Statement of George E. Mueller, Associate Admin. for Manned Space Flight, NASA, before the Committee on Aeronautical and Space Sciences, U.S. Senate (2 volumes bound together)

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Statement of

George E. Mueller

Associate Administrator for Manned Space Flight

before the

Committee on Aeronautical and Space Sciences

United States Senate

Volume I - Text

(Illustrations for this text are contained in Volume II)

TABLE OF CONTENTS

SUMMARY

Mr. Chairman and Members of the Committee

It is a pleasure to meet once again with the Committee on Aeronautical and Space Sciences to report on our Manned Space Flight activities for the past year and to outline plans for the coming fiscal year.

It is a particular pleasure to be able to report very substantial progress since the last time I testified before you. As we near the accomplishment of the Apollo program goal, I would like to take the opportunity to thank you for the many contributions you have made to its forward progress over the past decade. The wise counsel and continued support of this Committee was an essential element in the success that has been achieved to date.

The Apollo 7, Apollo 8 and Apollo 9 missions have brought us within striking distance of success in this ten-year enterprise, one of the most demanding entered upon by this or any other nation. The final preparatory step is to be taken in the Apollo 10 mission, scheduled for next month. Success in that flight will permit us to undertake the first lunar landing mission and safe return of the astronauts this summer. These two remaining milestones are quite difficult and complicated. They require the utmost of our men and machines. We have therefore resolved to maintain rigid emphasis on every detail and function in the preparations for these missions.

In this statement, I plan to review briefly our objectives, some of the benefits that have been realized thus far, the status of the ongoing program of Apollo and Apollo Applications flight missions, which is scheduled to be completed in 1972. I will cover the activities in this program proposed for fiscal year 1970. Then I will outline some of the steps we are taking to move out toward new goals for the 1970s. Finally, I will report on the proposed funding for the program in the coming fiscal year.

At first, therefore, let us examine the program objectives. In a statement March 27, 1969, to the Committee on Foreign Relations, Secretary of State Rogers discussed that the role of the United States in the world derives among other things, "from our economic strength and the dynamics of our technology." Regarding international cooperation, the Secretary said:

> "Science and technology is an area in which the United States has a unique contribution to make and we hope to continue to be an initiator in this field in the years to come."

The worldwide attention paid to the Apollo missions in recent months indicates that success in the space program may contribute in many ways to our nation's needs in the conduct of foreign relations.

It is in this light that I would like to review the objectives of the manned space flight programs. Here is a chart (M64-68) that we have used every year since I first met with this Committee in 1964. These objectives are fundamental guideposts that I believe are just as pertinent today as they were five years ago. A continuing goal is United States leadership in space. We have come a long way in establishing man's capabilities and in establishing the necessary national competence. And with the lunar landing will signify the exploration of space will be truly under way.

During the last decade, this Committee has published a number of comprehensive, well documented and thoughtful analyses of the international competition for space achievement and its impact on world affairs. There is little need for me to add to these analyses except to emphasize that the competition still persists.

Recent statements by Soviet cosmonauts have declared an intention to move rapidly toward the lunar landing, possibly by this fall. We know that the Soviets are investing very heavily in space and other advanced research and development. Their investment represents a greater share of their gross national product than does ours. Thus we can expect this competition to continue with important demonstrations of their capability in the months to come.

The significance of another aspect of this competition has become increasingly evident in recent years. That is its relationship to the development of new technology, a dominant factor in the economic competition among the industrial nations of the world. Thus there is competition with friends as well as with potential adversaries.

For all of these reasons, I believe our country should welcome competition in space. Competition has been the principal cause of the success of the capitalist system. I cannot think of any reason why we should not welcome the same type of stimulus internationally. But regardless of our desires, the competition does exist and we would not wish our nation to fall behind.

Another international aspect of the program, I believe, is the great interest and enthusiasm for space exploration on the part of people all over the world. We were most gratified by the reaction to the Apollo 8 lunar orbital mission and by the kindnesses to Astronaut Frank Borman on his European visit earlier this year.

It would appear that the common interest of people everywhere in space exploration tends to break down international barriers between people. There seems little doubt that it brings us closer together with people of other Western and allied countries. It may also have this effect between our people and those of the more closed societies.

Next, let us consider the benefits our nation realizes from space activities. I would like to call your attention to some of those that have resulted from our efforts in manned space flight.

BENEFITS OF THE MANNED SPACE FLIGHT PROGRAM

One of the most significant of these benefits is the computer industry, an excellent example of the potential economic impact of new technology. The first computers appeared in the period just after World War II. Now this industry grosses $20 billion a year and provides gainful employment for 800,000 Americans--more than one of every 100 jobs in this country.

A principal cause of the expansion of this industry has been the rapid development of computer technology, largely stimulated by the requirements of federal research and development programs. Manned space flight has been a major element of this stimulus. For the Mercury flights, our computers performed one million calculations a minute. This rate has been increased fifty times for Apollo--to eighty billion calculations a day. The NASA complex of more than 600 computers is one of the largest automatic data processing systems in the world.

Another area of technology that has been advanced by the space program is television. By application of the techniques of ultraminiaturization, a television camera was developed measuring twenty and a quarter cubic inches in volume--about the size of a volume of this Committee's hearings on the NASA Authorization. The black and white images that are transmitted have a resolution that meets conventional industry requirements. A review is now in progress to decide on the matter of flight qualification of this camera. With a camera of this small size, television techniques are available for many new applications in business, education and the management of large enterprises.

An unusual problem encountered in the Apollo program was the need to be sure of being able to remove an injured workman from inside the Saturn fuel tanks, which have access holes only a foot and a half wide. This problem was solved by designing and producing an orthopedic stretcher that holds a victim essentially in traction while he is carried through such a hole. Fortunately, we have never had an accident serious enough to require use of this stretcher to remove a workman from a Saturn tank. But like all of the precautions taken in this program, it remains available in the event of need.

Such a device may be of value in recovering an injured miner or a mountain climber who may be trapped in an inaccessible location. If so, the device is available to be developed for use by other government programs and by the general public.

Another example of technology transfer resulted from the need in the Apollo spacecraft development work to devise a rapid test for identifying metals without destroying or damaging the piece being tested. The need was filled by a technique of measuring the electrical potential between the test metal and a drop of water. This method is now being used for testing zirconium used as cladding metal for nuclear reactors, which must be purified to a very high degree.

Several new products are now on the market as the result of progress in the use of aluminized mylar plastic begun by industry and accelerated by its use in the Echo balloon satellites, astronauts' space suits, and as insulation for components and subsystems in other spacecraft. One company is producing an aluminized mylar camping blanket, which weighs only a few ounces and can be folded up to carry in a pocket or handbag.

Other uses of technology originating the Manned Space Flight program include fireproof beta cloth used for the Apollo space suits, improved techniques for welding a variety of metals, an ultrasonic device that can help a physician determine bone integrity, an image amplifier for medical x-ray equipment, an electrical device for monitoring heart activity, an application to heart research using temperature-controlled astronaut underwear, a pressure transducer for measuring the strength of structures, and a clean-room air sampler of value in monitoring the purity of air in a wide variety of situations.

There are many other examples of new products, new processes and new ways of doing things that are contributing directly to the growth of the real wealth in our country. I am convinced that much more is yet to come in the next few years.

But we may ultimately find even greater significance in the way that the space program forces the intermingling of people of all disciplines--from medicine and the life sciences through physics, chemistry, astronomy and engineering to economics and public administration. It may be that such intermingling can point the way toward finding solutions to some of national and international problems that have not been solved thus far by specialists in a single discipline.

A very real benefit, I believe, is the stimulus provided by space flight requirements to the technology of perfection in U. S. industry. There are 15 million parts in the Saturn V launch vehicle. In the four flights to date, we have experienced only five failures. Such results are not easy to achieve. To do so requires constant attention, by the government customer and throughout the industry contractor structure. Attention must be paid throughout the cycle from conception through design, manufacturing, test and acceptance. If this degree of perfection can be achieved in space flight, it can also be achieved in consumer goods--if the customer wants it.

Still another effect is in the form of community and regional progress in the areas of the country in which the space program is carried out. This has been particularly true in the areas surrounding the government installations responsible for management of the manned space flight portion of our program.

Community progress is particularly noteworthy in certain regions of the country. One is reminded of the impact on people in other areas of the country when unskilled and semi-skilled workers moved to aircraft factories in World War II. These people kept their skills after the war. It was a permanent change in their way of life.

Thus we can see that the economic, social and institutional effects of our space program are spreading throughout our society. It has widened our horizons, permeated our economy, inspired invention, stimulated productivity and served as a yardstick by which we can measure precision and reliability.

There is also the effect on education. As you know, space exploration inspires young people particularly those who are interested in science and engineering. The NASA university program encourages this tendency. One of the results has been the emergence of some very capable, very young engineers. For example, those who compute the trajectories for the Apollo 8 and subsequent lunar flights have an average age of 23. They are at the Instrumentation Laboratory of the Massachusetts Institute of Technology.

In the Apollo program we have taken the most advanced step to date in the development and utilization of ability to mobilize government, industry and the scientific and educational institutions of our country to achieve a great national goal--without coercion, working through the free play of our institutions and the marketplace and with the enthusiastic consent of all concerned.

The ability to do this, I believe, is a perfectly valid index of the strength, maturity and indeed the greatness of our nation. If a country can stay the course of a peaceful decade-long program to land men on the moon and return them safely to earth, who can say that nation cannot solve its other problems?

Often we are asked why we should spend money on space when we have these other problems that deserve attention. This question deserved a thoughtful answer.

I believe we can and should do more to meet the needs of man on earth. In addition, I believe that we must take the steps necessary to assure that our economy continues to grow as it has been growing in recent years. For the solution to the problems of our times depends on the continued creation of new wealth through growth of our economy. The space program does this by upgrading people, creating new regional and industrial capabilities and fostering the introduction of thousands of new products, new processes and new ways of doing things--more effectively, more reliably and at lower cost.

We need, therefore, to provide for technological advance even as we concern ourselves with human needs. The space program, as we have seen, has contributed directly to improving life on earth. But there is much more to be gained than the creation of facilities and communities devoted to space flight. The adventure and the fact of space flight affect, enrich and improve our national growth and every facet of our life on earth. I believe it can and will do more in the months and years to come.

One more point seems appropriate here. Our efforts in the manned space flight program in the 1960s has been directed to provide the United States with capability to investigate and to use the potential contributions that man can make in space flight. We have made considerable progress toward this objective. But further experimentation is needed.

Therefore I believe that a strong program of continuing development of manned space flight is justified by the needs to advance the nation's overall position in space and to experiment with the wide range of scientific and practical applications of both manned and automated flight of future potential importance.

Now let us turn to the status of the manned space flight program.

STATUS OF THE ONGOING PROGRAM

In the Apollo program, the successful results of the three manned flights beginning last October have verified that technical and management maturity have been achieved and that the necessary operational capability is within our grasp.

As mentioned earlier, this progress was accompanied by a planning problem. During the preparation of the budget for fiscal year 1970, President Johnson directed the postponement of any decisions that might unnecessarily commit the incoming Administration. Accordingly, the programs after Apollo were presented in the scope necessary to keep open the options for decision by President Nixon's Administration.

One of the decisions postponed affected the exploration of the moon in the period following the first lunar landing. Under the budget submitted in January, firm plans were made for three additional lunar missions. As the momentum of the Apollo program has increased in the last six months, it has become increasingly evident that we should plan ahead on the assumption of making the first successful landing and return to earth on Apollo 11. Thus we can expect to be able to move ahead with lunar exploration on earlier flights than anticipated a few months ago.

The January plans did not provide for the necessary equipment for use on the moon's surface to fully capitalize on the opportunities provided by the fact of achieving this milestone in human progress.

However, the budget amendment transmitted to the Congress by President Nixon on April 15 proposes to capitalize on these opportunities and to continue lunar exploration missions with Apollo equipment until 1972.

Perhaps a word on the Apollo mission numbering is in order here. The Apollo 11 mission will be the sixth flight of the Apollo-Saturn V vehicle. This results from the fact that five earlier missions employed the Apollo-Saturn IB vehicle. Thus the 15 Apollo-Saturn V vehicles will permit us to reach Apollo 20.

Let me briefly review some overall considerations regarding our activities on the moon. A primary purpose of course it to capitalize on this opportunity to extend man's horizons to encompass a new world and to provide the insight and perspective resulting from new space capabilities. In addition, the moon will provide the opportunity to cement ties of international cooperation, just as has been done in Antarctica and in the exploration of other frontiers of the earth.

Now let me turn to some of the more specific objectives of lunar exploration.

The first is to understand dynamic processes on earth through direct comparison of the earth and the moon. The physical properties of the moon and the observations of the earth from the moon can tell us much, for example, about the cause of earthquakes--bringing us that much closer to the time when they can be predicted just as we predict weather.

A second objective is to evaluate the natural resources of the moon and its 14.6 million square miles of real estate. These resources include not only minerals of a nature yet to be determined, they also include a uniquely available combination of high vacuum and a gravitational field one-sixth as strong as that of the earth. On the results of this evaluation will depend our decision some years from now as to whether there is sufficient potential to justify establishing a lunar station.

A third goal is to use the moon as an island near our shores to which we can voyage in these early years of the space age to develop man's potential to function as an explorer on another planet. With the experience of operating on the moon over the next few years, we will be in a better position to assess the value and timing of manned flights to the planets.

Finally, by exploring the moon we have the opportunity to gain new insights in understanding the solar system and its origin and perhaps to gain clues to the origin of life. As an objective for exploration in the solar system, the moon ranks after Mars in the judgment of the scientific world. But it has the advantage of nearness. It is reachable here and now. Thus the concentration of scientific attention on this available object can produce very substantial additions to understanding of the universe during the next few years.

Now let us examine the lunar exploration program. The initial phases of this program have been defined. The first will consist of landings that sample the major classes of regions that are accessible in the equatorial region on the visible face of the moon. In a sense, we will be establishing a set of norms. Then in later missions it will be possible to determine how and why certain anomalous areas differ from those norms.

On the first landing mission the principal goal will be to verify that the Apollo equipment is indeed capable of landing on the moon and that men can walk about and do useful work in the environment of its surface. During the limited time of this mission, the principal scientific objective will be to obtain samples of lunar soil and rock for return and analysis by scientists on earth. If circumstances permit, the astronauts will also carry out initial geological prospecting of the nearby areas and emplace instruments for automatic operation after their departure.

One of the instruments to be emplaced is a reflector to return a laser beam from the earth back to the earth to measure the distance between the earth and the moon to an accuracy of a few inches in a quarter-million miles. This experiment will also provide a test of a theory that may assist in predicting earthquakes. The other instruments are a solar-powered seismometer that will make an initial attempt to detect moonquakes, and an aluminum-foil detector for solar wind particles.

As you know, the scientists of the world are eagerly awaiting the results of the manned exploration of the moon. Altogether, 142 scientists have been selected to analyze the returned samples. The number includes 35 from other countries--Canada, Great Britain, Australia, Switzerland, Finland, West Germany and Japan.

On subsequent landing and return missions to different locations, it is planned that the astronauts will obtain other samples for analysis on earth, prospect those locations and emplace the Apollo Lunar Surface Experiment Package (ALSEP) a sophisticated set of devices with a a nuclear isotope power supply that will facilitate long-life operation.

The first phase of lunar exploration will consist of landings at four sites. Two of these will be in lowlands or maria--one in the east, probably an older area, and one in the west.

The other two landings will be in the two major classes of highlands--sheets of debris from the very large craters and simpler upland sites. For each of these classes we have identified accessible sites that do not require pinpoint accuracy. Thus we can use the same Apollo vehicle as on the initial landing, without modification.

But the establishment of these four norms is only the beginning of the task that must be performed to determine whether major activities on the moon are warranted. The next phase is a sampling of the major classes of anomalies through landings at selected sites. In these landings, we will prospect and obtain samples from volcanic locations, sinuous river-like channelways, fracture zones and major impact craters such as Copernicus. I must say I look forward to the day when men will first visit that majestic and awesome manifestation of the processes of Nature. Here is a picture of Copernicus taken by the Lunar Orbiter. (SL 68-736)

However, the exploration of these rugged areas must wait until we develop a degree of confidence in operating in the lunar environment and until some modest extensions of capability are available. The January budget would have authorized us to continue studies aimed at achieving these product improvements, which include extensions of astronaut mobility, limited modifications of the spacecraft modules to increase their effectiveness and operational lifetime, and additional scientific instruments.

With the new equipment the astronauts will be able to extend their exploration distance from some 100 yards to about 3 miles from the landing site. Extravehicular stay time will be increased from four to thirty-six man hours. The lunar module will be upgraded to increase surface stay time from one to three days. The command module will be upgraded to extend mission durations to 16 days and to carry photographic and sensor equipment. The April budget amendment authorizes us to develop these improvements for use in 1971 and 1972.

Following completion of these initial lunar exploration phases and assessment of the knowledge and experienced gained in them, we will be in a position to proceed to a decision on whether to build up capability at a single location on the moon by revisiting the same site. This might lead in turn to a later decision regarding semi-permanent or permanent operation of a lunar station with observatory, research and other facilities. The information gained in the first 10 lunar missions will permit us to decide with considerable confidence where to locate such a station.

The program for fiscal year 1970 calls for proceeding in an orderly fashion into the initial phases of this program, learning as we go, assessing what we have learned at periodic intervals and modifying plans as indicated by these assessments.

Now let us turn to the Apollo Applications program.

This year Apollo Applications forms a part of a new budget line item, Space Flight Operations, which encompasses our post-Apollo manned space flight research and development activities.

Fiscal Year 1970 plans in Apollo Applications provide for continuation of flight hardware development and for integration of modified subsystems into hardware for five earth-orbital flights. We have been working to accomplish the first flight of the Orbital Workshop in 1971, followed by a revisit mission and the Solar Astronomy mission within the next year. The April budget amendment has reduced the resources available this year. It now appears that the initial flight will be late in 1971 or early in 1972. However it is still our goal to complete the program in 1972. Thus both the presently planned program of lunar exploration and the Apollo Applications program will end at about the same time.

To preserve our options for the period immediately following these two programs, the April budget amendment also includes funds to allow the procurement of long lead items for resuming production of the Saturn V launch vehicle beyond the fifteen in the Apollo program. This decision enables us to avoid the expense and loss of skills that would have resulted from a shutdown and later restart of the work on this most powerful U.S. launch vehicle, but does not commit us to a specific production rate. If the budget is approved the first of these vehicles will be delivered for flight in 1973.

Let me repeat that the purpose of this decision is to retain the option of using the Saturn V in 1973. No decision has been made as to whether these vehicles will be used for lunar missions, earth-orbital missions, planetary missions or some other potential application yet to be defined.

Now let us move on toward the future. As we approach the operational phase of these two limited utilizations of Apollo capability for lunar exploration and earth-orbital activities, we must focus on the direction of the space activities of the middle and later 1970s.

IMPLEMENTING THE FUTURE PROGRAM

To assist in selecting this course, we asked the Science and Technology Advisory Committee for Manned Space Flight to conduct a study of the uses of manned space flight in the decade beginning in 1975. We are most fortunate to have had available the advice and assistance of this distinguished body for the past five years. Its numbers include three Nobel laureates--chairman Charles H. Townes, Luis Alvarez and William Shockley. Another outstanding member has been Dr. Lee A. DuBridge, who participated in the deliberations in this study last December at La Jolla, California. He resigned following his appointment as President Nixon's science adviser and thus did not take part in the preparation of the written proceedings.

A copy of the first volume of the proceedings has been provided to each member of your Committee. Volume II, consisting of a number of supporting scientific and technical appendices, will be back from the printers in about a month.

I believe you will find this study to be most significant. One reason, I believe, is that the committee considered space activity from the viewpoint of national policy rather than merely as a scientific or technical question. The proceedings are summarized in the first five pages, which state what the committee believes to be the overall policy considerations and then reaches six conclusions. Let me list those conclusions briefly:

1. The United States should remain in the forefront of all major categories of space activity, including space sciences, solar system exploration, manned flight capability, and economic applications.

2. It is reasonable to utilize 1/2 to 1 percent of the gross national product for the civilian space program.

3. Five program elements are of major importance and should be strongly supported. They are:

a. Agressive planetary exploration as recommended by the Space Science Board of the National Academy of Sciences.

b. Economic applications activities of the general nature recommended by the recently concluded study carried out by the National Academy of Sciences.

c. Continuation of lunar exploration following the Apollo landing.

d. A vigorous program of astronomical observations in earth orbit.

e. Extension of manned flight capability in earth orbit to longer duration and to permit application for scientific and technological purposes.

4. Development of a manned low-cost transportation system and plans for its use deserve high priority.

5. The use of long-duration manned space station appears to be a logical step in the evolution of manned flight capability.

6. Observatories and laboratories should be placed in earth orbit with facilities for astronomy, earth applications, space physics, life sciences and new materials development. The extent of manned attendance desirable in each of these areas must be decided by appropriate studies and early experiments.

I agree with these conclusions. Within the resources available, I believe we should agressively implement them. The program we are presenting to you is responsive to these conclusions, but implements them only partially within the resources available at this time.

Now what are the implications of these recommendations for the manned space flight program, beyond the ongoing activities described earlier in this statement? There would appear to be two that deserve special attention. One is with respect to low-cost manned transportation. The second relates to the space station.

In my judgment, the future of manned space flight is clearly dependent on the degree to which costs can be reduced. As you know, all present U.S. space vehicles are not reused after a single flight, unlike any other form of transportation. Through reusability, it would appear that very substantial reductions in costs can be achieved. The technology is available. In recent years, substantial progress has been achieved in engine technology, in lifting bodies and in system design.

Under present technology, the Saturn IB, Titan III and Saturn V launch vehicles can be employed to place payloads in low earth orbit at costs in the range of $500 to $1,500 a pound, depending on production and launch rates. The very large payload capacity of the Saturn V--about a quarter-million pounds--enables it to achieve the lower limit of this range.

New space transportation concepts based on newly emerging technology, with emphasis on operational simplicity, can result in cost reductions approaching a factor of ten by the middle 1970s. With the maturing of operational experience later in the decade, even greater cost reductions can occur--just as did occur when jet aircraft were introduced into the airline business.

This cost reduction should provide a number of benefits. At present, the costs are also very high for equipment designed for use in space. To some degree, these costs result from the demands of the space environment. But in addition, very high reliability standards--much higher than those on earth--must be met by such equipment. If reduced transportation costs could permit planning on maintenance, repair and replacement of parts and components, it might well be possible to reduce substantially the original equipment costs. In addition, the reduced costs would permit use of heavier equipment with greater design margins, thus permitting a reduction in the amount of costly testing of space flight equipment.

The Department of Defense is intensely interested in the potential of such cost reduction. A joint NASA-Air Force study is now under way to determine the requirements for lower-cost systems and whether it would make sense to develop such a system under joint sponsorship. In addition, we are studying how to reduce the cost of transportation to the moon. It is possible that the nuclear rocket may form a part of such a system..

As you know from our reports in previous years, the presence of man in space can provide a significant advantage in the case of unexpected events during a mission. Man's role is to apply his judgment to make adjustments, change modes, repair or replace equipment, or shift to other activities as indicated by these events. In addition, he can select special events to observe and use his judgment to increase the range of discrimination on the basis of which to make such selections. But the decision on whether to include man in a space mission frequently hinges on the comparison of costs. If the transportation costs can be reduced substantially, man's use can increase and eventually it may actually be less expensive to use man than to design machines to replace him. But this of course is something only future experience can demonstrate.

Regarding the space station, we believe that the proper step at present is to move directly toward a large station. We believe such a station might be assembled in orbit in modular fashion over a period of years. Our thinking on the details of such a station has begun to crystallize. A major step in this process was accomplished in February of this year, when we brought together specialists from throughout NASA and interested elements of the Department of Defense at a space station technology symposium.

During the remainder of the current fiscal year the studies of low-cost space transportation and the space station are being supplemented by studies conducted by several contractors. In fiscal year 1970, we plan to complete the definition of both programs.

In the meantime, President Nixon's Space Task Group is devoting its energies to both of these matters with the aim of recommending a space policy for the 1970s, which will establish guideposts for the actions on the budget for fiscal year 1971.

Now let me turn to the cost of all these activities in fiscal year 1970.

FUNDING REQUIREMENTS

For the three manned space flight research and development programs--Apollo, Space Flight Operations and Advanced Manned Missions--we propose in our plan a total of $2,036.7 million for fiscal year 1970. This is $29.0 million higher than the January budget. This total for all of manned space flight R&D is approximately the amount Congress authorized for Apollo alone in fiscal year 1969. The total represents a request for new obligational authority of $1,919 million and a carryover of $117 million of fiscal year 1969 funding authority appropriated by the Congress but not released by the Bureau of the Budget because of the limitations imposed by the Revenue and Expenditure Control Act of 1968.

Our request for fiscal year 1970 is 40% less than the funds we received in fiscal year 1966. During these four years, because of general inflation and because of the recently negotiated labor settlements in the aerospace industry, we estimate that the costs to NASA of obtaining goods and services increased by about 20%. It appears that with our funding request for fiscal year 1970 and this impact of inflation, our level of activity will be reduced to that supported eight years ago--in fiscal year 1962.

The decrease in our funding is reflected in our manpower. With this request, by June 1970, employment on the Manned Space Flight program is expected to be only about 1/3 of the 300,000 employment peak that was reached in February 1966. Our employment in June 1970 will be at its lowest point since June 1962.

The skill balance, inherent in any capability concept, between design, production, test, and launch is being rapidly dissipated. Our contractor personnel requirements during FY 1970 will be heavily concentrated in the areas of checkout, test, and launch. Our utilization of design personnel is down to a small fraction of that of several years ago. Those subcontractor and vendor efforts still remaining are rapidly being ended. Unless funds are provided for post-Apollo Saturn V production, we would in the next year dissipate the manufacturing and production capability that was established to bring the manned space flight program into being. This chart shows the manpower impact. (MC 69-4410)

For Apollo, the fiscal year 1970 budget provides $1.691 billion. This is $40 million higher than the January budget. Apollo includes $90 million for Lunar Exploration.

For Space Flight Operations, the fiscal year 1970 operating plan is $343.1 million and includes $251.8 million for Apollo Applications, $36.3 million for Operations, $46 million for Saturn V production, and $9.0 million for the space station and low-cost transportation studies. This represents a net reduction of $11 million below the January budget--a decrease of $57 million for Apollo Applications and an increase of $46 million for Saturn V production. The request for new obligational authority is only $225.6 million since $117.5 million of FY 1969 funds withheld last year will be applied to our operating plan in fiscal year 1970.

For Advanced Manned Missions, we are requesting $2.5 million in fiscal year 1970.

In the Construction of Facilities, the fiscal year 1970 budget provides $14.25 million for construction of facilities at the three manned space flight field centers. This includes $12.5 million at the Kennedy Space Center and $1.75 million at the Manned Spacecraft Center. The construction at Kennedy Space Center will be modifications of launch facilities for Apollo Applications. The single project at Manned Spacecraft Center will provide additional generation equipment to assure noninterruptible power to the Mission Control Center during longer duration Apollo Applications flight operations.

In Research and Program Management, the fiscal year 1970 budget provides $307.45 million for this function (formerly called Administrative Operations) at the three manned space flight field centers. Center totals are:

Kennedy Space Center	$97.5 million
Manned Spacecraft Center	97.8 million
Marshall Space Flight Center	112.2 million

Altogether, the fiscal year 1970 request totals $2.2409 billion for manned space flight, as follows:

Research and Development	$1,919.2 million
Construction of Facilities	14.25 million
Research and Program Management	307.45 million
	$2,240.9 million

This program permits us to make use of our manned space flight capabilities through 1972. It allows us to proceed with definition of a space station and low-cost transportation for use later in the 1970s. We will be supporting the President's Space Task Group in its deliberations on space goals for the 1970s, which will provide a basis for the budget for Fiscal Year 1971.

Here is a chart that summarizes our funding request for FY 1970. (MC 69-4380).

Mr. Chairman, this completes my prepared statement.

APOLLO PROGRAM

INTRODUCTION

Apollo (MA66-9411) in 1968 was a program highlighted by progress on all fronts. The program has matured to the point where this progress is best illustrated by discussion and analysis of the four missions flown during calendar year 1968 and Apollo 9 in 1969. Their successes and problems will be reviewed as will the objectives and plans of the missions to follow.

REVIEW OF MISSIONS - 1968 and 1969

Apollo 5

Apollo 5 (MA68-5639), the first of the 1968 missions, was launched in January and was discussed in detail with you during last year's hearings. Apollo 5 was a successful initial test of the unmanned Lunar Module and marked a major step in the flight verification of Apollo hardware. It provided data for evaluating second stage (S-IVB/IU) orbital performance, Lunar Module staging and verified the Lunar Module structure and operation of the ascent and descent propulsion systems. The Saturn IB launch vehicle placed Lunar Module I in an earth orbit of 88 by 120 nautical miles.

Three firings of the descent propulsion system and two firings of the ascent propulsion system were carried out successfully.

The ascent propulsion system was ignited in a test of the "fire-in-the-hole" maneuver wherein the two stages are separated and the ascent stage engine ignited simultaneously with shutdown of the descent stage. Such a maneuver is required to insure a safe lift-off from the lunar surface or during a descent to the lunar surface if a safe abort is required prior to touchdown.

One minor anomaly occurred at the time of the first descent engine firing. The engine started as planned, but was shut down after slightly more than four seconds by the Lunar Module guidance subsystem when the velocity increase was less than the predicted rate.

Analysis of the problem during the flight revealed that it was caused by the guidance software and a decision was made to revert to an alternate mission plan. This alternate plan also provided for meeting the mission's primary objectives and was successfully executed by the flight operations team.

The efficient performance of Lunar Module 1 in this first flight was a significant achievement. This spacecraft is specifically designed to operate in space and on the lunar surface. Both descent and ascent propulsion systems worked satisfactorily for this critical aspect of lunar missions.

Accordingly, it was concluded that a second unmanned test utilizing Lunar Module 2 would not be necessary. This latter vehicle was subsequently assigned to "pogo" ground tests conducted after the

Apollo 6 mission. Lunar Module 2 is now to be used in simulated drop tests to be accomplished prior to the lunar landing mission.

Apollo 6

Apollo 6 (MA68-6168), the second Saturn V to be flight tested, was launched on April 4, 1968. The mission which lasted for 9 hours and 50 minutes demonstrated the structural and thermal integrity and compatibility of the three-stage Saturn V launch vehicle and spacecraft, confirmed the launch loads and verified the dynamic characteristics of the flight operations. It further demonstrated separation of the stages and launch vehicle guidance and control. A planned restart of the third stage engine was not accomplished. The spacecraft service propulsion engine was fired for 445 seconds to reach the target earth-intersecting elliptical orbit with an apogee of 12,000 nautical miles. The Command Module returned to the earth's atmosphere (400,000 ft.) at a velocity of 32,819 ft/sec. compared to the programmed 36,500 ft/sec.

The spacecraft landed within 50 miles of the target landing point and was recovered. Charring of the Command Module heatshield was similar to that on the Apollo 4 spacecraft 017 and Command and Service Module 011 flown on AS 202 in August of 1966.

The unified hatch for quick exit of the crew, a modification made after the Apollo spacecraft fire on January 27, 1967, was in good condition after the flight.

Resolution of Apollo 6 Anomalies

The Apollo 6 flight, however, encountered three significant problems in the launch vehicle that required resolution before the Saturn V could be manned.

"Pogo" Problem

During the latter portion of first stage boost a longitudinal (pogo-stick type) oscillation in the launch vehicle at the frequency of about 5 cycles per second produced a "pogo" effect and undesirable G-loading on the spacecraft. At 130 seconds after launch the peak-to-peak acceleration excursions reached about 0.7_g in the spacecraft. "Pogo" is a phenomenon of oscillating, longitudinal accelerations produced by a coupling of reinforcing vibrations between the structure and the propulsion system. Vibration from engine operation at a particular frequency is transmitted at a natural frequency of the structure. The structure in turn amplifies these pertubations from the propulsion system. If unchecked, the pogo-stick like vibrations could cause a mission abort due to the induced G-loadings on the astronauts in the spacecraft.

A group at the Marshall Space Flight Center, which had been involved in earlier analyses of possible "pogo" on the Saturn launch vehicles, was reactivated. Included were senior personnel from Marshall, the Manned Spacecraft Center in Houston, Langley and the affected contractors. Several other contractors, with "pogo" experience on other launch vehicles were consulted as well. One of the astronauts was also included in the group on a full time assignment basis.

A logic network (MA69-4287) was developed to set down, in sequence, the events and activities required at the centers which would ultimately result in a selected solution. The "pogo" working group was, in reality, a technical steering committee for a very comprehensive effort involving hundreds of people. Major meetings were held approximately once a month to review the status of the investigation and testing. This rather formal process of working level reviews by the technical steering committee permitted the communication necessary to screen the ten or so candidate solutions and reduce them ultimately to the one chosen for implementation.

This solution, established on July 15, 1968, involves the filling of an existing liquid oxygen line pre-valve cavity with helium gas, and is called the pre-valve accumulator approach. (MA69-4286) This makes an excellent accumulator, changing the resonant frequency, has the further attraction of fitting very well into existing hardware and provides the greatest margin for "pogo" correction to the Saturn V vehicle.

Lunar Module Adapter Structure Problem

Three seconds after peak "pogo" oscillations were recorded on Apollo 6, a non-critical failure occurred in the spacecraft Lunar Module adapter. However, the space vehicle continued on through the maximum longitudinal G-loading without further structural failure.

Post mission failure analysis revealed that this was most likely to have resulted from a localized area of debonding. A rigorous program of ultrasonic inspection, tension/shear pull test, and venting of the core through the inner face sheet has since been applied to all adapters, and they have been insulated with cork.

Augmented Spark Igniter (ASI) Problem

Operation of the five-engine S-II second stage of Apollo 6 was near nominal until approximately 3 minutes and 45 seconds after launch when temperatures in the aft section began to change. At 5 minutes and 18 seconds, the thrust of one engine decreased suddenly. Premature cutoff occurred at 6 minutes and 52 seconds. A second engine shutdown one second later. The vehicle remained stable and the three remaining engines burned to near fuel depletion to compensate for the two engines out. Complete second stage shutdown occurred 58 seconds later than originally planned.

Third stage first first-burn performance was normal. Due to the perturbed initial conditions, however, the flight program was not able to converge on both altitude and velocity requirements. Consequently, the burn was 29 seconds longer than planned; the cutoff velocity was high and the parking orbit was off nominal with apogee of 196 nautical miles and a perigee of 96 nautical miles. After two revolutions in the parking orbit, third stage restart was attempted but not achieved.

The anomalies involving both the second and third stage engines were identified as failure in the fuel line feeding the J-2 engines augmented spark igniter. Ground testing demonstrated that fluid flow-induced vibration in the flexible bellows section of the line was the cause of the failure. This vibration phenomenon had been masked in previous ground testing because of the damping effects of liquid air condensed on the exterior of the bellows. Condensation of liquid air on the bellows surface occurred in the ambient conditions of the ground tests but not in the vacuum environment (MA68-6967). The igniter lines were redesigned to eliminate the bellows section and a qualification test program verified the correction (MA68-6969). The corrected J-2 engine was later flown successfully in the second stage of the Saturn IB launch vehicle on the Apollo 7 mission and on the Saturn V upper stages during the Apollo 8 mission.

The premature cutoff of the second engine of the Apollo 6 vehicle's second stage was traced to erroneous wiring of the engine prevalve to the cutoff circuit of the engine that failed first. Procedures were established to prevent recurrence of this kind of error.

These are all excellent examples of the value of NASA's total systems engineering approach. The appropriately designed and located instrumentation, thorough documentation of manufacturing and test phases and engineering capability in depth, both in and out of NASA, made expeditious solution of these problems possible. In fact, even definition of the problems was dependent on the reconstruction of many variables, tested remotely.

It is normal to expect that a major program such as Apollo be thorough and rigorous. Such thoroughness requires investment in high caliber personnel, equipment and procedures. This investment, however, pays dividends by reducing the frequency of problem occurrence to a minimum and further by providing the facts and means to identify and solve them with confidence when they do occur. The solution of these problems, achieved without flight testing of an additional full scale Saturn V, resulted in significant cost savings.

Apollo 7

The Apollo 7 (MP68-7223) flight of October 11-22, 1968, has been termed a perfect mission. This first manned Command and Service Module incorporated all the changes resulting from the post accident (January 1967 fire) reevaluation and redesign. It was also the first time a manned spacecraft carried out a long duration mission on its first flight. All 59 of its engineering test objectives were achieved.

Following a normal lift-off and boost phase, the combination of the manned Command and Service Module spacecraft and the second stage was inserted into a 123 by 153 nautical mile orbit. The crew manually controlled the spacecraft-second stage combination until the stage was separated about 2 hours and 55 minutes after launch. Immediately after the spacecraft separated from the stage, the crew performed a spacecraft transposition and simulated docking with the spent stage. This exercise was followed by a rendezvous sequence which was completed 30 hours after launch. Other activities during the mission included orbit changes, intravehicular activity, photography and live television.

All space vehicle systems performed satisfactorily throughout their expected lifetime or for the duration of the mission. Some minor anomalies were reported. Recovery of the flight crew and Command Module was successfully accomplished. (MC69-4378)

Plans for the Apollo 8 mission were approved and the launch scheduled for no earlier than December 21, 1968. The Apollo 8 or "C-Prime" mission was planned to be open-ended up to and including 10 lunar orbits.

"C-Prime" (Apollo 8) Decision Factors

Apollo 7 and, particularly, Apollo 8 clearly illustrate the merit of capitalizing on success and planning open-ended missions. Apollo 8 (AS-503) was originally planned as a third unmanned Saturn V test flight. The decision to man Apollo 8 was justified by Apollo 6's generally good performance and by the high degree of confidence in the solutions generated for the "pogo", Augumented Spark Igniter (ASI) and spacecraft Lunar Module Adapter (SLA) problems.

The 10.8-day Apollo 7 (AS-205) mission was an unqualified success and clearly certified that the Command and Service Module was a space-worthy craft. This, thereby, permitted expansion of the open ended Apollo 8 mission planning to include lunar orbit. Apollo 8's potential, thereby, was maximized while retaining the flexibility to limit the mission to less ambitious objectives if operational conditions so dictated.

The decision to fly Apollo 8 in a "C-Prime" mission was announced on November 12, 1968, following a long series of intensive investigations and reviews by the Apollo Design Certification Review Board comprised of Manned Space Flight's Center Directors under my Chairmanship; a second review by a group of Senior Corporate Officials of companies directly involved in the Apollo Programs and a third and final review by Dr. Paine and other members of NASA's senior staff. The decision to expand Apollo 8 planning to include a lunar mission was recognized to involve some additional risk. In our judgment, however, after a very extensive assessment we felt that the progression of risk between the successful Apollo 7 mission and the lunar Apollo 8 mission was a normal progression of risks to be faced in a logically stepped development flight test program. The new risks were summarized in two categories--one dominated by the necessity that the spacecraft Service Propulsion System (SPS) operate properly in order to leave lunar orbit for return to earth. The other included the risks inherent in the fact that the spacecraft and crew would be almost three days from earth rather than one-half to three hours as in low earth orbital mission. This latter fact placed increased reliance on the dependability of the life support system and the electrical power system.

The question of the severity of these risks is summarized on (MA69-4280). Redundancy was provided to plan against failings of both people and equipment. Ground and flight tests of the spacecraft had already demonstrated excellent performance and proper margins with respect to design conditions. In the area of consumables we were able to provide large margins and because we were flying without the Lunar Module, the service propulsion system propellant supply could be provided with a very considerable margin.

Other factors to be considered in the question of risk assessment were the things we were able to do to make it the safest possible mission to meet the established objectives (MA69-4285). For example, we planned to launch in daylight.

A free return trajectory was to be maintained all the way to lunar orbit insertion. The significance of this fact is that right up to that commit point where the main spacecraft engine was fired to accomplish insertion into lunar orbit, the option to fly past the moon and return to earth could be exercised by not doing anything beyond making small mid-course corrections. These corrections could be accomplished by firing the small reaction control engines.

We planned a minimum time in lunar orbit, ten revolutions in approximately twenty hours. We also were able to reduce the planned return time from the ordinarily contemplated 72 hours to 58 hours. This was possible due to the additional propellant supply already mentioned and the demonstrated heat shield capability.

Overall, we felt very fortunate to be in a position to attempt to carry out the flight and take one significant step in the whole series of steps required to get up to a full lunar landing capability. Particularly, this involved flying the very complex spacecraft in a lunar mission without the additional complexity of the Lunar Module.

As a result of the crew and operational experience, the element of added demonstration and data gathering provided by the successful Apollo 8 mission, the probability of success in a lunar landing mission has been very much enhanced.

Apollo 8 ("C-Prime")

Apollo 8 (MA68-7626) was launched from the Kennedy Space Center's Launch Complex 39 on December 21, 1968, precisely at 7:51 a.m., as planned. It was an open-ended mission with the objective of proving the capability of the Apollo Command and Service Module and the crew to operate at lunar distances. A Test Article (LTA-B) to simulate the Lunar Module was carried as ballast.

The Apollo 8 mission generated an international impact favorable beyond expectation; e.g., issuance of commemorative stamp by an Iron Curtain country - Hungary. The more significant of the many "firsts" accomplished include:

. The Apollo 8 crew ventured farther (233,000 miles) and faster (24,695 statute miles per hour) than man ever previously flew.

. This world's first live TV portrait from deep space and lunar distances. (MA69-4290)

. The Apollo 8 crew members were the first to escape the gravity of earth and experience that of the moon.

. First men to orbit the moon.

. First men to lose total contact with the earth while circling the back side of the moon.

. First men to see the back side of the moon (MA69-4291).

The mission was carried out on a step-by-step "commit point" basis. The significance of this approach is that decisions of whether to continue the mission, return to earth, or to revert to an alternate mission mode were made before each major maneuver--based on the assessment of the status of spacecraft systems and crew.

The major maneuvers (MA69-4085) included:

1. Translunar injection-initiated by reignition of the Saturn IVB propulsion system at the time of 2 hours, 50 minutes, and 37 seconds. This maneuver lasted for 5 minutes and 19 seconds. Only two minor midcourse corrections were made during translunar coast.

2. Lunar Orbit Insertion - performed by firing the Service Module Propulsion system at 69 hours, 8 minutes, 20 seconds for a period of 246.5 seconds. The lunar orbit phase (10 orbits) involved numerous landing-site/landmark sightings, lunar photography and preparation for transearth injection.

3. Transearth Injection - This extremely critical firing of the Service Propulsion System was conducted at 89 hours, 19 minutes, 17 seconds into the flight and was 203 seconds in duration. Only one minor midcourse correction was made during transearth coast.

The Command Module landed in the Pacific within a few thousand yards of the USS Yorktown after a 147-hour, 0 minute, 42-second flight.

Viewed either as an entity or dissected to any possible degree, the Apollo 8 mission was a superb success. It's performance might be summed up in this way:

- All systems performed as designed.
- Consumables usage was as predicted and always at a safe level.

- Communications quality was excellent including six transmissions via live television.
- Onboard guidance and navigation was excellent.
- Thermal balance was always within limits.
- The crew satisfactorily performed all flight plan functions and achieved all photographic objectives.

APOLLO 9

The Apollo 9 space vehicle (MP 69-5111) comprised of the SA-504 Saturn V launch vehicle, Command and Service Module 104 and Lunar Module 3 (MP 69-5122) was successfully launched on March 3, 1969, at 11:00 a.m., from Cape Kennedy. The mission lasted ten days in earth orbit, during which critical manuevers involving the Lunar Module and the Command and Service Module were conducted . Simulations of the lunar mission manuevers were flawlessly executed and splashdown occured into the Atlantic on March 13th.

The Lunar Module, flown for the first time with men aboard, operated with a precision matching that of the previously validated Command and Service Module. The Lunar Module's performance thus completed the certification of major hardware required prior to attempting a lunar landing. As with Apollo 7 and 8, the international impact which resulted from Apollo 9 was such as to inspire President Nixon's personal congratulations to include "The epic flight of Apollo 9 will be recorded in history as 10 days that thrilled the World."

The Lunar Module is a key hardware item for the lunar landing, providing the transportation and life support to and from lunar orbit and life support on the lunar surface.

The schedule for the first half of the flight programmed more work than any other previous mission. The crowded schedule was calculated to insure that major mission objectives would be accomplished even in the event of an earlier-than-planned return. The final five days were devoted to a more relaxed routine of landmark tracking, experimental Earth photography and the regular engineering checkouts.

The highlight and most critical element of the mission involved the activities leading up to and the conduct of orbital manuevers of spacecraft separation,rendezvous and docking. On March 7, the Lunar Module separated from the Command and Service Module. This separation followed transfer of the Commander and Lunar Module pilot through a connecting tunnel to the Lunar Module. A series of three discrete engine firings placed the Lunar Module initially three miles from the CSM in an equal but different orbit, secondly, placed it eleven miles further away and finally, approximately seventy-eight miles away from the Command and Service Module.

The Command and Service Module (MP 69-5121) remained passive while the Lunar Module undertook rendezvous on its own power, using radar and instruments. It caught up with the target Command and Service Module and re-checked systems while paused at a distance of 100 feet. Once satisfied that conditions were satisfactory, the LM inched toward the Command and Service Module and locked with pinpoint accuracy.

All Apollo 9 primary objectives were achieved successfully. All launch vehicle systems performed satisfactorily throughout their expected lifetime with the exception of inability to dump propellants following the third S-IVB burn.

All spacecraft systems functioned well and without any major anomalies. Those minor discrepancies which did occur were primarily procedural and, either corrected in flight without impact, or involved instrumentation errors which could be checked by other means. Temperatures and usage rates of consumables remained within normal limits throughout the mission.

Some of the more significant mission achievements of the Apollo 9 mission include:

- First manned Lunar Module systems performance demonstration.
- First Lunar Module-Active rendezvous and dock.
- First Command and Service Module - Active dock.
- First intervehicular transfer of astronauts in shirt sleeve environment between docked interface of two vehicles.
- First Apollo extravehicular activity (MP 69-5124)
- First in-flight depressurization and hatch opening of Lunar Module and Command Module (MC 69-5287)
- Largest payload ever placed in orbit.

The flexibility of Apollo mission planning was again demonstrated by the change in splashdown site during the missicn. Splashdown, originally planned for southwest Bermuda on revolution 151 was relocated to about 600 miles east of Cuba on revolution 152 because of the threat of marginal wind and sea conditions.

APOLLO PROGRAM PHASING

As it has since program inception, Apollo mission planning continues to provide the basis for orderly and validated progress to the lunar landing. The plan has been designed to provide flexibility to cope with problems and still be able to capitalize on success. This flexibility, for example, allowed for the transfer of mainline Apollo missions from the Saturn IB to the Saturn V as soon as the latter demonstrated its readiness for manned flights. This milestone transfer was achieved during 1968 and, as a result, all remaining Apollo missions will employ the Saturn V launch vehicle.

Apollo-Saturn missions have been grouped into eight flight development phases (MA69-4289). At this time, we have successfully conducted the planned activities of all the phases shown with the exception of the planned mainline missions F (Lunar Mission Development) and G (Lunar Missions). As illustrated, these are manned missions and will be conducted at lunar distances.

The number of actual launches required to accomplish the objectives of these mission phases will continut to depend on the degree of success achieved on each.

Mission F - Lunar Mission Development

Phase F mission objectives are primarily concerned with demonstration of performance of the crew, space vehicle and mission support during a manned Saturn V mission, again with manned Command and Service and Lunar Modules. The unique difference from mission D, however, is that F will operate in a cislunar and lunar environment rather than in earth orbit.

Primary objectives:

1. Demonstrate crew/space vehicle/mission support facilities performance during a manned lunar mission with the Command and Service Module and Lunar Module. 2. Evaluate Lunar Module performance in the cislunar and lunar environment.

Mission G-1 - First Lunar Landing Mission

Profile - Mission G (MA68-6082)

The launch translunar injection, coast and lunar orbit insertion phases will be as described in the F Mission above. In lieu of simulation, however, the Lunar Module Descent Propulsion System shall be used for actual descent to the lunar surface. The astronauts will observe and report on their surroundings and carry out new experiments. They will emplace long-lived instrumentation, and most importantly, return lunar rock and soil to scientists for evaluation here on earth.

During the initial visit, live television pictures of lunar features and astronaut activities will be transmitted to earth. Panoramas will be photographed and movies taken of the landing, surface activities and the ascent.

Surface activities are planned during one scheduled extravehicular activity (EVA) period of up to three hours duration. Gemini experience showed that a slow increase in EVA complexity was necessary to operate under zero gravity. The 1/6 gravity environment of the lunar surface cannot be completely simulated on earth and, therefore, a conservative approach has been adopted.

Most of the astronaut activities on the first mission will be conducted within fifty feet of the Lunar Module and data regarding these tasks will be obtained to provide answers to immediate questions and as the basis for more complex missions.

After familiarizing himself with the new environment, the astronaut will collect a contingency lunar soil sample (SM69-353) weighing three to five pounds. This will be taken to ensure that some lunar soil will be returned to earth in the event the mission is forced to terminate prematurely. Geological tools will then be unpacked and a larger sample return container filled with specimens.

These rocks, together with the astronauts and their spacecraft, will be brought back to the Lunar Receiving Laboratory at Houston (SM69-318). This facility will be the site for debriefing, preliminary examination, precautionary quarantine and subsequent release of men and samples.

While they are on the lunar surface the astronauts will deploy three experiments.

First, a solar-powered seismometer (MA68-7512) to measure moonquakes and thereby form a picture of the internal structure of the moon, for comparison with the deep interior of the earth.

Second, a multi-piece glass mirror to reflect the light of ruby lasers mounted in telescopes on earth (SM69-347). We expect to measure the quarter million miles between the earth and moon to an accuracy of six inches, thereby increasing our knowledge about the moon's size, shape and interior, the length of the earth's day, movements of the earth's pole, and possible drift of our continents. We may even discover something new about relativity; a field discovered by Einstein and on which the Atomic Age is based.

Third, an aluminum foil will absorb particles from the solar wind for analysis here on earth, to learn more about the elements that make up the solar wind, about the formation of the elements themselves, the origin of the solar system, and history of the atmosphere.

These experiments have an international flavor. Scientists from about a dozen countries will receive lunar samples for analyses; astronomers of all nations will be able to direct their telescopes at the laser retrofeflector; and a Swiss team will analyze the solar wind foil.

If sufficient time remains, the astronauts will fill a second sample return container in a more selective manner with greater effort to photograph, describe, and pack the samples.

Meanwhile, their companion in lunar orbit will closely monitor the astronauts communications while he photographs their landing point and future landing sites. Then his companions will rejoin him for their return to earth as the first men to have walked on the moon.

PRODUCTION AND TEST

Saturn IB Launch Vehicle

The successful Apollo 5 and Apollo 7 missions employed Saturn IB launch vehicles. These mission achievements, coupled with the readiness of the Saturn V launch vehicle for manned flight (Apollo 8), concluded present Apollo requirements for the Saturn IB. Of the original 12 Saturn IB vehicles procured for the Apollo Program, 5 were used in vehicle and spacecraft development missions. The remaining 7 are planned for use in

Apollo Applications. In the unlikely event of problems with the Saturn V, they can be used for Apollo earth orbital missions with the Command and Service Module or the Lunar Module.

Saturn V Launch Vehicle

The major objective planned for the Saturn V launch vehicle in 1968 was its man-rating. This objective was achieved with Apollo 6 and through an extensive series of ground tests which verified the corrective actions instituted to resolve the Apollo 6 "pogo," augumented spark igniter, and spacecraft lunar module adapter anomalies. The successful flights of Apollo 8 and 9 demonstrated the validity of the man-rating.

The Apollo Program has procured 15 Saturn V vehicles. Three of these were flown through December 1968, and five Saturn V launches are planned in calendar year 1969. Chart (MA66-9694) illustrates graphically the advanced state of production of the remaining Saturn V vehicles.

Command and Service Module

The Command and Service Module achieved operational maturity in 1968. Command and Service Modules were flown on Apollo 6, 7, 8, and 9. Spacecraft 020, was launched on the Apollo 6 mission on April 4, 1968, and performed with a high degree of success. The three manned Block II spacecraft 101, 103, and 104 flown on Apollo 7, 8, and 9 respectively, performed so well, that they have naturally tended to overshadow the significance of earlier achievements.

As a result of the major changes incorporated into the Block II spacecraft, the ground test programs established to certify the spacecraft for manned flight were redefined in 1967. These tests included requalification of the earth landing systems, structural hatch tests, a very comprehensive flammability program, land and water impact testing. Also included in this redefined series were post-landing flotation, static structural and thermal vacuum tests. Rigorous ground testing of the spacecraft in support of the "pogo" analysis previously discussed, was also conducted during this period.

The thermal vacuum test, utilizing Command and Service Module ground test spacecraft 2TV-1, was one of the most significant in the program. Incorporated in this vehicle were the most advanced nonflammable materials which evolved from the flammability program tests as well as the hardware revisions reflecting the Block II configuration. Only minor anomalies were experienced during the manned thermal vacuum testing and resulted in the unanimous approval by the astronauts and engineers that spacecraft 101 on Apollo 7 be manned.

The Apollo 7 flight achieved all mission objectives and the Command and Service Module performed flawlessly. This textbook flight and the successful ground test programs led to the decision to fly spacecraft 103 in a lunar orbital mission.

Once again, the performance of the spacecraft was excellent and validates the statement made earlier that the Command and Service Module is now a more mature, operational spacecraft.

A total of four Block II Command and Service Modules were delivered to the Kennedy Space Center during 1968 (MA66-9695-B). The last two, 104 and 106 proceeded through checkout at that center early in calendar year 1969 and future deliveries are scheduled on two month intervals beginning with Spacecraft 107 in January. Spacecraft planned for delivery in 1969 and 1970 are on schedule at the North American Rockwell Space Divison Plant in Downey, California.

Lunar Module

During 1968 Lunar Module emphasis was placed on the continued incorporation of mandatory changes, the conduct of the ground tests constraining manned flights, and on the maintenance of the spacecraft weight within the budgeted level.

The design verification and qualification test programs of the two competing injectors for the ascent engine, initiated during 1967, continued until September. A decision was made to incorporate the backup injector into the existing engine design beginning with the unit for Lunar Module 3.

One of the more time consuming problems encountered during checkout of Lunar Module 3 at the Kennedy Space Center was an electromagnetic interference (EMI) problem which affected performance of the rendezvous radar. Solution of the difficulty was really more tedious and time consuming than it was complex in that it required extensive isolation and shielding of the numerous circuits in the spacecraft to determine the source. Due to these checkout delays, Lunar Module 3 was reassigned to Apollo 9 for the accomplishment of Mission D objectives. The electromagnetic interference difficulty was subsequently eliminated and Lunar Module 3 approved for the Apollo 9 mission.

As with the Command and Service Module, the thermal vacuum ground test of the Lunar Module was a very significant achievement required prior to the decision to man Lunar Module 3. The spacecraft cleared this test constraint very successfully in June 1968. The thermal vacuum tests constraining the lunar landing mission were completed in November of 1968.

Three Lunar Modules (2, 3, and 4) were delivered to NASA in calendar year 1968 (MA66-9695-A). Delivery of Lunar Module 5 was accomplished in January 1969, and Lunar Module 6 was delivered to Cape Kennedy in March. Subsequent planned deliveries will support Apollo requirements.

Software

The redefinition of requirements and development problems also had their impact on the delivery of flight software programs required for the guidance systems of both the launch vehicle and the two Apollo spacecraft. In recognition of this problem, we advised you last year that a special review team was established to find whether any actions could be taken to improve the development and verification process of these programs. Improved visibility and control were also objectives of the review team.

The team investigated all aspects of the software programs; the requirements--which were simply the question of what we are asking the computer to do, and the responses--which are, what are we going to do? Establishment of requirements presented some unanticipated difficulties. They did many things, far too numerous and varied to review here. In a broad sense, however, the effect was a formalization of the management of these very complex programs with a much improved degree of control.

The review team met a great many times. It was composed of representatives from NASA Headquarters and its Centers, the systems engineering contractor, and industry. The status of software development has been upgraded such that it is now in support of Apollo schedules.

MISSION OPERATIONS

Mission Operations activities include the provision of the resources necessary to launch, control, and recover manned missions. It also includes the provision of trained flight and ground crews to accomplish mission objectives. (MC69-4095).

The operations resource baseline includes: Flight Crew Operations, Launch Support and Launch Instrumentation, Mission Control, detailing requirements for support of the Manned Space Flight Network, Mission Planning and Analysis, and Recovery Operations. This is the functional area of the Office of Manned Space Flight that interfaces with other National Aeronautics and Space Administration Activities and with the Department of Defense.

During 1968, most of the operations baseline was declared operational and our flight test program was reestablished. Our operations resources were once again actively applied in support of missions.

Support of the four Apollo missions flown during 1968 provided the opportunity to develop valuable and broader experience in control of spacecraft and launch vehicles, particularly the Saturn V.

Apollo 5 marked the first time flight control hardware and software peculiar to the Lunar Module were operated in support of a mission.

Apollo 6 provided our ground flight controllers with additional and new experience in controlling Saturn V vehicles. The off-nominal performance of this vehicle described on pages 37 through 41 created a situation wherein our controllers were required to successfully cope with in-flight anomalies. The experience in forming real time alternative decisions and conduct of alternate missions to achieve worthwhile objectives was invaluable.

Apollo 7, 8, and 9 marked the return of man to our missions. The experience and the success achieved in these missions have served to strengthen the confidence of the ground controllers in their equipment and themselves. Ground and flight crews were more than equal to their responsibilities and functioned successfully to conclude these complex and precedent setting missions.

Mission operations is prepared to support the remaining missions leading to the initial lunar landing and subsequent landings in our efforts to conduct further lunar exploration. New to these coming missions will be the requirement to support a manned Lunar Module in earth orbit, at lunar distances and in a landing mode on the lunar surface.

Ground resources must thereafter be capable of receiving the anticipated extensive data from the surface experiments packages planned for emplacement there.

Flight Crew Operations

General

Flight Crew Operations is a multi-faceted activity which encompasses all the manned space flight functions that are directly related to the crew. Astronaut technical contributions are essential from basic design of a manned space flight system through final operation of each craft. The diverse events which compose this activity can be summarized in the two major categories of astronaut status and training device status.

Astronaut Status

Sixty-six astronauts have been selected between 1959 and 1967. One is the Director and one is Deputy Director of Flight Crew Operations, Manned Spacecraft Center; one is Chief of the Astronaut Office, Manned Spacecraft Center; six have resigned; eight are deceased, and forty-nine are active as astronauts.

During 1968, thirty-one active astronauts were assigned as prime crew, backup crew, or support team for Apollo 7, 8, 9, and 10. One has since become the above-mentioned Deputy Director. Seven were assigned to participate in Apollo Applications development and three were involved in advanced mission support. The remaining nine active astronauts, members of the most recent scientist-astronaut group, began their basic flight training which will be completed this year. Also, this year, approximately thirty active astronauts will function as prime, backup, or support crews for the planned Apollo missions leading to the initial lunar landing. The remaining astronauts will participate in Apollo Applications development and advanced mission support.

Training Device Status

The three Apollo Command Module Simulators supported training for Apollo 7, 8, and 9 in 1968, and are now in use for Apollo 10 and 11. The two Apollo Lunar Module Simulators became operational in 1968 and are now supporting training for Apollo 10 and 11.

The first two Lunar Landing Training Vehicles (LLTV) completed their ground testing during 1968. The crash on the final acceptance test flight of LLTV number 1 has been analyzed and the conclusions have been incorporated in the flight testing and operational training use of the number 2 vehicle. Vehicle number 3 began combined test and maintenance crew training in 1968. The earlier loss of a prototype unit also resulted in some equipment and procedure changes which have been incorporated. Full scale mock-ups of six of the various Apollo Applications crew stations began fabrication during 1968 and two others were delivered and used for initial Apollo Applications crew training.

This year, the Apollo simulators and trainers will be rapidly cycled from support of one mission to another since flight configurations have reached a significant level of standardization. Fabrication and delivery of Apollo Applications mock-ups will be continued.

Mission Control Systems

(MC69-4096) The Mission Control Center at Houston completed pre-mission program development and testing and provided real-time flight control for all Apollo missions last year. During this period, several Mission Control Center hardware modifications were completed and others initiated to provide improved system reliability and backup capability in support of an active mission. Installation of electronic computer switchover and restart hardware to improve the switchover to a backup mission support computer was installed, tested, and placed in operation.

The capacity of the flight controller data display system for single mission support was increased by approximately 40 percent by providing for the sharing of existing display channels between the two mission control areas.

In the latter part of 1968, a development contract was awarded for improved digital television equipment to increase the capacity and improve the quality of the Mission Control Center display system. A plan was completed for modest modification of the Mission Control Center for specific support of the Apollo Lunar Surface Experiments Package, with implementation to be completed prior to the first lunar landing mission.

Compatibility and performance evaluation testing of the spacecraft communication system and associated ground station equipment continued and included the completion of testing and evaluation of an operationally equipped Apollo Range Instrument Aircraft. The Apollo Range Instrumentation Aircraft serves as a Manned Space Flight Network Station during insertion into translunar orbit. Preparations for Lunar Module detailed tests, combined systems tests, and simulation of a lunar landing mission were started.

The Manned Spacecraft Center developed prototype digital Spacecraft Television Scan Converter was placed in operation to support Manned Spacecraft Center off-line television conversion requirements of Apollo 7 television, but the operational evaluation of the prototype

Video Multiplexer System was delayed until 1969. Development of a system to provide real-time predictions of spacecraft communication parameters during various phases of an active mission was initiated, as was development of an improved system to produce background and reference slides for the Mission Control Center display system.

Major emphasis will be placed on development of Mission Control Center software and further refinement of operations and maintenance procedures in preparation for the major activity of the Apollo Program, the lunar landing mission in 1969. The Apollo Lunar Surface Experiments Package Support system will be completed and tested for operational readiness, the data display system improved, and the communications Command and Telemetry System improved. The real-time communication prediction system will be completed, along with the Lunar Module electronic system compatibility testing, combined Apollo communication system evaluation testing, and communication simulation of a lunar landing mission.

Launch Instrumentation

Launch Instrumentation Systems are the meteorological, acoustic, hazard monitoring, lightning warning, telemetry, display, data recording, and computing systems used during pre-flight, countdown, and launch of space vehicles at Kennedy Space Center.

During 1968, the Launch Instrumentation Systems equipment for Flow 3 (Firing Room 3, Launch Umbilical Tower 3, Vehicle Assembly

Building Bay 2 and Pad B) was installed and became operational. Two hard copy machines were installed in the Central Instrumentation Facility and supported the Apollo 8 launch in December 1968; these units provide a copy of data displayed on television monitors, upon operator request. The Launch Instrumentation Systems at the Kennedy Space Center are operational to support Apollo pre-launch checkout, launch, and early flight phases. These systems were used to support the Apollo 5, 6, 7, and 8 in 1968 and Apollo 9 in 1969.

Launch Operational Communications

During 1968, major modifications to the Kennedy Space Center operational voice communications systems at Launch Complex 34 and in the Central Instrumentation Facility were completed. These modifications converted the systems to full duplex (4-wire) capability. The modified systems were successfully used to support Apollo 7 and pre-launch and launch operations. An expanded operational voice and television recording capability was implemented in the Kennedy Space Center Communications Distribution and Switching Center and used to support the first manned Apollo launch, Apollo 7. The centralized communications testing and switching capability was completed in 1968 and first used in support of Apollo 8. These expansions and improvements in the communications systems had been recommended in the Apollo accident investigations report. Early in 1969, the second operational television control center will become operational at Launch Complex 39 to permit support of simultaneous tests and to provide additional reliability.

Launch Information Exchange Facility

The Launch Information Exchange Facility and the Huntsville Operations Support Center at Marshall Space Flight Center provided real-time consultation support to the Kennedy Space Center during pre-launch and launch operations and to the Houston Mission Control Center during flight operations for Apollo 5, 6, 7, 8, and 9. Hard-copy equipment and a digital-to-television display system were installed in the Huntsville Operations Support Center early in 1968. The digital-to-TV display equipment will provide improved data display capability when it becomes fully operational in early 1969.

Recovery

The National Aeronautics and Space Administration and the Department of Defense completed a joint review of manned space flight recovery requirements and recovery support resources. The review indicated that the Mercury, Gemini, and Apollo programs demonstrated significant reductions in recovery support, as experience and confidence was gained in each program's flight operations.

The NASA and DOD planning for future manned recovery operations (1970-1975) recognizes the past experience and forecasts a trend of further reductions in recovery support requirements, as system reliability and confidence is gained in Apollo Applications and the Manned Orbital Laboratory programs.

Annual joint NASA-DOD reviews of recovery requirements and support resources will continue to update and refine recovery planning. Investigation of new recovery techniques will be considered in these reviews.

Manned Space Flight Network (MSFN)

All Apollo ships and aircraft are operational and are supporting missions. Fixed sites of the Manned Space Flight Network have been checked out and tested and are ready to support lunar operations.

Launch Support

Launch Complexes (LC) 34/37 are being transferred to caretaker status and will be maintained pending phase up of Apollo Applications requirements. Cost savings will amount to $14.9M during fiscal year 1969 and $6.0M during fiscal year 1970.

An organized study, sponsored by Mission Operations, has been started within all the program offices of NASA, to update and delete operational support requirements. This year the study will be completed and implementation of study findings will begin. Initial assessment of requirements indicates that some reductions will be possible.

The Department of Defense launch area abort recovery forces have demonstrated successfully their capability to perform during darkness in the launch area. Land, surf and sea demonstrations were conducted recently and were completely acceptable. This now provides a night manned lunar launch capability. Kennedy Space Center and Eastern Test Range have undertaken a joint study to identify support services with potential economies under consolidated or single management of certain base support functions. The consolidation of photographic support under a single contractor, which is in effect this year, is an example of the type of area to be studied. The joint Kennedy Space Center and Eastern Test Range recommendations should be available late this year.

Operations Management

As resources are acquired in the various functional areas, it becomes more important to assure that documentation is generated to define the existence and extend of these resources. Such documentation not only assists in the management of the resources, but it serves to advise other managers of the existence of the resources, and, therefore, tends to guard against duplication of responsibility, authority, effort, and real resources.

Last year two operations source management documents were started. One was a Mission Operations Plan which will define the organization of operations resources in Office of Manned Space Flight. It defines the authorities and responsibilities of operations activities to each other and to outside activities. It essentially defines the organizational and management resources devoted to the functional area of Mission Operations.

The second document is a Mission Operations Specification. This document defines the real operations resources baseline. In the conduct of the Mercury, Gemini, and Apollo programs we have created a tremendous operational capability. This capability was originally specified and was controlled by and within the respective flight programs. Office of Manned Space Flight in general and Mission Operations in particular have reached a stage of maturity that demands a separation of management of this very large capability from flight programs. It is, therefore, important that the existing operations baseline be defined and controlled separately. The Mission Operations Specification will define the baseline.

This year we expect to complete the Mission Operations Plan (organizational baseline) and Mission Operations Specification (material and human baseline) and institute a Configuration Management System in Mission Operations to assure a smooth transfer of operations from a phasing down Apollo Program to support following programs. It assures stability in this very large and important area.

For fiscal year 1969, a new formula has been provided by the Bureau of the Budget on the cost sharing between NASA and DOD for the Eastern Test Range support. This revised formula provides guidelines for NASA to share 40 percent of the direct range operations costs (e.g., range safety, instrumentation), except for Apollo range instrumentation (A/RIA) operations, where NASA pays 85 percent of their operating cost. For range support (e.g., transportation, utilities, buildings and grounds maintenance), NASA pays only for the direct support received from NASA equipment and facilities.

NASA and DOD are currently refining the various additional new tasks and cost categories that the revised formula encompasses. Kennedy Space Center, in conjunction with Eastern Test Range, is establishing and detailing accounting and cost review procedures to support the implementation of the new formula guidelines.

In fiscal year 1970, NASA will continue to review and clarify its essential requirements for Eastern Test Range operations and support, to assist in further economies.

LUNAR EXPLORATION

The fiscal year 1970 budget as amended in April 1969 by the new Administration includes funds which will make it possible for the nation to capitalize on its developed space capability through continued and effective exploration of the moon. This budget provides the necessary funds to initiate development and production of required systems and improvements as well as to continue studies of advanced mobility aids designed to extend the astronauts' exploration radius. The Apollo Program was conceived, designed, and developed as a program to achieve for the United States a capability for the manned exploration of space. The capability was to be demonstrated by landing a man on the moon and returning him safely to earth. In May of 1961, President Kennedy committed the nation to achieving the lunar landing in this decade.

While the recent successful Apollo flights give promise that this objective will be accomplished within the timeframe established by President Kennedy, at least one more complex manned mission must be successfully carried out before a lunar landing is attempted and it is, therefore, not possible to predict with certainty which mission will be the first lunar landing attempt.

Because of the uncertainty regarding the number of developmental flights required before the landing is accomplished, the planning and development of the Apollo capability has included acquisition of a sufficient quantity of hardware items and operational facilities to achieve the program's initial objective with a reasonable allowance for possible contingencies. In other words, NASA is prepared to fly more than one more mission before a lunar landing attempt and more than one attempt if the circumstances warrant. On the other hand, continued success and early accomplishment of the Apollo objective would make available Apollo hardware for continued utilization and development of this nation's capabilities in manned space flight.

Our plans for Saturn V launch vehicles which remain after the initial lunar landing are to use them for continuing lunar exploration, which includes a number of manned landings, the emplacement of experiment packages on the surface of the moon, and other activities to increase not only our operational capabilities in space but also to increase our store of scientific data which is so necessary to translate the results of manned space efforts into benefits for all mankind. All the Apollo/Saturn V space vehicles following accomplishment of Mission F (Lunar Mission Development Phase) are configured for lunar landings.

The current Apollo schedule provides for five flights in 1969, the last three of which are being configured to carry out a lunar landing. Assuming a successful manned lunar landing and return on the Apollo 11 mission in the summer of 1969, we plan to reduce the number of Apollo launches in fiscal year 1970 from five to three. Once the national goal has been achieved, the lunar exploration phase will be conducted at a rate of approximately three launches per year.

For several years now, we have been examining the degree to which we should continue to explore the moon; what we might reasonably expect to learn; what the benefits of lunar exploration might be in terms of national, scientific, technological, and economic benefits. We have evaluated how much we can expect to do with the Apollo system as it is presently configured and have identified areas in which we can make incremental improvements to the present equipment to accommodate the initial added requirements of a lunar exploration program. Although we cannot state with certainty when the first lunar landing will be accomplished, we have developed a logical phasing of lunar exploration missions after the first landing.

Let us look first, however, at why lunar exploration is of great importance to our nation. First, the significance of international leadership has been evidenced by the favorable world reaction to the very successful Apollo 7, 8 and 9 missions. This will be the first opportunity for man to carry out exploration of another planet in the solar system and in so doing provide the means for possible true international cooperation on another planet. This could take the form similar to that in the Antarctic when the Russians achieve the capability of carrying out their lunar exploration program. I have already mentioned the fact that the lunar exploration program will provide the basis for capitalizing on our Apollo capability.

Secondly, we will broaden and deepen our base of scientific knowledge through a factual understanding of the origin, evolution, present characteristics, and historical relationships of the moon to the earth and the solar system. Questions such as whether the moon was formed with the earth or captured later, and possible clues to the origin of life might be answered through our planned exploration. To quote the President's Science Advisory Committee, "Answers to these questions may profoundly affect our views of the evolution of the solar system and its place, as well as man's, in the larger scheme of things.

Many planets have moons, but ours is the largest in relation to its planet. This implies that the two bodies may have been formed in the same manner at the same time. If true, the moon may be a book containing the secret of the earth's first billion years of life.

This record is lost on the earth which is subjected to the wear and tear of erosion by atmosphere and water.

Until now natural phenomenon that can affect man could be studied only on earth. Now we believe many things that happen on earth also happen on the moon. By comparing similarities and contrasting differences, man may be able to arrive at a greater understanding of the fundamental processes that affect the earth; for example, the mechanisms that cause earthquakes and volcanic eruptions, and the processes responsible for concentrating ore deposits. The orbits of Apollo 8 and the Lunar Orbiters were disturbed by mass concentrations beneath the circular lunar seas. These may be hugh meteors that struck the moon with such force that they melted and sank into the interior, or they may be iron deposits.

A third reason for continuing lunar exploration is to examine the potential of the moon for possible benefits of man here on earth. For example, we will be able to evaluate the moon's natural resources, assess the moon as a base for future scientific and space operations as well as to evaluate the utility of a lunar base.

The fourth, and a very important reason,is the experience which will be gained in space operations while conducting the missions for exploration of the moon. We will learn about man's capabilities and limitations as a space explorer. Some day man will move on to other planets; the moon is now an accessible and potentially attractive training ground.

It is difficult to look far ahead. We do not have the basic information which early lunar landings will furnish and we can only speculate today about the feasibility of the moon as a base for an observatory or a permanent science station--about exploiting its environment of low gravity and high vacuum--about its potential for natural resources. The eventual goal of a lunar base would bring into focus the steps that must precede it, just as Apollo was important in establishing the objectives of Mercury, Gemini, Surveyor, and Orbiter. Critical to future consideration of a lunar base goal is information on the lunar environment, location of natural resources and strategic sites that could serve multiple purposes. A long-range goal like the lunar base would direct technological advances, stimulate public interest, and attain subsidiary objectives with earth application such as food synthesis, environmental control, and recovery of useful elements from rock.

To summarize the points I have made, through exploring the moon we hope to make fundamental advances in:

1. This nation's position as an international leader in space exploration and the establishment of a basis for possible international cooperation. Scientific cooperation in unfolding the moon's secrets may show the way toward peaceful coexistence.

2. The base of scientific knowledge pertaining to an improved understanding of the solar system and its origin, including clues to the origin of life.

3. Evaluating potential exploration of the moon for its natural resources and as a base for lunar and other planetary exploration.

4. Experience in space operations such as in logistics support for man on a distant planet, development of greater capability for exploration, i.e., lunar rover, flying vehicles and shelters.

We are not alone in our belief in the value of going to the moon. In 1959, five years before we sent our first spacecraft to the moon, the Russians impacted the first man-made object on the lunar surface. In subsequent years, they took the first picture of the far-side, made the first controlled landing, placed the first orbiter around the moon, and returned the first capsule to earth from lunar orbit. We may assume their future aims are similar to ours.

We have developed a lunar exploration program with planned landings at ten sites, four of which lie essentially in the zones of the initial Apollo lunar landing candidate sites. The first landing, if the launch is on schedule this summer, will be in an Eastern Mare region (MA69-4228) and the second in another Mare of different characteristics in the western region (MC69-4773).

The third flight will be directed to a highland, flat region characterized by the Fra Mauro formation. The fourth landing will be the first attempt to land in the cratered highlands near the Crater Censorius (SM69-354).

The fifth landing mission is planned for the Littrow area which is characterized by dark volcanic material.

The next visit will be to the impacted Crater Tycho (SL68-738) which is the site of the Surveyor VII landing.

This will be followed by a landing mission in the Marius Hills area (SL68-723) with its many volcanic domes.

The eighth landing is planned for Schröter's Valley (MA68-7407) with the purpose of looking for and examining possible transient events and to learn more about the red flares which have been seen in the area.

Hyginus Rille (SL68-716) will be the site of the ninth landing mission where we will be looking for volcanic craters in the Linear Rille to determine whether or not its origin is volcanic.

The Crater Copernicus (SL68-736) is the site where we will be looking for deep seated material which will have come from deep below the surface by the explosive force which formed the crater.

The sites, which have been discussed briefly, were chosen after discussions with the Science and Technology Committee, our experimentors, and our science advisory groups. This represents the latest thinking on the subject.

Initial steps required, in order to provide a greater capability in the basic Apollo system for lunar exploration, involve the maximum economical improvements in lunar staytime, astronaut mobility and instrumentation. These include (1) improved space suits, (2) improvements to the Portable Life Support System (PLSS) to increase the EVA time on the lunar surface, (3) modifications to the lunar module to provide a minimum of 3 days staytime on the lunar surface, (4) modifications to the Command and Service Module, including added scientific instruments to permit orbital survey of the moon, and (5) the procurement of additional Apollo Lunar Surface Experiment Packages.

Beyond these modifications and additions to the basic Apollo systems, there is a need to continue study and definition of more advanced aids to lunar exploration, such as lunar roving vehicles and flying vehicles to give greater mobility and traverse distance on the lunar surface, shelters to extend the astronaut staytime on the moon and the concept of dual missions to maximize the returns from each exploratory visit to the moon.

Space Suit

Astronaut mobility is a key element in effective manned lunar surface exploration. Ultimately, mobility aids will take the form of lunar rovers and flyers.

Studies have indicated that astronaut mobility can be gained by the adoption of a constant volume suit. This type suit reduces the amount of energy expended in movement by improvements to joint design, incorporating rotary bearings, rolling convolutes and constant volume bellows. This suit requires simpler fabrication techniques than current models and offers opportunities for improved quality control. Also, the constant volume suit does not involve an entirely new development effort in that it uses a considerable amount of existing Apollo technology - materials, thermal meteoroid garment layup, extravehicular visor assembly, helmets and connectors for life support system.

Portable Life Support System (PLSS)

As the constraints imposed by the space suit are relaxed it will also be necessary to provide improvements to the current Portable Life Support System to permit a longer life support capability while the astronaut is outside the Lunar Module. Some gain in this direction can be provided by incorporating an additional battery and water tank.

Extended Lunar Module Staytime

The current staytime capability of the Lunar Module is approximately 36 hours, with the initial missions planned for less than 24 hours. Within either of these periods there is a fixed period of time required for a checkout of Lunar Module systems just after touchdown and again before lift-off. These checkout periods will remain essentially constant regardless of overall duration of the surface mission. Therefore, additional staytime can be devoted to lunar exploration. Modifications to increase staytime will include adding water and oxygen tanks, batteries, crew provisions, enlarging the descent propellant tank and providing a greater measure of habitability. Funding for these modifications, designed to increase Lunar Module staytime to approximately 3 days, is included in the FY 1970 budget as amended in April 1969 in accordance with the policy of the new Administration.

Command and Service Module Modifications and Instruments

A variety of scientific instruments has been studied over the past few years, with a view to providing an orbital scientific capability for the Command and Service Module (SM69-431). These instruments include cameras and other remote sensors which will permit detailed geologic and geochemical study of the interrelationships of surface features on the moon and allow some scientific extrapolation of the data returned from samples and other surface measurements. The installation of science instruments and the overall increase in mission duration imposed by extended surface staytime would require some modifications to the basic Command and Service Module. The amended FY 1970 budget will support the upgrading of Command and Service Modules to extend mission duration capability to 16 days and equip them with the selected photographic and sensor packages.

Apollo Lunar Surface Experiment Package (ALSEP) (SM69-427)

The Apollo Lunar Surface Experiment Package is the basic geophysical tool for lunar exploration. It is designed to measure the internal structure of the moon, determine the heat flow from the interior of the moon and monitor the solar wind and radiation environment. To get an accurate picture of the internal structure of the moon, it will be necessary to emplace ALSEP stations in networks. At the present time, there are only four ALSEPS in the program although the amended FY 1970 budget provides funds for procurement of additional and improved ALSEPS. These improved ALSEPS will allow continuation of a seismic network on the moon and permit measurement over an extended period of time of such lunar activities as heat flow, solar wind and charged particles.

Advanced Lunar Supporting Systems

To expand further our lunar exploration capability, we are continuing studies of more extensive supporting systems. Beyond improved suit mobility, there will be a need for versatile mobility aids which will permit the astronauts to visit areas of difficult access but high scientific interest. A lunar flying unit would provide not only greater range of travel over the lunar surface, but also a vertical mobility for exploration of crater walls and steep terrain. Another mobility aid under active study is the roving vehicle (SM 69-448) which would make possible more far ranging automated traverses over the lunar surface and increase the capability for gathering lunar samples. To further increase staytime for the astronauts to accomplish complex investigations on the lunar surface, studies are being pursued on the concept of landing shelters and logistics support at the site by an automated lander.

Lunar Exploration Mission Phasing

Following the first successful lunar landing mission, an initial phase of lunar exploration is planned. This phase will consist of three missions which are currently well defined. Each will use the Apollo Saturn V equipment, essentially in its present configuration, and each will have as a primary scientific objective sampling, deployment of an Apollo Lunar Surface Experiment Package and detailed geological foot traverses. The three Apollo Lunar Surface Experiment Packages required and other supporting equipment are already available.

Planned landing sites and astronaut activities for the early missions to the moon are geared to the current capabilities of the Apollo system. As a result, scientific data from the initial landings will be limited generally to that which is available from the broad homogenous areas of the moon, that is, the mares and certain highland sites. To gain information about the more scientifically rewarding sites will require improvements in the Apollo system capabilities which I have described so that we can enhance landing accuracy, ability to reach specific sites, staytime, instrumentation, payload, and mobility on the lunar surface.

Later phases of lunar exploration will continue and expand the investigations initiated in the first phase. Improvements to the Apollo system will be incorporated as they become available. The time the astronauts spend outside the Lunar Module will be increased and the radius of exploration will be extended. Orbital surveys will be conducted to correlate with the data gathered during the surface investigations.

Mission planning for lunar exploration will retain the necessary degree of flexibility to permit later missions to take advantage of what we learn on early flights and to permit optimum use of system improvements as they become available.

SUMMARY

The major Manned Space Flight milestone schedule for 1968 was achieved in December with the Apollo 8 mission. The specific milestone (MC68-5185) was the flight of the first manned Apollo Saturn V. Last year we reported that the momentum, lost early in 1967, had been regained after a complete reassessment of the Apollo Program; that the foundations of Apollo were materially strengthened and ready for the challenges to come. The Apollo progress reflected in 1968's accomplishments and climaxed by the NASA team's performance in Apollo 8 and Apollo 9 are evidence that our confidence was soundly placed.

As with all progressive efforts, Apollo looks forward to the continued challenge of our planned operations in 1969. A successful Apollo 10 mission will pave the way for the accomplishment of the Apollo mission--the successful landing on the moon and return.

This accomplishment will mark the beginning of a period of lunar exploration planned for the Apollo Program. The primary goal is to assess the utilization of the moon in the interests of our nation and its potential for benefiting the world.

SPACE FLIGHT OPERATIONS

The Space Flight Operations program has as one of its objectives the development and operation of a manned space station that can be launched in the mid-1970's. The general requirements of the space station including logistic systems which will provide this country with the capability to conduct long-term space operations are now defined, and study efforts are being conducted on narrowing the range of alternatives. The station will be able to operate in earth orbit on a semi-permanent basis, and its systems and configuration will be designed to accommodate payloads of varying size and complexity. The configuration will have a basic capability to incorporate complete experiment modules, to replace life support and other modules, and to take on new experiment modules after the station is in orbit. It will also accommodate increases in crew size from the initial complement. This adaptability will allow the space station to respond to technological advances and new operational techniques.

The development of a versatile space station is clearly the key toward developing more effective space operations and broadening the range of activities that can be conducted in the unique environment of space. The total system consists of a long duration, multipurpose space station where men can live and work for extended periods and a logistic system for carrying men, supplies, and experiment modules to and from the orbiting station. The productive long-term use of the space environment depends on the ability to reduce the high cost of putting payloads into orbit. The introduction of recoverable and reusable systems is a potential means of reducing these costs, simplifying the operational procedures, and providing convenient and economical roundtrip transportation to and from an orbiting space station.

The combination of a flexible base for earth orbital operation and an economical means for reaching the station and returning to earth will be the next major step in using the frontiers of space to maintain the vitality and forward progress of our society during the next decade. It will provide a natural focal point for advancement of science and technology and a platform for increasing the benefits of space to mankind.

Once the space station system is established, its use for research, observations, and operational activities can be determined on the basis of priorities and resources available at a given point in time. With the advantages of added volume, operational flexibility, and built-in versatility, the space station system opens great opportunities for expanding and improving the quality and quantity of information obtained about earth resources, oceanography, weather prediction and control, disaster warnings, air and sea traffic control and safety, cartography, and scientific investigations. The lifetime and capabilities of the station will extend knowledge of the effects of long-term space operations on man's physiology and psychology. In addition, the space station will provide a base for continued development of the systems and technology required to increase man's ability to live and work comfortably in space and to progress toward practical solutions in establishing, operating, repairing, and maintaining permanent orbital stations. This body of knowledge will open the door to increased productivity and versatility in future space operations, including permanent bases which could be used as launching platforms, refueling stations, and sophisticated observatories and working laboratories.

Initial Space Flight Operations will be conducted in the Apollo Applications Program, which is built on the strong base of flight experience, ground facilities, and trained manpower developed in the Apollo program. Apollo Applications employs the Saturn I Workshop, the Apollo Telescope Mount, and basic space vehicle hardware developed and procured in Apollo. This basic hardware is being modified to meet the unique requirements of the Apollo Applications missions and to capitalize on the Apollo-developed capability by accomplishing a limited but carefully selected spectrum of scientific, technological and medical investigations. The program is a progressive step toward the establishment of a long-term space flight operations capability in the Space Station, and furnishes information which will be used to reach sound decisions on the content and configuration of our future operations in the space environment.

The United States has an investment in technology, facilities, management skills, operational techniques and hardware equipment developed in the Gemini and Apollo programs. The Space Flight Operations program is directed toward increasing the scientific, technical and economic return on this investment. Continued use of this national capability is essential if this nation is to continue its industrial and technical growth and maintain its role as a technological leader of the world.

This section of my statement represents a new category within the NASA budget, which encompasses the earth orbital manned space flight research and development activity projected for the 1970's.

In the budget amendment for Fiscal Year 1970, Space Flight Operations requirements comprise the following elements which I will now discuss: the Apollo Applications Program, the Space Station, Saturn V Production and Operations. I will begin with Apollo Applications.

APOLLO APPLICATIONS PROGRAM

INTRODUCTION

The Apollo Program is providing the nation with the capabilities and resources for continued operations in space. The Apollo Applications Program is designed to capitalize on these Apollo-developed capabilities and resources to accomplish a limited but carefully selected spectrum of scientific, technological and medical investigations. This program will expand our activities and knowledge in the areas of earth orbital operations, experiments and practical applications and will teach us more about man's usefulness in space. Apollo Applications is a progressive step forward leading to the establishment of a broad space operations program.

The Apollo Applications Program will provide the basic information which will be used to reach sound decisions on the content and configuration of future space operations utilizing manned space flight capabilities and resources.

With the funding included in the original budget request for the Apollo Applications Program, earth orbital operations were planned beginning in mid-1971. The amended budget will require restructuring and some reorientation of program content as well as delays in the start of Apollo Applications missions. Specific action is being taken to suspend production of Saturn IB vehicles 213 and 214 and to slow down efforts related to the backup Workshop and Apollo Telescope Mount described below. In addition the start of Apollo Applications missions will be delayed a minimum of five months. It had been planned that, if required, backup missions could be launched five months after the initial launch dates for the Workshop and Apollo Telescope Mount missions. The budget amendment will delay the backup missions an additional three to four months.

OBJECTIVES

The objectives (ML68-6015) of the Apollo Applications Program are:

a. Long Duration Space Flight of Men and Systems. Long duration space flights of men and systems is an objective that will make use of the unique capabilities of man as a participant in space flight activities. Techniques will be developed for measuring the life of systems and subsystems of space vehicles. Man's psychological responses and aptitudes in space will be determined and evaluated. Man's post-mission adaptation to the terrestrial environment will be analyzed as a function of progressively longer missions. The need for artificial gravity will be determined as well as the increments by which mission duration can be increased.

b. Scientific Investigations in Earth Orbit. Scientific investigations in the Apollo Applications Program are designed to take advantage of space operations to learn more about the universe, the space environment, and the phenomena that exist in the solar system that affect the environment of man on earth.

c. Applications in Earth Orbit. Applications experiments include the development and evaluation of efficient techniques utilizing man for sensor operation, discrimination, data selection and evaluation, manned control, maintenance and repair, assembly and set-up, and mobility involved in various operations. These experiments include studies in meteorology, earth resources and communications. The proper relationship between manned and unmanned applications operations will be determined.

d. Effective and Economical Approach to the Development of a Basis for Potential Future Space Programs. Our efforts to make maximum use of existing hardware and capabilities are focused in the Apollo Applications Program. Utilizing Apollo-Saturn capabilities that have been developed will enable us to fly Apollo Applications missions at a small fraction of the initial development cost. These Apollo Applications missions will provide the development of the capability for man to operate in space for increasingly longer periods of time. The technology developed by Apollo Applications will provide the basis for future long duration space station design and development. In addition, manned operational requirements for future extended lunar operations will be further defined as a result of Apollo Applications missions.

MISSIONS

To fulfill the Apollo Applications Program objectives, flight missions are planned for progressively increased mission duration and for performing experiments in the areas of medicine, science, technology, operations, and applications. Apollo Applications missions are based on the concept of the maximum utilization of existing hardware and the use of launch vehicles and spacecraft developed for the Apollo Program (ML 67-7074). Mission planning is also based on concepts of revisit, reuse, resupply and repair of equipment in earth orbit. A policy of open-ended mission duration will be maintained. Individual flights will have a specific duration goal of 28 days and 56 days with standard procedures for terminating the mission in the event that crew or equipment dictate. The total operating period, including the period of space storage of equipment between manned usage will be months or more. Apollo Applications flights will lead to the mid-1970's long-duration space station program. New operating techniques will be developed and the base of knowledge will be expanded.

Saturn I Workshop

The Saturn I Workshop (MC 68-5607) consists of the spent Saturn IB second stage (S-IVB stage), an Airlock Module (AM), and a Multiple

Docking Adapter (MDA). The Airlock Module and the Multiple Docking Adapter are carried in the volume occupied by the Lunar Module on an Apollo lunar mission.

After powered flight, the spent S-IVB stage will be vented and the liquid hydrogen tank of this stage will be used as a living and working area for the crew. Two-thirds of this tank will be devoted to a laboratory and maintenance area which will be equipped to perform various experiments and maintenance functions. The crew quarters will occupy the remaining one-third of the volume and will be equipped with compartments for sleep, food management, waste management, and exercise/experiment performance. A portion of the crew quarters structure and facilities will be installed prior to launch. The remaining portion will be installed by the crew in orbit.

The Airlock Module (ML 69-4296) provides access to the Workshop from the Command and Service Module and the Multiple Docking Adapter. In addition the Airlock Module permits egress into space through a hatch without depressurization of the workshop or the spacecraft. The Airlock Module also provides environmental control, power, communications and control functions.

The environmental control system of the Airlock Module provides thermal and atmosphere control of the Workshop. The environmental control system also provides environmental control for astronaut extra-vehicular activities (EVA) outside the Workshop.

The electrical power system of the Airlock Module includes batteries for Workshop operations on the dark side of the earth, as well as power regulation and distribution to the other modules in the cluster.

The Airlock Communication System includes voice, experiment data, telemetry, tracking and ground command electronic equipment which is mounted in the Airlock Module. Displays and controls are also provided in the Airlock Module to permit flight management operations and attitude control of the assembled Saturn I Workshop Cluster.

The Multiple Docking Adapter (ML 68-5909) provides docking accommodations in space for the Command and Service Module (ML 68-5911) and the Lunar Module Apollo Telescope Mount (ML 68-6244). In addition, during the launch phase, it provides for the storage of most of the experiments and several habitability systems. An optical quality window for earth viewing and a scientific airlock for the conduct of experiments requiring vacuum exposure are provided.

Saturn I Workshop Mission

The Saturn I Workshop Mission requires the separate launch of two Saturn IB vehicles to establish and begin operation of the orbital workshop in earth orbit (ML 69-4270). The first flight is unmanned and is designated AAP-2. It consists of a Saturn IB launch vehicle with the second stage (S-IVB Stage) configured for conversion to the orbital workshop including the Airlock Module and the Multiple Docking Adapter. The orbital workshop (Spent S-IVB Stage) is placed in orbit. The second flight (designated AAP-1) also utilizes a Saturn IB launch vehicle to launch a manned Command and Service Module to rendezvous with the orbital workshop (ML 69-4270). The second stage of the Saturn IB used for the AAP-1 flight is not in the workshop configuration and is expended when the Command and Service Module are placed in orbit to rendezvous with the Workshop from the AAP-2 flight.

The three-man crew launched separately on the AAP-1 flight, will begin to activate the orbital workshop after rendezvous and docking operations (MC 68-5515). Following venting operations the hydrogen tank of the S-IVB Stage will be repressurized with a two gas atmosphere of oxygen and nitrogen. The crew will transfer from the Command Module through the Multiple Docking Adapter and the Airlock Module into the orbital workshop, and complete preparation of the crew quarters (MC 68-5513). Elements of the space station will have already been pre-installed in the S-IVB Stage before launch. The AAP-1 and AAP-2 Mission orbital configuration is shown here (MC 68-5689).

The Saturn Workshop Mission emphasizes medical and habitability experiments but also includes a significant number of science, engineering and technology experiments (ML 69-4301).

Limited medical data has been obtained in the Mercury, Gemini and Apollo programs in missions ranging up to 14 days. In order to provide data for evaluating man's capabilities to operate in space for considerably longer periods of time, a more complete set of medical experiments, supported by extensive ground based studies, has been defined for this mission.

They cover the areas of greatest medical interest to permit evaluation of man's physiological responses and his aptitudes in space in progressively longer duration zero g missions. Data obtained will generate an understanding of the basic mechanics of adaptation to the space flight environment and will evaluate more fully whether there is a need for artificial gravity in future long duration space stations.

Habitability experiments include crew quarters evaluation, food and food preparation, personal hygiene provisions, evaluation of space suits, and the testing of mobility devices (MC 69-4269). Engineering experiments include such tasks as electron beam welding, tube joining assemblies, gravity substitute work bench, and astronaut extra-vehicular activities.

Finally, various scientific and technology experiments will be conducted including Multi-band Terrain Photography utilizing handheld cameras.

The primary mission objectives are shown in this chart (MC 68-5062). The planned duration for activating and operating the orbital workshop as a habitable space structure in this mission is 28 days. The effects of long duration space flight on the crew will be evaluated. Scientific, engineering and technological data needed for development of advanced space vehicles such as a space station will be obtained.

After completion of experimental activities, the equipment in the Workshop, Airlock Module and Multiple Docking Adapter will be deactivated and placed in a standby mode for orbital storage. The crew will then return to the Command Module and the Command and Service Modules will be separated from the Multiple Docking Adapter. The Service Module Propulsion System will be used to place the Command Module on an earth return trajectory and the Workshop will remain in earth orbit in storage condition ready for subsequent revisits and reuse.

Saturn I Workshop Revisit Mission

The first Saturn I Workshop revisit mission uses a single Saturn IB launch of a three-man Command and Service Module to rendezvous and dock with the Workshop stored in orbit at the completion of the previous mission discussed above. This mission consists of one flight and is designated AAP-3A (ML 69-4372). The concept of revisiting a habitable space structure after a period of several months of untended storage in orbit will be tested. The planned duration of this mission is a period of up to 56 days. The progressive extension of mission length to systematically test and evaluate the ability of both man and equipment to function effectively for long periods of time in space is a prime revisit mission objective. For this reason, the primary in-flight experiment emphasis will be in the medical area. Other new activities will include reactivation of experimental equipment employed in the Saturn I Workshop Mission (AAP-1 and AAP-2 flights) plus continued evaluation of the utility of the various habitability subsystems and accommodations of the Workshop. The results of the first mission will be used to refine the second mission operating procedures. Similarly, the result of the second mission will be used to improve equipment and operating plans for subsequent missions.

The medical and behavioral investigative effort initiated on the Saturn I Mission (AAP-1 and AAP-2 flights) will be continued on this revisit mission to determine and evaluate the effects of this longer duration on the crew's physiological and performance proficiency.

The five areas of medical interest are:

1. Cardiovascular function, including hematology.

2. Respiratory metabolism and energy expenditure during measured workloads.

3. Musculoskeletal function and nutritional balance.

4. Neurophysiology of the vestibular system and sleep.

5. Crew reaction to weightlessness as measured by time and motion studies.

These investigations will provide a clear picture of the function of these major body systems.

Solar Astronomy Mission

The third Apollo Applications mission uses the orbitally stored Saturn I Workshop as a base of operations for the manned Apollo Telescope Mount (ATM) solar observatory (ML69-4372). A Saturn IB launch vehicle launches a modified three-man Command Module and Service Module which are configured for mission durations up to 56 days. This flight is designated AAP-3. The AAP-3 Command Module and Service Module will rendezvous with the cluster and dock to the Multiple Docking Adapter. A second Saturn IB launches an unmanned Lunar Module (LM) ascent stage configured to carry the Apollo Telescope Mount (ATM) with its payload of solar telescopes. This flight is designated AAP-4. An automatic rendezvous technique will be employed to place the LM/ATM close enough to the cluster to accommodate remote control of the LM/ATM by the crew from the cluster. The LM/ATM will then be docked to the Multiple Docking Adapter by this remote control method. The Workshop will then be reactivated.

The orbital configuration of the Solar Astronomy Mission is shown here (MA68-7001). This mission will be the first flight test of equipment and operating concepts for future manned and man-tended astronomical observatories. It makes the first manned operation of high resolution solar telescopes and spectrographs for observing dynamic phenomena on the surface and in the corona of the sun in wavelengths which are obscured or diffused by the earth's atmosphere. The Apollo Telescope Mount experiments are shown in this chart (ML69-4293).

The Apollo Telescope Mount experiments are designed to scientifically study the sun. The surface of the sun, the observable sunspot cycle, and the nature and pattern of the solar flare activity, may hold the key to understanding the basic forces and elements which control the solar system. The unmanned Orbiting Solar Observatory (OSO) spacecraft provided the first opportunity to study the sun without the interference of the earth's atmosphere. The Apollo Telescope Mount will provide a significant increase in the quality and depth of our knowledge of the sun by providing greater pointing accuracy than was possible with the smaller Orbiting Solar Observatory; a capability of film return which can provide better quality pictures than has previously been possible; and a selective discrimination capability provided by the crew member who will manage the instruments to permit the gathering of data on phenomena of the greatest scientific interest.

The substantial scientific benefits of the Solar Astronomy mission will make a significant contribution to the knowledge required to plan future space operations activities. It will test the effectiveness of man's combined capabilities of scientific judgment, reasoning, and motor response in the orbital operation of complex scientific instruments to a greater degree than any previous manned experiment. It will provide a much more extensive and valid understanding of the future utility of manned space flight. The Solar Astronomy mission also incorporates a number of technological and operational concepts which are under active consideration as integral elements of the Space Station. These include: launch, rendezvous, and docking of a sophisticated unmanned experiment payload; the use of control moment gyros for stabilization and control; the use of gravity gradient torque in momentum management; and the use of a large gimballed system for precise pointing and stabilization of major instruments.

Crew activities are structured around the operation of this solar observatory. Medical observations on the crew during this open-ended 56-day mission will add significantly to the data base on man's reaction to the space environment. These activities can be conducted on a minimum interference basis with the solar experiment operations.

Should the Saturn I Workshop not be available for reuse, contingency plans have been made to fly the Solar Astronomy mission (AAP-3 and AAP-4 flights) decoupled from the Saturn I Workshop orbital assembly. This mission would involve operating the Lunar Module/Apollo Telescope Mount in combination with the Command Module and Service Module only for a period of up to 28 days.

Apollo Applications Backup Missions

Backup hardware is planned to be available to permit backup missions in the event of the failure of any of the flights that support the Saturn I Workshop mission or the Solar Astronomy mission. This hardware is as follows:

1. A backup Saturn I Workshop including the associated Airlock Module and Multiple Docking Adapter.

2. A backup Lunar Module/Apollo Telescope Mount.

3. One additional backup Command and Service Module.

PROGRAM STATUS

Apollo Applications Contracts

There are four basic categories of Apollo Applications hardware contracts. In the first category, hardware, such as Saturn IB launch vehicles and Command and Service Modules, from the basic Apollo program is being provided. In the second category, contractual actions are being taken to modify selected Apollo hardware for Apollo Applications missions. The duration of Apollo Applications missions requires modification of selected Apollo spacecraft systems to extend the lifetime of the equipment. The Apollo spacecraft, designed to provide for a 14-day operational capability, is being modified to support flight missions lasting 28 and 56 days. In the third category, specific Apollo Applications peculiar systems, subsystems and experiments contracts have been initiated with various contractors. In the fourth category, the Marshall Space Flight Center is performing inhouse development and assembly of selected systems and subsystems.

A discussion of these contracts in terms of mission hardware configuration, follows:

Saturn I Workshop

The key to extending the time man can spend in space is the Saturn I Workshop (ML69-4274). The basic module of this system is an S-IVB stage modified to provide living and working quarters for three men up to eight weeks. The Workshop includes an Airlock which will permit crew transfer from the Command and Service Module to the workshop without extravehicular activity and a Multiple Docking Adapter which will permit more than one space vehicle to rendezvous and dock with the Workshop.

The modifications to the basic S-IVB stage to convert it into the Workshop are being accomplished by the McDonnell Douglas Corporation, Missile and Space Systems Division, Huntington Beach, California. Fiscal Year 1969 funding is providing for the necessary design, definition, procurement and fabrication of test articles, as well as the initiation of preliminary development test effort. Fiscal Year 1970 funds will be used in extensive development and qualification tests of components and subsystems, and will include zero "g" simulation and design verification testing. Fabrication of modification kits will be initiated.

Airlock Module

The Airlock Module (ML69-4295)(ML69-4335) is under development by the McDonnell Douglas Corporation, Astronautics Division, St. Louis, Missouri. In FY 1969, the basic design was established; test plans were formulated; and fabrication of the structural test article and zero "g" trainer were completed. FY 1970 effort will emphasize the development and qualification tests of components and subsystems, completion of major static, dynamic and acoustic tests, and fabrication of the initial flight unit.

Multiple Docking Adapter

The Multiple Docking Adapter (ML69-4230) is being developed in-house at the Marshall Space Flight Center, Huntsville, Alabama. During Fiscal Year 1969 activity is focusing on the basic design, definition, test plans, fabrication of an engineering mock-up, a neutral buoyancy mock-up, and a structural test article. Fiscal Year 1970 efforts will concentrate on the development and qualification test of the components and sub-assemblies; completion of the neutral buoyancy and 1-g trainers; completion of static, dynamic and acoustic development tests; and the start of fabrication of the first flight article.

Apollo Telescope Mount

The Marshall Space Flight Center is responsible for major subsystem development of the Apollo Telescope Mount (ML69-4341). The ascent stage of an Apollo Lunar Module (AAP LM-A) will be modified under contract to Grumman Aircraft Engineering Corporation, Bethpage, Long Island, New York, and will serve as a command post for two astronauts conducting the solar experiments on the Apollo Telescope Mount (ML69-4344)(ML69-4345). The Lunar Module descent stage is replaced by a structural rack with associated power and pointing equipment. The rack also houses the solar experiments.

Fabrication and assembly of a preliminary mock-up and a neutral buoyancy test article was completed in FY 1968. These units have been recently updated to incorporate results of the continuing design work. Fabrication of a structural test unit is currently in process with testing scheduled to begin in FY 1970. Prototype unit fabrication will be initiated early in FY 1970, with flight unit fabrication starting later in the year. Five specific experiments involving 13 major instruments have been selected for flight on the Apollo Telescope Mount and are currently in the process of fabrication. These include:

Experiment	Developer	Location
While Light Coronagraph	High Altitude Observatory	Boulder, Colorado
Ultra-Violet Spectro-Heliograph	Naval Research Laboratory	Washington, D.C.
X-ray Spectrographic Telescope	American Science and Engineering Company	Cambridge, Mass.
Dual X-ray Telescope	Goddard Space Flight Center	Greenbelt, Maryland
Ultra-Violet Scanning Spectrometer	Harvard College Observatory	Cambridge, Mass.

In addition, the experimental instruments subsystems for the Apollo Telescope Mount are under contract to several firms. For example, the Control Moment Gyroscopes of the Pointing Control System are contracted to the Bendix Corporation, Teterboro, New Jersey. Batteries are contracted to the Eagle Picher Corporation, Joplin, Missouri. The Lunar Module ascent stage modifications are currently in the detailed design definition phase. A one-g mock-up has been completed and neutral buoyancy and zero-g test hardware will be completed early in FY 1970. Febrication of the structural test article and flight unit will begin in early FY 1970.

Launch Vehicles

The initial flight missions of the Apollo Applications Program will utilize Saturn IB launch vehicles procured within the Apollo Program. In addition to the vehicles procured in Apollo, two Saturn IB's, 213 and 214, were required in the event that repeat Workshop and Solar Astronomy missions are required to obtain primary objectives. Funding in Fiscal Year 1970 will cover storage and maintenance costs required for the Saturn IB's provided by Apollo. Funding limitations will prevent production of vehicles 213 and 214 at this time.

Launch vehicle procurement is under the cognizance of the Marshall Space Flight Center, utilizing the same contractors who are producing the stages and engines for the Apollo vehicles.

Payload Integration

Considerable emphasis is being placed on the integration of payloads so that the various experiments and flight modules will result in a properly functioning system. This payload integration effort includes mission payload analysis and systems engineering, and program management support for the incorporation of experiment payloads into the Apollo Applications space vehicles. It provides requirements, plans and program data for the proper interfacing of payloads; performance and interface specifications of payloads; design, test, and checkout plans and procedures for payloads; and ground and in-flight support equipment necessary to insure payload performance. Engineering analysis and design of the incorporation of spacecraft and payloads into a coordinated space system qualified for flight is also included. Fiscal Year 1967 efforts were related to preliminary definition of the payload integration requirements. Fiscal Year 1968 funds supported studies, mission planning as it affects payloads, and the implementation of design and development on the control and display panel for Apollo Telescope Mount. Fiscal Year 1969 and 1970 funding support continued efforts in integration of the mission and hardware elements of the cluster from the point of orbital insertion through post-flight data evaluation; verification of technical performance; efforts associated with the design, development and fabrication of payload hardware; and studies and analyses to define the requirements of mission alternatives. The Martin Company, Denver, Colorado, is the prime contractor for payload integration.

SPACE STATION

INTRODUCTION

Last year I indicated that we were going through the necessary in-house preliminaries to utilize the requested FY 1969 funds on definition of a Saturn V Workshop in the Apollo Applications Program and on a Space Station to follow the Apollo Applications Program. Within the funding levels that finally emerged for Fiscal Year 1969, it was apparent that the pace of our program was being slowed to the point that maintenance of this sequence would be inefficient and only marginally effective in advancing space flight technology and the national interest. To maintain space technology as the cutting edge of progress, we must step out with programs that demand advancement along a broad front. That means increased capability, greater program flexibility, increased responsiveness; and the realities of today make it clear that operating costs must be sustantially lowered. We, therefore, believe that the next step in earth-orbiting manned space flight must be a new, semi-permanent space station which includes, as part of the system, a new low cost transportation capability. A discussion of the role and objectives of this space station system is presented in my next section. Accordingly, we intend to bypass the intermediate steps of more advanced Apollo Applications Program workshops, intermediate launch vehicles and logistics craft, in favor of going directly to the design of a space station and a logistic system for lowering transportation costs by an order of magnitude or more. We believe such a space station system should be in being in the mid-1970's.

I should like to turn next to a discussion of the role and objectives of the space station. I will then follow with a description of the space station program and system as we now see them. Since the antecedents of the space station and its related transportation system lie in the Advanced Manned Missions studies, I will defer discussing the study background of the station system until I take up the subject of these studies a little later.

ROLE OF THE SPACE STATION

First of all, the Space Station Program will provide for continued development of a national capability. It is in the views of those people in NASA who have examined the program in depth our next step in developing increased capability for operating in space.

We believe it will provide us with an international recognition of United States space capability, because it will be a truly visible sign in the skies of our space operations. The space stations we are talking about are large enough, and will fly in an earth orbit so almost everyone on earth will actually be able to see them and feel their existence.

It will be the first time that we can really have men of international background in space. Until we get the low cost logistic supply system and a large enough space station, we won't be able to afford to have men of other nationalities come with us and thereby have a truly international space program.[1] We would look forward to bringing scientists, engineers, and many other kinds of people into the space station program from all over the world.

A space station will provide broad support for various activities, such as oceanography, meteorology, and geophysics. It will support biomedical laboratories, physical science laboratories, and solar and stellar observatories. These are the kinds of things that can be done in just one scientific area in our space station operations in the future.

Another category of things supporting the need for a space station is our potential for exploiting the space environment. This includes advanced earth resources research, such as agriculture, fisheries, hydrology, forestry, and minerals. There are a great many resources that can be supported from a space station in conjunction with the unmanned satellite program that will be carried out in the future in this very important area. Other general areas for exploiting space environment, are materials processing such as the growth of crystal composites. Another is as a base for building large structures because it is clear that in the years ahead we will want to build large structures in space. The space station itself will provide us with a place where we can provide for the support and maintenance of our unmanned satellite and thus drastically reduce the cost of their operation, and we will provide for the modification, repair, and maintenance of instruments and equipment in the space station itself.

The Space Station Program will introduce a new, more mature and routine mode of space operations. Man will live and work in space for long periods of time. A large scale of operations will develop, perhaps with a single large orbital facility or perhaps with several smaller facilities in the orbits required to meet specific uses. Men will be ferried between these stations and ground in reusable land landing spacecraft. The station will be used by multiple agencies of the government or industry to satisfy a broad spectrum of space uses. The orbital stations will become more autonomous, both in terms of command and control and in terms of life support commodities. All of these factors will lead to lower cost of space operations and a resultant increase in use of this major resource. The precise nature of the mature program is dependent upon the uses which evolve from the pilot phases of the Space Station operation. Hence, two sets of requirements exist. The first firm set of requirements are determined by the uses we are now defining for the initial phases of the Space Station Program. The second set of requirements will become definitive as the pilot program of space station activities is conducted.

Objectives

First, one may ask "What is a space station?" Perhaps the simplest answer would be "A space station is a central point for many activities in space, and located in the most advantageous position in space."

The objectives of the space station program are:

1. To conduct beneficial space applications programs, scientific investigations, and technological and engineering experiments.

2. To demonstrate the practicality of establishing, operating, and maintaining long duration manned orbital stations.

3. To utilize earth orbital manned flights for test and development of equipment and operational techniques applicable to lunar and planetary exploration.

4. To extend technology and develop space systems and subsystems required to increase useful life by at least several orders of magnitude.

5. To develop new operational techniques and equipment which can demonstrate substantial reductions in unit operating costs.

6. To extend the present knowledge of the long term biomedical and behavioral characteristics of man in space.

DEVELOPMENT PLAN

Since the space station is the first manned space flight project to move through the Agency's Phased Project Planning System, allow me to digress briefly to familiarize you with this procedure while using the space station as an illustration.

It is NASA policy to undertake the implementation of major research and development projects only on the basis of plans and analyses that clearly define the work to be done, its programmatic, managerial, resources and schedule implications, and an assurance that the required technology can be made available. Phased Project Planning is a phased approach to the planning and conduct of such activity. NASA identifies four phases as follows: Phase A - Preliminary Analysis, Phase B - Definition, Phase C - Design, and Phase D - Development/Operations. The work content of each of the first three phases is directed toward developing information needed to support the major decision to go into the next phase. Initiation of a phase, or its completion, does not, however, imply commitment to the next phase. I should emphasize that Phased Project Planning progresses on a total project basis (technical, resources, timing, contracting, management consideration, etc.).

Phase A is primarily an in-house effort which involves the analysis of alternate overall project approaches or concepts for accomplishing a proposed agency technical objective or mission. In this phase the more promising space station concepts which have been examined in the Advanced Manned Missions study effort were identified and analyzed. Those project approaches were selected which are worthy of further refinement. In addition, an across-the-board assessment of our status in all pertinent areas has been documented. This Phase A process culminated in a decision by the Administrator to initiate Phase B.

The Definition Phase of the Space Station Program is being initiated in FY 1969 with a series of Phase B Program Definition and Supporting Studies performed under contract with industry. An experiment/payload program has been formulated by NASA to be used in the contractual studies as a basis for design of the station and supporting systems. In parallel with these studies, a contracted experiment definition effort and a supporting development effort will be conducted to provide the advanced systems required to assure smooth transition into the design and development phases of the program. The major purpose of the Phase B effort will be an in-depth evaluation of the preferred concepts for the Space Station Program including the logistic system, facilities, and the development of technical and management data from which NASA can make a selection of a recommended single program concept. Substantial utilization of NASA in-house test, checkout and launch facilities and contractor fabrication facilities will be required for the Space Station Program. The impact of the program on these facilities and the interrelationship of this program with other NASA flight programs will also be a part of Phase B.

The Phase C Design effort, which will be initiated in FY 1970, will define in-depth the programmatic elements selected in Phase B for the conduct of the updated experiment/payload program, and will provide preliminary designs for those program elements requiring significant hardware development in Phase D. The Phase C effort will generate realistic costs and schedules for the selected systems and will provide management with the basis for a decision to proceed into the Phase D Development. Specifically, the Phase C effort will provide competitive preliminary designs for the Space Station, its subsystems and any separable modules, the logistic system including the logistic spacecraft and launch vehicles, and any special safety or escape devices needed. The Phase C effort will also examine in-depth the ground-based facilities and operations required to support the Space Station. The program elements will be separated into manageable packages for development by industrial concerns. It is anticipated that competitive contracts will be let for most program elements and parallel design competitions will be considered for critical program elements such as the station itself, the logistic spacecraft, etc. The experiment/payload program developed in Phase B will be updated prior to commencement of Phase C, incorporating the results of the planning effort performed during Phase B in parallel with the Phase B contracted studies.

The primary Phase C design effort will be supported by a continuing experiment definition program and by development of experiments which are in the updated experiment/payload program. Advanced development effort will be continued on critical subsystems identified in Phase B.

At the end of the Phase C contracts, each contractor will submit a report of pertinent results and a proposal for implementing Phase D. Following management approval of Phase C results and selection of preferred designs for any program elements designed competitively, the Phase C contractor efforts will be extended into Phase D. Phase D will complete the design and engineering of all program elements and will include fabrication, development, testing and mission operations.

SPACE STATION DESCRIPTION

The Space Station envisaged in this program is a significantly more advanced concept than the Saturn I Workshop in the Apollo Applications Program. The goal is the establishment of a multi-purpose, general usage station, suitable for achieving operational goals in a variety of disciplines. Even though we are now only entering the Definition phase, the general features of the system can be discerned and I should like to turn next to a description of the system. It should be understood, however, that our position on these matters is not so inflexible that we could not change should subsequent study results or operational and technological experience indicate that to be either necessary or highly desirable.

Configurations

Demands for adaptability and multiple usage will be met in large measure by modular design techniques, both with respect to the basic configuration and payload packages. MT69-4101 shows one such concept which includes a new, advanced logistics vehicle about which more will be said later. MT69-4100 illustrates a possible interior arrangement for this station.

Modular Arrangement

The initial plan is to develop a set of modules to make up the space station and its payload packages. The initial space station of the mid-1970 period might consist of an assembly of a few of these basic modules.

Types of Modules

Broadly speaking three classes of modules can be distinguished in building up a space station. They are utility modules, living quarters, and experiment modules. Among them provisions must be made for all the functions associated with living and working. These include sleeping, personal hygience, eating, recreation, support systems, command and control, docking and cargo handling, storage, maintenance and repair, laboratory and experiment space.

Leaving aside laboratory and experiment space for the moment I should like to illustrate some things that have come out of our conceptual design work as to the appearance and layout of core modules which are basic to the station. MT 69-4556 shows a possible layout for a command and control deck. This is somewhat analogous to the bridge of a ship although it would necessarily be somewhat more complex. It would also be a communications center from which the commander would keep in touch with activities throughout the station as well as maintain a link with the ground as necessary.

Crew quarters might be laid out as shown in MT 69-4555. As we now see it each man should have his own area of privacy. The man in the back is taking some exercise on a bicycle type of device. The tunnel which runs through the center of each of these modules provides the means of transfer from deck to deck. It also could be outfitted to provide a final place of refuge until rescue in the event of a catastrophic failure of some sort. Drawing on Navy experience, we know that special attention must be given to provide pleasant, comfortable surroundings in order to mitigate the effects of confinement and isolation. MT 69-4557 shows a private room design that is both functional and pleasant.

An engine room module will accomodate storage and supply for atmospheric gases, electrical power distribution, environmental control, and other vital subsystems. A possible engine room layout is illustrated in MT 69-4554. Consoles provide for constant monitoring of subsystems operation. Storage vessels occupy a portion of the volume.

Growth Potential

Through careful selection, design and arrangement of the various types of modules, the initial space station could be augmented if requirements exist. In this manner, we would have flexibility for crew size, additional laboratory facilities, or other special purpose equipment as new engineering, scientific and operational needs arise.

The space station system could provide, for example, a utilization of either zero "g" or artificial "g" modes dependent on the nature of the actual environment desired.

The space complex will thus be a functionally flexible assembly of modules, capable of expansion or modification to meet changing requirements in a manner similar to the modifications of ground research facilities. One concept of how this evolution could proceed is illustrated in MT 69-4303. At the left, provision for an articial gravity experiment is shown as an early possibility. While a hard and fast requirement for artificial gravity has not yet emerged, it could be a great boon in many of the ordinary living and working activities on the space station. On the other hand, most experimental work that is projected for the space station requires a stable zero "g" platform. An early experiment of this type would provide considerable insight into the problems of designing for,and operating with, artificial gravity. The illustrated scheme provides for a central hub, which does not rotate, surrounded by a rotating ring to which artificial gravity types of modules can be attached. The beauty of such a flexible design is that, within limits, proportion between the two different requirements can be varied widely. If zero "g" modules are required they are added in one direction, if artificial "g" modules are required they can be added in the other direction.

The space station is planned for 10 years of continuous operation. This will be achieved by fundamentally high reliability subsystems designs plus provisions for maintenance and repair, refurbishment and replacement, and expendables replenishment. This represents a different kind of modularity and is illustrated in MT 69-4534 by breaking open an engine room. The use of wider design margins in the design of space station equipment will also be a means of reducing costly test programs to assure reliability and safety. Crew productivity over this period of time will be assured by rotation at three to six-month intervals and by bringing up new experiment packages and modules as they become available and can be accommodated by the station workload. Productivity will be further enhanced by the use of a comprehensive onboard data system for checkout, experiments system monitoring, communications, and other functions thereby freeing the crew as far as possible to capitalize on the human capabilities for research and experimentation.

Present Design Concepts

At present we plan to study a station initially sized for a crew of 12 with an internal payload support volume of at least 10,000 cubic feet. For this size station, total electrical power will vary up to 30 kilowatts and perhaps more to accommodate peak loads. Power can be supplied by solar panel arrays but incorporation of a nuclear electrical power supply will be desirable for some applications.

The long lifetime requirement assures that technology in all the foregoing areas, and others such as environmental control, is pushed forcefully but not at the cost of unacceptable technological and investment risk.

A relatively high accuracy attitude stablization system will be incorporated for both earth centered and celestial inertial orientations according to the nature of the experiment program requirements. Systems of horizon scanners, star trackers, and rate gyros can provide an adequate sensing capability. Control moment gyros and conventional thrusters can furnish activation forces adequate for most station and experiment requirements. Experiment stability requirements beyond the basic station capability will be provided by the particular experiment package.

The nominal design orbit of the station will be inclined 50° to 55° to the equator at an altitude of 200 to 300 nautical miles. This altitude represents a compromise between the requirements of earth viewing experiments for low altitudes and the penalties associated with atmospheric drag. The Space Station system design will be compatible with polar orbits and would be adaptable in some form to 24 hour synchronous orbit.

Shuttle System

The case for a space shuttle involves the further development of the world-leading air transportation capability that this country has enjoyed since the Second World War. The first shuttle type operations to and from space will not only have a profound effect upon our ability to use space effectively but will largely determine the international leadership in transportation. Almost as important as the development of a low-cost transportation system, is the provision of a transportation system for use by non-astronauts. We are talking about payloads of the order of 25,000 pounds which is about the payload capacity of a DC-3. This payload capacity must be devoted to passengers or cargo, or split up between them. I should add here that these shuttles will have a relatively slow acceleration going into space and coming back. We should not exceed three gravities, which is low enough so that almost everyone could take such a trip.

Our studies have shown that a low-cost shuttle system is the key to the economical operation of a space station. The principal factor of low cost comes from the reuse of the equipment. If we use a commercial aircraft transport only once as we now use a Saturn V, people wouldn't be able to afford to travel across the United States. The same consideration is true of our space shuttles of the future. It must be used many times, employing air-line type operations.

We plan that the development of a space shuttle should be implemented in parallel with the space station. Logistic systems for personnel rotation, expendables resupply, and experiments and experiment module delivery represent a major share of the manned earth orbiting space station flight program costs. Planning studies conducted by both the Department of Defense and NASA, past and present, unanimously underscore the importance of, and the need for, a more operationally effective and cost effective manned round-trip earth orbital transportation system. MT68-7234 exhibits the results of one such study. Note that in the second year nearly 70 percent of the operational costs are consumed by the logistics part of the operations. The viability and success of long duration space station flight programs are critically dependent on the availability of a cost effective and versatile round-trip transportation system.

It is readily apparent that many common factors bear on the cargo module makeup in any logistics system. As an example, provisions for handling liquid and solid resupply expendables, specialized space station support equipment, and experiment modules must be satisfied by the system design and operational modes. Desired cargo handling design and operational characteristics of interest include provision for large modules up to 1500 cubic feet in volume. It is evident that system versatility for discretionary cargo delivery and return is an uppermost consideration.

There is little question that logistics spacecraft should be designed for land landing in routine operations, and provide high confidence for crew survival in the event of emergency landing at unprepared land sites or on water. These desirable terminal descent and landing characteristics of spacecraft can be achieved by precision land landing employing either unpowered glide with fixed or variable geometry, or propulsion to provide controllable lift over drag ratio. MT68-7243 and MC68-6674 summarize the desired operational characteristics and the planning perspective for a logistics system including these and a number of other aspects.

One approach to such a system consists of a new integrated logistic space vehicle system which would utilize advanced technologies and techniques, such as one and one-half stage to orbit concepts consisting of a reusable, integral launch and reentry vehicle with low cost, high mass-fraction, expendable propellant tanks attached to the sides of the vehicle. The recoverable vehicle contains all of the systems required for boost into orbit (including the booster engines), mission accomplishment in orbit, and reentry. In this concept we show it as a vertical take-off, horizontal landing vehicle which contains all of the costly hardware elements of the system, thus permitting the recovery and reuse of these elements. The boost propellant tankage is not recovered because it is one of the least costly elements of the system and one of the most penalizing to recover in terms of added weight to the reentry vehicle. MT69-4376, MT69-4375, and MC68-6609 show one such concept and its operational cycle. An alternative core vehicle is illustrated in MC68-6600; it uses a versatile payload pallet instead of the more or less conventional personnel and cargo arrangement shown on MT69-4375. This kind of integral launch and reentry vehicle offers great potential in terms of operations cost improvements. Other concepts with greater or lesser degrees of reusability are being studied.

The Triamese shown in MT69-4549 is an example of a fully reusable concept. Three elements, nearly identical in external appearance, are joined together in parallel for launch as shown. Internally, all three have the same basic structure and propulsion systems. The outer two are tankers,however, while the central element provides for transportation of personnel and cargo. The operational cycle for this system is depicted in MT69-4551. Two engines in each section are ignited for liftoff. As the central element uses propellants, however, they are replenished by drawing off from the outer two. When the contents of the latter are exhausted, they are staged off and the central vehicle continues on into orbit. All three elements are manned, have deployable wings and conventional turbofan engines for controlled subsonic flight back to the base. The obvious advantages of this concept over the previous example are full reusability and controllability for all elements of the vehicle.

It should be noted, however, that if station and shuttle are to be operational in the mid-1970's, then the technological investment risks for this type of vehicle are higher than for the Space Station itself; this is due to the fact that the applicable technology is not as mature at this time and a carefully thought through development and test program for new components will be required. We are, therefore, continuing to consider extensions or derivatives of existing systems. However, we should not delay the decision to develop these new promising concepts, because any delay would rob us of an early opportunity to lower operational costs. On this basis, I believe it would be wise to proceed to the design and implementation of an advanced reusable space transport.

Experiments for Space Station

I should like to turn next to the major experimental areas that we are currently emphasizing and from which we expect to obtain most of the experiments for the Space Station. The Space Station's ability to accommodate a wide range of activities in considerable depth and with great flexibility will offer the investigator a situation that is far superior to anything that can be made available up to that point in time, including the Saturn I Workshop. Pre-Phase A and Phase A activities have led to a baseline program whose productivity will probably be limited only by the financial support it receives. Since this productivity is a major reason for having a Space Station, I wish to emphasize that experiment definition efforts must parallel configuration and transportation studies in Phase B. Experiments in all categories strongly influence the extent and nature of crew participation, electrical power requirements, volume, mounting or modularization and so on. In most instances we probably know as much about the experiments as we do the station configuration and this relationship must be maintained.

The word "science" always comes to our lips when we talk about Space Stations and this may very well be the exclusive orientation at the outset. Nevertheless, much of the proposed scientific work has the potential of maturing into activity more properly termed "applied." By virtue of its inherent adaptability, the station and its versatile transportation system should easily accommodate this changing role. In those areas which become "applied," the returns to mankind will be more direct and tangible than is usually the case with pure science. Let me now describe the experiment payload packages under consideration for this program.

Biomedical/Behavioral

With respect to the physiological aspects of this program, the objectives are to determine the effects of the space environment on man for increasing durations, to develop real time indices of functional impairment, and to develop a supportive environment and conditioning procedures to offset any ill effects of space flight and reentry. The Integrated Medical Behavioral Laboratory Measurement System comprises the basic flight hardware needed to obtain required medical/behavioral data. MT69-4520 shows a laboratory concept which provides for animal work as well.

The behavioral part of the program consists of man/machine evaluations designed to a great extent around the useful activities the astronauts will carry out with the spacecraft systems and the scientific experiments themselves. The objectives here are to determine the degree of degradation of human performance in space, to develop supporting facilities and procedures to overcome such degradation, to acquire experience in man's performance of a wide variety of useful space operations, both intravehicular and extravehicular, and to enable early planning and design to optimize man's role in future space systems.

Industrial Processes

The advent of a continuous zero g environment opens exciting possibilities for utilization of unique conditions in the space environment to carry out certain manufacturing processes. The absence of gravity in orbital space stations may make it possible to produce new and greatly improved materials, to manufacture products more precisely, and to process materials in new and different ways. The levitation melting of materials free of the contamination of the crucible, the growing of single large crystals with vastly reduced dislocations, the blending, alloying and conversion of compacted powders into castings are but a few of the possible processes that may be vastly enhanced by the absence of the strong gravitational effect of the earth. MT69-4519 illustrates a module for this work which can operate either attached to the station or free-flying.

The objective in this experiment area is to investigate the feasibility of, and explore the basic technology necessary for, exploiting space as a medium for industrial manufacturing processes uniquely dependent on a zero g environment. The possibility exists that early experiments will produce something of direct commercial importance which can be produced nowhere else.

Astronomy

The advantages of operating in space to avoid the spectral masking and geometric resolution limitations imposed by the atmosphere, together with the importance of astronomy to our understanding of the universe and to our future space program, make this field a high priority space effort. It appears at this time that manned systems can offer important assistance in providing large, high-reliability, long duration, versatile telescope systems in space. The objectives in the astronomy area are to operate large, high-performance, high reliability telescopes and survey instruments above the atmosphere in order to study radiation from the sun, planets, and stars throughout the spectral regions from high energy gamma rays to long wavelength radio waves. Four packages are under consideration as a reasonably balanced program of initial exploration leading toward more advanced astronomy observatories in the late 70's and 80's. They build on the Apollo Telescope Mount technology developed in the Apollo Applications Program and include a Survey Group, a High-Energy package, a Solar package, and a Stellar package. MT69-4517A depicts a more advanced telescope module which can operate manned or unmanned, attached to the station or free-flying.

Earth Resources

This field includes remote monitoring of surface and atmospheric features from manned spacecraft and includes investigations in the areas of agriculture, forestry, hydrology, oceanography, geodesy, geology, meteorology, etc. The initial space applications program on manned vehicles is intended primarily to contribute significantly to the development of operational earth applications sensors through flight testing of selected experiment systems. This will provide desired baseline data for design of advanced operational systems, some of which may be automated. Objectives include determining man's useful role as an observer in the selection of special targets of opportunity, or as an onboard adjuster, maintainer, data compactor, etc.

Space Physics

The objectives in this area are to investigate the astrophysical aspects of space radiation, to study the space environment and the interactions of the spacecraft with that environment in near earth orbit, and to utilize the spacecraft as an observation platform to study airglow, the zodiacal light and the gegenschein. The access to radiation energies that are orders of magnitude higher than can be attained in existing or contemplated terrestrial facilities is of fundamental importance in this area. Three experiments packages are being considered for this area; they are: Exposed Experiments, Hi-Energy Cosmic Ray, and Subsatellite. The latter is an instrument carrier associated with, but operated in a detached mode from, the space station, it may also carry earth resources instruments.

Space Biology

Most of the current bioscience program is handled well by automated satellites. As manned station technology evolves, however, it is expected that both the automated and manned programs will furnish flight platforms. The general objectives of space biology experiments are to study significant biological effects associated with, or due to, peculiarities of the space environment such as zero g, radiation and absence of diurnal cycles, and to develop techniques applicable in later exobiological investigations. Two packages have presently been identified as especially well-suited to manned missions: Small Vertebrates and Bio D- and Bio E-Plants.

Advanced Technology

In this area we treat those basic subsystem and material advances which require validation and qualification in the Space Station environment. These contrast with the other described packages in not being derived from user-oriented applications or scientific experiments but are solely concerned with spacecraft and operations for more advanced missions and spacecraft. Investigations that may prove worthwhile are spacecraft fault location and repair, micrometeoroid puncture studies, degradation of materials and surfaces, and subsystem elements where liquids, gases, and solids interact and gravitational forces are normally important. Subsystems themselves such as nuclear reactors, artificial gravity producing systems, advanced space suits, and manipulators may also be tested.

FY 1970 SPACE STATION PLANS

At, or near, completion of the Space Station definition studies, a comprehensive in-house analytical review will be conducted to complete Phase B and support the decision to enter Phase C. The $9.0 million requested for FY 1970 will be used to initiate Phase C - Design of the Space Station system. The design effort will encompass all aspects of the system. It is anticipated that several separate competitive contracts will be let. Preferred designs will be carried into Phase D.

SATURN V PRODUCTION

The Saturn V launch vehicle is the most powerful ever to be developed, produced and proven in space. The Saturn V is the free world's largest booster and the only launch vehicle capable of lifting large payloads into earth orbit or carrying out manned missions to lunar distances. It possesses six times the payload capability of the nation's intermediate size booster. With this performance, the vehicle has the ability to meet the requirements for lunar exploration, for Workshop and Space Station launches and for future planetary missions. The United States has no immediate plans to develop any other booster of equal or greater lift off power, since the Saturn V provides the nation with the basic launch vehicle capability to carry outa variety of space operations in the 1970's. No funding was included in the original FY 1970 budget request to provide for production of Saturn V's beyond the fifteen vehicles procured for the Apollo Program. However, $46,000,000 is included in the FY 1970 budget amendment for this purpose.

The follow-on Saturn V will be upgraded to be the only launch vehicle capable of placing over 160 tons into earth-orbit, 60 tons to lunar distances, and 20 tons to planetary distances. Therefore, this versatile launch vehicle is the key to capitalizing on the gains of the nation's first decade in space and realizing returns on the skills, technology, equipment and facilities created in Apollo. The Saturn V provides the payload capability required for a progressive space program in the

1970's including continued lunar exploration and future missions such as the space station or deep-space missions.

The production capability created for Saturn V launch vehicles is dissipating at a rapid rate. The last of the Apollo Saturn V launch vehicles is well into assembly. All basic subcontractor hardware has been delivered for the instrument units and for the engines. In addition, all of the Apollo F-1 and J-2 engines will be delivered by the end of 1969. A continuation of the present trend will result, at best, in expensive shutdown and startup costs and at, worst, in complete loss of capability. Skills lost through dispersion of manpower will have to be re-established. Tooling will have to be refurbished and manufacturing qualification status of all parts will have to be restored. The longer the restart operations are delayed the greater the impact and the more difficult and costly the startup.

The FY 1970 budget amendment will stem the current downward trend. These funds will be applied to the procurement of long lead items, and to the reactivation of critical vendor and supplier sources whose deliveries have already been completed. In addition, the FY 1970 budget amendment request will be used for the stabilization of those subcontractors, suppliers, and vendors still working on Saturn V hardware and to begin certain long-lead time fabrication at major contractor plants. The funding plan includes all vehicle stages, the instrument unit and the F-1 and J-2 engines. The funding plan will allow initiation of Saturn V production with the delivery of the first launch vehicle in 1973.

Future Saturn V launch vehicles can be produced with increased performance. Engineering design, manufacturing and test operations will be optimized and restructured to reduce costs. Full advantage will be taken of the learning experience accumulated to date. Efforts will be directed toward a simplified, standardized launch vehicle with increased performance at lower cost.

OPERATIONS

LAUNCH, FLIGHT, AND RECOVERY

This activity funds only the unique project requirements of Apollo Applications space flight operations. The basic support for manned space flight launch, flight, and recovery operations is funded under Apollo.

Operations include efforts at the Kennedy Space Center and the Manned Spacecraft Center that are directly involved with pre-launch, launch, flight, crew, and recovery planning activities. Fiscal Year 1970 funds are required for mission planning and analysis; initiation of procurement for an Apollo Telescope Mount simulator; trainer modifications to Apollo Applications configurations; maintenance of Saturn IB launch capability including equipment and systems in storage, by keeping in a condition of good repair to permit reactivation to support Apollo Applications launches; final definition and design of launch complex modifications to accommodate Apollo Applications unique hardware; test planning and procedures for checkout of previously **deactivated** equipment and systems as well as Apollo Applications unique hardware and documentation planning for reactivation of launch complexes for Apollo Applications.

TECHNICAL

Technical operations provide for integrated technical support, review, and analysis of the Apollo Applications missions. These services include the development of functional and performance standards consistent with mission objectives; mission planning; technical integration and evaluation test objectives and integration; mission and systems specifications; trajectory analysis; checkout effectiveness; and technical documentation.

ADVANCED MANNED MISSIONS

INTRODUCTION

In previous years the Advanced Manned Missions Program has studied a wide spectrum of advanced systems and examined many different space flight missions concepts. The program was realigned last year to more effectively concentrate on the task of establishing the manned earth orbital space flight program which could follow the Apollo Applications Program. At the hearings last year, we proposed a program for Fiscal Year 1969 that would reflect the emphasis we are placing on manned earth orbital space flight through increased activity in space station studies.

Before going on to our FY 1970 Advanced Studies plans, I would like to discuss some of our past study work as it applies to the space station program which I presented above.

COMPLETED STUDIES

The roots of the present Space Station Program lie in a series of studies and concepts dating back to 1962. MT68-7395 and MT68-7398 illustrate the trends and highlight certain areas. I should like to briefly describe a few of the more significant studies noted in the figures.

The Manned Orbital Research Laboratory (MORL) Study

Douglas Aircraft configured a six- to nine-man orbital space laboratory capable of being launched on a Saturn IB into low earth orbit.

Crew and supplies would be ferried to and from the laboratory using an Apollo or Gemini spacecraft augmented by a new cargo and propulsion module. Subsystems using advanced technologies were selected including such new developments as oxygen recovery from carbon dioxide and electric power generation using a nuclear isotope-Brayton generation system. Onboard artificial gravity would be provided either by using a 22-foot diameter centrifuge internal to the laboratory or by connecting the station to the spent S-IVB launching stage and rotating the entire system.

The Basic Subsystem Module (BSM) Study

General Dynamics examined the concept of packaging the basic subsystems and crew quarters as separate modules, each module capable of being launched separately or stacked. This concept allowed the flexible usage of different combinations of modules to meet different mission requirements. Various degrees of subsystem technology were examined, ranging from use of existing Apollo or Manned Orbital Laboratory (MOL) developments to the use of the advanced subsystems such as those considered in the MORL study. This activity provided a multiple independent module approach in an attempt to achieve flexibility to changes in funding or mission requirements over those for integral concepts.

Earth Orbital Space Station (EOSS) Study

Douglas Aircraft examined the feasibility of using the structure of an S-IVB stage, fitted on the ground as an orbital laboratory and launched on a Saturn V to accomplish a broad selection of NASA mission requirements. Extensive modifications were made to the stage to allow for the installation of subsystems and experiments. The station was sized to support a crew of six men and near-term technology subsystems were selected. The study established the feasibility of the concept and indicated that there were potential savings in time and cost due to minimizing changes to existing structures and systems.

Saturn V Single Launch Space Station Study

In parallel with the Douglas EOSS study, Boeing Aircraft examined a competing concept based on a new structure to capitalize fully on the payload capability of the Saturn V. For simplification, the concept assumed no resupply which thereby reduced the operational support cost of an early space station capability. Crew rotation would be performed only as necessary. Existing technology subsystems were selected to support a crew of six for a one-year mission. All expendables for the mission were carried aboard the laboratory on its initial launch. The study concluded that although such a mission was feasible, it was extremely inflexible since no capability existed to change the mission after launch. It was further concluded that the cost savings hoped for in this approach could not be fully realized due to the anticipated failure rates of subsystems which could cause mission abort or require resupply after a fraction of the planned mission duration.

Evaluation of the Manned Orbital Laboratory (MOL) to Accomplish NASA Earth Orbital Mission Objectives

A classified study was conducted by Douglas to determine the capability of the Air Force MOL to accomplish NASA long duration earth orbital objectives. It identified the major limitations of the MOL for NASA mission objectives such as, limited crew size, limited free habitable volume, limited payload, no rendezvous and docking capability, no orbital storage and reuse capability, and restricted on-board and extra-vehicular capabilities. The study determined that modifications required to achieve a one-year duration were extensive and that the associated program costs were near those of a new program. Furthermore, due to the severe limitations of the system upon the potential ability for man to live and operate productively in space, the multiple single launch approach proved unsatisfactory. As a result of this study, an extended MOL was considered too limited to provide a significant, cost-effective step toward achieving NASA's long duration objectives.

No single configuration studied met all the requirements NASA could project for the 1970-1980 decade and still lie within the projected funding limitations. Using the information developed in the above studies, NASA conducted two internal studies with the objective of defining a program which would be responsive to the needs of a mid-1970 mission. A brief description of these studies follow:

Satum V Workshop Study

This activity was conducted by a study group made up of NASA personnel from MSC, MSFC, KSC, and LaRC and directed by a broader group from NASA and DOD. The study examined two levels of Saturn V orbital workshop designs. The first consisted of a 1971-72 station based on existing technology. The other considered a higher level of technology for flight in the mid-1970's. The two major conclusions were (1) the formulated programs lacked adequate flexibility to respond to likely changes in direction and funding, (2) long life subsystems require major developments and supporting techniques such as checkout and inflight maintenance.

The Intermediate Orbital Workshop (IOWS) Studies

The IOWS studies were conducted independently by the staffs at LaRC, MSC, and MSFC to define a moderate cost approach to a space laboratory. Each center worked to the same guidelines, namely, to develop a station which could support a crew of three to nine men, with a nominal life of two years. The program would incorporate provisions for flexibility in terms of variations in missions and changes in funding levels. Maintainable subsystems were selected to achieve the mission durations. A nominal orbit of 200 nautical miles and 55° inclination was selected with the requirement that the basic design be compatible with synchronous or polar missions. Within these guidelines three concepts emerged which will be used as the basis for further comparative evaluations in Phase B.

CURRENT STUDIES

Space Station Studies

Along with contracted studies considerable in-house effort will be expended to support Phase B.

For the contracted efforts we are letting two parallel Space Station definition contracts. The contractors will work independently of each other with one study managed by the Manned Spacecraft Center in Houston and the other by the Marshall Space Flight Center in Huntsville. The contractors will be required to examine alternative approaches to the Space Station system, treating all aspects including configuration, ground support, facilities, flight and ground crew activities, onboard checkout and fault isolation, safety, experiments and experiment modules, and information management. Only a portion of this definition effort will be devoted to the advanced low cost transportation or space shuttle system for the space station, inasmuch as separate companion studies are exploring this in depth, as explained below.

Specific areas have been identified which require additional study in support of the Space Station definition effort. It is our intent to utilize the capabilities of industry in separately contracted studies to provide NASA with conceptual designs and trade-off data in selected areas. This will augment NASA resources and provide input to the prime definition studies. The selected areas include Experiment Definition, Space Station Information Management, and Experiment Module Concepts. In addition, the Office of Manned Space Flight is contributing, along with OSSA and OART, to an Earth Orbital Experiment Program and Requirements Study in which a contractor will aid NASA in studying the useful and proper roles of manned and automated spacecraft by a detailed examination of implementation alternatives for NASA experiments.

Low Cost Transportation System Studies

Four studies of $300,000 each were initiated in February 1969 with McDonnell Douglas, North American Rockwell, General Dynamics, and Lockheed Missiles and Space. The purpose of these studies is to derive a conceptual design description, including all the elements of development and operations activity, for a spectrum of earth orbital round-trip transportation systems having the following characteristics: (1) an order of magnitude reduction over present systems in the recurring cost of operational utilization; (2) achieving significant advances in the inherent safety of the systems; and (3) having a system versatility and flexibility which will allow the system to respond to a variety of missions beyond the logistics application and to develop or evolve the capability to perform its stated mission in an improved fashion. These studies are scheduled for completion in September 1969.

All four studies are responding to a common set of mission characteristics and guidelines. The goal of very major reductions in the cost of recurring operations will be approached by seeking maximum reusability with minimum refurbishment, consistent with the basic concept class. All concepts will utilize land-landing at fixed sites and multi-flight life for reusable elements. Expendable elements will be of low cost design and facile in operational usage. The system concepts will attempt to minimize the ground support operations required and provide quick response capability. They will use a passenger comfort approach by providing low "g" forces and a shirt-sleeve environment. Large integral cargo holds will be provided with the possibility for alternate external cargo capability. All passenger and cargo off-loading will take place through intravehicular transfer. In terms of capacity, the systems are being sized nominally for a flight crew of two plus ten passengers. The nominal design discretionary cargo capability to a 270 nautical mile, 55° inclination orbit is 25,000 pounds, with a minimum of 2,500 pounds of return discretionary cargo capability.

The spectrum of concepts being studied is depicted on MT69-4637D, and embraces a range of concepts from low-cost expendable launch vehicle stages with advanced reusable spacecraft, to completely reusable systems having launch, on orbit, and reentry functions fully integrated. The McDonnell Douglas study will basically cover both ends of the spectrum of concepts as shown unshaded on MT69-4637. However, they will not work on the low lift-to-drag ratio spacecraft, the "flyback" reusable first stage, or the fully reusable system depicted as the Triamese concept. Thus, their efforts will be balanced between systems composed of expendable low cost liquid or solid first and second stages with reusable medium lift-to-drag ratio spacecraft, and stage and a half concepts wherein the boost propulsion is integral with the on-orbit and return elements, expending only the low cost tanks. These stage and a half systems will be investigated using a range of "zero" stages providing small ΔV to more fully optimized ΔV capability. The North American Rockwell study will concentrate on the low cost expendable launch vehicles with reusable spacecraft as shown unshaded on MT69-4637A. The Lockheed Missiles and

Space study will concentrate on the stage-and-a-half, stage-and-a-half with "zero" stage boost, and fully reusable Triamese concepts (MT69-4637C). The General Dynamics study is primarily concerned with the Triamese fully reusable concept, "flyback" first stages having expendable upper stages for manned and unmanned mission comparisons, and low cost expendable launch vehicles comprised of solid, liquid pressure-fed, and liquid pump fed stages with reusable medium lift-to-drag ratio spacecraft (MT69-4637B).

Tektite

I should like to mention a study recently completed in the Virgin Islands which is a little different than those we usually talk about in Advanced Manned Missions. This is the Tektite program jointly sponsored by NASA, the Navy, and the Department of Interior with the General Electric Company as prime contractor and the Coast Guard participating. Four marine scientists conducted a 60-day scientific research mission on the ocean floor at a depth of approximately 50 feet. Their habitat is pictured in MT69-5382. NASA will study the performance of these highly qualified and motivated men to assess methodologies and obtain data points for use in predicting man's behavior on long duration space flights. Common aspects of the two situations include: isolation from ready assistance, built-in hazardous conditions, the necessity to maintain a habitable enclosure in a hostile environment, and meaningful work to perform.

NASA's portion of the program is being managed by the Office of Manned Space Flight with assistance from the Office of Advanced Research and Technology, the Langley Research Center, and the Manned Spacecraft Center

FY 1970 ADVANCED MANNED MISSIONS STUDIES

In contrast to our utilization of FY 1969 Advanced Manned Missions study money to concentrate on the Space Station, we will in FY 1970 carry out a broad spectrum of studies which use industrial talents and capacity to supplement in-house activity. Plans for utilizing the proposed FY 1970 $2.5 million of Advanced Study Funds involves studies in the following areas:

Safety

Safety on lunar orbit and lunar surface missions will be studied; the studies will include identification of methods and systems for escape and rescue from such missions. Conceptual design of manned and unmanned earth-based rescue systems will be studied for low earth and geo-synchronous orbit missions. The impact of the projected use of such systems on the design and operation of Space Stations and lunar surface shelters and vehicles will be assessed.

Advanced Lunar Studies

Studies will be conducted on advanced systems which have the potential for utilization in the latter half of the 1970's. The studies will be concerned with spacecraft systems required to transport personnel and cargo to the moon and systems to provide shelter and support for exploration activities. System synthesis studies will provide planning data applicable to development of an early lunar station using Apollo system derivatives.

Advanced Space Station Studies

Advanced Space Station missions studies will include identification of advanced mission requirements and operational modes following initial Space Station operations. New modules required for second generation payloads and systems for missions such as those in synchronous orbit will be examined. The implications of deep space missions on these modules and systems may also be examined.

AEROSPACE MEDICINE

INTRODUCTION

As we look forward to our second decade of manned space flight we are reassessing the roles and missions of applied medicine as required for increasingly longer duration flights. NASA top management has identified, clarified, and delegated responsibilities to the three major program offices so as to provide maximum effectiveness in management, as well as strong technical support in the three complementary areas of basic research and development in the biosciences, in biotechnology and human research, and in aerospace medicine.

Aerospace Medicine and Technology Management

In December 1968, a charter was approved for NASA Aerospace Medicine and Space Biology which provides that the Office of Space Science and Applications (OSSA) will be responsible for carrying out basic research in space biology including exobiology, and lunar and planetary quarantine. Related experiments to be carried out on manned flight will be defined by the Office of Space Science and Applications and furnished to the Office of Manned Space Flight (OMSF), for development and integration into the flight mission.

The Office of Advanced Research and Technology (OART) will provide the broad-based research and development (R&D) foundation, including the supporting research and technology (SR&T), and will define related experiments for manned flight (similar to the procedures used by OSSA).

The Office of Manned Space Flight (OMSF) is responsible for all applied medicine in manned space flight. This includes applied technology, although if it should become apparent that there is a gap in critically needed hardware (i.e., next-in-order-development) to support mainstream manned space flight programs, necessary action will be initiated in conjunction with OART.

Specifically, the NASA Charter approved by top management states that OMSF will be responsible for all medical operational and medical safety aspects of manned space flight operations. It will design, develop, and test mainline systems and components of approved manned space flight projects. Finally, it will provide for a flight experiments program to include ground-based work required to support experiments, and will provide flight hardware, space vehicle integration, and operational support for experiments provided for flight on manned space flight projects. All experiments to be flown in manned space flight including those defined by OSSA and OART will be controlled with appropriate priorities by the Manned Space Flight Experiments Board of OMSF and the flight program offices in terms of flight opportunities.

In the NASA Aerospace Medicine and Space Biology Charter, NASA top management has also defined and steamlined the interfaces and channels of authority between NASA Headquarters and the various field centers.

Thus, as we face this transitional period from earth orbital to longer duration space flight, we believe we have realistically reassessed our total resources in terms of national objectives and the national economy, and have provided a sound organizational structure through which to manage the manned space flight program.

Through this next year, we will be further reassessing the professional resources offered by the medical profession and the allied sciences so as to bring their competence to bear most effectively upon our manned space flight goals. This will include not only the reassessment of our capabilities within NASA itself, but also the competence available to us from the scientific community and the Department of Defense.

Medical Implications of the Current Apollo Program

From the medical viewpoint, the Apollo Program now in progress represents an extension of the application of the traditional principles and practice of aerospace medicine to include the lunar environment. Hitherto the manned space flight experience has involved only ground-based experiments which simulated the space environment (except for weightlessness and combined stresses), and earth orbital flight. Now in the Apollo Program, for the first time man has ventured out of the range of the earth orbit and the gravitational forces of earth into areas where the major unknown factor is that of potential radiation hazards. For the first time, too, man has encountered the true weightlessness of space and the lunar environment which provides a gravitational pull of only one sixth of that experienced by man on earth. Both the flight to the moon beyond the earth orbital circuit and the reduced gravity of the lunar surface therefore have posed new dimensions of medical operational support required for manned space flight.

Medical requirements for the Apollo Program are dictated by three objectives which have been constant throughout the entire manned space program. In addition, a new objective has been added because of the scientific need to minimize contamination of the moon. For the first time man will be making physical contact with the lunar surface, and it is entirely possible that he could infect the ambient lunar surface with microorganisms carried from earth. This must be prevented if the lunar surface is to provide--as expected--the key for unlocking new scientific information.

All told, then, we have established four major objectives in terms of priority. First of all--as always--crew safety from the medical standpoint must be assured at all times; second, medical information required for mission management must be provided; third, provision must be made to assay the degree of man contributed contamination of the lunar environment; and, finally, the growing storehouse about the biomedical changes of man in space must continue as prelude to longer duration missions.

Responsible medical officials are meeting these objectives through three primary methods. First, they obtained from ground-based measurement or previous flight data considerable base line medical information about each individual astronaut so that they will have a yardstick by which to measure his normal and operational profile. Second, extensive post-flight medical examinations are given. In addition, during flight a limited number of physiological measurements are monitored by physicians on the ground. This inflight monitoring and the verbal reporting of the crew provide the third method of obtaining critical medical information about the dynamic physiological condition of the astronaut at any given time.

Unlike the previous Gemini Program, the Apollo Program does not undertake a formal medical experiments program specifically to learn more about the biomedical changes of man in space; such experiments will be carried out in post-Apollo Programs directed at longer duration flight. Since the medical experience gained in Gemini indicated what could be expected of man's physiological capabilities on a two-week lunar mission, the actual Apollo mission of shorter duration will merely add breadth to the total storehouse of manned space flight experience.

MEDICAL INFORMATION FROM THE APOLLO 7 AND APOLLO 8 FLIGHTS

By the end of December 1968, two manned Apollo flights had been flown, both of which provided substantial medical information required to meet the objectives of the subsequent lunar landing mission and its return to earth. The 11-day Apollo 7 flight was marred medically only by the routine upper respiratory difficulties experienced by crewmen Schirra, Eisele, and Cunningham. The Apollo 8 flight which involved moon orbital flight caused a minor flurry of concern when the crew experienced short term nausea.

Inflight Monitoring

Inflight physiological and environmental information for Apollo was concerned with determining the normal physiological changes unique to each astronaut in terms of his cardiovascular recovery pattern following exercise; the effects of various mission phases (e.g. launch); environmental changes (e.g. temperature); energy expenditure during crew activity; daily homeostatic variations (e.g. drowsiness after meals); and transient emotional changes (e.g. false alarms).

The Apollo biomedical harness consisted of skin sensors which would pick up each man's respiration and electrical heartbeat and send the information through wires into other electronic components in a belt. The impulses were then prepared for radio transmission from the spacecraft to the Mission Control Center at Houston where a physician was always on duty. Heart-rate and respiration-rate average, range, and deviation were computed and displayed on digital TV screens and recorded on strip charts. Blood pressure and body temperature were no longer taken as in the earlier manned flight programs.

During the Apollo 7 flight, the personal medical harness proved too fragile to withstand the stresses of the crew movement in flight, and as a result some electrocardiographic and respiration information was lost. It was therefore decided for Apollo 8 to return to a type of wiring similar to that used in the Gemini Program. As a special precaution against further loss of medical data, a complete spare harness was placed aboard the Apollo 8 space vehicle.

Radiation Monitoring

Radiation measurements actually obtained on the Apollo 8 flight demonstrated measured doses below even the predicated values. Because the Apollo 8 flight was the first to leave earth orbit, there was some concern about possible radiation hazards, although scientific evaluation had already indicated with respect to the Apollo 8 profile that the physical parameters of the space radiation environment were sufficiently well-known to make reasonable and defensible statements about the biological and/or medical effects attributable to ionizing radiation.

The nominal mission will encounter several different radiation environments before orbiting the moon and upon return to earth. In low earth orbit the first is the South Atlantic Anomaly and the residual artifically trapped radiation from high altitude nuclear testing. Gemini measured flight experience and subsequent calculations suggested radiation doses of 0.025 rad, too low to produce a demonstrable detrimental biological effect.

The next encounter would be with the inner and outer Van Allen Belts. The accumulated dose during transit through those zones would not exceed 2 to 5 rad. These doses are also not considered of demonstrable short term biological significance.

Superimposed upon these radiation exposures would be the contribution of galactic cosmic rays. Unlike the other two sources (Van Allen Belts and South Atlantic Anomaly), these rays are not limited to a specific transit time nor a specific distance from earth; therefore they are a relatively constant source during the entire mission. An average dose rate of 0.01 rad/day is quite reasonable to expect, thus accumulating 0.08 rad for the eight-day period of a lunar mission.

Defining a nominal mission as one devoid of a solar flare, the Apollo 8 mission would therefore be limited to the doses described above, namely a maximum of 2.2 - 5.2 rad. On a short duration lunar landing mission (8-10 days), the radiation of consequence would be associated with a solar flare. Only Class III (the highest importance category) flares are of sufficient flux and energy to contribute a significant body dose. Shielding, however, would be a major factor in dose assessment because exposure in the Command Module would afford sufficient protection to stay below demonstrable detrimental biologic efforts. Should the only real contribution to dose on a lunar landing mission be a Class III solar flare, the only biological responses possible if the flare occurred within the 8 - 10 day period of the mission would be malaise (listlessness), anorexia (loss of appetite), nausea, vomiting, a slight drop in lymphocytes (white blood cells), and perhaps a slight erythema (reddening of the skin). Based upon assessments of radiation dose versus biologic effects, one can conclude for early effects, 30 days or less following exposure, there would be no demonstrable detrimental biological effects, hence the clinical responses noted above would not be seen. This includes skin effect (reddening) from the degraded and low-energy particles that penetrate the shield.

With respect to possible long-term delayed effects, the total dose in the Command Module in the Class III flare situation is very much below the cataractogenic level (eye effects). In fact, it is below dose levels required to produce even a few vacuoles and/or opacities in the lenses of experimental monkeys. Similarly, it is an insufficient dose to produce long term skin effects and any increase in the spontaneous rate for leukemia and genetic changes will not, in the population at risk, be discernible nor solely attributable to radiation exposure.

Spacesuits

The Apollo intravehicular pressure garment assembly is a spacesuit consisting of a helmet, torso, and gloves which can be pressurized independently of the spacecraft. The outer layer is Teflon-coated Beta fabric woven of fiberglass strands with a restraint layer, a pressure bladder and an inner high-temperature nylon liner. Oxygen connection, communications and biomedical data lines are attached to fittings on the front of the torso. A one-piece constant wear garment, similar to "long johns," and of porous-knit cotton with a waist-to-neck zipper, is worn both as an undergarment for the spacesuit and as an inflight garment. Attach points for the biomedical harness also are provided.

The Apollo 8 crew wore the spacesuit until one hour after trans-lunar-injection. They then dressed in Teflon fabric inflight coveralls which provided warmth and had pockets for personal items. The coveralls were worn throughout the flight and during reentry. The soles of the garment were fitted with a special metal heel clip which fit in the couch heel restraint. Fitted fluorel foam pads on couch head-rests to provide head restraint during reentry were stowed until just prior to reentry. In contrast, the Apollo 7 crew partially donned the spacesuits for reentry. Previous Gemini and Mercury reentry phases were accomplished with the crew wearing complete spacesuit assemblies.

The crewmen wore communications carriers inside the pressure helmet. To provide backup, each carrier had two microphones and two earphones. A lightweight headset was worn as a substitute for the carrier with the inflight coveralls.

Following flight, the Apollo 8 crew strongly recommended that the suit be discontinued as a backup safety measure in case of cabin pressure failure, pointing to the increased reliability of the vehicle itself over the years and noting that in a real emergency the suit would be of questionable help. It was cumbersome and difficult to manage if it was to be donned in an emergency. This recommendation is under consideration for future flights.

Food

The Apollo 7 and Apollo 8 crews had a choice of more than 60 foods. Although the freeze-dried bite-size rehydrated foods represented a considerable advance over the Mercury foods, they still were a source of complaint from the crews. Among the items not previously available in Mercury were, for example, brownies, orange drink, beef cubes, and various puddings.

Each astronaut pre-selected his menu for the mission and each packet of three meals per day, averaging 2500 calories per man, was packed in separate packages numbered and colored for identification.

One advantage enjoyed by the Apollo crews over the Gemini crews was the addition of hot and cold running water. Water was delivered by three methods--a water gun for drinking water, and two water spigots at the food preparation station which provided hot and cold water at 155°F and 55°F respectively. The potable water gun dispensed limited liquid in increments of one-half ounce with each "squeeze" and food preparation spigots dispensed water by the ounce. The spacecraft potable water was provided from fuel cell by-product water.

The food in the opinion of both crews was too rich and too time consuming to prepare. Another complaint was that the water tasted too much of chlorine--a procedural matter capable of correction. The food problem must be resolved by improved technology.

One possible solution is the use of wet pack foods such as that currently planned for the Air Force Manned Orbiting Laboratory. On Christmas Day the Apollo 8 crew ate such a meal consisting of turkey with gravy and cranberry sauce. The viscosity of the food prevents it from floating in the weightless environment. The reaction of the crew was favorable.

Personal Hygiene

Crew personal hygiene equipment included body cleanliness items, a waste management system, and two medical kits.

Each crew member received with his pre-selected menu items a toothbrush and a 2-ounce tube of ingestible toothpaste. Each man-meal package contained a 3-5" by 4" wet-wipe cleansing towel. Also there were three packages of seven 12" by 12" dry towels and seven tissue dispensers containing 53 3-ply tissues each stowed beneath the command module pilot's couch.

Solid body wastes were collected in Gemini-type plastic defecation bags containing a germicide to prevent bacteria and gas formation. The bags were sealed after use and stowed in empty food containers for post-flight analysis. Urine collection devices could be used either while wearing the pressure suit or in the inflight coveralls. Urine was dumped overboard through the spacecraft urine dump valve.

The Apollo 8 crew made certain recommendations regarding the simplification of urine collection prior to dumping it overboard. The entire waste management system--primitive in comparison with other sophisticated subsystems in the spacecraft--left much to be desired. It was obvious that there must be technological breakthroughs before more adequate waste management systems could be designed.

Two medical kits measuring approximately 6" x 4.5" x 4" were used in the Apollo 7 and Apollo 8 flights, although it is planned to use only one of a larger size for later missions. The kits were stowed on the spacecraft lower equipment bay.

The contents of the medical kits for Apollo 8 were modified on the basis of experience gained in Apollo 7 and in terms of known reactions of certain crew members to certain medications through pretesting. For example, the critical need for rest and sleep led to the inclusion for the first time of sleeping pills in Apollo 8. In another instance, a substitute was made for aspirin tablets for one individual who was sensitive to aspirin. The kits, as finally modified for the Apollo 8 crew, included motion sickness injectors, pain suppression injectors, first aid ointment, eye drops, nasal sprays, assorted bandages and adhesive bandages, oral thermometer, space crew biomedical harnesses and sensors, ph testing paper, and spare urine cuffs. Pills in the medical kits included antibiotics, nausea, stimulant, pain killers, decongestant, diarrhea, aspirin, and sleeping tablets.

Work-Rest Cycle

Gemini experience had amply demonstrated that the astronauts did not sleep well in the space flight environment during the first three nights. This lack of rest on the part of the part of the Apollo crews prior to the stressful activities of the actual lunar landing could, it was recognized, prove extremely critical. The sleep-work cycle scheduled for Apollo 7 and 8 provided that at least one crew member would be awake at all times. The normal 24 hour cycle was 17 hours of work followed by seven hours of rest. Simultaneous rest periods were scheduled for the command module pilot and the lunar module pilot.

Sleeping positions in the command module were under the left and right couches, with heads toward the crew hatch. Two lightweight Beta sleeping bags were each supported by two longitudinal straps attached to lithium hydroxide storage boxes at one end and to the spacecraft vessel inner structure at the other end.

Following the Apollo 7 mission, additional restraint straps were added to the sleeping bags to provide greater sleeping comfort and body restraint in zero-g. The sleeping bags were also perforated to improve ventilation.

As one further measure, sleeping pills were introduced for the first time aboard the spacecraft, a type being chosen that would induce sleep but not such deep sleep as to preclude rapid rousing if necessary.

However, despite all efforts to improve the situation, including sleeping pills, the inability of the crew to obtain sufficient rest remained a critical problem throughout the Apollo 8 mission. One recommendation of the Apollo 8 crew was that the crew try to follow as nearly as possible the normal sleep-work cycle on earth, using Cape Kennedy time. It was their conclusion that all three crew members should sleep at the same time, with flight operations controlled from the ground. It was impossible, they reported, for two members to sleep while the third was awake, conversing with ground controllers, and moving about.

Both Apollo 7 and 8 crews felt they were overloaded with detail. They believed also that insufficient consideration had been given to the fact that it simply takes longer to perform comparable tasks in space than on the ground. The Apollo 8 crew specifically emphasized that space crews should be expected to perform only those functions which man, with his ability to make value judgments, can best perform; other routine tasks could be carried out by instrumentation.

Medical Results: Apollo 7

The Apollo 7 crew all suffered from colds during the mission. The causative agent was not identified. However, the confinement in a small cabin obviously facilitated the transfer of infectious organism from man to man. The environment apparently also encouraged the growth of some selective microorganisms.

At the time of recovery of the Apollo 7 team, all the crewmembers were essentially free of symptoms except for some small amount of residual nasal congestion. One astronaut had a mild infection of the middle ear which cleared within a few days after treatment was initiated.

Post-flight medical tests on the Apollo 7 crew indicated that they fared better than did the crew of the more confined Gemini 5 eight-day mission. A red blood cell decrease of 9 percent was noted in one crewman--a drop which is not considered of clinical significance. There were no significant alterations in plasma volumes, nor were there abnormalities in the antibacterial defense mechanisms. Post-flight tests showed an increase in stress-hormones, an increased white blood cell count, and an increase in blood glucose level, all caused probably by the flight itself, and particularly the reentry stresses. X-ray tests of bone density showed only mild changes and considerable variability of response.

To determine the physical fitness of the crew, members were bicycling both pre- and post-flight on an instrument where the workload was controlled automatically by the heart rate. There was a 70 percent loss of work performance noted at the 120 heart rate level post-flight. Work loss was less prominent at high rates--40 percent at 140 and 20 percent at 160. Within 24-48 hours after flight, work performance rates returned to normal.

Whereas in the previous Mercury and Gemini flights a tilt table had been used to determine the loss of tonus of the blood vessels, a new Lower Body Negative Pressure (LBNP) device was used instead on the Apollo 7 crew. All three crewmembers demonstrated significant increase in heart rate when subjected to the device in immediate post-flight examinations. There was also some increase in leg volume which would indicate that the tonus of the blood vessels was decreased and that blood was indeed being pooled in the lower extremities.

The Apollo spacecraft, being larger, permits greater mobility than the two-man Gemini vehicle. With increased confidence in the spacecraft and the life support systems, the use of the spacesuit was considerably restricted. Another change was the use of a mixed gas atmosphere (60 percent oxygen, 40 percent nitrogen) during launch, which eliminated the exposure of the astronauts to atmospheres containing high partial pressures of oxygen. There seems little doubt that the crew profited from these changes. Specifically, these benefits were demonstrated in the lack of loss of red blood cells and the return shortly after splashdown to normal ranges both in exercise capacity and tonus of the blood vessels.

Medical Results: Apollo 8

The only clinically significant disturbance during the flight was a mild gastrointestinal condition in the early phase of the flight. The Command Pilot vomited twice but his performance was not significantly impaired. The other two had experienced only vague symptoms of "stomach awareness." The astronauts themselves attributed these symptoms to the prior ingestion of sleeping pills and/or the initial reaction to free movement in zero g. Post-flight tests are being made to validate this assumption.

After splashdown and recovery, all three crewmen appeared fully alert and coordinated aboard the helicopter on arrival to the carrier. The Command Pilot had vomited while on the water but recovered from his nausea.

At this time the detailed physical and laboratory findings are not yet available. In general, the recovery day physical examination indicated all three crewmen were moderately fatigued and demonstrated moderate cardiovascular deconditioning. The work performance tests showed about the same degree of impairment as observed in the Apollo 7 crew.

In summary, with the exception of the in-flight gastrointestinal disturbance, the major physical complaint expressed by the crew involved fatigue.

Apollo 7 and Apollo 8 Conclusions

The first two manned space flights in the Apollo Program were successful from the medical viewpoint. Despite the respiratory ailments of Apollo 7 crew and the gastrointestinal upsets experienced by the Apollo 8 crew, there were no medical problems of significance.

The factor of fatigue is one that could assume medical significance but it is believed that this problem can be resolved by modifying the work/rest cycle.

All told, the medical performance of the Apollo 7 and Apollo 8 crews promised well for future manned space flight.

THE ROLE OF MEDICINE

IN LONG DURATION MANNED SPACE FLIGHT

As we determine our future goals in manned space flight, we must define with precision the roles and missions of man in space. To do this we will rely increasingly upon the scientific discipline of aerospace medicine and related technology to provide a critical tool with which to assess man's potential capability to perform in the space environment.

We approach the 1970's keenly aware of the vast disparity between our extensive knowledge of the hardware system which comprises spacecraft, launch vehicle and support, and our lack of knowledge about the reaction of an earth-bound "healthy man" suddenly placed in the hostile space environment as well as the dynamics of his functioning biological "system." We must identify and evaluate man's potential qualifications to function as an integral part of the man-machine system for longer duration flight even though we have yet to build a firm foundation of biomedical information upon which to make a valid judgment about these qualifications. We are nevertheless confident of our ability to overcome this scientific hurdle, even as we overcame the engineering constraints that faced us a decade ago.

At that time, you will recall, we had yet to demonstrate that we could in fact overcome the overwhelming engineering problems that faced us. The primary responsibility of the Aerospace Medical Community and allied scientists at that time was to assure that during the Mercury and Gemini period man could function during the relatively short exposure to the space environment so as to achieve predetermined engineering goals. Our first manned space flight program--Project Mercury--devoted essentially all its payload to support man in space and to assure his safe return to earth. The subsequent Gemini Program carried medical experiments, but they were secondary to the main mission objectives.

In our current Apollo Program, all but lunar scientific experiments have been removed. Through actual operational experience, however, we are adding constantly to our storehouse of medical experience, as was described earlier.

Now, looking to the decade of the 1970's, we begin a transitional phase toward an era of space exploration through long duration flight. In this second decade of manned space flight, major emphasis will necessarily be focused upon the actual capabilities, roles, and missions of man as he labors to perform useful tasks of a scientific and functional nature in the hostile environment of space. We will increase our effort to investigate, systematize, and develop an entirely new body of applied medicine and space biology so as to understand the significance of even minor changes in high-level performance of very healthy astronaut-type individuals; so as to extrapolate those conditions of health and productivity that can be expected under the dynamic conditions of space travel and exploration. On the basis of a solid foundation of scientific knowledge, we must be able to predict, chart, and interpret the course of man's physiological, psychological, and motor responses under the conditions of space travel.

This thrust of effort means, in short, that we must now reassess the function of aerospace medicine and technology, and now, in the second decade of manned space flight we are shifting emphasis from developing life support technology to that of advancing Aerospace Medicine as a science; to advance the corollary engineering capability by which we can measure accurately man's response to the dynamics of longer duration space flight.

We plan to do this through three major programs, each complementing the other to advance our state of knowledge. These are the Apollo Applications Program, the Advanced Manned Missions Programs, and the Lunar Exploration Program. These three programs all should go far in providing a systematic body of medical information required as a critical tool in long range manned space flight since, to advance our manned space goals, we must not only assess man's capabilities, but we must actually "qualify" him for flight--to use an engineering phrase--as we would a space vehicle or other hardware.

What do we mean by the phrase "to qualify man?" It involves not only evaluating man's broad performance capability in longer duration missions, but also involves gaining a broader understanding of the space-induced interaction of the physiological subsystems which make up the larger complex system known as man. Also it should bring a clearer understanding of the unique capabilities and capacities of the human organism; a more concise definition of the optimal contributions this system can make in meeting the critical performance requirements of space flight with its wide variety of objectives; and, finally, a more solid foundation of pre-flight data from which to extrapolate probable performance levels and to predict probable responses.

Apollo Applications Program (AAP)

What is necessary to qualify man for still longer duration space flight? The first step will be through a series of medical experiments in the Apollo Applications Program (AAP), a program which provides the first comprehensive flight test of man, equipment, and operating concepts leading to future manned and man-tended laboratories and astronomical observatories.

Five flights, three of which are manned, are currently programmed, one of 28 days duration and two of 56 days duration. The orbital workshop configuration, as you know, consists of the use of the Apollo command module, a multiple docking adapter, an airlock, and a spent hydrogen stage (S-IVB) which will be converted into living quarters and a laboratory.

The prime medical objective of this program is the functional qualification of man for longer duration flight. Certain critical inflight biomedical measurements are required to assure success in manned missions lasting two months or longer. Some physiological trends have been observed on past missions. It is necessary to understand these trends more completely--their onset, duration, and magnitude--and to determine the relative importance of weightlessness as the primary causative factor. Further understanding is required of the interacting influences over long durations of such man-made environment features as physical confinement and oxygen enriched atmospheres. The capability of the human organism to accommodate to environmental stresses must be understood as well as its ability to acclimatize and perhaps even adapt to continuing major alterations in the external environment.

It has been encouraging--but not conclusive--to observe the general similarities in the post-flight condition of the astronauts in the eight-day and fourteen-day Gemini missions. We must yet confirm whether or not we have been observing the natural processes of acclimatization rather than gradual and progressive impairment of the body subsystems. The inflight medical experiments proposed for the initial manned mission in the Apollo Applications Program will provide the first of the new knowledge required to explain the nature, time course, and the extent of human acclimatization to the space flight environment in earth orbit and to measure man's ability to work in space.

In order to carry out high priority medical experiments for the first three manned Apollo Applications missions, functional hardware and adequate working volumes will be provided so that the crew can accomplish the necessary experimental procedures including the collection of inflight data and preservation of specimens of body products for appropriate post-flight biochemical analysis. These inflight activities will begin as soon as possible after the crew and vehicle cluster are established in orbit, and will be integrated with the extensive group of scientific and engineering experiments planned for this program.

A set of medical experiments has been developed which we believe to be both feasible and within the scope of current plans for Apollo Applications missions. Addressed to the areas of greatest medical interest in the qualification of man for long duration space flight, there are initially five major areas of interest:

- cardiovascular function, including hematology;
- respiratory metabolism and energy expenditure during measured workloads;
- musculo-skeletal function and nutritional balance;
- neurophysiology of the vestibular system, and sleep; and
- crew reaction to weightlessness as measured by time and motion studies.

Each of these areas of interest has a number of specific experiments or tests, which will provide a clearer picture of the function of that particular body system. Let me describe one as an example. The cardiovascular study involves the inflight use of lower body negative pressure for the first time, in addition to the pre- and post-flight application.

The device tests the cardiovascular system reflexes which on earth normally operate to regulate regional blood pressure and distribution of blood throughout the body as postural changes occur. This is a vitally important measurement of cardiovascular system response. The inflight measurement will allow us, for the first time, to establish the onset, the rate of progression, and the severity of adverse functional changes in these responses. Since this procedure requires a medically trained observer we plan to conduct it using a physician-astronaut as part of the crew.

The other four areas mentioned are equally specific and detailed.

Medical Implications of the Space Station Program

In accordance with NASA planning for the Space Station Program, major consideration is being given to a configuration which will provide for prolonged biological studies of man, animals, and other organisms in earth orbit.

Current plans are for a semi-permanent orbital space station design which will emphasize the use of subsystems which can be maintained and repaired by the crew in flight and of a configuration which will meet payload and mission requirements. In addition to providing specific experiments to be conducted in the station, aerospace medicine and technology will participate in the determination of the volume within the space vehicle required for individuals to live and work in space effectively for long durations; and to habitability design considerations such as decor, provisions for sleeping arrangements, food preparation, waste management, personal hygiene, and the layout of working quarters. The extent and type of on-board medical care available will also be determined.

Primary medical mission objectives formulated for the Space Station Program thus far focus upon deepening our understanding of man's capabilities; upon improving methods to support him in the space environment for extended periods of time; and determinations of how best to make practical application of his potential capabilities.

Of all considerations, however, the two most pressing problems for aerospace medicine and its technology at this time are to extend our knowledge about the long-term biomedical and behavioral characteristics of man in space and to provide the means whereby his physiological capabilities in the space environment can be enhanced for long-duration missions. We must, therefore, build on our current bank of experience gained in the Mercury, Gemini, and Apollo programs which demonstrated that man can perform effectively in demanding situations during space flights lasting up to 14 days. The remaining Apollo flights and the Apollo Applications Program will add to this experience by providing additional information about the physical and mental performance of man in what must be considered the transitional point between short duration and longer duration space flight experience.

If we are to embark successfully on this new phase represented by longer duration flights, however, we must look beyond all these programs.

The Space Station Program as currently planned will determine and support man's capability to function for long periods in space by progressively prolonging his exposure time on successive missions beyond 56 days to as much as 180 days. The program will seek to determine the type and degree of supportive measures needed to optimize man's performance. Three or more crew members will be studied during each mission segment to provide a sound design base for further flights. Through comprehensive ground and flight research, validated by a series of progressively longer exposures to the space flight environment, biomedical and behavioral investigations will establish man's physiological responses and/or adaptations and aptitudes in space and his re-adaptation to the terrestrial environment. Evaluation is to be based upon measurements of cardiovascular, respiratory, metabolic and nutritional, neurological, endocrine, hematological, microbiological and immunological functions as well as individual and interpersonal behavior factors.

Basic flight hardware for medical/behavioral experiments in the future space station era is incorporated in the Integrated Medical Behavioral Laboratory Measurement System (IMBLMS), an independently designed series of modular subsystems that can be configured as a medical laboratory that can be incorporated into the Space Station. Intrinsically a measurement system--as the name implies--the Integrated Medical Behavioral Laboratory Measurement System (IMBLMS) provides an onboard capability for obtaining basic medical/behavioral data in the zero gravity environment. The Integrated Medical Behavioral Laboratory Measurement System (IMBLMS) currently will support individual measurements of those body functional areas which may be needed to provide an effective base to evaluate man's physiological status in orbit.

In summary, by the end of 1975-76, the Space Station Program as currently planned should result in the continuous exposure to the space environment of six men for as long as 180 days. Comprehensive medical/behavioral evaluations during this program will provide basic information required both for support of man during the flight missions and for future manned space flight programs.

MEDICAL IMPLICATIONS OF THE LUNAR EXPLORATION PROGRAM

The Lunar Exploration Program is still in the early planning stage. Medical information during lunar exploration is required for two main purposes:

1. To assure man's health and performance capability; and

2. To contribute to the information on the physiological effects of gravity by providing an intermediate reference point between earth gravity and weightlessness.

Insofar as health and performance are concerned, the most important requirements are the measurement of metabolic energy expenditure, and determination of the effects of the lunar environment upon visual performance. Actual lunar surface determinations on man are the only means of quantitatively evaluating task performance, of comparing different types of equipment, of assessing ground simulators, and of setting realistic safety limits on work performance.

The more refined measurements such as blood volume, red cell mass, lower body negative pressure, and biochemical studies must await the availability on the moon of more advanced experimental facilities.

MANNED SPACE FLIGHT FACILITIES

I will now give you the status of our Manned Space Flight facilities and a review of plans for FY 1970. As you recall, last year I reported that our major efforts would be directed toward a program plan for major maintenance and rehabilitation as well as those modifications considered essential to meet the needs of our program.

Manned Spacecraft Center

As of June 30, 1968, the facilities investment at the Manned Spacecraft Center reached $420.9 million. All facilities at this Center are essentially operational. During the past year, construction of the Flight Crew Training Facility was completed. The Procedure Development Simulator was installed within this facility and became operational in November 1968. This simulator and associated crew station is used for training astronauts in specific tasks of Apollo flight missions. Also completed was the Atmospheric Reentry Material and Structures Evaluation Facility, which provides the means for evaluating the reentry heat shield of the spacecraft under simulated heating and aerodynamic conditions.

During this period, the Lunar Receiving Laboratory underwent shakedown tests, subsystems simulations and practice runs to ready it for operation. Operating procedures as well as training of personnel has also taken place. The facility is now undergoing full system simulation of the actual operating mode and will be ready to support the manned lunar landing mission.

Our budget request for FY 1970 at the Manned Spacecraft Center consists of one project, addition to the emergency power building of the Mission Control Center. This addition will house additional generation equipment necessary to supply closely regulated noninterruptible power in support of our continuing manned space flight operations.

Kennedy Space Center

As of June 30, 1968, the total capital investment in the Kennedy Space Center totalled $1,050.5 million.

At Launch Complex 39, the entire complex as presently defined is now operational. Facilities completed during the past year include the High Bay No. 2 and Firing Room No. 3 of the Vehicle Assembly Building, Launch Umbilical Tower No. 3 and Launch Area B. Satisfactory prelaunch and/or launch operations have taken place at the Complex 39 facilities, in support of the Apollo program missions. The emergency egress slide wire system and the spacecraft land landing area for Launch Area A were also completed and made operational.

In the industrial area, the Communications Test and Switching Center, located in the Central Telephone Office, was completed, as was the activation of Acceptance Checkout Equipment Stations 5 and 6, in the operations and checkout building.

Work scheduled to be completed during the coming year includes the deepening of the Banana River Barge Channel; refurbishment and interconnection of the three zones of the industrial area high temperature hot water system; and the installation of spacecraft radar and communications checkout stations in the vehicle assembly building. Also included will be rehabilitation of and modification to elements of Complex 39. Other work currently underway includes the sandblasting and painting of the structures at Complexes 34 and 37 to preclude deterioration of these Complexes and maintain them in a standby status for the space flight operation program.

In fiscal year 1970, our request provides for the modifications to Launch Complexes 34 and 37, the operations and checkout building and other manned spacecraft facilities in support of the Apollo Applications Missions 1, 2, 3A, 3, and 4. This will include modifications to the umbilical towers, service structures and pad areas at the Complexes. Also requested is the construction of an 8,000 square foot high pressure gas maintenance operations building to replace twelve deteriorated, inadequate trailers. In addition, we are requesting that the existing portable electric generators serving launch critical facilities be replaced and consolidated into a small number of larger permanently installed generator stations. Also requested is the installation of the initial increment of a central power monitoring and control system to support all 5 substations on Merritt Island and Cape Kennedy, as well as the Air Force Critical Power Plant and the new generator substations.

Effectiveness of Maintenance Operations

Last year we reported that having completed the construction of facilities, our efforts were being geared toward the continued implementation of effective and efficient maintenance and operational programs at lower costs. It is worthy to note some of the areas where continued emphasis and effort is being exerted to achieve further cost reductions in the overall maintenance and operations program.

Utilities Conservation is one of the major areas where savings are effected at MSF installations through the continued implementation of the utilities control program including the management of utilities contracts and services. We are working closely with General Services Administration to provide recommendations to effect additional improvements.

We continue to pursue the analysis of the frequency with which maintenance services are performed. We are encouraging our facilities personnel to become more active in the formative stages of contracting for services like custodial, window cleaning, lawn cutting, and landscaping in order that the resulting contracts can be more easily administered as our funds become more critical.

We are emphasizing the need for our installation professional engineers to review the uses of computerized monitoring systems for our utilities systems where those systems have been installed to be sure they provide the economies for which they were designed.

Also, we are stressing the long range economies to be achieved by instituting a schedule of preventive maintenance for these automated monitoring and control systems.

Another area to be highlighted concerns the rehabilitation and improvements at various MSF locations. Most of our facilities will be over five years of age during this year. In order to maintain these facilities without excessive operating and maintenance expense, some level of planned major rehabilitation is required annually. In this regard, we are including requirements of planned rehabilitation and improvements at the Manned Space Flight Centers within an agency project for such effort. The areas described above are representative of the steps which have been taken to minimize operations and maintenance costs and yet assure the continuing availability of the NASA plant.

In summary, our construction of facilities program is now primarily geared to modifications of existing facilities to accommodate the Apollo Applications missions and maintenance of the extensive plant which has been brought into being over the past seven years. This program is designed to supplement a basic program of day-to-day maintenance which is in being at all our centers. This is an area we have given particular attention, not only in terms of effectiveness, but to assure accomplishment at the lowest possible cost.

The objectives of our management of the Manned Space Flight activities is to provide sound management of its current programs, secure its institutional base, preserve its technological capabilities and prepare for the challenge of space in the next decade.

MANAGEMENT

INTRODUCTION

During the past year we have seen great progress in the conduct of our Manned Space Flight programs. We have regained the momentum in the Apollo Program and have attained what we consider to be real achievements in terms of program performance and hardware reliability. Our stress on teamwork and having each one of the thousands of individuals working in our contractor plants and at our NASA Centers assume personal responsibility for their piece of the program have given us hardware which can be launched with a minimum of rework and "holds" prior to launch at the Kennedy Space Center. In fact, we have found that we have far fewer technical problems at KSC with the Saturn/Apollo hardware than we had with some of our earlier programs which were considerably less complex than is the Apollo Program.

Our most serious management concern over the last year and at the present time is to find ways of retaining intact this basic capability so that we do not have to rebuild it at some future time at considerable cost and effort. We have already started to dismantle some of this capability, with our overall employment in the private and Government sectors declining from a peak of 300,000 to 145,000 at the present time. We have been faced with situations which require us to get rid of some of our more successful performers as soon as a particular milestone is reached. For example, because of the very successful performance of the family of Saturn launch vehicles, we have been reducing both Civil Service and contractor personnel levels at the Marshall Space Flight Center for several years. Almost immediately upon completion of the Apollo 7 mission we were forced to release approximately 1,600 contractor personnel associated with the Saturn IB vehicle. This experience makes it difficult to continue to get good people to work on our programs because they feel that as soon as the hardware on which they are working becomes successful they are out of a job.

I do not want to paint the picture any blacker than necessary, but I do wish to express my very real concern that the capability which we have worked so long and hard to bring to the levels currently existing in the Apollo Program will be lost to the nation, only to be built up at some later time at great cost.

Key Personnel Changes

Since appearing before you last year, we have made a number of changes in key personnel in the Office of Manned Space Flight and the Manned Space Flight field installations.

Mr. Charles W. Mathews, who formerly served as Director of the Apollo Applications Program, and before that as the Manned Spacecraft Center Manager of the successful Gemini Program, has moved up to become my "across the board" deputy.

Mr. Charles J. Donlan, formerly Deputy Director of the Langley Research Center, has joined us as my Deputy for technical matters.

Mr. William C. Schneider has been named Director of Apollo Applications to replace Mr. Harold T. Luskin who died on November 25, 1968. Mr. Luskin was a recognized leader in the field of aerospace technology and his contributions to our programs will be missed very much. Mr. Schneider, as you know, has been with the Office of Manned Space Flight for several years and previously served as Apollo Mission Director, Gemini Mission Director and Deputy Director, Gemini Program.

Mr. George Hage, Deputy Director in the Apollo Program, has been assigned the additional job of Acting Mission Director of the Apollo Program.

Mr. William E. Stoney, who formerly served as Chief, Advanced Spacecraft Technology Division at MSC, has been named Deputy Director, (Engineering) in the Apollo Program Office.

Colonel V. John Lyle, USAF (Retired), has been named Deputy Director, Manned Space Flight Field Center Development. Prior to assuming this position, Colonel Lyle was one of my special assistants.

At MSC Mr. Wesley L. Hjornevik has moved up to become the Associate Director of the Center. He previously served as the MSC Director of Administration.

At KSC, Mr. David F. Callahan has been made Deputy Director, Administration. Mr. Callahan was formerly with the Chrysler Corporation.

Mr. John D. Hodge has been named Director of the newly established Advanced Missions Program Office at MSC. He previously served as Acting Director of the MSC Lunar Exploration Group and Chief, Flight Control Division.

At MSFC Dr. Ernst Stuhlinger has moved up to become the Associate Director for Science and Technical Analysis reporting directly to the Center Director. He previously served as the Director of the Space Sciences Laboratory, Research and Development Operations.

Dr. William R. Lucas, formerly Director of the Propulsion and Vehicle Engineering Laboratory, has been named the Director of Program Development.

Mr. David Newby has been named Director of Administration and Technical Services. Mr. Newby previously was the Associate Deputy Director, Administrative.

Astronaut Frank Borman, Commander of Apollo 8, was named Deputy Director, Flight Crew Operations, Manned Spacecraft Center, Houston.

Organization

There have been no major changes in the Office of Manned Space Flight organization during the past year. We are, however, presently examining our organization to determine whether new patterns need to be established to handle the programs being presented in this budget.

Some basic changes have been made in the MSC and MSFC organizations since I last appeared before this committee. At MSC we have established an Advanced Missions program office. This office is the focal point for all MSC advanced missions work and is responsible for planning and managing MSC's participation in such work.

We have also added an associate diretorship at MSC. This change strengthens the center management structure and provides better overall flexibility by placing responsibility for all administrative, contracting and program control functions in one organization.

A sizeable change has been made in the MSFC basic organization. This change was required to meet the changing workload of the Center and the changing roles and missions. These key changes are:

- The establishment of an Associate Director for Science.
- A restructuring of the line organization into four elements representing the major activities within the Center as follows:

  Director of Program Development

  Director of Administration and Technical Services

  Director of Program Management formerly Industrial Operation

  Director of Science and Engineering, formerly Research and Development Operations

Research and Program Management

As you know, we have changed the title of the Administrative Operations appropriation to Research and Program Management. The new title is much more descriptive of the work actually performed with these funds. It includes the salaries of all of our Civil Service staff, those performing technical and scientific functions as well as those involved in administrative type activities. It includes much of the electronic data processing equipment and services which are so vital to the performance of our programs, and the cost of the necessary institutional support services provided to us by support contractors. About 66 percent of the funds requested for Fiscal Year 1970 will be spent for Civil Service salaries and related expenses, 5 percent for the purchase, rental, operation, and maintenance of electronic data processing equipment, 15 percent for contractor provided support services and 14 percent for the remainder of the items making up this appropriation.

The management officials in the field centers and headquarters exercise close scrutiny over the use of the Research and Program Management resources. We have continued to use our basic management systems such as the management council reviews, the program operating plans, manpower and facilities reporting and special field reviews and analyses to insure that the management of these activities is sound. We have supplemented these regular management controls by the addition of a work package manpower reporting system, a consolidation of all logistics functions in the Office of Manned Space Flight and the extension of the Apollo data management system to all Manned Space Flight activities.

Planning Activities

During the past year, we have been involved in planning efforts to determine how to best apply the required reductions in our Civil Service and contractor work forces, and I will discuss these reductions at some length later. We are also involved in a number of continuing studies to assess the total institutional requirements needed to support the manned space flight programs being presented to you in this budget, as well as other logical and viable follow-on programs which may be performed in the future. In these studies, we are seeking to identify the manpower, facilities, equipment, etc., required to support our programs as well as any capability which we may have to perform other work.

Interagency Studies

During the past year, we have participated in joint studies with other agencies such as the Civil Service Commission and the Air Force. The Civil Service Commission joined with us in working out an agreement for lifting the Federal Court injunction which prevented the completion of a reduction-in-force at the Marshall Space Flight

Center early in 1968. They later worked with us on a study of two support services contracts at the Kennedy Space Center and have continued to work with us on general matters relating to support services contracts.

At the Kennedy Space Center, we are presently involved with the Air Force Eastern Test Range in a joint study to determine if economics can be effected through the consolidation of common support functions. We have already worked out an agreement with the Air Force Eastern Test Range for the consolidation of the photography function which we expect will result in considerable savings to both the Air Force and NASA.

Personnel Reductions

As the result of reductions in our research and development and Research and Program Management budgets, we have been cutting back manpower levels at both the hardware contractor plants and at the field installations. (MC 69-4395) The estimated reductions for Fiscal Year 1969 are as follows:

	Hardware Contractor	Support Contractor	Civil Service	Total
All locations	-23,581	+ 154	-747	-24,174
Manned Spacecraft Center (including White Sands Test Facility)	-15,734	+1,113	-221	-14,842

	Hardware Contractor	Support Contractor	Civil Service	Total
Marshall Space Flight Center (including Michoud Assembly Facility & Mississippi Test Facility)	- 5,901	-1,543	-525	- 7,969
Kennedy Space Center (including Western Test Range)	- 1,946	+ 584	- 1	- 1,363

The reductions in Civil Service manpower are expected to be accomplished through attrition. The skill mix of the Civil Service employees expected to leave by June 30, 1969, follows:

Engineers	Technicians	Administrative	All Other	Total
-417	-74	-193	-63	-747

In addition to the reductions shown above for Fiscal Year 1969, the Fiscal Year 1970 budget reflects a reduction in Civil Service personnel of 250 for the Manned Space Flight Centers. Any reduction in the in-house staff below these levels will seriously impair our ability to complete the Apollo Program, to proceed with the presently approved Apollo Applications Program and to perform meaningful planning for future manned programs. As we have reduced our contractor staffing levels, we have had to assume more responsibility with our Civil Service staff because some of these functions must be continued if we are to effectively operate our institutions.

Technology Utilization

Technical advances that may be useful outside the space program continue as by-products of the National Aeronautics and Space Administration's programs. The NASA Office of Technology Utilization, through single-sheet Tech Briefs or more detailed publications, communicates these advances to the technical industries and community.

Some examples of the technical innovations resulting from the National Aeronautics and Space Administration's programs are:

...The basic idea of the space helmet has been used in the design of a hood worn by patients in a children's clinic so that their consumption of oxygen can be measured while they perform exercises.

...A filtered air system which eliminates virtually all dust and airborne bacteria within minutes from the operating room and other medical environments has been developed. The National Aeronautics and Space Administration program for assembly of spacecraft in a dust free environment provided the scientific basis for these surgical and medical applications.

...A plastic-metallic spray for attaching heart electrodes to test pilots is being used experimentally in equipment with which electrocardiograms of ambulance patients can be flashed ahead by radio to a hospital receiving room.

...A sensor designed to count meteorite hits on a spacecraft is the basis of an instrument that, by measuring muscle tremors, may help doctors in early detection of certain neurological ailments, including Parkinson's disease.

...A meter used to measure the elasticity of bones in living people in a study of why bones become brittle with aging.

...An instrument designed to measure air pressure on small flight models in wind-tunnel tests has been adapted to measure blood pressure. The sensor is so small it can be inserted through a hypodermic needle and pass along an artery into the heart.

Examples of the use of space technology in industry and other non-medical fields include these:

...A 24-ounce, battery-operated television camera no bigger than a king-size pack of cigarettes, which photographs the separation of Saturn V rocket stages in flight, is on sale in a commercial version for monitoring industrial processes.

...Bearings now being marketed are coated with a ceramic-bonded dry lubricant developed for use at high temperatures in a vacuum where other lubricants evaporate.

...Research in developing models to display spacecraft trajectories has resulted in the marketing of a new education device that enables a student quickly to determine the relative positions of the planets on any day in this century.

...A modification of a National Aeronautics and Space Administration technique of polishing metal masters for shaping elliptical glass mirrors is being used industrially in making projections of bowling scores.

University Program

Man's flight to the moon with Apollo 8 is outstanding evidence of this nation's industrial and technological achievement. It was made possible through many scientific advancements, which while not necessarily individually noteworthy were nevertheless most significant in terms of mission success. Many of these scientific advances were first brought to light through research efforts in our universities which have contributed greatly in extending our knowledge and understanding of science.

During the past year, we continued to turn to the universities for support, particularly when a more complete or comprehensive understanding of a specific phenomenon was essential. For example, there was the problem of outgasing of some materials from the Apollo spacecraft. The cabin pressure of the Apollo spacecraft ranges from approximately 16 pounds PSI at launch to approximately 5 pounds PSI in flight. Temperatures in the spacecraft components range from 40 to 200 degrees Fahrenheit. Because of the natural laws of diffusion and the influence of pressure and temperature changes, some materials have a tendency to outgas, or release gases that are trapped in their molecular makeup under normal conditions.

Some of the gases released and their products were found to be potentially damaging to spacecraft circuits. Valuable assistance was obtained from the universities in resolving this problem.

Dr. Albert Zlatkis of the University of Houston assisted Manned Spacecraft Center personnel in selecting the proper instruments to isolate and identify troublesome gases in cabin atmospheres.

Dr. Margrave of Rice University, with expertise in the field of gas analysis, was able to advise MSC personnel on the development of mass spectroscopy capability.

Dr. Eli Freeman of Illinois Institute of Technology, an authority on thermogravimetric analysis, assisted Manned Spacecraft Center personnel in applying this analytical technique to the problem.

Dr. Lipsky of Yale University, who pioneered the adaptation of gas chromatograph to a mass spectroscopy, briefed Manned Spacecraft Center personnel on this situation and advised on the proper hardware to select.

Again, when the Saturn V showed a tendency to pogo, that is to develop hazardous oscillations, a number of universities contributed to the solution of this potentially dangerous problem.

The universities will continue to play a major role in analyzing the new data and material to be obtained in the planned lunar landing and provide valued guidance for investigations in the other manned space flight programs.

To further facilitate cooperation between the Manned Space Flight Centers and the universities, the Office of Manned Space Flight has, during the past year, established in each of its centers an Office of University Affairs.

These offices were established to work with our Headquarters Office of University Affairs in maintaining an open channel of communication between the National Aeronautics and Space Administration and the universities and assuring an equal opportunity to all universities to contribute to our programs.

FUNDING

Having described the program activity that we plan with our request for the next fiscal year, I would like now to detail the funding required to support these efforts. But before beginning, I would like to make an observation on the crucial juncture that confronts Manned Space Flight, and therefore the nation this year.

In examining a program, one should think of it as having three parts--a beginning, a maturation, and a conclusion. Of these three elements, perhaps the most critical is the beginning. For it is during this phase when the planning and preparation are undertaken to produce the benefits and rewards in future years.

The salutary endeavors of our program during the past year--the successful unmanned Lunar Module development flight of Apollo 5; the 11-day earth orbital mission of Apollo 7 with its first manned flight test of the Command and Service Module; and the first manned launch of the Saturn V, producing one of the most significant events in all history, the lunar orbital flight of Apollo 8; and the manned flight of the Lunar Module and its rendezvous and docking with the Command and Service Module during the Apollo 9 mission last month--were the results of the funding we received in earlier years. These accomplishments are a testament of the foresight of the President and the Congress during the decade we are now closing. The same foresight and wisdom must be applied today if we are to preserve for this country the capability to conduct manned space flights during the next decade for the benefit of all mankind.

Achievements in space are not easily gained. They are the result of long and laborious efforts in design, development, and production, supported by the commitment of substantial resources.

With the complexity of space hardware, there is no quick remedy to the consequences of the decisions of the past. The limited funding we have received during the past several years for our programs of the next decade has dictated that we proceed with limited and minimum efforts during the initial part of the next decade. With the amendment to our FY 1970 budget, we will be able to continue production of the Saturn V launch vehicle. However, with this amended budget we will also suspend the production of the Saturn IB launch vehicle, this nation's second most powerful rocket, and will complete only the assembly of the final two first stages for this vehicle. These two stages are so very close to being completed that we consider it both prudent and practical to finish them.

With this amended budget Manned Space Flight (MP69-4380) is requesting $2,240.9 million in new funding authority for fiscal year 1970; of this $1,919.2 million is required for Research and Development; $14.2 million for Construction of Facilities; and $307.5 million for Research and Program Management which was formerly called Administrative Operations.

The Research and Development request for all of Manned Space Flight is over $100 million less than the amount Congress authorized for Apollo alone in fiscal year 1969. So we are, in Manned Space Flight, continuing to come down the funding curve in a very marked manner. Our request for fiscal year 1970 is about 40 percent less than the funds we received in fiscal year 1966. During these four years, because of general inflation and because of the recently negotiated labor settlements in the aerospace industry, we estimate the cost to NASA of obtaining goods and services will have increased by about 20 percent. So with our funding request for fiscal year 1970, we will be able to support less than half the effort we were able to fund in fiscal year 1966.

The decrease in our funding is reflected in a corresponding decline in our manpower. (MC69-4410) With this request, by June 1970, employment on the Manned Space Flight program is expected to be only about 1/3 of the 300,000 employment peak that was reached in February 1966, and will be approaching a situation where the Manned Space Flight team, as it was conceived and developed, will have disintegrated, unless we receive the funding required to proceed into the next decade. As a point of comparison, our employment in June 1970 will be at its lowest point since June 1962, a point where only four months earlier, John Glenn had made his historic flight.

The skill balance, inherent in any capability concept, between design, production, test, and launch is rapidly dissipating. Our contractor personnel requirements during fiscal year 1970 will be heavily concentrated in the areas of checkout, test, and launch. Our requirements for design personnel are a small fraction of what they were several years ago. Those subcontractors and vendor efforts still remaining are rapidly being ended. However, with the budget amendment by President Nixon that allows us to reinitiate Saturn V production, we will be able to arrest this depletion of the manufacturing and production capability that was established for this country's efforts in peaceful manned space flight.

Besides follow-on Saturn V production, we are undertaking two new efforts in fiscal year 1970 - the Space Station and Lunar Exploration. The funding we have requested for these programs is minimal, $9 million for study efforts on the Space Station and $90 million for Lunar Exploration. These requests represent a commitment to the future for Manned Space Flight, and are the beginnings of further exploration of space which we believe will be very productive and beneficial to this country and to the world.

To delay this commitment is, I fear, to allow Manned Space Flight to slide to the point of extinguishment, beyond the stage of ready resuscitation.

The funding request for Manned Space Flight will permit a limited series of efforts for lunar exploration and in earth orbit during the early part of the next decade, and it will allow us to make the initial steps toward conserving the capability this country has developed for manned space exploration.

We have this year established a new program category--Space Flight Operations-- which incorporates Apollo Applications, follow-on Saturn V production and the Space Station. Because funding limitations have severely restricted the scope and promise of Apollo Applications, and confined its period of flight missions to the interval of a year, it no longer came to represent the earth orbital program that we felt this country should undertake during the 1970's. We feel the Space Flight Operations program, encompassing the future missions that Manned Space Flight proposes to undertake during the next decade, will be more reflective of our planning and efforts in the area.

Apollo

In fiscal year 1970, we are requesting (MP69-4047) $1,691 billion for the Apollo Program. This is nearly $335 million beneath our funding for this program in fiscal year 1969, and is nearly $1.3 billion less than our peak funding in fiscal year 1966.

Spacecraft

Apollo spacecraft requirements in fiscal year 1970 are $653.8 million. This represents a reduction of $250 million from fiscal year 1969. During the next fiscal year, eleven Command and Service Modules and seven Lunar Modules will be in the process of production and checkout at North American Rockwell and at Grumman. The Guidance and Navigation Units for the Command and Service Module and the Lunar Module will be checked out in fiscal year 1970 and their computer programs modified as required. Spacecraft funding also supports the checkout of the assembled spacecraft at the contractor plant and at the test and launch sites; reliability and quality assurance efforts; various mission planning and performance analysis studies and simulation and training.

This project also funds spacecraft support activities such as test operations, crew equipment, space suits, and scientific equipment and instrumentation.

No change was made in our funding requirements for Apollo Spacecraft or Saturn V by the recent budget amendment.

Saturn V

For the Saturn V vehicle, we are requesting $496.7 million which is over 40 percent less than our funding for this project in fiscal year 1968.

In fiscal year 1970, the manufacturing and assembly of the various stages will be completed and the last of the engines for the Saturn V vehicle will be delivered. The funding we request will support these concluding production efforts and also the checkout and test of the stages. We are requesting $46 million in FY 1970 funds in our Space Flight Operations Program for follow-on production of the Saturn V vehicle. We will be maintaining a flight data analysis and a problem solving capability at the various stage and engine contractors.

Our Saturn V funding will also be used for operating electrical and mechanical support equipment required to test and checkout the stages, instrument units, and associated hardware. Additionally, our request provides for our stage test operations; transportation of stages and engines; propellants; systems integration and computation and engineering services including reliability, quality control, and inspection.

Lunar Exploration

Lunar exploration includes the activity necessary to expand the capabilities and usefulness of basic Apollo hardware. Of the $90 million in our amended funding request for fiscal year 1970 $11 million will be used for the definition of modifications to Apollo hardware, new system requirements, and experiments for flights in the 1973-1975 time period.

The remaining $79 million will fund the activity necessary to expand the capabilities and usefulness of basic Apollo hardware. We will modify the Apollo Lunar Module to allow for a three-day staytime on the Lunar surface, and a 16-day mission capability for the Command and Service Module. These funds will also be used to develop equipment to extend the astronaut's mobility and radius of exploration from the Lunar Module. Finally, these funds will provide experiment payloads for six Apollo/Saturn V vehicles that presently have no experiment payloads.

Operations

This project category provides for crew training and the launch, flight, recovery, and technical support for manned space flights. Apollo funds the basic capability to conduct manned flights, regardless of program. The operations project under Space Flight Operations funds only those particular Apollo Applications requirements.

In fiscal 1970, we are requesting $450.6 million for operations, a decrease of approximately $95 million from our fiscal year 1969 requirements. Three manned Saturn V launches are planned during the fiscal year.

The amended budget request reflects a reduction of $39 million from the original submission to the Congress. This was the result of reducing our number of planned launches in FY 1970 from five to three on the assumption that Apollo 11 will be successful as the initial manned lunar landing. In the event that this flight is not a successful lunar landing, the launch rate would continue on a 2 1/2 month schedule until success is achieved. If this becomes necessary, some or all of the projected $39 million savings would be needed to support this flight rate.

Our funding in this project is used to check out and launch the spacecraft and launch vehicles at the John F. Kennedy Space Center including the operation of the launch complex facilities and the engineering, technical, and instrumentation facilities at this Center.

The other major portion of our Operations funding supports the Manned Spacecraft Center and its efforts in the areas of astronaut training, mission planning, simulation, and control. The Center controls flight operations from lift-off through recovery. From the funds we receive in this project, we reimburse the Department of Defense for their expenses in the areas of launch support and recovery.

The final principal area in our Operations project that we fund is for the systems engineering for the integrated technical support review and analysis of the entire Apollo Program, and for the supporting development necessary for product improvement.

Saturn IB

Fiscal year 1969 was the last year of Apollo funding for the Saturn IB vehicle. The Apollo 7 mission with Astronauts Schirra, Eisele, and Cunningham was the last planned Apollo mission using this vehicle, although in the event of problems with the Saturn V, the remaining Saturn IB vehicles can be used for earth orbital CSM/LM operations.

Engine Development

Fiscal year 1968 was the last year of funding for this project.

Space Flight Operations

This new program (MP69-4379) represents Manned Space Flight's continuing development of a manned capability during the next decade. The initial efforts in this program will be conducted under Apollo Applications and will culminate in the operation of a Space Station.

Our amended budget plan for Space Flight Operations is for $343.1 million, however, we are requesting only $225.6 million in new obligation authority since the Bureau of the Budget will release $117.5 million in fiscal year 1969 authority that had been withheld from apportionment pursuant to the Revenue and Expenditure Control Act of 1968.

This request is the lowest request we have made for our planned earth orbital program after Apollo in the last three years. In fiscal year 1968, we requested $454.7 million for Apollo Applications from the Congress. In fiscal year 1969, we requested $439.6 million for Apollo Applications.

Available appropriations for these two years (MP69-4046) are $253.2 million in fiscal year 1968 and $150.0 million in fiscal year 1969, which is nearly 50 percent reduction from our request, and we were forced to severely reduce the operations and activity we had planned. Apollo Applications now consists of five launches and three missions. The amended budget suspends production on the two launch vehicles that were being produced for Apollo Applications.

Our amended budget plan for fiscal year 1970 for Apollo Applications is $251.8 million. This number, of course, reflects the application of the $117.5 in fiscal year 1969 authority that is being released to us in fiscal year 1970 by the Bureau of the Budget.

With the amended budget, we were required to reduce our fiscal year 1970 plan for Apollo Applications by $57 million. To accomplish this, we suspended production of the last two Saturn IB vehicles, and restructured and reoriented the program. We have delayed the start of Apollo Applications missions by a minimum of five months and slowed down efforts on a backup Workshop and backup ATM.

Of the $251.8 million, $110.4 million will be used for spacecraft modification. The spacecraft modifications are required to extend the lifetime of selected spacecraft systems from the present 14-day Apollo capability to the 28- and 56-day duration of the Apollo Applications missions.

For payloads and experiments, our fiscal year 1970 requirement is for $141.4 million. These funds will be used to develop and produce the Workshop, the Airlock Module, the Multiple Docking Adapter, and the Apollo Telescope Mount with its associated scientific experiments. Funding will also provide for the development of other experiments and for the integration of experiments and mission hardware.

Our fiscal year 1970 requirement for the Space Station is $9.0 million (MP69-4048) which will be used for the development of preliminary design specifications and the definition of manufacturing, test, and support requirements.

In fiscal year 1970, for the Operations project under Space Flight Operations, our budget plan is $36.3 million. This funding will support preparatory efforts for the Apollo Applications unique requirements in the areas of launch, flight, and recovery operations at Kennedy Space Center and Manned Spacecraft Center, and for the integrated technical support, review, and analysis of Apollo Applications missions. The basic support for manned space flight launch, flight, and recovery operations is funded under Apollo.

The revised request will also provide $46 million for follow-on Saturn V production. The Saturn V is by far the largest launch vehicle ever developed and brought to operational status. No funding was included in the original fiscal year 1970 budget request to provide for production of Saturn V's beyond the fifteen vehicles procured for Apollo. The Saturn V production base is rapidly dissipating. The request will arrest the current downward trend and will be applied to the procurement of long leadtime items; to the reactivation of critical vendor and supplier sources whose deliveries have already been completed; to the stabilization of those subcontractors, suppliers, and vendors still working on Saturn V hardware; and to begin certain long-lead fabrication at major contractor plants.

Advanced Missions

In fiscal year 1970, we are requesting $2.5 million for our Advanced Missions Program. This is the same amount as our budget plan for fiscal year 1969. The funds will be used to examine methods and systems for astronaut escape and rescue on lunar and earth orbit missions; for advanced lunar studies in the areas of shelter and logistic transport systems and for advanced space station studies.

Construction of Facilities

Our Construction of Facilities fiscal year 1970 budget request for Manned Space Flight is for $14,250,000 (MP69-4381). The projects included in this request are: $8.0 million for modifications to Launch Complexes 34 and 37 at Cape Kennedy to adapt these facilities for the Apollo Applications missions; $1.0 million for modifications to the spacecraft checkout facilities at Kennedy Space Center so they can support the spacecraft payload and experiment hardware for Apollo Applications missions; $3.3 million for improvements to the electrical power generation systems at Kennedy Space Center to provide dependable emergency power and to assure continuity of power during critical operations; $200 thousand for a high pressure gas maintenance operations facility at Kennedy Space Center to provide adequate workspace for this operation; and $1,750,000 for a power generation facility for the Mission Control Center at the Manned Spacecraft Center. This facility will assure continuous operation during the long-duration Apollo Applications missions of the critical command and control systems during the next decade.

Research and Program Management

Our fiscal year 1970 request for Research and Program Management (MP69-4045) is $307,450,000. This is nearly $5 million beneath our requirements for fiscal year 1969.

In previous years, this budget category was titled Administrative Operations, but the title has been changed to more accurately reflect the type of effort and tasks being funded under this line item. No change in the content has been made.

Nearly two-thirds of the funding for Research and Program Management is required to pay the salaries and benefits of our civil service personnel (MP69-4050 - MP69-4049). The number of our civil service personnel at our Centers continue to decrease. In fiscal year 1968, we had nearly 14,000 at our Centers; in fiscal year 1969, we dropped to 13,285; and we are planning an additional 250 decrease in fiscal year 1970.

The remainder of our Research and Program Management funding is for travel; general purpose automatic data processing operations; facility operations such as maintenance and repair of our capital investment; technical services including libraries and engineering services; and for administrative supplies and equipment, communi-cations, printing, medical services, and our motor pool.