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MAN'S SPACE VENTURE

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Project Mercury, our initial man-in-space program, represented a "venture" in every sense of the word. It was an undertaking which was definitely speculative in the opinion of many people. Manned space flight ventured forth into a new and unknown physical environment, intellectually into new technologies of engineering and management, and sociologically into a new concept of large-size governmental support of technical development in peacetime without the impetus of war or defense.

It is difficult to discuss the venture of man into space because of the interrelationships of the three types of venturing noted above and because of the concurrent nature of the approaches to the many problems which faced us in this program. This is a review of part of the sociological or political climate that led to the decision to undertake the project, the technological background that permitted us to undertake it, and the problems that we faced in accomplishing the Nation's initial steps in manned space flight.

SOCIOLOGICAL CLIMATE

The United States has historically been in a position of leadership in all types of exploration, and the American people as a group have always had a competitive nature. With the advent of plans for the International Geophysical Year the exploratory and competitive nature of this country led to our planning to launch a small instrumented Earth satellite in order to derive the greatest benefit from this proposed period of new scientific exploration.

The previous leadership of the United States in the field of aviation has been based on continual research and development of means for flying higher, faster, and farther. It seemed only natural to many of us to extend this experience in manned aircraft flight into manned space flight as the next step in the "higher-faster-farther" game.

The relatively unexpected flight of the Soviet Sputnik on October 4, 1957, really sparked the competitive spirit of the Nation. Many groups advanced plans for regaining what appeared to be a loss of national prestige and a loss of our position of world leadership in science and technology. Consideration of these various proposals led the national administration and the Congress to embark on a new era in Federal support of technology. It was determined that the survival of this Nation in the present "Technological Age" depended upon the establishment of a broad capability in engineering and science and that a program of space exploration with relatively large-scale support by the Federal Government was a suitable focal point for this development of capability.

The passage of the National Aeronautics and Space Act of 1958, which established the NASA, was the first major step in this new venture of government into the large-scale development of technology in peacetime. Since this was a first step in a new venture, there were many questions upon which many individuals and groups held opinions but for which no one really knew the answer. Among these questions were:

(1) Just how large should be the Government's investment in such a speculative undertaking?

(2) What should be the division of effort between the manned and unmanned phases of this exploration?

(3) What should be the division of effort between the peaceful and the military or defense aspects of the program?

In the area of financial support, the space program started small in order to minimize the risk of potential waste. The support was built up as we learned what was needed, and it now appears to be approaching a leveling-off point. In the areas of "peaceful vs. military" and "manned vs. unmanned" efforts the problems, and the answers, have been rather intertwined. Since the capabilities of man in a space-flight environment were unknown, it appeared wise to devote part of the peaceful program to a determination of these capabilities before embarking on a military program to utilize these capabilities for national defense. In the unmanned program the differences between the civilian scientific and military defense applications were not easily visualized, and thus simultaneous "peaceful" and "military" programs were undertaken. The result of our experience has led us to a situation at present where the answers seem to be, as shown in figure 1:

(1) The total financial support is leveling off at about 7.5 to 8 billion dollars per year, just over 1 percent of our gross national product.

(2) The manned program is receiving about one-half of the total support.

(3) The civilian and military share about equally in the unmanned effort, and a military-manned program now seems to be getting underway.

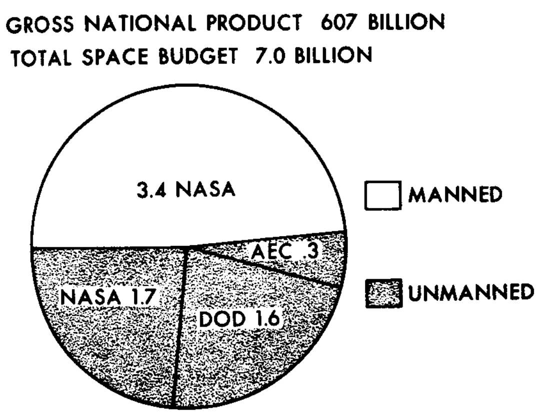

FIGURE 1.—Space budget for fiscal year 1964.

Thus we can see that the past 6 years of experience have developed partial answers to these questions, but the inherent lack of answers in the early days of the program did pose problems.

TECHNOLOGICAL BACKGROUND

Figure 2 shows a general outline of the development of the technological background that made it possible for this country to undertake a manned space-flight program. The research and development capacity of this country during the past several decades has lain in the basic research establishments like NACA and the universities, in the armed services, and in the industry. The primary contributions of each of these elements is listed on the left in figure 2. The application of these contributions was, up until 1958, devoted primarily to two areas: aircraft and missiles. The development of these two classes of vehicles produced technical knowledge in the disciplines shown in the center of figure 2. As indicated in the figure, the combined knowledge in these two areas resulted in the overall technical basis for manned space flight.

Some of the more specific items in this buildup of capability indicate some of the problems we faced.

REENTRY HEATING

One of the major new problems posed by the missile and space age was that of thermal protection of a vehicle during its reentry into the atmosphere from the high altitudes and high speeds associated with intercontinental-range ballistic missiles. H. J. Allen of the NACA Ames Aeronautical Laboratory proposed that the basic answer to this question lay in the use of very blunt high-drag reentry bodies. With such bodies most of the high kinetic and potential energy could be dissipated in the form of shock-wave drag, which heats the air, and only a small fraction is dissipated as skin-friction drag, which heats the body.

Various proposals were advanced for coping with the amount of heat that could go into the body. Among these were (1) the use of heat sinks, wherein the body material has a high enough heat capacity to absorb the thermal energy without melting; (2) the use of transpiration cooling, wherein a liquid or gas is ejected from the body into the boundary layer to prevent much of the heat from entering the body; and (3) the use of ablation, wherein the melting or decomposition of a thin layer of the body surface absorbs heat (as does the heat sink) and also the molten or decomposed material flows into the boundary layer and blocks part of the heat (as does transpiration cooling). The first and third methods were developed in ground and flight tests by the Air Force and the Army, and by the time Project Mercury was ready for serious consideration, the feasibility of both methods had been demonstrated.

The remaining questions then concerned such mat-

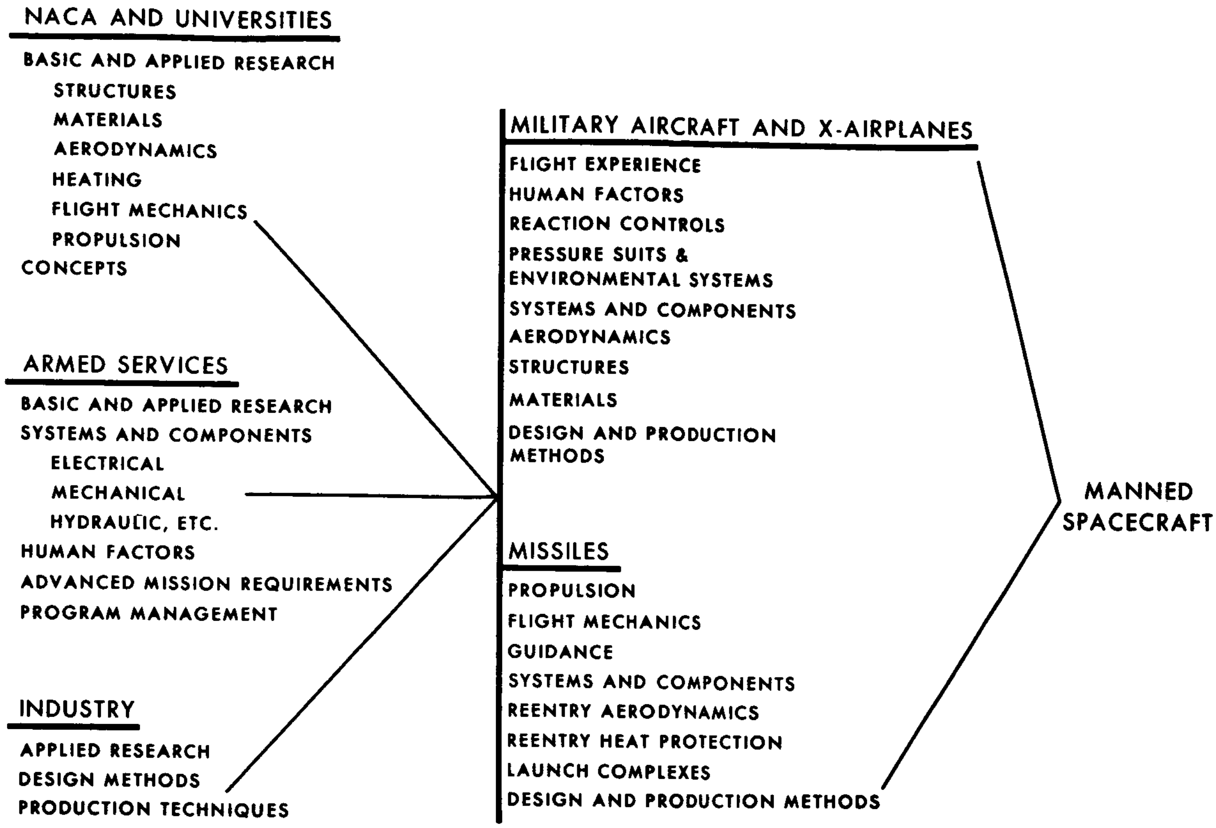

FIGURE 2.—Spacecraft development.

ters as material selection, fabrication techniques, structural design techniques, and weight trade-offs. These were answered by the design and development phases of Project Mercury.

REENTRY LOADS

Another example of technological problems of early manned space-flight planning is the question of reentry loads. Some of the first studies made in this area were based on a ground rule that the pilot should never be subjected to more than 12g of acceleration. This was based on aircraft flight experience with seated pilots. The earliest solution proposed was to use a lifting reentry body, which would inherently be heavier than a ballistic body and would thus require either that an extra stage of propulsion be added to the Atlas ICBM or that the program be delayed until a more powerful launch vehicle became available. The final solution, the one actually used in Mercury, was to use the Faget contoured couch which permitted the pilot to withstand safely the higher loads inherent in the ballistic design.

PROGRAM HISTORY

Preapproval Era

Prior to October 1958, when Project Mercury was officially started, a great deal of study effort was expended by various groups to define an adequate first step in a manned-space-flight program. Concurrent and independent (but coordinated) studies by the NACA, Air Force, Army, Navy, and ARPA culminated in the formation of a Joint Manned Satellite Panel by NACA and ARPA in the fall of 1958. This panel collected the results of the various studies and proposed to the Director of ARPA and the newly appointed Administrator of NASA a program that was accepted and approved in early October 1958. The program was as follows.

The initial approach to manned space flight should have two major objectives:

(1) Achieve manned Earth-orbital flight and recovery.

(2) Determine man's capabilities in a space-flight environment and in those environments to which he

would be subject upon going into and returning from space.

These basic principles should be adhered to in the project. These were the use of:

(1) The simplest and most reliable approach

(2) A minimum of new developments

(3) A progressive buildup of tests

The basic method for accomplishing the project should be the use of:

(1) A high-drag reentry vehicle

(2) An ICBM for the launch vehicle

(3) Retrorockets for initiating reentry

(4) A parachute descent after reentry

(5) An escape system to remove the spacecraft from the vicinity of a malfunctioning launch vehicle.

The above basic objectives, principles, and method initially established for Project Mercury have remained essentially unchanged throughout the life of the project.

Immediate Postapproval Era

On October 7, 1958, we were faced with an enormous task for which we were fairly well prepared technologically but relatively unprepared in organization, management, funding, schedule, and policy. We thus had to face immediately the problems in these many areas as well as the detailed technical problems.

Because of the unsettled nature of national policy during the year between Sputnik I and the official start of Mercury, the funds available for beginning such a program were limited. However, we were able to begin. Upon approval of the program, a multipronged effort began to:

(1) Define spacecraft specifications

(2) Select a spacecraft contractor

(3) Define launch-vehicle requirements

(4) Arrange for the launch vehicles to be supplied (Atlas by USAF, Redstone by Army, and Little Joe by NASA; see fig. 3)

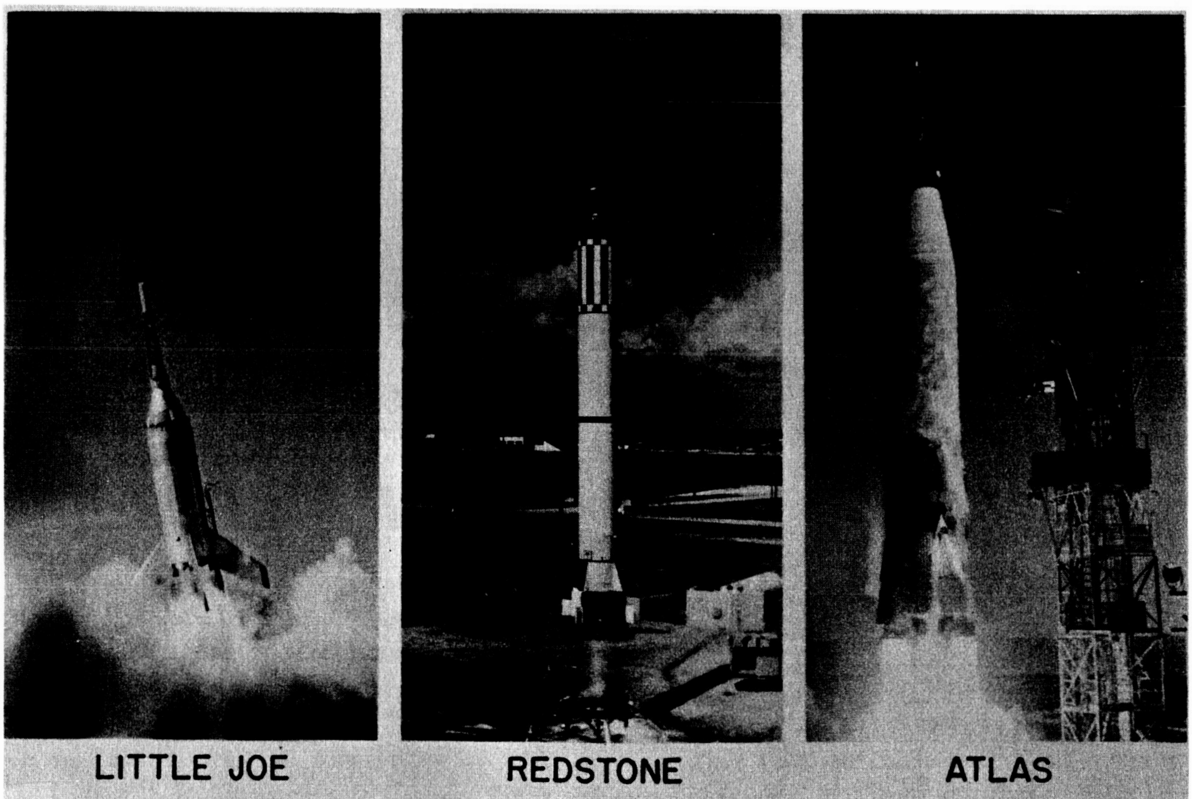

FIGURE 3.—Project Mercury launch vehicles.

(5) Build up a management organization
(6) Define mission and network requirements
(7) Select and train astronauts

Manufacturing and Development Period

The first year of the program, which covered the immediate postapproval era and the first half-year of the manufacturing and development period, saw the buildup of a management staff and the outlining of program, schedule, and budget through better definition of the job to be accomplished. The program was well enough defined by early in 1960 to allow estimates of cost and schedule that were very close to the final numbers.

The second year of the program, 1960, saw the appearance and solution of many of the technical hardware problems in the spacecraft and launch-vehicle systems. These problems appeared when detailed design, manufacturing, and test efforts showed that the state of the art in many systems such as parachutes, electrical power systems, electronics and so on, had not advanced as much as we had hoped. In fact, this advancement of the state of technology is one of the primary reasons for the whole space program—simply the need to make this Nation strong in all ways.

This second year of Project Mercury also saw the development of a set of functional relationships among the various Government and industry groups involved in Mercury. These relationships are shown in figure 4. This chart illustrates the complex nature of such a program and the large number of diverse groups whose talents must be drawn together to carry out successfully a manned space flight. These relationships have evolved and changed in detail during the past several years, but the basic pattern and spirit of cooperation have remained.

Program Growth Period

The birth of the present manned-lunar-landing program was another product of the 1960-61 period.

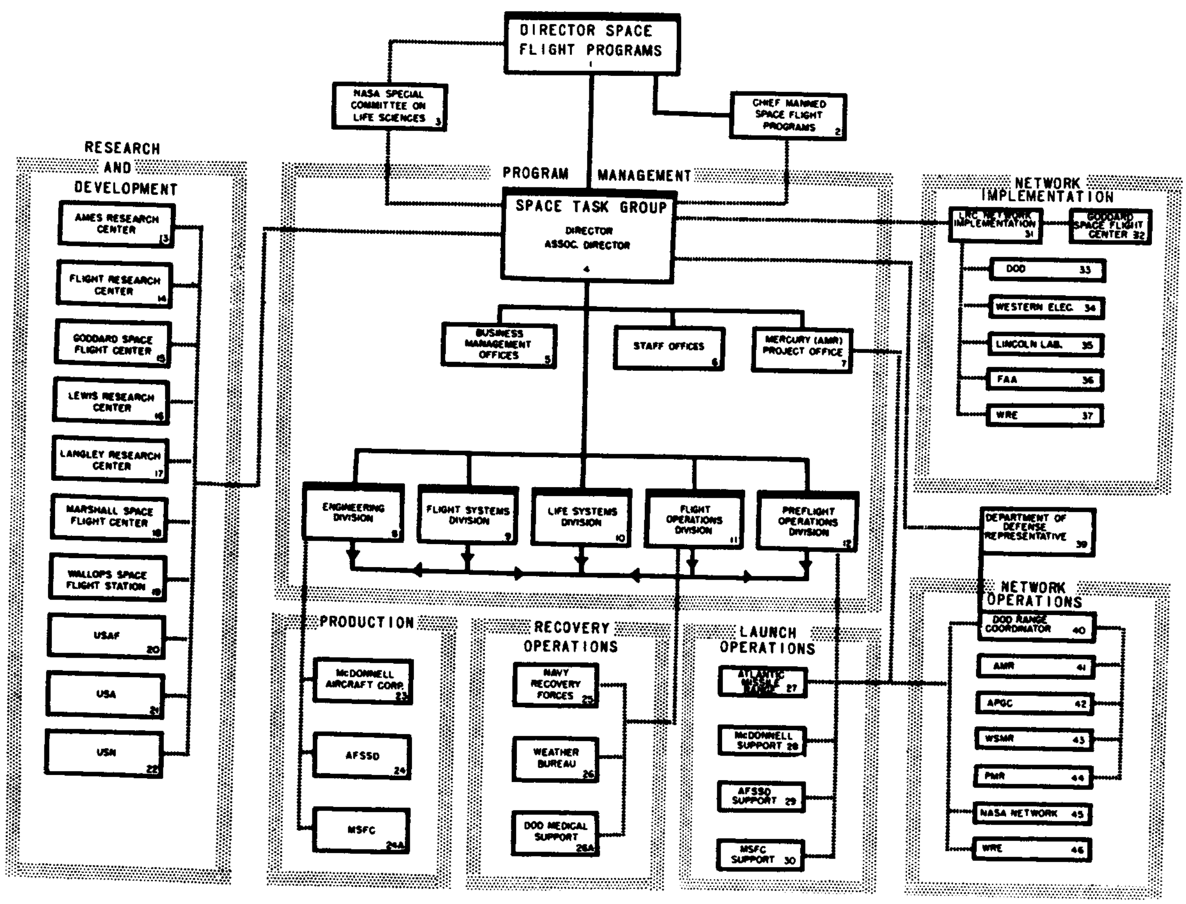

FIGURE 4.—Project Mercury functional relationships.

A study directed toward establishing our next major goals in manned space flight beyond Mercury indicated that a system which included a small Earth-orbiting laboratory and which was capable of circumlunar flight represented a step that was both significant and within the expected rate of development of our technology. During 1960 a research program was undertaken within NASA, and a design study and development program was started within industry, to better define the Apollo system and its capabilities.

Following Alan Shepard's flight on the Mercury-Redstone, the decision was made that the Apollo program would be focused on a manned lunar landing and return within the decade. Other events of the year were the decision to undertake Project Gemini as a step between Projects Mercury and Apollo.

Apollo, which will be discussed in more detail in subsequent papers, requires a really major step beyond Mercury in manned-space-flight technology. Requirements for mission control are as follows:

Mercury	*Apollo*
Up to 1 day	7 days
No maneuvering	Maneuvering
Near-Earth tracking	Near-Earth and deep-space tracking
Simple computing	Complex computing
Ballistic reentry	Reentry control
Recovery control	Recovery control
Training	Training

There is a marked increase in flight duration, maneuvering in space, more complex tracking and computing, and reentry control of a maneuverable spacecraft. All of these differences are accompanied by more complex spacecraft systems and hardware. The size of this step is a basic reason for the Gemini Project. Gemini will give us an intermediate task upon which we can focus to gain lead time in many of these technical areas. The Gemini spacecraft, for example, is larger than the Mercury (fig. 5) in order to carry two men and extra supplies to allow us to gain expe-

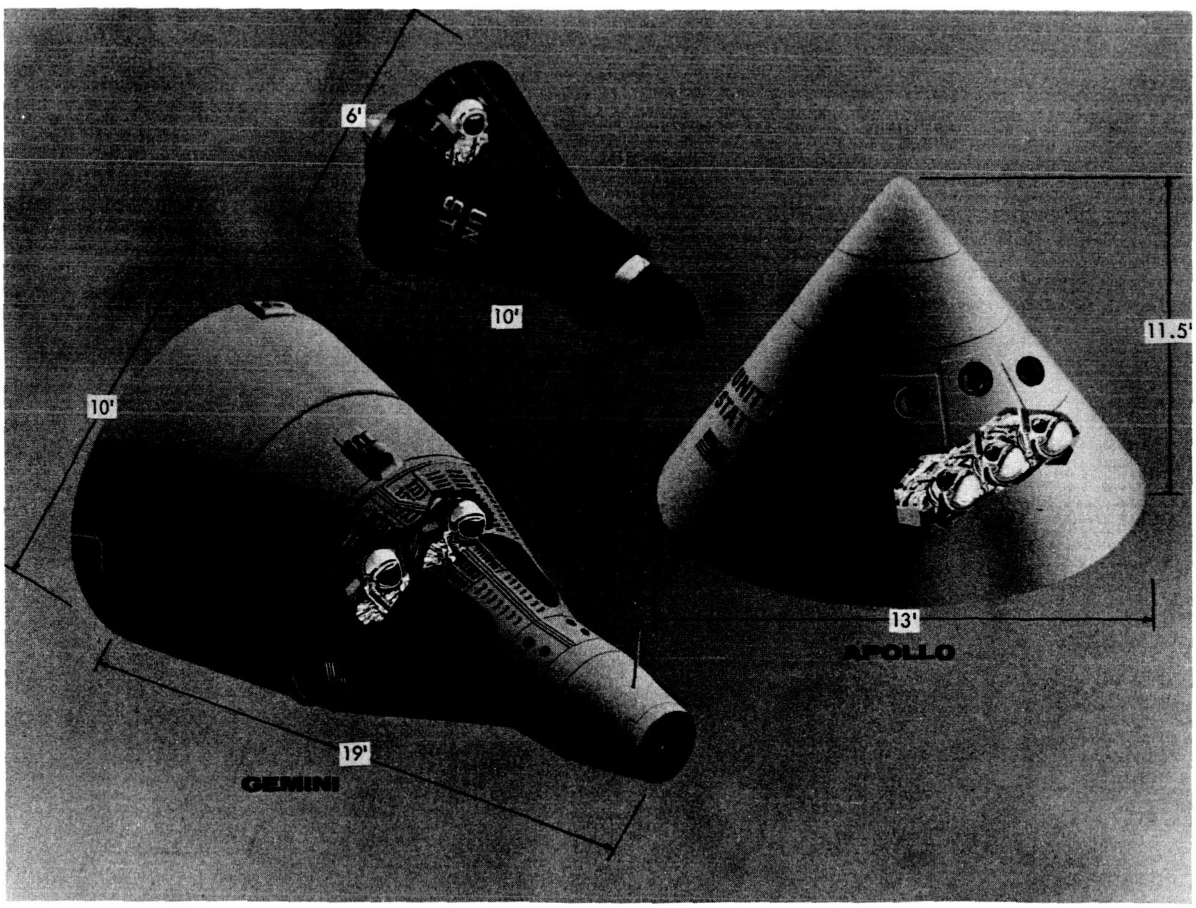

FIGURE 5.—Comparison of manned spacecraft.

rience with long-duration flights. Like Apollo, Gemini will have advanced navigation and control equipment to permit both space and reentry maneuvering. The Gemini mission objectives are as follows:

(1) Preflight checkout techniques
(2) Time-critical launch
(3) Variable launch azimuth
(4) Onboard guidance
(5) In-flight maneuvering (rendezvous and docking)
(6) Long-duration manned flights
(7) Advanced ground-control techniques
(8) Controlled lifting reentry
(9) More complex recovery
(10) Flight-crew training
(11) Ground-crew training

With Project Gemini we will be gaining experience and developing technology that will apply to the Apollo mission. The long-duration flights will give us a chance to exercise men and equipment for long periods of weightlessness in a space environment but close enough to Earth for return, in an emergency, within minutes or hours rather than days. The rendezvous exercises will permit us to develop optimum manual or automatic techniques of bringing two spacecraft together before we are committed to its actual use in the Apollo lunar orbit rendezvous. The use of such advanced systems as hypergolic-fuel reaction controls, onboard guidance computers, and fuel-cell batteries will allow us to learn and solve the problems with this type of equipment before the Apollo preflight schedule becomes critical.

Like 1961, 1962 saw us engaged in many concurrent efforts:

(1) The establishment of the Manned Spacecraft Center in temporary quarters in Houston
(2) The design and start of construction of the permanent Center facilities
(3) John Glenn's orbital flight, followed by those of Carpenter and Schirra
(4) The selection of contractors for the Lunar Excursion Module
(5) The various Saturn V stages
(6) The establishment of the Launch Operations Center (now John F. Kennedy Space Center, NASA) in Florida
(7) Continued design and fabrication of the Mercury, Gemini, and Apollo space vehicles

Going on into 1963, the fifth year, we saw the completion of Project Mercury with Gordon Cooper's highly successful 22-orbit flight, the continuation of detailed design, development, and fabrication efforts on Apollo hardware, and the extremely satisfactory series of successful flights of the Saturn I vehicle which will be used in early Apollo development flight tests and which has laid the groundwork for the design concepts of the Saturn V.

This year of 1964 has begun well. We have made our major move into the new Manned Spacecraft Center facilities; we have made a successful first flight of the Gemini space vehicle; the design of the Lunar Excursion Module has been established; and significant progress has been made in both the design, development, and fabrication of the Apollo space-vehicle system and in the ground facilities in Mississippi and Florida. We are looking forward to further flights of the Gemini this year and to an important series of flight tests of Apollo spacecraft and Saturn hardware during the year.