MAN'S FLIGHT IN SPACE

GEORGE E. MUELLER
Associate Administrator for Manned Space Flight
National Aeronautics and Space Administration

It is a pleasure to participate in this *Man in Space* session of the Fourth National Conference on the Peaceful Uses of Space. Dr. Gilruth has given an excellent review of the origins of manned space flight, the Mercury program, and the beginning of the flight phase of the Gemini program earlier this month.

The previous papers of this session have focused on the details of the Apollo program. Dr. Shea reported on the Apollo spacecraft, Dr. Rees discussed the Saturn launch vehicles, and Dr. Debus told of the plans and progress in the construction of the space port at the Kennedy Space Center.

This paper summarizes the progress to date in the Apollo effort and reviews some overall Apollo considerations and the benefits that the country will gain from Apollo. Figures 1 to 4—photographs and artists' drawings of facilities at the Marshall Space Flight Center, Kennedy Space Center, and Mississippi Test Operations Site—are a progress report on filling the pipeline for the nationwide Apollo effort.

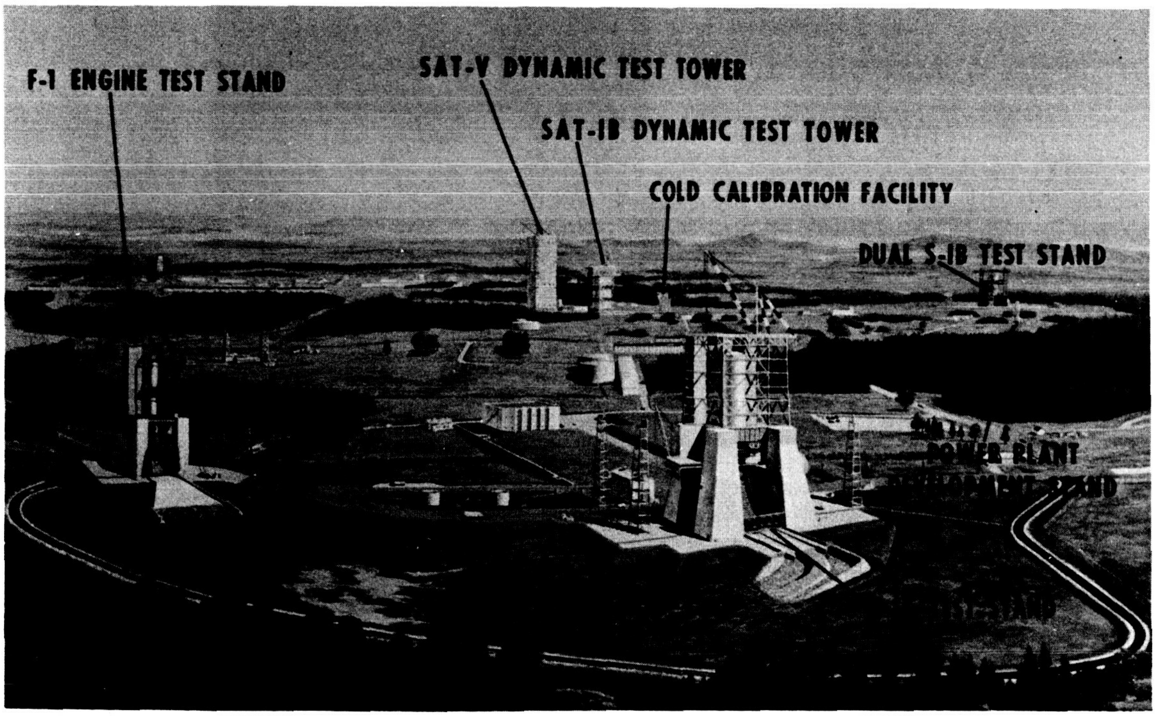

FIGURE 1.—Test area at Marshall Space Flight Center.

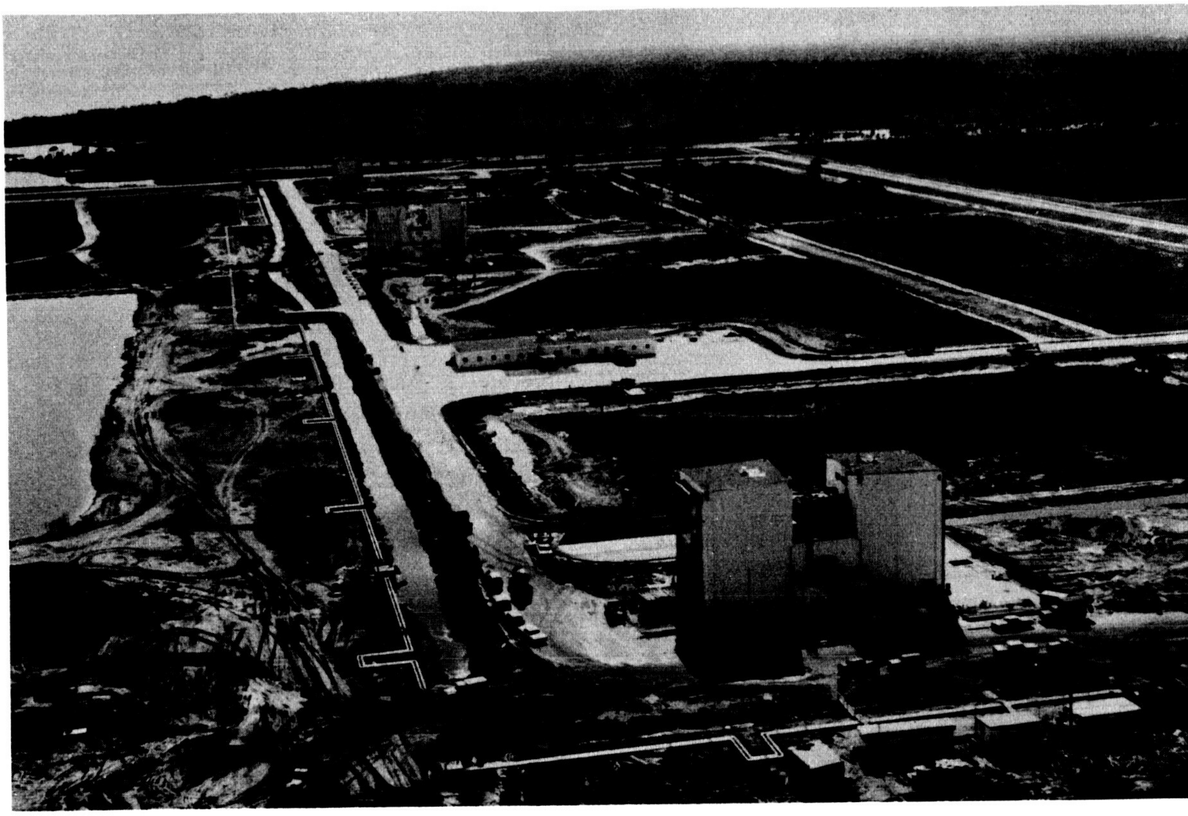

FIGURE 2.—Apollo spacecraft Fluid Test Complex at Kennedy Space Center (January 1964).

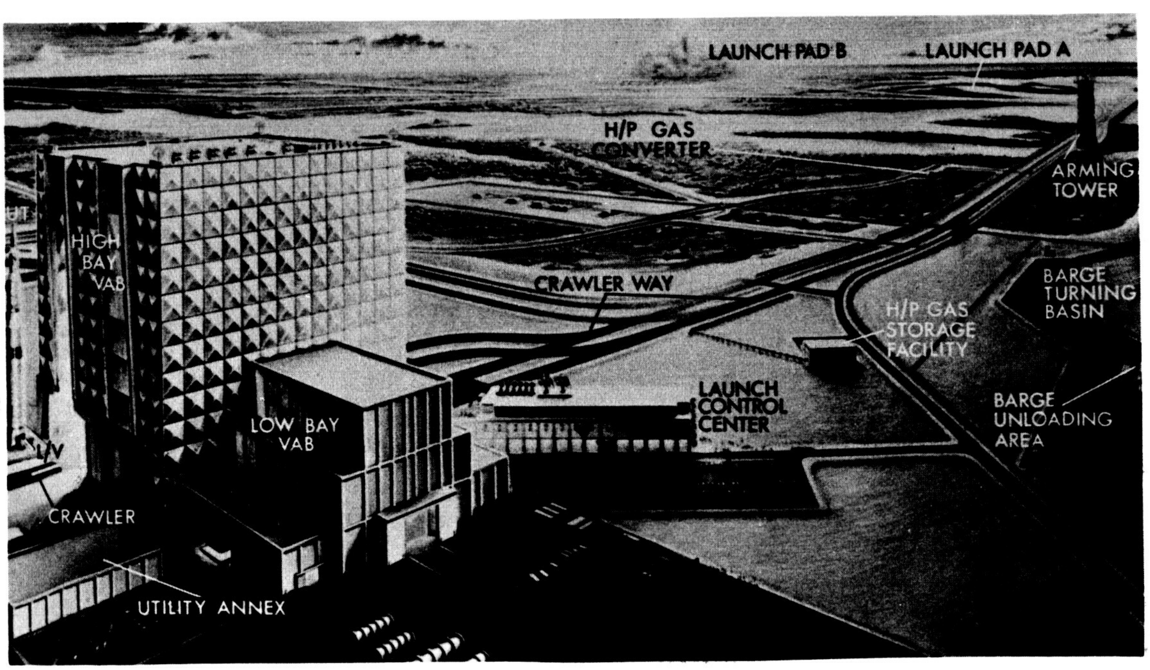

FIGURE 3.—Artist's sketch of vertical assembly building area at Kennedy Space Center.

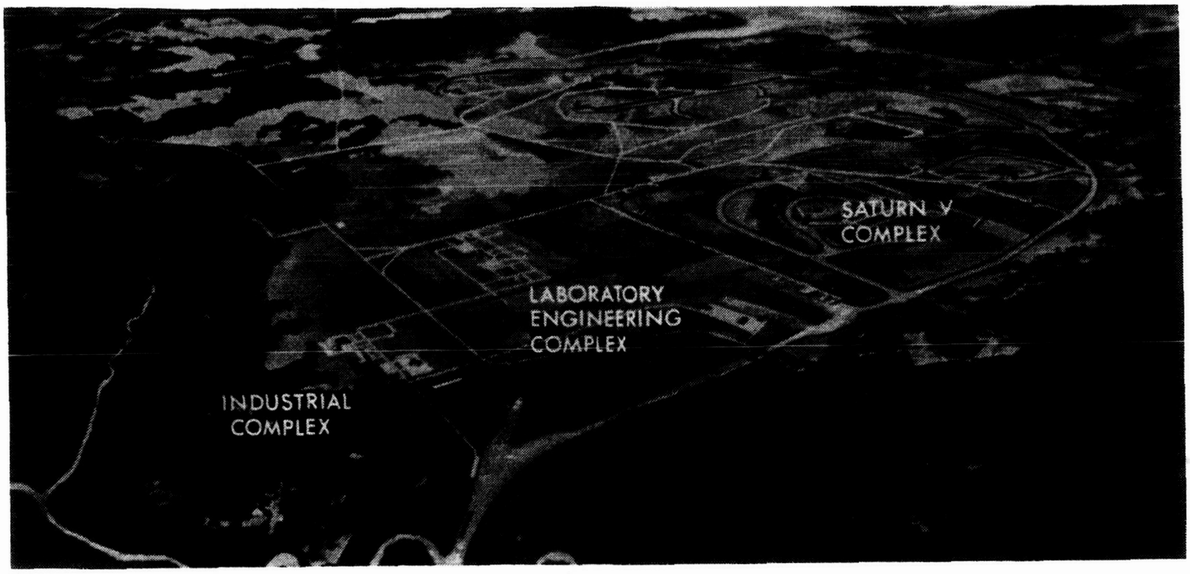

FIGURE 4.—Mississippi Test Operations Site plan. To be completed in 1966.

Much progress has been made in the Apollo program (fig. 5) which can be truly said to have been started in 1958, the year that Congress passed the Space Act. It was in that year that work began on the Saturn I launch vehicle, the F–1 engine, and the Centaur program, in which this country pioneered in the use of liquid hydrogen as a rocket fuel.

It was because of the progress of these efforts, as well as that in the Mercury program, that it was possible to broaden and accelerate our country's efforts in space (fig. 6) 3 years ago this spring, and that President Kennedy could set as a national goal the beginning of manned lunar exploration in this decade.

In recent months, we have carried out a series of reviews of the progress of development of the systems and subsystems within the overall Apollo system. We could find no technological problems of such a major nature that they would interfere with the accomplishment of the program on schedule. Indeed, we could not find one that is not yielding to hard work.

It appears that the most challenging technical task before us is the integration of all of the systems and subsystems—in making them all work properly together. The flight schedule, therefore, is laid out in a way calculated to permit carrying out this integration as early as possible.

We have also recently reviewed a number of matters related to the overall pace of Apollo. We have compared the Apollo pace with that of other major research and development programs carried out by the United States in the past. We have examined the impact on total cost of possible changes in the Apollo schedule; and we have studied the relationship between the pace and the conditions in the space environment.

The overall time phasing, we found, is actually quite conservative. The Apollo spacecraft is being developed on a schedule 4 years longer than was needed for the Mercury spacecraft, and 2 years longer than was needed to produce the B-58 bomber. The Saturn IB and Saturn V launch vehicles are being developed on a schedule 2 years longer than that of the Atlas missile, and 1 year longer than was required for the Titan. The total duration scheduled for the Apollo program is longer than that of any previous United States research and development effort.

The Apollo job, of course, is a big one, and we will need all of the time allotted. The number of parts, components, and subsystems is greater, and they must function for longer periods of time. But the problems lend themselves to orderly solutions; no new inventions or breakthroughs are required. We have generated a high degree of momentum, and the work is going forward effectively and efficiently.

Our recent reviews also examined how the pace affects total cost. In particular, we looked into the

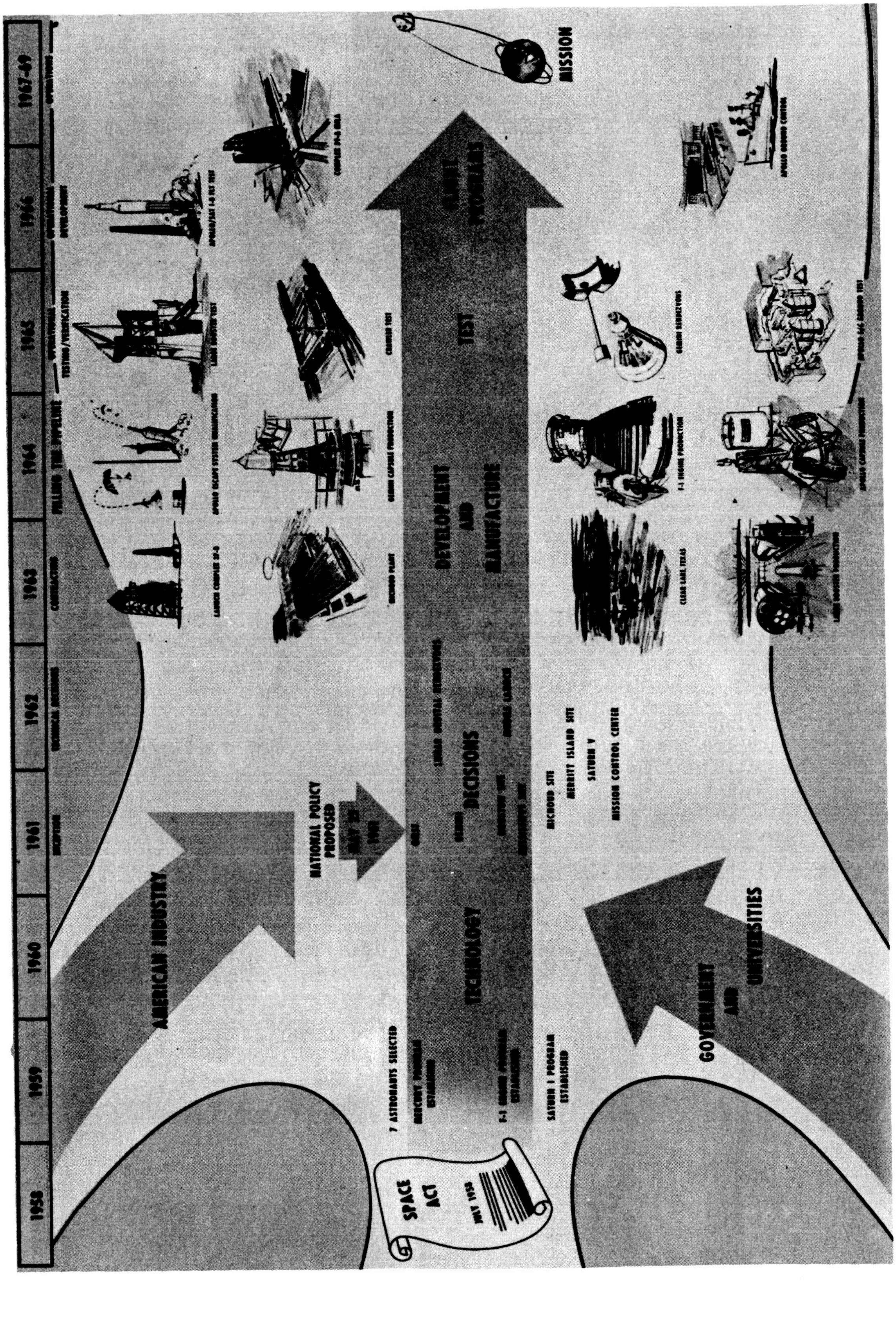

FIGURE 5.—Evolution of the Apollo program.

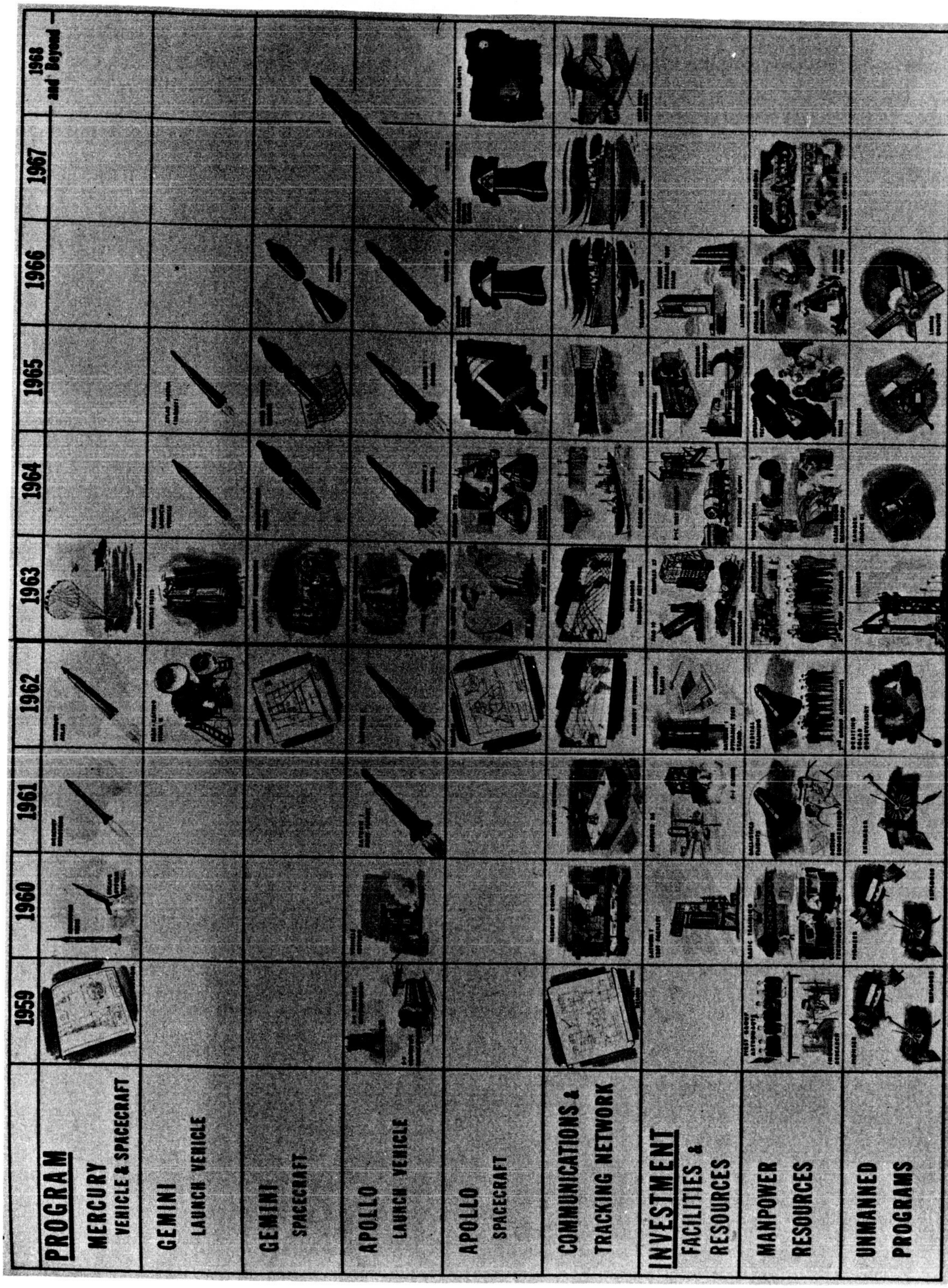

FIGURE 6.—Elements of manned space flight program.

effect on total cost that would be caused by a slowing of the effort and a stretchout of the completion date to the 1970's. This was done in great detail. We studied, subsystem by subsystem, the resource requirements associated with the present schedules. To do this, we analyzed thoroughly the requirements in man-hours for the work to be done in engineering and manufacturing. Then we added the costs of overhead and the operating burden needed to support the work, not only within the NASA organization but in those of the contractors and subcontractors involved.

We found upon completion of the calculations that if the remaining 6 years of work were stretched out over 12 years the total cost of the presently approved manned space flight program would increase by about 30 percent, or about $6 billion. The economic considerations, therefore, support the maintenance of the present schedule. It is $6 billion cheaper to continue on the course we are now following than to set out on a new course at this late date.

Still another area of review of the Apollo pace was the effect of conditions in the space environment. We looked into the matter of meteoroids in space. We examined the effect of radiation in space, and we studied the question of conditions on the Moon's surface.

With respect to meteoroids, present knowledge mainly originates in the data from the Explorer XVI satellite launched by NASA on December 16, 1962, and visual and radar ground observations of meteor arrivals in the upper atmosphere. The results from Explorer XVI indicate that the rate of puncture of the Apollo spacecraft skin by meteoroids would be considerably less than had been anticipated earlier on the basis of indirect calculations from ground observations.

Further meteoroid information will be obtained on the 8th, 9th, and 10th flights of the Saturn I, which we anticipate will provide confirmation of the Apollo spacecraft design criteria. As additional data are obtained, we will continue to review this matter very carefully. However, it is not expected that meteoroids will constitute a major problem in the planning or scheduling of the first manned lunar exploration.

We reviewed the potential radiation hazard from cosmic rays originating elsewhere in the galaxy, charged particles trapped in the Van Allen radiation belts, and high-energy particles ejected during solar flares. The danger from the cosmic rays and the Van Allen belts during typical Apollo missions is negligible. Solar-flare protons are largely diverted by the Earth's magnetic field and, therefore, do not present a hazard in the portion of the Apollo trajectory below the belts. Therefore, the only portion of the mission about which there is any need for detailed solar-flare calculations is that part in which the spacecraft is in flight beyond the Van Allen belts.

The permissible safe limits for radiation are based on a 1962 report of a working group set up by the Man in Space Committee of the Space Science Board of the National Academy of Sciences. The most important limit recommended by this group is that of 100 rads as the maximum permissible dose received by the blood-forming organs.

In our reviews, we looked into the dose that would have been received within the command module by astronauts on a normal Apollo mission if one had taken place during a large solar flare. We found that in the largest recorded flare, that of July 1959, the dose to the blood-forming organs would have been 15 rads. Thus, the worst flare known would have given the astronauts only 15 percent of the allowable safe dose.

Altogether, the evidence available indicates that radiation does not present a hazard that would prevent manned lunar exploration in this decade. In fact, we have encountered no serious evidence that would indicate that radiation would be a factor in scheduling the first lunar mission.

The third environmental matter reviewed was the selection of the lunar-landing site. Present information on the surface of the Moon is based on observations from Earth, analysis of radar echoes, analysis of the rate of arrival of meteors, and analogies to Earth. Study of this information indicates that it will be possible to find many suitable sites for landings on the Moon. The landing gear of the lunar excursion module (LEM) is being designed to cope with a wide variety of possible surface conditions, and the LEM is capable of lateral flight so that a satisfactory landing site can be chosen by the astronauts.

We anticipate that further information regarding conditions on the Moon will be provided by the unmanned lunar missions—Ranger, Surveyor, and Lunar Orbiter—and that this information will confirm the design criteria being established for the LEM. Apollo plans are proceeding on the assumption that these programs will be capable of providing all the information needed for site selection.

Altogether, we found that the present Apollo schedule is soundly conceived, compatible with economy, and in phase with the scientific and technological progress that will be needed to cope with the space environment.

Some of the returns that the Nation obtains from the Apollo investment are so well understood that they need be merely mentioned in passing. It is clear, for example, that the demonstration of the ability to conduct manned exploration of the Moon (fig. 7) will greatly increase United States prestige and influence in an area in which another nation has held the lead. It is equally clear that the exploration of the Moon expands human knowledge to a very large degree. And it is clear that the conduct of a program of research and development on the scale of Apollo contributes significantly to general technological advance in the form of new materials, methods, and processes, and in the resulting stimulus to the Nation's economic growth.

Still another set of benefits from Apollo are the rapid advancement of United States capability in space and the ability to undertake whatever space activities the national interest may require. There are seven major elements in this capability—people, industrial base, ground facilities, launch vehicles, spacecraft, operational know-how, and the ability to manage research and development. Together, they add up to space power, which provides this Nation with freedom of action in this new medium.

First, and most important is people. We estimate that a quarter million people are now at work on manned space projects throughout the United States. Their numbers will increase to about 300,000 by next year, when the effort on the presently approved manned space flight program reaches its peak.

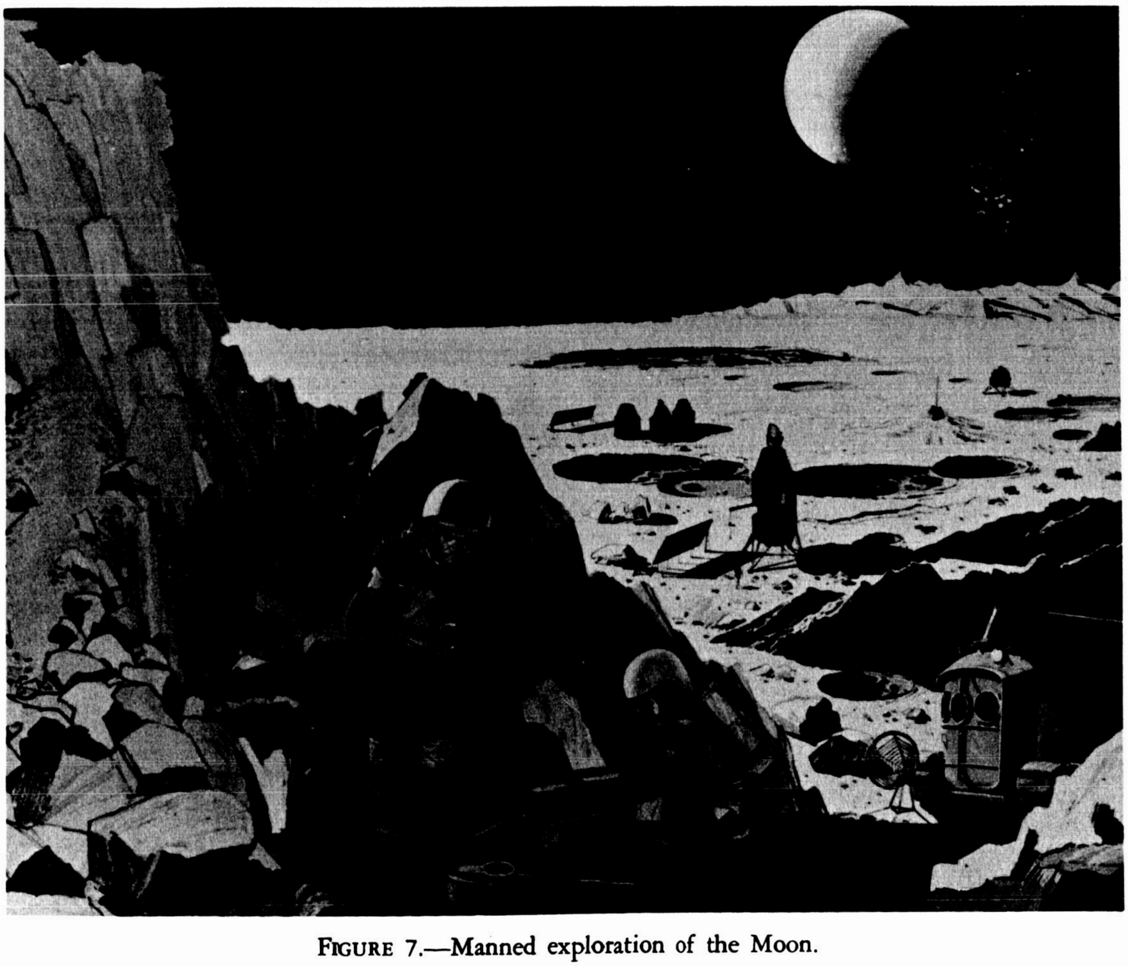

FIGURE 7.—Manned exploration of the Moon.

At this maximum level, the team will include about 45,000 scientists and engineers, about 2.8 percent of the total national employment of scientists and engineers. This number is substantial, of course, but it is clear that the requirements for manned space flight do not strain the national supply of highly qualified manpower. In fact, quite the opposite is the case. Industry has repeatedly informed us that it has available the people to undertake additional efforts beyond those contemplated in the present programs.

A second element of capability is the industrial team that has been assembled. Every region of the country is participating. In some areas, the work is focused in the NASA Centers and military installations; in others, prime contractors are prominent; in still others, subcontractors, supplier and vendors play the major role. The effort is truly national.

Third are the ground installations needed to operate in space. These include institutional, design and manufacturing, testing, launching, and operational facilities in many parts of the United States, and the network of tracking stations around the world.

Earlier in this session, Dr. Debus focused attention on the facilities of the Nation's space port at Merritt Island, Fla. An extremely important item is the launch vehicle. The Saturn vehicles (fig. 8) being developed in the Apollo program will make the United States second to none in this vital area.

Dr. Rees pointed out the capabilities that these vehicles and the facilities for their production will provide to the country upon completion of the present program.

Another element of capability is the Apollo spacecraft, described by Dr. Shea, in which three astronauts will be able to navigate and maneuver, make rendezvous with other spacecraft, and remain in orbit for extended periods of time. The two-man LEM, the first U.S. spacecraft designed wholly for operation beyond the Earth's atmosphere, will provide us with the ability to carry on a number of experiments in earth orbit for the first time. Figures 9 and 10 show manned orbiting laboratory (MOL) and ferry system concepts.

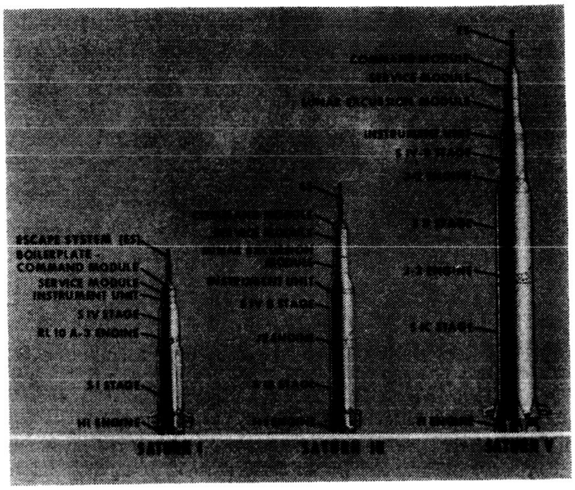

FIGURE 8.—Saturn vehicles for Apollo program.

An extremely important dividend from the Apollo investment is experience and know-how in operations. We are learning what must be done on the ground and in flight; in vehicle assembly and automatic checkout; in launching space vehicles on time; in tracking and telemetering and transmitting vast quantities of information; in calculating flight paths and midcourse maneuvers; in landing on another astronomical

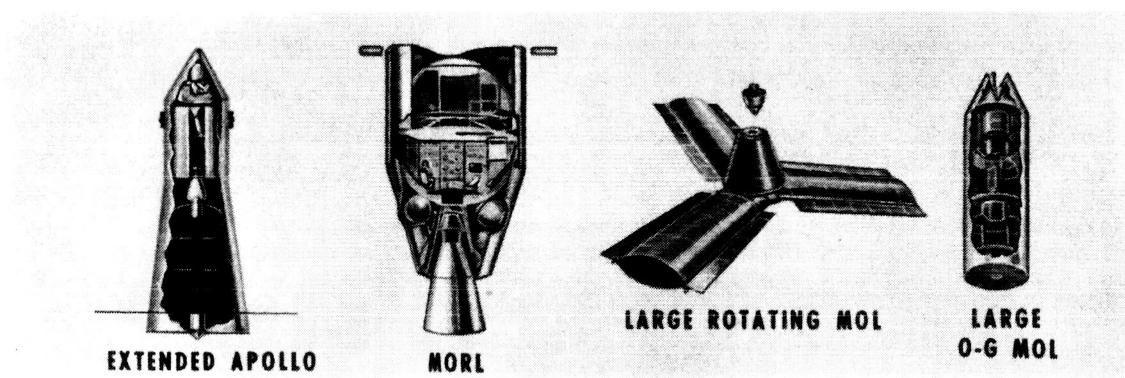

FIGURE 9.—Manned orbiting laboratory concepts.

FIGURE 10.—Ferry systems.

body and taking off without the assistance of a ground crew; in returning to the atmosphere at 7 miles per second; in controlling the flight path through the atmosphere; and in returning to Earth on land or water. We are learning how to conduct such a mission, involving two spacecraft, at a distance up to a quarter-million miles from the earth. Figure 11 is a typical Apollo mission profile for a lunar orbital rendezvous.

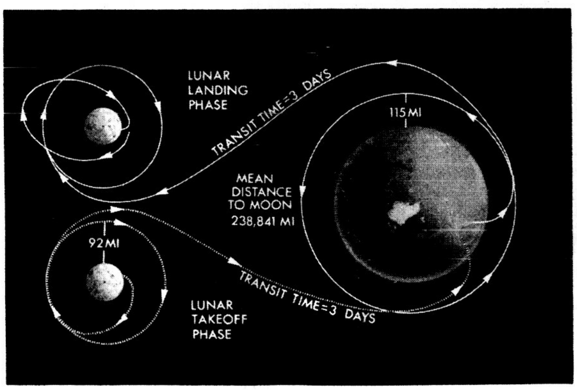

FIGURE 11.—Typical profile of lunar orbital rendezvous mode mission.

Finally, in Apollo we are taking a long stride forward in the creation of the ability to manage a very large research and development effort. From the Manhattan Project of World War II to the ballistic missile programs of the 1950's was one very large step. Now we have moved on to a program even more extensive in scope, managed at three locations under the overall direction of the Apollo Program Office in Washington.

In this development of national capability—people, industry, facilities, launch vehicles, spacecraft, operations, and management—NASA in the Apollo program is carrying forward the work begun a half century ago by its predecessor agency, the National Advisory Committee for Aeronautics (NACA).

Like NACA, the space agency is concentrating its efforts on research and development. The only significant difference is that NASA also conducts operations in space. Thus, we are developing the methods of operation in space as well as the needed technology.

Many of the most significant advances in military and civil aviation resulted from fundamentals of flight developed by NACA. Frequently, this work was carried out with the sole objective of solving basic problems of flight. It did not wait for any statement of a specific military or civilian requirement. The requirements developed naturally after it became known what capabilities it was possible to develop.

In 1943, Secretary of the Navy Frank Knox stated that the Navy's World War II fighter aircraft, the Corsair, Wildcat, and Hellcat, were possible only because they were based on such fundamentals developed by NACA as wing sections, cooling methods, and high-lift devices. "The great sea victories that have broken Japan's expanding grip in the Pacific," Secretary Knox said, "would not have been possible without the contributions of the NACA."

Last December, we saw the first major example of the application to military use of the manned space flight capability developed by NASA—the decision of the Department of Defense to use the Gemini hardware (fig. 12) and experience as the basis of its Manned Orbiting Laboratory program. The capability developed in Apollo will also be available if required to fill the needs of the Department of Defense. This national competence will serve the country long after the Apollo program has been completed.

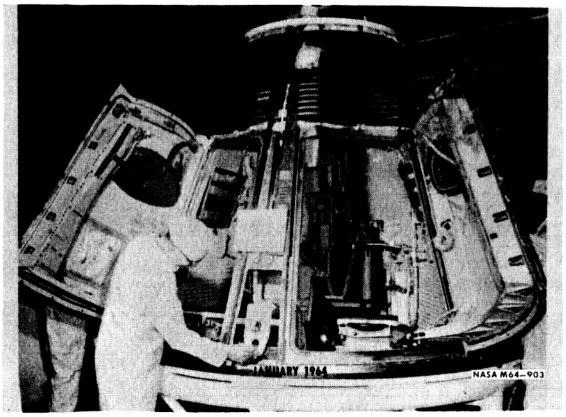

FIGURE 12.—Gemini spacecraft No. 2 in systems test.

In fact, fully 90 percent of the work now in progress in Apollo would be done to create space power even if there were no Moon and the program had an entirely different ultimate goal. In the Apollo program, the Moon is the focus of this great national effort to make the United States clearly first in space. It is a clear objective, toward which we find it possible to organize the work in an effective, efficient manner, at a carefully coordinated rate.

Apollo is an orderly program. Its momentum has been increasing steadily for almost 3 years. We will reach maximum effort next year. The funding proposals now before Congress will bring us halfway to the Moon.

With your support, we will arrive on schedule.