVELOPMENTS
3. PROGRESSIVE BUILD-UP OF TESTS

METHOD

1. DRAG VEHICLE
2. ICBM BOOSTER
3. RETRO ROCKET
4. PARACHUTE DESCENT
5. ESCAPE SYSTEM

Figure 1.- Project Mercury. NASA

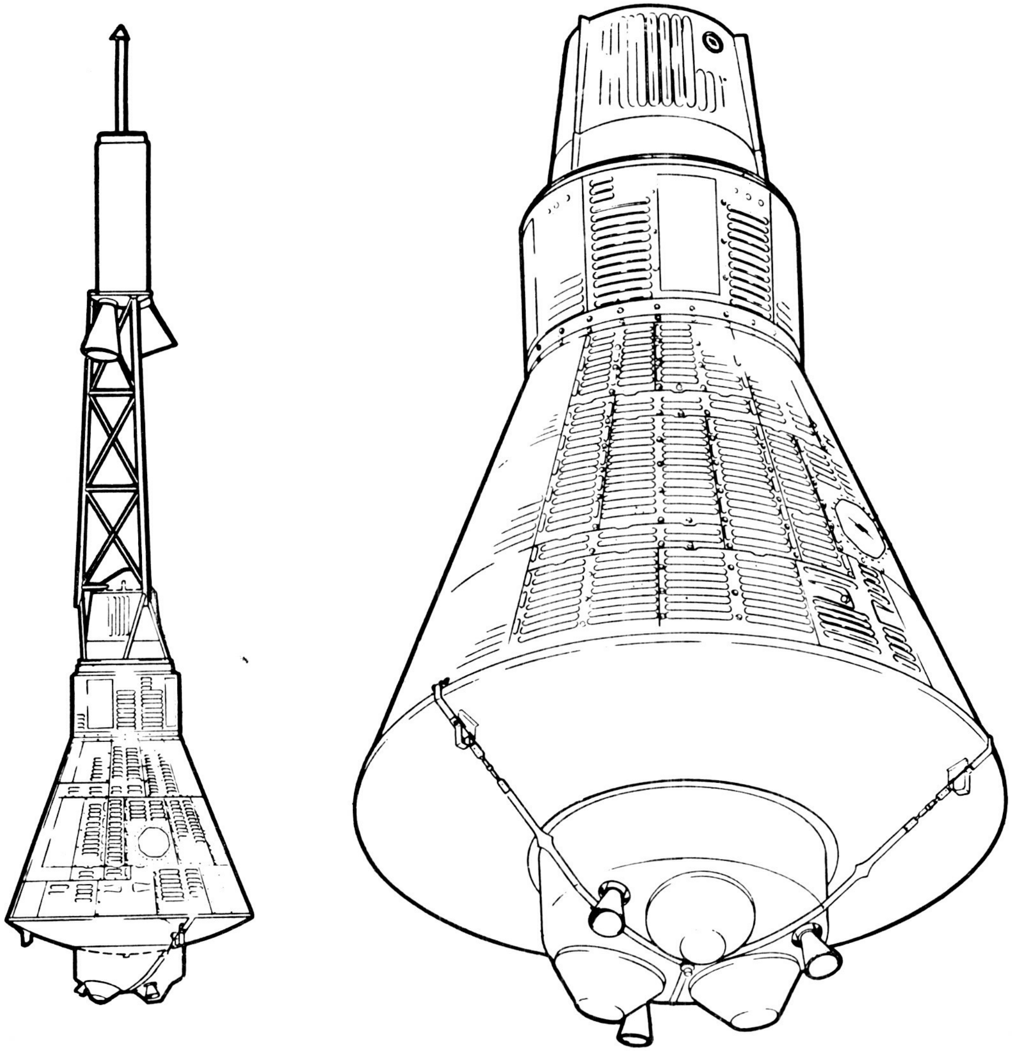

Figure 2.- Capsule and escape system configuration. NASA

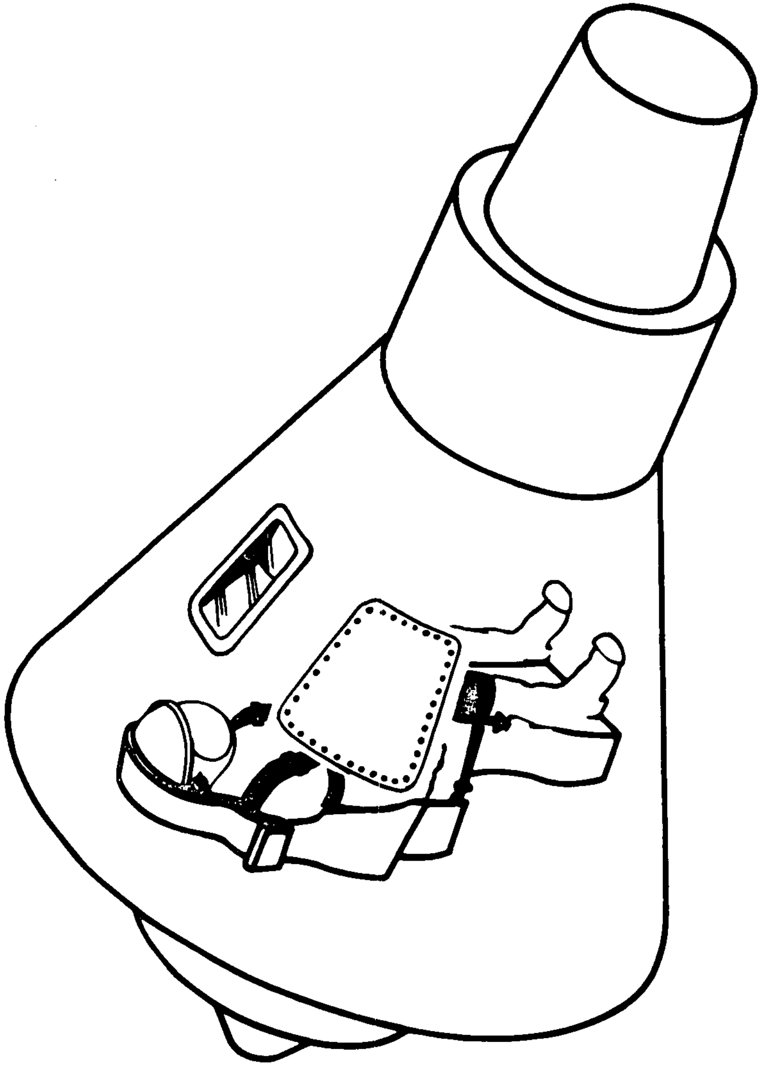

Figure 3.- View showing relationship of pilot, window, and emergency egress.

NASA

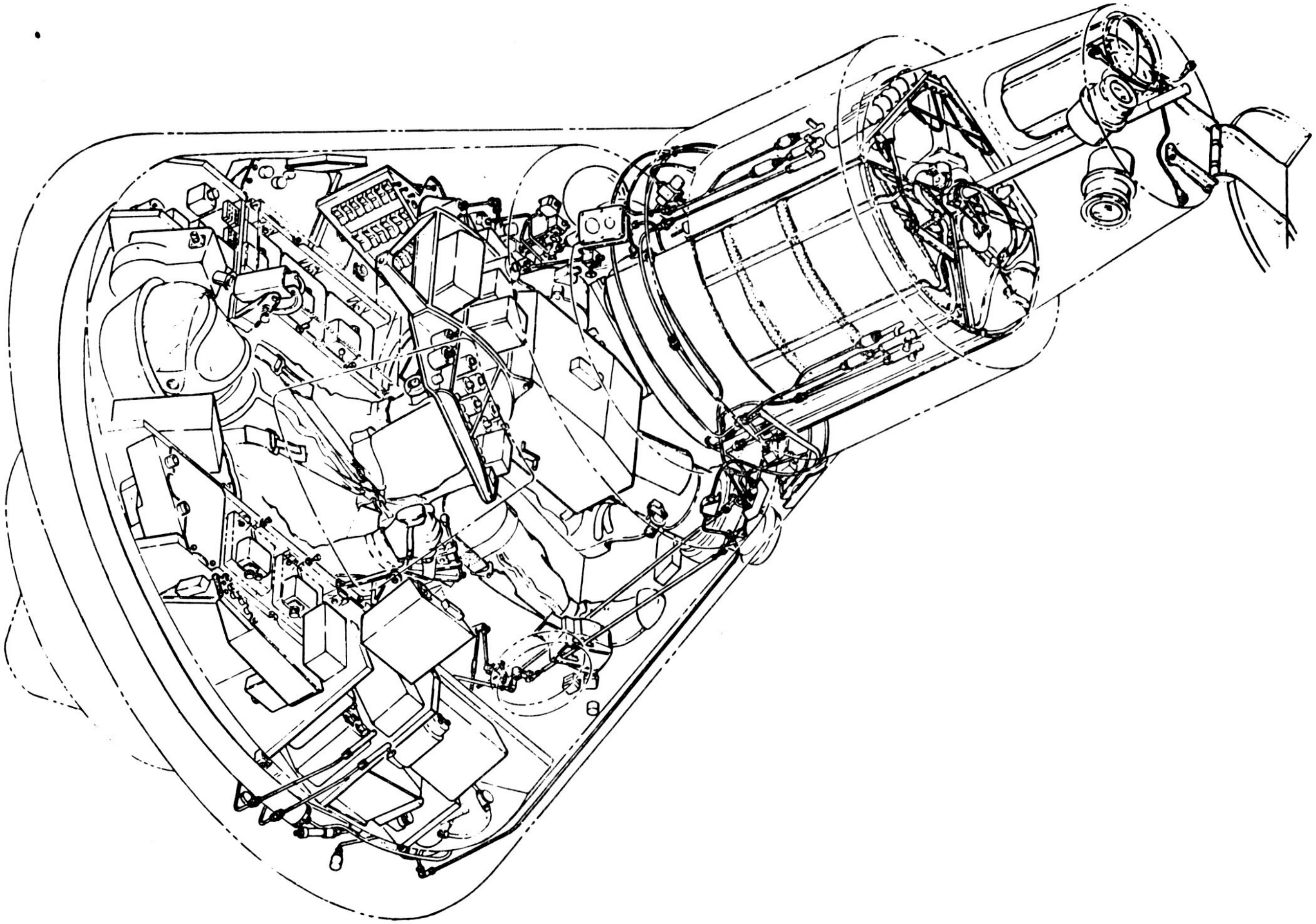

Figure 4.- Capsule internal arrangement. NASA

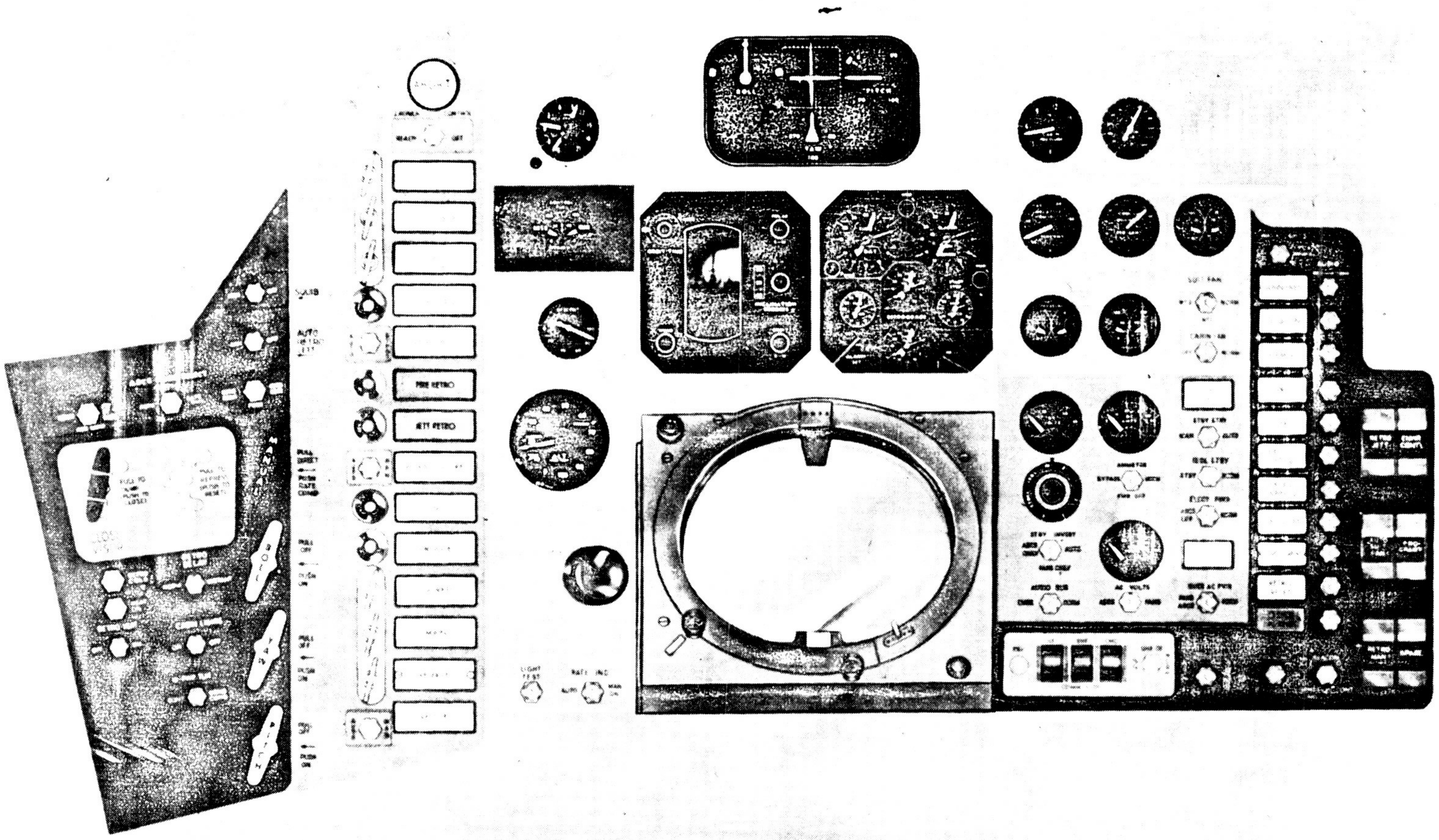

Figure 5.- Pilot's panel.

B-59-1028
NASA

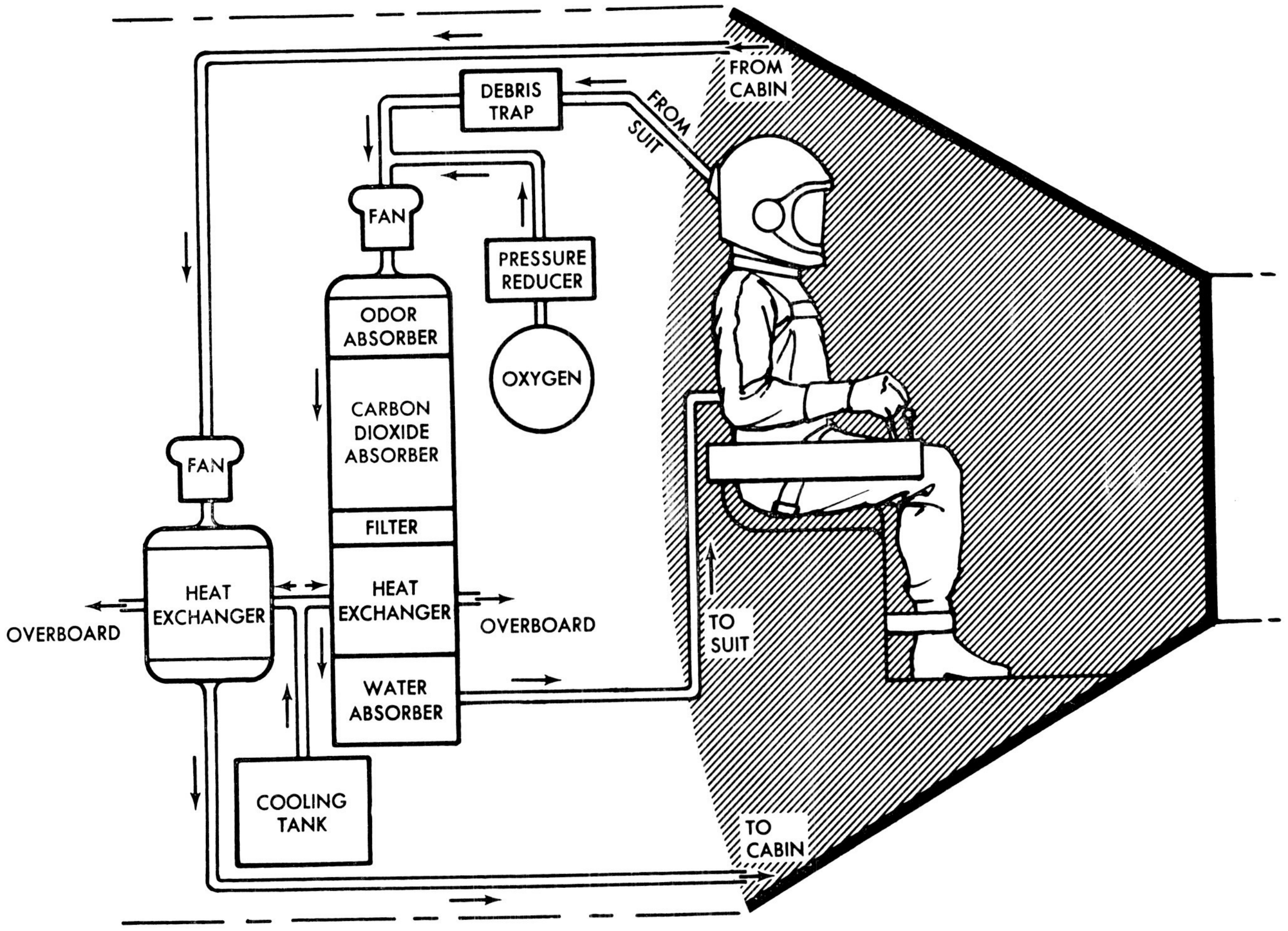

Figure 6.- The Mercury environmental control system.

NASA

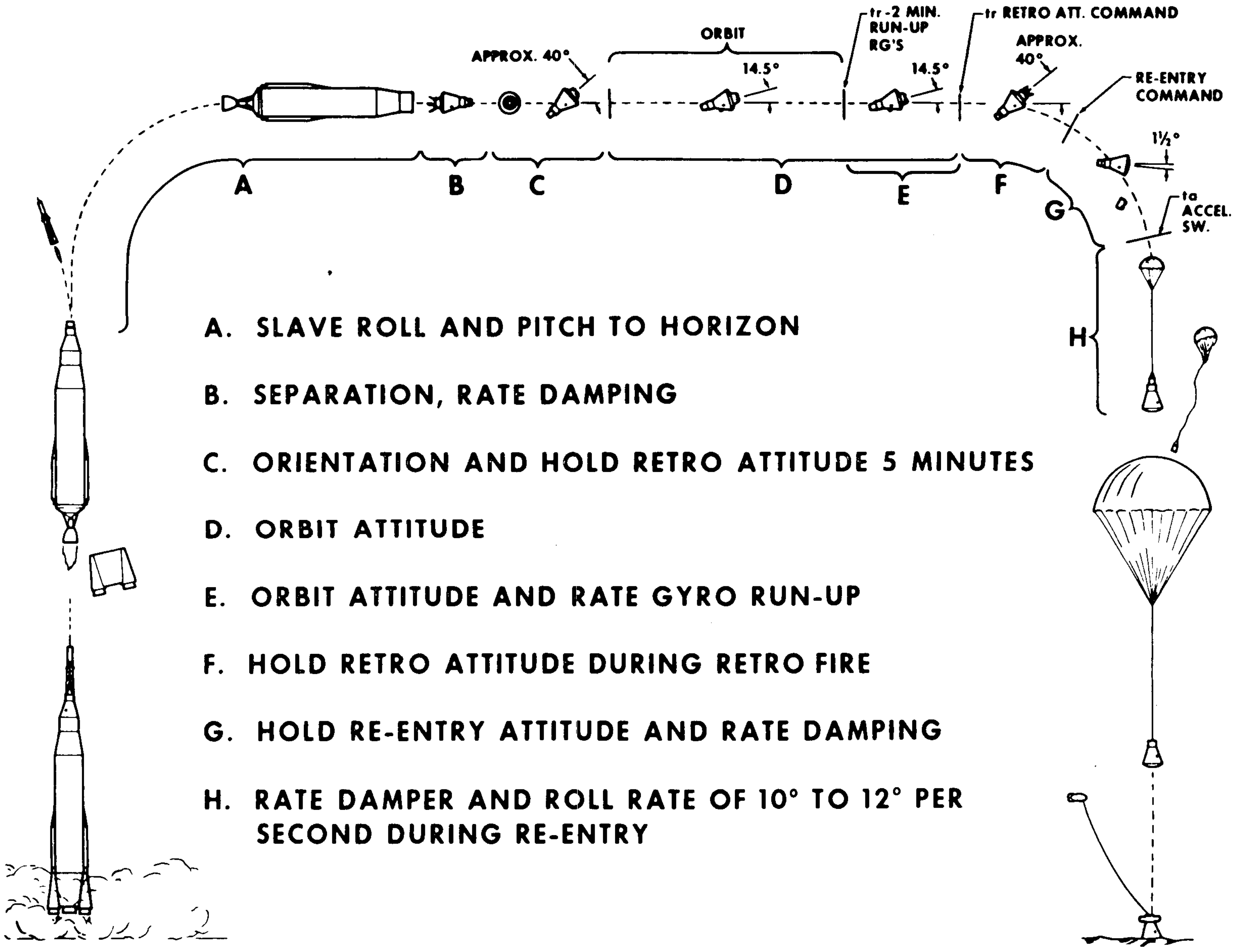

Figure 7.- Automatic stabilization control system normal operation.

NASA

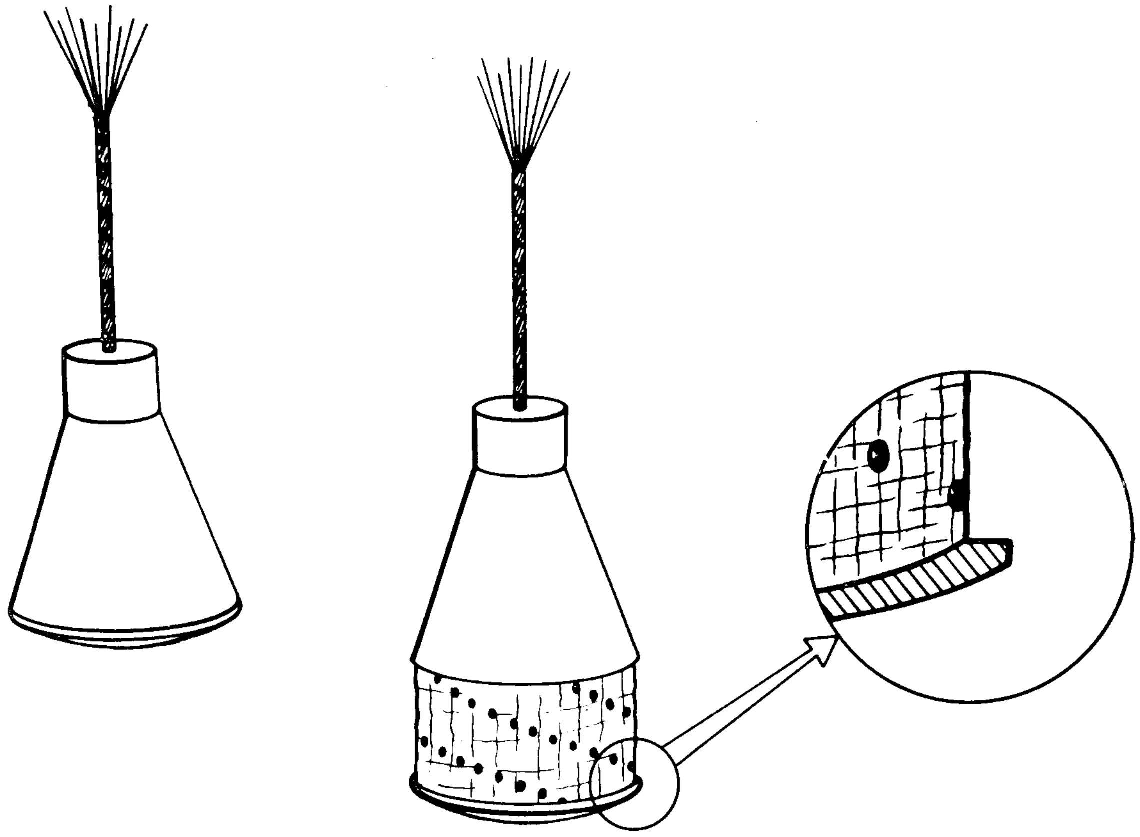

Figure 8.- Air cushion for impact attenuation. NASA

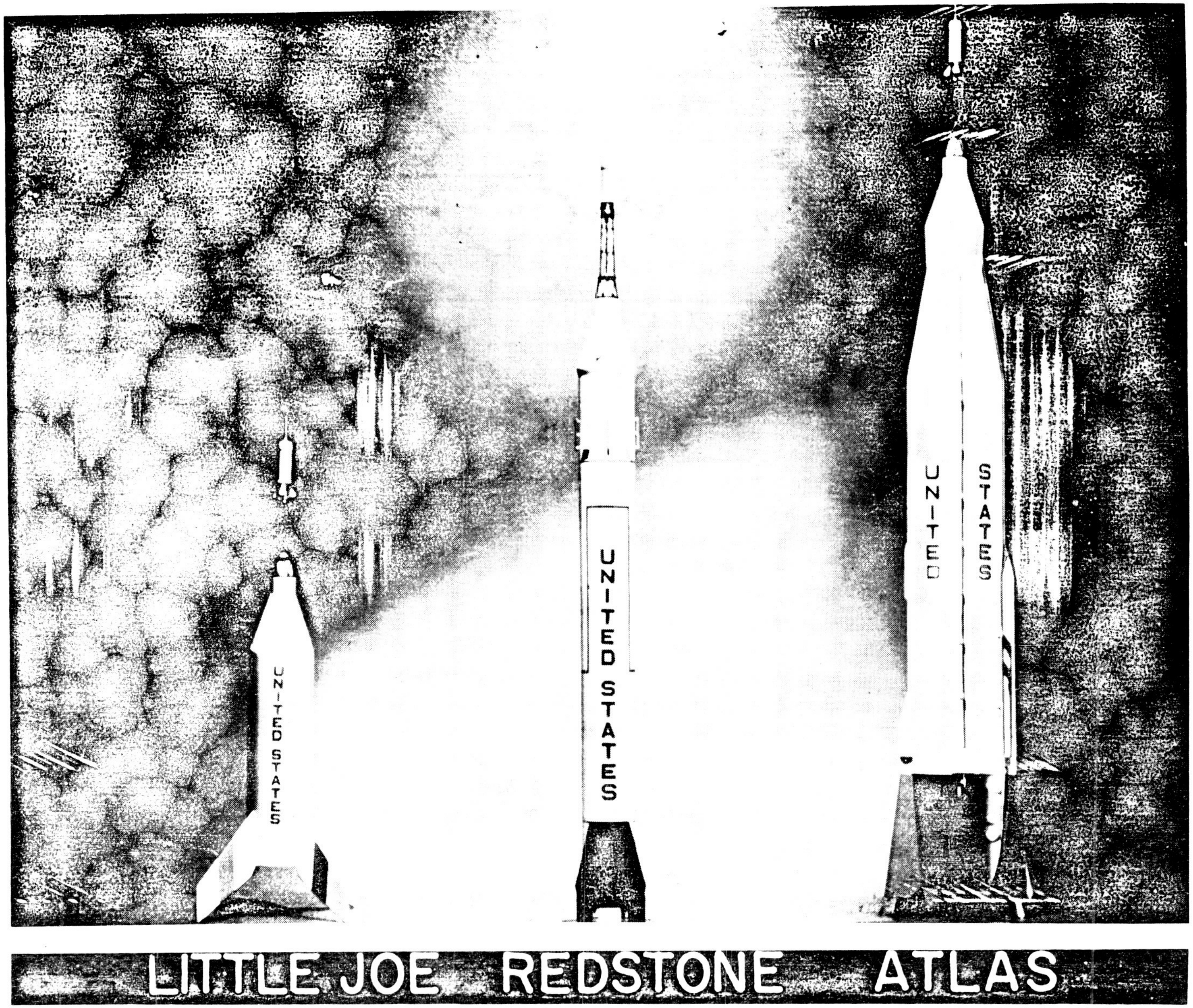

Figure 9.- Project Mercury flight-test vehicles. NASA

STANDARD BOOSTER HARDWARE

SELECTION OF INDIVIDUAL COMPONENTS AND SUBSYSTEMS

    Nominal Performance

MARKING OF PARTS

100-PERCENT INSPECTION OF PARTS

COMPREHENSIVE ROLL-OUT INSPECTION

FLIGHT SAFETY REVIEW

Figure 10.- Booster quality assurance.   NASA

1. USE OF EXISTING TRACKING STATIONS
2. USE OF AMR FOR NORMAL LANDING
3. REMAIN OVER CONTINENTAL U.S. FOR CONSIDERABLE TIME FOR TRACKING DURING ORBIT AND REENTRY
4. ORBIT OVER FRIENDLY TERRITORY AND IN TEMPERATE ZONE

Figure 11.- Project Mercury orbit selection criteria.

NASA

1. CONTINUOUS TRACKING FROM HAWAII TO BERMUDA
2. RETRO-TIMER RESET AND GROUND COMMAND CAPABILITIES DURING EACH ORBIT
3. CONTINUOUS CONTACT DURING LAUNCH AND THROUGH INSERTION
4. MAINTAIN FREQUENT VOICE AND TELEMETRY CONTACT
5. CONTINUOUS IMPACT PREDICTION

Figure 12.- Project Mercury ground station selection criteria.

NASA

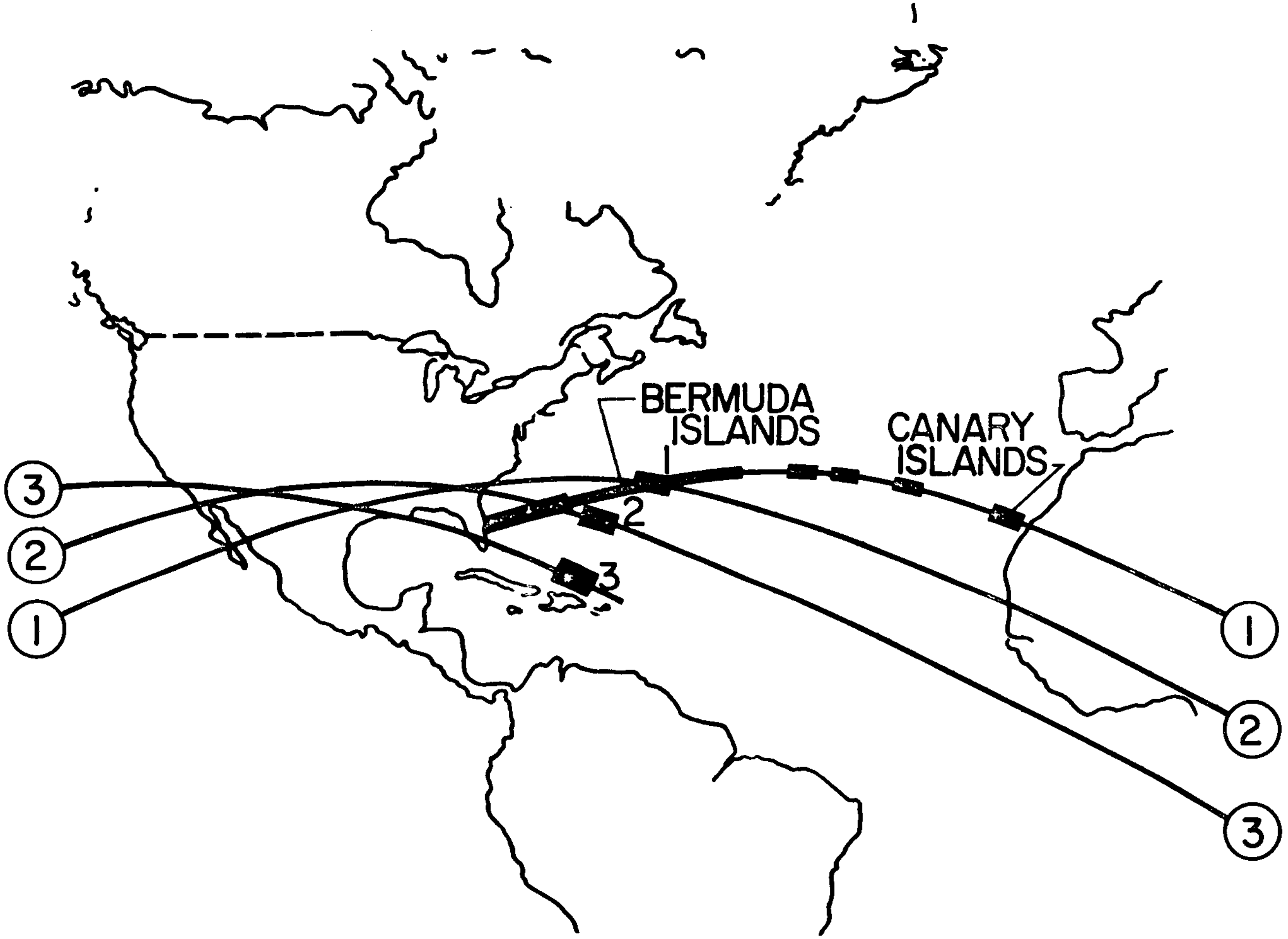

Figure 13.- Project Mercury anticipated recovery areas. NASA

NASA - Langley Field, Va.

SOME EXAMPLES OF RESEARCH OBSERVATIONS OF THE BIOLOGICAL EFFECTS OF PROLONGED WEIGHTLESSNESS WHICH PROJECT MERCURY MAKES POSSIBLE

PHYSIOLOGICAL	PSYCHOLOGICAL	TASK PERFORMANCE
Function of the circulatory system	Orientation	Attitude control
Eating and drinking	Time estimation	Capsule systems monitoring
Pre and post flight tests of stress reactions	Autokinesis and occulogyric illusions	Navigation

Figure 14.- Examples of Mercury aeromedical research.

NASA