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1968 NASA AUTHORIZATION

HEARINGS

BEFORE THE

SUBCOMMITTEE ON MANNED SPACE FLIGHT

OF THE

COMMITTEE ON SCIENCE AND ASTRONAUTICS

U.S. HOUSE OF REPRESENTATIVES

NINETIETH CONGRESS

FIRST SESSION

ON

H.R. 4450, H.R. 6470

(Superseded by H.R. 10340)

MARCH 14, 15, 16, 20, AND 21, 1967

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1968 NASA AUTHORIZATION

TUESDAY, MARCH 14, 1967

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON MANNED SPACE FLIGHT,
Washington, D.C.

The subcommittee met, pursuant to call, in room 2318, Rayburn House Office Building, at 10 a.m., the Honorable Olin E. Teague (chairman of the subcommittee) presiding.

Mr. TEAGUE. The committee will come to order.

Dr. Mueller, it is a pleasure to welcome you and members of your staff to our first subcommittee meeting on NASA's fiscal year 1967 authorization. The successful completion of the Gemini program and the major success that NASA has achieved in the Apollo program speaks well for the dedication and capability of NASA's managers, engineers, and scientists who are contributing not only to a successful lunar landing, but also to the technological vitality of the country.

The recent tragic accident at Cape Kennedy serves to highlight for all of us not only the dangers but the complexity of the tasks which you and all personnel both in NASA and in industry have undertaken. We look forward to a thorough and candid report on the causes and the remedial actions necessary to maintain national confidence in our manned space effort.

Based on a recent survey by the NASA Oversight Subcommittee, we have reason to have confidence in NASA's ability to meet the problems identified in this recent accident as well as to surmount the continuing engineering problems that a program such as Apollo is bound to have.

The identification of an Apollo Applications program during these hearings is most important. As I have said before, NASA's plans for manned space effort after the initial lunar landing need to provide a maximum return on our current investment in the national space program.

I urge you to take full advantage of these hearings to present to the subcommittee, the Congress, and to the people a clear statement of plan and purpose in manned flight.

I assume you are going to summarize your statement?

Dr. MUELLER. I will summarize the statement, although, with the chairman's permission, I will read some of it.

Mr. TEAGUE. The members may break in and ask questions as we go along.

STATEMENT OF DR. GEORGE E. MUELLER, ASSOCIATE ADMINISTRATOR FOR MANNED SPACE FLIGHT, NASA

Dr. MUELLER. I would like to begin with a review of the Gemini program, Mr. Chairman, and its accomplishments during the past year.

GEMINI PROGRAM

Gemini, of course, is the Nation's second major manned space flight program, completed its flight phase on November 15, 1966, with the recovery of the Gemini XII spacecraft. Since that date, personnel, equipment, and facilities from the Gemini program have been integrated into other manned space flight programs such as the Apollo, Apollo Applications, Advanced Manned Missions, and the Department of Defense's Manned Orbiting Laboratory. By the end of fiscal year 1967 all Gemini contracts will have been terminated, but the technical and information utilization phase of the program will continue in follow-on programs. During this presentation, I will discuss the transition from Gemini in more detail, attempting to show the contribution of Gemini to overall manned space flight.

The past year was a year in which the operational capabilities of manned space flight were further demonstrated and the operational techniques expanded with the Gemini program looking toward the Apollo and Apollo Applications activity of the future. In the five manned Gemini flights accomplished in 1966, rendezvous missions directly contributing to the Apollo rendezvous requirements for lunar flight were explored and the technologies demonstrated. In this presentation, I would like to show how the Gemini flights contributed to meeting the Gemini objectives and then how meeting these objectives contributes to the Apollo, Apollo Applications and the potential future space flight mission. I will begin by updating the information presented to this subcommittee last year, covering the accomplishments of the Gemini program during 1966.

GEMINI VIII

Last year I reported on the Gemini missions through Gemini VII. Gemini VIII, the sixth manned flight and the first mission to have a successful Agena target vehicle flight, was launched in March 1966. This mission accomplished rendezvous and achieved the first docking (fig. 1, MG67-5812) of two vehicles in space, before early termination of the mission because of a spacecraft control system malfunction. The crew landed successfully in a secondary recovery area in the western Pacific. Recovery was carried out quickly by a secondary recovery force using planned emergency procedures.

A significant payoff of the Gemini VIII flight was the demonstration of techniques required for the rendezvous and docking of the Apollo spacecraft command and lunar modules in lunar orbit during the lunar landing mission. The accomplishment of rendezvous and docking also paves the way for future assembly of the orbital workshop planned in the Apollo Applications program as well as space stations of the future.

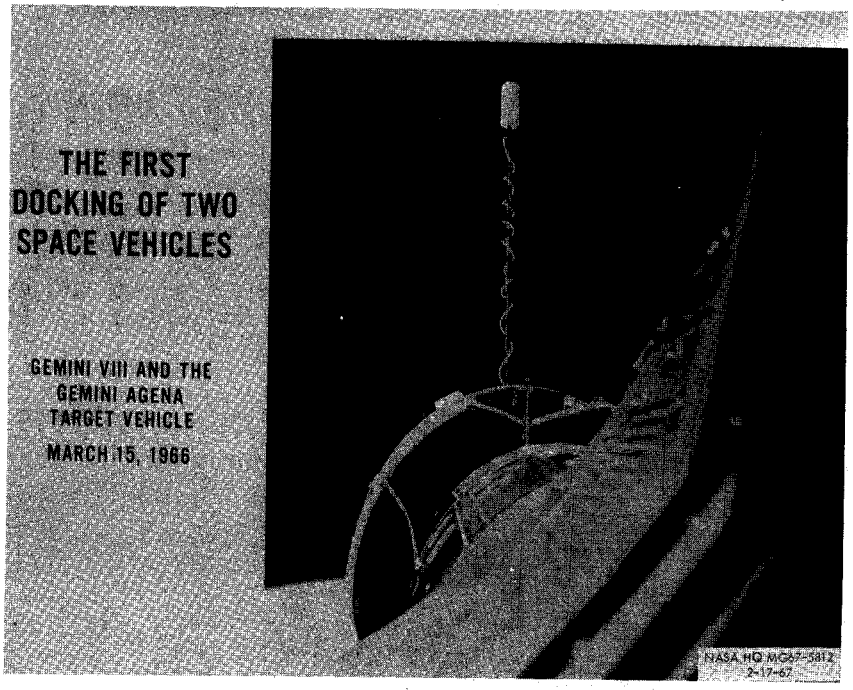

FIGURE 1

Open-ended mission concept

You will recall that the Gemini VIII flight was terminated early as a result of a short circuit in the wiring to a spacecraft thruster. Nevertheless, the primary mission objectives had been met and a philosophy which I described to the full committee on March 7 as the open ended mission concept continued to evolve with that mission. This concept will be implemented upon Apollo and Apollo Applications flights.

All future Apollo/Saturn missions will be open ended; that is, the duration of each mission and the operational sequences attempted will not be rigidly limited by the flight plan. This concept of open ended flight tests essentially says that we will continue a flight toward the ultimate mission goals so long as either there is no problem with the crew or the basic hardware or so long as we have sufficient expendable supplies for continued operations.

At various points during the mission the decision can be made to proceed to the next decision point or to terminate the mission, depending upon its current status. In this way, the accomplishments of each mission will not be limited to predetermined levels, and we will be able to take full advantage of success as it occurs. At the same time, we will have the option of terminating the mission at any intermediate decision point because of problems or operating limitations encountered.

GEMINI IX

Use of augmented target docking adapter

The Gemini IX flight which was attempted on May 17, 1966, almost 2 months to the day after the Gemini VIII flight, was scrubbed due to the failure of the Atlas to propel the target vehicle into orbit. To obtain a suitable rendezvous target vehicle for Gemini IX, the Augmented Target Docking Adapter (ATDA) was then prepared for launch. This contingency vehicle development had been initiated following the failure of the Gemini VI target vehicle in October 1965. The ATDA illustrated here was in essence a target vehicle without propulsion but with an attitude control system and with a docking adapter (fig. 2, MG66–8988).

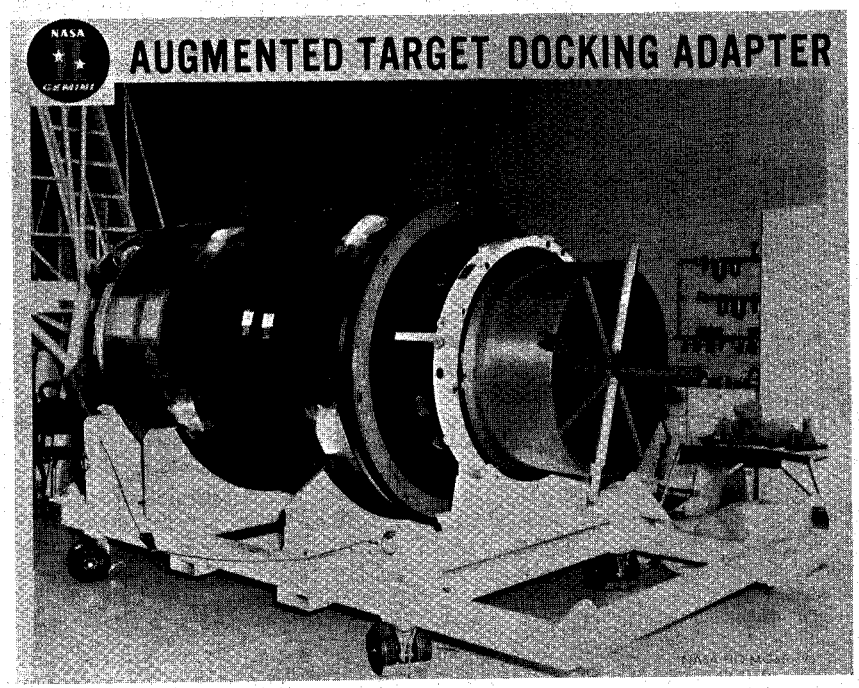

FIGURE 2

The early delivery of target launch vehicles permitted the Gemini IX mission, now designated Gemini IX–A, to be rescheduled and launched on June 3, 1966. The ATDA heat shield failed to separate and docking was precluded after rendezvous. The configuration of the unseparated heat shield became known as the "angry alligator" shown in this view (fig. 3, MG67–5813).

Shift to alternate mission

With the primary mission of Gemini IX–A precluded, a decision was made to shift to the preplanned alternate mission. This alternate mission provided significant scientific and technological information.

Three different rendezvous were completed. The initial rendezvous

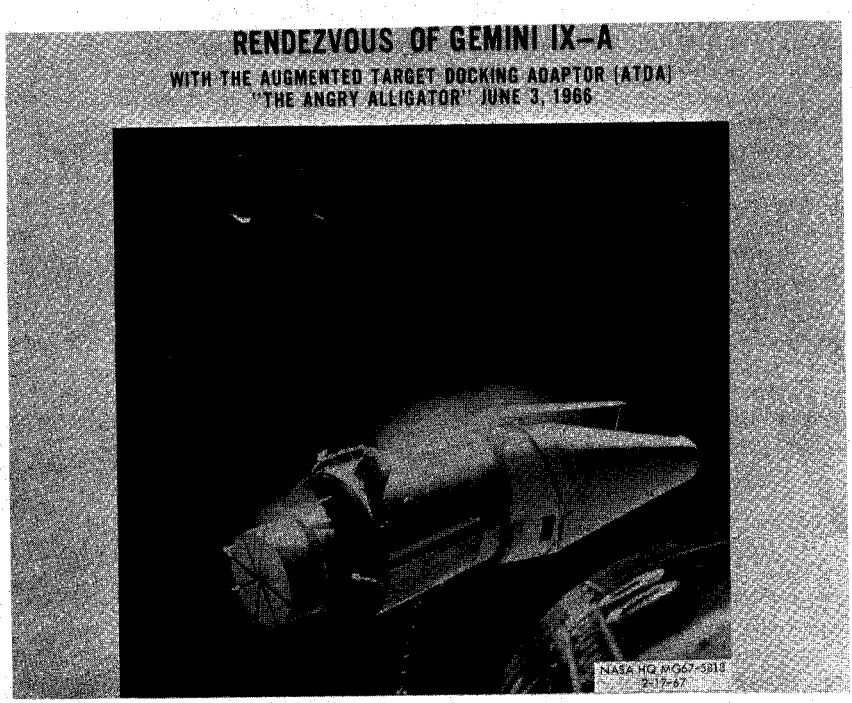

FIGURE 3

simulated the planned Apollo lunar module rendezvous with the command and service module. Two additional rendezvous maneuvers were later executed, the last being an extremely difficult lunar module abort simulation.

Numerous experiments were performed and a long period of extravehicular activity (EVA) was conducted. The excessive work levels experienced during EVA on this mission required termination of this activity earler than intended. From this experience, we recognize the requirement for additional study of EVA training, procedures, workloads, and restraints.

The shift to the alternate mission for Gemini IX, as well as the early termination of Gemini VIII, had further significance. These experiences led to further development of the open ended mission concept previously described.

GEMINI X

Gemini X was launched on July 18, 1966 and rendezvoused and docked as planned with the Agena X target vehicle during the fourth spacecraft revolution, using the ascent rendezvous mode. Later, the Agena X primary and secondary propulsion systems were used in docked vehicle maneuvers to raise the combined vehicle to an altitude record of 414 nautical miles, and to position Gemini X for rendezvous with the Agena VIII target vehicle still orbiting from the Gemini VIII mission. After separation from Agena X, the Gemini X space-

craft then rendezvoused with Agena VIII, completing the first double rendezvous maneuvers in space.

These rendezvousing, docking, and maneuvering exercises laid the foundation for the design of future applications missions. The maneuvering of one vehicle, using the propulsion of a second to rendezvous with a third craft previously parked in orbit, combines the precise elements involved in the first Apollo Applications program alternate mission.

During the EVA on the Gemini X mission, the astronaut micrometeorite experiment was retrieved by the astronaut from the Agena VIII target vehicle where it had been collecting data over a 2-month period. Thus the astronaut demonstrated capability to perform useful work outside the spacecraft. A previous standup EVA had been cut short due to eye irritation and the umbilical EVA involving retrieval of the experiment from the Agena VIII was shortened because of low maneuvering fuel supply.

GEMINI XI

Gemini XI was launched on September 12, 1966, and completed a rendezvous with the target vehicle during its first revolution, using on-board computer information exclusively. This rendezvous was most efficient as far as time is concerned and will find future application such as in the resupply of spacecraft where time may be a factor in rendezvous. Later in the mission a second rendezvous called a coincident orbit rendezvous was performed. This type of rendezvous is most efficient in conserving fuel, but requires significant tracking time. It will find later application on missions where fuel efficiency is required.

During a period of unbilical EVA performed while the spacecraft and target vehicle were docked, several experiments were accomplished and the astronaut succeeded in attaching a 100-foot tether connecting the two vehicles.

With the docking maneuver the Gemini spacecraft and propulsion stage were assembled into a new spacecraft combination and launched out of the Agena orbit into a new, high orbit of 741 nautical miles altitude. These assembly techniques will be essential in Apollo and Apollo Applications when the Apollo spacecraft is docked with the lunar module and the orbital workshop, Apollo telescope mount, and lunar mapping and survey system are assembled for the Apollo Applications mission.

Following the orbital maneuver, Gemini XI carried out a number of photographic experiments during more than 3 hours of high altitude, high velocity orbiting. Photographic observations of our Earth's surface and its characteristics during Gemini XI and other Gemini missions are important because of the applicability of these experiments to man's benefit on Earth.

During a later period of EVA standup after return to low earth orbit, a number of astronomical observations, as well as scientific experiments, were successfully completed. Similar experiments will be continued in the Apollo program and to a greater degree in Apollo Applications missions.

Use of tether for station keeping

Of considerable importance to the future was the tether exercise conducted on this mission. The experiment involved undocking the two vehicles, extending the connected tether to its full 100-foot length, and rotating the systems of two vehicles using the spacecraft thrusters. This method of multivehicle station keeping, which requires a minimum use of fuel, will be invaluable for application in future programs, since centrifugal force produced by this technique provides a radial-acceleration which may find application as a means of providing a special artificial gravity.

GEMINI XII

The Gemini XII mission commenced on November 11, 1966, and a rendezvous and docking with an Agena target vehicle was accomplished during the third spacecraft revolution.

A planned high altitude excursion using the Agena propulsion systems was deleted because of a suspected anomaly in the Agena. In lieu of this, a rendezvous with a solar eclipse on November 12, 1966, was executed by the combined Gemini Agena vehicle and eclipse photographs free from the effects of our atmosphere were obtained.

Successful extravehicular activity

For the Gemini XII mission great care was taken with EVA preparations because of the difficulties which had been experienced earlier. EVA tasks were carefully redesigned and training was intensified. The EVA was designed to provide more fundamental baseline information on man's ability to function in the space environment to insure that this constraint does not exist in Apollo and Apollo Applications.

Three separate periods of EVA were conducted on Gemini XII and all were completely successful. A special EVA report now in preparation will provide future planners and astronauts with a complete synopsis and analysis of all of the Gemini EVA experience as a base for further use of man as a worker in space.

Before continuing this discussion of the Gemini program with a review of the six Gemini objectives, I would like first to show a film which summarizes the Gemini achievements. The script for the film is attached as appendix B to this statement.

GEMINI OBJECTIVES

I would now like to turn to the six Gemini objectives; first showing how these objectives were met and then how in meeting the objectives Gemini has laid the foundation for future space activity.

INVESTIGATE LONG DURATION FLIGHT

The Gemini objectives are shown on this chart (fig. 4, M65–5187). At the close of 1965, long duration flights of up to 14 days were completed. The analysis of these flight data has opened the way for the 28- and 56-day missions planned in the Apollo Applications program and other follow-on programs for the immediate future. The total Mercury and Gemini space flights experience provide approximately 2,000 man-hours weightless exposure for evaluating predicted effects of space flight versus actual findings.

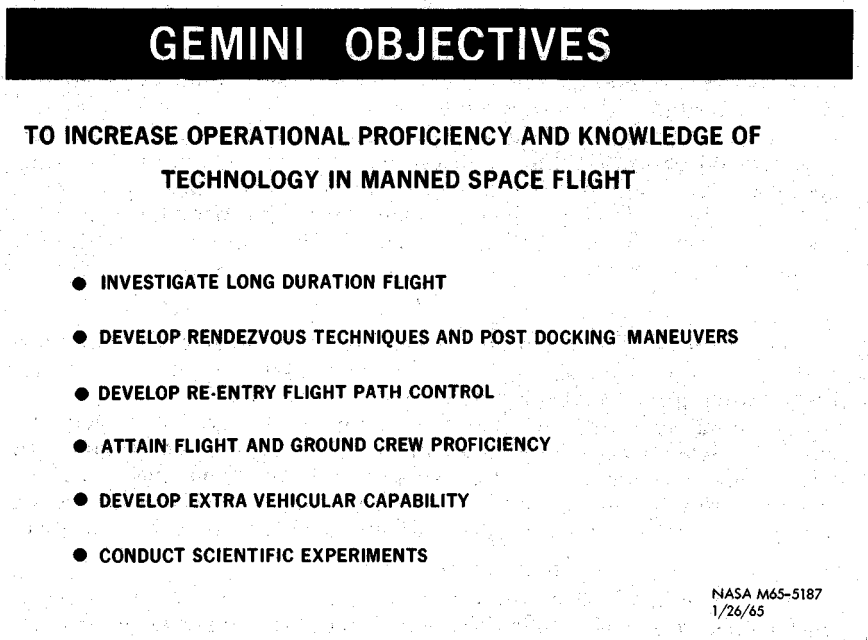

FIGURE 4

In general, the environmental hazards and effects on man appear to be of less magnitude than originally anticipated. The principal physiological changes noted were orthostatism for some 50 hours postflight as measured with a tilt table; reduced red-cell mass of 5 to 20 percent; and reduced X-ray density (calcium) in the oscalcis and the small finger.

No abnormal psychological reactions have been observed, and no vestibular disturbances have occurred that were related to flight. Although much remains to be learned, it appears that if man is properly supported his limitations will not be a barrier to the exploration of the universe.

Medical experiments program

Specifically, the four major objectives of the medical experiments program, which was a major activity in the investigation of long duration flights, were to determine effects, mechanisms, predictive means, and most effective preventive or correct measures.

All of the Gemini experiments were directed toward the first objective, the determination of the effects of space flight on man and the time courses of these effects. Experiments such as the phonoelectrocardiogram, bioassay of body fluids, mineral balance, human otolith function, and the red cell mass and blood volume studies are all contributing data on mechanisms by which these effects are manifested. The in-flight exerciser may prove to be of value as an in-flight predictive index of circulatory changes as they might unfavorably affect postflight activities. Cardiovascular reflex is the evaluation of a technique to prevent circulatory de-adaptation during space flight.

The medical experiments program as designed enables us to effectively plan to carry out long duration manned missions of the future. Our data appear to confirm from a medical viewpoint the feasibility of the Apollo lunar landing mission and they support the practicality of currently planning a 28- to 30-day mission.

For example, the phonoelectrocardiographic experiment brought forth no evidence of change relatable to the space environment. This is in contrast to Soviet interpretations of their seismocardiographic data. The validity of these negative findings is given some support by the absence of evidence of myocardial disturbance by any other method of measurement utilized.

The bioassay of body fluids has provided a beginning insight into the mechanisms of several physiological responses of man to space flight. The continuation of this effort in future missions will be followed with very close interest by those who have a responsibility for flight crew support in manned space flight.

The bone densitometry experiment has demonstrated what has long been anticipated that there is ineed a reduction of bone density during space flight. Although these changes have not been severe, this experiment has further shown that bone density reduction in the nonweight bearing bones of the upper extremities was clearly more pronounced than that seen in the same areas during equivalent periods of bed rest on earth. Paradoxically, bone density was seemingly less affected by the 14-day flight than by either the 4- or 8-day flights. The reasons for this are not clear but here again, individual variation must be separated from the favorable influences of diminished thermal stress, increased food and water intake, and increased exercise program which characterized environment and events of the 14-day flight.

The mineral balance experiment has shown a moderately elevated calcium output and a greater than anticipated output of nitrogen and phosphorus. The need for a simple and accurate urinary sampling system is apparent as the value of this investigative effort to prognostications of flight crew support for protractive manned flights of the future. The electroencephalographic analysis of sleep has accurately portrayed the sleep patterns which did occur during flight.

Human otolith function experiment elicited little or no evidence to suggest a change in otolith function during flights of up to 14 days in the Gemini configuration. The Soviets indicated that their astronauts had experienced space flight nausea and postflight difficulties. The absence of this adverse experience in our own flights tends to verify our crew selection criteria and training procedures as compared with those employed by the Soviets.

While our total data points are still too few to establish the absolute absence of otolith effect, we can now assume with reasonable confidence that there probably will be no untoward otolith effect of practical significance within 14 days. The pursuit of this investigation in Apollo flight crews who, like the Soviet cosmonauts will not be restrained within the spacecraft, will add further clarifying data. Repetition during longer flights of the future will be necessary to extend the time line since the possibility of the later occurrence of

otolith changes cannot be ruled out. The investigation of semicircular canal effects is planned for the Apollo Applications program.

Although the medical program is very young, it has also yielded data which promise to contribute to our knowledge of basic physiology, particularly in the areas of red cell enzymology, and dehydration and fluid balance. In summary, we have investigated long duration flights up to 14 days and have obtained data which provide a basis for expecting man to be able to function in space for a period of up to 28 days. The investigations begun in the Mercury program and carried a step further in the Gemini program will be further expanded during Apollo and carried forward a major step in Apollo Applications, eventually leading to data in support of longer duration manned flights, flights of up to 1 year or more in the future.

DEVELOP RENDEZVOUS TECHNIQUES; POSTDOCKING MANEUVERS; REENTRY FLIGHT PATH CONTROL

The second Gemini objective, to develop rendezvous techniques and postdocking maneuvers, has been demonstrated on several Gemini flights, as has the objective to develop reentry flight path control. I have discussed these elements briefly in my introductory remarks and they have been further depicted in a Gemini film shown here today. You will recall that last year before this committee we presented a film showing the various modes of rendezvous that would be attempted on the Gemini program. All of these rendezvous modes have been successfully demonstrated, providing basic information for meeting the rendezvous requirements of the Apollo and Apollo Applications programs and advanced missions under study.

FLIGHT AND GROUND CREW PROFICIENCY

The fourth Gemini objective, to attain flight ground crew proficiency, has been demonstrated throughout the 12-Gemini flight program. As the Gemini flight program progressed, more mission elements were included in each successive flight. This intensification of the activity during a mission impacted on all facets of the space flight organization—from prelaunch preparation to crew training, equipment readiness, checkout, flight planning, mission scheduling and crew workload; from mission control to postflight data recovery, crew debriefing, mission analysis, and documentation.

The latter Gemini missions were both training and testing to determine how far the manner flight organization had come toward developing the operational proficiency so essential to future programs.

During the last flights a number of serious anomalies were encountered. The operational capability, however, had matured to a level required for the Gemini program and developed to the point that it was possible to cope with these anomalies, work around them, and still achieve our mission objectives.

The experience and data gained from the Gemini program will be invaluable during the review of our planning for the more complex Apollo and Apollo Applications missions.

DEVELOP EXTRAVEHICULAR CAPABILITY

The fifth Gemini objective, to develop extravehicular capability, has been previously covered and was illustrated in the Gemini film. We have developed techniques in over 12 hours of EVA which will be valuable in Apollo. These techniques provide a solid baseline from which we can develop the more sophisticated EVA requirements required in Apollo Applications. I would therefore like to move on to the last Gemini objective, the conduct of scientific experiments, and spend a few moments discussing the results obtained and their contribution to science and the follow-on manned space flight effort.

GEMINI EXPERIMENTS

The Gemini experiments introduced many scientific and technical organizations into the Nation's space program. Some of the Nation's leading scientists were the principal investigators on the manned experiment platform provided by Gemini. In accomplishing this manned space flight objective on Gemini, the experiment program provided additional information on man's ability to perform useful functions in the space environment, and provided data which will materially aid the design of many Apollo and Apollo Applications experiments as those programs progress.

Fifty-two different experiments were conducted in the Gemini program, as summarized in this chart (fig. 5, MC67–5877). Generally

EXPERIMENT PROGRAM SUMMARY

SPONSORING AGENCY	NO. OF EXPERIMENTS	TOTAL EXP MISSIONS
• SCIENTIFIC		
• OSSA(S)	17	47
• TECHNOLOGICAL		
• OART (T)	2	2
• OMSF (MSC)	10	18
• DOD (D)	15	26
• MEDICAL		
• MEDICAL (M)	8	18
TOTALS	52	111

NASA HQ MC 67-5877
2/23/67

FIGURE 5

each experiment was flown several times to take advantage of varying flight conditions.

This resulted in 11 experiment missions with an average of 11 experiments per mission. The largest number of experiments, 20, was carried on the 14-day Gemini VII mission.

SCIENTIFIC, TECHNOLOGICAL, AND MEDICAL EXPERIMENTS

The experiments were divided into three categories, scientific, technological, and medical. There were 17 scientific experiments conducted during the program. The scientific experiment program was interdisciplinary in character and comprised investigations in the fields of astronomy, biology, geology, meteorology, and physics. Over half of the experiments were photographic in technique, indicating that the investigators wished to take advantage of the flight crew availability to guide and select the targets and to return the film for a permanent record. A photograph frequently clarifies data which otherwise are ambiguous.

The 27 technological experiments were conducted in support of spacecraft development and operational techniques. The eight medical experiments, each conducted a number of times, were directed toward determining more subtle effects than might be determined from the regular operational medical measurements in preflight and postflight examinations.

EXPERIMENT INVESTIGATORS

The Gemini experiments were proposed from many sources including universities, laboratories, hospitals, industry, and various Government agencies. Several investigators were often associated with a single experiment and they in turn may have had different affiliations. This table presents the principal investigators of the Gemini experiments and their affiliations together with the missions for which the experiments were assigned (figs. 6, 7, 8, and 9, MC67–5880–81–82–83). Subsequent to the selections of the experiments and the principal investigators, a very close personal association was maintained with the experimenter, the spacecraft contractor, the crew, mission planner, and the real time operations personnel. This experience will provide a basis for relationships in the future with the Apollo and Apollo Applications programs where experiment capacity is significantly increased over that of the Gemini program.

CREW TRAINING

The diversity of the Gemini experiments required considerable training by the crew. The training began with briefings by the experimenter to explain the experiment, the proposed method of operation, the probable training required, and the expected results. After the techniques were evolved for the various experiments, plans for crew training were developed. Planetarium briefings were included as well as flight simulator training with celestial backgrounds. Also included were aircraft flights to provide operational familiarity with hardware; zero gravity aircraft flights for experiments requiring ex-

PRINCIPAL INVESTIGATORS AND AFFILIATIONS

PART I

NAME	EXPERIMENTER	AFFIL	MISSIONS
ZODIACAL PHOTOGRAPHY	NEY	U OF M	V, VIII, IX, X
SEA URCHIN EGG GROWTH	YOUNG	AMES	III
FROG EGG GROWTH	YOUNG	AMES	VIII, XII
RADIATION ON BLOOD	BENDER	AEC	III, XI
TERRAIN PHOTOGRAPHY	LOWMAN	GSFC	IV, V, VI, VII, X, XI, XII
WEATHER PHOTOGRAPHY	NAGLER, SOULES	USWB	IV, V, VI, VII, X, XI, XII
CLOUD TOP SPECTROMETER	SAIEDY	ESSA	V, VIII
VISUAL ACUITY	DUNTLEY	U OF C	V, VII
NUCLEAR EMULSION	SHAPIRO FICHTEL	NRL GSFC	VIII, XI
AGENA MICRO COLLECT	HEMENWAY	DUDLEY	VIII, IX, X, XII
AIRGLOW PHOTOGRAPHY	KOOMEN	NRL	IX, XI, XII
MICROMETEORITE COLLECT	HEMENWAY	DUDLEY	IX, X, XII
UV ASTRONOMICAL CAMERA	HENIZE	NWU	X, XI, XII
ION WAKE MEASUREMENT	MEDVED	EOS	X, XI
LIBRATION PHOTOGRAPHY	MORRIS	USGS	XII
DIM SKY ORTHICON	HEMENWAY	DUDLEY	XI
DAYTIME SODIUM CLOUD	BLAMONT	CNRS	XII

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FIGURE 6

PRINCIPAL INVESTIGATORS AND AFFILIATIONS

PART II

NAME	EXPERIMENTER	AFFIL	MISSIONS
REENTRY COMMUNICATIONS	SCHROEDER	LRC	III
MANUAL SPACE NAVIGATION	SMITH CREER	AMES	XII
ELECTROSTATIC CHARGE	LAFFERTY	MSC	IV, V
PROTON-ELECTRON SPECTROMETER	MARBACH	MSC	IV, VII
FLUX-GATE MAGNETOMETER	WOMACK	MSC	IV, VII, X, XII
OPTICAL COMMUNICATION	LILLY	MSC	VII
LUNAR SPECTRAL REFLECTANCE	STOKES	MSC	X
BETA SPECTROMETER	MARBACH	MSC	X, XII
BREMSSTRAHLUNG SPECTROMETER	LINDSEY	MSC	X, XII
COLOR PATCH PHOTOGRAPHY	BRINKMAN	MSC	X
EARTHS LIMB PHOTOGRAPHY	PETERSEN	MIT	IV
LANDMARK MEASUREMENTS	MANRY	MSC	VII, X

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FIGURE 7

PRINCIPAL INVESTIGATORS AND AFFILIATIONS

PART III

NAME	EXPERIMENTER	AFFIL	MISSIONS
BASIC OBJECT PHOTO	KOZUMA	SSD	V
NEARBY OBJECT PHOTO	KOZUMA	SSD	V
MASS DETERMINATION	HAMBORSKI	SSD	VIII, XI
SPACE OBJ RADIOMETRY	BRENTNALL	SSD	V, VII
STAR OCCULTATION NAVIG	JORRIS	AFAL	VII, X
SURFACE PHOTOGRAPHY	KOZUMA	SSD	V
CELESTIAL RADIOMETRY	LOVETT	AFCRL	V, VII
RADIATION IN SC	JANNI	AFWL	IV, VI
SIMPLE NAVIGATION	SILVA	AFAL	IV, VII
ION ATTITUDE CONTROL	SAGALYN	AFCRL	X, XII
MANEUVERING UNIT	GIVENS	SSD	IX
ASTRONAUT VISIBILITY	DUNTLEY	UOFC	V, VII
UHF-VHF POLARIZATION	ELLIS	NRL	VIII, IX
IMAGE INTENSIFICATION	SHOPPLE	NADC	VIII, XI
POWER TOOL	MAY	AFAPL	VIII, XI

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FIGURE 8

PRINCIPAL INVESTIGATORS AND AFFILIATIONS

PART IV

NAME	EXPERIMENTER	AFFIL	MISSIONS
CARDIOVASCULAR CONDITIONING	DIETLEIN	MSC	V, VII
EXERCISER	RAPP	MSC	IV, V, VII
PHONOCARDIOGRAM	JOHNSON	MSC	IV, V, VII
BIOASSAYS BODY FLUIDS	LIPSCOMB	MSC	VII, VIII, IX
BONE DEMINERALIZATION	MACK	TWU	IV, V, VII
CALCIUM BALANCE STUDY	WHEDON	NIH	VII
INFLIGHT SLEEP ANALYSIS	KELLOWAY	BAYLOR	VII
HUMAN OTOLITH FUNCTION	GRAYBIEL	USNSAM	V, VII

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FIGURE 9

travehicular activity; and baseline studies for medical and visibility experiments.

These activities and others coupled with the continued discussions between crew and experimenters were considered essential to the successful completion of the experiment.

Mr. FULTON. The ion wake measurement, is that just the turbulence of the ions or is that an ion engine starter?

Dr. MUELLER. That is the wake that is associated with the re-entry maneuver and has to do with the ionization of the air. Actually, there are two. One was an attempt to make measurements of the ionization in space and the other was to measure the ionization during re-entry so we actually have two such experiments.

Mr. FULTON. Glenn saw something going along with him. Have they ever identified what that was?

Dr. MUELLER. The presumption is that these were—the so-called snowflakes that he saw, is that what you are referring to, Mr. Fulton?

Mr. FULTON. Yes.

Dr. MUELLER. These were identified as recombination products of the exhaust of the little thrusters.

Mr. FULTON. Hydrogen peroxide?

Dr. MUELLER. I suppose in that case it was.

Mr. FULTON. On the dim sky orthicon, could you describe that?

Dr. MUELLER. Yes, that was a very sensitive orthicon designed to permit you to see very light and very dark objects—not black.

Mr. FULTON. You would see, hear, and taste an orthicon?

Dr. MUELLER. The orthicon is used in your television transmitter system. It will detect light of lower intensity than your eyes can detect. It provides a light amplification.

Mr. FULTON. What happens on your eggs?

Dr. MUELLER. The egg experiment conducted by Dr. Young was a very interesting experiment, I saw it when Dr. Young and I were on board the carrier.

Mr. FULTON. It sounds interesting, that is why I asked.

Dr. MUELLER. It allows frog eggs to develop in a zero gravity environment, and then fixing them to see whether in the course of their development there were any changes in the growth pattern because of the zero gravity environment. From that set of experiments we found there were no changes in the development. Dr. Young had expected to see some bifurcation of the embryo but that did not occur.

Mr. GURNEY. Dr. Mueller, I have two questions: I expect you have requests for many experiments on these Gemini flights. Who determines what experiments are to be performed and can you give us a specific example of how man's useful knowledge has been materially increased by any of these experiments?

Dr. MUELLER. In answer to your first question, there is a selection process involved in each of the classes of experiments. In the case of the science experiments, for example, the original screening is done by subcommittees of the NASA Planning Coordination Steering Committee. They, in turn, then pass the experiments to a second group that look into their feasibility and desirability and there they are

categorized. The lunar exploration working group of that committee recommends experiments to Dr. Newell. Dr. Newell selects the experiments and recommends them to the Manned Space Flight Experiments board where all the experiments from technology, science, applications and medicine are brought together and a priority is established for their flight and these, in turn, are passed on to the program office for implementation on flights, so the final assignment is by the Manned Space Flights Experiments Board which includes Dr. Newell, Dr. Adams, Dr. Fink of the Department of Defense and General Ferguson of the Air Force, and I am the chairman of that board, so that we have a cross-section of the agency in the selection of the experiments and it is a joint operation of the Department of Defense and ourselves.

That same board, incidentally, is also responsible for assigning science, applications and technological experiments to the Manned Orbiting Laboratory. We have a joint agreement in this area.

With respect to direct results from the flight program, those have been, up to this time in a couple of areas; perhaps the most significant from the standpoint of the man on the street have been the pictures taken by the Gemini crews of the Earth and of the air masses that give you an understanding of the meteorology. It has been found out from the experience of the scientists who have been analyzing these pictures that the addition of color to the kinds of pictures that they were able to obtain from the unmanned satellites has been a significant improvement in their ability to carry out and understand the geology and meteorology of the systems.

One thing, for example, they were able to determine that a crater which had been thought to be an impact crater was in fact caused by erosion effects of a volcanic intrusion and I have another example as I go through this.

I was discussing the training for carrying out the experiments.

An understanding by the crew, not only of the mechanical operation of the experiment, but also the objectives and underlying principles, was required to allow the crew to exercise their selective and visual capabilities. The crew served, literally, as laboratory assistants to the scientists stationed on the Earth. Future flight crews with a scientist astronaut member will provide increased support to the experimenter on Earth. In some instances the scientist astronaut will be the investigator and designer of the experiment.

The integration of the experiments into the spacecraft and into the flight operation is a large, often underestimated, task.

EXPERIMENTS INTEGRATION

The experiments generally have a variety of requirements which often conflicted or interacted. Modifications incorporated in the flight operations had to maintain the integrity of the experiments while at the same time they had to represent a compromise when conflicting activity was involved. Since one major objective of Gemini was to provide an orbiting experiment platform, the conduct of experiments had a priority second only to astronaut safety and mission success.

The fundamentals developed in handling numerous experiments on the Gemini program have contributed significantly to the planning on the Apollo program and the Apollo Applications program. In summing up the experiment integration activity and looking forward to the future, it can be concluded that the success of an experiment is highly dependent upon the participation of the experimenter in many phases of the program. These phases include design integration, mission planning, crew training, checkout and real-time support of the operation. Of course, crew understanding is vital to achieving maximum benefit from man in space. This experience has done much to smooth experiment integration in the Apollo, Apollo Applications, and Manned Orbiting Laboratory (MOL) programs.

SYNOPTIC TERRAIN PHOTOGRAPHY

I believe it would be worthwhile spending just a moment looking at some of the experiments conducted on the Gemini program. One experiment called synoptic terrain photography was devoted to a study of the Earth's terrain and was performed successfully on the Gemini IV, V, VI–A, VII, IX–A, X, XI, and XII missions. Approximately 2,400 color pictures were obtained and are usable for geology, geography, oceanography, hydrology, egrology, and agronomy. As an example, a photograph shown here taken on Gemini XII, appears to have considerable potential value in the study of continental drifts

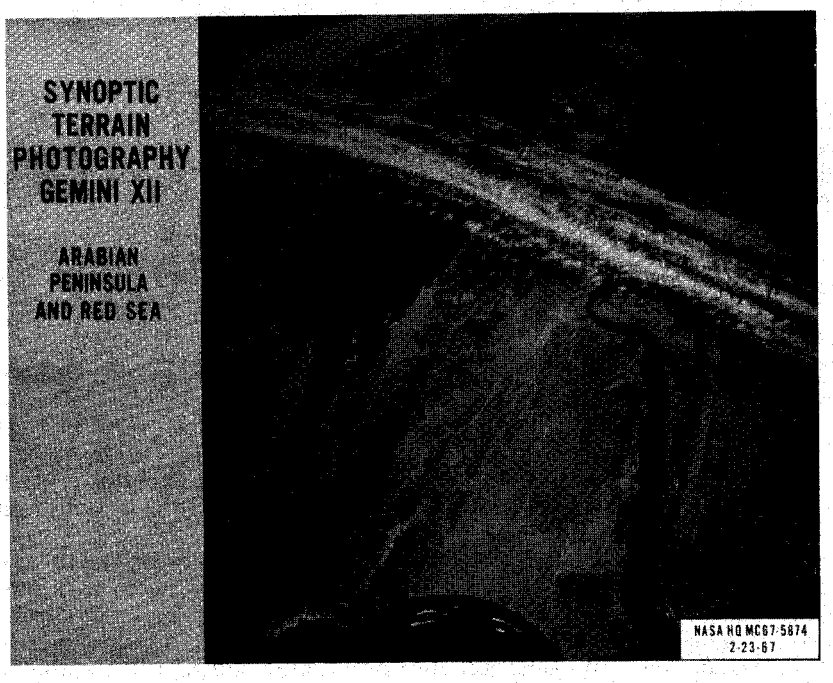

FIGURE 10

(fig. 10, MC67–5874). Proponents of this theory consider that the Red Sea, which structurally is a large down-dropped block, represents incipient continental drift; that is, the Arabian Peninsula is considered to be drifting away and rotating from Africa. The photograph may provide new evidence on this possibility by providing a synoptic view of the regional geology. Further studies of this sort are planned on Apollo and Apollo Applications programs. The next photograph, also taken on Gemini XII, demonstrates the potential value of orbital photography in studies of recent sedimentation (fig. 11, MC67–5876).

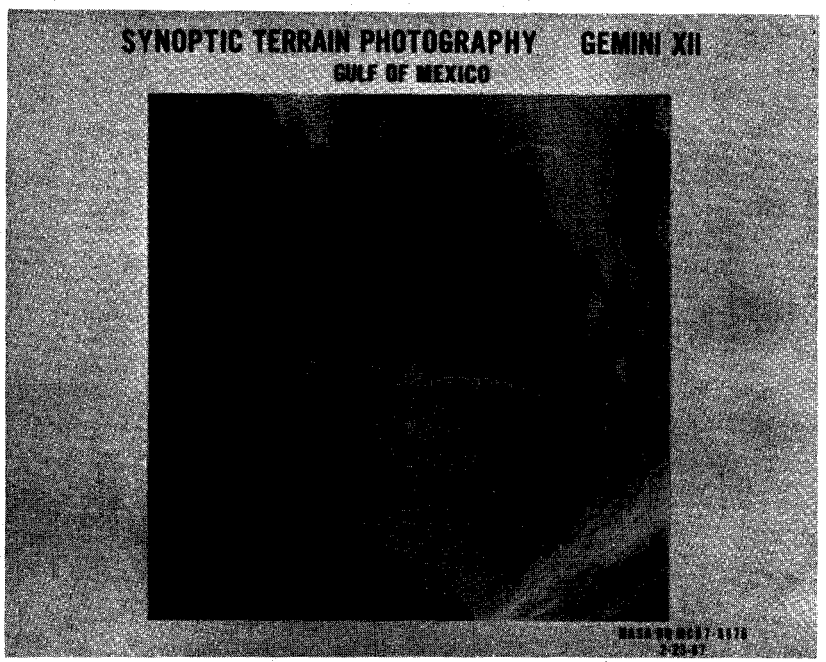

FIGURE 11

The portion of the Gulf of Mexico shown in this photograph has been extensively studied and, when used in conjunction with other Gemini photographs, may provide an extremely useful standard area for interpretation of similar pictures of near shore areas. Also evident in this photograph to the trained eye are indications of shrimp feeding grounds and water pollution. Notice also the flow of air pollution in the atmosphere.

These earlier Gemini studies have provided only a brief look at the planet we live on and have served principally as a stimulus to the scientific and industrial communities to devise new experiments and applications for the forthcoming Apollo and Apollo Applications programs.

To enable the many scientific disciplines and industrial interests to glean information from space photographs of the Earth's terrain and weather, collections of color photographs of the Earth from the

various Gemini missions are being published by the Government Printing Office in a series of atlases. The first, covering Gemini flights III, IV, and V, will be available after March 1967 as document No. NASA SP–129. These atlases are to be printed in full color, giving a true translation of the photographic color negatives which various scientists have found can yield more information than can black and white photographs. Scientists in various disciplines from the United States and foreign countries are already using these photographs in research projects involving the Earth's sciences, such as meteorology and oceanography. The space photographs of the Earth are also being incorporated in textbooks for high schools and colleges and in many cases add a new dimension to study by researchers and students. It is planned that photographs taken during Gemini missions VI–A through VII will be published in subsequent volumes.

EXPERIMENTS PROGRAM SUCCESS

The success of the Gemini experiments program is measured by new or confirmed information provided for engineering management and scientific disciplines, as indicated by the performance summary shown in this table (fig. 12, MC67–5910). The experience gained from the

EXPERIMENT PERFORMANCE STATUS

GEMINI MISSION	LAUNCHED	ACCOMPLISHED	PROBLEMS
III	3	2	EQUIP
IV	11	11	
V	17	16	MISSION
VI-A	3	3	
VII	20	17	EQUIP
VIII	10	1	MISSION
IX-A	7	6	MISSION
X	15	12	MISSION
XI	11	10	MISSION
XII	14	12	EQUIP
TOTALS	111	90	

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2/24/67

FIGURE 12

Gemini experiments program has provided an invaluable baseline of knowledge and experience for future manned space flight programs and has provided insight into the benefits to mankind that may be

realized as we progress further toward applying this new knowledge and technology to the more advanced Apollo and Apollo Applications missions, and to the Air Force Manned Orbiting Laboratory program.

UTILIZATION OF GEMINI RESOURCES

Earlier in this statement I mentioned briefly the utilization of the resources developed under the Gemini program; that is, the personnel, the hardware, and facilities. I would like to spend a few moments now discussing this aspect of the Gemini program in more detail. You recognize that the Gemini resources fall into many categories. There is, of course, the flight hardware and its associated checkout and test equipment. Also I would like now to say a few words about the results of our management of the Gemini program.

May I have the next slide, please?

As we see here (fig. 13, MG66–8791), this is what we call a trend chart as most of you have had an opportunity to see in times past. It represents a continuing record as to when you predict a launch will occur and when it actually occurs. As you can see, beginning in about 1963, we predicted that Gemini I would be launched at the end of that year. In fact, it was launched a few months later in March of 1964.

If you look at Gemini II, which was the equivalent of our Apollo Saturn 201 or 202 flights where we had an unmanned spacecraft for

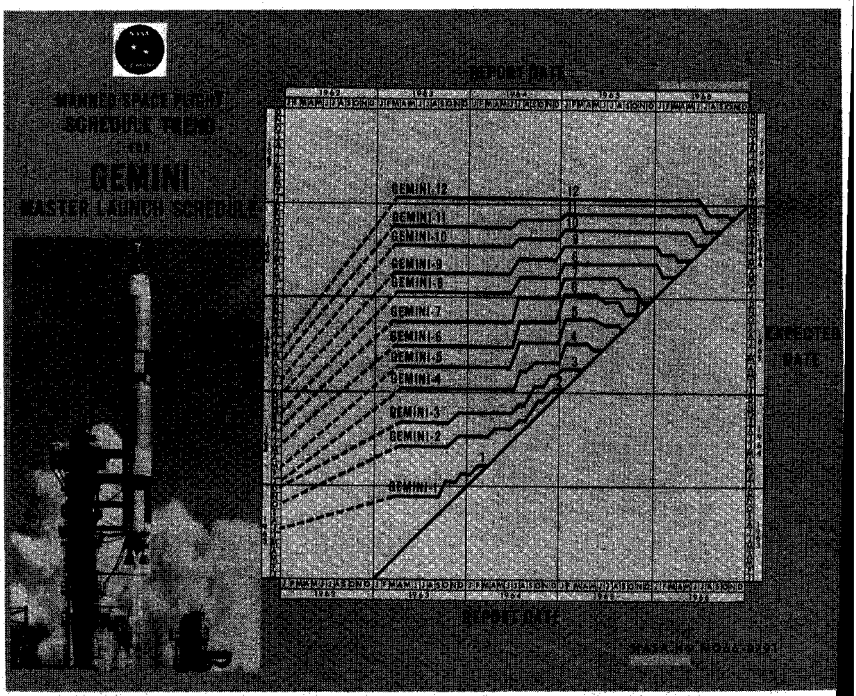

FIGURE 13

a reentry heat shield test, it was in 1963 predicted to be launched sometime in 1964.

In fact, because of the series of events, not the least of which was a set of hurricanes and almost everything that could possibly happen, seemed to have happened to Gemini II, we finally launched it in January of 1965.

Gemini III, our first manned Gemini flight, was launched some 3 months later. As we continued downstream, you will note the phenomena that we are quite proud of in the Gemini program and that is as we gained experience, we were beginning to be able to move the launch dates forward, so that by the time we reached Gemini XII, we actually completed the program some 2 months or more ahead of the schedule that we established in 1963.

I think this represents the ability to capitalize on the maturity of the spacecraft, the ability to use the experience that you gained earlier to improve your schedule posture.

I might also add that during the course of this set of flights, we did introduce rather major modifications from flight to flight based upon the experience that we gained in the preceding flight. So that many changes, for example, a new set of experiments in EVA and a new set of restraints, were implemented on Gemini XI and XII in 3 months. We achieved a level of maturity in the organization, so that we are able to accomplish rather major changes from flight to flight and yet maintain a fairly tight and efficient launch schedule. One of the reasons for desiring to have a relatively short turn around from flight to flight is the maintenance of proficiency of the launch crews themselves and of the flight operation crews.

It is important in being sure that you can carry out these missions so as to have a reasonable frequency of launches so that the crew does not forget from flight to flight how to carry on the next mission.

The next slide (fig. 14, MG 67–5821) is another way of looking at our experience in Gemini. This measures the number of man-hours required to complete the acceptance testing of the Gemini spacecraft. You will note on Gemini II it took some 600,000 man-hours to go through acceptance testing. By Gemini III, we were around 300,000 man-hours and by Gemini IV we were down to 120,000 man-hours. This represents the kind of learning one expects to gain in going through the early phases of checkout and gaining an understanding of the problems involved in the acceptance testing of these involved spacecraft.

We ended up with between 116 and 120,000 hours for each of the succeeding spacecraft.

Next slide (fig. 15, MG 66–9430) : I thought it would be interesting to note the variation in cost and the manpower in the McDonnell contract as an example of the interaction of the management of the program, the maturity of the program, and the phasing of the program with respect to the actual flight schedules. You will note here that a combination of actions were taken in 1964, the fiscal year 1964; one of these was to establish an effective date for an incentive contract in about April of that year.

Another was to introduce our configuration control board, which we introduced about that time throughout our Manned Space Flight

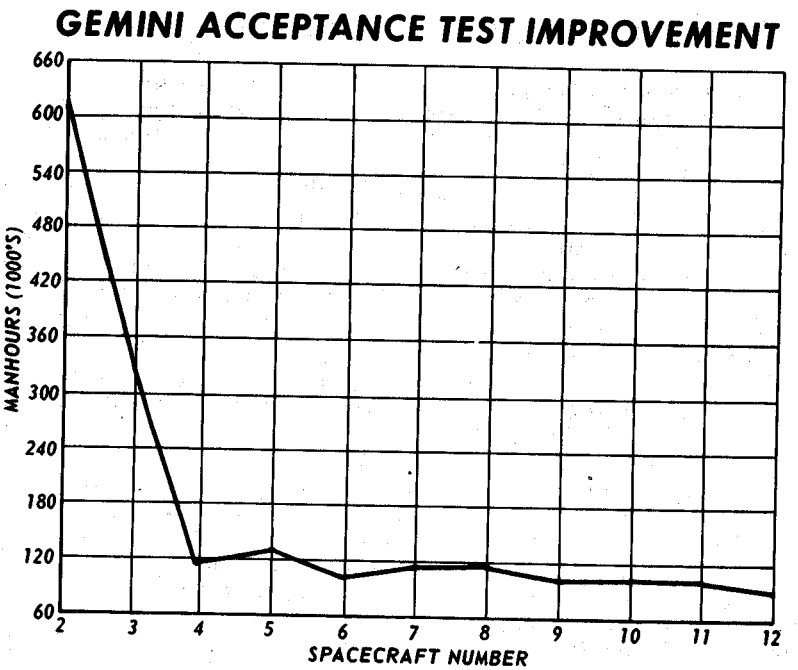

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FIGURE 14

programs. At certain times during the course of the contract, we also had to impose cost ceilings in order to live within our budget. That was a constraint that wasn't necessarily good, but at least it made it possible to stay within the budget.

You will note that after the first flight, the actual manpower curve began to fall off very rapidly, in fact it began to fall off before the first flight and continued to fall off at a pretty rapid rate as our learning curve improved. The same thing is true as to costs because the manpower and cost curves of these contracts follow fairly closely together; although there is not a 1-to-1 relationship, clearly the manpower is going down and the cost should go down as well. The reason I bring this out is that it explains in part the phase we are in in the Apollo program and why we expect the actual cost to go down in future years even though the flight program will be increasing in intensity. It turns out the development phase requires considerably more manpower both because of the rather extensive ground program and because of the design effort which is phasing out which permits us to go down in this fashion.

Next slide (fig. 16, MG 66–8768).

I thought it would be worthwhile to look at the overall cost trend. The final cost is not in on Gemini at this point, but to some extent we were able to finish the program early and while to some extent, we

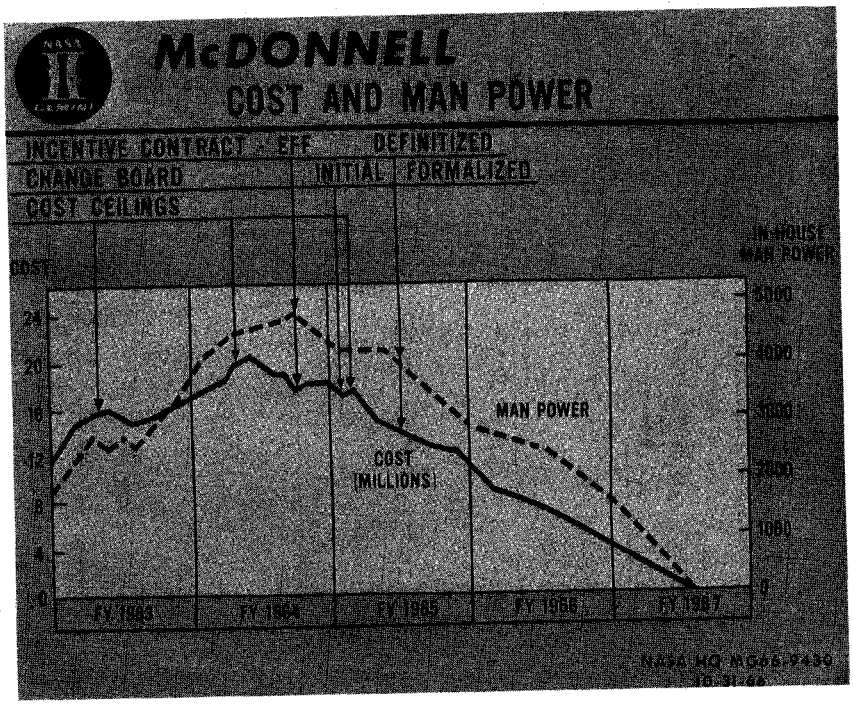

FIGURE 15

were learning how to operate more efficiently, the actual cost projections for completion have gone from $1.350 billion in fiscal 1964 down to $1.290 billion by the end of fiscal 1967.

Now, earlier in this statement I mentioned briefly the utilization of the resources developed under the Gemini program; that is, the personnel, the hardware, and facilities. I would like to spend a few moments now discussing this aspect of the Gemini program in more detail. You recognize that the Gemini resources fall into many categories.

There is, of course, the flight hardware and its associated checkout and test equipment. Also launch, flight, and recovery operations which were provided as a service function to Gemini were a major program resource. Finally, the people who managed and directed the program and who are in fact responsible for its success are the most important resources because their experience cannot be replaced.

FLIGHT HARDWARE

Gemini hardware is finding its way into many programs and activities. One of these is the Air Force Manned Orbiting Laboratory (MOL), because of certain basic similarities is making use of significant amounts of both flight and ground equipment. Two flown Gemini spacecraft have been transferred and a third will be transferred this spring. The Air Force has estimated that the saving to the MOL program realized by reusing Gemini equipment may equal $50 million.

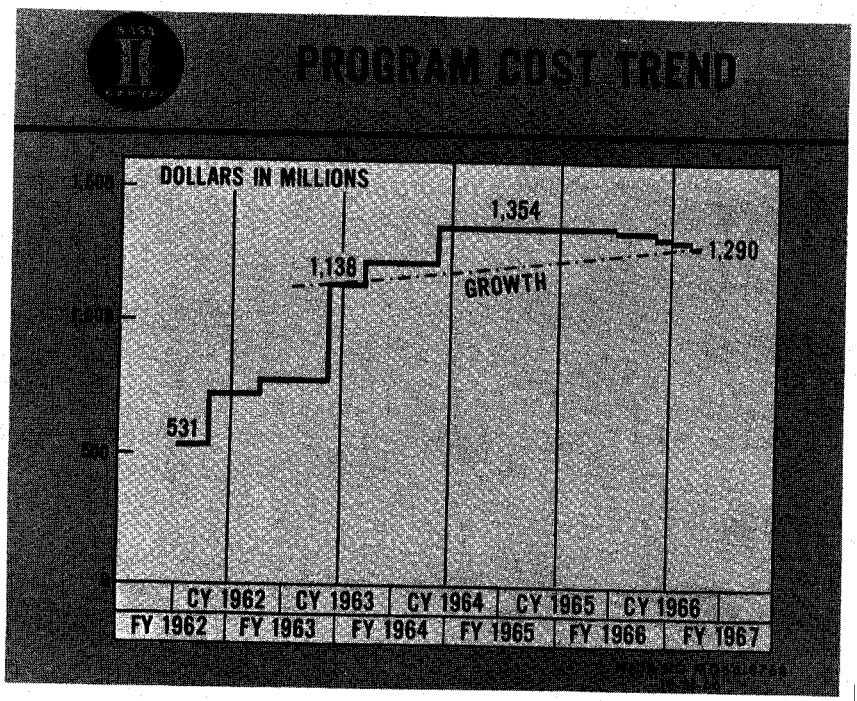

FIGURE 16

An additional saving of approximately $10 million was realized during the development of the heat shield qualification spacecraft. This program involved refurbishing the Gemini II spacecraft and providing it with a new heat shield that incorporated a personnel transfer hatch. The program was managed by the Gemini program office under Air Force direction and was highly successful.

In addition to the MOL program, numerous other uses have been made of Gemini equipment. Gemini fuel cells, for example, have been transferred to the NASA biosatellite program and to the Navy's Marine Engineering Laboratory for experimental use. Flight computers are being put to such diverse use as components of a collision avoidance experiment to be undertaken by the Federal Aviation Agency; components of a development program by the Department of Defense; and as part of an experiment for the Apollo Applications program. The Apollo and Apollo Applications program will reuse significant amounts of Gemini equipment in direct support. Finally, Gemini spacecraft have been exhibited in a number of foreign countries and have been viewed by more than 1 million people. A spacecraft to be exhibited at the Canadian International Exposition will be seen by an estimated 45 million visitors.

OPERATIONAL RESOURCES

The operational resources developed and perfected during Gemini are now available to support Apollo and Apollo Applications pro-

grams. The Air Force personnel who provided Gemini with such magnificent support have moved on to Air Force programs, principally MOL. The facilities such as the Mission Control Center that were developed and perfected during Gemini are now being configured to support the Apollo flight program. The personnel who manned the Gemini Program Offices in the Manned Spacecraft Center and the Headquarters have been reassigned.

Of the Gemini people in Houston, about one-third have been assigned to the new Apollo Applications Office and one-third to the Apollo Spacecraft Program Office. The balance were assigned within the Engineering and Development and Flight Operations Directorates of the Center. Headquarters Gemini Program Office personnel have been reassigned to all elements of Manned Space Flight, the largest number going to the Apollo Applications Program Office. Flight operations and launch operations personnel have been integrated into the Apollo program.

Utilization of experience

A major effort is being made to assure that every possible utilization is made of Gemini experience. In the area of personnel Charles W. Mathews, formerly the Gemini Program Manager at MSC, has been assigned as the Apollo Applications Program Director; and William C. Schneider, formerly Gemini Mission Director, will be heading the Mission Operations Directorate for the Apollo Applications program. Another example is Leroy Day, formerly Deputy Director, Gemini Test, who is now the Director Apollo Test.

Summary documentation is being prepared and like all periodic Gemini reports will be widely distributed. Special reports and topics judged to be especially pertinent to Apollo and Apollo Applications are being written. A report by the Gemini Executives Group to the Apollo Executives Group in January resulted in the exchange of the information relating to experience of Gemini's major contractors to Apollo's major contractors. The reports were frank and thorough, providing technical and managerial experiences and ideas that are expected to benefit Apollo significantly.

CONCLUSION

In summary, 1966 was a successful year for the Gemini program. Five manned missions were conducted during the year with the 12th and last mission coming in November. Each mission made significant contributions to Gemini objectives and to national space goals. The program objectives were met; moreover, the techniques and procedures used to pursue all objectives including safety were examined in painstaking detail. They were varied from mission to mission, and in certain instances during a mission, to achieve maximum breadth and depth of experience. Gemini has fulfilled its promise to provide a baseline of technology needed for future Manned Space Flight.

During 1966, development of the Gemini operational flight system was refined and completed. Flight systems reached a level of proficiency that made possible continued progress on every mission in spite of several anomalies. Multiple vehicle techniques, contingency

and alternate planning philosophies, training plans, and mission planning techniques were devised and perfected for use in later missions. These data will provide significant inputs into the Apollo and Apollo Applications programs, which in turn will provide information required to ultimately attain continuous operations of man in space.

Gemini's contributions to the Nation's expanding technology will enable the Nation's scientists and industry to exploit the new dimension of space and to apply this knowledge to a wide variety of beneficial programs, many of which I will discuss as we proceed in these hearings through the Apollo, Apollo Applications, and Advanced Manned Missions programs.

Appendix A

Launch date: April 8, 1964.
Designation: Gemini I.
Crew: Unmanned.
Remarks: Gemini spacecraft launched into orbit by modified Titan II booster. Spacecraft decayed during 69th orbit over South Atlantic Ocean, with all tests objectives achieved. Purpose of flight was to test the Titan launch vehicle system; Gemini spacecraft structural integrity; spacecraft launch vehicle compatibility; and to demonstrate the launch vehicle and guidance systems.

Launch date: January 19, 1965.
Designation: Gemini II.
Crew: Unmanned.
Remarks: Gemini spacecraft launched into suborbital flight, splashing down approximately 1,848 nautical miles southeast of Cape Kennedy, Fla. Major mission objectives, all successfully accomplished, were to demonstrate basic structural integrity of spacecraft throughout the flight environment; and to verify the adequacy of reentry heat protection. In addition, satisfactory performance was demonstrated by flight control, life support, retrograde rocket, recovery and landing, and other systems critical to flight safety and mission success. Duration, 22 minutes.

Launch date: March 23, 1965.
Designation: Gemini III.
Crew: Virgil I. Grissom and John W. Young.
Remarks: Gemini spacecraft launched into three-revolution orbital flight by modified Titan II booster (Gemini-Titan 3). First U.S. two-man spaceflight, Grissom first man in space for second time. One orbital maneuver was conducted in each of the three orbits. During first orbit the apogee was lowered from 139 miles to 105 miles and the perigee from 100 miles to 98 miles; in second orbit a series of maneuvers produced a translational movement changing inclination by one-fiftieth of a degree; in third orbit the perigee was lowered to 52 miles. Manual control was exercised throughout the reentry phase, using the limited lifting characteristics of the spacecraft to steer toward touchdown. Two of three experiments were performed; experiment on effect of weightlessness on sea-urchin eggs during fertilization and cell division failed; successful experiments were effect of weightlessness in interaction with radiation on white blood cells and injection of fluid into the reentry plasma sheath in attempt to attenuate communication blackout. Duration, 4 hours, 53 minutes.

Launch date: June 3, 1965.
Designation: Gemini IV.
Crew: James A. McDivitt and Edward H. White II.

Remarks: Gemini spacecraft launched into orbit by modified Titan II booster (Gemini-Titan 4). Four-day, 62-revolution endurance mission to test crew and spacecraft in buildup to longer missions. Eleven scientific and engineering experiments, in addition to basic medical checks on 4 days of exposure to the space environment, measured radiation, electrostatic charge, proton-electron flow, and geomagnetic fields. Synoptic weather and terrain photography was accomplished, as well as two-color photographs of the earth's limb. Navigation measurements were conducted, in-flight phonocardiograms taken, and bone demineralization measurements made. Attempt to rendezvous with spent second stage was abandoned when spacecraft fuel consumption became excessive. White spent 22 minutes outside the spacecraft in extravehicular activity, propelling himself with an oxygen-jet gun. During spacewalk he was attached to the spacecraft with a 25-ft. tether-and-oxygen line; he carried emergency oxygen and camera. Spacecraft computer malfunction necessitated a ballistic reentry sequence. First mission controlled from new Mission Control Center at Manned Spacecraft Center, Houston, Tex. Duration, 97 hours, 56 minutes.

Launch date: August 21, 1965.
Designation: Gemini V.
Crew: L. Gordon Cooper, Jr., and Charles Conrad, Jr.
Remarks: Gemini spacecraft launched into orbit by modified Titan II booster (Gemini-Titan 5). Eight-day, 120-revolution endurance mission confirmed the physiological feasibility of Apollo lunar landing mission. Several major records set by United States: longest manned spaceflight in time and distance, total man-hours in space, and most manned flights. First flight of fuel cell electrical power system. During first orbit, perigee was raised to 106 miles from initial 100 miles. At beginning of second orbit a Radar Evaluation Pod was ejected; the Gemini V rendezvous radar furnished range and range rate data on this target for 40 minutes. On August 23 a simulated rendezvous was conducted with a series of four maneuvers through two orbits which raised the perigee to 124 miles and lowered the apogee to 192.6 miles. Sixteen of seventeen experiments were successfully conducted: five medical experiments measured physiological effects; extensive weather and terrain photography was conducted; visual observations of missile launches and ground patterns were made; and zodiacal light was photographed. Only experiment canceled was photography of the Radar Evaluation Pod. Voice communication was conducted with Sea Lab II under the Pacific Ocean. Duration, 190 hours, 55 minutes.

Launch date: December 4, 1965.
Designation: Gemini VII.
Crew: Frank Borman and James A. Lovell, Jr.
Remarks: Gemini spacecraft boosted into orbit by modified Titan II booster (Gemini-Titan 7). Fourteen-day, 206-revolution endurance mission, longest scheduled flight in Gemini program. Station-keeping conducted with booster second stage after separation; spacecraft maneuvered to raise apogee from original 100 miles to 138 miles to serve as rendezvous target for Gemini VI. On December 7 orbit

was adjusted to 197 miles apogee 145 miles perigee, then on December 9 perigee was raised to 185.8 miles and apogee lowered to 188.3 miles. Missile reentry was observed over Pacific on December 14. Accurate controlled reentry was made, landing 7.6 miles from target. One astronaut at a time doffed his pressure suit to enhance comfort. No adverse physiological effects from 2 weeks in the space environment. Twenty experiments were incorporated into the mission, ranging from detailed medical measurements and sleep analysis to earth photography and radiometry measurements. Duration, 330 hours, 35 minutes.

Launch date: December 15, 1965.
Designation: Gemini VI–A.
Crew: Walter M. Schirra, Jr., and Thomas P. Stafford.
Remarks: Gemini spacecraft launched into 16 revolution orbital flight by modified Titan II booster (Gemini-Titan 6). This spacecraft-booster combination was originally ready for launch on October 25 but held when Agena target vehicle failed to orbit. Rescheduled to rendezvous with Gemini VII as target, launch attemped on December 12 but aborted when the first stage engine shut down immediately after ignition. Initial orbit was: apogee, 161 miles, perigee 100 miles; a series of posigrade maneuvers began the rendezvous chase and shortened the initial 1,200 miles separation distance to 730 miles. During second revolution the distance was reduced to 300 miles with another thruster firing, followed by a plane change to match Gemini VII's orbit. Orbit was adjusted to near circular at beginning of third revolution; as fourth revolution began, the terminal phase of rendezvous was initiated, resulting in approach to within 1 foot of Gemini VII. Stationkeeping and fly-around maneuvers were conducted for 5 hours, 19 minutes. Controlled reentry to landing within 13 miles of prime recovery ship. Duration—25 hours, 51 minutes.

Launch date: March 16 1966.
Designation: Gemini VIII.
Crew: Neil A. Armstrong and David R. Scott.
Remarks: Gemini spacecraft launched into orbit by modified Titan II booster, 1 hour 41 minutes after Gemini Agena Target Vehicle (GATV) Atlas booster combination. Rendezvous with the GATV was accomplished in fourth orbit, 6 hours after launch, and first docking of two vehicles in space achieved 33 minutes later. After 28 minutes of flight in the docked configuration a thruster in the orbital attitude maneuvering system stuck open and spacecraft began to spin. Gemini spacecraft was undocked from GATV and, after 25 minutes, was stabilized by use of reentry control system. Mission terminated early after 6½ revolutions, landing in secondary recovery area in Western Pacific. Scheduled extravehicular activity (EVA) was not accomplished. GATV was placed in a "storage" orbit for later use as a rendezvous target. Duration—10 hours, 41 minutes.

Launch date: June 3, 1966.
Designation: Gemini IX–A.
Crew: Thomas P. Stafford and Eugene A. Cernan.
Remarks: First mission attempt made on May 17 when an Atlas booster engine failed at 121 seconds after lift off, and the GATV failed

to reach orbit. A backup mission utilizing Augmented Target Docking Adapter (ATDA) as the target, scheduled for June 1.

The ADTA was placed into orbit on June 1 with an Atlas booster, but inability of Gemini spacecraft to receive final guidance information caused postponement of Gemini launch to June 3 when spacecraft was launched into 45-revolution orbital flight by its modified Titan II booster. Rendezvous with ATDA achieved on third orbit. Crew confirmed that shroud covering the docking collar had failed to separate and docking was canceled. Two additional rendezvous performed as planned, one using visual techniques and the last from above the ATDA. EVA delayed from June 4 to June 5 due to crew fatigue. After 1 hour of EVA, Cernan's visor accumulated fog and communications between Stafford and Cernan were poor as Cernan checked out the Astronaut Maneuvering Unit (AMU) in the adapter section of the spacecraft. Planned use of the self-contained life support and propulsion systems to maneuver with the AMU was canceled. Total 2 hours, 7 minutes EVA. Radio polarization and photographic experiments were conducted in addition to micrometoroid collection. Controlled reentry to 0.42 miles of target. Duration—72 hours, 21 minutes.

Launch date: July 18, 1966.
Designation: Gemini X.
Crew: John W. Young and Michael Collins.

Remarks: GATV-Atlas booster combination launched 100 minutes before Gemini spacecraft launched into orbit by modified Titan II booster. Rendezvous and docking with GATV accomplished in fourth orbit of 43-revolution flight. GATV engine used to propel the docked combination to record altitude, then proper orbit to rendezvous with GATV from Gemini VIII. After separation from GATV, Gemini IX–A effected rendezvous with the passive target. First period of stand up EVA was terminated at 50 minutes when both crewmen suffered eye irritation. Second EVA period, after rendezvous with passive GATV, consisted of Collins on umbilical moving to GATV and recovering micrometeorite experiment package. Umbilical EVA terminated after 39 minutes to conserve maneuvering fuel. Of 14 scheduled experiments, data was obtained on 12. First rendezvous with two different spacecraft, first extensive test of docked spacecraft, first post-docking maneuvers using propulsion unit and fuel of target vehicle, first crewman to touch another spacecraft. New altitude and speed (17,700 statute mile per hour) records for manned space flight. Duration—70 hours, 47 minutes.

Launch date: September 12, 1966.
Designation: Gemini XI.
Crew: Charles Conrad, Jr., and Richard F. Gordon, Jr.

Remarks: GATV–Atlas booster combination launched 1 hour 37 minutes before Gemini spacecraft launched into orbit by modified Titan II booster within 2-second launch window. Rendezvous accomplishes on first orbit of 44-revolution flight using on-board information exclusively. Docking at 1 hour 34 minutes after launch. Docking accomplished twice by each crewman. During umbilical EVA, Gordon removed the nuclear emulsion experiment package and

attached tether between Gemini spacecraft and GATV. Excessive fatigue from these activities caused early termination of EVA at 33 minutes. After returning to, and repressurizing spacecraft, the hatch was opened for 3 minutes to jettison umbilical EVA equipment. Using GATV primary propulsion system, docked configuration was propelled to new altitude and speed (17,943 statute miles per hour) records. Hatch opened third time for 2 hours 10 minutes standup EVA during which scheduled photography was accomplished. Two spacecraft undocked and station keeping by use of 100 feet nylon tether exercised with a slow spin rate imparted to the tethered combination. After separation of the tether, a second rendezvous with GATV was conducted from 25 mile separation. Reentry sequence was fully automatic for the first time with impact 2.9 miles from the aiming point. Ten of eleven scheduled experiments were conducted as planned, power tool evaluation canceled due to shortened umbilical EVA. Duration—71 hours, 17 minutes.

Launch date: November 11, 1966.
Designation: Gemini XII.
Crew: James A. Lovell, Jr., and Edwin E. Aldrin, Jr.
Remarks: GATV–Atlas booster combination launched 1 hour 38 minutes before Gemini spacecraft launched into orbit by modified Titan II booster. Rendezvous accomplished in third orbit of 59-revolution flight with docking 4 hours 14 minutes after Gemini launch. Scheduled boost of docked Gemini–GATV combination into higher orbit canceled due to pressure fluctuations in GATV primary propulsion system. The docked combination was maneuvered to obtain photographs of solar eclipse during the 10th revolution. Two standup EVA periods, on first and third days, totaled 3 hours 34 minutes. On second day, Aldrin conducted 2 hours 6 minutes umbilical EVA, testing restraint devices to overcome body positioning problems experienced on prior flights. Resting frequently, Aldrin utilized portable hand rails, foot restraints, and various tethers. He completed 19 tasks, demonstrating useful EVA work was feasible with proper planning and restraint devices. Gemini and GATV spacecraft undocked, remaining joined by 100 foot tether for station keeping and gravity gradient stabilization experiment. Fourteen experiments conducted. Automatic reentry sequence used for second time. Duration—94 hours, 35 minutes.

APPENDIX B

SCRIPT FOR THE 12 GEMINI

(16-mm. color-sound motion picture)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Gemini III was the first manned Gemini to be launched. It had been preceded by two earlier unmanned test flights.

Ten manned test flights would tackle six objectives. The program would—

Investigate long-duration flight;
Develop rendezvous techniques and postdocking maneuvers;

Develop reentry flight path control;
Develop extra vehicular capability;
Attain flight and ground crew proficiency; and
Conduct scientific experiments.

Gemini III completed three successful orbits on March 23, 1965.

It had begun 19 months of manned spaceflight accomplishments.

On the very next flight, the long-duration mission headed the list of objectives. Long duration is fundamental to spaceflight.

If Man could not withstand a zero-gravity environment for extended periods, two things were obvious.

Either our future flights would be limited, or gravity would have to be induced artificially in flight.

There were three long-duration missions: 4 days of Gemini IV, 8 days of Gemini V—the length of a lunar mission—and an extended mission of 14 days on Gemini VII.

Long duration was a test of the endurance of both spacecraft and crew. On the spacecraft side, Gemini V was powered by fuel cells for the first time. They replaced conventional batteries.

Fuel cells were also flown successfully on all missions from VII through XII.

This is important because batteries are inadequate for many future space missions at the power levels needed. Apollo, for example, will use similar fuel cells.

Medical aspects of the flight were closely studied: for such everyday matters as the ability to eat and sleep in space and for longer term results.

When Fank Borman and Jim Lovell completed 14 days in Gemini VII, we had basic answers.

We can medically commit crews to flights up to 30 days—a necessary condition for Man's role in Apollo and the Orbital Workshop.

The first rendezvous in space occurred December 15, 1965, between two spacecraft: Gemini VIA and Gemini VII.

Over Hawaii, in the fourth orbit, Pilot Stafford reported the decreasing distance between the two spacecraft:

"One hundred fifty feet.

"One hundred fifty feet, and holding, Wally."

As station keeping continued, Gemini VIA moved within a foot of Gemini VII. It was a successful beginning which saw Gemini complete ten rendezvous with target vehicles in less than a year. Seven different modes were investigated.

An 11th rendezvous to photograph a solar eclipse was achieved on Gemini XII.

To those of us who followed the flights from the sidelines—listening to reports from television—rendezvous seemed almost like an automatic exercise. But because something is done well does not mean that it was easy to do. Rendezvous required 3 years of theoretical preparation—integrating space mathematics into the constraints of the mission and hardware.

Approximately 100,000 hours were spent on computer computations.

When crews were assigned to specific rendezvous flights, each prime and each backup crew trained for approximately 400 hours in simula

tors—a total of almost 5,000 man-hours of rendezvous simulation. It was never automatic.

Gemini IXA gave us our first sophisticated rendezvous experience. Command Pilot Stafford, a veteran of Gemini VIA, completed three different rendezvous within 24 hours with his angry alligator.

Within 12 orbits, Astronaut Stafford completed his initial rendezvous, then performed an optical rerendezvous using onboard calculations of the pilot as a backup, and finally simulated a type of rendezvous above the target vehicle which would follow a lunar abort.

A dual rendezvous was performed between Gemini X and the Agena VIII target vehicle still in orbit from an earlier launch. It was a passive target vehicle.

Gemini XI achieved an M equals one rendezvous—or rendezvous in the first orbit. This was a direct ascent rendezvous and simulated still another type of rendezvous following a lunar abort.

During the first rendezvous, Gemini VIA had moved within 1 foot of Gemini VII, but, of course, the two spacecraft could not dock.

The first space dock came in March 1966. The spacecraft was Gemini VIII. Astronaut Armstrong moves in very slowly, making his final approach, until he is about 3 feet from the target. He then holds his position, reading the status display panel on the Agena.

When he docks, the Gemini-Agena configuration will remain stable for almost 30 minutes. The control problems which developed were unrelated to the first successful dock in space.

Gemini completed nine successful dockings. Both crew members performed dockings on the final two missions, XI and XII.

One important aspect of docking is that it allows a crew to utilize the propulsion system of another spacecraft for further maneuvers.

The Agena Target Vehicle has a primary propulsion system with 16,000 pounds of thrust.

The primary propulsion system of Agena was first ignited in docked configuration by Command Pilot Young on Gemini X—and it lifted his spacecraft to a new orbital altitude record of 414 nautical miles.

Again on Gemini XI, the primary propulsion system was lit in a white blaze of energy, and quickly propelled the crew to 741 nautical miles, shattering the previous record.

"Carnarvan, this is Gemini Eleven."

"Go ahead, Eleven."

"The world really is round from up here."

"Got a good view, have you?"

"Have we ever! I mean it is spectacular—fantastic."

A major postdocking maneuver was the experiment with a 100-foot Dacron line, or tether, connected to both spacecraft.

The command pilot gradually plays out the tether until it becomes taut.

On Gemini XI and again Gemini XII, we stabilized the spacecraft on the tether without further use of thrusters. Two techniques were used: the spinup mode on Gemini XI and the gravity gradient on Gemini XII.

Gemini's demonstration of docking and postdocking techniques—coupled with a long duration capability—has helped emphasize the continuing utility of manned space missions.

Man can assemble vehicles by docking and by tether.

He can maneuver them with propulsion burns of spacecraft already in orbit.

He can maintain a fixed orientation of space stations without expending maneuvering fuel.

In short, we can assemble an Orbital Workshop and conduct scientific investigations in it for periods up to a month.

Controlled reentry was an objective on all flights. We are looking at the glowing air in the wake of spacecraft reentry. The command pilot controlled reentry on the first eight manned flights. On the final two missions, the computer alone automatically controlled the descent. (Of course, the pilot was available for backup control.)

On the first three manned flights, Gemini III through V, our landing accuracy was only 57.5 nautical miles from the planned impact point. This distance soon improved.

Wally Schirra landed Gemini VI–A within 7 nautical miles of the planned impact point.

Gemini VIII, despite an orbital abort, landed within 1.1 nautical miles of the planned secondary impact point.

Although it came down 8,000 miles from the primary target area, it achieved the second best landing accuracy.

Tom Stafford shaved that distance to four-tenths of a mile on Gemini IX–A, establishing a remarkable record. Overall, the average miss distance of the last seven flights was 3.6 nautical miles.

This gives us confidence in planning Apollo. Crews will be returning from the Moon at about 25,000 miles an hour. To land safely within a 3,200-mile footprint, they must hit a reentry corridor within 2° of the planned flight path.

The sheer act of a man opening the Gemini hatch and going into space made extra vehicular activity unique among the program objectives.

Ed White completed a successful 22-minute space walk during Gemini IV. He experienced no disorientation. He maneuvered well with the handheld maneuvering unit. And his physiological reactions were very close to what had been predicted from ground tests.

Four additional EVA flights were flown as Gemini progressed from relatively uncomplicated space walking to meaningful space work by an EVA pilot.

On three flights, Gemini IX–A, X, and XI, the pilot faced problems of body control and workload. Two answers evolved:

A new underwater training program for crews and the increased use of body restraints during work sessions.

Astronaut Cernan had nine pieces of body restraint equipment during in his Gemini IX–A flight.

We progressively developed and refined restraint equipment until 44 pieces were flown on Gemini XII.

We also added underwater simulation of zero gravity conditions to train the prime and backup crews of Gemini XII.

This gave them a greater continuity of training than is possible in the parabola of aircraft flight.

Buzz Aldrin put to work the experience gained from four flights and underwater training.

He completed 19 tasks in a 2-hour 9-minute EVA. He performed such fundamental space work as: activating an experiment, tightening and untightening bolts with an Apollo torque wrench, making electrical connections, and cleaning up his work area.

In all, Gemini amassed 12 hours, 22 minutes of EVA experience. It included space walking, standup EVA for photography, and space work.

Gemini EVA has given us assurance that man can work and explore in the vacuum of space, whether that work be on the Moon or on orbiting space stations.

The Gemini program provided depth in both flight and ground crew proficiency.

It trained a staff of flight controllers skilled in handling complex missions.

It was therefore quite logical that a Gemini flight director was at the same console for the first Apollo flight.

The experience of many other Gemini controllers will also be utilized by Apollo.

We came to take for granted the work of the crews at Cape Kennedy who successfully launched 12 Gemini vehicles.

In addition, they demonstrated a dual launch capability. Four Agena target vehicles and one augmented target docking adapter were launched successfully.

Recovery personnel of the Department of Defense and NASA reduced the number of recovery ships 50 percent between Gemini IV and Gemini XII.

At the same time, they increased spacecraft retrieval efficiency by 50 percent.

The record of the flight crews is, of course, better known. When the last spacecraft splashed down, Gemini had logged 1,940 man-hours Almost 40 times as great as Mercury.

In cooperation with the scientific community, Gemini flew 52 experiments.

Participating were scientists such as Dr. E. P. Ney, director of the institute of physics at the University of Minnesota.

Over 2,400 synoptic weather and terrain photographs were taken. Two thousand of these supplied useful information to scientists.

The aerial mapping potential of manned flights is best illustrated by the Gemini IX–A flight over Peru.

In one pass, Gemini IX–A mapped 80 percent of the country. It took just 3 minutes.

These photographs were supplied to the Peruvian Government.

Commercial uses have been many. This Texas coastal area shows the larval distribution of shrimp.

One commercial fisherman reported that he learned more by studying this photograph than by fishing the gulf for 25 years.

Weather photographs have been equally rewarding, enabling us to study the vortex of storms, and buildup of storm regions in successive photo passes.

Gemini has also photographed sources of air pollution over cities, channels of rivers, and the flow of jet streams. The International

Affairs Office of NASA makes available such information to interested scientists of all countries.

These 52 experiments—the 1,940 man-hours of the 12 Gemini—and the six objectives are now over.

But the 12 Gemini have given us experience and confidence to tackle the next goals of manned spaceflight: to land for the first time on the Moon, explore it, and return to Earth—to acquire new scientific knowledge in orbital workshops—and to reach out toward interplanetary exploration.

Now, Mr. Chairman, that finishes what I had planned to say about Gemini. If there are questions, I can answer them.

Mr. TEAGUE. Are there any questions?

I believe there are no questions.

Mr. Waggonner would like to ask a question.

Mr. WAGGONNER. You said the final Gemini cost had not yet been determined. What is the present estimate?

Dr. MUELLER. The best estimate we have is $1.29 billion. The contracts terminations are still being negotiated, though, and it will be several months before those are complete.

Mr. WAGGONNER. At one point you estimated it might be $1.35 billion. Do you attribute that to your cost plus fixed fee contract?

Dr. MUELLER. The cost plus percentage fee did, in fact, contribute I believe, substantially. Those incentives were also designed in a way to make it evident that the Government wished to move forward with the program and help also to move the schedule forward.

Mr. TEAGUE. Mr. Roudebush, did you have a question?

Mr. ROUDEBUSH. Just one quick one, George. I have a purpose in asking this. On the Gemini capsules, we bought 15 originally and we utilized 12.

Dr. MUELLER. As I understand it we bought and utilized a total of 12 Gemini spacecraft.

Mr. ROUDEBUSH. We purchased 12.

Dr. MUELLER. Yes.

Mr. ROUDEBUSH. What has been the disposition of these capsules? Where are they?

Dr. MUELLER. Three are being transferred to the Air Force. Two of them are being used, or at least the subsystems were being used, for the Apollo Applications program. There are several that are being exhibited, one is being selected for permanent exhibit in the Smithsonian and I would assume that most of them will be disposed of in this fashion.

Mr. ROUDEBUSH. You have no specific plans. The reason I bring this up, these are historic aircraft. I hope we will be able to maintain some for viewing by the future generations. How about our Mercurys, too, George? Where are they?

Dr. MUELLER. I believe that the Mercury capsules have all been assigned to exhibitions, that is to museums or used for some of the traveling expositions that, for example, go to the Paris Air Show or the Canadian World's Fair.

Mr. ROUDEBUSH. You haven't given any of these away, have you? They are just on loan.

Dr. MUELLER. That is correct.
Mr. ROUDEBUSH. Thank you.
(Following for the record:)

DISPOSITION OF GEMINI SPACECRAFT

Gemini 1: Not recovered.
Gemini 2: MOL Program.
Gemini 3: MOL Program.
Gemini 3A: MOL Program (test article).
Gemini 4: Smithsonian Institution.
Gemini 5: On display at MSC.
Gemini 6: In storage at St. Louis.
Gemini 7: Expo–67.
Gemini 8: In storage at St. Louis.
Gemini 9: In storage at MSC.
Gemini 10: In Australia on tour.
Gemini 11: In storage at St. Louis.
Gemini 12: In storage at St. Louis.

Dr. MUELLER. I would like to turn now to our annual report for the fiscal year beginning in July. I had previously submitted supplemental data to the statement I presented before the full committee on March 7 and will, with the permission of the chairman, during the next several days bring out the key elements of the supplemental data which describe the activities and programs of Manned Space Flight, accomplishments over the past year, and activities planned with the fiscal year 1968 budget under consideration by the committee.

Before going into the Manned Space Flight program in depth, I would like to reiterate the key points brought out by Dr. Seamans in his testimony before the full committee on March 1. He stated as follows:

> First, this FY 1968 request represents the first true post-Apollo decisions. These decisions reflect our thinking, the review and endorsements of the Bureau of the Budget and the President's Science Advisory Committee, and the judgment of the President. As such, the important aspects to stress is that these are real and forthright decisions, ones that can be clearly accepted or rejected but that are not susceptible to compromises or halfway measures. Their crux is the question of a determination to continue a dynamic U.S. presence in space—or, of an overt decision to abandon the challenges, difficulties, and rewards of space capability. Second, nearly all of the budget is dedicated, not to the steps planned to forward the Nation's capability in new areas, but to the support and completion of those major space and aeronautics tasks that have been authorized and funded in the past. This on-going effort has been the successful backbone of our scientific and technological advances since the inception of the Agency, and commands the greatest part of our management attention and of our resources, both manpower and money. Third, every major undertaking in the field of research and development has built in an inherent risk, an uncertainty factor. I would like to underline this characteristic in our budget today. The exampel of the Apollo 204 accident during simulated launch conditions must be a reminder that we must work at the far edge of today's technology in order to build tomorrow's and that we can not always accurately assess in advance the cost in time or money, and most importantly in lives, of reaching national objectives and achieving national goals. The budget before you was prepared before the accident; our first impression is that the corrective actions we plan can be balanced within the overall totals by unavoidable delays and judicious rescheduling of effort, but we are not yet clear as to the full impact of the accident upon both our FY 1967 and 1968 resource planning. More than ever in the past, the unexpected has added uncertainty to our program.

I believe that these points made by Dr. Seamans are significant to our discussions as the subcommittee considers the fiscal year 1968 budget

for Manned Space Flight. We have just presented the results of a highly successful Gemini program which has now been completed.

Mr. RUMSFELD. You read Dr. Seamans' statement that this budget can be either accepted or rejected, but that it is not susceptible to compromise or halfway measures.

What does this mean, George?

Dr. MUELLER. That essentially by the time the Bureau of the Budget and the President have completed their examination of the budget that we have presented, it was pared down to those elements that were considered to be essential if we were to have a continuing space program and in particular, a continuing manned space program.

The basic problem that we have has quite clearly been stated before this committee last year and was approved by this committee last year in terms of holding open an option to go forward in fiscal 1968 with a Manned Space Flight program.

I believe that Dr. Seamans is pointing out that you have to make a decision this year either to go forward or not to go forward. There isn't any way of holding the option open 1 more year by a small amount of money this year.

Mr. RUMSFELD. I don't want to belabor the point, but, with all respect, I am not impressed by that statement by Dr. Seamans.

There are some who suggest this budget doesn't provide for a dynamic space program, as Dr. Seamans alleges. Further, I don't see how he can suggest that this budget is not susceptible to changes by Congress.

Certainly it is. It seems to me that every year NASA comes in and says: We are at the crossroads, Congress must do exactly what is requested or we are going to go down to the road to something terrible. Nothing can be changed or the program is over, and so forth.

Admittedly, you don't do this, and I should have brought it up with Dr. Seamans instead of you, but I believe the Congress should look at this budget request and make its decisions. It is not, as Dr. Seamans suggests, a take it or leave it proposition. I don't believe the statement by Dr. Seamans contributes much to these hearings.

Dr. MUELLER. I'm sorry, Mr. Rumsfeld, I didn't mean to waste your time.

Mr. TEAGUE. Any other questions?

What is this investigation going to cost? Can you make an estimate?

Dr. MUELLER. You mean of the basic investigation itself?

Mr. TEAGUE. The basic investigation itself.

Dr. MUELLER. I presume that one could evaluate that in terms of the number of people that we have working on the problem and the time. We have about 1,500 people now engaged in one aspect or another of investigating the accident and they will have worked for something like 2 months, so that we will have some 3,000 man-months of effort going into the accident itself. As I recall, our average cost per man-year at the present time is about $17,000, so that if my arithmetic doesn't fail me, we have about 250 man-years times $17,000 or about $4 million.

Mr. TEAGUE. Mr. Waggonner?

Mr. WAGGONNER. Did I understand you to say that this budget was prepared before the 204 accident and that it is your opinion and the opinion of NASA that whatever changes that are made mandatory when the investigation is finally completed in the program can be taken care of within the framework of the budget which was proposed prior to the accident by reprograming or reallocating the Apollo money?

Dr. MUELLER. As you will recall in the testimony that we presented to the Senate Space Committee a couple of weeks ago, we had an early look at the results of the investigation and an early look at the kinds of things or possibilities that we were studying, among which choices would have to be made.

If those projections of the problem are correct, then the changes will be of such a magnitude that I believe they can be accommodated within the basic Apollo budget, that we have both in fiscal 1967 and in fiscal 1968.

What this reflects, actually, is somewhat better than anticipated experience in the launch vehicle and a poorer than anticipated experience in the spacecraft.

There will have to be a reallocation of funds within the launch vehicle and spacecraft, but the total would appear to be within our ability to accommodate.

Mr. WAGGONNER. You are not saying you predict the changes in the spacecraft will be of no magnitude?

Dr. MUELLER. No, sir.

Mr. TEAGUE. Mr. Gurney?

Mr. GURNEY. Since we are touching upon the accident, let me ask one or two questions.

I notice we are going into this thing in detail later on when the report comes out, but there have been some disturbing news stories coming out recently and it might be well to comment on it right here.

There was one, in Sunday's Post, by an A.P. writer. Statements in it were made like this: That there were so many troubles in the Apollo spacecraft program that some people in industry felt the Apollo project was falling apart at the seams.

Then there was another statement that quoted one of the NASA people telling newsmen that there were something like 20,000 failures at one time or another in the test of the Apollo cabin and engine sections.

What I am saying is that the news reports or speculation reports on the accident certainly are giving a different color to the fact that there was something wrong with the program.

Do you just want to comment on that generally?

Dr. MUELLER. Let me say that the material, by and large, that was presented in that particular article had been covered and was taken actually from the testimony prepared by NASA for the Senate Space Committee and earlier reports which NASA had made to the industry and the country. Particularly, "20,000 failures" was a part of the discussion that was held at the symposium of the Manned Spacecraft Center several months ago in trying to bring the public up to date on the status of the program.

You will recall that I had a history of the acceptance testing of the Gemini spacecraft in the presentation I gave just a few moments ago

and you will notice the very large number of hours that were required in the first checkout and acceptance of the Gemini spacecraft.

Those large number of hours, sometimes like 10 times the eventual hours required to check it out, represented the discrepancies that had to be fixed, "squawks" that something had to be done about. Now, if you recognize, too, that the Apollo spacecraft is 10 times as complex as the Gemini spacecraft, it is not surprising that you have 20,000 discrepancies. In fact, we have regarded this as being a nominal situation in the first model of a development spacecraft. Maybe half of those represent problems in getting the paperwork up to date because we do keep a very careful record of each of the spacecraft components and we do want to make sure that the records are up to date before it leaves the factory. So every paper that isn't properly filled out, properly signed and so on, there is a record made of it and the proper action has to be taken before we will accept the spacecraft and that goes right on through.

Now, I think that one has to recognize that in any development program the way you learn is by finding things wrong and fixing them and the way the people learn to manufacture and the way the people learn to carry out the checkout, the way the people learn to think for launch, is not by doing everything right the first time because you don't know enough about the spacecraft to be able to do it right without having gone through the procedures once and found out how they really worked.

I don't recall the Apollo program in an overall sense as being in difficulty. I sincerely believe that the basic Apollo spacecraft design is sound and that the reason we can accommodate the changes that we are anticipating within our budget is that the design was basically sound and the changes that are required are going to be relatively nominal.

That doesn't mean they are negligible. They aren't large changes. They don't represent basic design flaws and basic difficulties in the test and checkout areas.

Mr. GURNEY. In other words, the many discrepancies that were referred to, perhaps it might be fair to say show the worth and excellence of the test program and the discrepancies that you have are not more than you would normally expect?

Dr. MUELLER. That is correct.

Mr. TEAGUE. Mr. Rumsfeld?

Mr. RUMSFELD. On this same subject, not with respect to the specifics of the accident but on procedures, I notice on page 21 of your supplemental material you say "Our procedures have in the past required that each test be conducted, be reviewed from the safety standpoint."

On page 11, you say "most of the spacecraft systems are adequate for safety" and so forth.

That review is conducted within NASA, is that correct?

Dr. MUELLER. As a matter of fact as I guess I explained last year, we have a series of reviews of the spacecraft and the launch vehicle.

Mr. RUMSFELD. Are any apart from NASA?

Dr. MUELLER. The President's Science Advisory Committee had a subcommittee under Dr. Frank Long that spent 6 months reviewing in great detail, the designs and procedures and so on that were used.

You will recall they have a paragraph in their report to the President on the future programs and I believe that their conclusion was that we were doing all that one could do and they were relatively optimistic about the results of what we were doing.

Mr. RUMSFELD. I am advised that in the development of the nuclear submarines and the Polaris submarines there were independent review boards that were apart from the AEC and apart from the Navy. They were not connected with the Government or Navy and they participated in an independent review.

I am further advised that the concept of an independent review is credited with some of the successes achieved.

I quite agree with you the way you learn is by trying things, but to the extent that they can be talked through prior to some unfortunate situation, this is what we are all seeking.

Has that possibility of an independent review board within NASA been considered and rejected or does one exist?

Dr. MUELLER. Several actually exist at varing degrees of independence. The Science and Technology Committee has participated in the PSAC Committee review and also conducted its own independent reviews of the work we are doing. That Committee is composed of some of our outstanding engineers and scientists in the country who have had great previous experience in this kind of activity.

We also, of course, use a system of design reviews internal to both contractor and our own organization. Generally the design reviews are conducted by people who are independent of the people that did the design in the first instance.

In other words, we take expertise from elsewhere in our organization, apply it to the problems associated with our anticipated problems.

We have also established a design certification review board which is composed of myself and the center directors where we rather carefully go through the design itself and the procedures that have been developed for using the equipment.

Mr. RUMSFELD. Are these essentially safety review boards?

Dr. MUELLER. In the case of design certification review board, it is devoted almost entirely to whether this system is safe for man to fly. That is the one aim it has and if you will notice the proceedings of this board, you will find that at the end of each engineers systems presentation, he certifies that his system is ready for manned flight. We have tried very carefully to get a meaningful set of checks and balances in both the design, the implementation, and the operations areas.

Mr. RUMSFELD. Are you personally familiar with the independent review boards that I was referring to with respect to the nuclear submarines?

Dr. MUELLER. Yes, I am.

Mr. RUMSFELD. Do you compare what NASA has with that and say they are similar?

Dr. MUELLER. I think they are both similar and independent. We actually penetrate rather deeper in the design than they did. We had a similar setup too in the ballistic missile program. What we tried to do was to add to that rather than subtract from it.

Mr. RUMSFELD. Thank you.

Mr. TEAGUE. Mr. Roudebush?

Mr. ROUDEBUSH. In conjunction with Mr. Gurney's line of questioning, I wonder how the number of failures in the Apollo that you have experienced so far compares with the number of failures you had in Gemini and previous to that in Mercury before your first flight?

Dr. MUELLER. I am trying to gather that data together right now.

Mr. ROUDEBUSH. Will you submit it for the record?

(The information as requested is as follows:)

In conjunction with Mr. Gurney's line of questioning, I wonder how the number of failures in the Apollo that you have experienced so far compares with the number of failures you had in Gemini and previous to that in Mercury before your first flight?

Answer: Summarized in the table below is a direct comparison of the number of failures prior to the first manned flight in the Apollo spacecraft, to the Mercury and Gemini programs. (Notice there was an error in the original number of 20,000 failures for the Apollo CSM. This number is more accurately subscribed to the total Apollo spacecraft.) The increase reflects the increasing size and complexity of the programs. There are, for example, 21,600 drawings of 1,500,000 parts and assemblies on Apollo as contrasted with 6,100 drawings of 268,000 parts and assemblies on Gemini.

Item	Mercury	Gemini	Apollo
Failures—prior to 1st manned flight	1,300	4,600	15,100

The use of the term failure can be misleading. The failure reporting system makes no distinction between a material defect, a broken part, a procedural error, or out-of-specification operation. Each failure report does mean, however, that a senior member of the appropriate engineering staff reviews the item for proper action.

Mr. TEAGUE. A newspaper article said they were practically the same—about either Gemini or Mercury.

Dr. MUELLER. I believe that we will find that certainly with respect to the complexity, if you take into account the difference in complexity of the vehicle, it is better in the Apollo than it was in Gemini or Mercury.

Mr. FUQUA. There were press reports since the Apollo tragedy that the prime contractor was doing a very important job and there was some feeling in NASA that maybe another contractor should take over that job.

I wonder if you could add a little light to this?

Dr. MUELLER. Well, the prime contractor in the Apollo program is at this point in time doing a creditable job in my view.

Mr. FUQUA. At this point?

Dr. MUELLER. At this point in time. Now, I think that one has to put this in perspective and look at what happens to each of our experiences with each of our major contractors.

You have got to recognize that we really are learning a new technology. We are also learning how to manage very large programs, programs that are different than any program that the Nation has undertaken in the past.

The program that we are doing is one that is producing a very complex system and we are only producing something like 15 Saturn V's and 12 Saturn I–B's and the requisite spacecraft, so you don't

have the same kind of production base and the same kind of ability to learn by breaking equipment.

In every case—that includes our experience on Mercury and Gemini, it includes our experience on the launch vehicles, the Gemini launch vehicles as well as the stage contractors on the Saturn V—there has been a period in the development cycle where we had difficulties, both with the management of the program, the organization of the contractor, and in many cases our own organizational setup and in the technical details of how to carry out the program.

We have adopted a system of working with the contractor trying to transfer from contractor to contractor knowledge, from the NASA people to the contractor the knowledge that we have.

In the course of doing this, we have adopted various techniques, we have created, if you will, for the McDonnell Co. a new method of managing their subcontractors or subsystem development and that works successfully in McDonnell and we apply it to other companies in the organization.

So I think that you will find that there is a cycle and there is a period of time when everybody is discouraged because that first article is having problems and you have to learn how to do it, you have to transfer enough knowledge and enough energy and cause people to learn how to do this thing both themselves and with help from outside.

I would say that North American has had more problems than other contractors but on the other hand it is, in fact, our largest contractor, but in proportion to the size of the task they have, I would say that they have fewer problems and certainly at the present time they are comparable to any of our other contractors.

Mr. FUQUA. Getting back to my original question, was consideration ever given in NASA to changing their contractors if they had so many problems that they appeared insurmountable, so you did give consideration to changing contractors?

Dr. MUELLER. I don't know of any case where we really looked at changing contractors in the present programs.

Mr. FUQUA. Then that report then is false?

Dr. MUELLER. To my knowledge, yes.

Mr. TEAGUE. Mr. Gurney?

Mr. GURNEY. Let us talk a little about your checking-up system.

I know the contractors have quality control people and safety people whose job it is specifically to look after those areas and make sure that the contractors do their job.

What kind of a system do you have to sort of check up on the checkers? I mean by that most systems have sort of a surprise inspection to make sure that people who are charged with the job are doing the job; do you have that kind of a system?

Dr. MUELLER. Yes.

Mr. GURNEY. Let us be a little more specific about it. Take down at the Cape, for example, as a flight is being readied and there are certain safety procedures to be adhered to, the contractor is supposed to be doing his job here and so is NASA, but these people work together and it is a human thing, for example, for your Government man, I suppose, to be considered as — unpopular — that is his job. He has

got to be that in order to do his job. It is also human that no one likes to be in that role.

How do you make sure that he does continue to be unpopular, as he is supposed to be in order to get the job done and he doesn't get a nice working relationship with his counterpart on the contractor's side and maybe something slips by that shouldn't?

Do you have a headquarters man that comes down occasionally and checks up? How do you practically go about that human thing of making sure that people are doing the quality job and safety job?

Dr. MUELLER. We have a reliability and quality group at headquarters which does do field inspections; we also, before submitting to a flight have a final review by our senior people who have not been involved in the checkout, both headquarters and field centers, other than Kennedy, that do go down through and audit it.

For example, that goes back to the factory. Before we accept the spacecraft, there is a team that spends several weeks going through the spacecraft making sure that all of the proper forms have been filled out, catching any discrepancies that have not been picked up before.

Since the accident, we have of course been very carefully examining both 012 and 014 in an attempt to find out whether our quality processes were good.

That is one of the basic questions and so far the results indicate that they were good.

We also have been going back looking at other spacecraft just to be sure that our procedures are good. We do, therefore, have both quality audits, if you will, by independent groups from headquarters and from the centers other than those directly involved and we also have final inspections by program people who have not been directly involved in the checkout whose one objective is to make this go.

There is a continuing observation and check and balance by the flight crews themselves who really do an effective and independent job of assessing the quality of the spacecraft and have a very considerable effect on making sure that the quality is good.

Mr. GURNEY. Your field people from headquarters, do they make surprise inspections to see what is going on?

Dr. MUELLER. Yes, sir; so do our program managers.

Mr. TEAGUE. Do you have any questions?

Mr. ROUDEBUSH. George, I don't want to prolong this Apollo accident, but I think it is very important to get it clarified in our committee's mind.

Was there any pessimism expressed by the astronauts about the success of the Apollo mission? One of the newspapers said one of our astronauts expressed a great deal of pessimism about the success and reliability of it. He, according to the newspaper article, "Hung a lemon on it."

Are you aware of any such criticism, and how much attention do you pay to the reports of the astronauts after these simulated training flights?

Dr. MUELLER. Let me try to answer that in two phases, if I may, since you have asked two questions, I think.

One, with respect to the spacecraft itself, I always have an opportunity to talk to the crew sort of separate from the normal day-to-day

operations and the flight crew for 204 did early in the checkout procedure raise some questions about the quality of that spacecraft.

Those questions were answered, corrective measures were taken, and before the spacecraft left the factory, they were completely satisfied that this spacecraft was as good as any spacecraft they have had experience with and that was their personal opinion.

We continued that as we got down to the cape and they continued to hold that opinion so that they had no doubt about the flight-worthiness of the spacecraft itself during the course of the checkout operation.

I think as we had earlier in Gemini, there were working problems and there are still problems in getting the simulators up to full operational capacity. In the early Gemini flights we had some problems in getting the simulators into the final flight configurations. The reason is that the simulators have to follow the flight hardware in a development cycle so they are several months behind in the flight hardware configurations in the course of the development cycles.

Also in the case of the Apollo program, we have taken advantage of what we learned in the Gemini and we have considerably more sophisticated simulated training equipment, and it has to be, because we are trying to develop here the capability of carrying out the lunar landing.

So there is a more sophisticated training equipment that is now in operation and was in operation during the course of the last several months of the Apollo training cycle. I think that again this problem has been solved.

First you have to recognize that you have problems before you can solve them. It is an unfortunate thing that the first time we build something it doesn't work perfectly—that is just characteristic of a complex system.

Mr. ROUDEBUSH. All of the complaints of the astronauts concerning the preliminary operation were looked into?

Dr. MUELLER. Yes, sir, and all of the real complaints were corrected.

Mr. ROUDEBUSH. What do you mean by real complaints?

Dr. MUELLER. Well, sometimes people will just complain about the color of the paint or something like that, but anything that had any real impact on the trainer or on the program had been corrected.

Mr. TEAGUE. George, I would like to ask a couple of the committeemen a question and they can answer or not.

Two of them have been to North American, Los Angeles, and have been through the spacecraft and they have been through the cleaning room. I would like to ask them what their impression was.

Mr. Gurney.

Mr. GURNEY. It looked like a pretty thorough job to me. I am not an engineer.

Mr. TEAGUE. Mr. Cabell.

Mr. CABELL. I was definitely impressed by the enthusiasm and by the keen interest they were taking in their work, even down to the mechanics and certainly I was not competent to be able to judge the quality of the work other than by the atmosphere which I thought was good.

I thought it was, under the circumstances out at North American, for example, excellent.

Mr. TEAGUE. Please continue.

Dr. MUELLER. The interest of this committee is well known as regards the future national space objectives. The report on this subject issued by Mr. Teague, the chairman of the Subcommittee on NASA Oversight on July 26, 1966, entitled "Future National Space Objectives," succinctly brought forth the considerations. With the chairman's permission I would like to quote several excerpts from this report.

In the letter of the report to the Honorable George P. Miller, chairman of the Committee on Science and Aeronautics, the Honorable Olin E. Teague, chairman of the Subcommittee on NASA Oversight, stated the following:

> Most important, however, is the identification of the need to make positive bold decisions on future national goals in space at the earliest possible time. To further delay these important decisions fails to serve the best interest of the people of this country and the free world.

In the conclusions of the report it was stated "the technology base now exists * * * to define objectives for a concerted program of exploration and exploitation in space during the 1970's." It further provided "criteria to develop a balanced well ordered national space program" and went on to state that "within the framework of the criteria * * * the national space program may be considered in reference to its near term—1967–76—and long term—1976–85—as to emphasis. For the near term, it is possible to utilize existing technology base to extend orbital stay time eventually leading to the establishment of a manned earth orbital system, and to extend the manned lunar stay time capability—possibly utilizing the lunar surface for an operational base—while expanding early detailed unmanned scientific exploration of the solar system and initiating manned flybys of the planets. For the longer term it is feasible to extend manned operation to landings on other planetary bodies and to extend the unmanned scientific explorations of space to the limits of our solar system and beyond."

In fiscal year 1966 the committee supported the Manned Space Flight efforts to define a follow-on program to Apollo. Further, in fiscal year 1967, this committee permitted us to hold open the options, thus permitting the maintenance of the technology base built over the past several years for the Apollo program. As we proceed through these hearings, I think the foresight of this committee's conclusions as published in the report of future national space objectives will become clearly evident. We will be showing plans to utilize the existing technology base to extend orbital stay time. We will be showing our plans to extend manned lunar stay time as well as our study effort leading to manned planetary flyby and to eventual manned planetary landings. We will also be showing the activity in Apollo Applications which will lead to the development of subsystems necessary to longer space flights.

With these considerations in mind, let me now review our progress against the objectives of Manned Space Flight. Here (M64–68) are the general objectives which are unchanged. Next (M64–61) are the specific objectives of the three manned space flight programs, Mercury,

Gemini, and Apollo. These objectives for Gemini and Apollo also remain unchanged from last year. The achievements of the past year reflect substantial progress toward the accomplishment of all of these objectives, both general and specific. We have completed all of the Gemini program objectives as I discussed earlier this morning. We did not accomplish the Gemini program objectives and the flights during the past year without difficulties, nor is it realistic to assume that we can accomplish the Apollo objectives without experiencing difficulties.

During the discussion of Apollo, I will cover the program status in detail and will show the accomplishments and the difficulties we have experienced over the last year in their total view. I believe it is important that the Apollo program progress be looked at in its total context, particularly in light of the recent unfortunate accident. There has been significant progress made which has been overshadowed by the tragic loss of three brave men—close colleagues to all of us in the program. It is only in retrospect that this shadow can be pierced to place the total Apollo program in its proper balance. The efforts of upward to 300,000 people have been devoted to this great challenge of landing a man on the Moon and returning him safely to Earth in this decade. The astronauts who have given their lives for this program were devoted to this goal. The greatest tribute that this Nation can pay to these brave men is to accomplish the goals that they worked so hard and gave their lives to help us meet. As I stated before the full committee, I do believe that we still have a reasonable possibility of meeting the major milestones for the Apollo program which were established in 1963 (MC65–5185). In particular, although the probability is lowered, I believe we will be able to land men on the Moon and return them safely to Earth before 1970.

In all our considerations of the current Apollo program and future programs, we have had the benefit of information and studies from several sources. The Committee on Science and Astronautics has provided us with invaluable information over the past several years. I have cited today the study effort published in 1966 on the "Future National Space Objectives." The studies on "Apollo Program and Progress" which were conducted last year and again this year have proven to be extremely useful in our program considerations, as have the new publications on "Space Flight Emergencies and Space Flight Safety" and the "Practical Values of the National Space Program" (fig. 15, MC67–5996).

The President's Science Advisory Committee (PSAC) published a report in February 1967 titled "Space Program in the Post-Apollo Period." I would like to spend a few moments discussing this report as it affects the Manned Space Flight future and relate the Manned Space Flight program you are considering today to the recommendations of the President's Science Advisory Committee. I will brief the recommendations from the PSAC report which have a significant impact on Manned Space Flight, then relate these recommendations to the Apollo Applications program.

Under lunar exploration, PSAC recommends manned expeditions at the rate of one and two per year (fig. 16, MC67–5990). Under the Apollo Applications program plans for our follow-on Apollo

CONGRESSIONAL AND OTHER REPORTS AFFECTING MANNED SPACE FLIGHT

- APOLLO PROGRAM AND PROGRESS
- SPACE FLIGHT EMERGENCIES AND SPACE FLIGHT SAFETY—A SURVEY
- PRACTICAL VALUES OF THE NATIONAL SPACE PROGRAM
- PRESIDENT'S SCIENTIFIC ADVISORY COMMITTEE REPORT- FEBRUARY, 1967- SPACE PROGRAM IN THE POST-APOLLO PERIOD

NASA HQ MC67- 5996
3/13/67

FIGURE 15

PRESIDENT'S SCIENCE ADVISORY COMMITTEE REPORT

FEBRUARY, 1967

RECOMMENDATIONS AFFECTING MANNED SPACE FLIGHT	APOLLO APPLICATIONS PLAN
LUNAR EXPLORATION	
MANNED EXPEDITIONS ONE AND TWO PER YEAR	PRIME OBJECTIVE - FOLLOW-ON MISSIONS
MANNED LOGISTICS SUPPORT	LUNAR MODULE (LM) SHELTER/TAXI
EXPLORE PARTS OF MOON NOT ACCESSIBLE TO APOLLO-SYSTEM DURING 1975-80	FOLLOW-ON MISSIONS OBJECTIVE

NASA HQ. MC 67-5990
3/13/67

FIGURE 16

Applications missions, this is a prime objective, as shown on the chart (fig. 17, MC67-5412)—extended lunar exploration.

A second recommendation under lunar exploration is that a manned logistics support system should be developed for lunar stay. Under Apollo Appplications planning we have a program to develop a lunar module shelter taxi which I discussed before this committee last year as an advanced manned mission study effort. Later I will cover this in more detail when we discuss the Apollo Applications program.

A third recommendation of PSAC was to explore during 1975–80 parts of the Moon not accessible to Apollo. This, too, is a follow-on missions objective of the Apollo Applications and currently in our advanced manned mission plans there are definition and design studies on mobile lunar exploration.

Mr. RUMSFELD. Are there any safety recommendations made by PSAC that will show up in these slides?

Dr. MUELLER. Are you thinking of space rescue versus safety?

Mr. RUMSFELD. As I recall in your response to my questions, you indicated that PSAC represented to some extent something comparable to an independent review board and you were mentioning their recommendation in manned space flight. Do you have any recommendations from them that relate to safety?

Dr. MUELLER. To the best of my knowledge, although they did look into our safety practices, they did not recommend any changes. I believe there are no recommendations in their report on safety per se.

Mr. RUMSFELD. Thank you.

Mr. TEAGUE. Mr. Gurney?

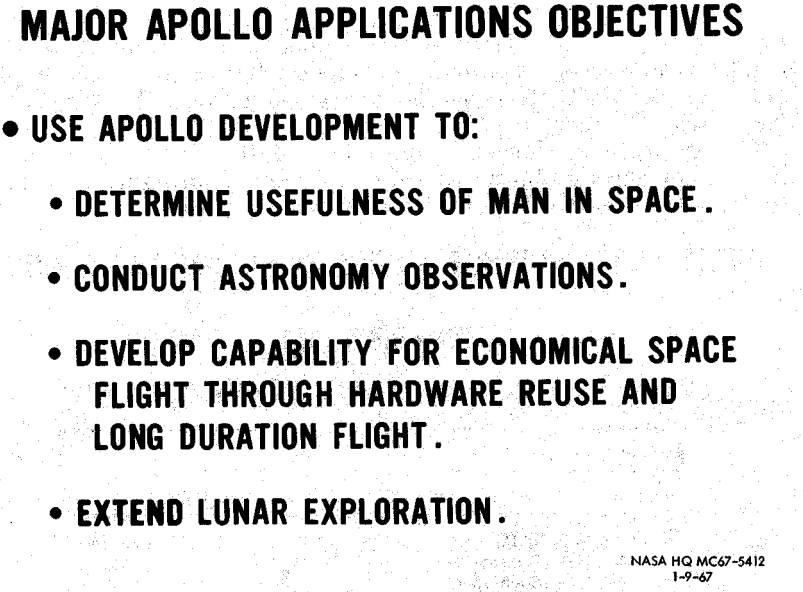

FIGURE 17

Mr. GURNEY. I think our chairman, Mr. Teague, has made comment from time to time on the possibility of a rescue vehicle. Do you contemplate this taxi concept as a rescue vehicle also?

Dr. MUELLER. So far, our studies of the extended lunar operations have not led us to believe that a taxi as a rescue vehicle would be a reasonable next step and the reason is the very long storage time that would be required on the lunar surface and the problems that are associated with that long storage time. However, that is one of the things that we are looking at in the course of these studies.

Mr. GURNEY. I was thinking more of the rescue vehicle in connection with earth orbital missions rather than lunar missions.

Dr. MUELLER. We are jointly with the Air Force looking at various means for rescuing people from earth orbit, and there are studies going on in this area. The shelter taxi, itself, is not adaptable to that.

Mr. GURNEY. What is your time schedule if you have any on rescue vehicles?

Dr. MUELLER. At the present time, there is not a program nor a schedule for the development of a rescue vehicle.

Mr. TEAGUE. Well, George, isn't it true, though, that each thing you have done in the Gemini program has made some contribution to an eventual rescue——

Dr. MUELLER. Yes, sir.

Mr. TEAGUE. Your docking and extra vehicle dock all contribute to a rescue capability?

Dr. MUELLER. All those are steps which lead to the capability of carrying out a rescue mission.

Mr. TEAGUE. Continue.

Dr. MUELLER. Under the Planetary Exploration section of this report (fig. 18, MC67–5995) they recommend an early integrated study of relative effectiveness of man in planetary flyby and orbiter missions and that the effectiveness should be considered both for the manned and unmanned mode.

This recommendation is in line with one of our major Apollo Applications program objectives shown previously on figure 18 (MC67–5412)—to determine the usefulness of man in space.

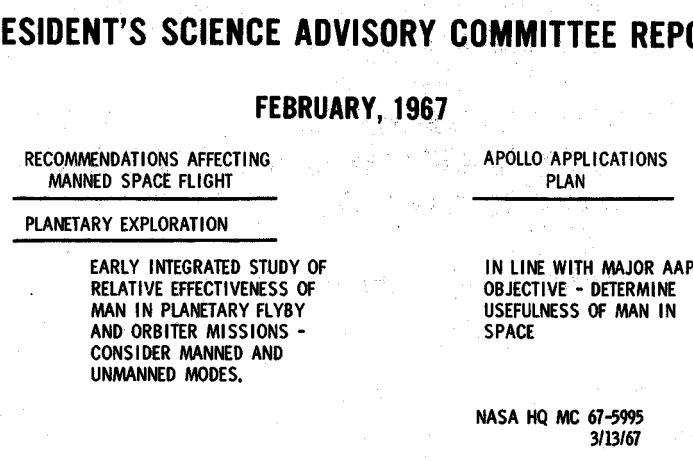

FIGURE 18

Under our Advanced Manned Missions study effort, we have a joint action group involving several elements of NASA studying the manned planetary flyby system requirements and manned planetary landing requirements. As you know from the presentation by Dr. Newell before the full committee, we have recommendations before the Congress to approve funding for the Voyager program in the fiscal year 1968 budget.

This program will provide useful data through unmanned flight to the planets. These flights will in turn, be significant to manned planetary activity. The Marshall Space Flight Center is a major participant in the Voyager program, thus providing a close tie between the manned and unmanned activity. Additionally, Dr. Adams in his presentation before the full committee defined the activities related to the nuclear engine NERVA II, which is an important development to a manned planetary landing program in the future.

Both the Voyager and the NERVA II systems require a launch vehicle of the Saturn V class for development and mission activity. The Apollo Applications program as we have presented it to the Congress will maintain the Saturn V capability for this useful work in meeting the Apollo Applications objectives as well as providing this capability for two programs.

Under the recommendations for a Manned Space Station (fig. 19, MC67–5994), the President's Science Advisory Committee report states that a launch in mid-1970's for the first module of the space

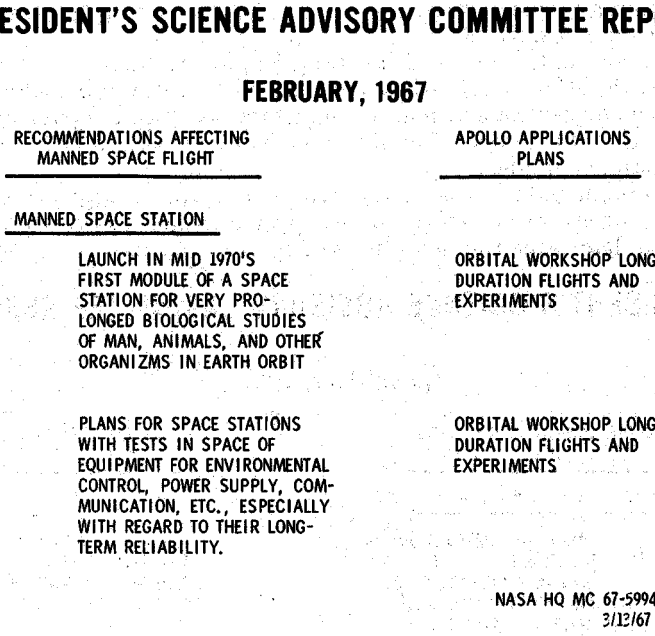

FIGURE 19

station for very prolonged biological studies of man, animal, and other organisms in Earth orbit is recommended. Within the Apollo Applications plans, the first step toward meeting this recommendation is the orbital workshop which can lead to long duration flights up to 2 months and experiments to determine the capability of man to function in this environment for periods up to 1 year. In the advanced manned mission planning effort we have a joint action group consisting of representatives of the NASA program offices who are studying Earth orbital missions of 1 year duration and longer.

The second recommendation of the Committee's report under Manned Space Station was for plans for space stations with test in space of equipment, especially that equipment related to long-term reliability. In the Apollo Applications plans, the orbital workshop will provide a testbed for experimentation in long duration flight subsystems and systems.

The advanced manned missions Earth orbital studies will extrapolate this information to the longer duration capability which in turn will be tested in followon Apollo Applications missions of up to 1 year duration, recommended by the President's Science Advisory Committee.

Mr. GURNEY. Back to the question I asked about a rescue vehicle, why wouldn't it be possible to have a vehicle with a dual capability, taxi, or shuttle vehicle and a rescue vehicle?

Dr. MUELLER. I am sure that it is possible, Mr. Gurney. There are limitations as to the availability, the ability of vehicles to rendezvous in orbit. There are only a few minutes on several orbits during the day in which one can actually carry out a rendezvous. So we are looking at not only a possibility of a rescue vehicle coming up from the ground but also incorporation of the equivalent of lifeboats with the orbiting vehicle so that you can return from orbit in the event of a failure.

Mr. GURNEY. Well, I know, of course, that you have a limited time to effect a rendezvous, but I can't understand why a vehicle can't have a dual capability. It has to get up, it has to get to the vehicle upstairs. These people have to get back. Why can't you incorporate both capabilities? Why don't you look at both capabilities?

Dr. MUELLER. We are looking at both capabilities, Mr. Gurney, in a single vehicle.

Mr. GURNEY. Let me put it this way: I thought your answer was that you are looking at the air taxi concept in connection with the Apollo Applications program of the long workshop flights, but you were not looking at a rescue capability in connection with the same program. That was something else over here and an entirely different thing. My question is in your Apollo Applications program, you are going to have a vehicle that goes from Earth up to this workshop and back again, isn't that correct?

Dr. MUELLER. Yes, sir.

Mr. GURNEY. Why does it not also include a rescue capability? Why couldn't it?

Dr. MUELLER. Well, let me be sure I can clarify an earlier point. The shelter taxi that I was discussing is a development that has to do with landing on the Moon, a dual landing.

Mr. GURNEY. I am talking about Earth orbital missions.

Dr. MUELLER. The spacecraft that we are using for the resupply of the orbital workshop is, of course, capable of returning some individuals from the orbital workshop. The problem we have is that in order to carry out the rendezvous we need to send at least one man and normally two men up into the orbital workshop that then leaves at most one or two, generally speaking, one vacant seat to bring someone down. Therefore one would have to have three of these devices if you used a two-man flight to go up there. That will be considerably improved if we can in fact develop the land landing capability with the Apollo spacecraft and the ability to carry six men because then that would carry four or five people back from orbit on a single vehicle that might have a reasonable rescue capability. So in a sense, we are working on that, we are trying to develop the capability for this kind of an operation.

Mr. GURNEY. I guess you have answered my questions. Let me finish it off with another question. In examining the air taxi concept or shuttle concept, is your rescue mission or factor in this being given as much emphasis as recently the shuttle capability?

Dr. MUELLER. In all honesty at this point in time, we are primarily concerned with the development of the capability of rendezvousing and refueling.

Mr. GURNEY. Don't you think it would be a good idea to think of the other thing. You have the propulsion that is sufficient enough even for a six-man spacecraft.

Dr. MUELLER. I only pointed out that we are, in fact, looking at the other as well, but the constraints of, among other things, the budget limits the amount of effort we can devote to many things that would be very desirable.

Mr. TEAGUE. Do you have any questions, Mr. Roudebush?

Mr. ROUDEBUSH. No.

Dr. MUELLER. In the area of Space Science in Earth Orbit, the PSAC recommended the establishment and Earth orbit of a number of astronomical facilities which by the end of the 1970's will constitute an orbiting astronomical observatory (fig. 20, MC67–5993). We will present to this committee as part of the Apollo Applications missions, the Apollo Telescope Mount, which is a necessary preliminary step toward achieving this goal. The Apollo Telescope Mount will place in orbit astronomical instruments capable of gathering important solar scientific data. Later, if the advanced manned missions studies reach fruition, manned Earth orbital telescopes of 38-inch, 60-inch, and finally 120-inch configurations can be placed in Earth orbit.

It is of interest to note that even a 38-inch telescope in Earth orbit would be superior to the 200-inch Mount Palomar telescope in effective resolution capability as well as in spectral range. The 120-inch telescope should increase our capability for resolving celestial objects by a factor of 20, extend range by four magnitudes of brightness and allow observations to detect planets the size of Jupiter in orbit about the closest star Alpha Centauri.

Continuing on with the recommendations of the PSAC report in the area of Biomedical Studies and the Qualifications of Manned Prolonged Space Missions (fig. 21, MC67–5989), they recommend that

PRESIDENT'S SCIENCE ADVISORY COMMITTEE REPORT

FEBRUARY, 1967

RECOMMENDATIONS AFFECTING MANNED SPACE FLIGHT	APOLLO APPLICATIONS PLANS
SPACE SCIENCE IN EARTH ORBIT	
ESTABLISH IN EARTH ORBIT A NUMBER OF ASTRONOMICAL FACILITIES, WHICH BY THE END OF THE 1970'S WILL CONSITUTE AN ORBITING ASTRONOMICAL OBSERVATORY.	ATM EXPERIMENT NECESSARY PRELIMINARY STEP - MAJOR AAP OBJECTIVE

NASA HQ MC 67-5993
3/13/67

FIGURE 20

PRESIDENT'S SCIENCE ADVISORY COMMITTEE REPORT

FEBRUARY, 1967

RECOMMENDATIONS AFFECTING MANNED SPACE FLIGHT	APOLLO APPLICATIONS PLANS
BIOMEDICAL STUDIES AND THE QUALIFICATION OF MAN FOR LONG SPACE MISSIONS	
1. PHYSIOLOGICAL AND PSYCHOLOGICAL STUDIES OF MAN FOR EXTENDED PERIODS IN SPACE. THESE EXPERIMENTS TO BE USEFUL IN PREDICTING PERFORMANCE IN INTERPLANETARY FLIGHT	1. IN LINE WITH DETERMINING USEFULNESS OF MAN IN SPACE AND LONG DURATION FLIGHT OBJECTIVES AND EXPERIMENTS
2. ORBITAL WORKSHOP EXPERIMENT SHOULD PROCEED	2. PART OF AAP MISSIONS
3. STUDY BE MADE OF THE SUITABILITY, COST AND AVAILABILITY OF TITAN III/MOL SYSTEMS FOR BIOMEDICAL STUDIES OF MAN FOR PERIODS UP TO 60 DAYS.	3. PART OF THE FUNCTION OF THE MANNED SPACE FLIGHT EXPERIMENTS BOARD AND THE AACB
4. USE THE MOL PROGRAM AS SOURCE OF DATA ON THE CAPABILITIES OF MAN FOR MISSIONS LASTING 14 TO 30 DAYS.	4. PART OF THE FUNCTION OF THE MANNED SPACE FLIGHT EXPERIMENTS BOARD WHICH IS JOINTLY CHAIRED BY THE DOD.
5. BIOMEDICAL STUDIES INVOLVE EXTENDED DURATION FLIGHTS OF 100 DAYS OR MORE, AND WILL REQUIRE MAJOR REDESIGN OF MOL COMPONENTS, OR MAJOR NEW DEVELOPMENTS IF BASED ON APOLLO HARDWARE. NASA MUST DETERMINE MOST EFFECTIVE AND ECONOMICAL APPROACH.	5. PART OF THE FUNCTION OF THE AACB AND MSFEB

NASA HQ MC 67-5989
3/13/67

FIGURE 21

physiological and psychological studies of man for extended periods in space be conducted and these experiments would be useful in predicting man's performance in interplanetary flight. In the Apollo Applications program the first objective as shown previously on figure 18 (MC67–5412) is to determine the usefulness of man in space and further, the PSAC recommendation ties in with our objective to perform longer duration flight as well as experiments.

Second, they believe as we do that the orbital workshop experiment should proceed.

This will be covered during the Apollo Applications presentation as part of the alternate Apollo Applications mission planning.

The third recommendation in this category is that a study be made of the suitability, cost, and availability of Titan III Manned Orbiting Laboratory systems for biomedical studies of man for periods up to 60 days (fig. 22, ML66–9787). Last year in my presentation covering the experiments program we mentioned the fact the Department of Defense does participate in the Manned Space Flight Experiments Board and as shown on the chart on the right they are continuing to participate.

In addition, the Aeronautics and Astronautics Coordinating Board is familiar to the members of the committee and does take such studies under its consideration and is continuing to study this area.

Similarly, the fourth recommendation is the use of the MOL program as a source of data on capabilities of man for missions lasting 14 to 30 days. This, too, is tied in with the function of the Manned

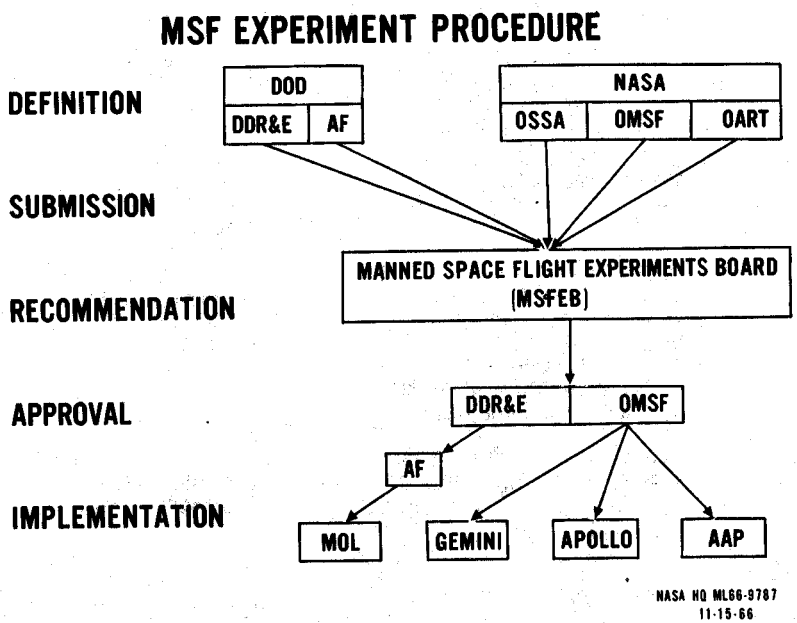

FIGURE 22

Space Flight Experiment Board which is, as I mentioned, jointly chaired by the Department of Defense and the other associate administrators of the NASA program offices.

The fifth recommendation relating to biomedical studies during extended flights of 100 days or more and determining the most effective and economical approach to this activity is carried out in the Apollo Applications plans through the orbital workshop—an embryonic space station that I mentioned during the full committee hearings, and which I will cover in more detail under Apollo Applications. With this mission and subsequent flights, we would be revisiting this equipment in orbit as shown on the third objective of the Apollo Applications program. Revisiting the cluster in orbit with a resupply of expendables and crew would be, in effect, making the first reuse of hardware which we consider the most economical approach at this time. It is our present thinking that through the reuse of hardware placed in orbit and through the extension of long duration flight to 28, 56, and upwards to 180 days and then a full year duration we gain the most cost effective utilization of space equipments.

The next recommendation of the PSAC report covers Space Applications—Manned and Unmanned (fig. 23, MC67-5991). The first

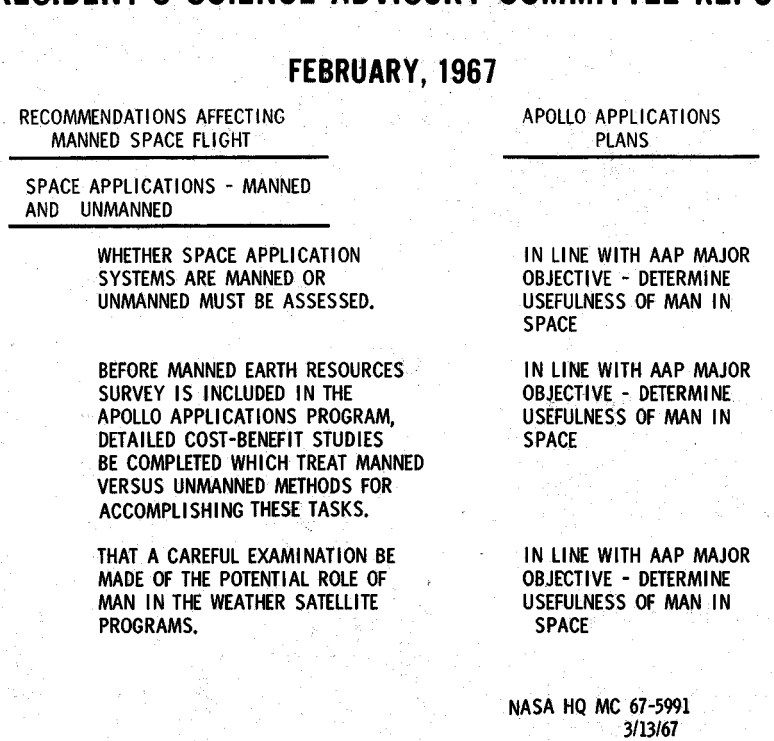

FIGURE 23

recommendation under this category considers that an assessment must be made of whether space applications should be manned or unmanned. I believe that this area probably requires some clarification. There appears to be some confusion with respect to the applications program of NASA and the Apollo Applications program. Mr. Jaffe presented to the full committee the applications program of NASA. Under the Office of Space Sciences and Applications, he is heading an overall NASA program to define applications in space regardless of the manned or unmanned aspect which in all instances requires selecting the most effective and economical means of getting the greatest return on our investment.

The Apollo Applications program is one element of this overall applications plan. In the Apollo Applications program there will be a capability for utilizing the launch vehicles and the spacecraft in unmanned as well as manned modes. We in Manned Space Flight are principally concerned with the manned aspect of the Apollo Applications program. As I have mentioned, however, the equipment developed under Apollo can be used in many areas. In any event, this PSAC recommendation is being met initially by one of the major objectives of AAP to determine how useful man is in space and in what activities will his capabilities best be utilized.

The second recommendation covers the cost-benefit studies necessary to an applications program for earth resources prior to inclusion in the Apollo Applications program. This also ties in with the first objective of Apollo Applications. Further, this particular aspect is one of the considerations that has led NASA to initiate a Practical Application symposium.

The third recommendation in the category of space applications is that a careful examination be made of the potential role of man in the weather satellite programs. This, too, is in line with the objectives of the Apollo Applications program and further is an area of considerable study by the U.S. Department of Commerce, Environmental Science Services Administration (ESSA). They are conducting studies of promising ways in which future manned and unmanned platforms might be used in assisting ESSA to carry forward their mission responsibilities.

The last area where we feel the recommendations of the PSAC report have a direct effect on the Manned Space Flight program is the area shown on this chart—Post Apollo Production Rates for the Saturn V, Apollo Spacecraft Modules, and Uprated Saturn I (fig. 24, MC67–5992) In their report PSAC recommended a Saturn V production rate of four per year. As shown the Apollo Applications program planned rate is four per year.

Secondly, they recommend a production of a minimum number of uprated Saturn I vehicles and we have established a production rate on the Apollo Applications program which we consider is the minimum level of effort to maintain this capability and it is for an average of four per year.

Thirdly, the study of the feasibility of four-man and six-man Apollo Command Module ferry systems is one of the follow-on mission objectives of the Apollo Applications program, that is, this conversion can result from developing a land-landing capability by modifying

PRESIDENT'S SCIENCE ADVISORY COMMITTEE REPORT

FEBRUARY, 1967

RECOMMENDATIONS AFFECTING MANNED SPACE FLIGHT	APOLLO APPLICATIONS PLANS
POST-APOLLO PRODUCTION RATES FOR THE SATURN V, APOLLO SPACECRAFT MODULES, AND UPRATED SATURN I	
1. SATURN V PRODUCTION - FOUR PER YEAR	1. AAP PLANNED RATE IS FOUR PER YEAR
2. PRODUCTION OF MINIMUM NUMBER UPRATED SATURN I VEHICLES	2. AAP PLANNED RATE IS FOUR PER YEAR
3. (a) STUDY FEASIBILITY OF A FOUR-MAN AND SIX-MAN APOLLO COMMAND MODULE FERRY-SYSTEM	3. (a)FOLLOW ON MISSION OBJECTIVE
(b) COMPARATIVE STUDY OF APOLLO COMMAND MODULE LAUNCHED BY AN UPRATED SATURN I BOOSTER OR BY A TITAN III-M BOOSTER.	(b) AACB JURISDICTION

NASA HQ MC 67-5992
3/13/67

FIGURE 24

the Apollo Command Module, thus leading to a four-man or six-man configuration. Additionally, under that recommendation, PSAC suggests a comparative study of the Apollo Command Module launched by an uprated Saturn I booster and a Titan IIIM booster. Studies of this nature are underway and have been for some time before the Astronautics and Aeronautics Coordinating Board (AACB) and will be continued in the future.

I believe that in the total analysis of the PSAC recommendations and the planning done for Apollo Applications in our advanced mission planning, that there is a considerable degree of congruence between our recommendations to the Congress and those of the PSAC to the President. Under the present tight budgetary limitations placed on NASA and Manned Space Flight, we are not able to meet all the recommendations of the PSAC and in some instances we are not able to carry them quite as far as they recommend. However, on balance, we feel that we have submitted to the Congress a program which will maintain a vigorous progress in space while providing worthwhile benefits in the several areas recommended by PSAC, although on a somewhat austere basis.

In concluding these introductary remarks, I would like to again go back to my presentation before the full committee and cite some

reasons why the Manned Space Flight program merits your support at this time (fig. 25, MC67–5971). There are points shown on this chart which I consider significant and worthy of some short discussion. First, through your support of the Manned Space Flight program, we will maintain the orderly pace of our progress in the space age at a time when there may be opportunities to move ahead of the Soviets in space achievement. It will guard against the possibility of technological "surprise" by supporting the continued advance of an industrial technology.

I would like to digress at this point to show you an outstanding example of this advancement in industrial technology which has evolved from the Manned Space Flight program—from the Gemini and more significantly from the Apollo developments. Figure 26, (MC67–5987) shows a young lady standing with a console which is called a Powercel Model 10A. This is a natural gas fuel cell powerplant being developed by Pratt-Whitney Aircraft. It provides more than 3,750 watts of electrical power. This air-cooled unit operates silently and has clean exhaust products, that is, carbon dioxide and water.

Pratt-Whitney Aircraft has delivered a unit of this type to a commercial gas distributor, for research and investigation of fuel cell

REASONS TO SUPPORT MANNED SPACE FLIGHT PROGRAM

- MAINTAIN ORDERLY PACE OF OUR PROGRESS
- GUARD AGAINST TECHNOLOGICAL "SURPRISE"
- MAINTAIN COMPETITIVE POSITION IN THE WORLD MARKET PLACE
- SUPPORT RESEARCH AND DEVELOPMENT VITAL TO SECURITY
- AVOID DISSIPATION OF SPACE CAPABILITY
- HOLD OPPORTUNITY TO RETURN DIRECT BENEFITS TO MAN
- TAKE ADVANTAGE OF OPPORTUNITIES FOR EXPANSION OF KNOWLEDGE
- PROVIDE THE MEANS TO MEET THE CHALLENGE OF THE FUTURE AT MODEST COST
- PROVIDE THE CAPABILITY TO EXPAND OUR SPACE ACTIVITY IF INTERNATIONAL SITUATION SHOULD CHANGE

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3-7-67

FIGURE 25

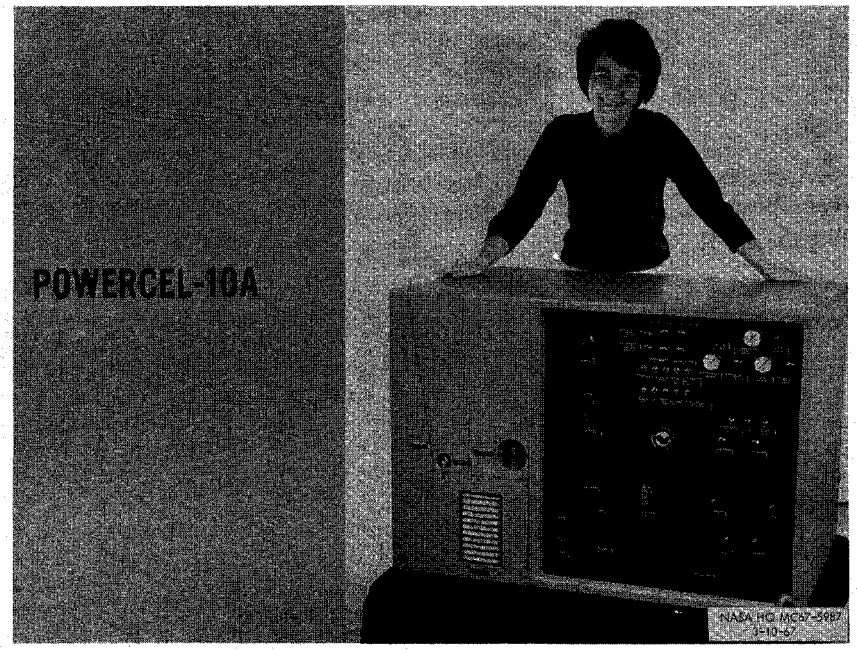

FIGURE 26

operating characteristics for household use. Jointly the Pratt-Whitney Corp. and 25 gas companies have invested about $26 million into the development and marketing of power cells. The forcing function which is permitting the development of this equipment as a marketable household item was the Apollo fuel cell which supplies the electrical power and drinking water for the Apollo Command Module.

This unit, which is an innovation of the Apollo fuel cell technology, is a self-contained system that may provide heat, air conditioning, and electrical power for homes at a higher efficiency than conventional systems while at the same time eliminating much of the air pollution resulting from power generation and home heating. Additionally, it would provide a system that would not be subjected to the conditions that developed in the New York area last year.

The next chart (fig. 27, MC67–5986) shows the relative efficiencies of fuel cell in comparison to a gasoline generator, a diesel generator, and a steam turbine generator system. As you can see the fuel cell is considerably more efficient in the production of electrical power. It has been estimated that if this fuel cell project is successful, then they see themselves marketing this product for homes in about 9 years. They feel that no new distribution lines will be needed to carry the extra gas to the homes because only a 20-percent increase in usage would be involved, an amount which they claim can be easily accommodated with

POWER SYSTEM EFFICIENCY RELATIONSHIPS

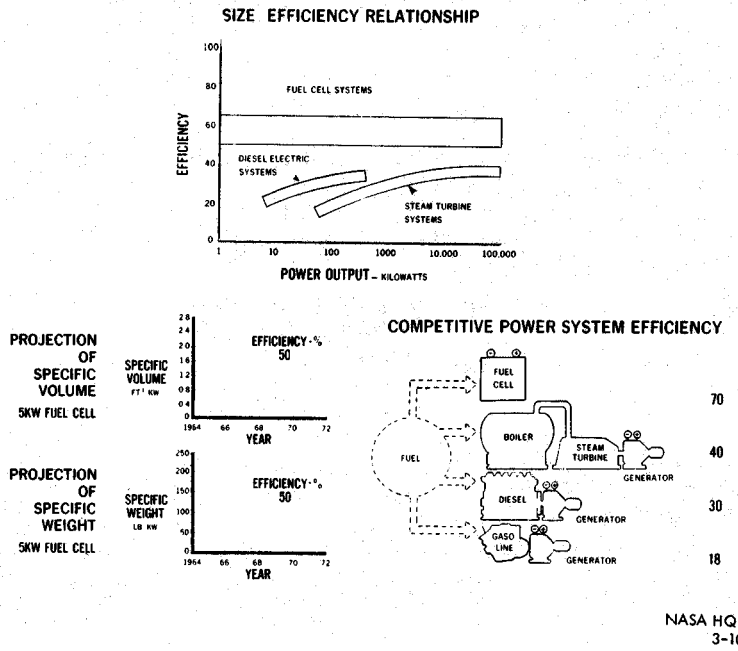

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FIGURE 27

the present system. I feel that the committee would be interested in this technology transfer from the space program, particularly in the light of advancing industrial technology and forming new markets for the civilian economy, which in the final analysis is the base of our economic posture.

Going on with the reasons (see fig. 25, MC67–5971) for supporting Manned Space Flight at this time—it will maintain the forward momentum that space technology has given our competitive position and the world marketplace through research and development for our industrial technology. Here again, the example I have just cited is significant. Further, the MSF program will support the broad base of research and development vital to our security as a nation.

It will take advantage of the tremendous opportunities for expansion of knowledge at a time when space-based astronomy and exploration embracing the whole field of space science show promise of breaking through into an era of real discovery.

It will provide the means to meet the challenge of the future in space at a relatively modest cost as measured against a percentage of gross national product. The peak was in fiscal year 1966 when NASA ex-

penditures totaled eighty-three hundredths of 1 percent of the gross national product. In the current fiscal year they are about seven-tenths of 1 percent. In the budget proposed for FY 1968 the total would be about sixty-six hundredths of 1 percent.

And finally it will provide the capability to expand our space activity if the international situation should change. The resulting stabilizing benefits would thus be insured because this proposed program would keep the space team together and in a position to respond to economic developments on the national scene.

A recent article in Fortune magazine of March 1967, titled "U.S. Economy Enters a New Era" which discusses the need for economics stimuli, states—

> That the great boom has come to an end and the performance is not likely to be matched in the next few years.

This article brings out important areas related to the space activity. The article shows that national defense, space, and other Federal purchases represent a narrow segment of the total gross national product.

Significantly, the article indicates that in an economy so big and so dynamic many possibilities are open for stimulation.

It indicates that—

> Technological innovations favor the kind of investment that results in the introduction of new products that may enlarge consumer demand. Many new consumer products only displace other products, but now and then a product comes along like that creates demand which wasn't there before. Such consumer products, in turn, engender new capital investment to make and market them.

Looking ahead beyond 5 years to the middle seventies, the article goes on to state, it is possible to discern potentialities for invigorated demand in accelerated growth—the evolution of new technologies and new ways of thinking systematically about the future will result in, among other things: an increase in overall economic efficiency, an array of products novel enough to create new demand for both producer and consumer goods, and an improved capacity to translate social aspirations into effective action.

It further states that—

> It takes time to move from technological innovations to marketable new products and it takes time also for new ways of thinking * * *. During the next several years, some of the most important new products will not be counted in the national income and product tabulations. These new products will be the new concepts plans and formulations that will gradually diminish the gap between our aspirations to achieve a greater society and our dimmed notions of how to achieve it or even of what it will be like when we do.

Yet space is a perfect example of Government funding which sets the pace of technology. However, as the article states:

> That although the space purchases came to around $6 billion last year, that with the Apollo development costs past their peak they will be declining in the next couple of years.

(The complete prepared statement of George E. Mueller follows:)

PREPARED STATEMENT OF GEORGE E. MUELLER, ASSOCIATE ADMINISTRATOR FOR MANNED SPACE FLIGHT, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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APOLLO PROGRAM

INTRODUCTION

In the Apollo program (fig. 1, MA66–9411), three Apollo/Saturn missions were successfully flown in 1966. We have experienced difficulties which we must expect when working, as we are, at the far edge of today's technology. We have been relatively successful in taking management actions to overcome these obstacles. However, the tragic accident of January 27, 1967, which took the lives of the three Apollo 204 astronauts, confronted us with a situation that eclipsed in severity any difficulties we have experienced to date in the program. As Mr. Webb mentioned to you on February 28, I will today discuss the pattern of work that we are undertaking as a result of the Apollo 204 accident.

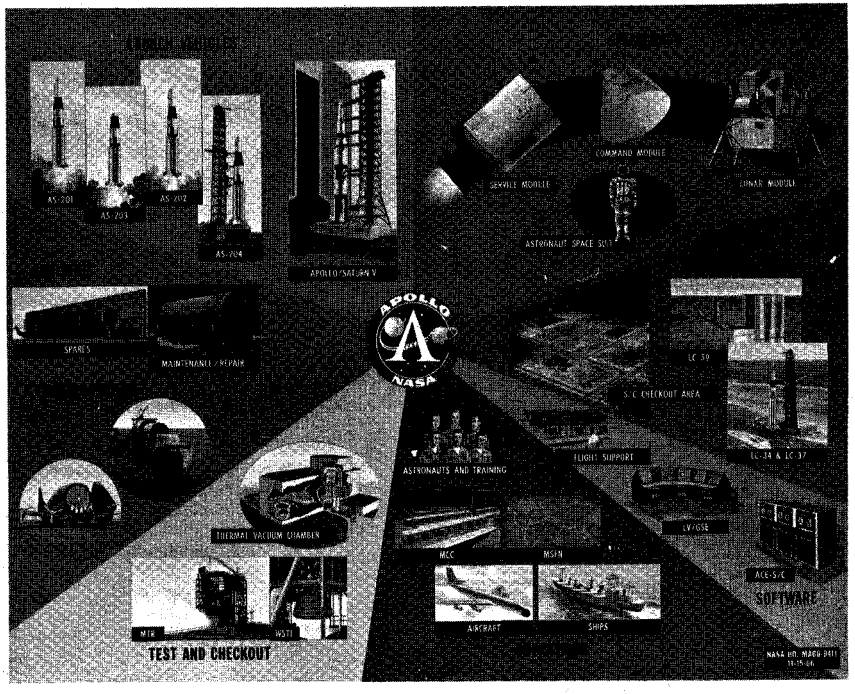


FIGURE 1

AS–204 accident

The fire in the Apollo spacecraft cabin occurred under conditions and using procedures which had been verified by 7 years of manned spacecraft operational experience. Standards of design, manufacture, test and operations which have been developed over the years had demonstrated that the possibility of a fire in the spacecraft cabin was remote. This background led to our considering this type of test as nonhazardous. The fire proves the approach we had been using of preventing fires by preventing their ignition is inadequate. We are introducing a three-prong approach to the prevention of fire in the future (fig. 2, MC67–5961). We will continue to minimize the possibility of ignition but will recognize that this possibility will always exist. We will take steps to limit and insofar as possible, eliminate the chance of a fire propagating once it is started and finally, we will arrange to minimize the consequences of a fire to the crew.

Efforts resulting from AS–204 fire

The Apollo organization of government, industry and universities has devoted all applicable talent and resources to matters arising from the AS–204 fire since it occurred. In our work, we have given highest priority to supporting the Apollo AS–204 Review Board in its investigation. We have concurrently undertaken analyses and design studies with the objective of identifying such changes in design or procedure as are necessary to assure a satisfactory solution of the fire hazard problem.

The work we are doing is in five general areas (fig. 3, MC67–5938). First, there is support of the Board in understanding the causes of the AS–204 fire and its propagation. Second, we are simulating the various phases of the fire through materials test, boilerplate ground tests and special experiments. Third, we are reviewing the Apollo design and implementation in light of the knowledge we have gained from the fire. This effort includes a review of all of our procedures to insure a reevaluation from a safety standpoint as well as a reevaluation of

APPROACH

IGNITION

- REDUCE PROBABILITY - CANNOT ABSOLUTELY ELIMINATE
- AREAS OF INVESTIGATION
  - MATERIALS
  - ELECTRICAL
  - QUALITY

PROPAGATION

- SIGNIFICANTLY REDUCE - POSSIBLY ELIMINATE
- AREAS OF INVESTIGATION
  - MATERIALS
  - LAYOUT
  - CONFIGURATION CONTROL

CONSEQUENCE

- AFFECTED BY
  - MATERIALS
  - CREW PROTECTION
  - FIRE DETECTION
  - FIRE EXTINGUISHER
  - ESCAPE PROVISIONS
  - PROCEDURES

NASA HQTRS.
MC67-5961

FIGURE 2

LINE OF ACTION

- **UNDERSTAND THE AS-204 FIRE**
  - **IGNITION SOURCES**
  - **FIRE PROPAGATION**
- **SIMULATE PHASES OF FIRE**
  - **MATERIAL TESTS**
  - **BOILER PLATE GROUND TESTS**
  - **SPECIAL EXPERIMENTS**
- **REVIEW APOLLO DESIGN AND IMPLEMENTATION IN LIGHT OF FIRE**
- **MAKE NECESSARY CHANGES**
  - **DESIGN**
  - **PROCEDURES**
- **EVALUATE REDESIGN**
  - **MATERIAL TESTS**
  - **BOILER PLATE GROUND TESTS**
  - **SPECIAL EXPERIMENTS**

NASA HQ MC67-5938
3-1-67

FIGURE 3

electrical power systems and cabling, communication systems, related specifications and qualification requirements, and quality control and inspection standards. The fourth area is the conduct of those designs and analyses that will implement changes identified by the Board and by our own review. Finally, we will need to evaluate the new designs and the new procedures to be sure that they are sound.

Specific actions, which I will cover in detail later, are being taken in fire detection, fire extinguishing, materials, cabin configuration, emergency egress, spacecraft atmospheres, and environmental control systems.

PROGRAM PROGRESS

Apollo/Saturn missions, ground testing at the Manned Spacecraft Center, the demonstration of the launch complex at Kennedy Space Center, and other events give us encouragement. The difficulties we have encountered in unmanned ground testing, though disappointing, yield engineering knowledge to the program. The many successes of 1966 and our capacity to react to expected obstacles demonstrate the overall stability of the program.

This stability rests upon our program objectives, unchanged since 1963 when they were first defined. The operational accomplishments of the Gemini program during 1966 have contributed considerably to our prime objectives of attaining United States leadership in manned space flight. The Apollo program is preparing to advance this objective as we move toward the lunar missions which will demonstrate a new level of manned space flight capability.

MISSION OBJECTIVES

Program phasing

The basic logic of our flight program incorporates seven major phases for the Apollo/Saturn flight schedule. This plan employs both the uprated Saturn I launch vehicle and the Saturn V (fig. 4, MC66–10,262). The sequence of the

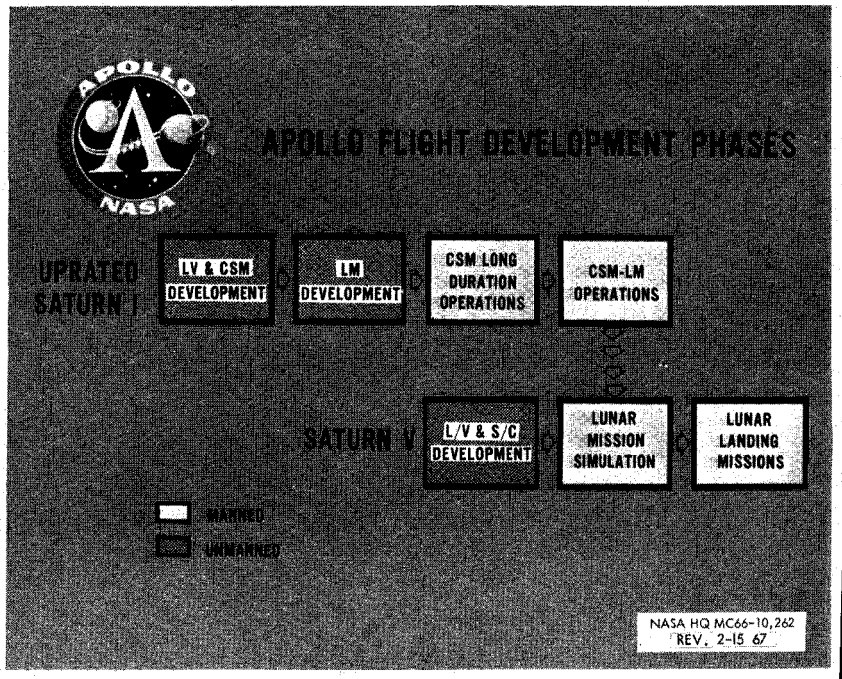


FIGURE 4

manned Command-Service Module flights and Lunar Module development flights on the uprated Saturn I launch vehicle has now been adjusted in the light of recent events.

The first Apollo/Saturn I program phase included unmanned launch vehicle and Command-Service Module flights and was completed with the successful AS–202 mission in August 1966. Remaining phases include unmanned Lunar Module development, manned Command-Service Module long duration operations, and manned missions involving orbital operation of the Command-Service Module with the Lunar Module. This last phase was planned to utilize uprated Saturn I vehicles in dual launches. All of the Apollo/Saturn I flights are limited to low earth orbits.

The first Saturn V phase consists of unmanned launch vehicle and spacecraft development flights. Manned lunar mission simulation flights with the Apollo Saturn V are the next to last phase of the program. The Apollo flight program will continue in the Apollo/Saturn V missions achieving manned lunar landing and return.

Flight mission timetable

To accomplish the manned lunar landing before the end of 1969, we established some time ago, a timetable for carrying out each of the flight mission phases (fig. 5, MC65–5185). Changes to the Apollo/Saturn schedule within these milestones were announced in November 1966 as the result of certain launch vehicle and spacecraft development difficulties. Because of the spacecraft fire in January 1967, the schedule was further modified in February 1967 (fig. 6, MC67–5782).

We plan to continue with the three unmanned launches—AS–206, 501, and 502—scheduled for 1967. AS–206 will be an unmanned qualification of the Lunar Module, while AS–501 and AS–502 will be unmanned qualification flights for the Saturn V launch vehicle and Command and Service Modules.

Manned flights, however, scheduled to begin in 1967, are under study and will be adjusted as necessary after the findings of the Apollo 204 Board have been assessed.

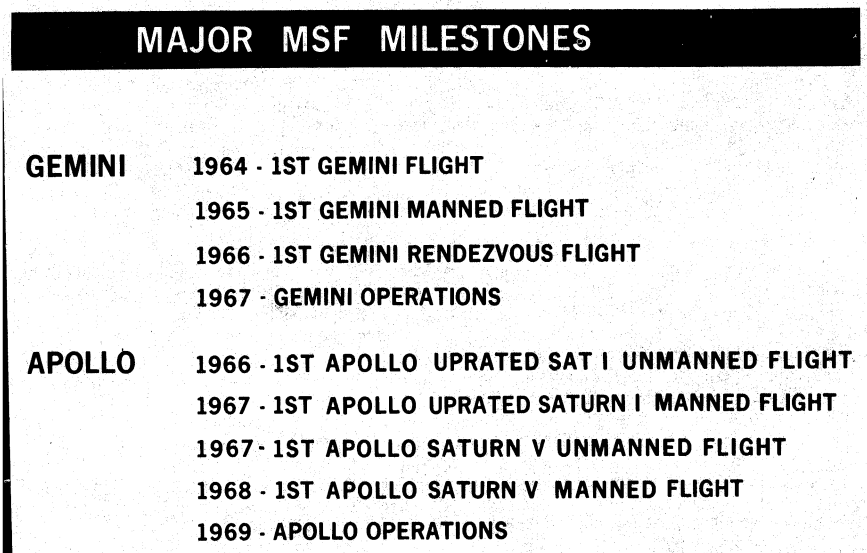


FIGURE 5

SCHEDULE MODIFICATION
FEBRUARY 1967

DECISIONS

AS 206	UNMANNED LM
AS 501, AS 502	UNMANNED L/V QUALIFICATION BLK II HEAT SHIELD QUAL.

NASA HQ MC-67 5782
2-13-67

FIGURE 6

Apollo/Saturn I missions

AS–201 unmanned flight

Three Apollo/Saturn I unmanned missions were completed in 1966 (fig. 7, MA66–9805). These unmanned flights were of major significance because the Apollo/Saturn I space vehicle represents a hard-core configuration upon which much of our launch vehicle and spacecraft development and operational techniques are based. These missions in 1966 represent the beginning of the payoff of the intense ground testing, site activation and management system developments that have characterized the program.

The AS–201 space vehicle, comprising the uprated Saturn I launch vehicle and Apollo spacecraft, was successfully flown from Launch Complex 34 at Cape Kennedy on February 26, 1966 (fig. 8, MA66–9105). It was placed on a suborbital trajectory with flight termination near Ascension Island. The purpose of this unmanned development flight test was to obtain information on the structural integrity and compatibility of the launch vehicle and the spacecraft and spacecraft heat shield performance during high heat rate entry.

AS–203 unmanned flight

The second Apollo/Saturn I space vehicle, AS–203, was successfully launched from Launch Complex 37 at Cape Kennedy on July 5, 1966 (fig. 9, MA66–7663). The threefold purpose of this unmanned mission was to verify the Saturn V upper stage system performance and operation early in the Apollo program; provide technological data pertinent to the behavior and management of liquid hydrogen in earth orbit; and continue development of the space vehicle for manned flights (fig. 10, MC66–10263).

The space vehicle consisted of an operational uprated Saturn I 1st stage and a Saturn I 2nd stage modified to simulate a Saturn V 3rd stage configuration. The 2nd stage was instrumented to obtain data on liquid hydrogen behavior. No spacecraft was flown on this mission. The 2nd stage, Instrument Unit and nose cone represented the heaviest U.S. satellite ever placed in orbit, with a weight of approximately 58,500 pounds.

AS–202 unmanned flight

The third Apollo/Saturn I space vehicle, AS–202, was successfully launched from Complex 34 at Cape Kennedy on August 25, 1966 (fig. 11, MA66–9171). This unmanned suborbital flight terminated in recovery of the Command Module in the vicinity of Wake Island in the Pacific. The purpose of the mission was to

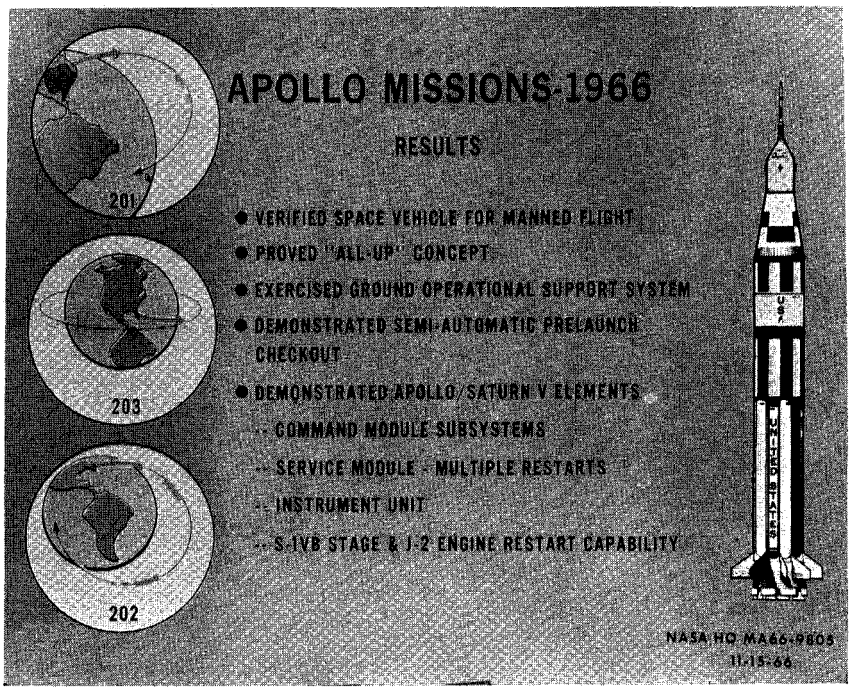


FIGURE 7

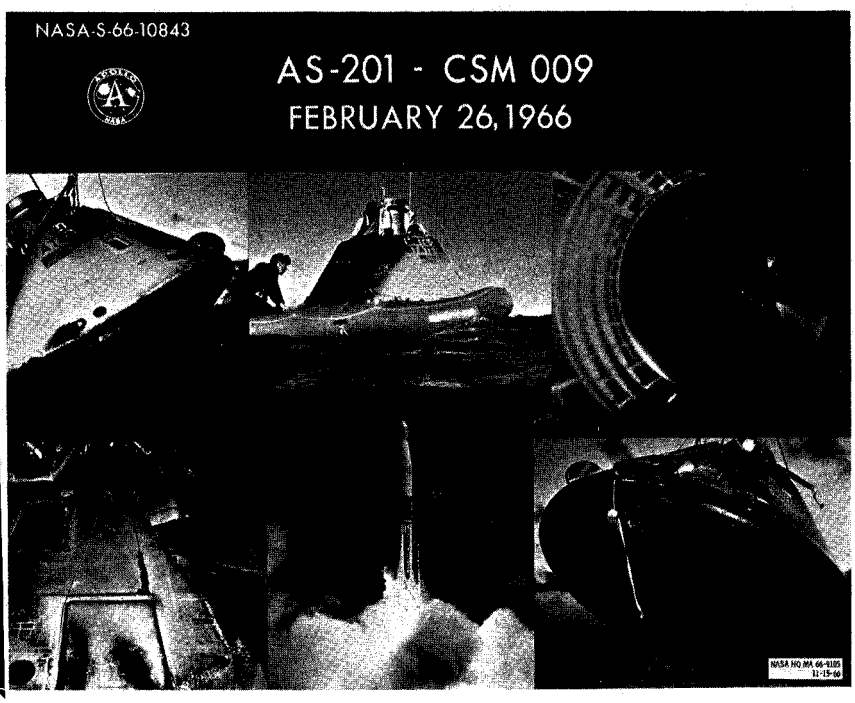


FIGURE 8

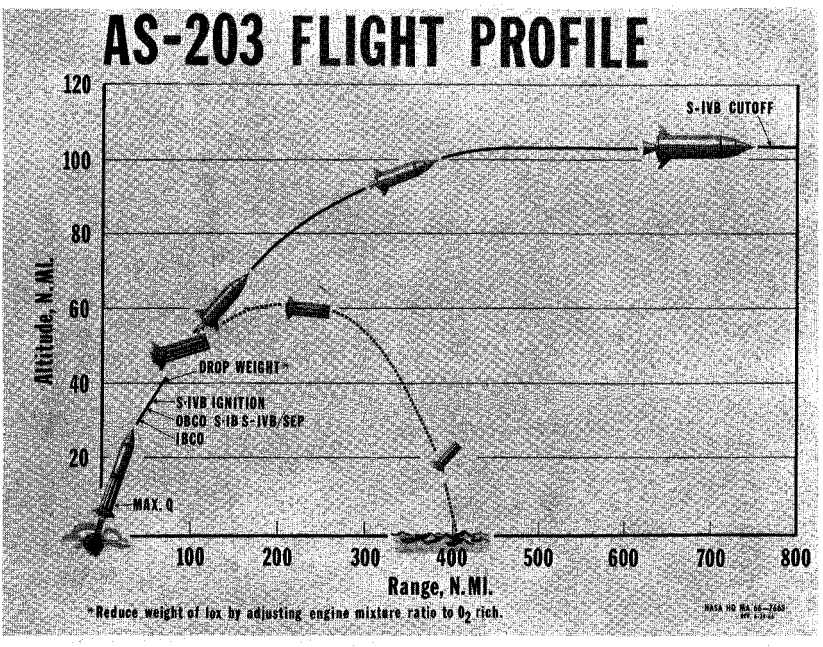


FIGURE 9

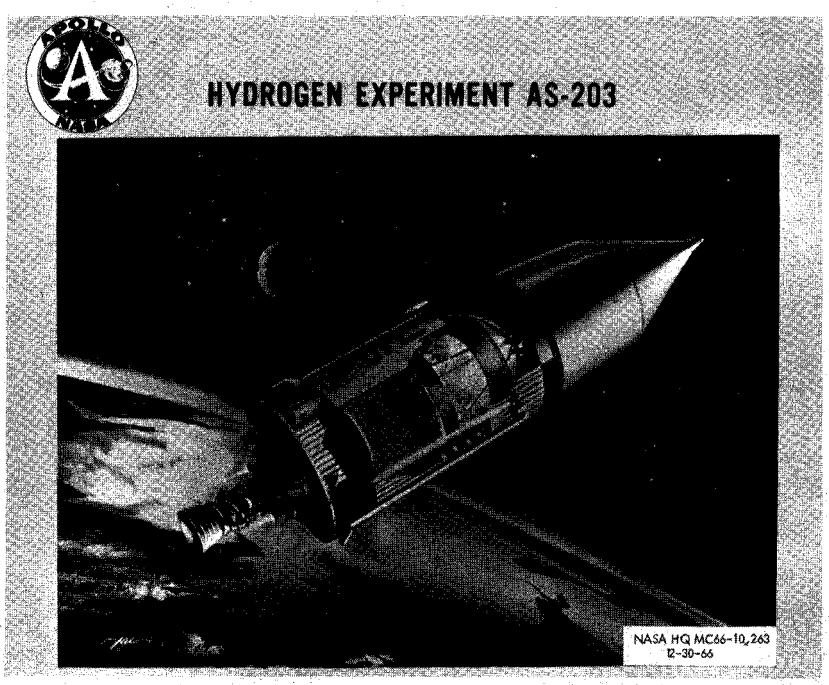


FIGURE 10

FIGURE 11

demonstrate the performance of the space vehicle in preparation for manned orbital missions. The mission provided the determination that the Command Module heat shield was adequately designed for entry from earth orbital missions.

The space vehicle consisted of an uprated Saturn I launch vehicle and a Block I Command and Service Module spacecraft with essentially all systems operational. This third and very complex mission was a major milestone in preparation for manned flight.

Loss of Apollo/Saturn 204

The success of the first three Apollo/Saturn I missions led to a decision to proceed to the second phase of the program, the Apollo/Saturn 204 manned mission. The flight was scheduled for launch February 21, 1967.

As I mentioned earlier, the AS-204 accident occurred under conditions and using procedures which had been verified by 7 years of manned spacecraft operational experience (fig. 12, MC67-5768; fig. 13, MC67-5765).

Work of Apollo 204 Review Board

Almost immediately, an Apollo 204 Review Board was appointed consisting of the following members: Dr. Floyd L. Tompson, Director, Langley Research Center, NASA, Chairman; Col. Frank Borman, Astronaut, Manned Spacecraft Center, NASA; Maxime Faget, Director, Engineering & Development, Manned Spacecraft Center, NASA; E. Barton Geer, Associate Chief, Flight Vehicles & Systems Division, Langley Research Center, NASA; Col. Charles F. Strang, Chief of Missiles & Space Safety Division, Air Force Inspector General, Norton Air Force Base, California; George C. White, Jr., Director, Reliability & Quality, Apollo Program Office, Headquarters, NASA; John Williams, Director, Spacecraft Operations, Kennedy Space Center, NASA; and Dr. Robert W. Van Dolah, Research Director, Bureau of Mines, Explosive Research Center.

To assist the Board in its investigation, an undamaged Block I Apollo spacecraft, Command Module 014, was shipped from the contractor plant to the Kennedy Space Center. This spacecraft was employed as a control to establish the conditions existing prior to the accident. Detailed disassembly of the burned

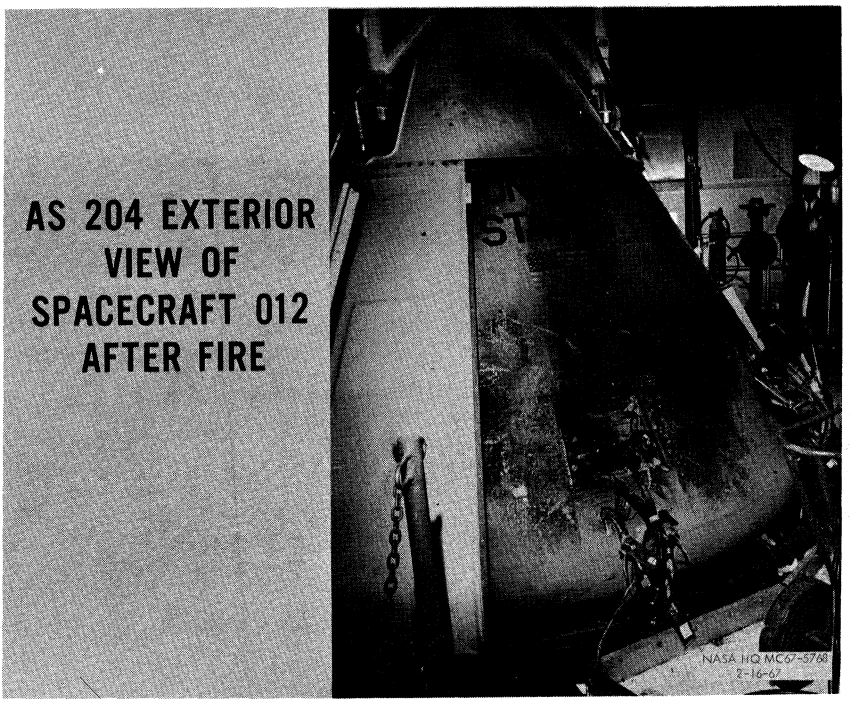


FIGURE 12

spacecraft and the control spacecraft was undertaken on a parallel, step-by-step basis.

In addition to analyses of recorded and physical data and equipment, the Board defined a series of investigative tasks and assigned them to 21 panels for execution. To date more than 1,500 individuals, from nine government agencies and departments in addition to NASA, from 31 industrial groups, and from several universities, have participated in this review and analysis.

Phases of fire

The Board has not identified the source of ignition. By the time it has completed its final report, it expects to have significantly narrowed the list of ignition sources that had a relatively high possibility of contributing to the initiation of a fire, but the possibility exists that no single source will ever be pinpointed.

Present evidence indicates that the fire had three distinct phases. The fire originated in the left, or command pilot side, in the front corner of the spacecraft, near the floor. It probably burned for several seconds without being noticed by the crew or recorded on instrumentation. Because it was below the couch level it was not visible at this stage. The fire spread and fed on nylon netting (installed to prevent objects from floating into equipment crevices while in zero g), Velcro fastening material (used to fasten equipment to the spacecraft interior), and the Environmental Control Unit insulation. The cabin pressure began to rise rapidly as the atmosphere became heated reaching an internal pressure estimated at 36 pounds per square inch, and the sealed cabin ruptured.

With the rupture of the cabin and the rush of flame and gas outside, the oxygen content of the cabin atmosphere was quickly reduced and the fire smoked heavily, laying a film of soot on many interior surfaces. This final phase of the fire was also characterized by continued localized burning. The environmental control system uses a water/glycol coolant that leaked from burnt or burst pipes. Both high and low pressure oxygen lines were connected with solder joints that

fail at temperatures below 400° F. The glycol mixture from the cooling system, acting as a fuel and supported by the flowing oxygen from the failed lines, caused continued hot burning in the left corner and melted a large hole in the floor there.

Reevaluation and redesign effort

The work of the Board will continue as the burned spacecraft and the 014 control spacecraft are carefully disassembled. In the meantime our review and reevaluation of decisions is paralleling the work of the Board. I would like to outline some of the salient features of this effort.

In particular, we are initiating actions to be responsive to each of the preliminary recommendations of the Apollo AS–204 Review Board. In this regard, we are taking steps to apply certain newly developed materials which are nonflammable in every possible place in the spacecraft. The non-metallic materials will be arranged so as to maintain fire breaks and the systems that contain oxygen and liquid combustibles will be made more fire and heat resistant. This new cabin configuration will be verified by full boilerplate flame tests. A new hatch is now being designed. Emergency procedures throughout the program are being revised to recognize the possibility of cabin fire. A comprehensive review of the specification, design, and qualification of spacecraft systems is under way. Studies of the tradeoffs between one and two gas atmospheres as well as studies of means to implement the Board recommendation for the elimination of pure oxygen at atmospheric pressures in prelaunch operations are under way.

You recognize, I am sure, that it will take time to complete the review and carry through the new designs to a point where proper decisions can be made. The work of the program is directed at a point where we can have sufficient information and test results to make the right set of decisions, which will provide a sound basis upon which to continue the orderly execution of the Apollo program.

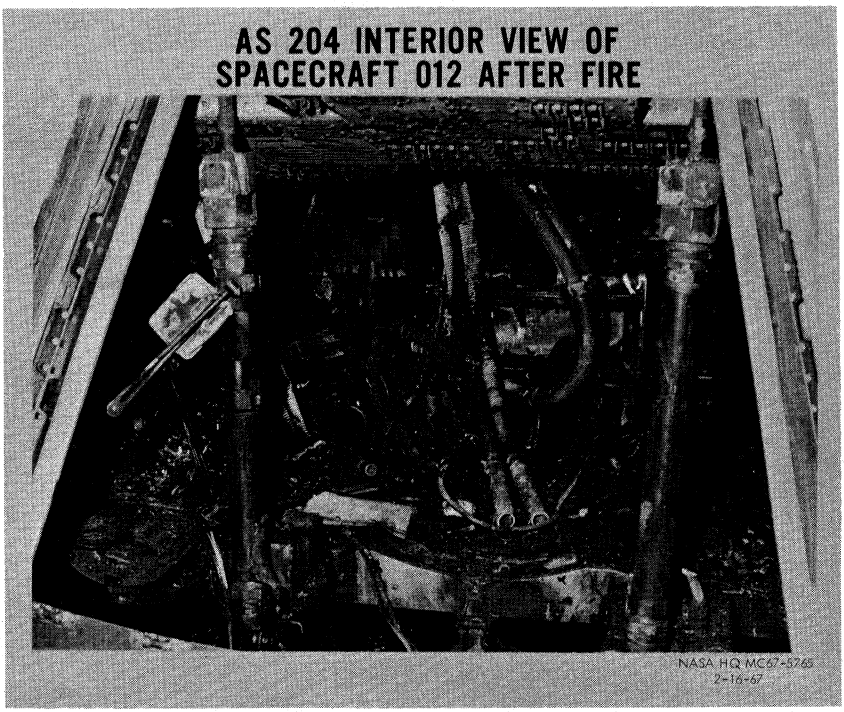


FIGURE 13

There is intense activity in progress throughout the Apollo program organization to determine the specific actions required to correct conditions which could have contributed to the AS–204 fire. Engineering design, procurement and fabrication are under way in many areas, in others we are still making studies to determine the best course of action to take.

As we have frequently stated before this Committee, crew safety is the principal consideration in scheduling manned space flight missions. We have never taken any step, either to save time or to save money, if that step would imperil the astronauts. We will continue to be guided by this overriding principle. We plan to continue spacecraft manufacturing and checkout except that which involves checkout in a pure oxygen atmosphere in the spacecraft.

We have a block concept in the Apollo program and we intend to stay with it. That means that we introduce those things in the first Block II spacecraft that we expect to have at the end of Block II. The first Block II spacecraft Command and Service Module, number 101, is the next spacecraft in the line at the North American Aviation plant at Downey, Calif. We plan to incorporate in spacecraft 101 all changes determined to be necessary as the result of the findings of the investigation of this accident.

Meanwhile, we plan to continue the manufacturing and checkout of spacecraft 101, since the review thus far indicates that most of the spacecraft systems are adequate for safety; thus they will not require changes. We expect to gain valuable experience in this first use of the operational checkout procedures for Block II spacecraft.

In parallel with this continued checkout of spacecraft 101 we will be carrying out the studies, tests and designs which I mentioned earlier. We believe that by early April the results of such studies, tests and designs, taken together with the findings and recommendations of the AS–204 Review Board, will permit us to make decisions on specific configuration and procedural changes. These decisions and the designs so developed will then be the basis for fabrication of such parts and subsystems as may be required.

As the necessary parts and subsystems become available we will progress through a period of rework and inspection. Whatever changes may be involved will be made on spacecraft 101 (fig. 14, MC67–5937). How long this change implementation period will take cannot be determined at this time, but we expect to be able to make reasonable estimates early in April.

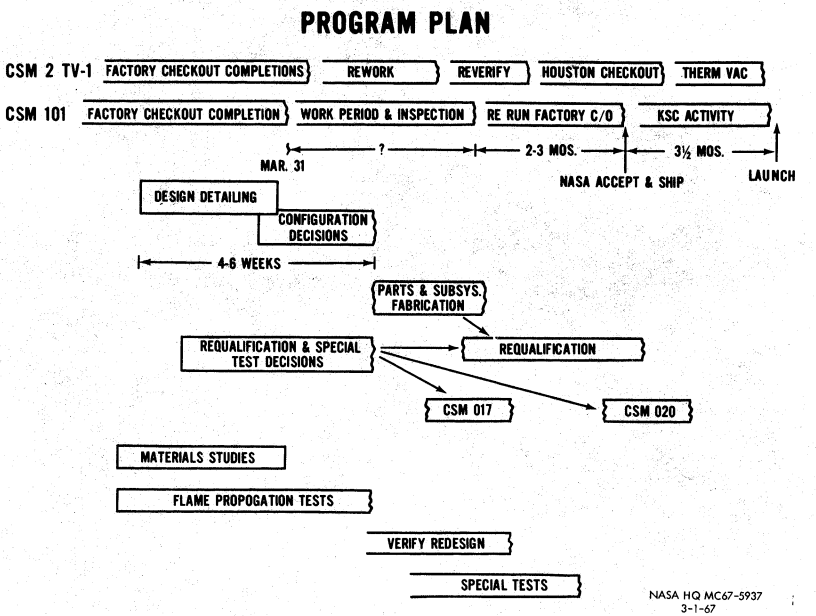


FIGURE 14

Following the change period, spacecraft 101 will then again undergo checkout. With the experience gained in the current checkout we might expect this to proceed smoothly and to require from two to three months. Following checkout of spacecraft 101, we plan to conduct the normal contract acceptance readiness review. The spacecraft will then be shipped to the Kennedy Space Center where it will undergo approximately four months of preparation, test and checkout prior to launch.

In parallel with the design and configuration decisions we must also decide which items will require requalification and what special tests must be conducted. Involved here is the normal program function of allocating units to flight spacecraft versus ground test and qualification test. To perform any unmanned flight tests that we may determine to be necessary, we have two spacecraft, numbers 017 and 020, which are scheduled for the first two Saturn V flights. We are planning to conduct these unmanned flights this year—to flight test the launch vehicle, to evaluate the performance of the spacecraft heat shield and to verify the spacecraft in orbital flight. These missions will afford the opportunity to flight test those changes that affect flight safety that may be made in procedures or hardware.

For ground test of spacecraft changes we have the 2TV–1, that is the thermal vacuum test article for Block II spacecraft. This test article, like spacecraft 101, is currently progressing through an initial series of operational checkout procedures. This article will be delivered to the Manned Spacecraft Center in Houston for the overall ground qualification of the Block II spacecraft. We plan that it will also be reworked and reverified before delivery to Houston for checkout and thermal vacuum tests, which are required to be successfully completed prior to launch of a manned Block II spacecraft.

This, then, is our current plan with respect to the Block II spacecraft. The impact on the first manned launch cannot be stated until we have determined the time required for rework and requalification.

It is quite possible that we will experience some impact also in our Lunar Module development program (fig. 15 MC67–5939). We have deferred detailed

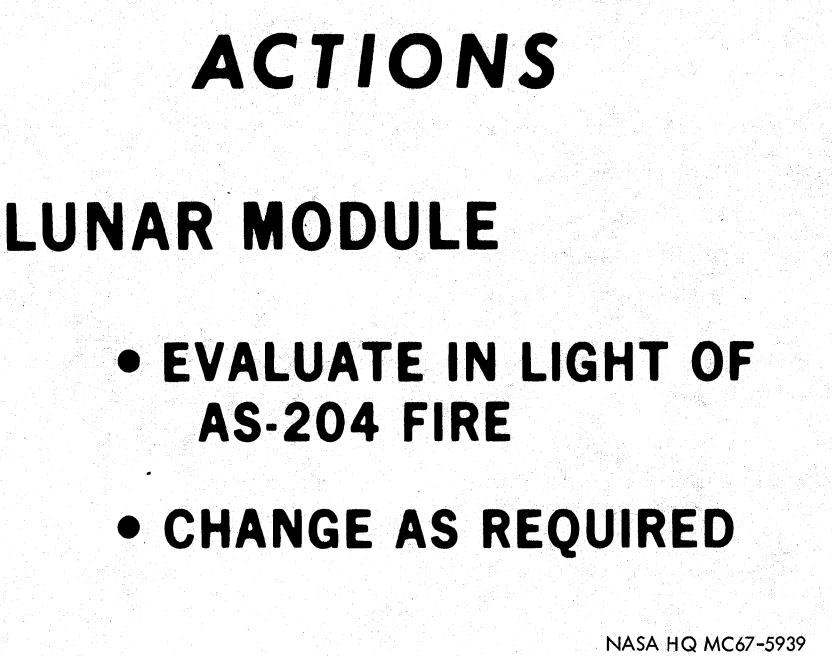


FIGURE 15

consideration of the Lunar Module until a basic understanding of the AS–204 accident could be developed. We will reevaluate the Lunar Module program in the context of changes in the Command Module and expect to complete this review in the next two months. To support this effort which we will begin shortly, we have had several representatives of the Lunar Module contractor, Grumman, participating in our studies and design reviews on the Command and Service Modules. More will be included as time goes on.

With respect to Lunar Module flight test, we plan to carry out the unmanned flight this year on AS–206. This will be primarily a test of the propulsion systems in orbital flight. LTA–8, the Lunar Module thermal vacuum test article will be available for ground test of any changes we may find necessary in the Lunar Module configuration.

In summary, then, we have a plan for the orderly accomplishment of required actions in the Apollo spacecraft program. We cannot at this time present a schedule of missions beyond the three unmanned launches planned for this year. Further definition of our schedules must await decisions yet to be made on the nature and extent of changes, which in turn will be based on the careful evaluation of the board findings and recommendations as well as the studies and tests now in progress. We will include in our schedules the time necessary to conduct a thorough program of reverification and requalification of changes. The general nature of our requalification will be similar to those we have conducted in the past, modified as appropriate to provide depth in selected areas based on what we have learned from the AS–204 accident and on what our analyses and tests indicate. Our policy of full qualification prior to manned flight will remain unchanged.

With respect to the overall Apollo program effort we plan to maintain the present orderly pace of effort in the many areas of current activity, such as launch vehicles, facilities, ground support software, training, and so forth. Much of our capability to cope with unforeseen difficulties is dependent on maintaining the planned rate of progress in all possible facets of the program. This carefully developed planning has enabled us to accommodate previous problems in both the Gemini and Apollo programs, and most importantly, maintains the flexibility that will enable us to schedule our flight operations as necessary to continue our progress in Apollo.

Lunar Module flight test (unmanned)

Turning again to the Apollo program phasing, the next step is the unmanned flight test of the Lunar Module in low orbit with the uprated Saturn I. Formerly scheduled to follow the manned Apollo/Saturn I flight, it will now be flown first in view of the deferment of the manned flight pending the accident report evaluations. The Lunar Module itself constitutes a major advance in manned spacecraft. It is the first manned spacecraft designed to operate exclusively outside the earth's atmosphere. We are now reaching the peak of the effort on the Lunar Module.

In our unmanned flight schedule, we will carry out the AS–206 first test flight of the Lunar Module during calendar year 1967. The objective of this flight phase is to verify that the Lunar Module is ready for manned flight (fig. 16, MC67–5779; fig. 17, MC67–5793).

Apollo/Saturn I manned flights

The manned phase of the Apollo/Saturn I flights, when rescheduled, will consist of long-duration manned operations of the Command and Service Modules. One objective will be to demonstrate spacecraft and crew operations for missions as long as 14 days. The second is to evaluate performance of the spacecraft hardware in a low earth-orbital environment. These are the same objectives originally planned for the AS–204 mission.

Since the operational life of the spacecraft subsystems has not yet been demonstrated in flight, we have planned all of the manned Apollo missions as open-ended. By this we mean that the mission is laid out to consist of a series of decision points at which critical events occur. The decision points are separated by periods of continuing activity. Before and after each of these critical events, a complete review of vital systems, expendables and other aspects of

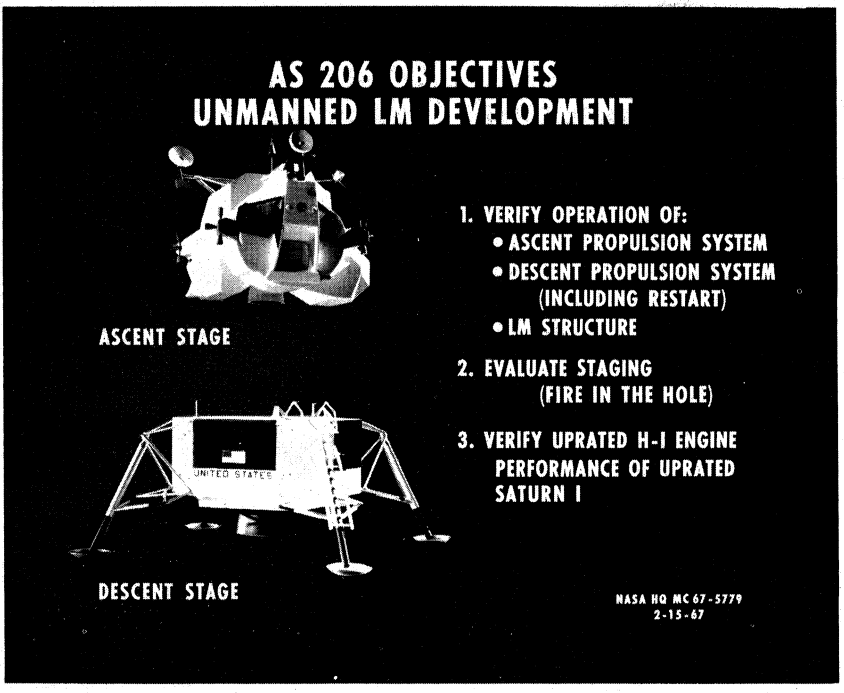


FIGURE 16

mission status is made. Each review leads to a decision whether to proceed to the next period of continuing activity, to an alternate mission, or return to earth.

Dual mission flights

In the final phase of flight tests planned for the uprated Saturn I launch vehicle, each mission except the last (AS–212) consists of two flights. In the dual missions, one vehicle carries the manned Command-Service Module. The second carries the unmanned Lunar Module, launched about a day later. The objectives are to achieve rendezvous and docking of the two vehicles in earth orbit, followed by astronaut transfer to the Lunar Module and manned operation to verify its functional capability. The astronauts will return to the Command Module to conclude the flight with entry, splashdown and recovery.

Apollo/Saturn V unmanned missions

In parallel with the Apollo/Saturn I, we are developing the Apollo/Saturn V launch vehicle, which is designed for the lunar missions. Two of the three stages are as yet untested in flight. The 3rd stage and the Instrument Unit benefit from the experience being gained with these systems in the Saturn I program.

Schedule adjustments

As I mentioned earlier, development difficulties caused a revision to the Apollo/Saturn V program schedule in November 1966. Spacecraft and launch vehicle concerns, particularly those connected with the 2nd stage of the Saturn V launch vehicle, caused us to adjust the first two Apollo/Saturn V missions. The first Saturn V flight, an unmanned orbital mission, was moved from the first to the second quarter of 1967. The second Saturn V flight, also unmanned, was rescheduled from the first to the second half of 1967. No rescheduling was required by the loss of a Saturn V 3rd stage during test in January 1967, because of the favorable production status of subsequent stages.

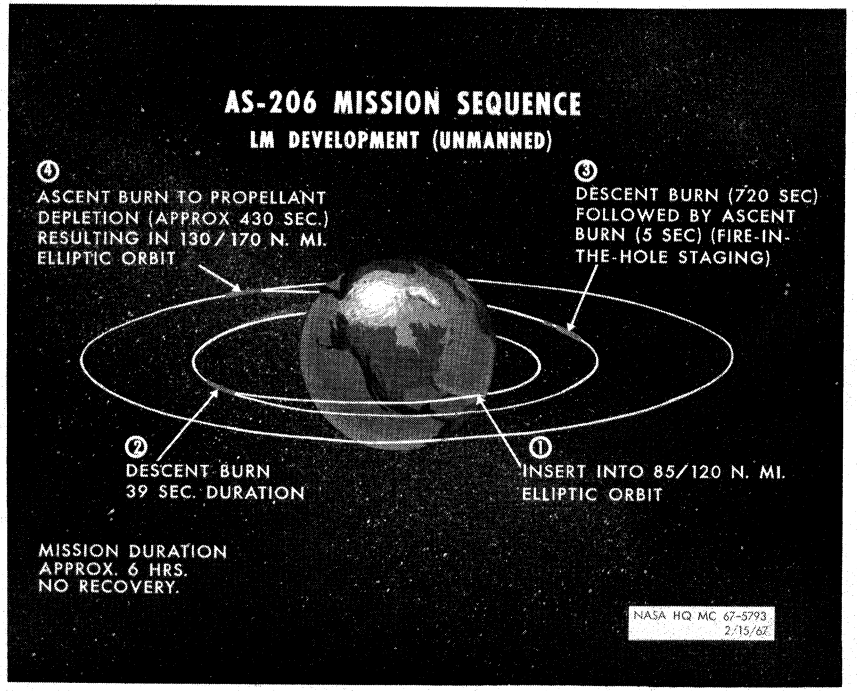


FIGURE 17

AS–501/2 unmanned missions

Unmanned flights of the Apollo/Saturn V space vehicle will begin with the AS–501 and AS–502 missions (fig. 18, MC66–10,266A). The main objectives of the unmanned flight phase are to develop the Saturn V space vehicle for manned flight and to demonstrate the adequacy of the Command Module heat protection and other systems for entry into the atmosphere at the speed of lunar return (fig. 19, MC67–5794; fig. 20, MC67–5795).

Apollo/Saturn V manned missions

The next to last phase of the Apollo program will be the use of the Apollo Saturn V space vehicle for manned lunar mission simulations in elliptical earth orbit. In these flights, all phases of a lunar landing mission will be simulated on the same time schedule as the actual mission.

Here again, we will be using open-ended flight plans. There are nine periods of continuing activity during a lunar mission in which some time is available for considered review of mission status. They are prelaunch, earth parking orbit, translunar coast, lunar orbit prior to Lunar Module descent, Lunar Module descent, lunar surface stay, Lunar Module ascent, lunar orbit after rendezvous, and transearth coast. In the earth orbital simulation mission all of these periods are available except lunar surface stay.

The first attempt at a lunar landing would be scheduled as an open-ended mission in line with previous practice. I have confidence that the mission can be carried out within the approved program of 27 uprated Saturn I and Saturn V vehicles and the associated Apollo spacecraft. Under present planning, 13 of the 15 Saturn V vehicles are to be launched by 1970. I do believe that we still have a reasonable possibility of meeting the major milestones for the Apollo program which were established in 1963. In particular, although the probability is lowered, I believe we will be able to land men on the moon and return them safely to earth before 1970.

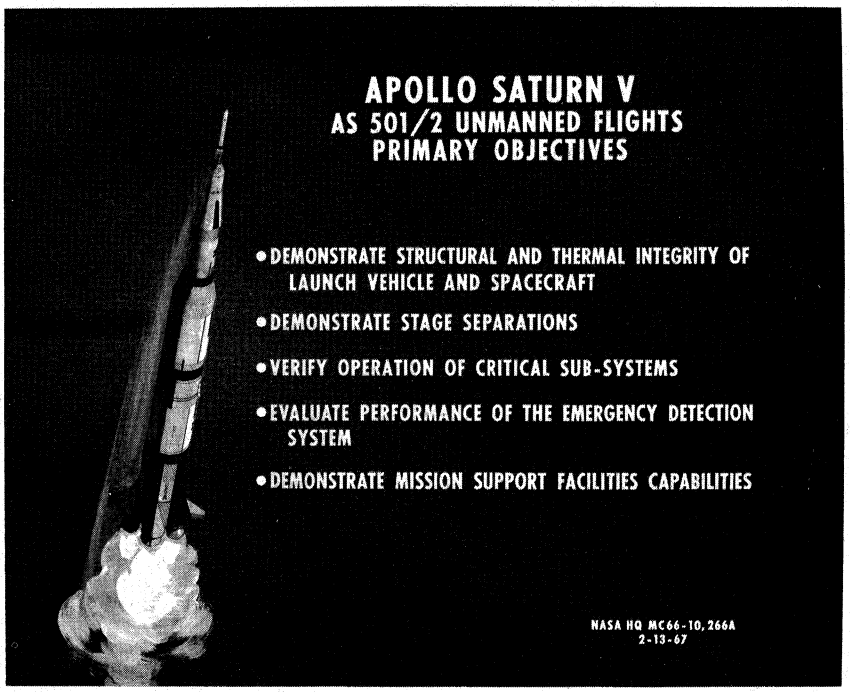


FIGURE 18

PROGRAM HARDWARE AND SOFTWARE

Space vehicle ground qualification and certification for flight have been a major Apollo effort during 1966. This extensive qualification and test program is conducted to assure that the hardware has reached a point of maturity where subsequent flight verification tests are likely to be successful.

Ground qualification and flight certification for the Apollo Saturn I launch vehicle were completed in 1966 while similar effort for the Saturn V launch vehicle is nearing completion.

The spacecraft for the AS–204 mission had gone through the scheduled exhaustive test program, beginning with spacecraft subsystem acceptance tests. Further testing was conducted from the time the subsystems had been assembled in the Command Module in March 1966, through a series of integrated tests at the factory ending in August 1966, and continuing at Kennedy Space Center after delivery of the Command Module in August.

During the entire fabrication and test program leading toward the scheduled launch of this Apollo spacecraft, a number of Qualification Tests or Certification Test Requirements were completed on the most critical components to ensure the adequacy of the spacecraft for manned flight. All of these test conditions are more exacting than those the spacecraft components would be expected to encounter during an actual mission.

Approximately one-half of the qualification and certification testing for the Block I Command-Service Module is applicable to the Block II configuration. The testing required to complete the certification of the Block II Command-Service Module and Lunar Module is progressing.

I would like next to describe the work and the progress of our studies and designs. I will cover our activities in reviewing the Apollo design as well as specific actions being taken in fire detection, fire extinguishing, materials, cabin configuration, emergency egress, spacecraft atmospheres, and environmental control systems.

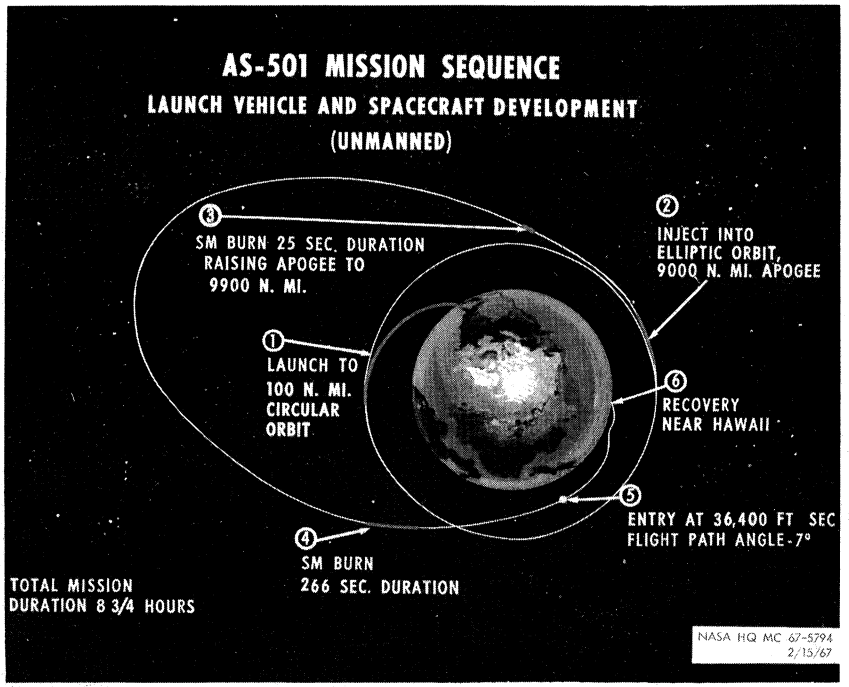


FIGURE 19

REVIEW OF DESIGN AND IMPLEMENTATION IN LIGHT OF THE AS–204 ACCIDENT

Procedures

Our procedures have in the past required that each test to be conducted be reviewed from the safety standpoint. We will now ensure that the review assume the possibility of fire in the spacecraft cabin and provide for careful identification of hazardous test conditions and establishment of appropriate emergency equipment, personnel procedures, and training.

We will tighten procedures and safeguards to ensure that materials in the spacecraft cabin are controlled, recognizing the possibility of fire, and that the test configuration of the spacecraft fully take this possibility into account. Finally, we are taking steps to ensure the early availability of procedures so that adequate reviews are carried out.

Electrical system

A reevaluation of the electrical power system and cabling is under way to determine whether or not changes of cable design, fabrication and routing will provide greater assurance of protection from damage and therefore improved assurance that we have done all that is practical to minimize potential ignition sources.

Communications system

The AS–204 accident occurred while the checkout countdown was being held to rectify communications difficulties. While there is no indication that this was directly a factor in the fire, it is nevertheless important that the many interconnecting organizational elements be able to communicate efficiently at all times. We are, therefore, reviewing all circuits, interconnections, monitoring and checkout procedures to determine whether or not changes are required to improve the total communications system.

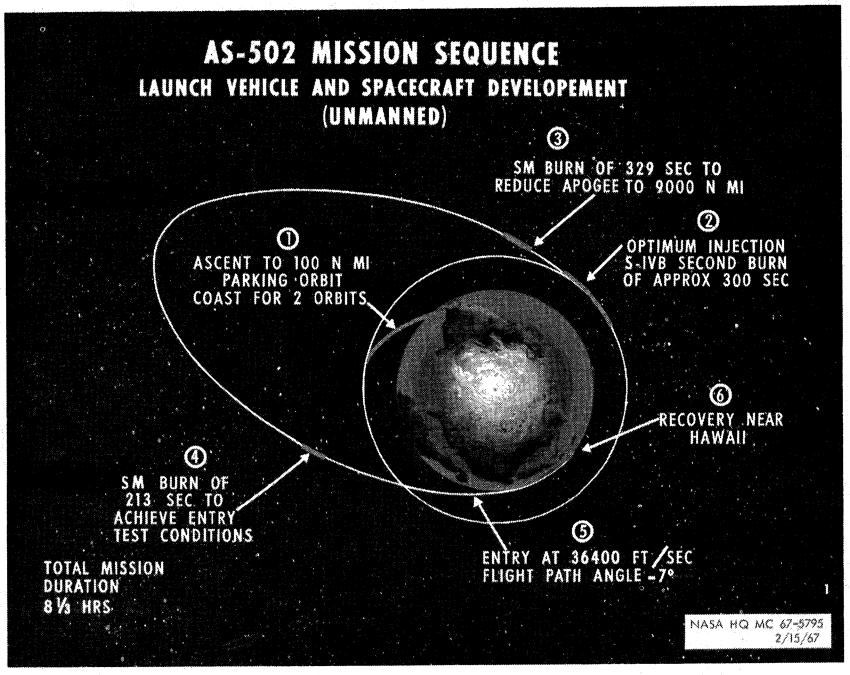


FIGURE 20

Fire detection

Equipment with which to detect fire in space vehicles has always been a matter of interest; however, suitable detectors with adequate reliability have been difficult to develop. We have made some progress in our continuing development program and we are now evaluating those developments and also checking with other organizations to determine whether or not we can now incorporate suitable and reliable sensors into the Apollo spacecraft.

Fire extinguishing

Much work has been done to develop equipment and techniques for extinguishing fires in space vehicles. Since the AS–204 fire, we have accelerated our work and have undertaken additional test programs.

The extinguishment methods under study and test include chemical extinguishing agents, dilution of the oxygen atmosphere with inert gases, cabin depressurization and water sprays.

In the fire extinguishment tests to date, it appears that chemical and inert gas extinguishers are ineffective. The gas streams for such extinguishers entrain sufficient oxygen from the spacecraft atmosphere to cause the fire to burn more vigorously rather than to be extinguished. This is true even for such chemicals as bromotrifluoromethane (CF_3Bn) which appears to be quite effective for aircraft fires.

The tests performed using inert gases such as nitrogen as a dilutant indicate that the turbulence caused by the introduction of the gas causes more intense burning.

The most effective fire extinguisher we have found to date is a water spray. On the other hand the detrimental effects of water on electrical equipment together with complexity and weight considerations make the usefulness of this system doubtful.

Additional tests are planned to determine combustion characteristics in simulated Command Module interiors. The Command Module for these tests will be a boilerplate spacecraft and will include tests with both present and modified interior arrangements.

Special tests have been and are being performed to understand the combustion characteristics of various materials in zero gravity. Test results to date indicate that, after ignition, flames disapear due to lack of convection currents, then reappear when convection is reestablished. We believe that in a spacecraft there will be sufficient movement of the atmosphere by fans or crew motion so that this cannot be counted on as a reliable method of fire extinguishment.

The results of the many tests run to date have not been encouraging. Additional effort is under way, however. and every possibility is being reexamined. Careful consideration must be given to the tradeoffs involved. The provision of a limited capability for fire extinguishment at the expense of reduced reliability and increase in the possibility of a toxic environment must be carefully weighed before any decision is possible.

Cabin materials

With regard to the materials used and contained in the spacecraft cabin, I would like to summarize why we attach so much significance to materials selection and control.

For a fire to exist there must be an atmosphere containing sufficient oxygen to support combustion; there must be a source of ignition; and there must be combustible materials available to be ignited. As far as the atmosphere is concerned, an atmosphere which will support life will also support combustion. Therefore, the first answer to the fire hazard problem must be fire prevention in terms of strict control of both potential ignition sources and combustible materials.

The fact is now clear that we will not be able to eliminate completely ignition sources in the cabin. We will continue to take every precaution to minimize possible ignition sources, but we cannot expect perfecton. This means that the remaining technique of fire prevention—materials selection and the control of the geometry of their use—demands our utmost in care and attention.

Objectives

Our objectives in the selection and use of materials are many.

First, we are reviewing the latest developments in material technology so as to replace potentially combustible materials with less flammable or non-flammable materials. Some needs can only be met using potentially flammable materials; the astronauts' food is an example. However, care must be taken that at every opportunity, materials are selected which give us the most fire protection while still satisfying the basic need.

Second, we want to locate materials physically so as to inhibit ignition (fig. 21, MC67–5955). Ordinarily this requires that any potentially combustible materials be kept some distance away from possible ignition sources.

Third, we want to arrange materials to inhibit fire propagation. This is usually accomplished by assuring physical separation between small pieces of materials which might be potentially combustible.

Fourth, we want to store potentially flammable materials in fire resistant containers.

Fifth, we want to minimize the amount of potentially combustible materials exposed in the cabin at any one time, either on the ground or in flight.

Sixth, we want to exercise rigorous control over the introduction of materials into the cabin during manufacture and test. This includes both flight articles such as the astronauts' spacesuits and non-flight articles, such as test procedures books.

We believe we have exercised care in every one of these areas in the past. However, in light of the AS–204 accident, we are reviewing each area to make sure that we are doing everything that we should.

I would like to report in more detail on our status in the area of new materials.

Relative propagation rates

This chart shows the relative propagation rates of nomex, which is the material used in our spacesuits, as compared with two new materials: teflon and fiberglass (fig. 22, MC67–5964). As you can see, the rate of propagation of fire does vary

ACTIONS

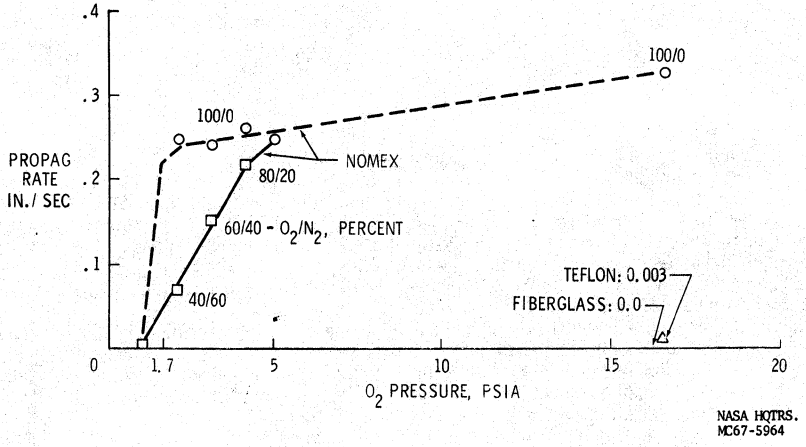
CABIN CONFIGURATION

- ARRANGE MATERIALS TO INHIBIT IGNITION AND PROPAGATION
- FOOD STORED IN FIRE RESISTANT CONTAINERS

NASA HQTRS.
MC67-5955

FIGURE 21

COMBUSTION AS A FUNCTION OF O_2 TOTAL PRESSURE, O_2 PARTIAL PRESSURE, TYPE OF MATERIAL



NASA HQTRS.
MC67-5964

FIGURE 22

with the partial pressure of oxygen and with a mixture of oxygen and nitrogen. The important point to make is that over the range of oxygen pressures in which we operate, the variation and propagation is only a factor of two or three, while by going to totally new material, such as teflon, the propagation rate at the 5 pounds per square inch pressure of pure oxygen—which we have used in our spacecraft cabins—is zero, as is that of fiberglass. Our approach then is one of selecting materials insofar as is possible which do not propagate flame in any atmosphere.

Classes of materials

We can divide the materials in the spacecraft cabin into a number of different classes, but I would like to discuss four with you today; fabrics, fasteners, films and foams (fig. 23, MC67-5965).

FABRIC DEVELOPMENT

	ADVANTAGES	PROBLEMS OR DISADVANTAGES
• BETA FIBER	MELTING TEMP 1540°F DOES NOT BURN	FABRICATION TECHNIQUES ABRASION RESISTANCE
• TEFLON MATERIAL	MELTING TEMP 550°F SELF EXTINGUISHING	FABRICATION TECHNIQUES TOXICITY

NASA HQTRS.
MC67-5965

FIGURE 23

In fabrics, we are considering, among other materials, the use of Beta cloth, which is a new glass fiber cloth, to replace our current fabric material which melts in the range of 400–700° F and will support combustion. The new fiber has a melting temperature of about 1500° F and does not burn. One of the problems with the new fiber is that making garments out of it requires the development of new fabrication techniques. At this point it appears promising. We believe that enough of it can be produced to meet our requirements and that the fabrication problems can be solved.

I might mention also that one of the problems with previous glass fibers has been the dermatological effects when the fabric is worn next to the skin. Preliminary tests of prototype clothing made with the new fiber appear promising in this respect also. A number of people have worn underclothing of this material for some months without any adverse reaction.

A second problem with Beta cloth is that of abrasion resistance. Many of the applications, such as in the outer covering for a spacesuit, require a high order of resistance to abrasion and so far it has not been possible to develop a tight enough weave to provide adequate abrasion resistance in this cloth. A second fabric that is being evaluated and in which there have been some recent developments is that of teflon. Teflon has the advantage of being self-extinguishing in a 5 pounds per square inch oxygen atmosphere. Because of its hardness and smoothness new techniques for fabrication have to be developed before we can apply it. Also, in the thin cross-sections required for nets and similar materials, we need to evaluate the possible toxicity when exposed to flame.

We do feel that these two materials can be developed and applied to meet most of the requirements for low or zero flammability materials in the spacecraft.

We are also considering new materials for fasteners. Some type of fastener must be available for crew convenience while operating in the weightless environment. Otherwise, it could be most cumbersome keeping everything "tied down." In the past, the fastener material has been Nylon Velcro which supports combustion in a pure oxygen atmosphere. We are considering several possibilities for replacing this material. One is a steel Velcro, which has excellent fire protection properties, but has been judged to be too abrasive for our use when fabricated as a hook and pile fastener using the currently available techniques. Another material being considered is teflon. This material is self-extinguishing in terms of its burning characteristics, but fabrication techniques have not been developed. We do know, however, that using more conventional fasteners such as snaps and hooks and eyes will meet the need for fire resistant fasteners in the spacecraft. In the meantime we are continuing to explore the use of new materials for this application.

Films are used in the spacecraft cabin in the form of bags for containing food, for fecal collection and for containing various small articles of equipment. Here again we are considering teflon as a possible replacement material, but for this application the oxygen permeability of the material as a film must be verified. Other new materials are also being considered.

Foams are used for thermal insulation and for equipment protection inside the cabin. A high density teflon foam is available now. A low density foam is preferred and is being developed. We are also investigating the availability and applicability of silicone foams. Our investigations in this area are promising, but some development work is undoubtedly required.

In summary, we do expect to be able to replace or protect all the very flammable materials in the spacecraft.

Spacecraft atmosphere

We are continuing tradeoff studies on spacecraft atmosphere for each operational phase of the Apollo program. These studies include one versus two gas tradeoffs, evaluation of the prelaunch atmosphere and a fire resistant oxygen system.

Pad operations

With regard to the spacecraft atmosphere during pad checkout and launch operations, our tradeoff studies, which are still in process, are indicating that serious consideration should be given to the use of air in the cabin, with the crew on pure oxygen in the spacesuit loop, to improve safety.

Air, which contains 79 percent nitrogen, is attractive for the cabin atmosphere, because it greatly decreases the fire hazard while providing the capability to support life if there is a failure in the oxygen supply to the suit loop. This decrease in fire hazard, in conjunction with a reduction of cabin combustibles, improved egress capability and the normal provisions for pad rescue and fire fighting instituted during hazardous operations, will greatly reduce the crew risk during pad operations. A cabin atmosphere of pure nitrogen would further reduce the fire hazard but is not favored because it will not support life in case of a suit disconnect or other suit leak. During the prelaunch period, as a precaution against dysbarism (bends) after ascent, the suit loop would be held at slightly higher pressure than the cabin, and continuously monitored by gas sensors to assure complete denitrogenation of the crew at launch.

Launch phase

During the launch ascent phase, the cabin and suit loop would bleed down to space flight pressure. With the crew remaining on the suit loop, oxygen would then be supplied to the cabin to enrich its atmosphere. We are studying several alternative procedures for this enrichment. These include (1) cabin decompression, followed by repressurization; (2) partial decompression followed by oxygen replenishment; and (3) gradual enrichment by replenishment of normal cabin leakage with oxygen. These procedures offer tradeoffs, which are now being considered, between the system weight, and the time which is required to achieve the desired atmosphere.

Space flight

For the atmosphere in space flight, we continue to favor the choice of oxygen for the cabin and suit loop at 5 pounds per square inch absolute (psia). The following five factors are included among those being considered.

First, pure oxygen eliminates the danger of dysbarism (bends) in case of sudden decompression.

Second, physiological considerations require that the partial pressure of oxygen be maintained no lower than the equivalent of 3.5 pounds per square inch absolute of 100 percent oxygen for life support, and no higher than the equivalent of 7.5 psia 100 percent oxygen for extended exposure to avoid toxicity.

Third, an oxygen partial pressure somewhat higher than 3.5 psia equivalent is desirable to increase the margin of safety in event of cabin leak from micrometeoroid puncture or other cause.

Fourth, a one-gas system is simpler than a multigas system, since it uses less components, requires no partial pressure gauges, and thus offers greater reliability.

Fifth, pure oxygen in the pressure range required for life support presents a definite fire hazard. A physiologically acceptable two-gas system at a pressure within the present spacecraft structural limitation does not appear to offer a large reduction in fire hazard over a 5 psia pure oxygen atmosphere.

Our tradeoff studies continue to indicate that for missions of Apollo duration, within feasible limits of pressure for structures and space suits, and coupled with an intensive cabin materials selection process, the 5 psia oxygen atmosphere provides the highest over-all crew safety. In continuing comparisons with candidate two gas atmospheres, it appears to provide the best balance among fire hazard, system reliability and physiological risks.

Reentry

Our current planning is to retain the present practice of initiating reentry with the 5 psia oxygen atmosphere in the cabin. During reentry, atmospheric venting into the cabin begins as the Command Module descends below about 27,000 feet. Continuing dilution of the oxygen cabin atmosphere during descent will result in a 47 percent oxygen content at splashdown, and the post-landing ventilation system will quickly replace this with normal atmosphere. Initiation of reentry with the oxygen cabin atmosphere appears preferable to decompression or replacement of oxygen with an inert gas because it eliminates the risk of asphyxiation in event of trouble with the suit loop. We are currently reexamining the fire risks during the brief periods of high deceleration during reentry to see if the tradeoffs are affected.

A final point on spacecraft atmosphere is that we are considering the usefulness to the crew of individual, fire resistant emergency oxygen supplies and masks similar to those used in aircraft practice. It appears that such a system might provide additional protection for the crew in the event of fire.

Emergency egress

In the area of emergency egress we are proceeding with a complete review of the spacecraft design and procedures (fig. 24, MC67–5958). In this review we are including a study of rapid opening hatches, modifications to the launch complex to improve egress, and the tradeoffs between prelaunch safety and safety during flight and recovery. One of the most significant changes already in work is the redesign of the crew hatch. Our objective is to provide a hatch which permits safe and reliable operations under normal conditions while providing for rapid egress or rescue in the event of an emergency condition on the ground. Concurrently its reliability must be such that it will operate only when required. In other words the emergency condition must not be triggered by external heat, structural loads or other mechanical or electrical operations.

In the course of our review, several hatch concepts have been considered. Before discussing some of the alternatives, I will briefly review the present hatch configuration. The requirements for return from the moon have dictated a different spacecraft design from that of Mercury and Gemini. Both structural and heat loads are substantially higher. Therefore, the Apollo heat shield surrounds the inner pressure cell. Consequently, the present Apollo hatch is a multiple hatch system consisting of a heat shield hatch and an inner hatch. The heat shield hatch is hinged and swings outward after being mechanically

ACTIONS

EMERGENCY EGRESS

- RAPID OPENING HATCH
- PAD CONSIDERATIONS
- FLIGHT SAFETY CONSIDERATIONS
- RECOVERY CONSIDERATIONS

NASA HQTRS.
MC67-5958

FIGURE 24

unlatched as a manual operation. The inner hatch is not hinged and opens inward. Internal pressure provides sealing loads on the inner hatch, thus resulting in a lightweight system.

One concept we have examined involves minimum modification to the present two hatch system. It utilizes a hot gas generator system to release the heat shield hatch and a Mercury-type "hatch within a hatch," for the inner hatch. The inner hatch is opened by a mild detonating cord which fractures the ring of bolts, thus providing an opening for emergency egress. This system is complex and does not appear to satisfy both the normal mission requirements and the emergency egress needs.

A second consideration was a three-man size hatch to provide an opening large enough for simultaneous three-man egress. This concept presents the problem of a major spacecraft redesign because new load paths must be provided in the structure. Although the opening could be cut with a linear shaped charge, such an operation may aggravate the emergency and, of course, represents a potentially dangerous failure point during flight and during water recovery. We all remember the dangerous situation that Grissom experienced on an early Mercury flight when the blow-off hatch of the capsule was inadvertently actuated when he was on the water. The spacecraft was lost in the Atlantic and Grissom barely escaped drowning.

The third concept we have examined is the unified or integrated hatch system shown here (fig. 25, MC67–5969). This system has been selected as the most promising, and detailed design work is under way. It is a single hatch which swings outward with a latch mechanism similar to that used on the present heat shield hatch and on the Gemini hatch. It can be opened in about two seconds by pressure generated by a hot gas actuator which is triggered by a percussion initiator. A manual mechanism is provided to open or close the hatch from either the inside or outside under normal operating conditions. It is a non-load carrying hatch with a Gemini type seal.

In carrying out this design, we are making use of the same type of hatch closure that was developed in the Gemini program. However, because of the two-shell structure, it is necessary to develop, as may be seen in the next chart (fig. 26, MC67–5968), a means for sealing the heat shield joint against reentry heat penetration under all possible relative motions of the outer heat shield seal with respect to the inner pressure seal. At the same time the inner pres-

UNIFIED HATCH

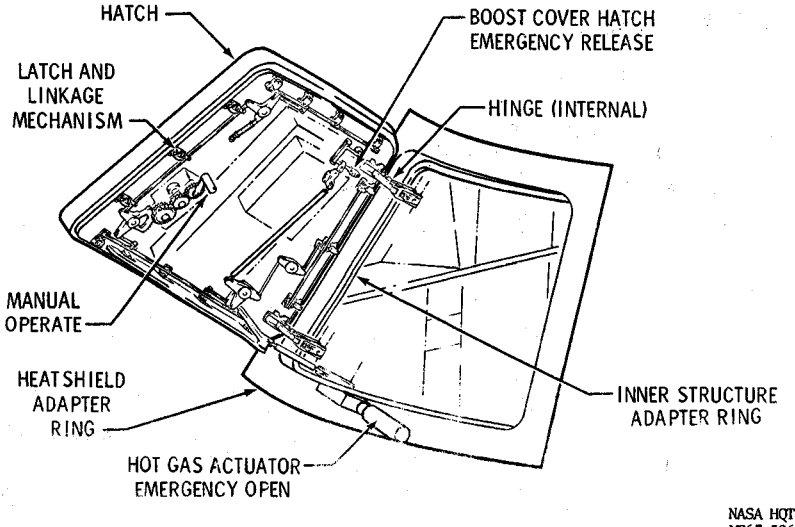


FIGURE 25

UNIFIED HATCH

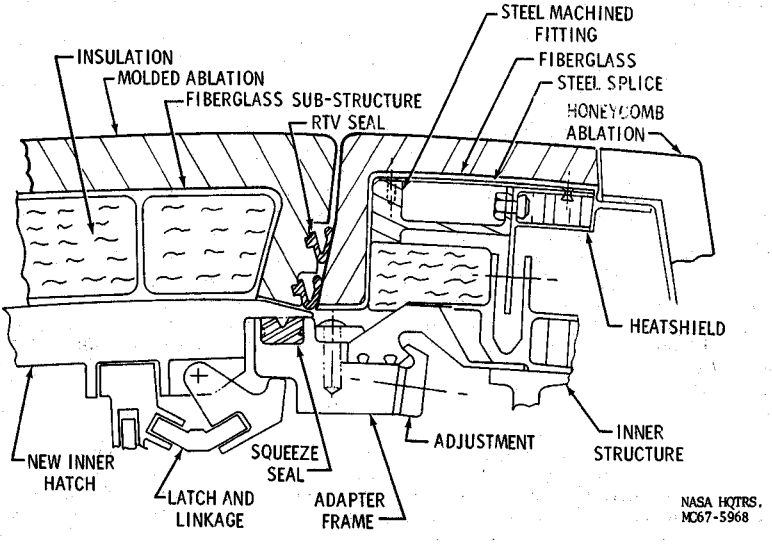


FIGURE 26

sure shell seal must be capable of multiple opening and closing and carrying out extravehicular activities in flight. The approach we have adopted is shown in the chart and has the advantage of being applicable with minor modifications to the present structure of the spacecraft.

The redesigned hatch must be fully tested and qualified before manned flight.

We are also reviewing the launch complex to identify changes that will be necessary to mate with the redesigned hatch and to insure that the emergency egress route permits as rapid movement of the crew as possible.

Environmental Control System

The Environmental Control System is being reexamined with emphasis on materials, failure modes, choice of fluids, maintenance and servicing.

Particular attention is being devoted to improving fire resistance by careful selection of materials used and the types of plumbing connections with the aim of minimizing the potential of leakage or joint failure as well as improving the maintenance and servicing of the system (fig. 27, MC67–5967). Changes being

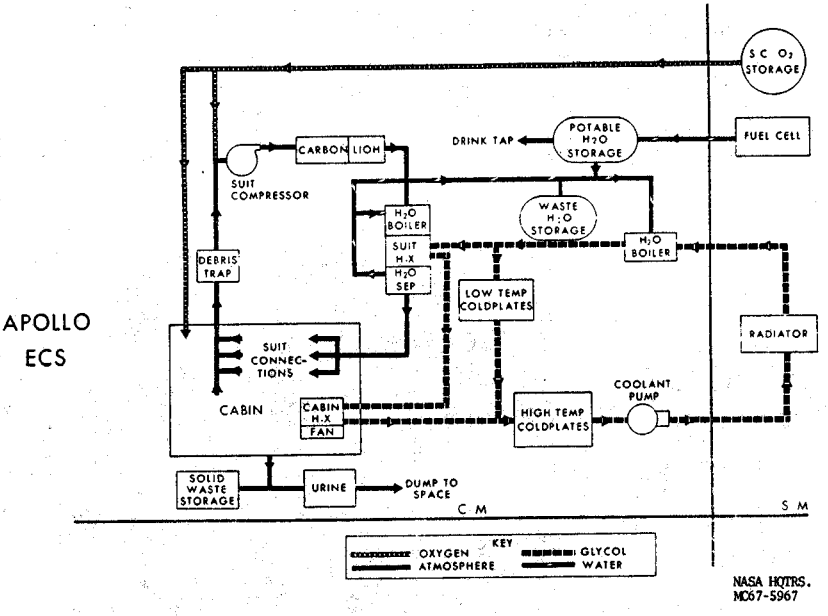


FIGURE 27

studied include the incorporation of improved mechanical or pressure joints, the relative merits of mechanical versus brazed joints, the feasibility of eliminating soldered joints, and the relative merits of steel versus aluminum tubing.

We are analyzing and conducting tradeoff studies to determine the feasibility of eliminating the present coolant fluid from the crew compartment. In this connection we are investigating other coolant fluids to determine if an alternate fluid with better fire resistance than water glycol could be used. Of all the fluids considered, approximately 46, four have been selected as potential candidates. None of the alternate fluids have thermal characteristics comparable to water glycol; however, three are considered non-combustible in air. Substitution of any of these coolant fluids will result in increased electrical power requirements, weight, increased water boiling during maximum heating, a new pump design and verification testing.

A second approach is replacement of the glycol in the cabin by water while leaving the mixture of water and glycol in the Service Module. This can be accomplished by adding heat exchangers and additional pumps.

A third approach involves the examination of the flammability characteristics of other mixtures of water and glycol. In any event the thermal characteristics of the Apollo spacecraft are quite delicately balanced and care must be taken in evaluating tradeoff studies that any changes do not decrease the possibility of success not only of the mission but of the performance of the environmental control system, since the safety of the astronauts depends directly upon its successful operations.

Finally, the design of the environmental control system is being reviewed with a view to improving its maintainability and serviceability.

HARDWARE DEVELOPMENT

Uprated Saturn I launch vehicle

The three successful unmanned missions in 1966 verified the design of the uprated Saturn I vehicle and the use of liquid hydrogen as a fuel in the upper stage. In September, a Design Certification Review Board was convened to assess the maturity of the design of the uprated Saturn I for manned flight. Based on the results of this review and successful completion of qualification testing, the uprated Saturn I is considered man-rated.

1st stage

During 1966 the 1st stage of the uprated Saturn I performed well (fig. 28, MA66–10,267). Five stages have been delivered to KSC. Three of these performed nominally in flight and two are being readied for flights in 1967. The remaining seven flight stages are in various conditions of fabrication, assembly,

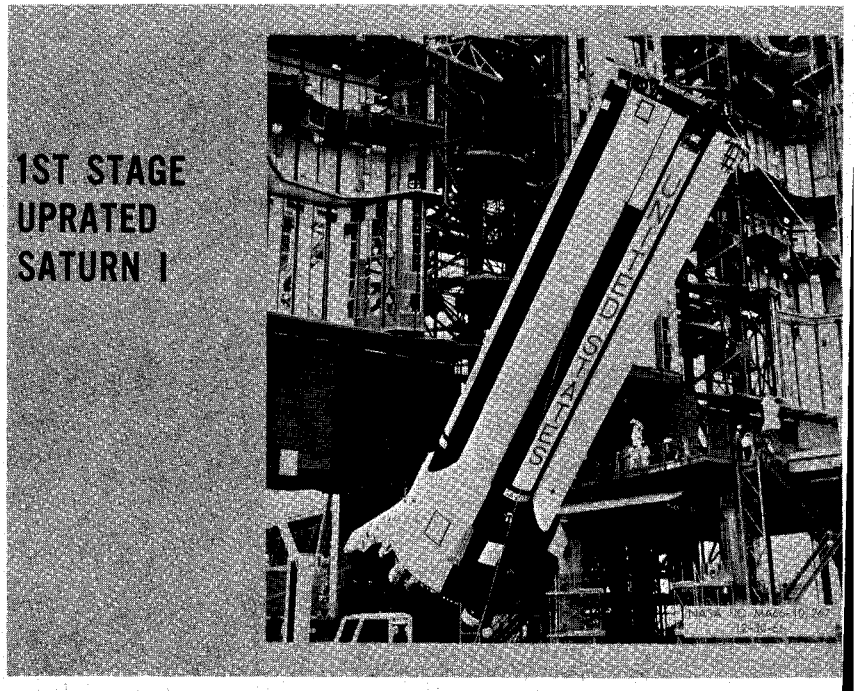


FIGURE 28

or checkout (fig. 29, MA66–9694A). Four of these will be delivered to KSC during 1967 and the last three during 1968. Qualification of all 1st stage flight critical components was completed during 1966.

2nd stage

During 1966 the uprated Saturn I 2nd stage (S–IVB) also performed well (fig. 30, MA66–10,268). Five stages have been delivered to KSC and three have been flown successfully. The remaining seven flight stages are in the pipeline with four to be delivered in 1967 and the last three in 1968. The 2nd stage of the uprated Saturn I also serves as the 3rd stage of the Saturn V launch vehicle. S–IVB stages for the Saturn V are also in the pipeline. It was a stage of this configuration that was destroyed prior to a test firing January 20, 1967 at the Sacramento Test Facility. One Saturn V stage was delivered to KSC in 1966 and six others are in varying degrees of fabrication or checkout. The remaining eight stages for the Saturn V will be in the pipeline in 1967 and completed in 1968 and 1969.

Instrument Unit

The Instrument Unit, common to both uprated Saturn I and Saturn V, houses electrical and mechanical equipment which guides, controls, and monitors vehicle performance from liftoff to payload injection (fig. 31, MA66–10,286).

During 1966 we completed ground qualification testing of nearly all components of the Instrument Unit for both the uprated Saturn I and Saturn V launch vehicles. The Instrument Unit successfully operated during the flights of AS–201, AS–203 and AS–202 and, as a result, we have high confidence in its flight performance. Two additional Saturn I Units were delivered to KSC and the Instrument Unit for the first Apollo/Saturn manned flight started through checkout at the launch site in 1966 in preparation for a 1967 launch.

Follow-on procurement of uprated Saturn I vehicles which offer a versatile means for conducting a variety of earth orbital missions, will be discussed under Apollo Applications.

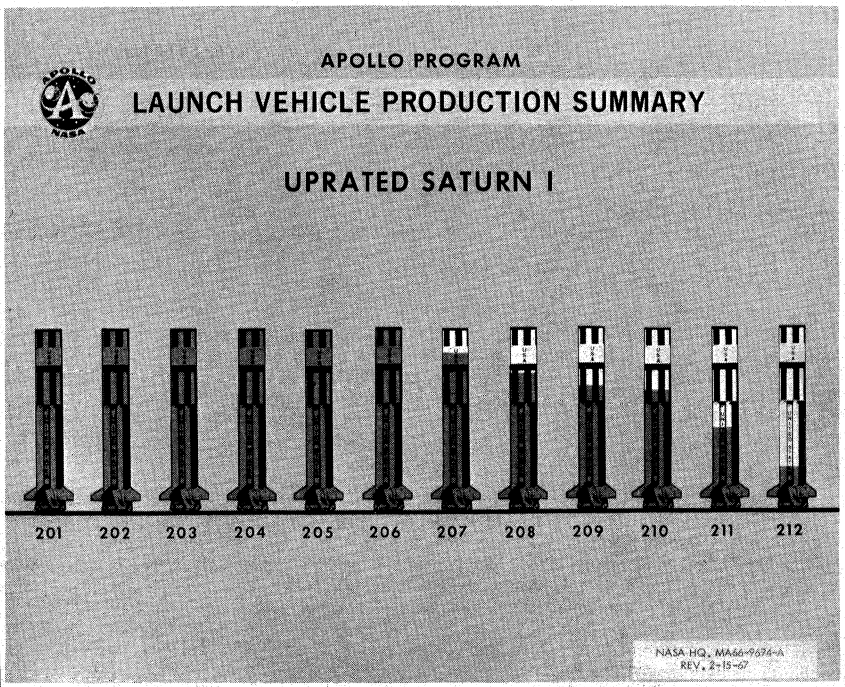


FIGURE 29

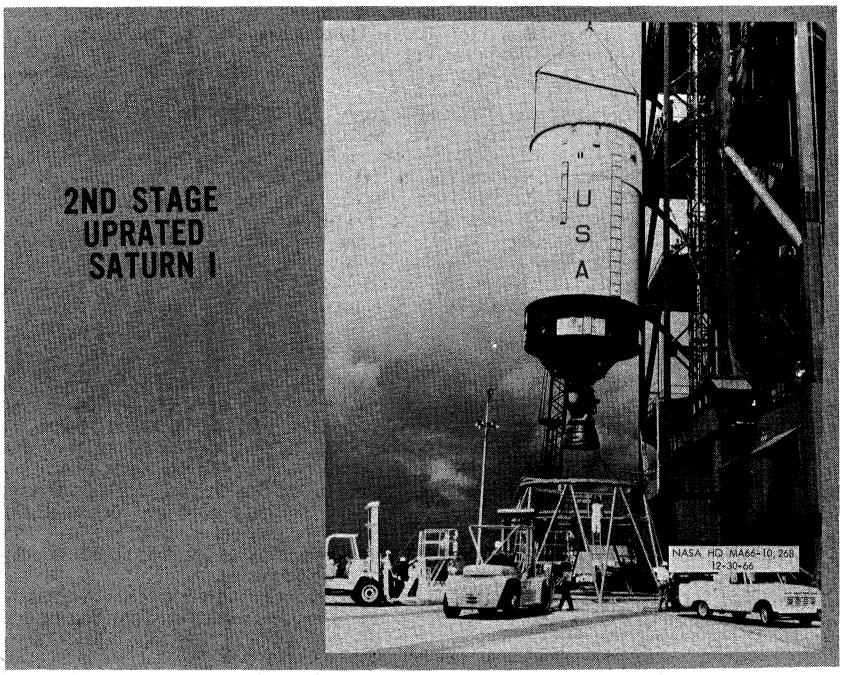


FIGURE 30

Saturn V launch vehicle

1967 will be the year of flight test for the Saturn V launch vehicle. The years of design and ground development are nearly complete. The first flight vehicle has been delivered to the launch site, backed up by a full pipeline of vehicles and complete maturity in manufacturing capability (fig. 32, MA66–9694–B).

As part of the 1966 activities we completed nearly all of the major stage ground testing efforts. The major portions of the components qualification were accomplished, and only a small portion of the qualification program remains to be completed in 1967.

500–F facilities checkout vehicle

In 1966 we delivered the Saturn V 500–F vehicle to KSC and used it to verify the operations and functions of the Saturn V launch facilities. These included the Launch Umbilical Tower, the Mobile Service Structure, Launch Control Center Firing Room No. 1, and Launch Pad 39A at Launch Complex 39 (fig. 33, MC66–10,397). This non-flight facilities checkout version of the Saturn V provided the necessary verification and valuable training prior to operations with flight hardware.

1st stage

Component qualification testing was essentially completed in 1966 for the Saturn V 1st stage (fig. 34, MA66–9237). Reliability testing will be completed by about midyear 1967. The 1st stage program pipeline was filled with the delivery of the first flight article to Launch Complex 39. This was accomplished without any significant hardware or procedural problems.

During 1966 we successfully completed acceptance test firings on the first three flight stages of the 1st stage. S–IC–3, the third of these flight stages, was the first contractor-produced 1st stage to be static fired. We delivered S–IC–1 to KSC in September 1966 where the stage was later erected on Launch Umbilical Tower No. 1 to begin checkout of the first Saturn V launch vehicle.

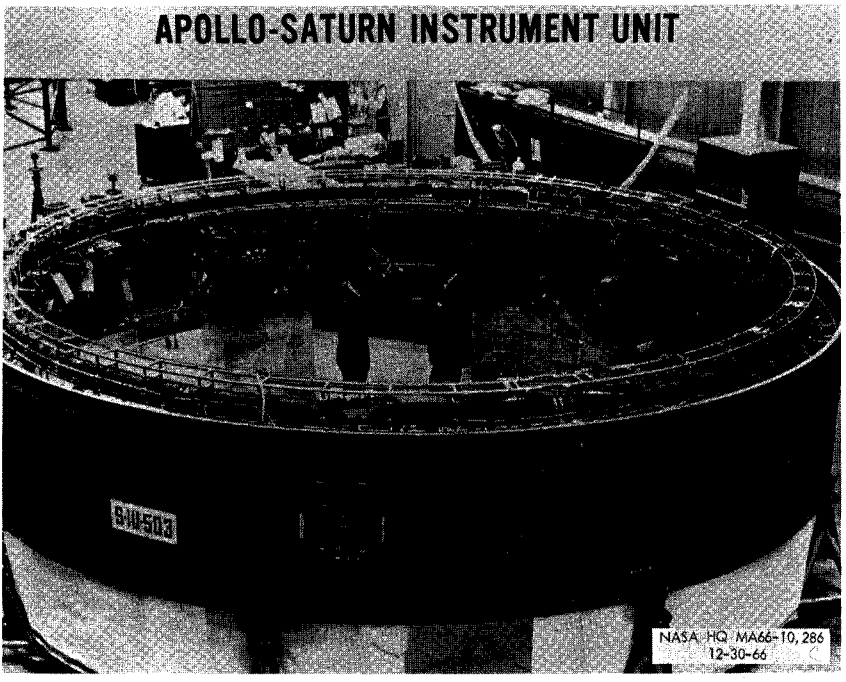


FIGURE 31

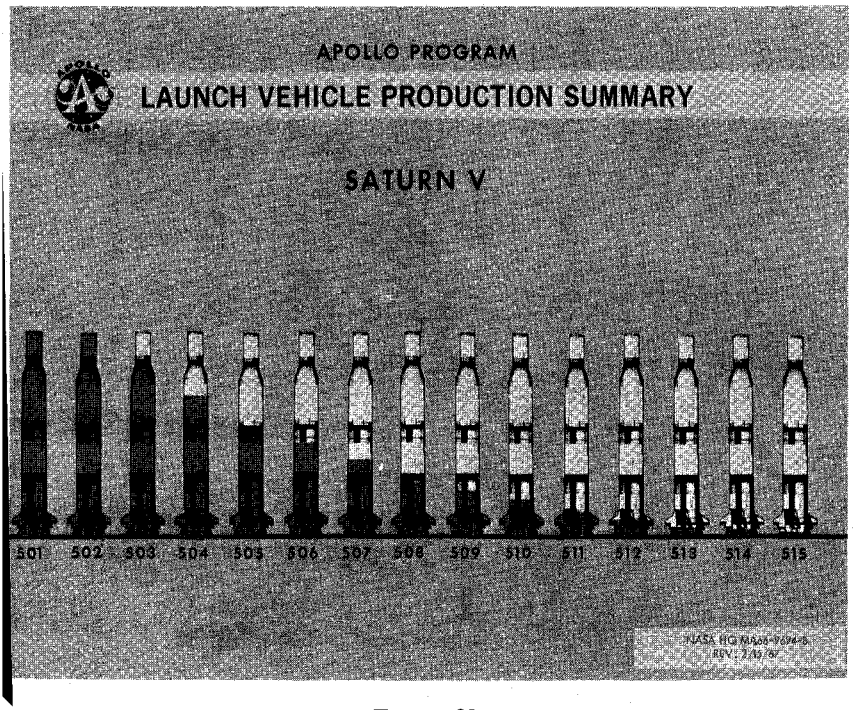


FIGURE 32

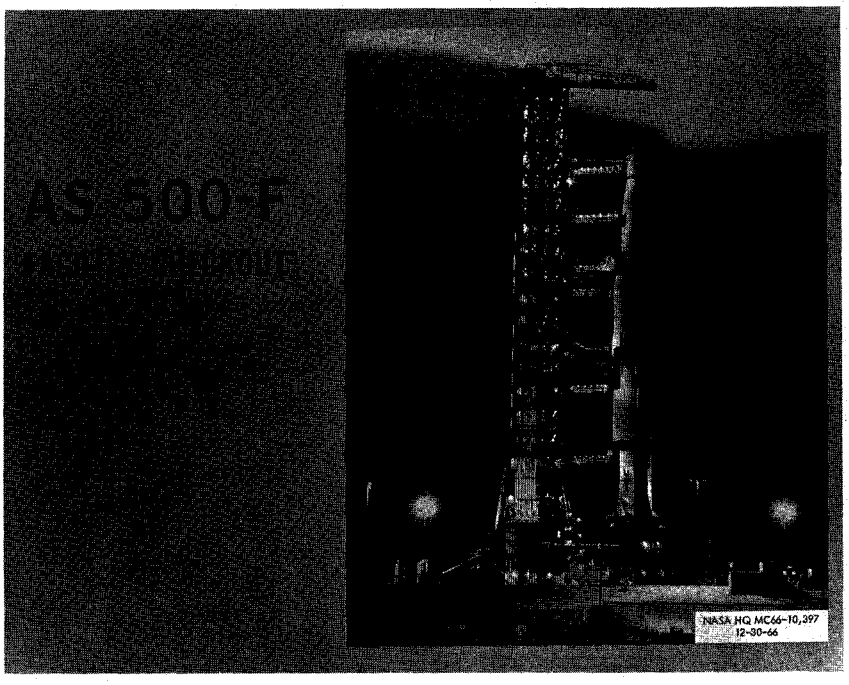


FIGURE 33

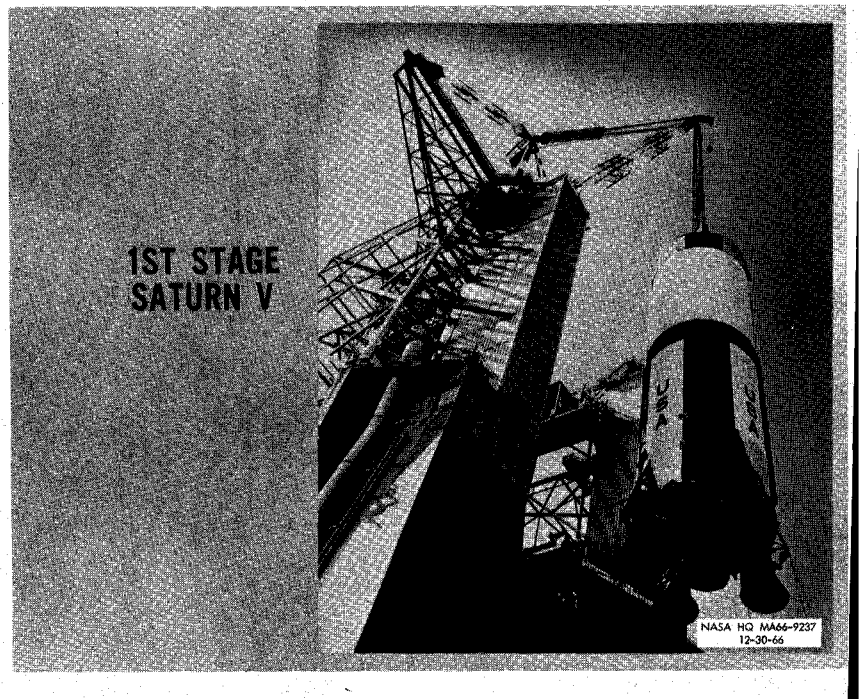


FIGURE 34

During 1967 we plan to static fire three more stages for flight acceptance; S–IC–4, –5, and –6, and we plan to deliver S–IC–2, –3, –4, and –5 to KSC.

The S–IC All Systems stage that successfully completed ground test in early 1966, was delivered to Mississippi Test Facility in October for checkout of the first S–IC All Systems stage will include a static firing to be accomplished in the first quarter of 1967.

In May 1966 the S–IC–Dynamic stage was placed in the Saturn V dynamic test stand at MSFC for checkout of the stand and its data acquisition system in preparation for the Saturn V launch vehicle dynamic testing. On March 3, 1967 the first firing of the S–IC–T stage was successfully carried out at Mississippi Test Facility.

2nd stage

Although the Saturn V 2nd stage continues to be the pacing item in the development of the launch vehicle, positive progress was made during 1966 (fig. 35, MC65–11,367). Further confidence was gained from the manufacturing checkout results of the flight hardware and the two successful static firings of the first flight 2nd stage at the Mississippi Test Facility late in 1966. Along with the static firings of S–II–1, we completed manufacturing checkout on S–II–2 (MC65–11,367). The manufacturing checkout results of all the 2nd stages processed to date, the S–II–T, S–II–1, and S–II–2, confirm the design of the mechanical and electrical/electronic systems.

In 1967 we plan to deliver three stages to MTF for acceptance testing, and to complete manufacturing and checkout on four stages.

In May 1966 we lost the S–II All Systems Stage (fig. 36, MA66–9250). When the accident occurred, we had completed 773 seconds of a planned 885 seconds static firing program in preparation for the acceptance firing of the flight stages. The destruction of the stage resulted from an inadvertent over-pressurization of the liquid hydrogen tank with gaseous helium during a leak test. Damage to the test stand was minor.

Subsequent to the loss of this ground test article, we inaugurated a Saturn V 2nd stage confidence improvement program to verify the design of this stage and provide confidence to commit it first to unmanned flight and later to a manned launch. The confidence improvement program consists of further test firings of the Battleship as well as the first and second flight stages prior to their delivery to the launch area where they will be integrated into early Saturn V flight vehicles.

In order to make most efficient use of our hardware, the S–II All-Systems Stage was also to be utilized in the Saturn V 500–D vehicle for the dynamic test program. The loss of this stage made it necessary to realign our plans.

After carefully reviewing the program requirements and available alternatives, we assigned the S–II Facility stage to the dynamic test program. This resulted in a slight delay of the dynamic testing since the facility stage was being employed in the Saturn V 500–F facilities testing at KSC. In spite of the delays, our ground test schedule supports the flight tests which will be starting this year.

The impact of the All-Systems stage loss on the launch of the AS–501 space vehicle amounted essentially to the additional time required for the static firings conducted with the first flight stage (S–II–1).

To minimize the impact at KSC of the delayed delivery of the S–II stage, an S–II "spacer," already constructed, was shipped to Cape Kennedy to enable the 3rd stage and spacecraft to be stacked for checkout purposes in the Vehicle Assembly Building (fig. 37, MA67–5796). This inexpensive expedient will significantly minimize the delay of the AS–501 launch. It will also be used in the checkout of the AS–502 and AS–503 vehicles since the S–II delivery is also pacing these launch dates.

3rd stage

The first 3rd stage flight stage arrived at KSC in August 1966 for prelaunch checkout in preparation for the first Saturn V unmanned mission (AS–501). The second 3rd stage flight stage was delivered to KSC on February 21, 1967. This stage will go through prelaunch checkout for the second Saturn V unmanned mission (AS–502).

On January 20 the 3rd stage of the AS–503 flight vehicle was inadvertently destroyed during countdown for a test firing. The accident took place at the Douglas Sacramento test facility in California. The stage was completely destroyed while the test stand received substantial, but repairable, damage (fig. 38, MC67–5707).

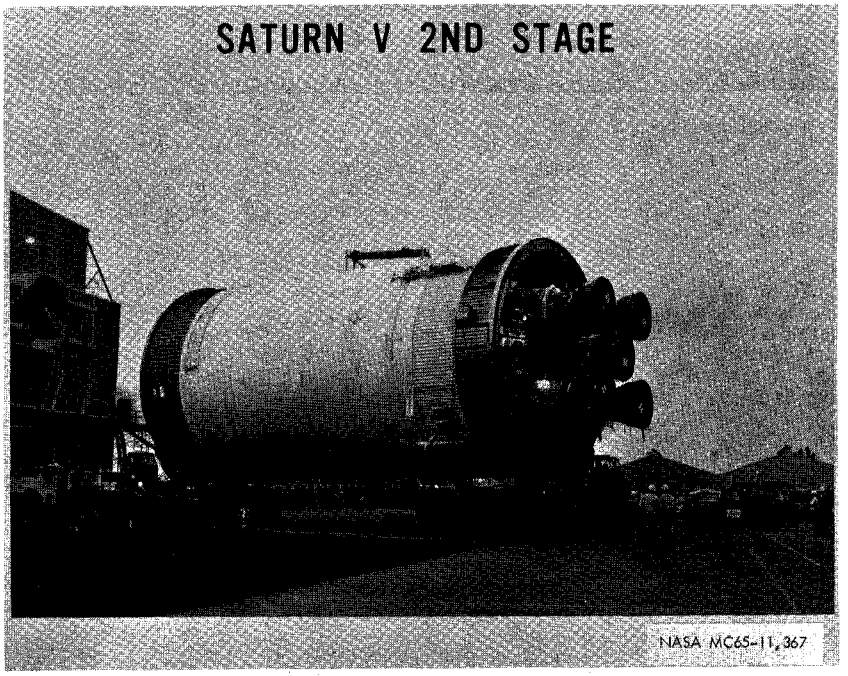


FIGURE 35

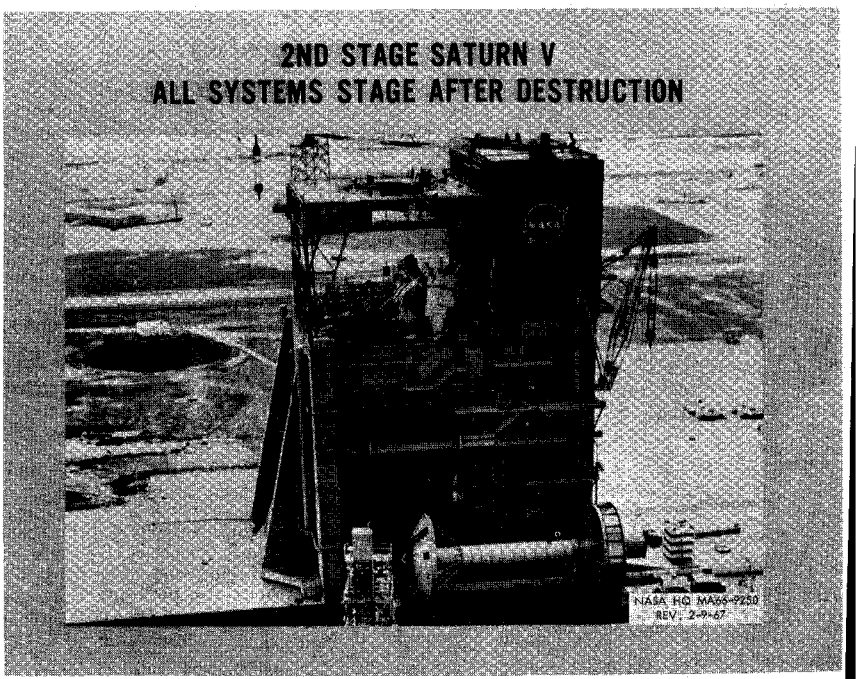


FIGURE 36

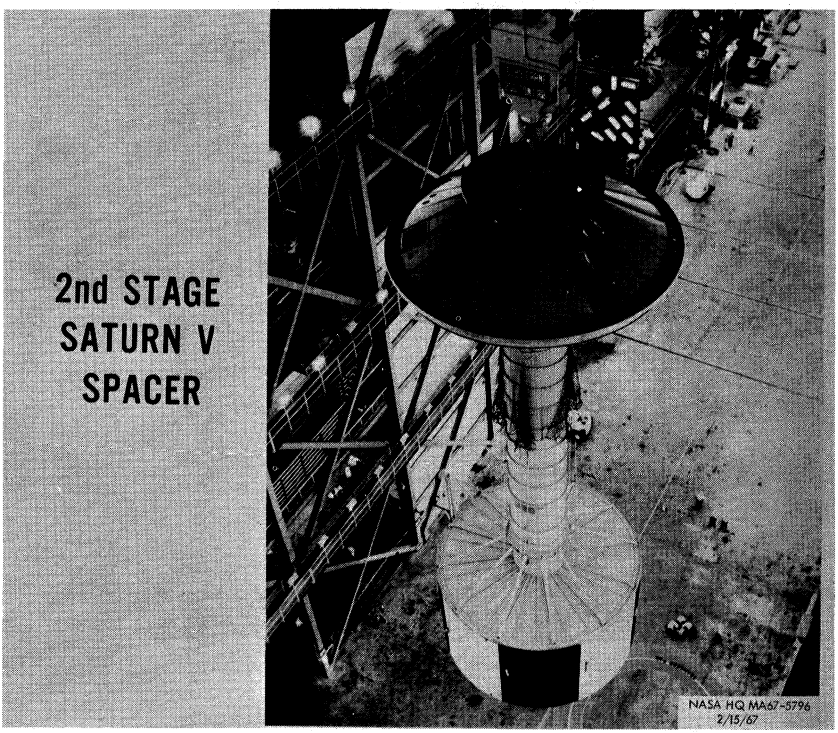


FIGURE 37

There is no impact on the early phases of our current launch schedule since the production schedule is at a point where it can accommodate an advancement of the stages to the next earlier flight.

Saturn launch vehicle engines

In 1966 we completed the qualification of our launch vehicle engines—the H–1, J–2, and F–1 (fig. 39, MA66–9215). The H–1 engine is used in a cluster of 8 on the uprated Saturn I 1st stage. The J–2 engine is used singly in the S–IVB stage, which serves as the 2nd stage for the uprated Saturn I and the 3rd stage for Saturn V, and in a cluster of 5 on the 2nd stage for Saturn V. The F–1 engine is used in a cluster of 5 on the Saturn V 1st stage.

H–1 engine

The H–1 engine was uprated to 205,000 pounds thrust and completed requalification at this level in June 1966. This uprating, accomplished with minimum modification to the engine, provides additional payload margin on the uprated Saturn I vehicle. Our flight worthiness verification testing is continuing under the sustaining engineering effort together with the flight program. H–1 production engine deliveries for the first stage of the uprated Saturn I were completed in 1966.

J–2 engine

Qualification of the uprated J–2 engine was completed in September 1966. Thrust of the uprated J–2 varies from 205,000 to 230,000 pounds depending upon the fuel mixture ratio. This uprated engine will be used in the upper stages of both the uprated Saturn I (effective on AS–207) and Saturn V (effective on AS–504), providing greater payload margins for these manned vehicles. Sustaining engineering and flight support will continue through 1967.

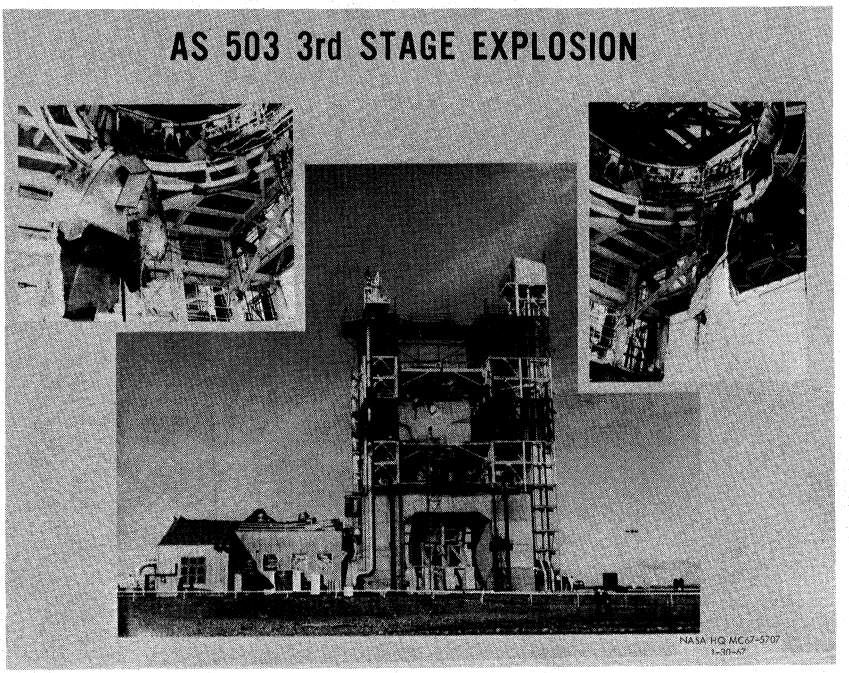


FIGURE 38

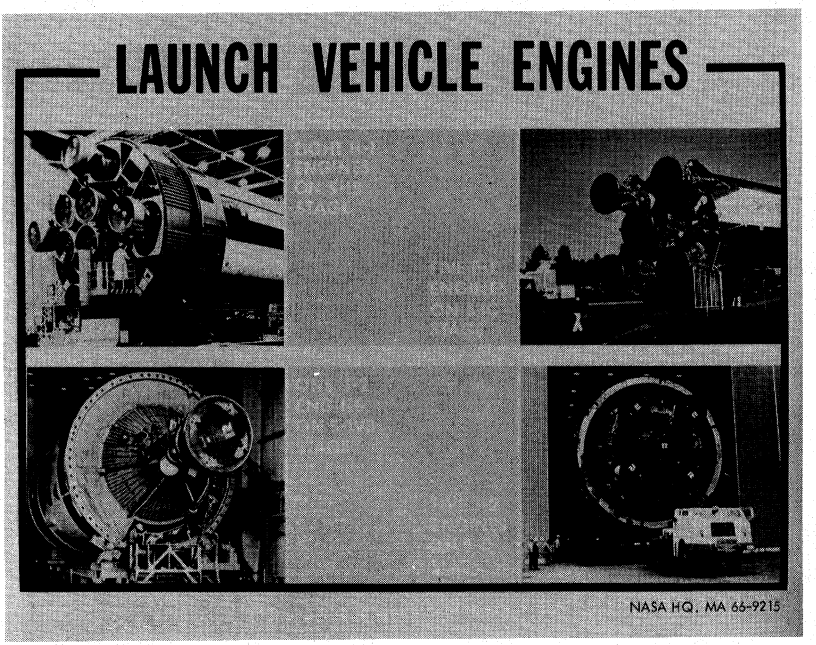


FIGURE 39

F–1 engine

The F–1 engine, now rated as 1,522,000 pound thrust, completed qualification in September 1966 and will be flown for the first time in the AS–501 vehicle early this year. As a result of this uprating from the F–1 original 1,500,000 pound thrust, the total thrust of the Saturn V 1st stage is now 7,610,000 pounds.

Sustaining engineering and flight support for the F–1 engine will continue in 1967. Fifty-one engines have been delivered from F–1 engine production in support of ground testing and flight 1st stages. During 1967, 30 additional engines will be delivered. Apollo production will be completed in 1968.

Apollo spacecraft

As with the launch vehicles, flight spacecraft and spacecraft test articles have been shipped to the launch site in Florida from the manufacturers' plants (fig. 40, MA66–9695–B). Most of the subsystems ground testing for the Command and Service Module Block I spacecraft was completed by mid 1966. The Command and Service Module Launch Escape System testing on Little Joe II vehicles at White Sands was concluded and personnel and equipment were withdrawn. Lunar Module subsystems testing was started in the first half of 1966 on about half the key subsystems, subsystems testing to be completed in 1967. By the end of 1966, the majority of the first Lunar Module flight constraining ground tests were completed. Lunar Module propulsion testing at White Sands will continue into 1967.

During 1966, Critical Design Reviews were conducted on the Block II Command-Service Module and on the Lunar Module. As I mentioned earlier, we are carefully reviewing our procedures and will be instituting design modifications as data becomes available from the AS–204 Review Board.

Ground testing of the Block II Command and Service Module, configured for lunar flights, has begun on flight test type spacecraft, restrained from any

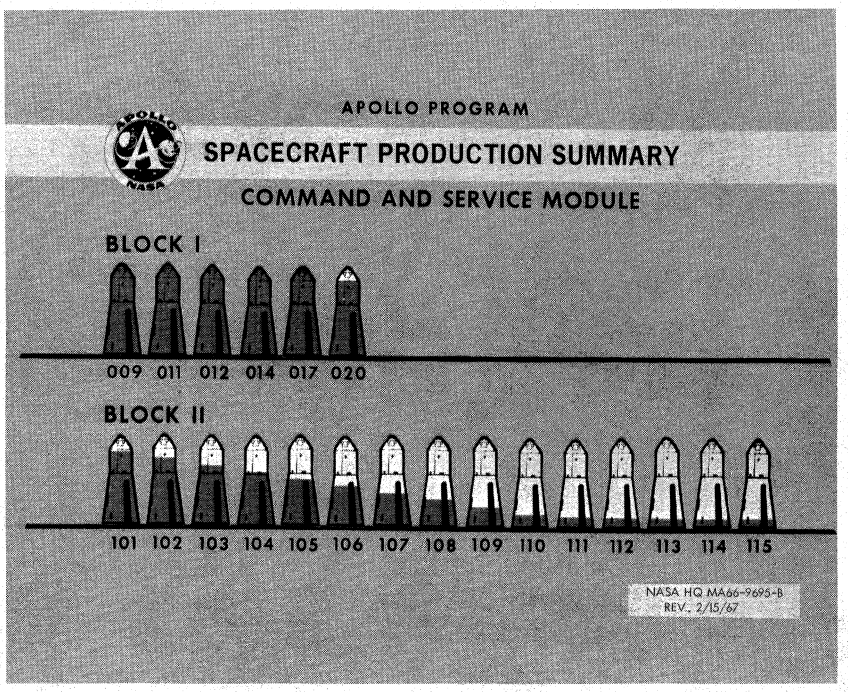


FIGURE 40

testing using a pure oxygen environment pending findings of the Review Board. The Block II is similar to the Block I with the addition of a docking configuration. It was initiated in 1962 when the Lunar Orbit Rendezvous Mode for lunar landing was selected. The adapters for Block II are the same as flown with the Block I spacecraft and require no additional testing.

Adapter Section

Testing of the Adapter Sections, which will house the Apollo Lunar Module spacecraft on future flights, was successfully concluded. Adapter Section units for Apollo Saturn flights with the Lunar Module are now being fabricated at Tulsa and delivered to KSC and MSC by helicopter (fig. 41, MC66–10,271).

Lunar Module

The Lunar Module development program follows the Command and Service Modules by about one year. Qualification and major ground testing will be completed in 1967, although, as I mentioned, it is quite possible that we will experience some impact from the AS–204 accident in our Lunar Module development program.

During 1966, major components were integrated in various subsystem tests and their operation was verified. The component qualification test program started last year is continuing.

The Lunar Module subsystem and vehicle development is supported by a number of major hardware articles, including Engineering Test Models, Propulsion Test Rigs, and Lunar Module Test Articles. Engineering Test Models are continuing in use to obtain specific design performance information, such as thermal-vacuum and RF transmission characteristics. Propulsion Test Rigs have been actively used at the engine contractors, Arnold Engineering Development Center, and the White Sands Test Facility. The engine test program at the Arnold Center has been completed on the ascent and descent engines and supplemental testing is continuing at the engine contractor's plant.

FIGURE 41

Lunar Module Test Articles are used in the development program to verify subsystem and vehicle operational and performance requirements. Major tests include structural, dynamic, propulsion, thermal-vacuum, and integrated systems, and each of these vehicles removes specific ground test constraints on initial flight missions. Two of these ground test articles have been refurbished for flight tests on the first two Saturn V flights.

During 1966, fabrication and assembly effort increased on a number of flight and test vehicles. The structural test article, LTA–3, successfully completed its tests at MSC. The electrical integration test article, LTA–1, has completed tests at the Grumman plant in Long Island, New York. The thermal vacuum test vehicle, LTA–8, is undergoing final tests at the contractor's facility before being sent to the thermal vacuum chamber at MSC.

The first flight test vehicle, LTA–10R, a refurbished test article, has been delivered to KSC. The refurbished vehicle is ballasted for overall weight and approximate center of gravity and moment of inertia of the Lunar Module. It is instrumented and will be flown on the first Saturn V booster (AS–501) to determine compatibility, structural integrity, and response of the simulated Lunar Module to the boost environment. The first flight Lunar Module, LM–1, is nearing completion at the contractor's plant, and will be flown unmanned on the AS–206 mission to verify subsystem operation in the space environment. The module will be programmed for a complete series of propulsion tests.

In addition to the first and second Lunar Modules now in the checkout phase at Grumman, five other vehicles are in various stages of fabribation, assembly, and installation. Long lead procurement has been initiated on all of the remaining Lunar Modules. Four of these vehicles will be delivered in 1967 (fig. 42, MA66–9695–A).

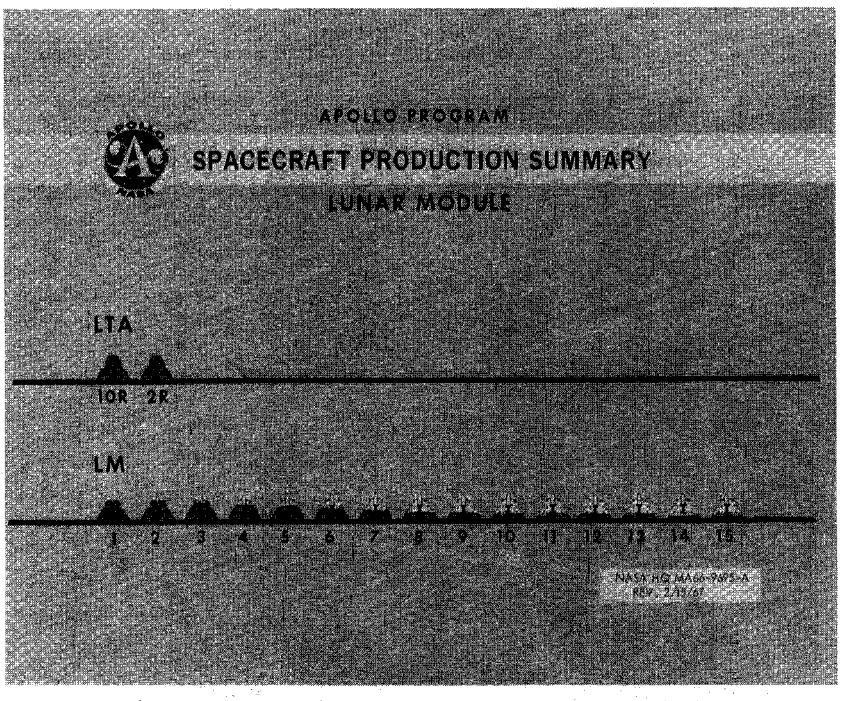


FIGURE 42

Command and Service Module development

Command and Service Module development difficulties have been encountered during 1966, principally in the service propulsion tanks and in the Environmental Control System.

Stress corrosion of titanium propellant tanks

Last year I reported the problem of stress corrosion with the titanium propellant tanks and the nitrogen tetroxide oxidizer. We resolved that problem by adding an inhibiting agent to nitrogen tetroxide, allowing us to use the tanks safely without a hardware change. An extensive test program has verified that a small amount of nitric oxide (less than 1 percent) effectively stops the stress corrosion.

More recently, another fluid incompatibility with titanium has been encountered: methyl alcohol (methanol). In late October 1966, one of the titanium tanks in the Service Module of Spacecraft 017, planned for use on the first Apollo/Saturn V flight, failed during pressure test at the North American Aviation plant (fig. 43, MA66–9169). One of the two main fuel tanks exploded, causing extensive damage to the Service Module. Methyl alcohol was used for this test to avoid using the actual propellant, a hydrazine blend which is toxic. The tank that failed had successfully passed several acceptance "proof" pressure tests previously at significantly higher levels of stress than that at which it failed. From analysis of the failed tank and from laboratory specimen tests at the Manned Spacecraft Center, Langley Research Center, North American Aviation, and Boeing Co., we have determined that the titanium alloy from which these tanks are made is very susceptible to stress corrosion cracking under methyl alcohol exposure. This phenomenon has been observed and verified at stress levels of approximately 100,000 psi, which corresponds to our tank operating pressure.

We immediately alerted the technical community to this incompatibility and are documenting and making available all test data. Although the use of methyl alcohol as a test fluid has been stopped, this difficulty highlights the importance.

FIGURE 43

of the emphasis we have already placed on the subjects of stress corrosion and material incompatibility. As the Apollo program progresses these technical discoveries push the technology frontier a little further out.

An Apollo program directive has been issued which requires thorough test revalidation of the compatibility of all use fluids with their tank materials.

Environmental Control Unit

The Environmental Control Unit experienced technical difficulties during the past year that resulted in delays to the test program requiring redesign and requalification of the system.

As a result of this occurrence, early in November we placed a modified Environmental Control System in the Command and Service Module of the AS–204 space vehicle undergoing prelaunch testing at KSC. Spacecraft for all flights will now use the requalified Environmental Control System.

Lunar Module development

We foresee no major engineering problems remaining to be resolved in the development of the Lunar Module. We have experienced the type of difficulties you might expect in such a development effort. However, additional ground and flight testing is required to demonstrate that the configuration is acceptable for the lunar mission.

Landing radar

The need for additional testing is particularly true of the landing radar, where performance under flight conditions has yet to be demonstrated. An intensive ground test program is being conducted including flight tests with radar installed on helicopters and fixed wing aircraft. Tests are also planned on the Lunar Module development flight missions to measure radar performance in the vibration, temperature, and engine plume environment of the spacecraft. We were much encouraged by the performance of the Surveyor I radar, which is similar to the one used on the Lunar Module.

Engines

In the descent and ascent engine area, we encountered obstacles which delayed the start of the qualification program (fig. 44, MA66–9185; fig. 45, MA66–9186).

The descent engine was experiencing erosion of the ablative engine throat and low performance which were corrected by minor changes to the injector design.

The ascent engine had difficulties with chamber erosion and instability, both of which were related to injector construction methods.

The results of the LM–1 flight tests are expected to verify performance of the propulsion systems.

Weight of Lunar Module

Last year we were faced with a potentially serious weight growth trend on the Lunar Module and a weight improvement program was started. This effort has reflected in a continuing weight decrease during 1966. The vehicle is below the control weight at this time. The weight margin can be used to advantage in loading additional propellant on board.

CHECKOUT, TEST, AND LAUNCH OPERATION FACILITIES

Launch vehicle checkout facilities

Activation of the stage checkout facilities to support the Saturn V program continued as planned during the past year. Static test stands and factory post-static test facilities became operational for the checkout of the 1st, 2nd and 3rd stages, and the Instrument Unit.

Michoud Assembly Facility

The second factory checkout position for the Saturn V 1st stage was activated at the Michoud Assembly Facility near New Orleans, Louisiana in August and handled the factory checkout of the S–IC–4. Analysis of our experiences shows that the two checkout positions can handle the maximum planned flow rate of six stages per year in both factory and post-static checkout.

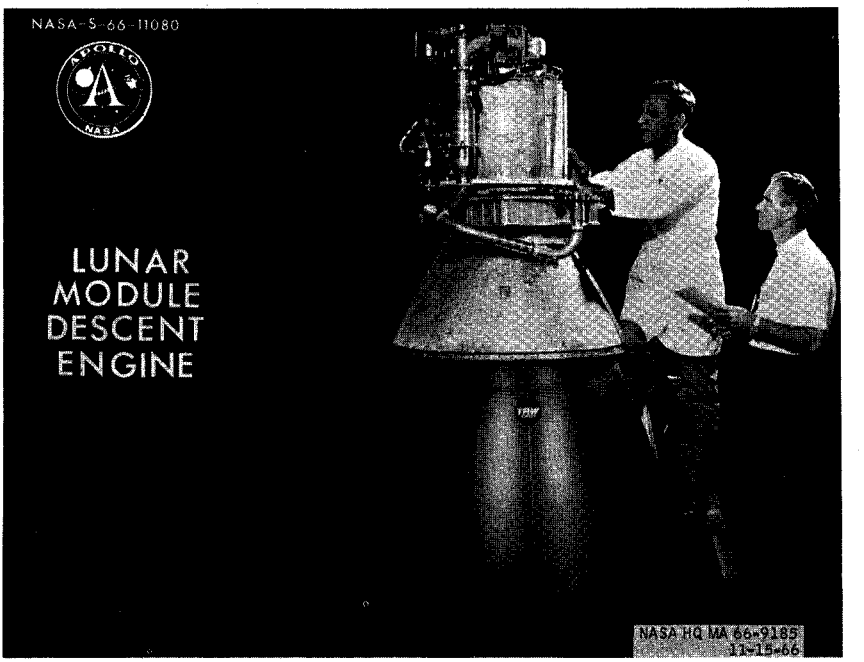


FIGURE 44

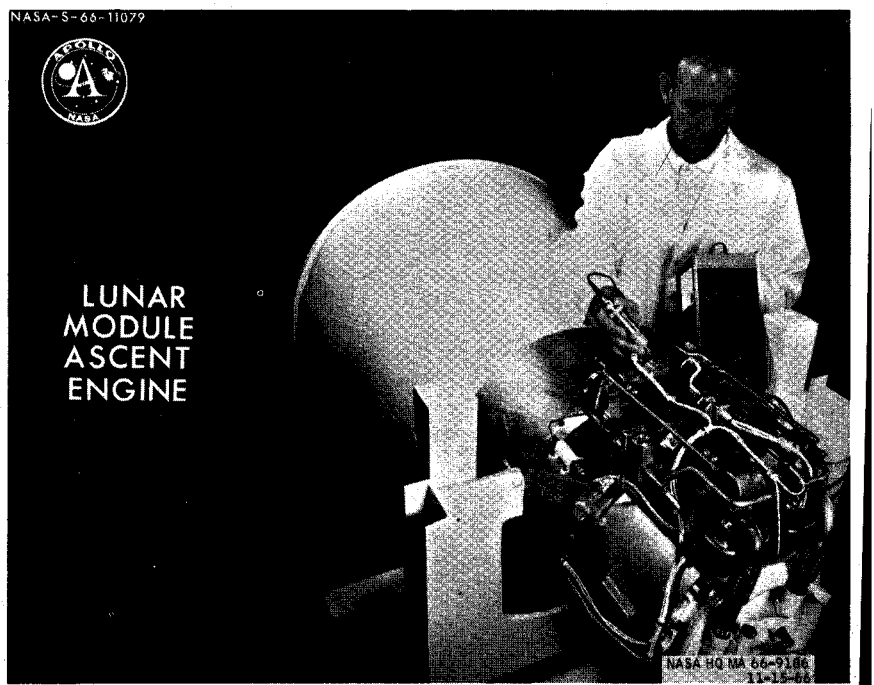


FIGURE 45

Mississippi Test Facility

At Mississippi Test Facility, the first Saturn V 2nd stage static test stand became operational in April 1966 (fig. 46; MA66–9226). Work progressed toward operational status in early 1967 for both the second S–II static test stand and the first side of the 1st stage dual static test stand. The second position of the latter stand will not be activated unless required later in the program.

Seal Beach, California

Activation of the first factory checkout station at Seal Beach, California, was completed in April 1966 to accept the arrival of the S–II–1 Saturn V 2nd stage. Activation of the second factory checkout station at Seal Beach is underway and will be completed by mid-1967.

Huntsville, Alabama

IBM activated the Instrument Unit Checkout station at Huntsville in May 1966 in time for the factory checkout of the first Saturn V Instrument Unit. This facility completes our planned Factory Checkout capability for the Instrument Unit.

MSFC activated the Saturn V System Development Facility in April. This breadboard facility is designed to verify the operational capability of our launch vehicle checkout equipment and to develop and validate the checkout procedures and computer programs.

Spacecraft factory checkout facilities

Command and Service Module checkout

During 1966, we increased our checkout capability from three to four Integrated Test Stands for Command and Service Module checkout at the North American Aviation plant. This was made possible by overhaul and activation

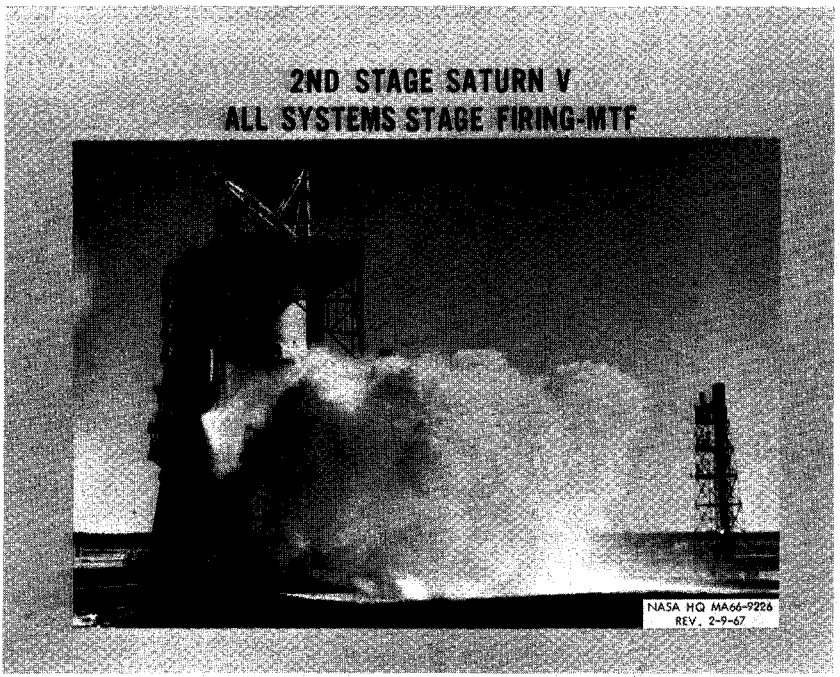


FIGURE 46

of a test stand previously used for developmental testing of the house spacecraft. The four stations were constructed as two sets of two stations each and share much common ground support equipment.

Approximately 50 additional ground equipment units were required to support the checkout of the Block II spacecraft. Definition and manufacture of these new requirements were completed during 1966. Later, the first complete activation was accomplished for Block II testing in two test stands at North American Aviation.

Lunar Module checkout

Four factory integrated test stands were activated last year at Grumman Aircraft Engineering Corporation. Three stands are to be used for acceptance checkout of completed Lunar Modules. The fourth, which is a wooden stand used for electro-magnetic compatibility tests, was used for house spacecraft developmental testing.

A large quantity of ground support equipment produced for Command and Service Module use also has been allocated to satisfy ground support needs for the Lunar Module. This common use equipment consists mainly of test signal command devices and fluid servicing equipment.

The requirement for a third Automatic Checkout Equipment station for Lunar Module checkout became apparent during 1966. The last station to be produced was expedited and its timely installation at Grumman averted a checkout bottle neck before it occurred. During the summer of 1967, this checkout problem will no longer exist and the added Automatic Checkout Equipment station will be removed from Bethpage for installation as the fifth station at KSC.

Spacecraft checkout facilities at KSC

The Industrial Area Facilities at KSC have been activated for the Block I Apollo Saturn I missions. Ground support equipment modifications will be required, however, for Block II Command and Service Module checkout at the propulsion static firing pad and in the altitude chamber. These modifications will be accomplished early in 1967.

Ground support equipment installation and associated activation tasks started during the early fall of 1966 and are almost completed to support Lunar Module checkout. During the summer of 1966, the installation of a third and fourth Automatic Checkout Equipment station was completed for spacecraft checkout support. We have deferred installation of the fifth station until the summer of 1967, allowing additional support for factory checkout of the Lunar Module.

Launch operation facilities

Launch Complex 34/37

Launch Complex 34, whose conversion for launching the uprated Saturn I was completed last year, was since utilized for two unmanned Saturn I launches and will be used for the first manned Apollo Saturn I mission (fig. 47, MC66–5457).

Possible changes required in the launch pad as a result of the AS–204 Saturn I was launched from this complex (fig. 48, MC66–5449). Launch Complex 37 for uprated Saturn I launches was completed in 1966 and an Apollo/Saturn I was launched from this complex (fig 48, MC66–5449). Launch Complex 37 also has now been modified for Lunar Module launches with the Apollo/Saturn I.

Assembly of the Apollo/Saturn I is performed on Launch Complexes 34 and 37 as the stages are received from the factory. The spacecraft modules are checked out in the Industrial Area at KSC prior to mating with the launch vehicle.

Launch Complex 34 currently has the capability of assembling, checking out, and launching the Saturn I with the Apollo Command and Service Module.

Launch Complex 37, when modifications are completed early in 1967, will have the capability of launching the uprated Apollo/Saturn I with the Lunar Module. Plans are now proceeding so that in 1968 Launch Complex 37 will also be able to launch an Apollo/Saturn I with a Command and Service Module.

Launch Complex 39

Construction of Launch Complex 39 (fig. 49, MC66–5446) for the Saturn V launch vehicle is well along, and we have completed the Wet Test of Pad A utilizing the 500–F vehicle. Individual stage propellant as well as multiple simultaneous propellant loading was demonstrated, proving the capabilities of

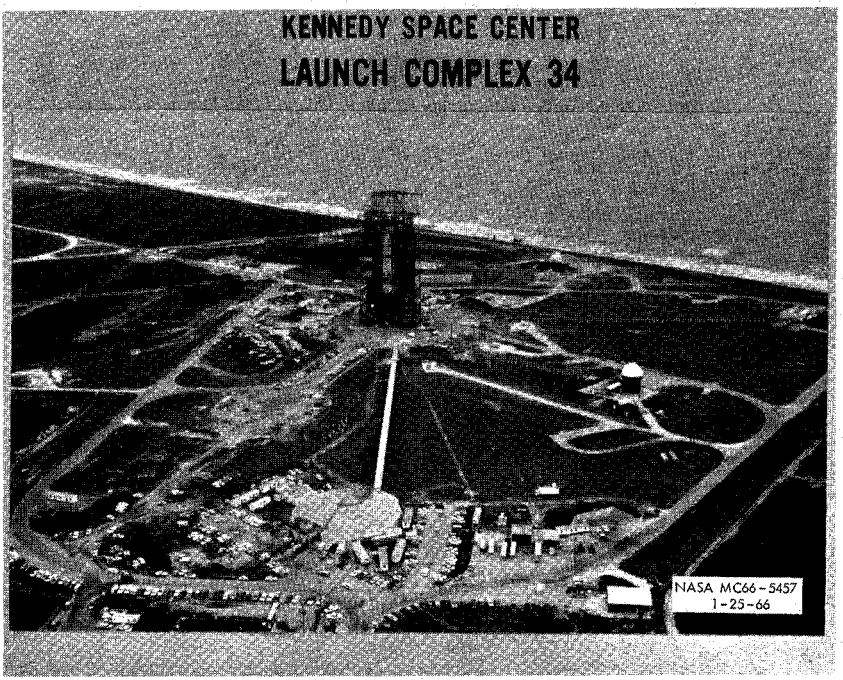


FIGURE 47

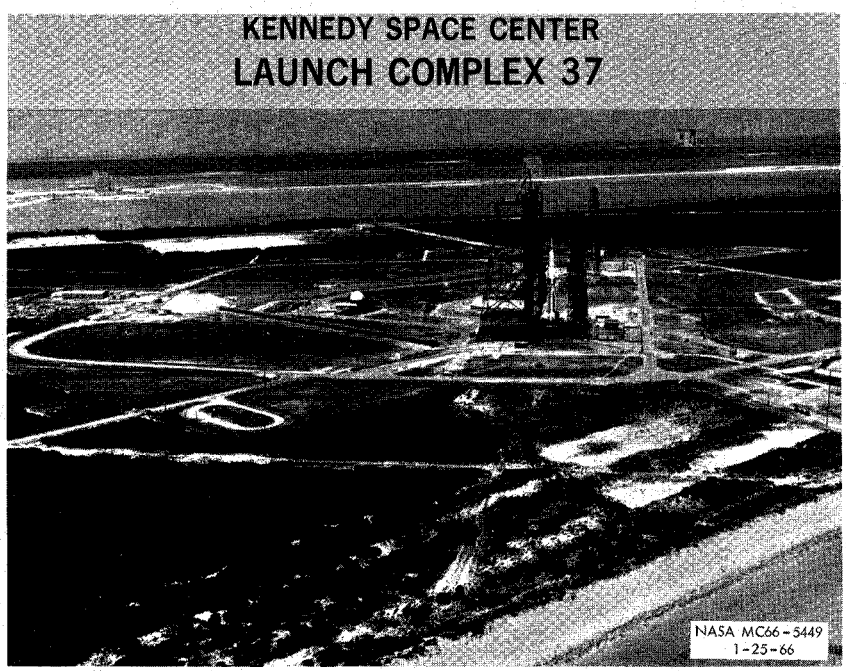


FIGURE 48

Launch Complex 39 for the first Saturn V launch. Since we resolved the bearing problem, the Crawler-Transporters have performed satisfactorily in several moves of the Launch Umbilical Tower, both unloaded and loaded with the 500–F vehicle. Tests also were performed by moving the Mobile Service Structure to Pad A for a compatibility check with the Launch Umbilical Tower and the 500–F vehicle (fig. 50, MC67–5429).

Launch Complex 39 will be fully operational in 1968. At that time, it will have three of its four high bay areas activated and will have two Crawler-Transporters, three Launch Umbilical Towers, one Mobile Service Structure, two pads and three instrumented firing rooms in operation.

One Launch Umbilical Tower and one firing room have been completed to date.

Modifications to the Instrument Unit, 2nd stage and 3rd stage can be performed in the low bay area of the Vehicle Assembly Building at Launch Complex 39. The entire Saturn V vehicle is erected on the Launch Umbilical Tower in the high bay area of the Vehicle Assembly Building (fig. 51, MC67–5011). Checkout is performed in this protected area prior to the move to the launch pads.

Software

Following the delivery of operating systems and test programs for AS–201, the Marshall Space Flight Center delivered on schedule the succeeding computer programs for AS–202, AS–203 and AS–204. Each new programming package has included software for automating additional test functions.

Launch operations

Training of personnel

Last year I reported on an anticipated problem in the training of certain personnel required for operation of the Vehicle Assembly Building at KSC (fig. 52, MC66–10,276). Since then we have been able to provide training for all launch

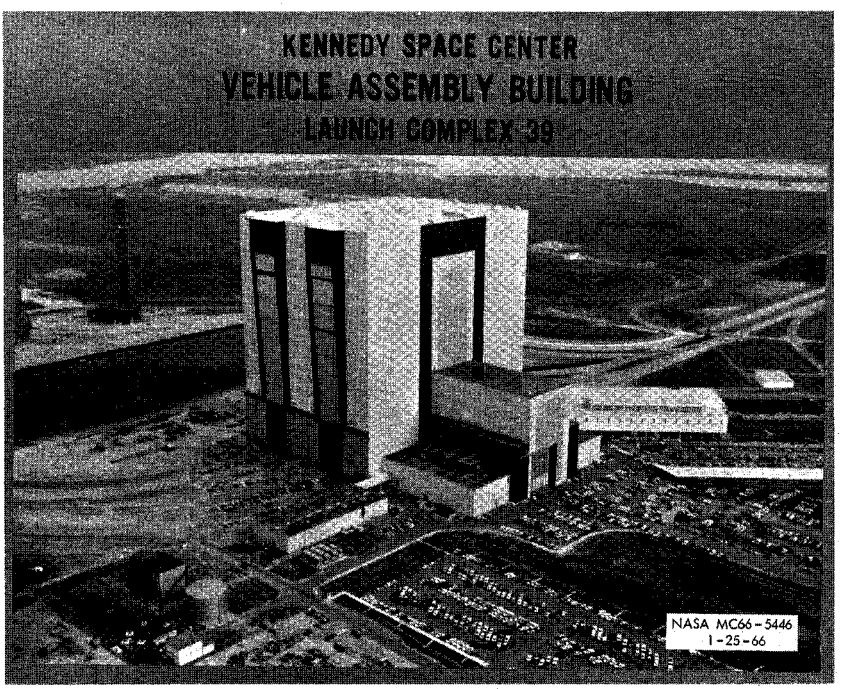


FIGURE 49

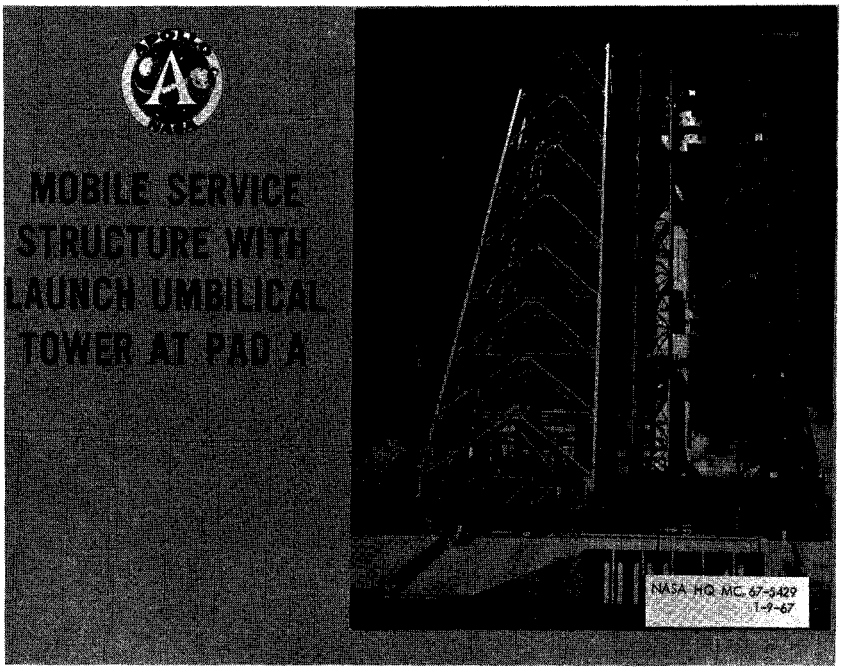


FIGURE 50

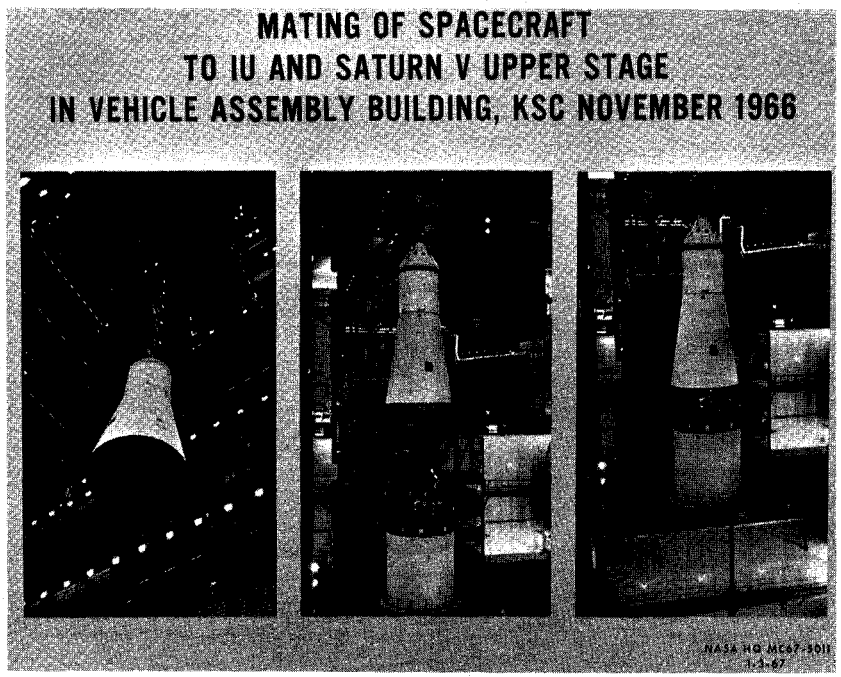


FIGURE 51

LAUNCH OPERATIONS PROBLEMS RESOLVED

- TRAINING OF PERSONNEL
- CHECK OUT SYSTEMS
- COMPUTER PROGRAMS
- VAB CRANES
- SWING ARMS
- LOX FAILURE

NASA HQ MC66-10,276
12-30-66

FIGURE 52

support personnel in connection with the extensive facility checkout operations with the Saturn V 500–F vehicle at KSC last summer. This operation not only verified the mechanical and electrical interfaces of the systems, but it provided personnel training and experience in handling large quantities of liquid oxygen and liquid hydrogen; the operation of the Crawler-Transporter under load conditions; the operation of cranes in the Vehicle Assembly Building; and assembly, check-out and disassembly by the large checkout team which prepares the Apollo/Saturn space vehicle for launch.

Checkout systems

The checkout system for the Saturn V launch vehicle consists of seven computers and more than 1300 panels of electrical support equipment. More than 3000 cables are required to interconnect all this equipment. We successfully manufactured, installed and tested on schedule the first Saturn V checkout system and utilized it for the Wet Test of 500–F at Launch Complex 39, Pad A, as well as checkout of AS–501. This success was achieved by utilization of advanced management techniques, the excellent support of the industrial suppliers, and the hard work of the personnel furnished by our industrial support team.

Computer programs

We overcame our major computer program difficulties in 1966, completing computer program tasks on schedule. Computer programs for the Wet Test at 500–F at Pad A and for the checkout of AS–501 were developed and delivered. The timely delivery of working programs was achieved by the cooperative efforts of the support contractor.

Swing arms

We have been able to expedite the lagging deliveries of swing arms by working closely with the contractor. Qualification of the first set of arms, originally intended for use with the AS–501 flight, was delayed until after Pad A activation so that a set of arms would be available to support the 500–F Wet Test in April.

The second set of arms was qualified in time to support the erection and checkout of AS–501 in October. The third set of arms is expected to be qualified

early in 1967 in time to support AS–502. Qualification of the original set is expected to be completed in mid 1967.

Launch Complex 39 liquid oxygen propellant system

A flexible section of an 18-inch liquid oxygen transfer line ruptured during a Pad 39A facility checkout test in August 1966. The tank inner shell dimpled from low internal pressure resulting from the liquid oxygen discharge. The liquid oxygen discharge also displaced piping and caused minor damage to the tank foundations and nearby machinery (fig. 53, MA66–9029).

All damage was repaired and modifications to the system were made to prevent a recurrence. The complete repair, modification, and tank refilling was accomplished in approximately one month.

RELIABILITY AND QUALITY ASSURANCE

Reliability and Quality engineering disciplines in the Apollo program help to provide check and balance between systems engineering and manufacturing activities and to certify that the hardware for a mission is in a state of readiness.

Proven reliability engineering techniques are being applied by Manned Space Flight Reliability and Quality Assurance.

The reliability disciplines previously applied in the program ground test actvities had to be modified in the past year to satisfy the new requirements imposed by flight test. A number of reliability engineering disciplines contribute to and culminate with the Flight Readiness Review.

Workmanship and quality are as important, if not more important to the reliability and safety of equipment as is the fundamental design. We believe we have maintained a vigorous and effective quality control and inspection program. The careful disassembly of the AS–204 spacecraft being accomplished under the direction of the AS–204 Review Board provides a unique opportunity to determine whether or not there have been shortcomings in this area. We will follow this disassembly through step by step and take such actions as are indicated if quality and inspection deficiencies are found.

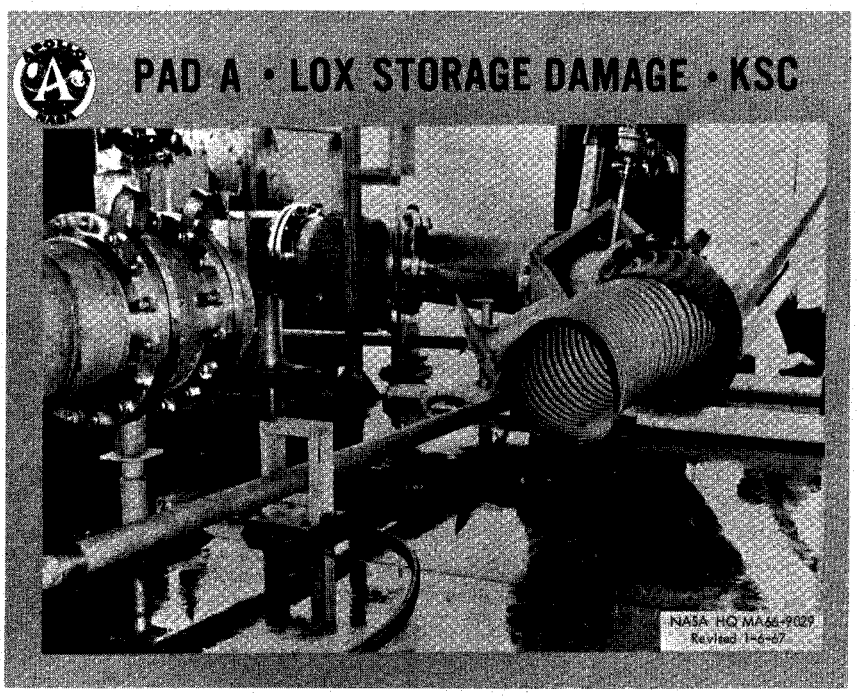


FIGURE 53

APOLLO MANAGEMENT

Baseline management concept

On previous occasions we have emphasized the importance of defining an integrated and balanced schedule-cost-performance baseline for the Apollo program, and having sufficient visibility through all elements of the program to measure progress against the baseline (fig. 54, MC65-6041). It is equally important to the Apollo Applications program and is being carried forward into that effort.

Problems cause the various elements of the program to get out of balance. It is the responsibility of management to evaluate existing conditions and prepare to make whatever material and programmatic changes necessary, while concurrently moving all other elements of the effort along at an appropriate pace. I believe that the total Apollo management team is proving itself effective in this respect.

The prevailing challenge to management is to minimize the impact of management and engineering difficulties on the overall program. The passage of time will validate our success in this endeavor.

Reviews

Reviews and assessments continue to play an important part in the management process. The Management Council, on which both my Center Directors and I serve, reviews on a monthly basis the Apollo program progress and problems as they are presented by the Apollo Program Director, his staff, and the Center Program Managers. These presentations are followed by an Executive Session in which major problem areas are discussed.

Additionally, a series of reviews has been developed and undertaken to assure the technical adequacy of the system and equipment (fig. 55, MA66-9614A).

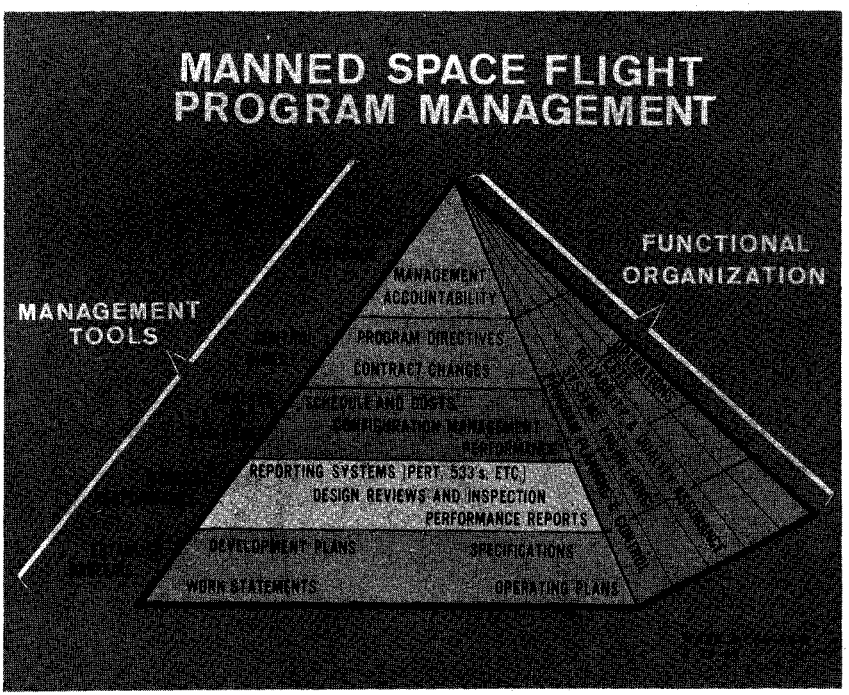


FIGURE 54

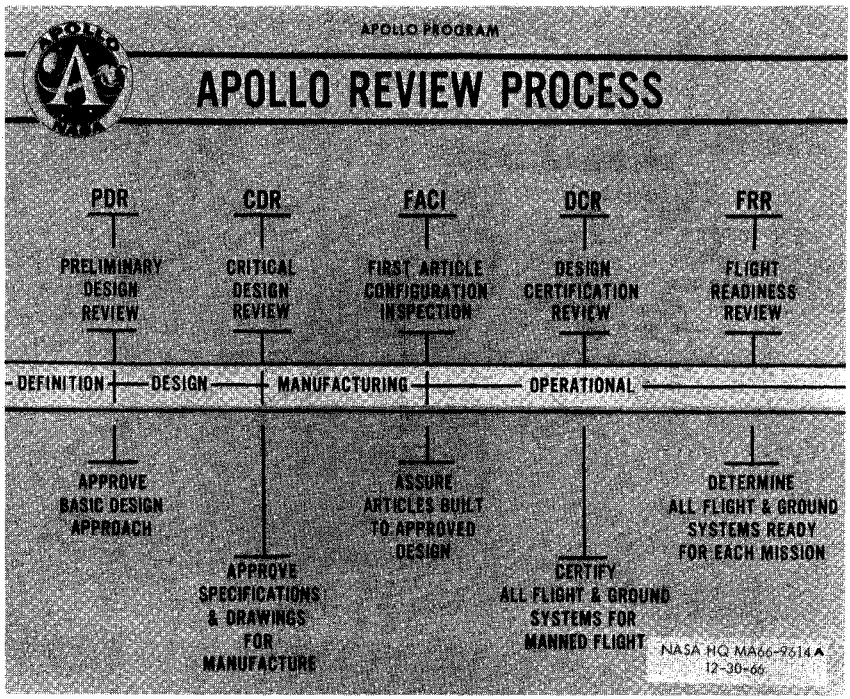


FIGURE 55

These reviews, inspections, and certifications are oriented to the hardware development and mission phases of the Apollo program. They progressively insure, at appropriate points in the program life cycle, that sufficient visibility is obtained of the status of design, manufacture, and testing to determine the integrity of the system prior to mission accomplishment.

Data management

The area of data management has continued to receive strong attention in the Apollo program in the interests of both increased efficiency and decreased cost. Several specific systems were generated for this purpose (fig. 56, MA66-9684).

Automated data management information system

An automated data management information system was developed to provide for the interchange of data about documentation between the various Manned Space Flight Centers and the Apollo Program Office. This interchange is accomplished through the use of standard codes and terms which facilitate the direct use of the data by all organizations using the system. The information system provides current status of key program documents, and affords direct access to document data through a keyword index.

Automated document distribution control system

An automated program for the control of document distribution enables program information to be made available to those who need it at the time it is needed. Middleman handling of document copies has been reduced, and the number of document copies produced and distributed has been reduced.

Data costing, accounting and reductions

Further concentration on cost reduction has been brought about by creation of an ad hoc subcommittee for cost accounting and identification. Standard

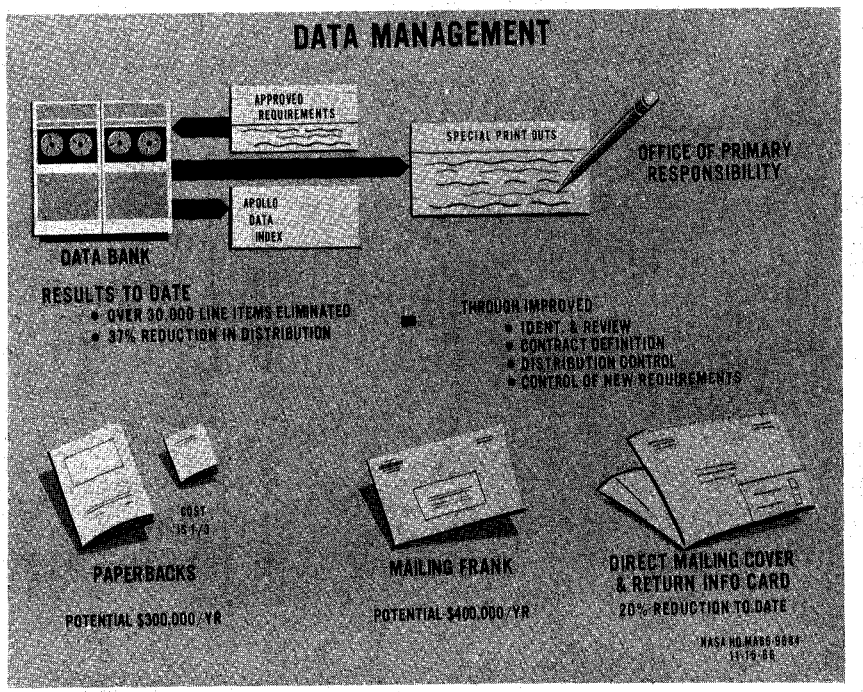


FIGURE 56

cost guidelines and cost criteria in data management are being applied to Apollo and other Manned Space Flight programs at a resulting reduction in data cost.

Other data management progress has been achieved through the initiation of data value engineering, data preparation standards, an automated cost summary system, and maximum use of Apollo-generated data.

Configuration management

We have been implementing the techniques and disciplines of configuration management on Apollo for the past several years. These methods of managing the adequacy and accuracy of each major element of Apollo hardware and software have provided us with the technical design requirements and hardware baselines on which our research and development is based.

We have instituted rigid change control disciplines at all Center and contractor levels to minimize the number of changes being made and approve only those absolutely necessary (fig. 57, MA65–9332).

LOGISTICS

Development of the Apollo Saturn logistics base during the past year has resulted in identification and implementation of the various elements of the support program as they apply to the mission. The Apollo Logistics Requirements Plan, which established the principles of the logistics base, has become the guideline and evaluation medium for the Manned Space Flight Centers and contractors.

The need for early, adequate, and continuous emphasis in the logistics support areas was acknowledged and underscored during the NASA Manned Space Flight Logistics Symposium at Huntsville, Alabama in August. The symposium was attended by top management from NASA, the Department of Defense, and industry.

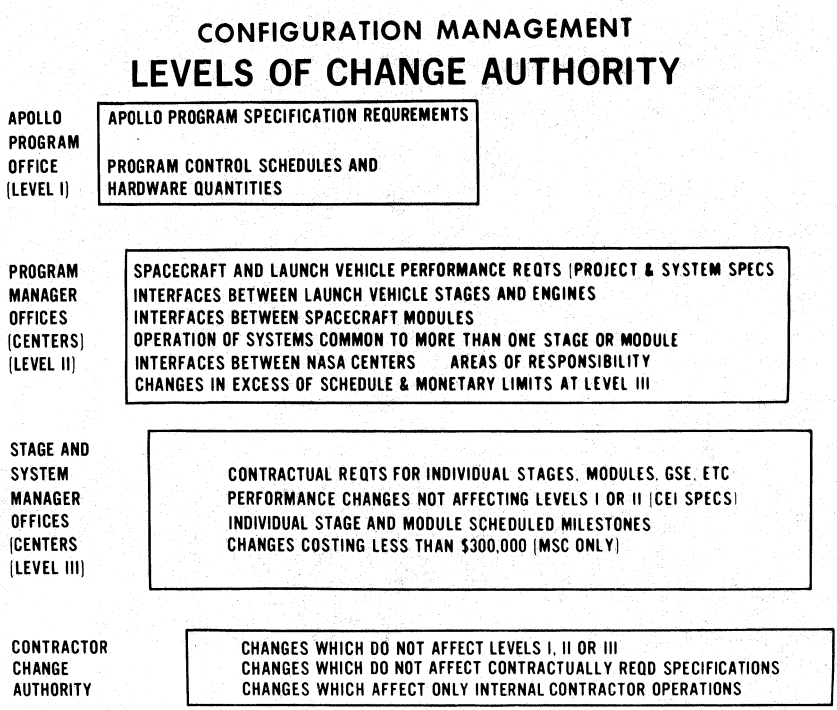


FIGURE 57

Assessment of the logistics program in 1966, carried out on a continuing basis in the light of overall program goals, disclosed the need for additional policy guidelines in the maintenance and supply areas and the possibility of significant reductions in program support requirements.

Agreement regarding propellants and pressurants

Based on an agreement in 1966 between the Air Force and NASA, the Air Force Logistics Command will procure, distribute and manage certain propellants and pressurants for both agencies under the single manager concept. Air Force support will be effected at those locations where analyses and experience by NASA and the Air Force indicate that such support will be of advantage to the Government and in the public interest through economy and efficiency of operations.

Transportation

Marine transportation

Progress of considerable magnitude in the marine shipment of Saturn items has been accomplished during the past year (fig. 58, MA66–9713A).

We have barged five uprated Saturn I 1st stages from Huntsville, Alabama to KSC. Delivery of the 1st stage of the Saturn V was made by the specially converted USN ship, PT. BARROW, from Michoud to KSC. This ship is provided by the DOD to NASA on a cross-servicing agreement at much lower cost than could be obtained in the commercial market.

Air transport

During 1966 we delivered three 2nd stages for the uprated Saturn I from California to KSC, utilizing the Super Guppy Aircraft. This aircraft, supplemented by the Guppy, an Air Force C–133B, and military helicopters, has provided responsive program support to meet NASA critical test objectives by

delivery of the major Saturn/Apollo/Gemini end items. Hardware shipped to meet these objectives includes Apollo Command Modules, Service Modules, and heat shields: Lunar Module Adapters; Saturn Instrument Units; Lunar Module Test Articles; mockups and simulators; F–1 engines; Gemini spacecraft and launch vehicles (fig. 59, MA66–9713B).

EXPERIMENTS

As with the Gemini program, the accumulation of experimental data in a variety of categories is an objective of Apollo. Experiments can be broken down into three areas of emphasis; in-flight, long-term lunar surface experimentation, and geological (fig. 60, MA66–9770).

During the part of the Apollo program when earth orbital flights are being conducted to qualify systems for the lunar landing mission, some weight and volume capability and crew time will be available for the conduct of experiments. Many of these experiments, particularly in the medical field, will be expanded or improved to carry further the work initiated on the Gemini program. Others will be directed toward improved spacecraft design and operational techniques. A number of new scientifically oriented experiments are being introduced, to conduct astronomical investigations not possible from under the earth's atmosphere or to take advantage of the extended stay times under zero gravity conditions.

The long-term lunar surface study is carried out by the Apollo Lunar Surface Experiments Package (ALSEP). This is a self-contained package of technically advanced scientific instruments which will be placed on the moon by the astronauts in a deployed condition, to make measurements for one year or more after astronaut departure (fig. 61, MA66–9806). Passive and active seismic experiments, lunar heat flow experiments, solar wind and charged particle lunar environment experiments are some of the major items to be performed by this array. Electric power for controlling the experiments and transmitting data to earth will be supplied by a radioisotopic thermoelectric generator.

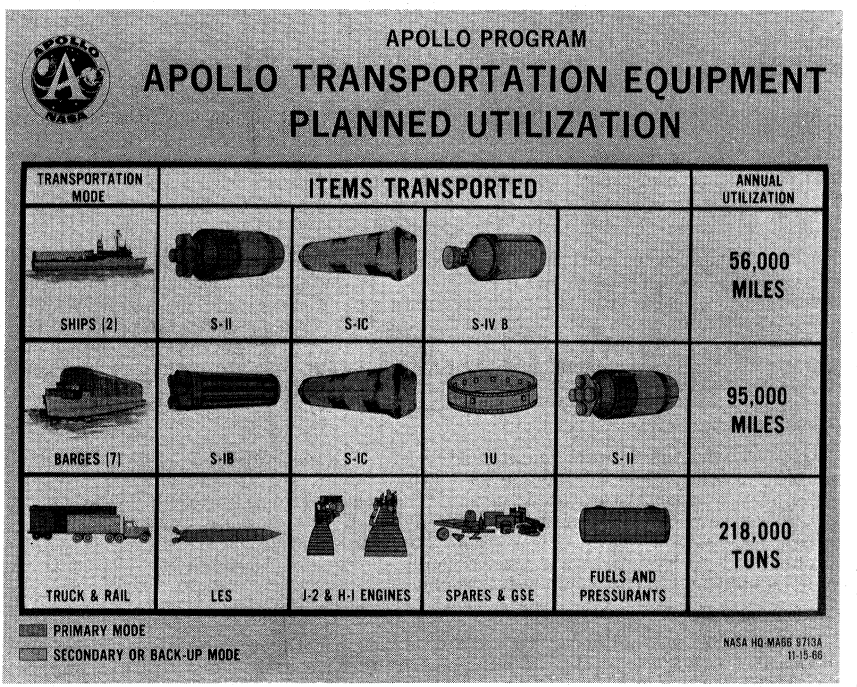


FIGURE 58

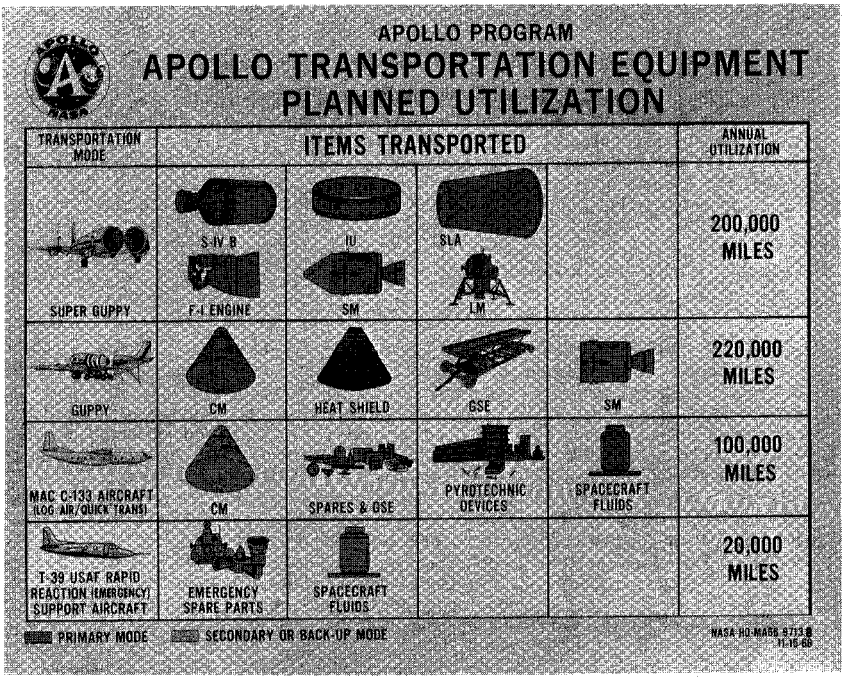


FIGURE 59

APOLLO PROGRAM

THE APOLLO EXPERIMENTS PROGRAM

- **IN FLIGHT EXPERIMENTS**
  - AIRLOCK
  - MEDICAL
  - SCIENTIFIC
  - TECHNOLOGICAL
  - DOD
- **APOLLO LUNAR SURFACE EXPERIMENTS PACKAGE**
  - MAGNETOMETER
  - ION DETECTOR
  - SEISMOMETERS
  - SOLAR WIND
  - HEAT FLOW
  - ELECTRON/PROTON
- **LUNAR GEOLOGICAL AND SURVEY**
  - HAND TOOLS
  - SAMPLE CONTAINER
  - LM TV
  - MAPPING AND SURVEY SYSTEM

NASA HQ MA66-9770
11-15-66

FIGURE 60

The Lunar Geological Experiment is designed to make maximum use of the astronauts as geological observers. This experiment will involve selection of lunar samples, recording by photography the sampling sites, packaging and returning the samples to earth.

The samples, to be used for biology, geochemistry, geophysics and other scientific disciplines, will be delivered to the Lunar Receiving Laboratory at the Manned Spacecraft Center. This facility is under construction for use in the initial receipt, processing, and safeguarding the integrity of, and biological containment of, lunar material returned to earth by Apollo missions; and for biologically isolating the returned spacecraft, astronauts, and associated support personnel. The receiving laboratory will provide the means to certify the safe release of all material and personnel and to perform highly time dependent experiments such as radiation counting and gas analysis.

RESOURCES

Last year a potential cost problem for fiscal year 1967 on the order of $200 million was identified. Time validated our concern, and as a consequence we took stern action to turn the cost curve down (fig. 62, MC66–10277).

We enjoined the presidents of our major contractors to find ways of reducing costs by about 10 percent. Members of my staff and I visited these plants personally to emphasize this need. Reductions in support activities at the centers also were effected by the Center Directors. The effects of our cost reduction activities is reflected in cost rates. The average monthly cost rate for total Apollo R&D for the second quarter of fiscal year 1967 was $250 million compared with $282 million for the third quarter of fiscal year 1966.

We emphasized reductions in contractor manpower since that represents the bulk of our costs. Although the critical design stages and periods of peak production have passed in some areas, our reductions are being carried out with care to preclude schedule and performance degradation.

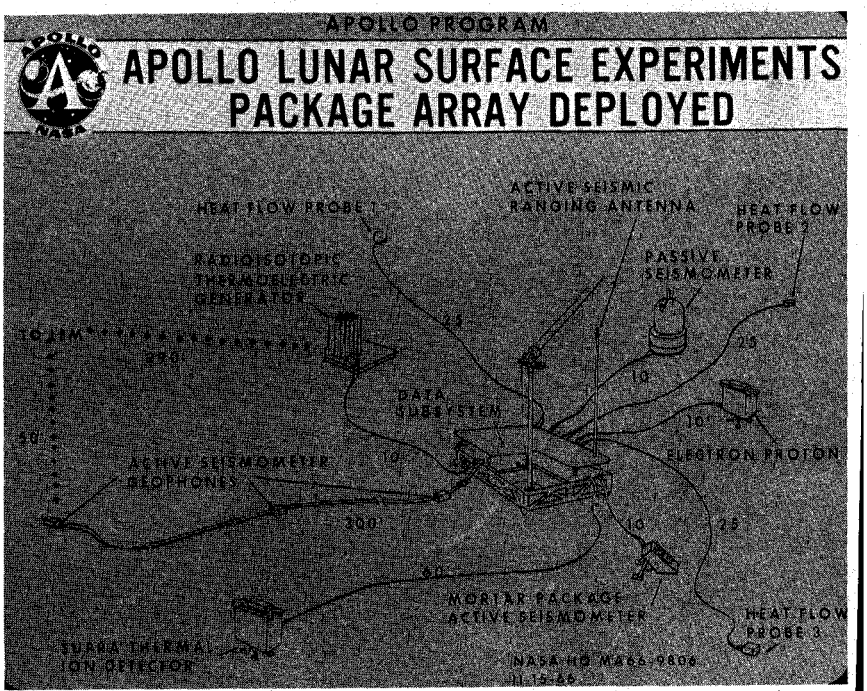


FIGURE 61

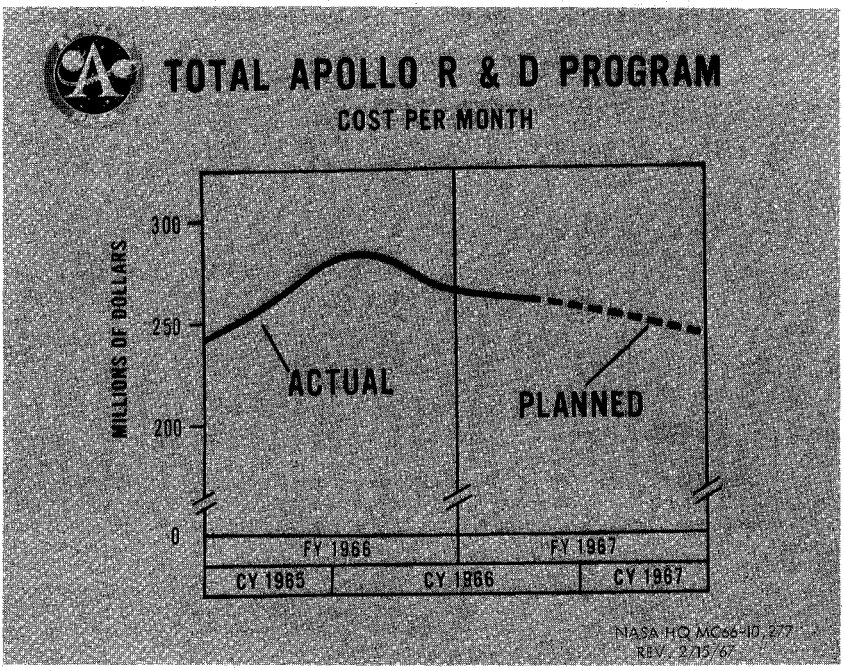


FIGURE 62

Our efforts to reduce cost are succeeding. Although the fiscal year 1967 funding situation remains tight we nevertheless are hopeful that we will be able to cover all of our requirements. Our estimated requirements for fiscal year 1968 are a logical extension of contractor and center effort into that year. However, estimates covering actions resulting from the AS–204 accident are not included.

Our current estimates represent an extremely tight management of dollars, with our uncosted obligations providing little or no flexibility to cover additional costs. Our current estimates of costs would project uncosted obligations of approximately $170 million by the end of fiscal year 1967. This amount must cover a large number of outstanding contractual obligations and is about the minimum amount against which we could manage. It would provide little or no flexibility to cover problems when they arise.

We are not clear as to the full impact of the AS–204 accident upon our fiscal year 1967 and fiscal year 1968 resources planning. We are certain that there will be an effect and it will be larger in fiscal year 1968 than in fiscal year 1969. Should the AS–204 findings require actions having a sizeable cost impact, we shall be faced with financial problems even more challenging than those of the past year.

At this time, we are concerned that program detractors will use the recent unfortunate accident to suggest that a slowdown in our effort will result in savings. Aside from the fact that our colleagues gave their lives for this challenging program there is false economy in cutting back now.

The Apollo program has advanced to a point that the flexibility for making program cuts to avoid cost becomes extremely limited from a management viewpoint. During the initial design phase of a program, there is an opportunity for decisions which affect costs. During this period in Apollo, the overall scope of the program was determined, an optimum time span for overall development and operations established, and design alternatives selected which determined total cost. When the program moved from the design to the test phase, flexibility in curtailing costs was greatly reduced because management alternatives were

limited. Once the program reached the production phase, opportunities for reducing cost were further limited to substitutions of components and materials, improved manufacturing techniques, and the like.

Today, as the Apollo program moves toward the flight operations phase, all of the hardware is either in being, in advanced stages of production or on procurement for long lead items. I know of no possible plan for completing the missions and achieving program objectives which can be implemented with lower funding than the program presented to the Congress. A program stretch-out would result in a greater overall program cost than will the plans we are now following. In fact, a cutback in our rate of funding in fiscal year 1968 would actually increase our costs substantially in fiscal year 1969 because the rate of decline of people on the program is, as you can see, already perilously fast. To increase the rate would intolerably introduce inefficiencies and dislocations that would force costs up to fiscal year 1969 as well as delaying the program. For example, all of the long lead time items for the last Apollo/Saturn V spacecraft and launch vehicles have already been placed on order and we would have to revise our whole procurement scheduling if our resources were reduced.

SUMMARY

In summary, 1966 has been a period of great activity as we move toward attainment of our program goals.

With respect to the overall Apollo program effort, we plan to maintain the present orderly pace of effort in the many areas of current activity, such as launch vehicles, facilities, ground support software, training, and so forth. Much of our capability to cope with unforeseen difficulties is dependent on maintaining planned rates of progress in all possible facets of the program. This carefully developed planning has enabled us to accommodate previous problems in both the Gemini and Apollo programs, and most importantly, maintains the flexibility that will enable us to schedule our flight operations as necessary to continue our progress in Apollo.

I have reviewed the seven development phases planned to meet the Apollo major milestones. The first major phase—unmanned Apollo flights with the uprated Saturn I launch vehicle—was completed in 1966. The remaining phases planned for 1967, 1968, and 1969 require a series of earth orbital flights followed by a series of lunar-configured flights culminating in the lunar landing mission. These phases include the unmanned flights of the Lunar Module, Apollo/Saturn I manned flights, Apollo/Saturn V unmanned flights, dual mission flights of the manned Apollo/Saturn I and the Lunar Module, Apollo/Saturn V manned flights in earth orbit to simulate the lunar mission, and Apollo/Saturn V open-ended missions leading to lunar operations.

I do believe that we still have a reasonable possibility of meeting the major milestones for the Apollo program which were established in 1963. In particular, although the probability is lowered, I believe we will be able to land men on the moon and return them safely to earth before 1970.

APOLLO APPLICATIONS PROGRAM

INTRODUCTION

I would now like to turn to a major post-Apollo program effort recommended for authorization this year. The Apollo Project is a great endeavor to achieve preeminence in space to be demonstrated by landing men on the moon and returning them safely to earth. In achieving this goal, the United States will have developed a broad base of equipment, trained manpower and industrial support that is capable of carrying out space missions beyond the manned lunar flights. Looking to the future, we have completed the definition of a program to follow Apollo.

The Apollo Applications program conceived is the best means of utilizing this broad-based Apollo capability and represents an effort as important and far-reaching in its implications as the Apollo effort upon which it is based. The program will begin to investigate man's role in the effective exploitation of the environment of space to meet the needs of mankind on the earth and, in the long term, to determine man's contribution to the exploration of the universe.

There are many reasons for undertaking this post-Apollo effort at this time. To cite a few:

Apollo Applications will maintain the orderly pace of our progress in the space age at a time when there may be opportunities to move ahead of the Soviets in space achievement. This program will guard against the possibility of technological "surprise" by supporting the continued advancement of an industrial technology. At the same time, it will maintain the forward momentum that space technology has given our competitive position in the world market place through research and development for our industrial technology.

Apollo Applications will support the broad base of research and development vital to our security as a nation. It will avoid the waste, the dissipation of a space capability assembled in painstaking fashion over the period of a decade. Furthermore, it will hold open the opportunity to return direct benefits to man on earth in the next phases of space activity, maintaining the momentum achieved thus far.

This first post-Apollo program will take advantage of the tremendous opportunities for expansion of knowledge at a time when space-based astronomy and exploration embracing the whole field of space science show promise of breaking through into an era of real discovery. It will provide the means to meet the challenge of the future in space at a relatively modest cost as measured against a percentage of the gross national product. The peak was in fiscal year 1966, when NASA expenditures totaled 0.83 of 1 percent of the gross national product. In the current fiscal year they are 0.73 of 1 percent. In the budget proposed for fiscal year 1968, the total would be 0.66 of 1 percent.

Finally, Apollo Applications will provide the capability to expand our space activity if the international situation should change. The resulting stabilizing benefits would thus be insured because this proposed program would keep the space team together, and in a position to respond to economic developments on the national scene.

Background

Through the Mercury and the Gemini programs, we have learned much about man's capabilities and limitations in space flight. We have demonstrated the utility of space crews and their ability to carry out complex mission plans, to conduct experiments, to accomplish extra-vehicular activity and to navigate in space both with and without ground based assistance. We will learn much more from the early Apollo missions.

Prior to 1970, the Gemini and Apollo programs, building on results of Mercury and Saturn I, will have provided the capability to explore space out to 250,000 miles from earth and to conduct manned operations and experiments on flights of up to two weeks duration. The uprated Saturn I and Saturn V boosters will have injected 20 to 140 tons of payload per launch, respectively, into near-earth orbit. The Saturn V will have sent 49 tons to the vicinity of the moon. The Apollo spacecraft will have sustained a three-man crew for two weeks in a two-compartment, modular, maneuverable vehicle and will have landed two men on the moon and returned them, with samples of lunar material, to earth. The U.S. manned space flight programs will have logged more than 500 man days in space, during which data and experience will have been acquired from more than 100 in-flight experiments.

Prospects

There are many exciting prospects for manned and unmanned space activities which potentially could reap great benefits, not only for this nation, but for the entire world.

Such possibilities could include meterological stations to track and study the nature and behavior of the atmosphere and the effects of solar activity on weather. It has been estimated by the National Academy of Sciences that through better weather forecasting alone, farmers, fuel producers, public utilities, construction industries, and water managers can save about $2.5 billion annually.

A second possibility is research stations to map and study the earth's resources which could provide a better way of life for millions of people and prepare to meet the future needs resulting from the current population "explosion."

Astronomical observatories to conduct solar and stellar observations outside the filtering effects of the earth's atmosphere are a third possibility. A fourth is assembly, maintenance and operaton of communication stations potentially capable of significantly increasing reliable world-wide communications and television coverage.

A fifth possibility is navigation and traffic control stations to achieve increased efficiency of transportation, particularly the operation of ships and aircraft.

A sixth possibility is furthering space technology by developing and using man's ability to assemble, test, repair and maintain large space structures. In addition, the presence of man in space with his abilities to reason, to analyze, to make decisions, and to improvise can contribute much to the scope and range of space activity. For example, Apollo Applications experiments performed by man on a wide variety of sensing devices can test the feasibility and utility of advanced types of meteorological observations and earth resource surveys from space. These experiments and tests will provide the data for decisions on future space systems—manned or unmanned—to derive additional practical benefits from space observations

To develop the capabilities to carry out such missions, we must learn much more about man's capabilities and limitations in space flight. We must determine, for example, how long man can operate effectively in space without returning to earth. We must learn the most effective means of accomplishing extravehicular activities such as those which would be required for the assembly of large structures in space and we must develop the most efficient and economical means of control and communications.

The Apollo-developed hardware gives us the means to study these requirements and to do it economically. The Apollo Applications program is designed to make use of this capability, by revisitation of hardware in orbit, by resupply, and by minor modification to provide expendables for longer duration of the spacecraft themselves.

Basically, the space vehicle designs developed to conduct the Apollo program will be used for Apollo Applications (fig. 63, MPR66–7783). New development requirements to adapt this hardware for Apollo Applications missions are modest and center primarily on increasing the life span of basic systems and subsystems to meet the requirements of longer duration missions.

We plan to demonstrate our ability to reuse basic orbiting space vehicle hardware. An orbital workshop will be established in space by using the spent 2nd stage of the uprated Saturn I launch vehicle which places a mission payload in orbit. This orbital workshop will provide an economical and convenient sheltered area for many operations in space capable of reactivation and reuse on subsequent launches. Its airlock and adapter, using Gemini subsystems and the capability of resupply, will provide for long duration missions. We believe

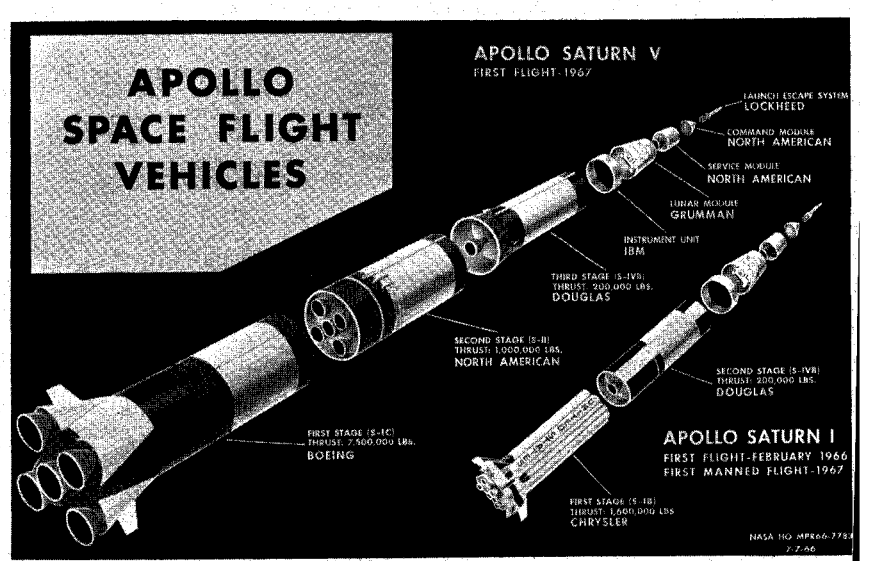


FIGURE 63

that by 1969 this assembly, which, in effect, is an embryonic economical space station, can be successfully established and used for a one month mission and can be left in orbit and functioning for reactivation and reuse on a later mission.

In the Apollo Applications program planning we have classified the flight activity into two categories—alternate missions and follow-on missions. The mission planning will be discussed in detail later, however.

The program of investigations and development to be carried forward in the Apollo Applications program will meet two basic objectives: to make unique contributions to practical applications, operational capabilities, science, and technology; and, at the same time, to place the nation in a position to assess, on the basis of valid scientific experimentation and actual experience, the value and feasibility of future space flight and the interrelated roles of manned and unmanned systems.

In support of these objectives, the principal areas toward which the fiscal year 1968 effort will be directed are the development of an extended flight capability, the conduct of manned astronomical observations from space, and the extended exploration of the moon.

Objectives

The major Apollo Applications objectives are shown in this chart (fig. 64, MC67–5412). The usefulness of man in space will be tested and evaluated in a large, controlled space station-like environment to evaluate human performance and engineering requirements. Man will perform scientific and applications experiments in this embryo space station to assess the value and feasibility of future space flight operations and the interrelated roles of manned and unmanned systems.

The acquisition of maximum yield of solar data during the next solar maximum is an alternate mission task under astronomy observations. During the alternate mission time cycle, operating modules for reuse will be placed in orbit.

Reuse of hardware and long duration flight

In the past I have described the all-up concept of testing; that is, to flight test the entire hardware system on one flight instead of incremental flight-testing of subsystems, modules and stages. I have already described in this presentation

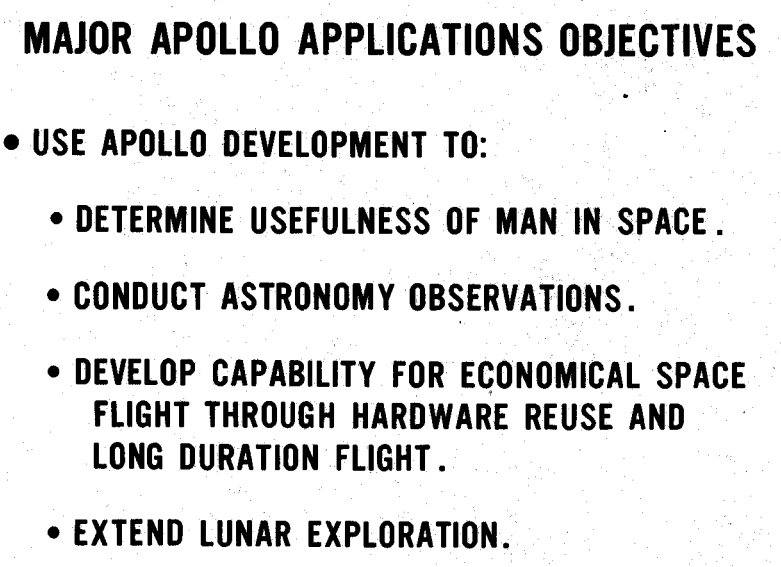


FIGURE 64

our open-ended mission concept, allowing each mission to proceed as far as it is capable of doing. In Apollo Applications we will implement a third concept—the reusability of hardware. This will be accomplished by resupply and reuse of hardware that is left in orbit from a previous mission. All of these concepts not only will give us the greatest opportunity to progress, but offer a significant advantage in letting us progress at a rate which is not expensive when compared to our previous manned space flight programs.

The early development of long duration flight capability is clearly one of the most important areas to be pressed forward, in that it is a key requirement for most of the possible significant advances in manned flight. Apollo Applications flights of up to one year or more in duration will represent a significant increase in the nation's operational capabilities in space and opportunities for important scientific and technological experimentation.

Apollo Applications experiments with a wide variety of sensing devices will test the feasibility and utility of advanced types of meteorological observation and earth resource survey systems from space. These experiments will provide the data for decisions on future systems—unmanned or manned—to derive additional practical benefits from space observations.

Extended duration flight experience is also necessary to provide a sound basis for those future decisions on manned programs of the greatest interest and potential, such as permanent manned facilities in space or manned flights to the planets. Year long flights can be achieved on the most economical basis by reusing modified Apollo space vehicles with resupply.

Extended lunar exploration

The Apollo Applications program will follow-up the first Apollo landings with additional lunar exploration missions of up to 14 days on the surface and for observation and mapping from lunar orbit. These missions will yield important additional scientific data about the moon and will also provide the information necessary for deciding whether our manned capabilities for exploration of the moon should be further developed and exploited.

APOLLO APPLICATIONS MISSIONS

The Apollo Applications program proposed for initiation in the fiscal year 1968 budget is based on an average annual launch rate of four uprated Saturn I and four Saturn V flights per year following those required for the manned lunar landing. The planned program will avoid any hiatus in the continued development of United States manned flight capability, will continue the availability of the nation's two most powerful rocket vehicles, and will not affect the on-going Apollo effort. Maximum economy will be achieved through the full utilization and extension of Apollo and Saturn developments.

The experimental payloads included in the Apollo Applications program are designed to provide significant data on the capabilities of man and equipment, and on their potential ability, as promptly and as economically as possible. These plans have the flexibility of employing for new missions any spacecraft and launch vehicles currently on order for the Apollo program that, in the event of early successes, are not required to meet Apollo objectives.

The Apollo Applications missions will build upon the base of flight experience, ground facilities, and trained manpower developed in past and current programs. Each mission is designed to take full advantage of the Apollo/Saturn system to make significant contributions to a wide range of objectives. Missions are planned to concurrently gain experience, test theory, perform experiments, and collect data. By establishing multiple objectives for each flight mission, a program limited to a minimum economical launch rate can achieve rapid progress and make great gains at low cost.

Key elements of this planning include the decision to use, modify and expand present Apollo systems capabilities rather than move toward whole new developments; the strategy of reusing basic hardware for many missions by storing it in orbit and returning later with fresh crews and expendables; and the approach of designing experiments that will gather important data while at the same time testing the experimental concepts themselves.

Alternate and follow-on categories

In the Apollo Applications program, the flight activity is classified into two categories, alternate missions and follow-on missions (fig. 65, MC66-5173).

APOLLO APPLICATIONS - MISSION CONCEPTS

ALTERNATE MISSIONS

USE OF BASIC LUNAR MISSION SPACE VEHICLES WHICH MAY BECOME AVAILABLE FROM THE APOLLO PROGRAM FOR APOLLO APPLICATIONS MISSIONS.

FOLLOW-ON MISSIONS

USE OF MODIFIED APOLLO SPACECRAFT WITH STANDARD SATURN LAUNCH VEHICLES FOR LONG DURATION MISSIONS IN EARTH AND LUNAR ORBIT AND ON THE LUNAR SURFACE.

NASA MC 66-5,173
REV. 1-9-67

FIGURE 65

ALTERNATE MISSIONS

Alternate missions to the basic Apollo program in 1968–1969 will use those basic lunar mission space vehicles which may become available from the Apollo program (fig. 66, MC67–5409). By that time, it is very possible that the mainstream of manned flights in the Apollo program will have shifted to the Saturn V launch vehicle and the remaining four uprated Saturn I launch vehicles and their associated spacecraft may become available for these alternate missions.

Apollo Applications operations during 1968–1969 will involve three kinds of missions. The first is qualification in earth orbit of the Apollo-developed Lunar Mapping and Survey System which will ultimately be used in Apollo Applications lunar orbit flights to map and survey the entire lunar surface. The second is long duration flights from 28–56 days, with associated experiments to be performed utilizing the orbital workshop facility. The third mission category is astronomical observatons to acquire solar data during the period of maximum solar activity. These missions also would develop the techniques of manned astronomical observations in space and assess their value and future possibilities.

Lunar Mapping and Survey System Test

The alternate Apollo mission program will be utilized to test in earth orbit the Apollo-developed Lunar Mapping and Survey System which will be used in follow-on Apollo Applications missions to study the moon in great detail. This system will be used in the 1970's in manned lunar orbiters to collect data for the purpose of compilation of complete lunar topographic map series at various scales from 1:2,500,000 to 1:250,000 with selected areas at still larger scales. Complete camera systems will be operated utilizing optical, infrared and other multi-spectral sensors. In addition to topographic maps, synoptic and detailed geologic maps of the total lunar surface will be prepared. The remote sensing equipment will also collect data on the gross compositional characteristics of lunar surface material for geochemical purposes and measure geophysical parameters from depths of microns to several kilometers.

The Lunar Mapping and Survey System tests may permit us to carry out at least elementary earth observations which will provide us with an early base of practical space flight experience to shape our long range earth resources program. In addition, data gathered in earth orbit by the multi-spectral cameras will be

APOLLO APPLICATIONS

APOLLO ALTERNATE MISSIONS

- USE OF BASIC APOLLO SPACE VEHICLES WHICH MAY BECOME AVAILABLE FROM THE MANNED LUNAR LANDING PROGRAM TO:

  1. ACQUIRE THE MAXIMUM YIELD OF SOLAR DATA DURING THE SOLAR MAXIMUM.
  2. PLACE IN ORBIT OPERATING MODULES FOR RE-USE.
  3. PROVIDE AN EARLY CAPABILITY FOR A LARGE ENVIRONMENTALLY CONTROLLED VOLUME TO EVALUATE HUMAN PERFORMANCE, ENGINEERING CONCEPTS AND TECHNOLOGY LEADING TO A SPACE STATION.
  4. DEMONSTRATE UP TO THREE MONTH ORBITAL FLIGHT CAPABILITY.

NASA HQ MC67-5409
2-21-67

FIGURE 66

utilized for reference and calibration purposes for the Lunar Mapping and Survey mission, which in turn may prove invaluable as a tool to unlock the mystery of the origin of the solar system.

Orbital workshop

The orbital workshop concept permits Apollo astronauts to work and perform experiments in the empty hydrogen tank of a spent Saturn I 2nd stage by means of a 65-inch diameter airlock between the Apollo spacecraft and hydrogen tank (fig. 67, MG66–8987). A hatch in the airlock will permit egress into space without depressurization of the tank or the spacecraft. In orbital flight the Command and Service Modules will dock with the airlock and the crew will activate systems to pressurize the spent hydrogen tank for habitation.

The orbital workshop will enable us to investigate the feasibility of using a launch vehicle spent stage in orbit as a large habitable space structure and develop the capability to carry out long duration manned space flight missions in such a structure.

The Airlock and Spent Saturn I 2nd Stage experiment, called the orbital workshop, is shown here (fig. 68, MG66–9611A). The airlock provides a physical connection between the docked Command Module and the uprated Saturn I 2nd stage. It also provides an airlock connection between the Command Module and the habitable 2nd stage hydrogen tank; oxygen and nitrogen for pressurization of the hydrogen tank; solar cell panels to provide electrical power for experiments in the airlock and for those to be performed in the spent stage; and environmental control for the airlock and the hydrogen tank.

Extension of the lifetime of the assembly is provided for by additional expendables stored on the airlock to support activities in the Command and Service Module and the orbital workshop. Experiment equipment for use in the orbital workshop is to be stored within the airlock during transport to orbit.

The interior of this tank will be modified to permit certain experimental operations to be conducted in a shirtsleeve environment within its 10,000 cubic foot enclosed space. A two-gas (oxygen/nitrogen) atmosphere life support and environmental control system, a modification of the Apollo system, is also planned. Efforts will include development of nitrogen storage tanks, partial pressure atmosphere sensors, and controls and the integration of associated hardware in the spacecraft. Gemini and Apollo subsystems, subassemblies, components and methods will be utilized wherever feasible.

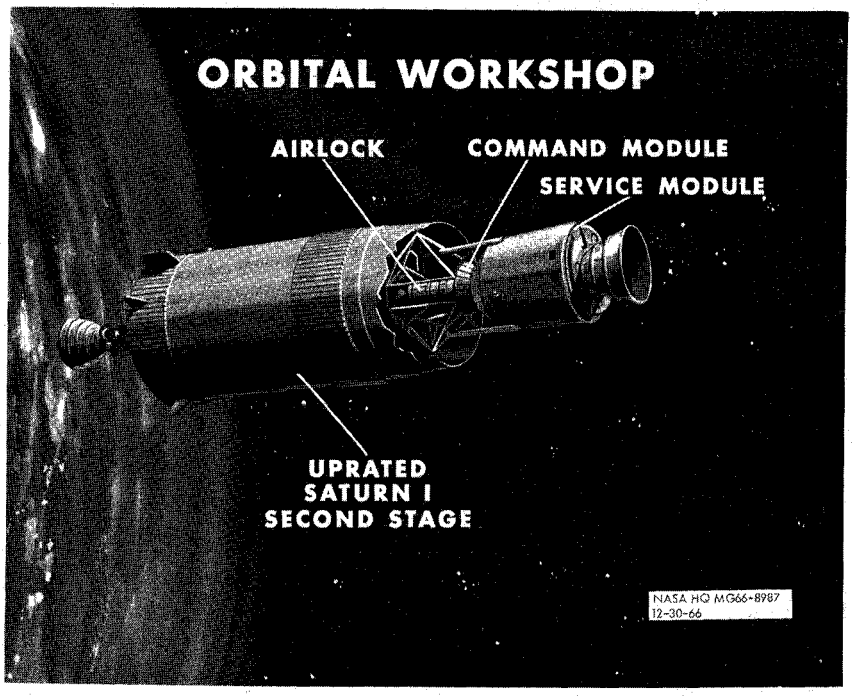


FIGURE 67

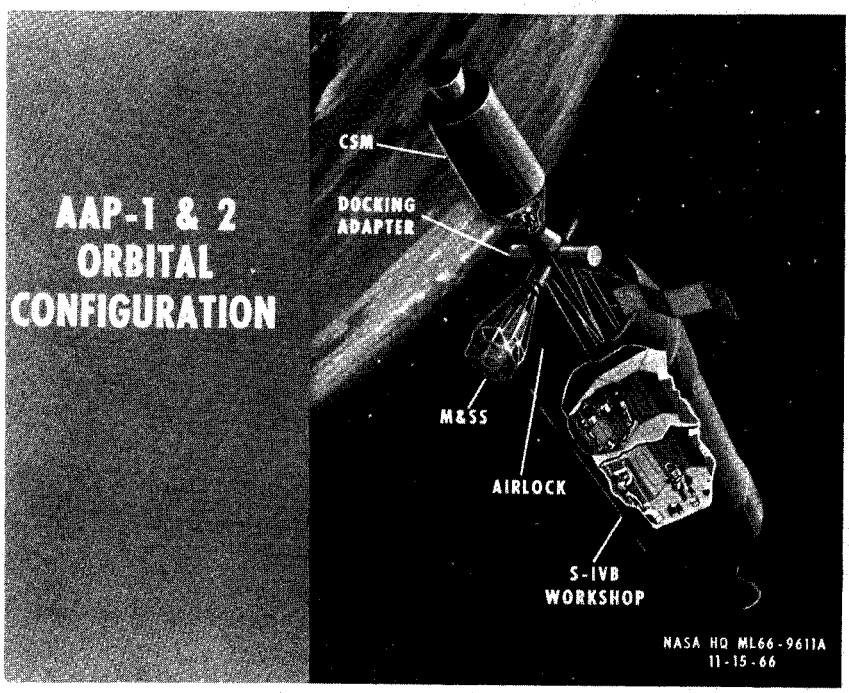


FIGURE 68

Advantages of orbital workshop

Successful completion of this experiment would provide several important advantages. The use of this orbital workshop experiment module involves minimal new development, thus allowing basic exploration of space station requirements within a reasonable funding level. It provides an early capability for a large, controlled environment to evaluate human performance and secure engineering data for future subsystem designs for both manned and unmanned spacecraft. It enables low-cost design validation and checkout of equipment requirements for long term habitability in zero gravity. Finally, this large protected volume in space can supplement a more sophisticated system for special purposes, such as biomedical experiments and protected tests of complete extravehicular operations.

The orbital workshop is an important new concept for an economical embryonic space station. Using manned vehicles as space platforms, the space station will provide the capability for carrying out many experiments in earth orbit. It increases our useful habitable workspace volume by a factor some 30 times greater than the Apollo Command Module itself provides.

A space station can be exploited to make many contributions in the major fields of space science, earth-oriented applications, and support for space operations.

Space Science experiments will be undertaken primarily for acquisition and expansion of fundamental knowledge encompassing the disciplines of astronomy/astrophysics, bioscience and the physical sciences.

Earth-oriented Applications will be those for which potential economic and social benefits can be identified. These include the areas of atmospheric science and technology including meteorology, aeronomy and air pollution; communications and navigation/traffic control; and earth-sciences and resources including agriculture/forestry, geology/hydrology, oceanography/marine technology, and geography.

Support for space operations will be aimed at developing techniques and technologies for advancing space applications, exploration and travel to other parts of the solar system. Specific areas of interest include those of biomedicine/behavior, advanced technology and supporting research, extravehicular engineering activities, operations techniques, and advanced mission spacecraft subsystems.

Orbital workshop experiments

The next chart (fig. 69, ML66–9785) lists engineering, medical, technology, and Department of Defense experiments which are planned to be flown on alternate Apollo missions. The orbital workshop experiments will be most useful in the development of a long duration space station which has potentially highly productive returns in terms of broad benefits to humanity.

Apollo Telescope Mount (ATM) experiment

The Apollo Telescope Mount (ATM) provides a new capability for a variety of solar and stellar scientific experiments to be performed above the earth's atmosphere (fig. 70, ML66–9610). The ATM provides a stabilized platform which can be carried on alternate Apollo missions to accommodate experiment instruments having a requirement for finely controlled pointing.

The ATM includes scientific instruments and supporting subsystems mounted in a structural rack attached to the ascent stage of an Apollo Lunar Module. The Lunar Module descent stage will not be used on ATM missions. The ATM rack will be equipped with a pointing control system consisting of control moment gyroscopes, fine control vernier gimbals, electronic control circuitry, and appropriate astronaut controls and displays. A thermal control system and a communications and data handling system are also included. Electrical power will be furnished by a solar array mounted to the ATM rack, with rechargeable batteries to maintain system loads during periods of darkness.

With such a configuration, the ATM can be operated in several possible modes to obtain the maximum amount of solar data within the limits of available astronaut time and the possible degrading effects of motion and contamination disturbances. The ATM configured Lunar Module can be operated either docked to the primary crew living quarters or separated from them by a tether if required to isolate the solar instruments from contamination or vehicle

APOLLO APPLICATIONS
ORBITAL WORKSHOP EXPERIMENTS

ENGINEERING

M466 SUITS & LUNAR HARDWARE
M469 ST-124 REMOVAL AND DISASSEMBLY
M479 ZERO-G FLAMMABILITY
M486 ASTRONAUT EVA EQUIPMENT
M487 HABITABILITY/CREW QUARTERS
M488 HIGH PRESSURE GAS EXPULSION
M489 HEAT EXCHANGER SERVICE
M491 SURFACE ADSORBED MATERIALS
M492 TUBE JOINING IN SPACE
M493 ELECTRON BEAM WELDING

MEDICAL

M018 VECTORCARDIOGRAM
M050 METABOLIC ACTIVITY
M051 CARDIOVASCULAR FUNCTION ASSESSMENT
M052 BONE AND MUSCLE CHANGES
M053 HUMAN VESTIBULAR FUNCTION
M054 NEUROLOGICAL STUDY (EEG)
M055 TIME AND MOTION STUDY

DEPARTMENT OF DEFENSE

D018 INTEGRATED MAINTENANCE
D019 SUIT DONNING AND SLEEP STATION EVALUATION
D020 ALTERNATE RESTRAINTS EVALUATION
D021 EXPANDABLE AIRLOCK TECHNOLOGY

TECHNOLOGY

T017 METEOROID IMPACT AND EROSION
T020 JET SHOES
T021 METEOROID VELOCITY
T022 HEAT PIPE

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REV. 2-7-67

FIGURE 69

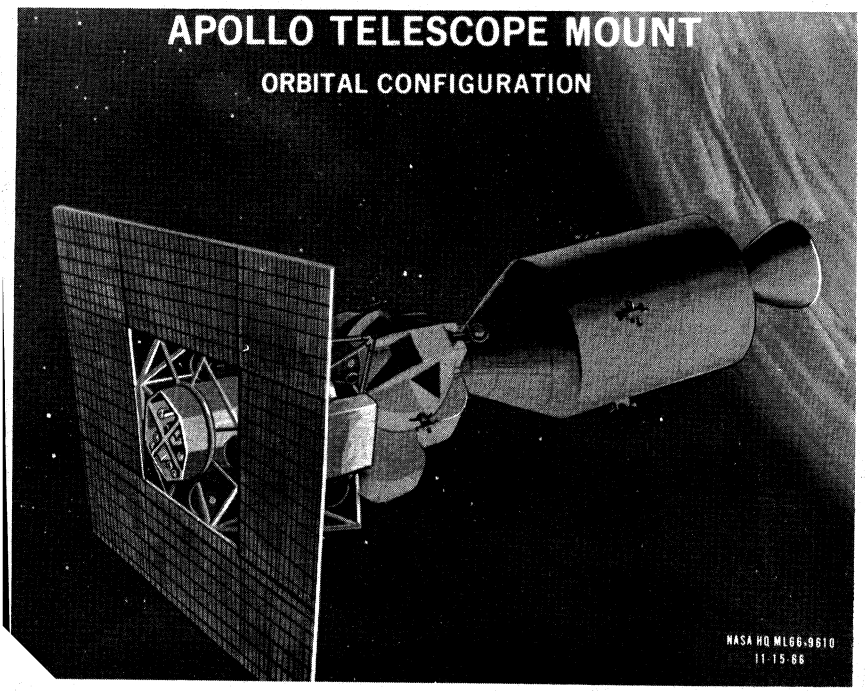

FIGURE 70

motions. This assembly can be stabilized by gravity gradient forces as demonstrated with Gemini-Agena tethering on Gemini XII.

The ATM is controlled by the astronauts to orient telescopes to selected solar activity regions or specific stellar targets, using a television monitor to locate targets of scientific value (fig. 71, ML66–9678). The ATM enables experiments to be conducted using the data gathering features of recoverable photographic film as well as of photometric techniques. Communications from scientists on the ground to the astronaut-observer will aid in the selection of targets and the data to be recorded. The ATM pointing control system can hold alignment with selected targets for long term photographic exposures.

The initial launch of the ATM is planned to conduct solar observations from low earth orbits beginning in 1969 to obtain data from the next period of maximum solar activity. A mission duration of up to 56 days is expected for the initial flight.

The ATM for the solar missions will accommodate the acquisition and holding of solar instruments to within 2.5 arc seconds of a target selected by the astronaut. The astronaut will have the capability of offsetting solar instruments up to 20 arc-minutes from the center of the solar disc. Offset pointing capabilities for other targets will be determined by the specific orientation sensors used.

The ATM provides the desirable capability of conducting space experiments with photographic data recovery. Film magazines can be recovered from the telescope cameras by the astronauts and stowed in the Command Module for the return to earth. Experiment designs selected for the first ATM launch take full advantage of this technique.

Five basic experiments to obtain solar data during the period of maximum solar activity have been selected for development for the initial ATM launches (fig. 72, ML67–5554). Supporting instruments are also being developed to make the scientific experiment instruments effective (fig. 73, ML67–5555). The combination of instruments involved in the overall ATM experiment platform will

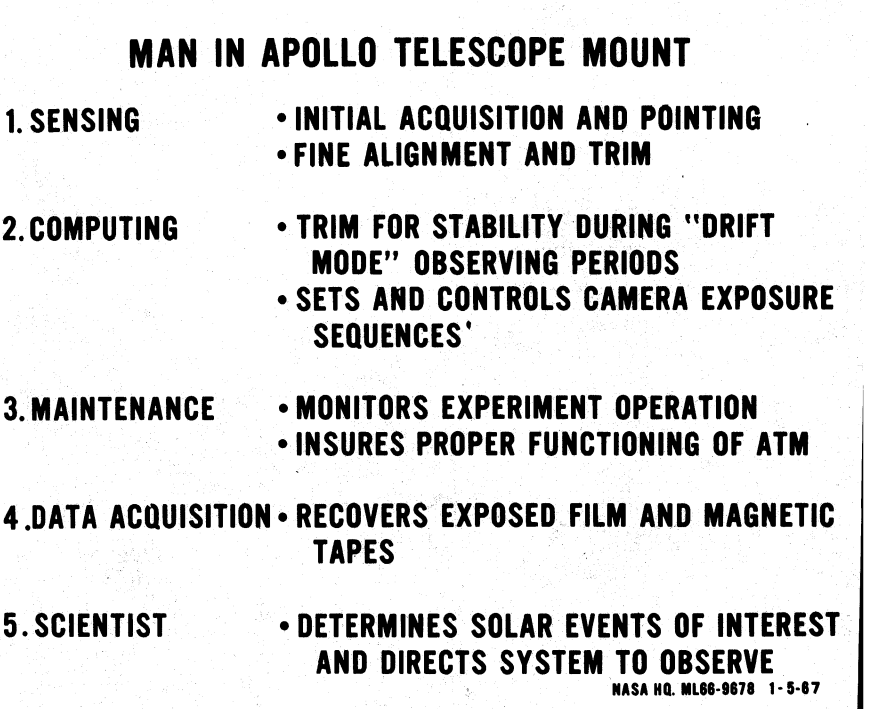

FIGURE 71

ATM SCIENTIFIC EXPERIMENTS

EXPERIMENT NUMBERS	ORGANIZATION	PRINCIPAL INVESTIGATOR	INSTRUMENT	PURPOSE
S052	HAO	DR. G. NEWKIRK	CORONAGRAPH	MONITOR THE BRIGHTNESS, FORM AND POLARIZATION OF THE SOLAR CORONA IN WHITE LIGHT.
S053	NRL	MR. J. D. PURCELL	CORONAL SPECTROHELIOGRAPH	MAKE HIGH-SPATIAL RESOLUTION MONOCHROMETRIC SOLAR IMAGES IN THE 160-650 ANGSTROM RANGE
			CHROMOSPHERIC SPECTROGRAPH	RECORD SOLAR SPECTRA IN THE 800-3000 ANGSTROM RANGE WITH HIGH SPECTRAL RESOLUTION
S054	AS&E	DR. R. GIACCONI	SPECTROGRAPHIC X-RAY TELESCOPE	STUDY SOLAR FLARE EMISSIONS IN THE SOFT X-RAY WAVELENGTHS (2-60 ANGSTROMS)
S055	HCO	DR. L. GOLDBERG	SPECTROHELIOMETRIC UV TELESCOPE	MAKE HIGH SPATIAL RESOLUTION SOLAR IMAGES IN THE 300-1400 ANGSTROM RANGE
			SPECTROMETRIC UV TELESCOPE	STUDY SOLAR SPECTRAL EMISSIONS WITH HIGH SPATIAL RESOLUTION IN THE 1450-2250 ANGSTROM RANGE
			HYDROGEN-ALPHA SPECTROHELIOGRAPH	MAKE HYDROGEN-ALPHA SPECTRO-HELIOGRAMS OF THE ENTIRE SOLAR DISC
S056	GSFC	MR. J. E. MILLIGAN	HI-RESOLUTION X-RAY TELESCOPE	OBTAIN TIME-HISTORIES OF THE DYNAMICS OF THE SOLAR ATMOSPHERE IN X-RAYS IN THE 3-100 ANGSTROM RANGE

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FIGURE 72

ATM SUPPORTING INSTRUMENTS

ORGANIZATION	PRINCIPAL INVESTIGATOR	INSTRUMENT	PURPOSE
HAO	DR. G. NEWKIRK	OCCULTING DISC ALIGNMENT SYSTEM	CENTER INTERNAL OCCULTING DISK TO MINIMIZE SCATTERED LIGHT
NRL	MR. J. D. PURCELL	EUV DISPLAY TELESCOPE	SOLAR DISPLAY IN EUV FOR MAIN TELESCOPE ORIENTATION
AS&E	DR. R. GIACCONI	X-RAY IMAGE DISSECTOR TUBE	X-RAY FLUX DETECTOR TO ORIENT X-RAY TELESCOPE
GSFC	MR. J. E. MILLIGAN	PROPORTIONAL COUNTERS	X-RAY FLUX DETECTOR TO ORIENT X-RAY TELESCOPE
MSFC	N.A.	HYDROGEN-ALPHA DISPLAY TELESCOPE	PRIMARY DISPLAY OF SOLAR DISC FOR TARGET SELECTION BY ASTRONAUT

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1-25-67

FIGURE 73

provide a wide spectral view of the phenomena that occur during the next solar activity cycle and should yield information of considerable value to our understanding of the basic processes of solar activity.

Apollo Applications alternate missions operations

The first mission (AAP–1) is planned for launch in 1968, with a payload and orbital configuration as shown in the next chart (fig. 74, ML66–9782A). The Command and Service Module carries three astronauts. The primary purpose of this mission is to test the Apollo-developed Lunar Mapping and Survey System. Test operations will be performed on the Lunar Mapping and Survey System in low earth orbit for 3–5 days.

The next chart (fig. 75, ML6–10,044) shows the mission sequence of how the first alternate mission (AAP–1) is supplemented by means of orbital transfer and rendezvous with the second alternate mission (AAP–2). After the Lunar Mapping and Survey System is in low altitude circular orbit for about 4 to 5 days, a Saturn I 2nd stage with airlock and docking adapter is launched unmanned into a high altitude circular orbit for use as an orbital workshop. The astronauts in the AAP–1 mission configuration perform a Hohmann transfer and rendezvous with the unmanned AAP–2 configuration. The orbital configuration of alternate missions AAP–1 and AAP–2 after rendezvous and docking is shown here (fig. 76, ML66–9611A). With this orbital configuration, the astronauts conduct airlock and spent stage operations for the remainder of the mission and perform experiments.

Upon completion of the orbital mission, the astronauts return to the Command and Service Module, separate it from the docking adapter, Lunar Mapping and Survey System and airlock and leave the airlock, adapter and spent stage in orbit in a gravity gradient orientation. The Command and Service Module performs a de-boost operation, the Command Module separates, enters the atmosphere and the scientist-astronauts are returned to earth. This completes the AAP–1 and AAP–2 missions with the orbital workshop remaining in orbital storage for the next series of alternate mission operations.

Apollo Applications mission AAP3 utilizes a Saturn I launch vehicle to place a Command and Service Module into a parking orbit with three astronauts aboard together with supplies and expendables for a mission of 28–56 days duration (fig. 77, ML6–10,043). The next mission, APP–4, takes place by launching the Apollo Telescope Mount attached to the Lunar Module ascent stage into a high parking orbit about a day later. The astronauts in the Command and Service Module perform a Hohmann transfer to a high altitude orbit and perform rendezvous operations with the Lunar Module/Apollo Telescope Mount (LM/ATM). Next this configuration achieves rendezvous with the orbital workshop in orbit from the AAP1 and AAP2 missions. This configuration is shown here (fig. 78, ML66–9611). ATM solar observatory experiments are then conducted along with biomedical and other experiments. After about 28–56 days of operations in space in the orbital workshop, the astronauts enter the Command and Service Module, separate from the orbital workshop and de-boost. The Command Module is then separated from the Service Module and the astronauts reenter the earth's atmosphere and return to earth. The entire sequence of the AAP1, AAP2, AAP3, and AAP4 missions is shown here (fig. 79, ML66–8975). The major benefits from the orbital workshop and ATM missions are indicated in the next chart (fig. 80, ML66–9790).

FOLLOW-ON MISSIONS

Follow-on missions are being planned to use modified Apollo flight hardware with Standard Saturn launch vehicles. The program of investigations and development to be carried forward in the follow-on missions will be directed toward the development of a long duration flight capability. In addition, manned and unmanned flights in earth orbit are under consideration to meet earth oriented applications and requirements including meteorology, communications and earth resources analysis. Flights in earth orbit, including high inclination and synchronous orbits, are also under study for astronomical observations and space physics experiments. Space operations and technology experiments are also being planned. The extended exploration of the moon in the follow-on missions program will involve a series of orbital surveys and lunar surface

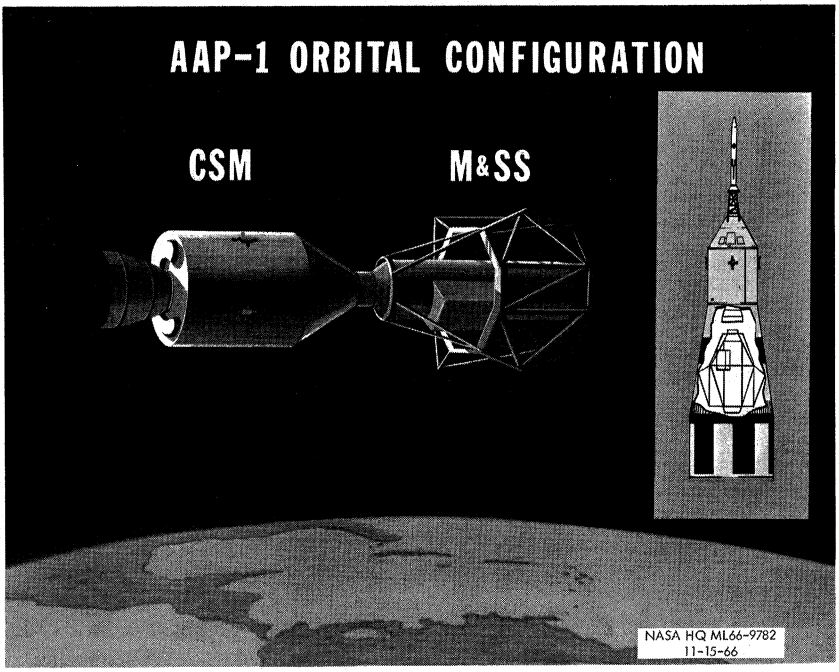

FIGURE 74

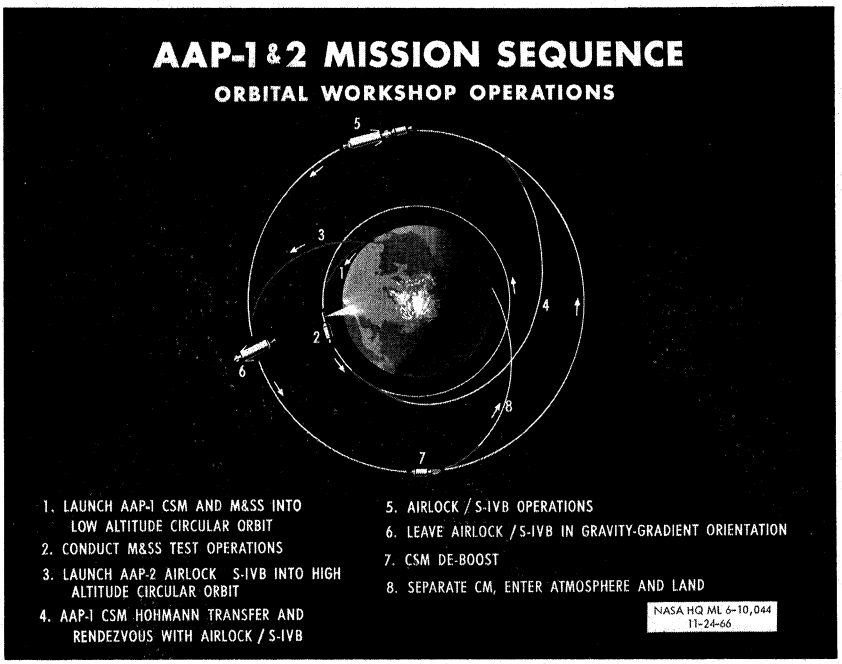

FIGURE 75

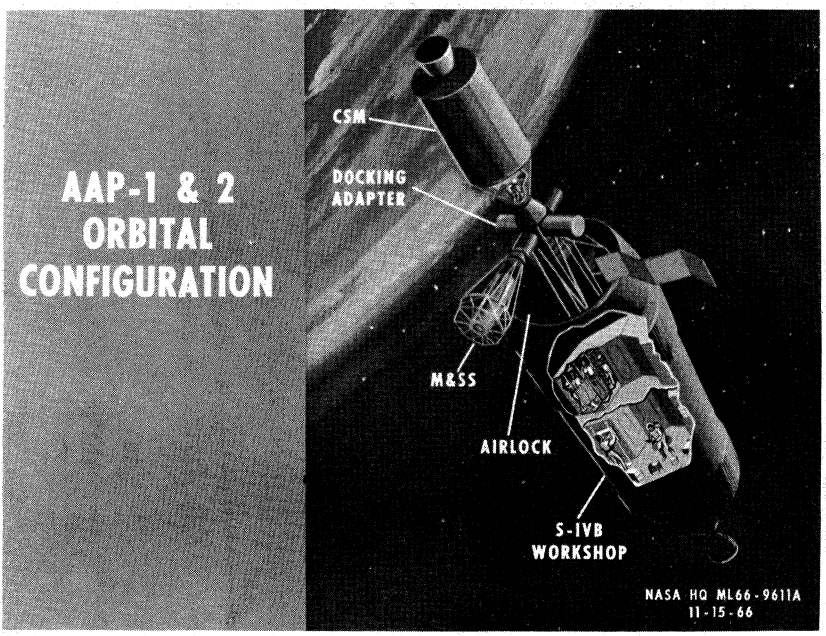

FIGURE 76

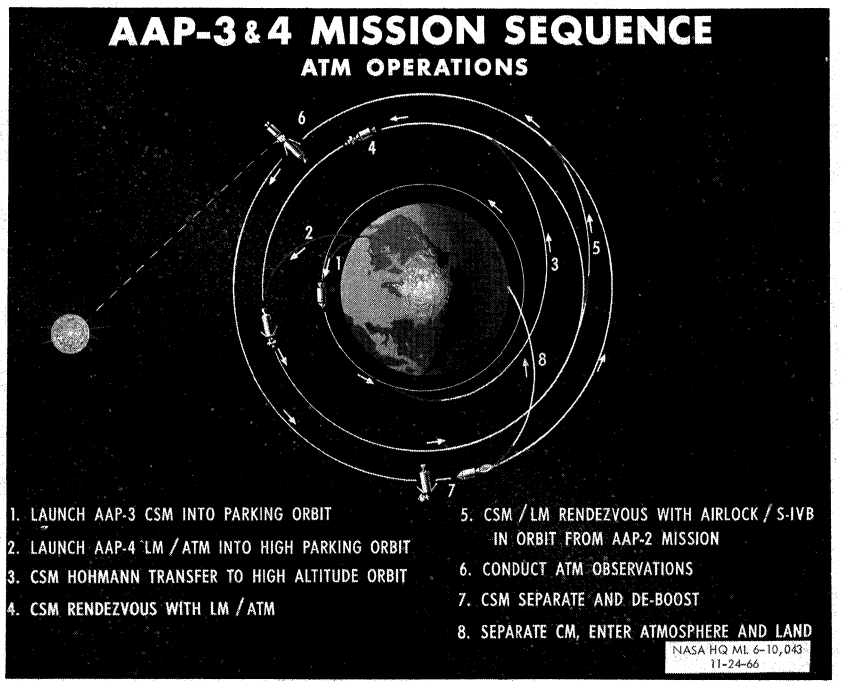

FIGURE 77

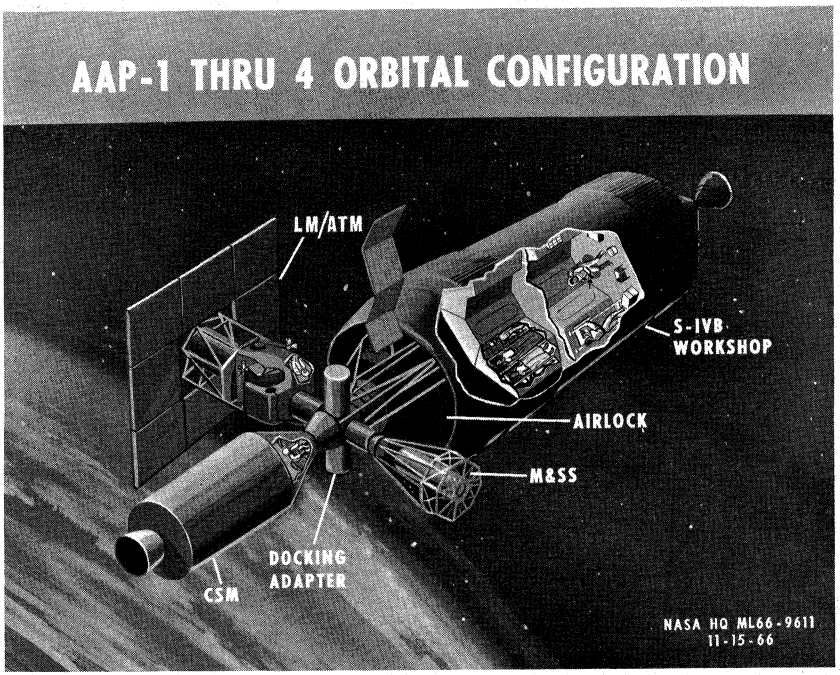

FIGURE 78

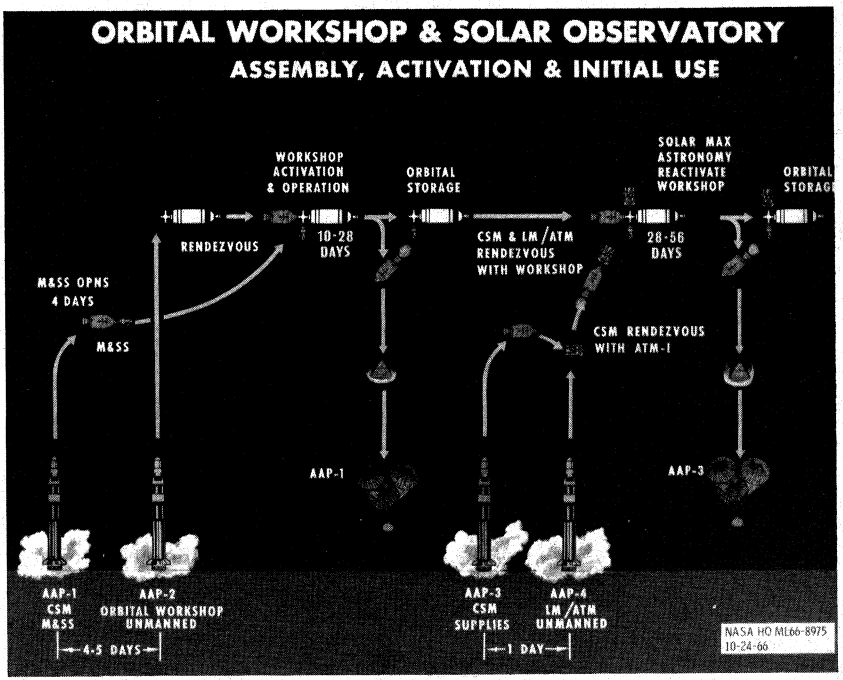

FIGURE 79

exploration operations. The Nerva II nuclear stage is planned for test as an upper stage on the Saturn V launch vehicle.

An example of the kinds of experiments payload packages under development for the follow-on missions program is shown here (fig. 81, ML66–9876). This chart shows a concept of a meteorology payload package assembled to meet a number of objectives. These include the flight testing of experimental meteorological instrumentation and the use of man's ability to direct sensors to meteorological events of moment to permit the improvement of knowledge of atmospheric composition and structure needed for long term forecasting of the weather.

Another example of an experiment payload package being considered for Apollo Applications follow-on mission involves Earth resources experiments (fig. 82, ML66–9873). Earth resources experiments will determine the agricultural, geological, and oceanographic information that can be obtained from orbit that would be useful for the evolution of earth resources on a global basis.

The above examples are typical of the payload packages under consideration in Apollo Applications follow-on missions. I shall now describe the overall follow-on missions program.

Long duration flight capability

The early development of long duration flight capability is clearly one of the most important areas to be pressed forward in the follow-on missions program. It is a key requirement for most of the possible significant advances in manned flight. Apollo Applications flights of up to 1 year or more in duration will represent a significant increase in the nation's operational capabilities in space and opportunities for important scientific and technological experimentation. Extended duration flight experience is also necessary to provide a sound basis for those future decisions on manned programs of the greatest interest and potential, such as permanent manned facilities in space or manned flights to the planets. Year long flights can be achieved on a cost-effective basis by reusing modified Apollo space vehicles with resupply.

The long duration flight objectives are to measure the effects on men and on manned systems of space flights of increasing duration; and to acquire operational experience with increasingly longer manned space flights. A third objective is to accomplish these flight objectives through modifications and adaptations

MAJOR BENEFITS FROM WORKSHOP AND ATM MISSIONS

- OBTAIN SOLAR ASTRONOMICAL OBSERVATIONS DURING PERIOD OF SOLAR MAXIMUM ACTIVITY
- DETERMINE MAN'S EFFECTIVENESS AS AN ASTRONOMICAL OBSERVER IN SPACE
- TEST ALTERNATE OPERATING MODES FOR FUTURE LARGE MANNED ORBITAL TELESCOPE
- DEVELOP CAPABILITY FOR REUSE OF SPACE HARDWARE WHICH WILL REDUCE PROGRAM COSTS
- DETERMINE EFFECTS OF EXTENDED DURATION SPACE ENVIRONMENT ON MEN AND SYSTEMS
- DETERMINE EFFECTS OF ARTIFICIAL GRAVITY ON MEN AND SYSTEMS
- DEVELOP EFFECTIVE MANNED EXTRAVEHICULAR CAPABILITY

NASA HQ ML66-9790
1-5-67

FIGURE 80

METEOROLOGY PAYLOAD PACKAGE (APP-A)

OBJECTIVES

- FLIGHT TEST EXPERIMENTAL METEOROLOGICAL INSTRUMENTATION.
- USE MAN'S ABILITY TO DIRECT SENSORS TO METEOROLOGICAL EVENTS OF MOMENT.
- COMBINE NUMEROUS SENSORS FOR SIMULTANEOUS OBSERVATION AND CORRELATION OF DATA.
- CONFIRM SPECTRAL SIGNATURES OF EARTH RESOURCES.
- FLIGHT TEST SOME INSTRUMENTS WHICH MAY CONTRIBUTE TO THE DETECTION OF AIR POLLUTION.
- IMPROVE KNOWLEDGE OF ATMOSPHERIC COMPOSITION AND STRUCTURE.
- TAKE ADVANTAGE OF INCREASED PAYLOAD CAPACITY AND VOLUME PROVIDED BY AAP MISSIONS.

PRINCIPAL EXPERIMENTS

- DAY-NIGHT CAMERA SYSTEM
- DIELECTRIC TAPE CAMERA SYSTEM
- MILLIMETER WAVE PROPAGATION
- MULTI-SPECTRAL PHOTOGRAPHY
- IR TEMPERATURE SOUNDING
- O_2 & H_2O MICROWAVE RADIOMETER
- IR FILTER WEDGE SPECTROMETER
- VISIBLE RADIATION POLARIZATION MEASUREMENTS
- STELLAR REFRACTION DENSITY MEASUREMENTS
- UHF SFERICS DETECTION
- IR INTERFEROMETER SPECTROMETER
- 15 MICRON GRATING SPECTROMETER
- MULTI-CHANNEL RADIOMETER
- SELECTIVE CHOPPER RADIOMETER

EXPECTED FLIGHT READINESS DATE: MID 1969

NASA HQ ML66-9876
11-15-66

FIGURE 81

EARTH RESOURCES PAYLOAD PACKAGE (APP-B)

OBJECTIVES

- ESTABLISH FEASIBILITY OF OBTAINING USEFUL DATA FROM ACTIVE AND PASSIVE REMOTE SENSORS.
- DEVELOP TECHNIQUES FOR EXTRAPOLATION AND CORRELATION OF DATA OBTAINED SIMULTANEOUSLY FROM SEVERAL REMOTE SENSORS.
- VERIFY METHODS FOR TRANSMISSION AND ANALYSIS OF LARGE AMOUNTS OF DATA.
- DETERMINE USEFULNESS OF MAN IN EARTH ORBITAL APPLICATIONS SPACECRAFT.
- OBTAIN EVIDENCE ON THE NEED FOR OPERATIONAL EARTH RESOURCES SPACE MISSION.
- UTILIZE PAYLOAD CAPACITY OF AAP MISSION.

PRINCIPAL EXPERIMENTS

- MULTIBAND CAMERA
- METRIC CAMERA
- PANORAMIC CAMERA
- TRACKING TELESCOPE
- WIDE-RANGE IMAGER
- RADAR IMAGER
- RADAR ALTIMETER AND SCATTEROMETER
- LASER ALTIMETER
- IR SPECTROMETER AND RADIOMETER
- PASSIVE MICROWAVE IMAGER AND RADIOMETER
- ABSORPTION SPECTROSCOPE
- UV SPECTROMETER

EXPECTED FLIGHT READINESS DATE: MID 1970

NASA HQ ML66-9873
11-15-66

FIGURE 82

of existing systems without a major new launch vehicle or spacecraft development. The existing systems used as modified for this program can serve as important elements of the systems that would be required for one or more of the projected next generation of manned space flight goals (fig. 83, MC67–5410).

During 1968–1969, extended mission duration can be achieved by packaging additional expendable supplies to supplement the nominal 14-day capability inherent in the basic Apollo spacecraft. The additional expendables can be packaged in modular form for transport to orbit either with the original spacecraft or subsequently on another launch vehicle for resupply as required. By this means, missions ranging from 28 to possibly 56 days duration are possible.

Beginning in 1969, mission duration could be progressively extended from approximately two months to one year or more. During 1971, the initial flight of a Command Module having a land landing capability is scheduled to take place. This system would allow establishing land landing as the primary mode, leading to cost recovery savings and facilitating refurbishment and reuse of the Command Module. In conjunction with land landing provision, the interior of the Command Module will be arranged to make provision for carrying 4 to 6 astronauts for short duration ferry missions.

In 1971, the objective is a one-year mission involving a Saturn V launch of a crew module derived from the Saturn S–IVB stage, with resupply by uprated Apollo spacecraft launched on the Saturn I.

The objectives for 1972 and 1973 are missions of greater than one year's duration as precursors of later earth orbital space stations or manned planetary flights. Suitable biomedical instrumentation is planned to monitor the effects on the crews of these long duration flights.

Land landing capability

The land landing capability planned for the Apollo Applications program will represent a major step in the advancement of a technology which will reduce the possibilities of crew injury and equipment damage during emergency landings, provide flexibility in the accomplishment of Apollo Applications and future manned space flight missions, and facilitate reuse of command modules returned from space. First flight availability is planned for 1971 with incorporation of

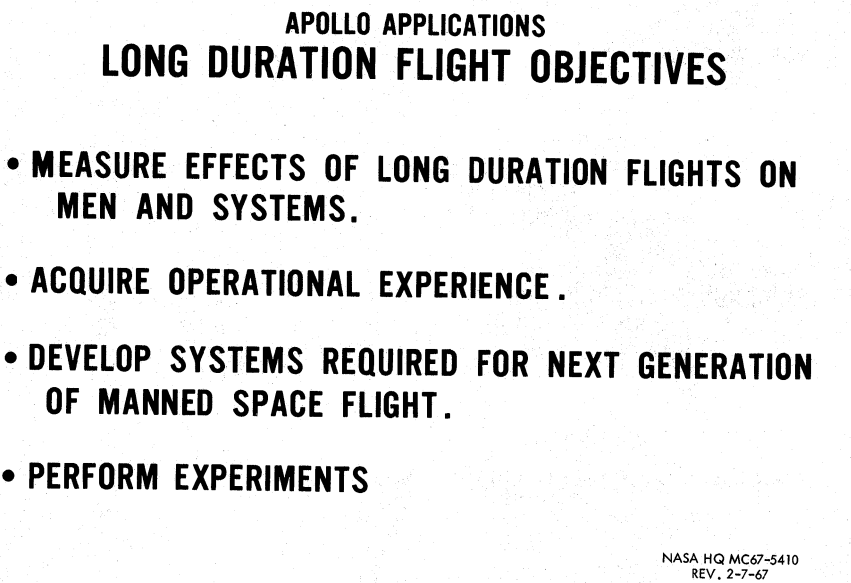

FIGURE 83

the system in all follow-on Apollo Applications missions. The technical objectives of a land landing system encompass the capabilities of the descent system to provide a greater glide range with maneuvering controls necessary to provide the crew with the ability to make a controlled touchdown (fig. 84, MC67–5763). The system will provide decreased impact velocities and the capability to return heavier payloads. In addition, the system retains the original water landing capability.

Since many of the Apollo Applications program missions are of long duration and open-ended, the capability to effect a land landing as well as a water landing, increases mission abort flexibility and capability with greater assurance of crew safety. The lower impact velocities will lessen the chances of crew injury during touchdown in abnormal landing conditions.

For several years, the NASA supporting development programs have investigated various configurations of descent systems for manned spacecraft (fig. 85, MC 67–5516). To meet the technical objectives of the Apollo Applications landing system, several gliding parachutes have been identified and tests performed on small scale models. They are the cloverleaf, the parawing, and the sailwing. Sufficient development effort on the cloverleaf configuration has verified its capability when used in conjunction with retro rockets for impact attenuation. Modifications to the Command Module are minimum and consist of structural configurations for storage and deployment of the parachutes and the mounting of the retro rockets.

The parawing and the sailwing have greater glide ranges and maneuverability control and if selected for the Apollo Applications program, could obviate the necessity for the retro rockets. It is planned to continue development and test of larger scale models of the sailwing and parawing to a point where a firm de-

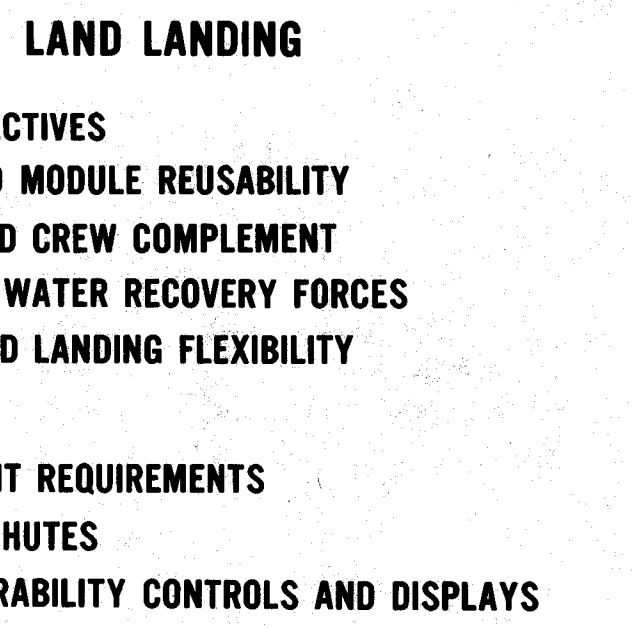

FIGURE 84

cision can be made, at which point end-item and interface specifications will be prepared for full scale development of the selected system. This decision would be made by 1968. Integrated systems development and test would be accomplished during 1968 and 1969 with first flight system available in 1970.

Increased astronaut accommodations

The reduced landing accelerations resulting from the land landing system minimize current crew seat requirements resulting in more useable volume in the Command Module. This will permit removal of existing couches and replacement with storable light-weight net couches, making the provision for carrying 4 to 6 astronauts for short duration ferry missions (fig. 86, ML67-6005). It further provides more crew volume for experimentation and other mission required operations. Studies are currently being conducted on refurbishment and reuse of Apollo Command Modules. Soft land landing recovery and reuse provides potential savings in refurbishment costs over that of water recovered spacecraft because of the noncorrosive land environments.

Life sciences experiments

Using the long duration follow-on missions in Apollo Applications, observations and experiments can be made to test man's behavior and his reactions to the spacecraft environment over long periods of time. Apollo Applications may not only permit extending man's time in space, but provide the capability for including trained medical observers on the mission and for investigating several means of therapy to counteract possible adverse effects of space flight.

Weightlessness

The effects of weightlessness on the cardiovascular and musculoskeletal systems are major areas of interest. No potential problems have been identified to date, even though blood pooling in the legs, dizziness, or a loss of calcium from the system had been anticipated as problems prior to the 14-day Gemini VII mission. Such symptoms could result from longer time exposure. It is therefore planned to carry out a well controlled series of medical experiments. For

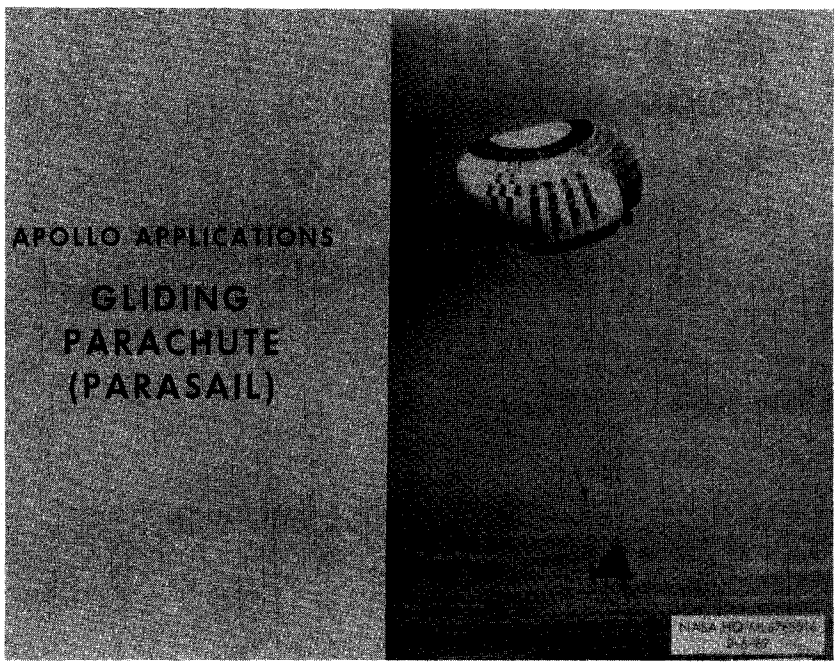

FIGURE 85

APOLLO APPLICATIONS CONCEPT FOR 6 MAN COMMAND MODULE

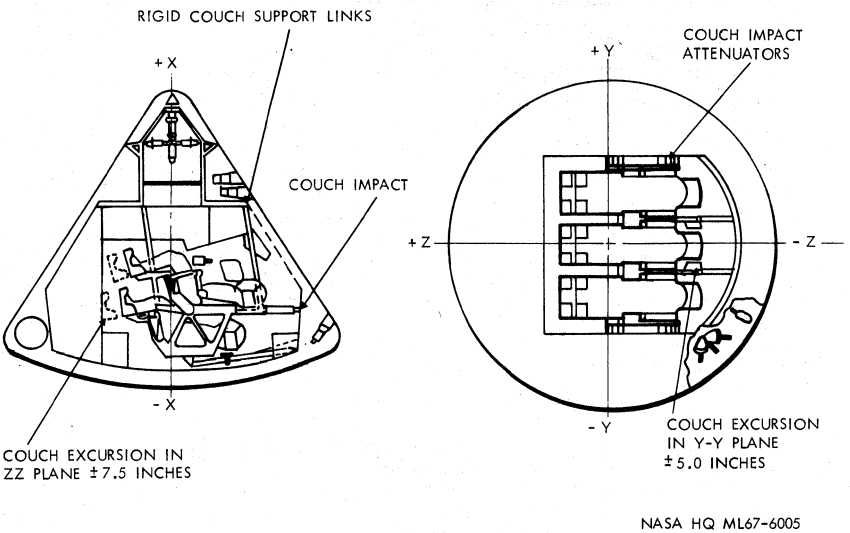

FIGURE 86

these experiments measurements would be made to monitor adequately the long term effects of weightlessness.

Various means of counteracting the zero gravity effects of space will be investigated in Apollo Applications. Conditioning exercises may be used. In addition, the creation of an artificial gravity environment such as a centrifuge or rotating spacecraft may also be needed. These needs would have extensive effects on plans for longer duration missions and for follow-on planetary missions.

Earth-oriented applications

In the whole broad area of the Space Applications program, follow-on Apollo Applications missions afford an excellent opportunity to conduct those Space Applications experiments for which concepts have been developed under the Supporting Research and Technology program of NASA but which must have these concepts verified in orbital flight before they are ready to be applied to long-life automated satellites for operational applications use.

Thus, in general we expect to fly on the Applications follow-on Apollo Applications flights, advanced instruments which would still require several years of additional development if we were to go directly to the automated spacecraft. While the basic rationale of the NASA Space Applications program, as well as its description and justification, is obviously under the purview of Dr. Homer Newell and the Office of Space Science and Applications, certain of the implications of these possibilities are covered in my ensuing discussion as a function of the potential of the follow-on Apollo Applications missions.

Meteorology

In Apollo Applications, we will ultimately have the capability for manned synchronous and high inclination earth orbital operations beginning in 1969–1970. Emphasis can be placed on manned operations but some experiments may be directed toward ultimate unmanned or intermittently manned systems. In these cases, man would be utilized to optimize measurement techniques and sensors, to evaluate, calibrate and checkout equipment in the space environment. By this means, highly reliable equipment could eventually be placed in auto-

mated satellites for some applications. Man would also be utilized to repair or replace malfunctioning units in large sophisticated earth orbital systems.

As a result of meteorological experiments in the Apollo Applications program, many benefits can be realized. The two basic purposes for the continued research and development in meteorology, both automated and manned, are (1) to explore and understand the motion and behavior of the atmosphere; and (2) to reduce the impact of the weather on daily operations private and public, and upon the economy of nations.

Economic value of improved forecasting

Improved weather forecasting techniques provided by manned earth-orbital weather station could afford annual savings of about $2.5 billion based on a recent report of the National Academy of Sciences—National Research Council. The report states:

"* * * we arrive at a total of around $2.5 billion (annually) that would be saved by farmers, fuel producers, public utilities, builders, and water managers if they were equipped with better forecasting tools. This does not take into account the economic benefits that might be obtained in the various industries associated with tourism and recreation, or the intangible savings to individual families."

Improved forecasting techniques could permit optimum routing of commercial ships and aircraft and provide a good weather warning service to commercial fishermen.

Earth resources

Apollo Applications follow-on manned flight operations will provide a platform for many earth sciences and resources experiments. The overall objectives of the Earth Resources Survey program are to determine those earth resource data which can be best acquired from space and to develop technological capabilities for the acquisition and utilization of such data.

As in meteorology, Apollo Applications follow-on missions will support this discipline by providing a test bed for the multi-spectral sensors that are required to obtain earth resources data. To a greater extent than in meteorology, man in space will play an important role in this effort and some of the follow-on mission operational flights will be manned.

Five broad areas related to the earth's resources have been identified as potentially beneficial for the application of space technology. These areas are Agriculture and Forestry Resources; Geology and Mineral Resources; Geography, Cartography and Cultural Resources; Hydrology and Water Resources; and Oceanography.

Agriculture and forestry resources

The ultimate responsibility of adequately feeding, clothing and sheltering today's expanding population rests in large part with the agriculture and forestry community. Since the land, water and mineral resources are finite quantities, these resources must be utilized efficiently to meet present and future needs.

The broad earth resources experiments program objectives are (1) increasing the yield/quality from lands in cultivation; (2) decreasing losses in production from infestation and forest fires; and (3) increasing cultivated acreage.

Geology and mineral resources

Geology is the science of the earth, its composition, structure, stratigraphy, and history. Mineral resources include iron, copper, and gold; oil and gas; sand, gravel, and limestone.

The main objectives in this program of spacecraftborne remote sensing instruments are (1) to develop means of mapping geology and geophysics on a regional basis; (2) to develop methods of predicting earthquakes and volcanic eruptions; (3) to delineate regions of mineral potential for subsequent detailed study; and (4) to provide new methods of investigating major structural units.

Geography, cartography, and cultural resources

Geography is specifically concerned with the spatial relationships of human activity and natural processes. This includes the static and dynamic patterns of the spatial distribution of man's activity, rural and urban settlement patterns and land use, and transportation networks.

Cartography is the science of map making and map revision. Both developing and industrial nations require accurate, current maps depicting natural resources, cultural features, and related topography. Follow-on Apollo Applications flights in earth orbit will enable man by the use of cameras and other remote sensors to scientifically photograph and obtain multi-spectral data from the entire surface of the earth to fulfill these requirements.

Hydrology and water resources

Hydrology is the science concerned with the study of the distribution, composition, quality and quantity of surface water and ground water on the land areas of the earth. Because water is generally a dynamic resource, it should be continuously evaluated, both in time and space, with respect to climatic and physical factors and human use. The availability of water is essential to the continuous human occupancy of any land area on the globe and an abundancy of water is needed for vigorous industrial or agricultural progress. Long duration manned flight operations will provide a platform for experiments to develop techniques for the study and inventory of large segments of our water supplies.

Oceanography

Oceanography is that collective science concerned with the understanding of the oceans. By its very nature, it is closely allied to a large number of separate scientific disciplines including biology, hydrology, geology, physics, meteorology, chemistry, and geodesy. Our knowledge of the oceans is not increasing commensurately with our ever increasing activity on and within the ocean itself.

A major objective of Apollo Applications follow-on missions experiments will be to develop methods to effectively utilize the vast economic potential of the oceans. Increased production of fish and other food from the sea is foreseen as well as the increased reliability of predicting sea state conditions. Synoptic and longrun monitoring of the sea/state can be made from orbital space platforms, with attendant estimates of wind strength and direction of the gross storm derived energy flux near coastlines, and of oceanic climatology. Sea ice movement and remote arctic and tropical floods could be monitored, and improved geologic mapping in structurally complex areas could be conducted.

Political and social benefits

The potential benefits in the application of remote multi-spectral sensing are impressive. Today more than two-thirds of the world's people suffer from hunger or malnutrition. The major political and social concerns of many national governments revolve about the problems of feeding their people. A host of international regional, national and private organizations are engaged in "food for peace" and "freedom from hunger" campaigns. All these activities have political and social as well as economic implications.

The economic development of African, Asian and South American countries is highly dependent upon improvement in their agriculture. All programs of agriculture development involve data gathering and processing. In the food-and-fiber surplus countries a continual search goes on for refinements and improvements in their survey and analytical methods. In many food-and-fiber deficient countries, programs are being initiated to develop systems of data gathering and analysis. In both groups of countries remote sensing techniques could greatly accelerate and expand the operations of data gathering and processing. Since individual nations would be involved, an overall policy sanctioned by the United Nations would have to be developed on how this data would be shared and made available to all nations.

Communications and navigation experiments

Within the Apollo Applications capabilities for communications operations in earth orbit and in the vicinity of the moon, some specific follow-on missions experiments under consideration will have a direct impact on the lives of the average citizen of the world during the early 1970's. For example, an Apollo Applications mission in synchronous, equatorial orbit has an enormous potential for conducting advanced communications experiments which involve in particular a combination of multi-kilowatt space power systems and large space erectable antennas; and also very large diameter lenticular passive radio reflectors. The tremendous payload capability of Apollo launch vehicles could be used

to demonstrate a capability in space for broadcasting either aural or television program material more directly to the user.

The possible application of Apollo hardware and astronaut participation in these communications areas is being studied by the Office of Space Science and Applications. A TV broadcast satellite could relay broadcasts to local distribution stations and enable television viewers in North America, South America, Europe and Africa to observe developing weather patterns on their home television sets (fig. 87, MC66–5200). Narrower beams could broadcast television direct to conventional TV receivers equipped with directional antennas and possibly preamplifiers.

These experimental, automated, earth orbiting communications satellites, capable of broadcasting voice or television directly to home or specialized community receivers, could provide worldwide coverage of events and entertainment. These stations could also provide access to educational facilities through transmission of educational programs, and could be of great use for broadcasting to a nation's entire population.

Earth orbiting communications satellites could accomplish much more. They could show how advanced space technology might help speed up the socio-economic development in critical areas of the world. They could further associate the U.S. with the peaceful exploration of space. At the same time, in a striking way, they could project U.S. concern with helping the developing areas of the world. They could bring the advantages of modern mass communications to regions lacking ground telecommunications or broadcast networks. They could bring modern teaching techniques to areas where educational facilities are limited or non-existent, promote health and hygiene, and population control. They could provide news and informational facilities previously lacking in underdeveloped regions. They could fortify tendencies toward national unity, provide more widespread cross-cultural fertilization and promote the utilization of a single language in areas where multiple languages or dialects are used. During emergencies, they could provide vital services as a supplement to terrestrial communications systems.

FIGURE 87

Experiments in the Apollo Applications flights could lead to manned or automated earth orbiting navigation and traffic control systems which could provide many benefits. Improved position fixing may reasonably be expected to increase efficiency of operation of all types of ships and aircraft by saving transit time and allowing greater margins of safety in passing obstructions.

In addition to the savings afforded by faster passages, merchant ship operations would benefit from better maintenance of schedules and avoidance of overtime and idle paid time of stevedores. Better position information is particularly needed when a vessel approaches landfall after several days at sea. Commercial fishing vessels can improve their economic situation if they can return expeditiously and accurately to favorable fishing areas.

Astronomy and space physics observations

Apollo Applications follow-on missions operations will provide opportunities for experimenters in the fields of Astronomy and Space Physics. Apollo Applications experiments will permit important and unique observations of the sun starting in 1969. At the same time, they will provide experience that is essential for the design and operation of future large telescopes in space, whether they be manned or unmanned, opening up a whole new chapter in the exploration and understanding of the universe.

Ultimately, the knowledge to be gained from a manned orbiting observatory in space may result in earthly benefits—benefits to each and every citizen of the world which far exceed that of any other application of the space program. This understanding could lead to the development of new sources of energy; to the acquisition of new and presently unknown materials; eventually to the contact of our culture with other cultures in other solar systems in the universe with results which are beyond our ability to predict or to comprehend.

Orbiting optical telescope

A typical orbital operational area concerns manned orbital astronomical observations using optical telescopes. Astronomical observations may be made on all stellar objects and the sun. Particularly, solar astronomy will be concentrated in the 1969–1971 period of peak solar activity which will not recur for 11 years. The orbital vantage point would allow optical astronomy free of atmospheric distortion and filtering.

Once a telescope is mounted on the Apollo spacecraft and placed in orbit, the astronauts would adjust and operate it. The film and plates would be returned by the astronaut at the end of the first mission, and it may be feasible for the telescope to be left in orbit to be reactivated when the astronaut returns on subsequent missions.

It is estimated that both the quality and quantity of the data from these experiments would be greater than what has been obtained previously. Man's ability to operate and maintain orbital telescopes would be tested, as well as systems and subsystems for future manned and unmanned astronomical missions.

Space Physics experiments

Space Physics experiments are also planned for astronomy missions. X-ray astronomy, ultra-violet spectroscopy, ion wake physics, and investigations of particles and fields are in this category.

Technology experiments

Technology experiments planned for follow-on Apollo Applications missions are focused upon the procurement of data in a space environment as needed for development of advanced systems for future missions. Initially, the required work space in orbit will be provided by a spent uprated Saturn I 2nd stage used as an orbital laboratory or workshop. Extravehicular activity experiments may involve the manned assembly and test of large structures such as radio and optical antennas; and the development of procedures for transfer, launch and recovery in space. Examples of the development of manipulative capability experiments include optical technology, manned locomotion and maneuvering (fig. 88, ML67–5534), maintenance and repair techniques, and the launch of unmanned satellites after they have been calibrated and checked out in orbit. Such launches may provide for a higher probability of successful operation and more accurate insertion into orbit.

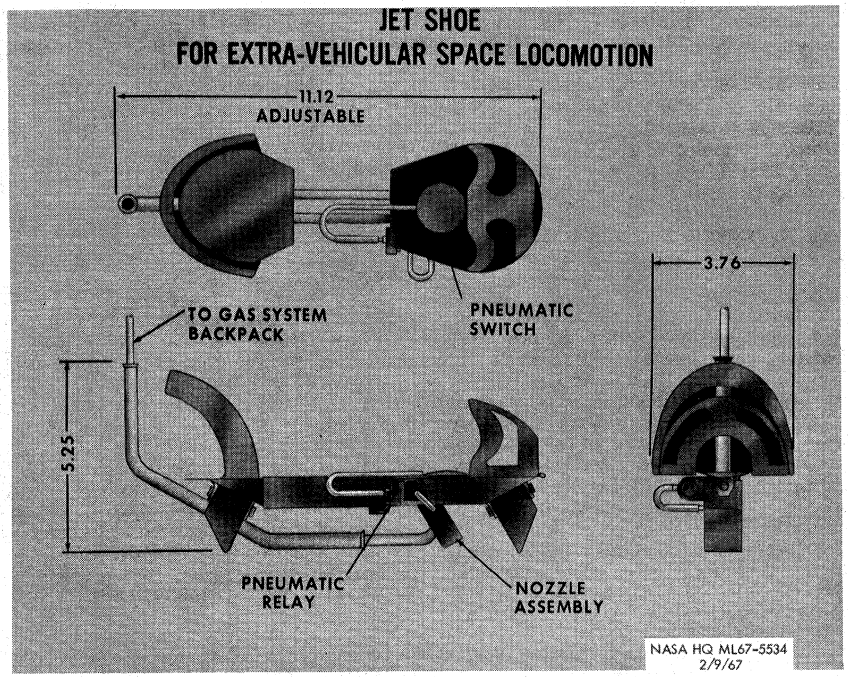

FIGURE 88

The Office of Space Science and Applications Voyager program will require the capability of the Saturn V launch for its planetary missions.

Follow-on lunar exploration missions

In addition to the earth orbital effort in Apollo Applications, follow-on lunar exploration missions are intended to extend knowledge of the moon gained from earlier programs, and to provide the basis for manned lunar stations. The missions include month-long lunar orbital missions with mapping survey cameras (fig. 89, ML66–9782) and multi-spectral sensors, and lunar surface explorations lasting two weeks with small surface vehicles, subsurface drills, and the emplacement of automatic scientific stations. Follow-on Apollo Applications lunar mission objectives also include the evaluation of the lunar surface for astronomical experiments.

With increased mission duration and extended area coverage potential of Apollo Applications, it will be possible to obtain definitive answers to a number of fundamental questions pertaining to the origin and history of the moon by means of lunar orbital missions (fig. 90, ML66–8965) and lunar surface exploration (fig. 91, MT6–10,142). Consistent with the basic objective of lunar exploration, various scientists have proposed experiments or investigations in such fields as biology, geology, geochemistry, geophysics, geodesy/cartography, astronomy and particles and fields. These experiments are under consideration for Apollo Applications follow-on missions and are described in the following discussion.

Biology

The scientists have recommended that biosciences should be pursued to the maximum in answering the fundamental questions regarding the origin of life and the development of life or life-precursors. To achieve this objective, investigations should be conducted primarily in organic chemistry and microbiology. A

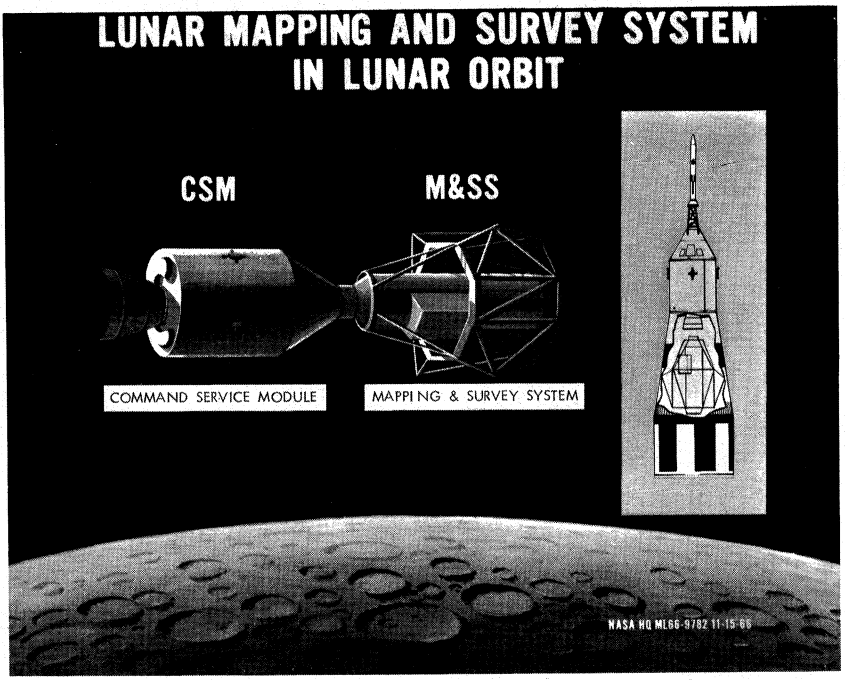

FIGURE 89

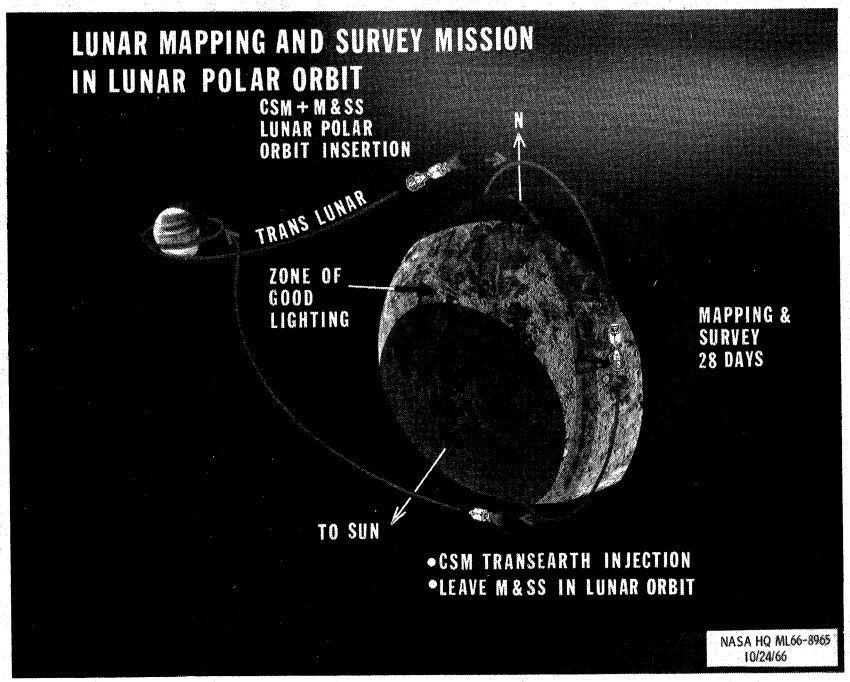

FIGURE 90

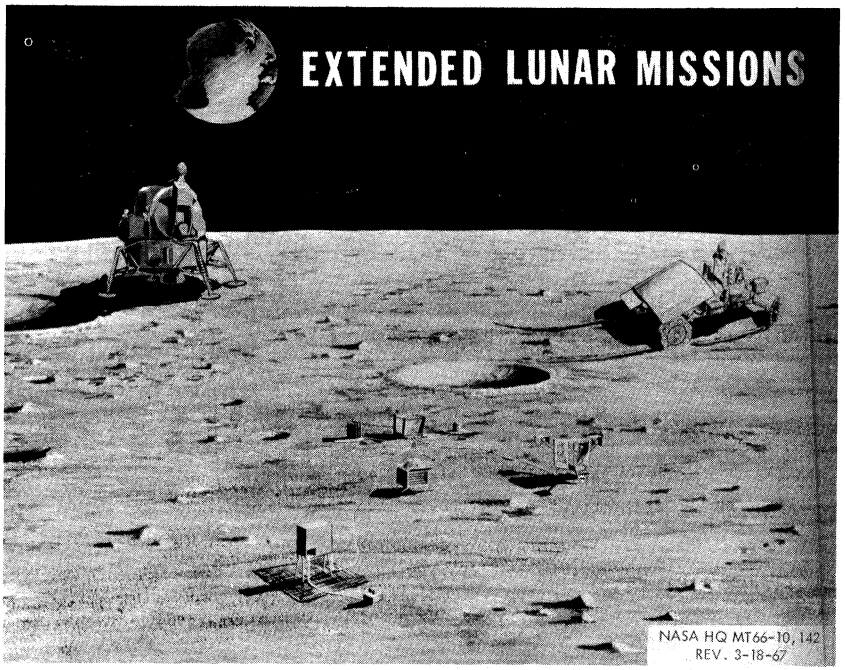

FIGURE 91

comprehensive program of organic-chemical and biological analysis of returned samples is recommended.

The organic chemistry experimentation should involve the search for proto-organic matter or organic material that would indicate, for example, whether the moon's present state represents a stage of the evolution of the earth prior to the emergence of living forms.

The microbiological experiments should involve the search for viable or non-viable organisms on or below the lunar surfaces. The search might logically include attempts to detect viable systems that biochemically or otherwise are completely different from known, reproducing earth forms. Also included should be a search for life-associated macro-molecules and other entities such as enzymes.

To conduct these searches, lunar surface materials should be sampled from various locations. Great care should be taken that these samples are not contaminated by earth material that would give a false indication of organic material on the moon.

As longer stay times, longer traverses and greater variety of sites become available, these searches should be continued. Of particular biological interest will be samples returned from deep below the surface or samples associated with traces of water. It will be desirable, when possible, to perform screening of samples on the moon by taking micrographs at high resolutions.

It would also be advantageous to use the manned orbiting spacecraft to put down probes that would contain packages for wet chemical analysis in remote locations not readily accessible to manned landings.

Later, when special facilities and biologists can be brought to the lunar surface, it should be possible to perform experiments with biological specimens on the moon. However, this phase should come after analyses have provided clear determinations of organic and microbiologic content on the moon.

Geology

The recommended exploration program for follow-on missions should provide the data for a detailed analysis of the geologic history of the moon and the major processes that have acted upon the surface and interior.

In the early Apollo missions, the major objective should be studies of the fine structure of the moon as revealed by study of the surface, mainly in the maria or plains areas, which appear to be surfaces formed by deposition and modified by post-depositional processes of several kinds. These areas include not only the marias, or lunar "seas," but also the plain-like features of certain upland regions.

In the limited time available for geological investigation on these missions, the primary question should be the nature and origin of the material underlying these plains. Specifically, the question is whether they are composed of lava flows and range from solid rock to rock froth; or whether they are ash or granular material pulverized by explosions of various types.

Another important question will be the nature and rate of the extremely slow processes that have operated on the moon's surface.

To obtain early answers to these questions, the explorers should gather lunar samples with the use of simple hand tools and should undertake lunar traverses. Immediately after the first Apollo landings, a systematic program of geologic mapping should be carried out with the use of data from manned missions in lunar orbit, preferably over the moon's poles for complete coverage.

The orbiting spacecraft should be capable of carrying and distributing lunar surface probes that would make measurements for calibrating remote sensors, characterize the fine geological features of the local area, and emplace scientific instruments.

In the lunar surface missions of the first 5 years following the initial Apollo landings, the geological objective should be to test detailed theories of the nature of the three major types of lunar terrain—the maria or lunar "seas," the cratered highlands, and a presumed thermally active crater such as Alphonsus.

In the latter half of the decade, the objective should be to obtain a broad regional integrated picture of the surface geology and crustal structure of the moon, by means of a series of traverses along the equatorial belt.

Geochemistry

The return to earth of lunar samples for analysis, the most important scientific objective of Apollo, has particular application to geochemistry. Seven objectives of geochemistry investigations on the returned samples have been recommended. These are (1) to compare the composition of the earth and the moon in terms of bulk chemistry and the ratios of certain elements and isotopes; (2) to compare the time scale of events in the moon's history with that of the earth's history; (3) to determine the evolution of the moon by establishing the relative ages of major events in its history; (4) to establish whether there is evidence of chemical differentiation on the moon or whether it has remained essentially unchanged since it was originally formed; (5) to establish the gross composition of the lunar surface as a whole; (6) to establish the relative roles played by internal and external processes in shaping the present surface topography; and (7) to determine whether the moon should be surveyed more exhaustively for resources, such as water, oxygen and energy sources, which would simplify lunar phase supplying and enable it to be used as a staging area for planetary exploration.

Analysis of lunar samples returned to earth should include determination of the abundance of elements, evidence of gas formation, separation of metallic phases, isotope investigations and other tests where suitable.

As it becomes possible for the explorer to spend longer times on the moon, field selection of samples will be necessary and some tests should be done on the moon, particularly of materials that may be altered by return to earth. Analytical devices should be carried to extend the power of the observer on the lunar surface to differentiate materials that are virtually similar and make an optimum selection of samples to be returned to earth for detailed examination.

Geophysics

The lunar surface experiment packages to be carried on the early Apollo missions represent a major opportunity for performing geophysical research. The packages should include the following instruments: magnetometer, heat flow probe, passive seismometer, active seismometer, lunar atmosphere detector, micrometeorite detectors and, if weight permits, a gravimeter.

Since geophysical observations are usually synoptic, it would be desirable to build up a net of observation points on the moon. In the follow-on Apollo Applications flights, traverses of about 10 kilometers from the landing point would be desirable to permit the emplacement of such a net. Probes dropped to the surface from lunar orbit would also contribute to the net.

When roving vehicles become available, gravity and magnetic anomalies associated with local and regional subsurface structures should be studied. Active seismic experiments with 10 kilometer profiles should be conducted.

If the magnetic field of the moon proves sufficiently strong, a magnetic survey from low orbit should be made. Also from orbit, use of an electro-magnetic pulse probe would provide significant geophysical information.

As more payload space becomes available, studies should be conducted to determine the maximum sensitivity that can be attained by seismometers emplaced on the moon and the efficiency of explosive and impact energy sources, which will transmit acoustic signals through the moon's interior. Analysis of these signals will provide information on the moon's interior, just as an understanding of the earth's interior is gained through analysis of the transmission of seismic reports of earthquakes.

After the average heat flow is determined, studies should be made of regions where the heat flow is anomalous. For detailed study of specific features of interest, dense networks of passive seismic stations should be emplaced, and seismic refraction, gravity and magnetic surveys conducted.

Geodesy/cartography

Geodetic and cartographic information is required for the moon in support of other scientific disciplines, especially geology and geophysics, since it provides the means of correlating theoretical and experimental results.

Tasks to be carried out include establishment of a coordinate system centered on the moon, description of the moon's gravitational field, derivation of the moon's center of gravity and distribution of mass, and establishment of a three-dimensional geodetic control system. Other tasks include systems for the collection, reduction, and presentation of photogrammetric data for lunar maps; measurements for complementary data such as rotation, librations, and lunar tides; and research and development programs for improving lunar geodetic information.

Intensive study should be undertaken to determine the design features of optimum camera systems for lunar geodesy and cartography. The cartographic camera should be coupled directly with a stellar camera and precise time should be available on the spacecraft. Precise altimetry is also necessary. Second priority should be assigned to the development of a high-resolution camera system.

Information on the lunar gravitational field would best be obtained by tracking lunar satellites from the moon itself. Laser altimeters should be developed for use from lunar orbits and radar and laser ranging should be undertaken from the earth to the moon to improve our knowledge of the moon's orbit and librations.

Astronomy

The moon offers a potential base for astronomical research. At the present time, available engineering and environmental information is insufficient to predict whether the moon's surface or a high earth orbit is better for this purpose. Studies should be started as soon as possible to determine the environment of the moon as it relates to an astronomical base.

In radio astronomy, a small, low-frequency radio telescope should be placed on the moon as early as possible to assist in obtaining environmental data. Feasibility studies should begin for a radio telescope array on the order of several kilometers, and a 100-foot dish antenna, both for operation in the latter portion of the 1970's.

In optical astronomy, a pilot telescope should be located on the moon in the early 1970's as an environment testing device. This telescope could serve as a research instrument as well as for site testing and could act as a prototype for the design and operation of a 100-inch telescope, should it prove desirable to place such an instrument on the moon. A lead time of about 15 years may be required for the construction of a 100-inch lunar telescope.

In X-ray and gamma ray astronomy, experiments should be conducted in the early 1970's to determine whether the lunar horizon or a crater rim might be used in locating such sources in space by the occultation method.

Lunar physics

Investigation should be conducted on the moon's surface to determine the relationship between the lunar magnetic field, if any, the solar wind and any shock front that might result from their interaction.

Particles and fields measurements should be carried out in lunar orbit and on the lunar surface by three-axis magnetometers and particle detectors. These instruments should be included simultaneously in the lunar surface experiment packages to be emplaced on the early Apollo missions and on lunar orbiting spacecraft.

Measurements should also be made of the vertical component of the lunar electric field, as early as possible in the Apollo program. Additional measurements should be made in orbit of reflected cosmic rays and neutrons, with the latter assisting in the search for water or ice on the moon.

In the early missions following the initial Apollo flights, coordinated measurements should be made of particles and fields at different attitudes, on the surface, about 10 meters above it, and in orbit of about 40 kilometers altitude.

Timing of Apollo Applications program

So far I have discussed what we can do with the Apollo equipment; now I would like to explain in more detail why it is essential to proceed with the Apollo Applications program in the fiscal year 1968 budget. The charts (fig. 92, MC67–5907; fig. 93, MC67–5906) show the status of Apollo Saturn launch vehicle and spacecraft procurement as of February 1967. Note that all of the uprated Saturn I launch vehicles have been procured and that the last of these are now in fabrication and assembly. Of the 15 Saturn V launch vehicles needed for the manned lunar landing, all have been ordered except the last five. However, long lead procurement has been authorized for these vehicles and they will soon be in the Apollo pipeline. Of the 21 Command and Service Modules, all have been ordered except the last three and again long lead procurement for these has been initiated. All of the 15 Lunar Modules have been ordered and they are in various stages of activity in the Apollo pipeline.

This chart (fig. 94, MC67–5917) shows the lead time relationship between the launch vehicles for the basic Apollo project and the follow-on Apollo Applications project.

APOLLO SPACECRAFT PROCUREMENT

STATUS AS OF FEB. 25, 1967

SPACECRAFT	BLOCK DESIGNATION	USED	ASSEMBLY COMPLETED	IN FABRICATION AND ASSEMBLY	ORDERED BUT NOT YET IN FABRICATION	LONG LEAD PROCUREMENT	TOTAL
COMMAND MODULE	BLOCK I	3	3	—	—	—	6 BLOCK I
	BLOCK II	—	2	7	3	3	15 BLOCK II
							GRAND TOTAL=21
SERVICE MODULE	BLOCK I	3	3	—	—	—	6 BLOCK I
	BLOCK II	—	2	7	3	3	15 BLOCK II
							GRAND TOTAL=21
LUNAR MODULE		—	3	4	8	—	GRAND TOTAL=15

NASA HQ MC67-5907
2-27-67

FIGURE 92

SATURN LAUNCH VEHICLE PROCUREMENT
STATUS AS OF FEB. 25, 1967

LAUNCH VEHICLE	STAGE	USED	ASSEMBLY COMPLETED	IN FABRICATION AND ASSEMBLY	ORDERED BUT NOT YET IN FABRICATION	LONG LEAD PROCUREMENT	TOTAL
UPRATED SATURN I	S-1B	3	7	2	—	—	12 S-1B
	S-IVB	3	7	2	—	—	12 S-IVB
	I.U.	3	4	5	—	—	12 I.U.
SATURN V	S-1C	—	5	5	—	5	15 S-1C
	S-II	—	3	7	—	5	15 S-II
	S-IVB	1	4	5	—	6	16 S-IVB
	I.U.	—	3	5	2	5	15 I.U.

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FIGURE 93

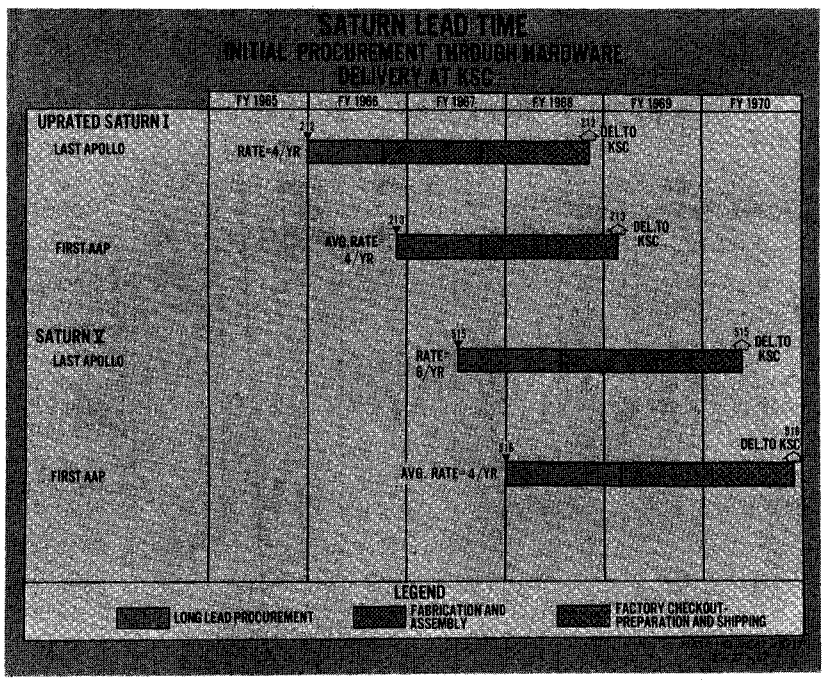

FIGURE 94

The various elements of the launch vehicles have slightly different lead times, but planning is such that all launch vehicle entities arrive at the Cape at the proper time for integration and launch. For clarity, the total vehicle lead times are shown in this chart.

The chart does not begin to show the complexity of the follow-on procurement situation for Apollo Applications. I believe, however, in the time available, it will help to clarify our funding requirements for fiscal year 1968.

The lead time problems we are currently facing—maintaining continuity of the capability developed for Apollo—are evident in this chart. Similar situations exist for the spacecraft and other Apollo equipments.

For Apollo we have an established production rate which delivers 4 uprated Saturn I launch vehicles per year to KSC. The top bar on this chart shows that we initiated the procurement of long lead time items for the last Apollo uprated Saturn I vehicle at the beginning of fiscal year 1966. This last vehicle will be delivered to the Kennedy Space Center the latter part of fiscal year 1968.

The second bar on the chart represents the procurement through delivery cycle for the first uprated Saturn I to be used for the follow-on Apollo Applications missions. Note that we initiated long lead time items last year.

Moving to the third and fourth bars on the chart we are showing similar data for the Saturn V launch vehicle.

In comparing the initiation of procurement for the Saturn V vehicles it should be noted that there is a change in production rates for follow-on procurement. This change results in different requirements for phasing the initial procurement in order to permit a smooth transition from higher to lower production levels. In fiscal year 1968, we have planned a minimum level of effort for the Saturn V. We then phased this effort with the current production rate to obtain the most effective cost structure.

This approach requires utilization of the capability needed to maintain the minimum level of effort over the shortest period. The ordering of follow-on Apollo Applications hardware as shown on the chart (MC67–5917, see p. 154) accomplishes the desired results.

This effort will permit us to accomplish significant results with the first follow-on Apollo Applications Saturn V vehicles and it will provide a means of maintaining the national capability referred to earlier. It will also allow a four per year rate in the future to meet the follow-on mission goals. The President's Science Advisory Committee in their report published in February 1967 recommended an average four per year rate for the Saturn V which we can provide if the required funding is available.

Similarly, we are requesting funding for experiments and mission support associated with this reduced rate of space vehicle delivery to use these vehicles in a broad spectrum of investigations of great value to human knowledge and to our national strength. Specifically, the equipment and mission support is provided for the Apollo Applications program missions I discussed earlier and the definition of other experiments and payloads for follow-on missions.

In summary, FY 1968 is a key year for exercising the options that this Committee permitted us to hold open in fiscal year 1967. If we fail to exercise the options we will begin to phase down the manned space flight activities and "mothball" the facilities.

As I mentioned, if we exercise our option we will maintain the momentum and capability of the space "team" that has been so painstakingly assembled over the past decade. We can provide near-term scientific and practical benefits. We can open up tremendous opportunities for the expansion of knowledge at a time when space-based astronomy and exploration show promise of breaking through into an era of real discovery. We can provide opportunities to return real benefits to the man in the street. We will maintain the forward momentum of U.S. technology in support of international competition and national security. We will develop options to guard against the possibility of technological "surprise." And we can provide a bridge to space exploration of the future, in time resulting in manned exploration of the solar system.

SUMMARY

In summary, Apollo Applications will maintain the orderly pace of our progress in the space age at a time when there may be opportunities to move ahead of the Soviets in space achievement.

It will guard against the possibility of technological "surprise" by supporting the continued advancement of an industrial technology.

It will maintain the forward momentum that space technology has given our competitive position in the world market place through research and development for our industrial technology.

It will support the broad base of research and development vital to our security as a nation.

It will avoid the waste, the dissipation of a space capability assembled in painstaking fashion over the period of a decade.

It will hold open the opportunity to return direct benefits to man on earth in the next phases of space activity, maintaining the momentum achieved thus far.

It will take advantage of the tremendous opportunities for expansion of knowledge at a time when space-based astronomy and exploration embracing the whole field of space science show promise of breaking through into an era of real discovery.

It will provide the means to meet the challenge of the future in space at a relatively modest cost as measured against a percentage of the gross national product. The peak was in fiscal year 1966, when NASA expenditures totaled 0.83 of 1 percent of the gross national product. In the current fiscal year they are 0.73 of 1 percent. In the budget proposed for fiscal year 1968, the total would be 0.66 of 1 percent.

Finally, it will provide the capability to expand our space activity if the international situation should change. The resulting stabilizing benefits would thus be insured because this proposed program would keep the space team together, and in a position to respond to economic developments on the national scene.

Mission Operations

A Year of Initial Flight Test

For mission operations, 1966 was a year of initial flight test of the Apollo space vehicle and exercise of mission operations support equipment (fig. 95, MA66-9631).

Two of the successful unmanned Apollo flights were from Launch Complex 34, and one from Launch Complex 37. We encountered a number of problems during

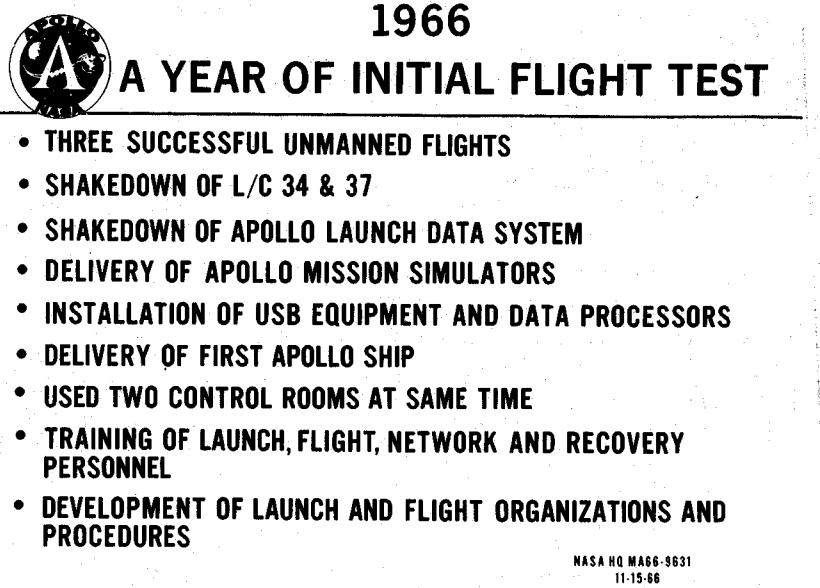

Figure 95

the checkout of these pads which had been modified for launching uprated vehicles.

Launch Complex 37 is now undergoing modifications for the Lunar Module and we still have Block II modifications to be made to Launch Complex 34. However, we have succeeded in eliminating the major problems from these two launch complexes, and now we are well along with Launch Complex 39 for the Saturn V flights.

In our flights, we had little difficulty after getting to the launch pad with our flight hardware. Most of the problems were in the ground support equipment and facility items.

The Apollo launch data system, which is located in the Central Instrumentation Facility at KSC, became operational in December 1965. This system replaces the similar Gemini launch data system which was located primarily in the Mission Control Center at Cape Kennedy. Except for a few minor programing problems during our three missions, performance of the Apollo launch data system was successful.

Two of our three Apollo mission simulators were delivered early in the year. These two simulators have been used in the preliminary training for our flight crews.

We are supported in our mission operations by NASA's Goddard Space Flight Center and the Office of Tracking and Data Acquisition. Both Goddard and OTDA and their contractors made excellent progress during the year in facility construction and in installation of the equipment associated with the Unified S–Band equipment. We were able to give three of the stations a limited test on AS–202. Final system testing for design confirmation will occur on later flights.

As we install the Unified S–Band equipment, we are also in the process of putting in new data processing equipment at most of our manned space flight network sites. We are upgrading to the UNIVAC 642–B computer which is replacing the smaller UNIVAC 1218 computer. This work will continue through 1967. We have had success with the first equipments put on line, and they will provide support during upcoming missions.

Our first Apollo instrumentation ship, the VANGUARD, arrived at the Eastern Test Range in the fall of 1966 to undergo testing. The ship went out to an instrumented portion of the range for a check of metric tracking accuracy, and during the Gemini XII mission did some C–Band tracking and some communications work.

As you may recall, when we originally designed the Mission Control Center at Houston we had the capability of conducting a live mission from one floor and conducting simulated training exercises on the second floor. This was not used until last year when, at some time during all three of our preparations for Apollo shots, we were conducting training exercises on the second floor while live Gemini flights were flown from the third floor. This capability is now being upgraded so that two unrelated simultaneous live missions will soon be possible.

The training of our operations personnel which commenced late in 1965, progressed throughout 1966. As the Gemini program began to phase down, many experienced Gemini personnel were made available for use in the Apollo program. In the middle of 1966, some of our more experienced people in the Apollo Saturn I program also began to move over and prepare for the Apollo Saturn V missions.

One fundamental change in our launch and flight organizations was made from those used in the Gemini program. The change reflects the organizational responsibility arising from use of the NASA Saturn launch vehicles instead of Air Force Titan boosters. This internal realignment at KSC, along with the realignment of personnel, served to strengthen our launch organization.

SOFTWARE PROGRAMS

I would now like to discuss some of the software involved in the operations programing for the equipment shown here (fig. 96, MA66–9660). This chart is really divided into two phases. On the lefthand side of the chart are the facilities used for processing the data during the launch phase. On the right-hand side are those used basically during the orbital phase of the mission.

The box at the top represents the two pieces of flight hardware, the launch vehicle digital computer and the Apollo guidance computer.

MSF TELEMETRY/COMMAND COMPUTER SYSTEM

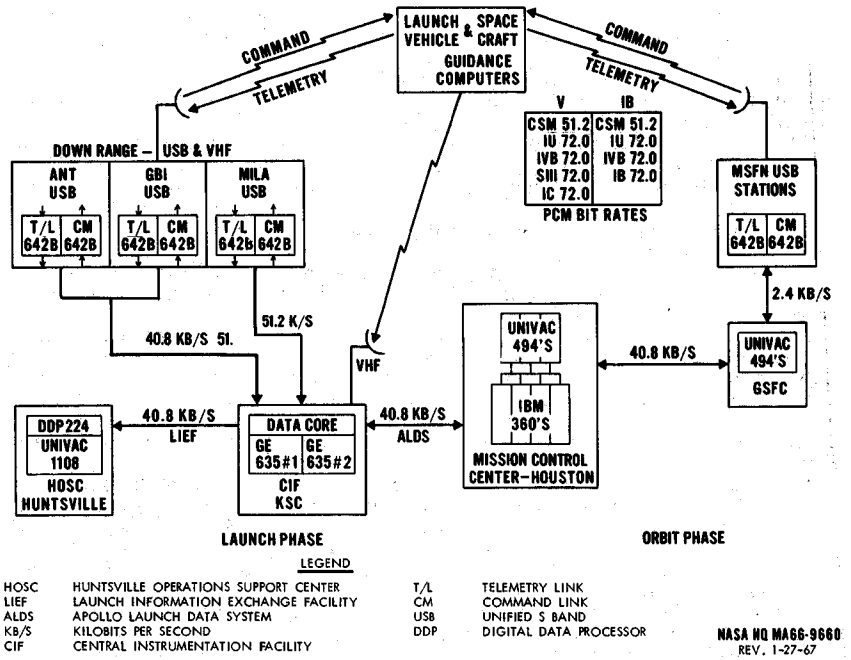

FIGURE 96

Information in the form of commands to the space vehicle and telemetry to the ground is processed by the three stations which are located in the Cape Kennedy area to cover the launch, and processed into the Data Core equipment, which is located in the Central Instrumentation Facility at the Cape. Data then is passed back to the Mission Control Center at Houston, where it is processed by the UNIVAC 494's, and IBM 360's. We also are processing data to Huntsville, where we can provide real-time off-line advice and assistance to the launch vehicle area.

After we get into orbit, the information is processed by the Manned Space Flight Network stations. It proceeds on to the 494 computers at Goddard Space Flight Center, then into the Control Center at Houston. During the three orbit life of the launch vehicle these data are passed to Huntsville.

Interface checkout problems

One of the major problems that we have is working out the interfaces between the various software programs and making sure that they operate together properly as we progress towards the mission.

Based upon our present experience, we estimate it will take us something like 48 days from the time we have all of the software available to mate it progressively, until we have checked it out with the launch pad, the Control Center and the Manned Space Flight Network. Our software programs, prepared by Goddard, must be available for delivery to the Manned Space Flight Network stations approximately two weeks before launch so that we then can conduct our final flight controller training.

Checkout of this software first progresses within the Mission Control Center where all of the hardware and software systems must be checked out. Next it

is integrated with the Manned Space Flight Network stations, using their remote site data processor programs. Then, after all of these interfaces have been checked, we mate it with the space vehicle on the launch pad, giving us our final overall verification.

In the case of the Apollo Saturn 202 flight, we were required to go through this process several times before we were able to debug the software. After we acquire more experience, we expect gradually to reduce the amount of testing required to resolve all of the interfaces. At the present time such testing is one of the major factors in our 61-day turn around time. This is the time between the completion of one mission and the launch of the next mission, if they are being conducted from the same floor of the Control Center.

MANNED SPACE FLIGHT NETWORK

Next, I wish to talk about the Manned Space Flight Network (fig. 97, MA66–8951).

Ground stations

This chart indicates the development of our Manned Space Flight ground stations, starting with the initial facilities when the equipment is delivered, as it progresses through system evaluation and testing, through network integration, and finally to operational status.

We have shown here the eleven 30-foot dish stations and the three 85-foot "deep-space" stations. At the bottom are some of the Gemini stations which will continue to be used for some time yet in the Apollo program.

As I pointed out earlier, three of the stations supported the AS–202 mission and gave us a limited test of our Unified S-Band tracking and communications capability. These were Merritt Island (MILA), Bermuda, and Carnarvon. All of the stations except Antigua and Canary will support the first manned flight. Prior to the time we get to the first Apollo Saturn V manned flight, all of them will be available to support our launches.

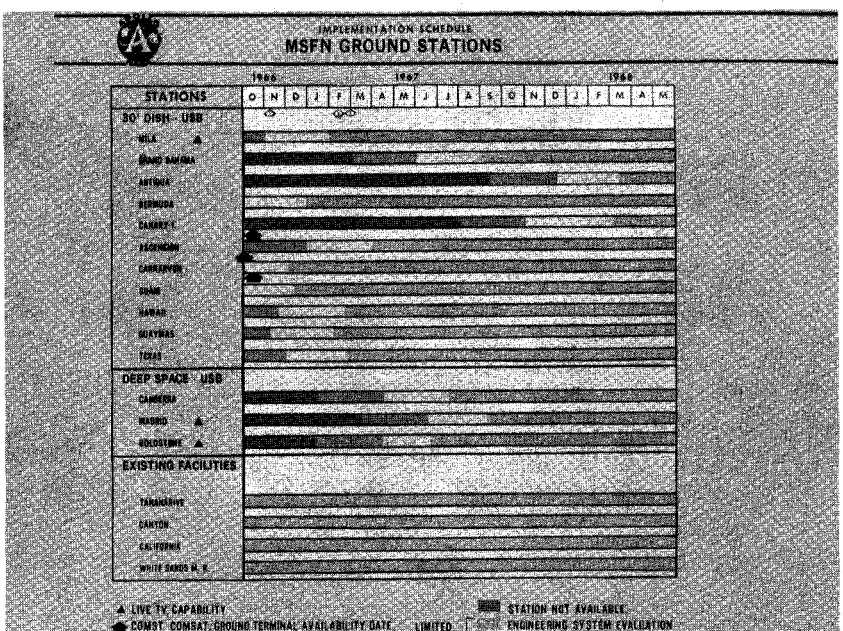

FIGURE 97

We have arranged with the Office of Tracking and Data Acquisition and with Goddard Space Flight Center to use these stations on a limited basis as they become operational, and then gradually to increase the system use to meet full requirements as we enter a completely operational configuration.

Communication satellites

As you know, our Manned Space Flight Network will utilize satellite communication services provided by the Communications Satellite Corporation. We have shown here the three stations which already have a Comsat ground facility. Service began February 5, 1967 using a Pacific satellite. A satellite for Atlantic coverage will be launched in March 1967.

We also will have three stations which are capable of handling live television—Merritt Island, Madrid, and Goldstone. The MILA capability is already in operation and will be used on the first manned mission, while the other two stations will come in at a later point in time, prior to the first lunar mission.

Ships and aircraft

This chart shows the implementation schedule for the ships and the eight instrumented aircraft (fig. 98, MA66–8950). Ships include three Apollo instrumentation ships, two reentry ships, and the two Gemini ships which will continue to be used until the Apollo ships become operational.

The VANGUARD is undergoing testing at Cape Kennedy and is ready for support of Apollo missions. It does not have a Comsat capability at the present time but will be brought back into the yard at a later date for modification. The REDSTONE and the MERCURY will have the Comsat capability when they are delivered.

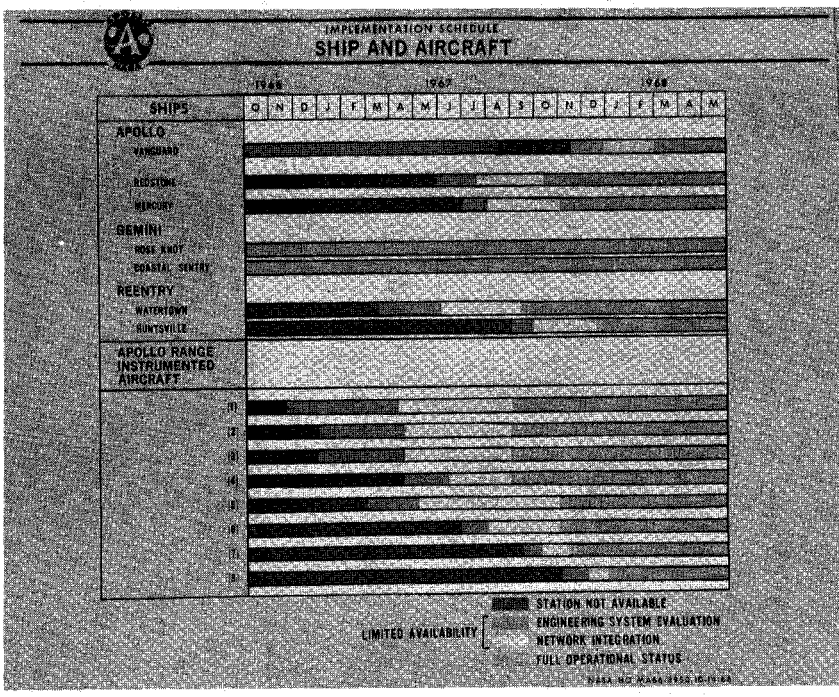

FIGURE 98

In the case of the aircraft, the first aircraft was used in the final Gemini flight on a test basis. It was able to receive Very High Frequency band telemetry and also to act as a voice relay from the Cape area back to the Mission Control Center at Houston.

We will use three aircraft on the first manned mission. As we get into the latter part of 1967, all of these aircraft will reach their full operational status. We plan to use them on a progressively increasing basis as we develop and check-out their capability.

I have several views of the ships and aircraft carrying communication equipment. This is the VANGUARD, showing the telemetry antenna, the Unified S-Band antenna, and other radar equipment (fig. 99, MA66–9418).

The next view shows more clearly a modification to the VANGUARD for the Comsat satellite capability in the forward portion of the ship (fig. 100, MA66–9633). To accommodate this rather large antenna it was necessary to modify the bridge area to maintain adequate visibility for navigation.

These are pictures of the first Apollo reentry ship and the instrumentation aircraft (fig. 101, MA66–9807; fig. 102, MA66–8958).

RECOVERY FORCE

I will discuss next the recovery force for manned space flight missions and recommendations that have been made for changes.

Early last year we were informed by the Navy that they saw difficulty in meeting our Apollo recovery requirements, particularly in 1968 (fig. 103, MA66–9919).

As a result of a continued series of discussions with the Navy, NASA reviewed its recovery requirements. This review continued throughout most of the summer, and by October of 1966 we had forwarded a revised list of ship requirements to General L. I. Davis, the DOD Manager of Manned Space Flight Support Operations. Most of the reductions which we were able to effect were in the AS–503

FIGURE 99

FIGURE 100

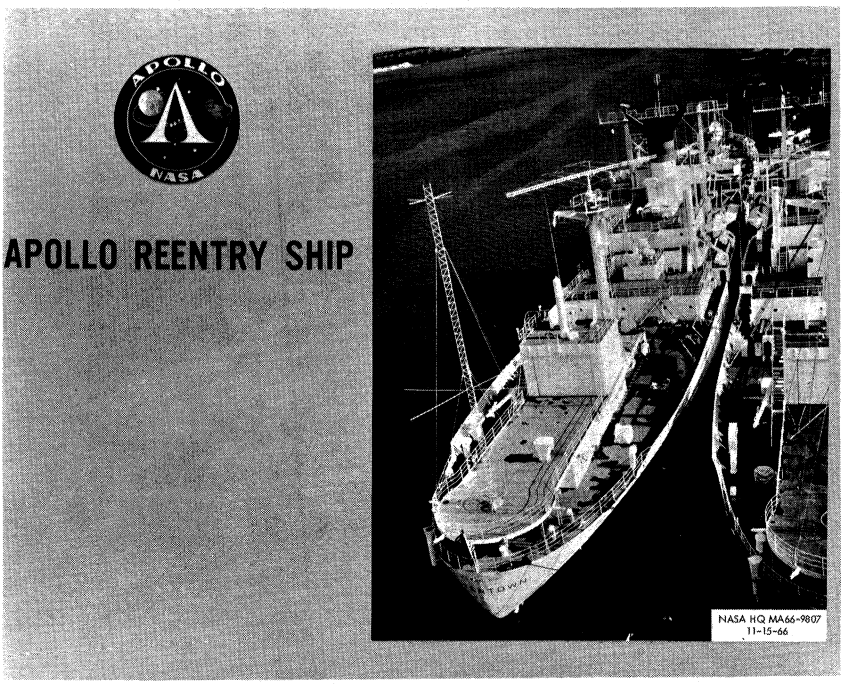

FIGURE 101

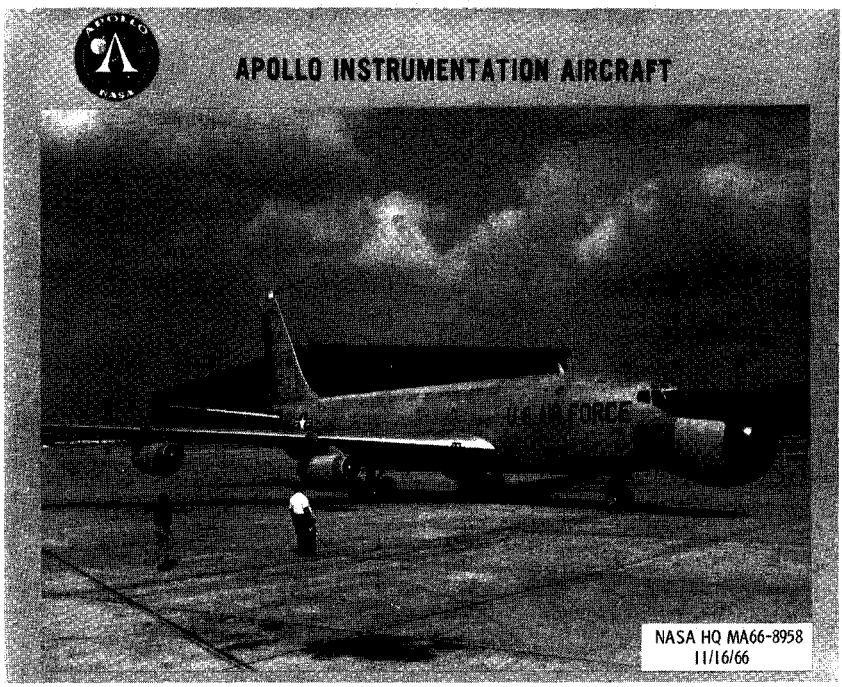

FIGURE 102

APOLLO PROGRAM

PROPOSED SPECIAL DOD RECOVERY FORCE

- NAVY HAS INDICATED INADEQUATE RESOURCES FOR RECOVERY SUPPORT
- NASA HAS REVIEWED APOLLO RECOVERY REQUIREMENTS
- NAVY HAS RECOMMENDED ACTIVATION OF A DEDICATED RECOVERY FORCE TO JCS
- JCS HAS RECOMMENDED APPROVAL OF NAVY PROGRAM CHANGE TO SECDEF
- AIR FORCE HAS RECOMMENDED RECOVERY BY HEAVY HELICOPTERS TO DOD
- DOD HAS RECOMMENDED NASA-DOD STUDY

NASA HQ MA66-9919
11-15-66

FIGURE 103

and AS–504 time periods. In the case of AS–503, we were able to reduce our ship requirements from 10 to 6, and in the case of AS–504 from 17 to 11.

OPERATIONAL CONSTRAINTS

As a final comment regarding Missions Operations, I would like to mention three of the potential constraints in the operations area which have been discussed previously (fig. 104, MA66–9832).

Based upon our present experience, we are constrained to a minimum of 61 days turn around time from the splash of one mission to the launch of the next mission.

I believe that as we get additional experience with our software and new equipment, that we will be able to reduce this time required. But at the moment it is one of our items of concern.

I have discussed also the availability of Apollo simulators and I have covered the status of the Apollo ships. It will be necessary for us to follow carefully the completion of this program throughout 1967 to make sure that the hardware stays on schedule and can provide the support that we need to meet our launch schedule.

In summary, 1967 will be a demanding year as we prepare for lunar flight (fig. 105, MA66–9588). Among the mission "firsts" planned are a Lunar Module flight and flights of the Apollo Saturn V space vehicle, which I have previously described in my discussion of the Apollo flight schedule.

In addition, we will achieve operational status of the huge and intricate Launch Complex 39. The Mission Control Center at Houston, Texas, will be converted to third-generation computers. The Manned Space Flight Network will be made completely operational for Apollo. The remaining Apollo training equipment and facilities will be made operational.

And finally, our astronauts, flight controllers, and launch crews will be training in preparation for lunar flight

APOLLO PROGRAM

POTENTIAL CONSTRAINTS

- MCC-H/MSFN TURNAROUND TIME BETWEEN MISSIONS
- SIMULATOR AVAILABILITY
- OPERATIONAL READINESS OF APOLLO SHIPS

NASA HQ MA66-9832
REV. 1-17-67

FIGURE 104

1967

THE YEAR OF LUNAR FLIGHT PREPARATIONS

- LAUNCH COMPLEX - 39 OPERATIONAL
- FIRST SATURN V OPERATION
- FIRST LUNAR MODULE FLIGHT
- MISSION CONTROL CENTER - HOUSTON CONVERTED TO THIRD GENERATION COMPUTERS.
- MANNED SPACEFLIGHT NETWORK COMPLETELY OPERATIONAL FOR APOLLO - SHIPS, AIRCRAFT, FIXED SITES, COMSAT
- REMAINING APOLLO TRAINING RESOURCES OPERATIONAL
- ASTRONAUTS, FLIGHT AND LAUNCH CREWS TRAINING FOR LUNAR FLIGHT

NASA HQ MA 66-9588
3/1/67

FIGURE 105

ADVANCED MANNED MISSIONS

INTRODUCTION

Just as our Mercury, Gemini, Apollo, and Apollo Applications programs have evolved from advanced studies of the past, so will the programs of the future evolve from our present advanced manned mission studies. The potential future missions defined by these studies have involved many considerations, not only those of NASA and other government agencies, but those of the scientific community as well as the recommendations of the President's Science Advisory Committee. Although our presently defined advanced program does not meet all of the specific recommendations contained in the President's Science Advisory Committee report published in February 1967, we are consistent in direction.

The applications program including the Apollo and near post-Apollo period are being discussed in some detail for this Committee by the Associate Administrator for Space Science and Applications, Dr. Homer Newell. I should like to review for you now some of the potential applications for a period farther into the 1970's and 1980's, as developed in our advanced manned mission studies.

The NASA effort to define our future missions has resulted in a well planned and carefully arranged program of studies. Within Manned Space Flight, we formed two Joint Planning Groups; one responsible for a study on manned planetary exploration and the other for a study on manned lunar exploration. In addition, results of several years of complete studies now have been reviewed by these Joint Planning Groups. Key technical and management people in NASA, both at the centers and in headquarters were involved in these reviews, thus insuring an adequate technical depth.

This NASA-wide effort was directed by a Planning Coordination Steering Committee, comprising members at the Deputy Associate Administrator level from the Offices of Manned Space Flight, Space Science and Applications, Advanced Research and Technology, Tracking and Data Acquisition, and other key individuals from each program office, providing a broad assessment. Reporting to this Steering Committee were NASA-wide working groups in Lunar Exploration, Planetary Exploration, Earth-Oriented Applications, Astronomy, and Life Sci-

ences. A Space Station Working Group later was added to integrate requirements and to consider corresponding configurations in earth orbit.

These in-house activities have, of course, drawn heavily upon the information obtained from our Advanced Study program over the past several years. But more important, the Planning Coordination Steering Committee has recognized the need for an integrated program utilizing each mode of operation, manned or unmanned where it is most effective.

Basic objectives unchanged

Throughout these planning efforts, the basic objectives we have previously reviewed with you have remained unchanged. We wish to explore the moon and the near planets; we wish to develop our capability to conduct earth orbital operations to serve science, particularly astronomy; to realize economic benefits to life on earth through earth-oriented applications; and to enhance our national security through R&D support of the Department of Defense and by developing new capabilities which are available for defense applications if needed. The pacing and scope of implementation, while recognizing current budgetary constraints, must be such as to stimulate a vigorous technology development which will lead toward U.S. preeminence in space activity.

MSF program evolution—Baseline program

The planning efforts I have described now enable us to define, as an example of possible options, a baseline program which eventually could logically grow out of Apollo Applications. This baseline program would provide long-duration earth orbital flight with a 9 to 12 man space station, and lead to manned planetary reconnaissance/exploration with the possibility of planetary sample return.

Three assumptions that we have made as the basic premise in defining the baseline program were that man will be used in space missions, that we will have an orbital laboratory workshop in being by 1970, and that we will maintain continuous space operations in the 1970's.

Our immediate objectives will be to determine the uses of men in space in four broad areas: to work over long periods of time; to make effective observations; to reduce the cost of acquiring scientific practical applications, and operational data; and to perform extended lunar exploration.

Manned space station

Such a baseline program is illustrated in these charts (fig. 106, MT66–10,256; fig. 107, MC66–5358A). In Apollo Applications, we could have 56 to 180 day earth orbital flights in 1968–69 evolving to 240 day missions in 1970 and a 1-year capability, with resupply and crew rotation, in 1971.

By 1973, we could fly a space station with an inherent 5-year lifetime which can have the potential of serving as the 2-year mission module for manned planetary exploration in 1975. In addition, it can provide a research and development and capability to advance our knowledge of astronomy, communications, and earth resources. At some point during the 1970's we would achieve the capability for continuous earth orbit. During this same time period, unmanned Mariner/Voyager missions would provide the necessary design validation data for the manned planetary spacecraft.

Manned planetary missions

A 1975 manned Mars exploration mission could have the capabilities of exploring Mars by remote sensors and, by means of an unmanned probe, of returning a sample of Mars surface material and atmosphere to earth for subsequent laboratory analysis. This mission could be followed by a triple planetary reconnaissance, Venus/Mars/Venus, in 1977. This later mission offers particular promise of early exploratory data on both nearby planets in the solar system with the possibility of sample return. It is important to note, however, that the opportunity for such a triple encounter may not occur again for a decade or more.

Manned lunar exploration

During this time period, manned lunar exploration could continue, starting with the Apollo Applications 3–14 day missions. Payload and mobility capability would be increased, employing a lunar survey module for surface exploration near the landing site. Later, manned scientific stations might be established with operational life times up to 3 months.

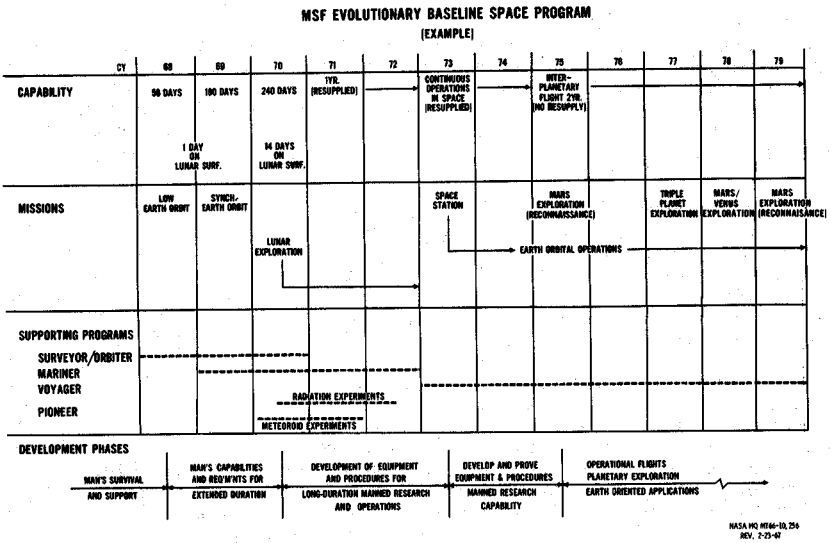

FIGURE 106

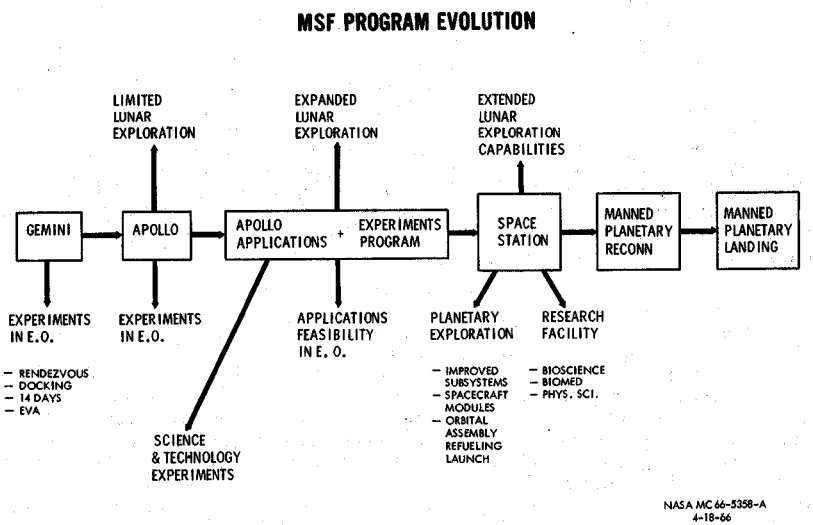

FIGURE 107

Decisions regarding the pace of mobility and payload delivery improvement after the Apollo Applications program will depend upon the scientific results of the Apollo Applications missions. Nevertheless, eventual establishment of a lunar base for extensive surface exploration remains an important scientific goal. In addition to its intrinsic scientific value, this advanced lunar activity could provide essential insight and system development required for interpreting planetary reconnaissance data as well as for undertaking planetary surface exploration.

Hardware for advanced missions

The space hardware required for this evolutionary program would be based, to the greatest extent possible, on a common family of modules which would have application to several missions. A space station could serve as the mission module for planetary reconnaissance as well as an advanced shelter on the lunar surface or as a lunar orbiting station. Similarly, certain of the modules for a Mars mission could also serve as the basis for the direct flight stages in the advanced lunar missions.

Step-by-step program decisions

In discussing possible future planetary missions, I want to emphasize that these missions may be viewed in terms of goals rather than in terms of early programmatic decisions implying long-term commitments. In fact, this example of an evolutionary baseline program has the unique advantage that the commitment for each step can be made complete in itself. Although each such decision prepares the way for the next development, it does not require a premature commitment to the next mission.

All of the proposed operations of Apollo Applications provide direct progress toward the manned space station capability. While meeting the experiment requirements of such a program, we also would be resolving basic questions with application to future programs, without future commitment. We thus can continue our evolutionary progress toward increased knowledge of space and towards a capability in the application of space technology.

I will now describe briefly the proposed implementation of the baseline program discussed, and indicate the studies required to support it.

EARTH ORBITAL MISSIONS

The manned earth orbital program is based on a progression of missions and experiments which began with the Mercury system. Advancement of the program has been achieved with Gemini and will continue to advance with the Apollo and the planned Apollo Applications programs.

The earth orbit experiment program objectives which I discussed here last year are still valid. Our inherent capability to carry them out has increased with our additional in-orbit manned flight experience and the availability of larger and more versatile payload carriers. This experience and hardware availability, coupled with the unique capabilities of man as an on-board investigator, indicates that manned spaceborne research is now both practical and potentially highly productive in terms of broad beneficial returns to humanity. In addition, missions now under study could also promote the capability to safely conduct deep space travel, and could provide continued effective research and development support to the Department of Defense.

Primary objectives

To meet our broad overall objectives, we are carrying on a study program with five succinct objectives (fig. 108, MT66–7996). First, we identify potentially important manned earth orbital missions and derive from these missions the system requirements. Based on the mission-derived system requirements, we determine attractive overall space station concepts capable of meeting these requirements. Then by comparative analyses of space station concepts and considerations of the projected technology base, we formulate an implementation plan, including station configuration for manned earth orbital missions. In addition, we define and evaluate supporting ferry/logistics/rescue concepts and auxiliary experiment facilities as an adjunct to the planned space station. Finally, we identify research and development technology requirements needed for space station implementation by analysis of realistic station configurations.

Mission requirements

As we progress into considerations of continuing manned earth orbital space flight capabilities, it becomes clear that a significant broadening of the total scope of experimentation utilizing man will occur. The catalytic ingredients necessary for an effective earth orbital experiment program are shown in this chart (fig. 109, MC66–5361).

MANNED EARTH ORBITAL ADVANCED STUDIES

PRIMARY OBJECTIVES:

DEVELOP EARTH ORBITAL PROGRAM PLANNING ALTERNATIVES TO SUPPORT MAJOR OBJECTIVES

- IDENTIFY IMPORTANT MANNED EARTH ORBITAL MISSIONS AND THEIR PROGRAM REQUIREMENTS
- EXPLORE ATTRACTIVE SYSTEMS CONCEPTS FOR IDENTIFIED MISSIONS
- EVALUATE LOGICAL PROGRAM ALTERNATIVES
- EVALUATE SUPPORTING FERRY/LOGISTICS/RESCUE CONCEPTS AND EXPERIMENT MODULES
- IDENTIFY R&D TECHNOLOGY AND DEVELOPMENT REQUIREMENTS

NASA HQ MT66-7996
12-30-66

FIGURE 108

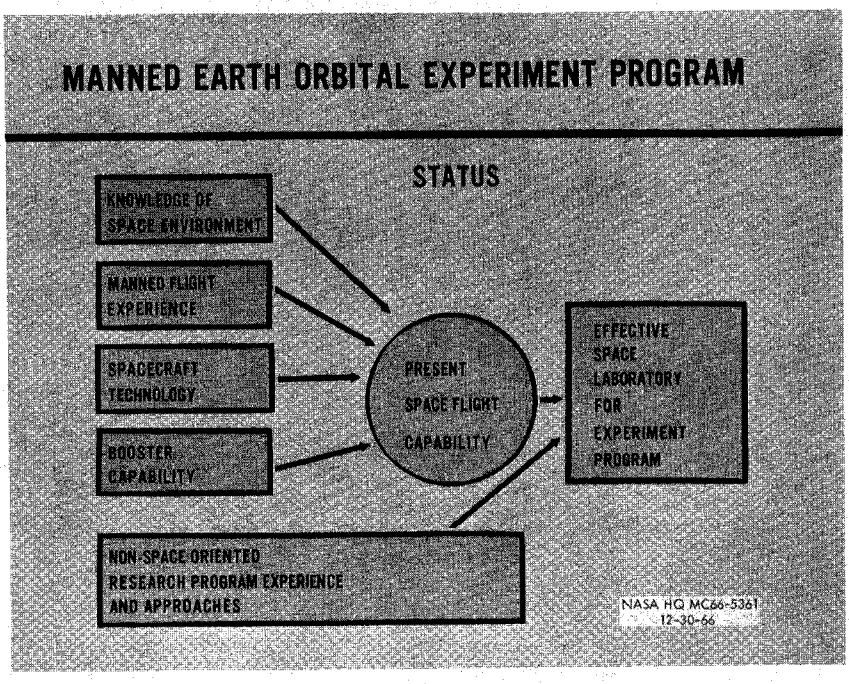

FIGURE 109

In the past eight years of orbital experimentation we have measured the environment in terms of radiation and meteoroid flux. We know the effects of up to 14 days of weightlessness on man and have performed space rendezvous and extravehicular operations. We know how to design and fabricate spacecraft to protect man and supply him with a shirtsleeve environment, electric power and sustenance for long mission durations. Our booster capability using the Saturn V launch vehicle will be nearly 100 times the capability of the Atlas which was used on the first manned flight. This increased launch vehicle capability makes possible the use of optimized instrumentation without weight limitation, such as that developed for airplane or ground military usages, with resultant cost savings. We also expect to have a nuclear stage in the late 1970's. These accomplishments sum to give the United States a major capability to perform space experimentation.

The availability of man in space as a participating scientist, coupled with our space technology experience and rapidly increasing payload capability, puts us in the position where we can begin to apply the research program experiences and approaches developed in ground laboratories to the planning and development of an effective orbital experiment program. The ground-based research experience has demonstrated the value of orienting the research program towards specific user goals and laying out systematic programs to accomplish these goals.

Manned earth orbital telescope

A proposed national facility offering large potential returns in terms of determining the dimensions and origins of the universe is the manned earth orbital telescope (fig. 110, MC66–5366). This instrument, with 120-inch near diffraction-limited optics, should increase our capability for resolving celestial objects by a factor of 20, extend range by four magnitudes of brightness, and allow observations into the infrared and ultraviolet ranges. Such a telescope should be able to detect planets the size of Jupiter in orbit about the closest star, Alpha Centauri.

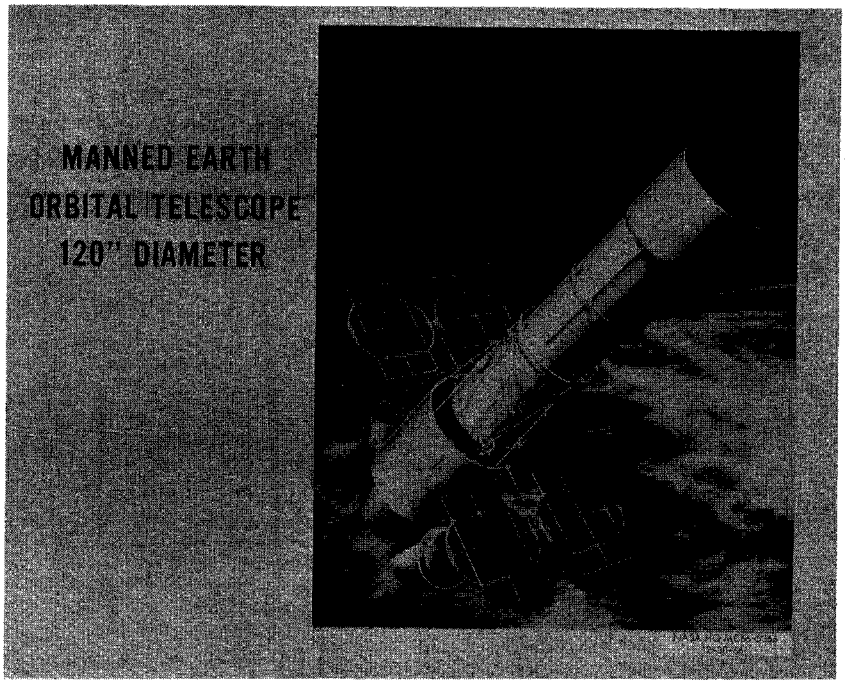

FIGURE 110

We foresee this instrument as an ultimate space capability to be obtained through a step-by-step program growing from a 38-inch telescope through a 60-inch size and finally to the 120-inch configuration. Some comparisons of orbital telescope capabilities with ground-based instruments are shown in the next chart (fig. 111, MC66-5597). It is of interest to note that even a 38-inch telescope in earth orbit will be superior to the 200-inch Mt. Palomar telescope in effective resolution capability as well as in spectral range.

Space station alternatives

Only during the past few years have we begun to focus on the use of a manned orbital space station for experimentation in areas other than those dealing directly with man's ability to survive in the orbital environment. We are currently identifying experiments as part of an integrated science and applications program.

Some key trends have developed from this overview of the total manned earth orbital experiment potential. Our total projected orbital experiment workload has grown from 10,000 man-hours at the end of 1963 to about 20,000 man-hours at the end of 1964 and at the end of 1965 approximately 50,000 man-hours had been identified for possible future implementation. A future annual workload of up to 50,000 or more experimental man-hours seems plausible to predict at this time.

About this projection we have structured a potential program of orbital experimental man-hours to meet the anticipated experiment workload. From the studies completed we have concluded that the Apollo Applications program will perform many of the critical pivotal experiments identified to date. These are the experiments which will facilitate effective future utilization of a larger station in a low-earth orbit of either a moderate latitude or a polar orbit.

Current trends in experiment identification indicate that in the early 1970's a crew of nine men would be fully occupied on a continuous basis in space. This appears to be well within our technical capabilities for such a time period.

We can further foresee the possible desirability of a station in synchronous orbit, primarily to exploit the advantages of continuous synoptic coverage of a

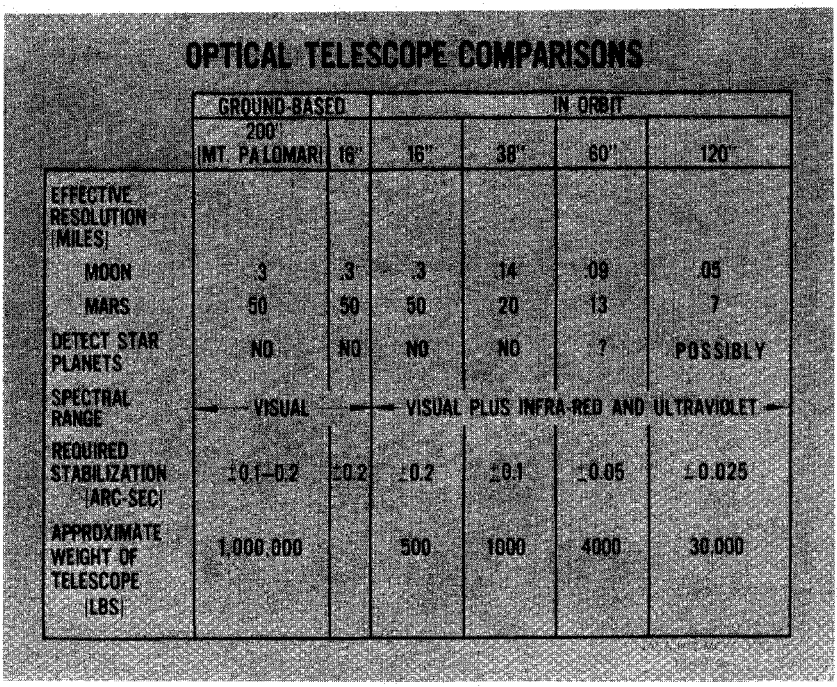

FIGURE 111

major segment of the earth that this orbit offers. This combination of a low-earth-orbit station and a synchronous station could provide a capability for approximately 50,000 experimental man-hours per year.

We have concluded from our mission studies that a long duration space station provides a critical connection between current plans and such major future decision as manned planetary exploration. There are a number of optional experimental paths being considered for the development of the space station. Inherent in each path is the introduction into the Apollo Applications program of a low-cost test article involving no new development, thus allowing basic exploration of space station requirements within a reasonable funding level. This type of approach will provide the necessary assurance that the ultimate space station design will meet all the experiment requirements and will resolve basic questions such as the desirability of artificial gravity.

Orbital workshop

One of the attractive alternatives utilizes a spent Saturn S-IVB stage as an orbital workshop (fig. 112, MC66–8987). The objective of this S-IVB experiment module would be to establish the feasibility of exploiting launch vehicle and spacecraft hardware placed into orbit for purposes beyond its basic function. Existing subsystems are used to provide and control the atmosphere. The additional advantages of the successful completion of the experiment would include (1) an early capability for a large, controlled environment to evaluate human performance and secure engineering data for future subsystem designs; (2) low-cost design validation and checkout of equipment requirements for long-term habitability in zero g; and (3) large protected volume in space which can supplement a more sophisticated system for special purposes such as biological experiments. Initial flights would require assembly of S-IVB orbital workshop components while in earth orbit; later missions of increased capability would be ground assembled.

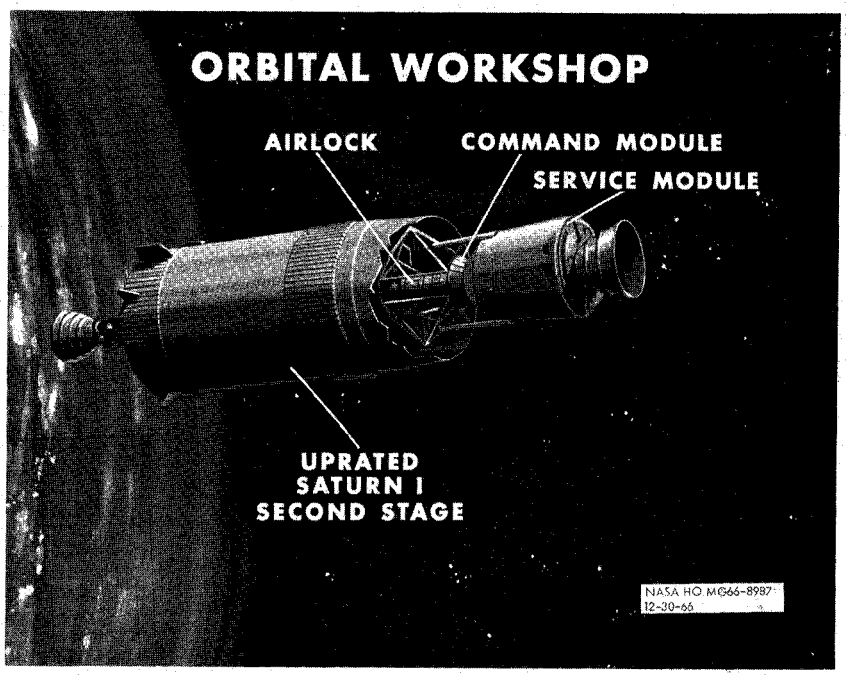

FIGURE 112

Ferry/logistics concepts

In considering future operation of space stations which require resupply, it is important to note the relationship between the original cost of the laboratory and the costs accumulated during the ferry/resupply operations to support the laboratory. Based on the resupply cost for a single six-to-nine man orbital laboratory using a logistics system based on an Apollo Command Module, in a single year the logistics cost equals the laboratory cost. In five years these costs more than double the original laboratory costs. This type of cost analysis has led us to consider more efficient resupply systems.

We are currently considering systems made up of the components shown on this chart (fig. 113, MT5–9715). Normally a logistics system would be made up of three major modular components. The first would be the reentry crew module which will contain the six-to-nine man crew during orbit insertion and during reentry. The second section of the logistics system would contain the cargo. This cargo compartment would be designed for maximum operational flexibility. The nominal configuration would contain the fuels, oxygen and foods to support the station and crew. A specially configured version could contain a large experiment instrument such as a telescope or a complete set of experimental subsystems. The third or propulsion section of the ferry/logistics vehicle is designed to meet the differing maneuverability requirement for rendezvous and de-orbit in near-earth or in synchronous orbits.

PLANETARY MISSIONS

Some interesting potentialities have developed as a result of recent studies in the area of advanced manned planetary missions. Considerable attention has been directed toward the formulation of an integrated planetary exploration plan that will provide the proper mix of manned and unmanned space exploration capabilities.

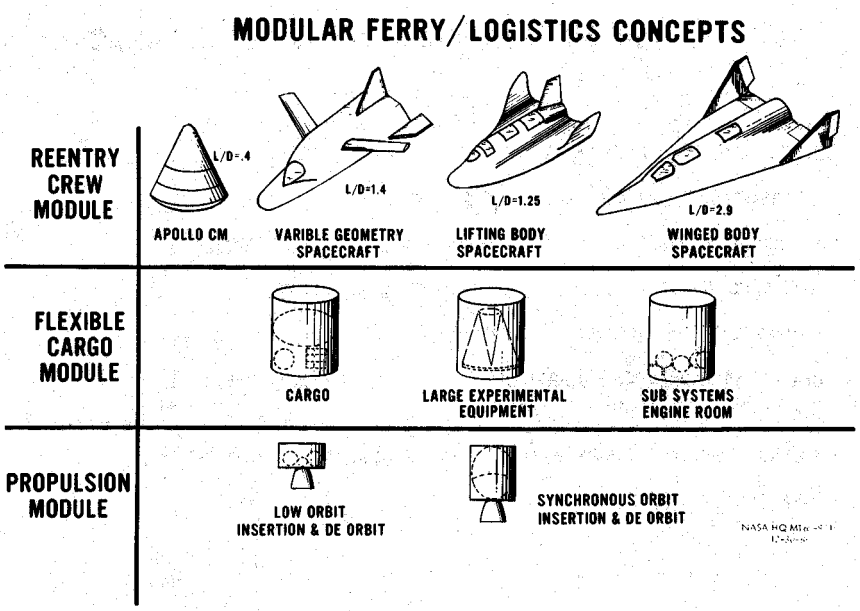

FIGURE 113

The inclusion of manned reconnaissance missions in planetary exploration activities could provide an opportunity to integrate the unique capabilities of both the manned and unmanned systems approaches to obtain data on the universe.

In previous presentations, I have outlined the primary objectives of planetary exploration. These have not changed. Our goal remains to improve man's knowledge of the origin and evolution of the solar system and the origin and evolution of life.

Manned Mars/Venus reconnaissance missions

The objectives of a possible manned Mars/Venus reconnaissance are shown here (fig. 114, MT66–10,201). Paramount is the capability to obtain and return to earth a sample of Martian surface and near-surface atmosphere. This Martian sample is obtained through deployment of an unmanned Mars Surface Sample Return probe. The manned Mars/Venus reconnaissance system allows significant increases in data acquisition capability, as well as major improvements in the quality of data obtained. The probability of successfully carrying out the experiments is enhanced by the presence of man and his ability to perform checkout, maintenance and repair, and to cope with the unanticipated.

Mission opportunities

The Mars and Venus free return reconnaissance mission possibilities that are of practical interest in the 1975 to 1980 time period are summarized in this chart (fig. 115, MT66–10,222). Opportunities for lowest energy Mars reconnaissance missions in this operational period occur approximately every 25 months. High energy missions are not considered to be within the capability of available chemical propulsion; the low energy reconnaissance missions are considered to have the most promise for use of systems based on Apollo/Saturn hardware.

These low energy missions are characterized by relatively short outbound trips of 130 to 145 days and longer inbound mission times for total mission durations of 660 to 690 days. The planet will be under observation, and scientific measurements will be taken for many weeks prior to and after actual encounter.

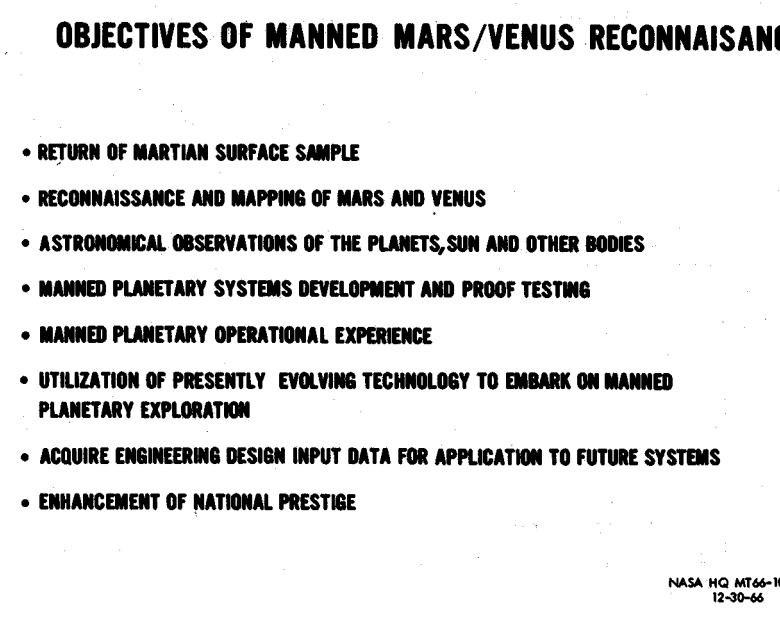

FIGURE 114

Opportunities for reconnaissance missions to Venus occur every 19.2 months. Venus reconnaissance missions are less demanding than Mars missions, total mission time being on the order of 1 year and energy requirements being approximately 80 percent of that required for Mars twilight missions.

Several mission variations on the basic Mars reconnaissance mission are available as possible follow-ons to a 1975 Mars twilight mission. Of particular interest among these are multiplanet reconnaissance missions. Multiplanet missions appear attractive because of the opportunity of exploring Venus, as well as avoiding mission profiles that go much beyond the Mars orbit near the asteroid belt. However, to date, only two opportunities for multi-planet reconnaissance missions have been identified during the 1975–1980 time period of interest.

Mission description and scientific return

Such a reconnaissance mission is a single impulse flight which makes a hyperbolic encounter with the planet, or planets, and provides a free return to earth. The manned reconnaissance spacecraft could carry a crew of four to six, a payload for inflight experiments and observations, planetary orbiting, impacting, and landing probes and a Mars Surface Sample Return probe. This flight system would be capable of experimentation in all fields of interest, including photography, exobiology, solid body and surface properties, and atmospheric properties, in addition to enroute experiments in astronomy, physics, and bio-medicine.

This chart shows a typical Mars Mission Profile (fig 116, MT66–10,212). The spacecraft proceeds along its trajectory with attitude control provided as necessary to maintain the desired orientation. During the interplanetary journey, many observations and measurements are made, and enroute experiments performed. Prior to Mars encounter, probes and orbiters are launched from the reconnaissance spacecraft. They are timed to arrive ahead of encounter, that is, the time of closest planetary approach by the manned spacecraft.

TYPICAL MARS/VENUS RECONNAISSANCE FLIGHT OPPORTUNITIES

LAUNCH DATE	LEGS IN DAYS	DURATION IN DAYS	ΔV INJECTION FEET PER SECOND	REENTRY VELOCITY FEET PER SECOND
MARS				
SEPT. '75	130/537	667	15,400	49,100
OCT. '77	145/533	678	14,800	48,700
NOV. '79	132/554	686	14,800	47,400
VENUS				
JUNE '75	117/250	367	12,000	44,600
JAN. '77	117/257	374	11,800	44,800
AUG. '78	116/249	365	11,800	43,300
APR. '80	109/250	359	12,000	45,000
VENUS/MARS				
DEC. '78	142/230/253	625	16,000	45,000
VENUS/MARS/VENUS				
FEB. '77		715	13,000	39,700

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FIGURE 115

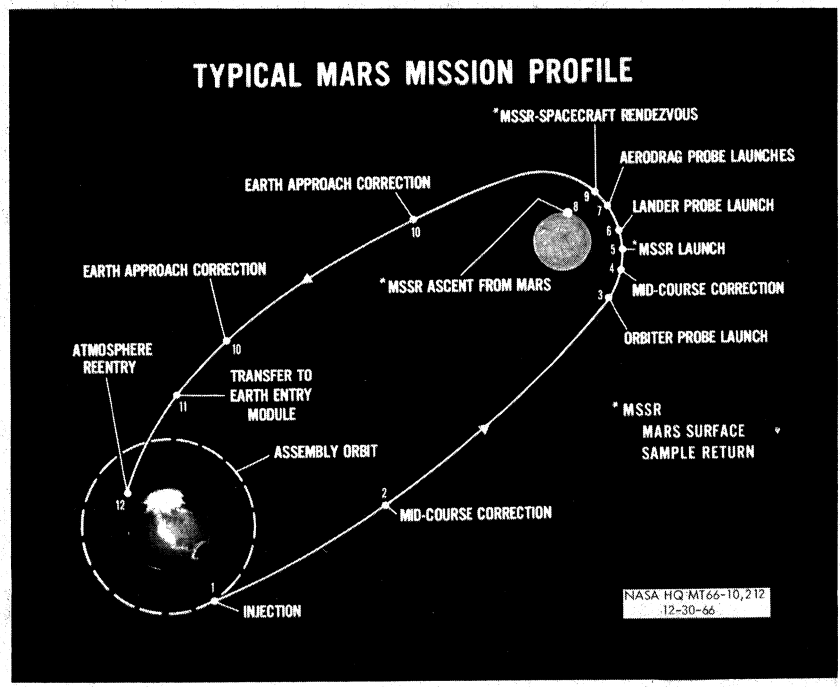

FIGURE 116

The principal scientific probe is the Mars Surface Sample Return probe. In addition, the payload could include orbiters, geological landers, and aerodrag impact probes. The Surface Sample Return probe gathers surface and atmosphere samples, and takes pictures. Upon completion of the sample gathering, the samples and film are launched with a return vehicle to rendezvous with the manned reconnaissance spacecraft. On the return leg of the trip, portions of the Mars samples and other reconnaissance data are analyzed and the significant results transmitted to earth.

Some days prior to earth encounter, the crew will transfer into the Earth Entry Module to perform final checkout, adjustment and stowage operations. The module is then separated from the interplanetary spacecraft and proceeds toward its atmospheric entry to earth. Landing and recovery are made on either land or sea at a location predictable well in advance.

We have studied a number of alternative flight systems to establish technical soundness of the mission concept as described in this presentation. Our studies have firmly established the potential scientific contributions, as well as the apparent feasibility of the manned mission concept.

Perhaps, at this time, I should present in condensed format the significant results which are to be gained from a Manned Mars/Venus reconnaissance mission. Such a summary of results is provided by these two charts (fig. 117, MT66–10,203; fig. 118, MT66–10,202).

I have tried to establish that, in the design of the flight system, we have leaned heavily on the concept of utilization and/or modification of present systems. This chart (fig. 119, MT66–6708) summarizes the major components of the mission and their development base. Also indicated are the technology extensions required. Let me make it clear that no major engineering break-

SIGNIFICANT RESULTS FROM MANNED MARS RECONNAISSANCE

SCIENTIFIC

RETURNED SURFACE SAMPLE:

- CHEMICAL COMPOSITION OF RETURNED SURFACE SAMPLE OF MARS.
- EXISTING OR FOSSIL LIFE FORM IN RETURNED SAMPLE.
- PHYSICAL PROPERTIES OF RETURNED SAMPLE.

PHOTOGRAPHY:

- MAPPING OF 85% OF MARTIAN SURFACE WITH RESOLUTION BETTER THAN ONE KM.
- SEASONAL VARIATIONS IN SUFACE AND ATMOSPHERE.
- MULTISPECTRAL IMAGING OF SURFACE AND ATMOSPHERE FOR COMPOSITITION, STRUCTURE,AND TEMPERATURE DISTRIBUTION.
- PHYSICAL SHAPE OF PLANET MARS.

ATMOSPHERE:

- ALTITUDE PROFILES OF ATMOSPHERIC TEMPERATURE, PRESSURE,DENSITY, AND COMPOSITION.
- LOCAL WEATHER VARIATION ON MARS SURFACE.

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12-30-66

FIGURE 117

SIGNIFICANT RESULTS FROM MANNED MARS RECONNAISSANCE (CON'T)

SOLID BODY PROPERTIES

- INTERNAL ACTIVITY OF PLANET.
- GRAVITATIONAL AND MAGNETIC FIELD OF PLANET.
- PHYSICAL PROPERTIES OF SURFACE.

ENROUTE EXPERIMENTS

- TELESCOPIC OBSERVATIONS OF MOONS OF MARS.
- STEREOPHOTOGRAPHS OF SOLAR EVENTS.
- LIFE HISTORY OF SUN SPOTS AND FLARES.
- VISUAL OBSERVATIONS OF SOLAR SYSTEM AND STELLAR OBJECTS.

TECHNOLOGICAL

- LONG TERM SPACE SYSTEMS CAPABILITIES.
- EXPLOITATION OF EXISTING HARDWARE.
- ENGINEERING DESIGN DATA FOR FUTURE SYSTEMS.
- VERIFICATION OF ENGINEERING DESIGN PHILOSOPHIES FOR PLANETARY MISSIONS.
- PLANETARY OPERATIONS EXPERIENCE.

PRESTIGE

- FIRST MANNED INTERPLANETARY FLIGHTS.

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12-30-66

FIGURE 118

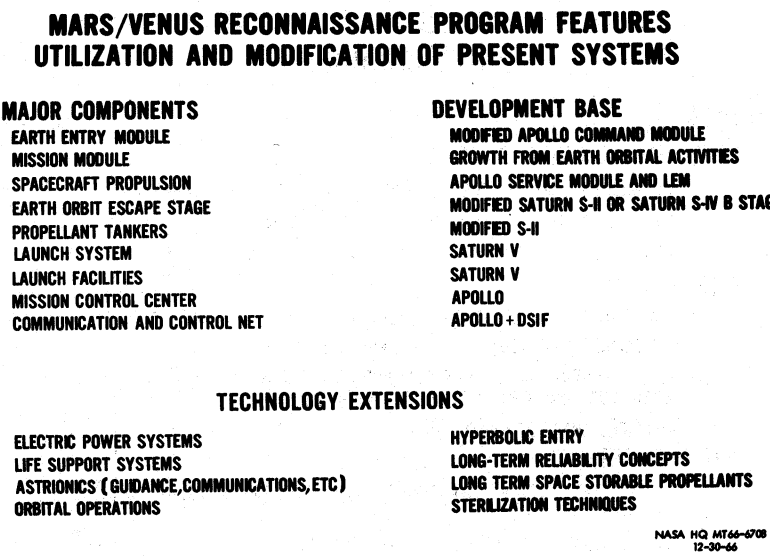

FIGURE 119

throughs are necessary for the accomplishment of a Mars/Venus reconnaissance in 1975. In fact, additional data on the target planet environments is not essential but would be useful to increase experiment return by improved systems measurement capability.

Manned Mars landing

Manned planetary reconnaissance missions are a logical step to obtaining the depth of information needed for making decisions regarding the objectives and systems requirements for manned landing missions. When the role of the reconnaissance mission is considered as an evolutionary step in developing a landing mission capability, then its major utility results from manned planetary systems development, proof testing and providing a base of operational experience. Whereas the reconnaissance mission is basically a relatively simple extrapolation of the Apollo and space station hardware, the landing or orbiting missions require many new hardware and systems developments.

As shown on this chart, a Mars landing mission would require uprating of the Saturn V or development of a more efficient post-Saturn launch vehicle (MC67–5865, see p. 184). Significant technological advancements in earth entry speed capabilities, environmental control/life support, and electrical power sources are indicated for planetary landing missions. Propulsion phases using nuclear rockets such as the Nerva Stage appear necessary for capture missions with manned Mars landing.

Future manned planetary mission studies

During the coming year, more detailed analyses of systems and subsystems related to the Mars/Venus reconnaissance mission capability are to be undertaken. Particular emphasis should be continued in the area of experiment definition incorporated in both the unmanned and manned spacecraft systems.

Examination of new systems capabilities to meet Mars/Venus manned mission requirements in a more efficient manner than provided by technology extrapolation is desirable. These studies will provide direction for technology in developing more advanced capability for solar system exploration. Definition of the experiments and systems development activities required of earlier programs must be accomplished to provide the best inputs for planning of manned planetary missions.

LUNAR MISSIONS

Study objectives

The lunar mission studies of the past year have concentrated on two objectives. One was to finalize the definition of Apollo Applications system elements in preparation for their development. The second was to establish a realistic basis for the objectives, requirements and systems for lunar exploration beyond that anticipated to be accomplished within the scope of the Apollo Applications program.

Continued support of the scientific community in the establishment of overall objectives has helped in providing focus to the program with respect to both scope and sequence. Engineering studies of potential systems have sharpened our understanding of the capabilities and costs of the follow-on program options which are being considered. The accomplishments of the Surveyor and Orbiter programs, however, have emphasized the need to develop plans which will assure the opportunity to incorporate incremental learning in our downstream program elements.

Support for scientific goals

As we progress beyond Apollo, the lunar exploration program is increasingly influenced by the nature of the scientific program which it supports. Although the scientific accomplishments of the Apollo program will have a significant influence on our understanding of the moon, the system elements of the program have been predominantly influenced by operational rather than scientific requirements. Logical program evolution beyond Apollo, on the other hand, is directly related to the objectives and requirements of scientific goals.

As we have analyzed the implications of these goals, it has become apparent that the early findings of the program may have a profound influence on the requirements to be imposed on later program systems. For this reason, it is not appropriate at this time to finalize the duration of the lunar portions of the Apollo Applications program, the specific sites which shall be explored during the program or the detailed experimental composition of latter missions. It is, however, appropriate and timely to examine the most effective methods of accomplishing projected goals so that, as we are able to establish specific goals, we can proceed with system development and mission operations without undue delay.

Evolution of lunar exploration program

In following this logic, and in anticipation of the results of the Apollo and Apollo Applications lunar landing missions, a candidate lunar exploration program has been laid out. The program follows the step-by-step concept discussed earlier and is shown in this chart (fig. 120, MC66–10,245). This concept presumes a motivation and resource capability to carry out a reasonably comprehensive lunar exploration.

The program is phased to permit the results of early missions to have maximum impact upon later system developments and missions. It delays the requirement for major new developments until after initial Apollo landings and projects the introduction of new system capability which can efficiently support missions over a wide range of expanding or diminishing program commitment. Both our broad and detailed program and system analysis is being performed against such a candidate program structure.

Three major scientific goals have been set for lunar exploration. The first is to develop, through scientific investigations, a comprehensive understanding of the lunar surface and interior. The second is to develop perspective in understanding our own planet and the solar system in which it resides. The third is to establish the role of the moon in future astronomical and space investigations of the solar system.

Apollo Applications missions

Since less than 1 percent of the moon will be studied during proposed surface missions, our broad understanding of the moon will come from information gathered by remote sensors flown in lunar orbit. The types of information which these sensors are best designed to obtain are topographic, geologic, magnetic, radiation temperature, gravity, and radiation and micrometeorite fluxes.

In addition to, and possibly simultaneously with the orbital missions, it would be necessary to conduct surface missions in order to make direct observations and

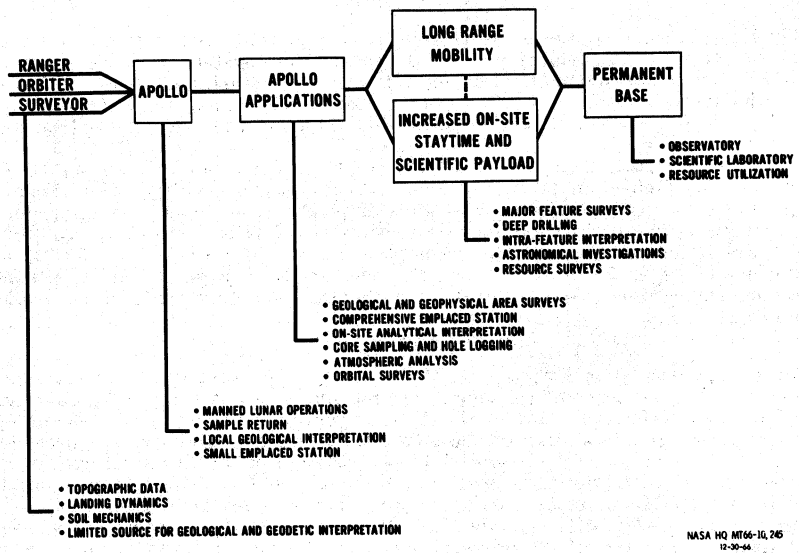

FIGURE 120

measurements. These measurements could have unique objectives as well as helping to support the interpretation of the orbital data.

Among the primary objectives which have been identified for surface missions are selective collection of surface and subsurface samples; geological mapping; geophysical surveys; logging of drill holes; and geodetic measurements. Other primary objectives are geochemical and petrological analysis to aid in selection of samples in situ analyses to measure unique properties that may be destroyed in transit; and physical properties measurements of lunar soils and surface materials.

Example payloads have been conceived for the surface missions in order to test operational concepts, payload and subsystem capabilities and to frame scientifically significant missions. This chart (fig. 121, MC66–10,246) lists a potential payload for a two-man 14 day mission.

Major pieces of equipment and long-lead-time experiment support systems are now under study. Among these are a moderate depth drill, a lunar surveying system, logging tools, and a large emplaced scientific station (fig. 122, MT66–8685). These pieces of equipment and the lunar scientific survey module (LSSM) are the major building blocks of the surface missions around which the scientific experiments and operational activities would be structured (fig. 123, MT66–9608).

Mobile lunar exploration

It has been recommended by NASA's scientific consultants that a mobile exploration phase utilizing vehicles with long range capabilities be initiated.

The three objectives of the mobile exploration phase would be to (1) broaden our knowledge of the moon in regional studies, (2) complete the evaluation of the moon as a site for observatories and laboratories, and (3) select candidate sites for future bases (fig. 124, MT66–10,247).

If at the end of the above phase, the feasibility of permanent bases was proven, the final stages of exploration could begin. Although the objectives for such a phase are necessarily incompletely understood, it is felt that such a base might be utilized primarily as an observatory and as a laboratory with the possibility that the processing of lunar materials to support the base would be carried out.

EXAMPLE AAP LUNAR SURFACE EXPLORATION PAYLOAD (LM SHELTER/TAXI MODE)

1. LUNAR SCIENTIFIC SURVEY MODULE
2. GEOPHYSICAL STATION
3. LUNAR SCIENTIFIC SURVEY MODULE MOUNTED DRILL
4. MULTIBAND PHOTOGRAPHY/RADIOMETRY
5. LUNAR SURVEYING SYSTEM
6. TOPOGRAPHIC/GEODETIC
7. ACTIVE SEISMIC
8. GRAVITY SURVEY
9. MAGNETIC SURVEY
10. PORTABLE GEOCHEMISTRY
11. GAS ANALYZER
12. SURFACE ELECTRICAL SURVEY
13. EROSION/EXPOSURE PANELS
14. BORE-HOLE LOG
15. HAND TOOLS
16. SAMPLE CONTAINERS
17. PHYSICAL PROPERTIES EQUIP.
18. DATA HANDLING SUBSYSTEM
19. NAVIGATION SUBSYSTEM
20. SYSTEMS INTEGRATION EQUIP.
21. LABORATORY EXPERIMENTS

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12-30-66

FIGURE 121

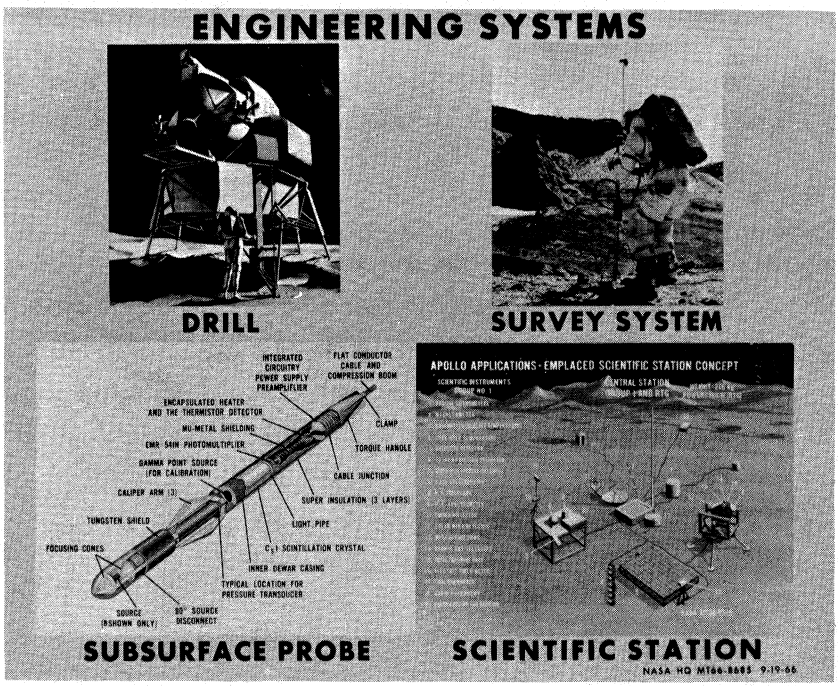

FIGURE 122

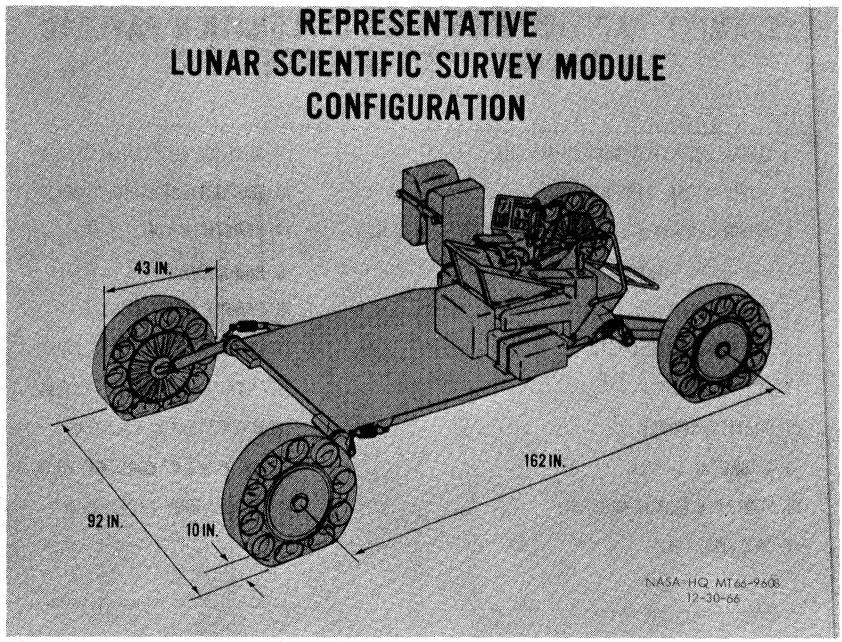

FIGURE 123

OBJECTIVES OF MOBILE LUNAR EXPLORATION PHASE

PRIMARY - BROADEN AND INTEGRATE OUR KNOWLEDGE OF THE MOON THROUGH LONG RANGE, LONG DURATION REGIONAL STUDIES. MOBILE MODE REQUIRED TO:

1. STUDY WIDELY SEPARATED SITES YET OBTAIN CORRELATIVE INTER-SITE INFORMATION.
2. PERFORM GEOPHYSICAL SURVEYS WITH WIDE STATION SPACING.
3. CONDUCT INTEGRATED SAMPLING WHICH CROSSES MAJORITY OF STRATIGRAPHIC UNITS.
4. PROVIDE CONTINUOUS "GROUND TRUTH" DATA FOR INTERPRETING ORBITAL SENSORS.

SECONDARY - COMPLETE EVALUATION OF MOON AS A SITE FOR OBSERVATORIES AND LABORATORIES.

- SELECT CANDIDATE SITES FOR FUTURE BASES.

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FIGURE 124

Expected planning

During this coming year we expect to further refine our advanced manned missions analysis of sequential program requirements and systems. This effort will be conducted in order to assess with more accuracy the program resource requirements and cost/effectiveness relationships.

We will continue to work closely in 1967 with the scientific community in the determination of valid scientific objectives. The coming Surveyor and Orbiter missions will provide additional data for site selection from the standpoints of suitability and scientific interest.

As Apollo Applications supporting systems proceed into detailed design and development phases, major concentration will be applied to the definition of the detailed accomplishments of Apollo Applications missions, to a better understanding of the probable effective duration of that phase of the program, and to an actual definition of follow-on phase system options.

As indicated earlier, planning of a lunar scientific exploration program involves a continual adjustment to growth in understanding of the moon itself, to change in emphasis as progress in scientific and space systems technology opens up new fields of opportunity, and to changes in resource availability. It is appropriate, therefore, that we avoid prejudging the total magnitude or span of lunar exploration. Our intent is, instead, one of developing adequate data on a number of paths to support valid decisions at the time that leadtime requires those decisions to be made.

FLIGHT VEHICLES

Flight vehicle studies have stressed three areas critical to future programs. These are Saturn Systems Uprating/Improvement, Operations Support, and Advanced Vehicle Systems. The dominant element of this study program is examination of the ways and means of exploiting the capabilities of existing Saturn systems and facilities for economic and versatile transportation support of future manned or unmanned programs in the 1970–1980 time period. These studies are in direct support of near- and far-term manned missions planning for earth orbital, lunar and planetary flights.

Saturn systems uprating/improvement

Exploratory studies of the Saturn I, Saturn V and Saturn Intermediates are being conducted to extend the payload capabilities and provide potential cost effective launch vehicles for future mission requirements. Saturn Intermediates are essentially 2-stage versions of the existing or uprated Saturn V configurations and bridge the payload performance regime between the potential capabilities of the Saturn I systems and the Saturn V.

Uprating considerations cover large solid rocket motors such as Minuteman, 120-inch, 156-inch and 260-inch diameter motors as well as improved and uprated Saturn engines, advanced upper-stage engine configurations (chemical and nuclear), liquid strap-on pods/engines, increased and new propellant implications, and advanced materials/structural applications. These studies provide guidance for NASA's research and technology efforts as well as providing program-related information such as payload performance, cost projections, development schedules and facility requirements.

It is evident from vehicle studies to date that a wide variety of Saturn vehicle options are possible which can substantially increase the Saturn family's mission performance for future programs. The potential indicated for the Saturn I ranges from the current 40,000 to 110,000 pounds payload in low earth orbit; the Saturn V from the current 280,000 pounds to 700,000 pounds; and the Saturn Intermediates from 110,000 to 260,000 pounds payload in low earth orbit.

Operations support

Supporting studies are being conducted to determine launch facility implications and improved operational concepts for launch of basic and improved Saturn vehicles for future missions and to establish both nonrecurring and recurring facility costs and development schedules accordingly.

Future manned space missions could be dependent in varying degrees on in-orbit propellants transfer, systems assembly, maintenance and checkout, to support both earth orbital missions and orbital launch operations for planetary missions; study of in-orbit propellants transfer is being initiated to determine

conceptual techniques for the transfer and checkout of cryogenic and non-cryogenic liquids under zero g conditions and to aid in determining both ground and inflight experiments for validating conceptual system designs.

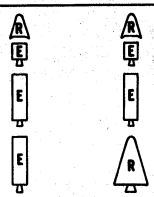
Advanced vehicle systems

Recovery and reuse of Saturn stages could have a major cost impact on future space operations; conceptual studies have been conducted of the recovery and reuse of large ballistic stages such as the Saturn V first stage. Economic promise was indicated for modest launch programs, but basic questions are as yet unanswered concerning system design and operations which critically affect the estimated economic impact for the ballistic mode of recovery. An experimental program could aid in reducing uncertainties relating to ballistic flight and terminal recovery, refurbishment operations, and stage or major subsystem reuse, as applicable to both existing Titan and Saturn stages and future ballistic launch vehicle systems. A study has been initiated to determine and to assess the test program alternatives that could aid in verifying the feasibility of ballistic stage recovery and reuse and which could provide data that are presently not available to designers.

A second area of interest here is the evolution of a versatile second-generation aerospace transportation system that could provide routine earth surface to orbit and return transportation for passengers and cargo. These reusable logistics support systems are being investigated to determine system candidates that can offer order of magnitude changes in improved operational flexibility and in reduced operational costs. Air transport type operational features including reliability, economy, payload flexibility, passenger safety/comfort, and inflight/intact abort capability have been considered in this planning activity. Such studies of advanced vehicle systems and operational modes for future earth orbital flight operations are being performed to determine and compare the options for cost-effective space logistics support and to provide advanced technology requirements.

Transportation trends for manned programs support are summarized in these charts (fig. 125, MT66–8032; fig. 126, MT67–5865). The areas as shown

TRANSPORTATION TRENDS - EARTH TO ORBIT AND RETURN
(MANNED PROGRAM SUPPORT)

TIME PERIOD	CURRENT	INTERMEDIATE	FUTURE
GENERALIZED VEHICLE CONCEPTS			
OPERATIONAL OBJECTIVES	• EXPERIMENTAL SYSTEMS DEVELOPMENTS • EXPLORATORY SPACE PROGRAMS	• INITIAL SPACE SYSTEMS LOGISTIC SUPPORT • IMPROVED OPERATIONAL FLEXIBILITY • GROWTH IN SPACE FUNCTIONAL CAPABILITY	• INCREASED LOGISTICS TRAFFIC • INCREASED SPACE SYSTEMS CAPABILITY • REDUCED OPERATIONAL AND SUPPORT SYSTEMS COST • IMPROVED OPERATIONAL CHARACTERISTICS-NOMINAL AND CONTINGENCY
DESIRED VEHICLE CHARACTERISTICS	• EXPENDABLE LAUNCH AND SPACECRAFT VEHICLES • WATER RECOVERY OF SPACECRAFT	• FLEXIBLE MAN-RATED LAUNCH VEHICLE CAPABILITIES • REUSABLE ENTRY SPACECRAFT • ORBITAL MANEUVERING PROPULSION • NOMINAL LAND-RECOVERY OF SPACECRAFT	• FULLY-REUSABLE VEHICLE SYSTEMS

E - EXPENDABLE UNIT R - REUSABLE UNIT

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12-30-66

FIGURE 125

have been studied extensively. We are determining the interrelationship of operational objectives and desired vehicle characteristics with advanced technology requirements, systems integration and operational characteristics.

SUMMARY

During the past year we have continued in a well planned and orderly fashion to explore the options which are open to us in our quest to determine the next major national space goal. We have evolved a step-by-step concept and have devised a base-line plan for a manned space flight program of the type which permits us to proceed with a minimum of commitment to the long range future.

We foresee the capability for continuous operations in earth orbit becoming available to us in the 1970's, leading to manned planetary reconnaissance and extended exploration of the lunar surface, in that same time period. All in turn could be pointed toward a possible manned mars landing in the decade of the 1980's, should such a national space goal be selected.

The funds requested for Advanced Manned Missions activity in fiscal year 1968 will permit us to pursue this program recognizing, however, that these efforts do not satisfy all the recommendations made by the scientific community and in the President's Science Advisory Committee report published in February 1967. We consider this program as being austere in its funding while moving toward a firmer understanding of the technology required to meet future needs.

MANNED SPACE FLIGHT FUNDING REQUIREMENTS

Let me turn next to the fiscal year 1968 funding required to maintain the Nation's Manned Space Flight Program. As outlined on this chart (fig. 127, MP67–5440), the fiscal year 1968 Manned Space Flight R. & D. requirements are $3,069.2 million. We are also requesting $27.9 million for Construction of Facilities, and $323.5 million for Administrative Operations at the three Manned Space

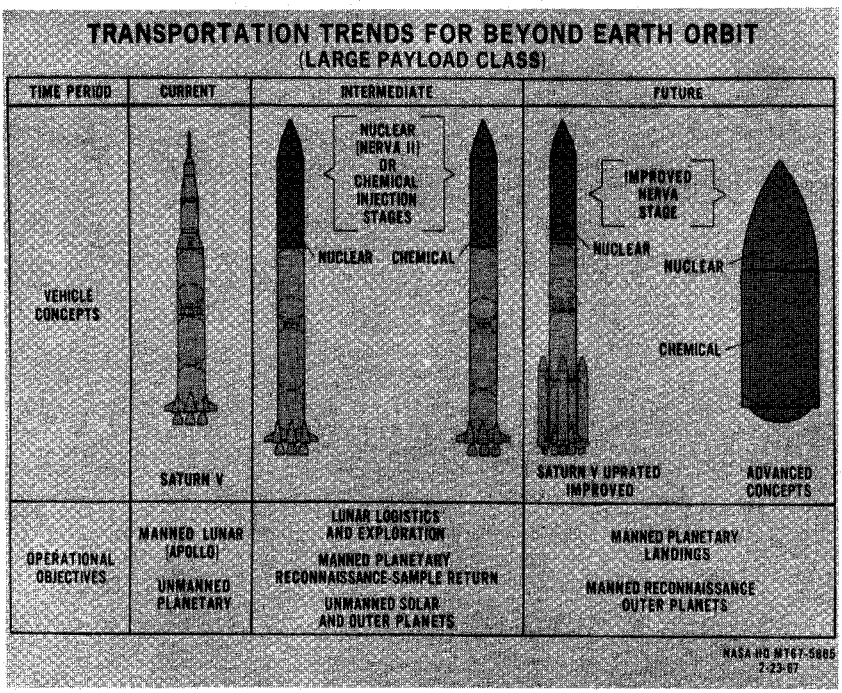

FIGURE 126

NASA

MANNED SPACE FLIGHT

FY 1968 BUDGET ESTIMATE

(MILLIONS OF DOLLARS)

	FY 1966	FY 1967	FY 1968
RESEARCH AND DEVELOPMENT	$3,199.5	$3024.0	$3,069.2
APOLLO	2,941.0	2916.2	2,606.5
APOLLO APPLICATIONS	51.2	80.0	454.7
ADVANCED MISSIONS	10.0	6.2	8.0
GEMINI	197.3	21.6	-0-
CONSTRUCTION OF FACILITIES	17.5	43.8	27.9
ADMINISTRATIVE OPERATIONS	296.9	315.4	323.5
TOTAL	$3513.9	$3,383.2	$3,420.6

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1-15-67

FIGURE 127

Flight Centers. I plan to address my remarks to our R. & D. requirements only, since Dr. Seamans will be covering the overall Agency requirements for Construction of Facilities and Administrative Operations.

RESEARCH AND DEVELOPMENT

Our fiscal year 1968 R. & D. requirements, amounting to $3,069.2 million, are broken into three line items: Apollo ($2,606.5 million); Apollo Applications ($454.7 million); and Advanced Missions ($8.0 million). Fiscal year 1967 was the last year of funding for the Gemini program.

APOLLO PROGRAM

The $2,606.5 million required to support our Apollo activity in fiscal year 1968 represents a decrease of $309.7 million from the fiscal year 1967 level. As indicated on this chart (fig. 128, MP67-5441), the fiscal year 1968 Apollo budget is divided into five line items: Spacecraft, Uprated Saturn I, Saturn V, and Engine Development, all of which show a decrease from fiscal year 1967; and Mission Support, which necessarily rises in fiscal year 1968 to meet the increased tempo of operational activity. This budget request was submitted before the accident on AS-204 and until the findings of the board have been analyzed, we will be unable to determine the extent of the work required or if additional costs may be involved.

As you know, our fiscal year 1967 Apollo funds are supporting peak activity in the production of spacecraft and launch vehicle hardware, as well as an intensive period of ground and flight qualification testing. During FY 1968, we will be heavily involved in assembly, checkout, and delivery of Apollo spacecraft

and Saturn launch vehicle hardware to meet the planned flight schedule. Fiscal year 1968 funds will also cover the increased requirements for pre-launch checkout and launch operations at the Kennedy Space Center, mission control activities at the Manned Spacecraft Center, and reimbursement to the Department of Defense for recovery forces as we move deeper into the operational phase of Apollo.

Spacecraft

Fiscal year 1968 funding requirements for the Apollo spacecraft are $1,036.3 million. The next chart (fig. 129, MP67–5438) shows the line items that are contained in this amount, which provides for continued production, test, checkout, and delivery of the spacecraft hardware—Command and Service Modules, Lunar Modules, and associated guidance and navigation units, as well as the integration, reliability, and checkout operations, and the important spacecraft support activities.

Command and Service Modules

The $494 million required for the Command and Service Modules in fiscal year 1968 continues the production, checkout and delivery of flight articles equipped for long-duration missions and rendezvous and docking maneuvers. The funds in this line item also provide for the development, procurement, integration, and installation of Apollo experimental hardware and flight experiments into the Command and Service Modules.

During fiscal year 1968, the first two Command and Service Modules capable of rendezvous and docking will be undergoing checkout at the Kennedy Space Center. Six additional Apollo Command and Service Modules are scheduled for completion of assembly and checkout at North American's Downey, California plant, followed by shipment to Kennedy in preparation for uprated Saturn I

MANNED SPACE FLIGHT

RESEARCH AND DEVELOPMENT

APOLLO

FY 1968 BUDGET ESTIMATE

(MILLIONS OF DOLLARS)

	FY 1966	FY 1967	FY 1968
SPACECRAFT	$ 1,233.8	$ 1,250.3	$ 1,036.3
UPRATED SATURN I	274.8	236.6	156.2
SATURN V	1,134.9	1,135.6	1,108.5
ENGINE DEVELOPMENT	133.2	49.8	24.5
MISSION SUPPORT	164.3	243.9	281.0
TOTAL	$2,941.0	$2,916.2	$2,606.5

NASA HQ MP67-5441
1-15-67

FIGURE 128

MANNED SPACE FLIGHT
RESEARCH AND DEVELOPMENT
APOLLO SPACECRAFT
FY 1968 BUDGET ESTIMATE
(MILLIONS OF DOLLARS)

	FY 1966	FY 1967	FY 1968
COMMAND AND SERVICE MODULES	612.8	560.4	494.0
LUNAR MODULE	362.6	472.5	373.1
GUIDANCE AND NAVIGATION	137.2	76.6	55.4
INTEGRATION, RELIABILITY AND CHECKOUT	32.3	30.0	23.2
SPACECRAFT SUPPORT	88.9	110.8	90.6
TOTAL	$ 1,233.8	$ 1,250.3	$ 1,036.3

NASA HQ MP67-5438
1-15-67

FIGURE 129

and Saturn V launches. The remaining seven Command and Service Modules configured for rendezvous and docking will be in various phases of assembly, systems installation, and in-plant checkout.

Lunar Modules

Our fiscal year 1968 estimate for the Lunar Module line item is $373.1 million. These funds provide for the work being done by the prime contractor, Grumman Aircraft Engineering Corporation, Bethpage, New York, as well as the experiments and experimental hardware that will be carried in the Lunar Module. Included are the Apollo Lunar Surface Experiments Package (ALSEP) and the tools that will be used to obtain samples from the lunar surface.

During FY 1968 a Lunar Module Test Article, refurbished after use in the Apollo Saturn V dynamic testing at Marshall, is scheduled to be launched on the second unmanned Saturn V qualification flight. In addition, major emphasis will be placed on the production, checkout, and delivery of flight lunar modules for manned rendezvous and docking missions. Five Lunar Modules are scheduled for delivery to Kennedy and the remaining seven will be undergoing structural assembly, subsystem installation, and in-plant checkout.

Guidance and navigation

Moving down to the next line item, we are requesting $55.4 million for the Apollo spacecraft guidance and navigation system in fiscal year 1968. This system was designed by the Massachusetts Institute of Technology. Prime contractor for the assembly and test of the production units is General Motors, AC Electronics Division in Milwaukee, Wisconsin. The on-board navigational computer and the optical subsystem, including a space sextant, sunfinders, and necessary display equipment, are produced, under subcontract, by the Raytheon Company of Waltham, Massachusetts, and the Kollsman Instrument Company of Elmhurst, New York, respectively.

During FY 1968, six guidance and navigation units for manned Apollo Command Modules will be delivered. Six Lunar Module units will also be delivered. By the end of the fiscal year, all but three guidance and navigation units will be in assembly or checkout.

Integration, reliability, and checkout

The fiscal year 1968 requirements for integration, reliability, and checkout, amounting to $23.2 million, provide for two basic areas. The first category includes engineering support to the Manned Spacecraft Center for activities such as maintenance and review of the Apollo spacecraft specifications, systems performance analyses, reliability and quality assurance, trend analysis of failure reports, mission planning and analysis, and interface control. Consistent with the increasing rate of hardware deliveries and flight missions, the FY 1968 activity will focus on spacecraft hardware verification, mission planning and analysis, and post-flight documentation.

The second category is the funding for the 12 Automatic Checkout Stations (ACE stations), which are located at the key Apollo spacecraft sites across the country. Three spacecraft ACE stations operate at North American's Downey plant; three at the Grumman plant; two at the Manned Spacecraft Center's Space Environmental Simulation Lab; and four at the Kennedy Space Center. These stations are required for rapid and reliable checkout of the separate and combined spacecraft systems in the process from fabrication and test to launch. Fiscal year 1968 funds cover the operation, maintenance, and updating of the ACE stations to meet mission requirements.

Spacecraft support

Apollo Spacecraft Support activities include the funding for test operations at contractor, NASA, and other government installations; crew equipment—including space suits; logistics; and instrumentation and scientific equipment. The $90.6 million requested for these activities in FY 1968 includes support of the various spacecraft test programs. Typical examples are the spacecraft and equipment environmental tests in Houston's vacuum chambers, spacecraft propulsion tests at the White Sands Test Facility in New Mexico, reaction control system testing at the Arnold Engineering Development Center in Tullahoma, Tennessee, and altitude chamber tests at the Kennedy Space Center.

The FY 1968 funds also provide for development and procurement of Apollo space suits and related crew equipment, EVA umbilicals, survival equipment, personal hygiene systems, and bioinstrumentation. Major effort will be devoted to manufacture and test of a space suit and portable life support system for lunar surface activities. Logistic funds are included for transportation of spacecraft hardware between locations, reimbursement to the Department of Defense for inspection services, and procurement of spacecraft fuels and propellants used in the test programs that I mentioned earlier. In addition, these support funds cover development and procurement of specialized flight research and test instrumentation for spacecraft development, such as signal conditioners, sensors, transmitters, ground support equipment, cameras, and radiation-measuring devices.

Uprated Saturn I

Moving on to the Saturn-class launch vehicles, the next chart (fig. 130, MP67–5437) identifies our fiscal year 1968 funding requirements for the uprated version of the Saturn I. As you are well aware, our record to date with the original and the uprated versions of the Saturn I vehicle has been excellent: 13 successes in 13 launches. Our FY 1968 request for the uprated Saturn I is $156.2 million—a decrease of $80.4 million from the FY 1967 level. The evolution from hardware production and delivery to operational use explains this decrease. Half of the vehicles in the currently approved program of 12 uprated Saturn I's have already been delivered to the Kennedy Space Center. Four additional launch vehicles are scheduled for delivery before the end of 1967, and the remaining two uprated Saturn I's are in fabrication, leading to delivery to Kennedy during 1968. Follow-on procurement of uprated Saturn I vehicles, which represent a major addition to our Nation's inventory of large launch vehicles and offer a versatile means for conducting a variety of earth orbital missions, will be discussed under Apollo Applications.

Each line item within the uprated Saturn I project, as you can see, is decreasing from the FY 1967 level.

MANNED SPACE FLIGHT
RESEARCH AND DEVELOPMENT
UPRATED SATURN I
FY 1968 BUDGET ESTIMATES
(MILLIONS OF DOLLARS)

	FY 1966	FY 1967	FY 1968
1st STAGE (S-IB)	51.6	43.1	30.5
2nd STAGE (S-IVB)	64.0	56.9	37.1
INSTRUMENT UNIT	47.7	40.6	22.6
GROUND SUPPORT EQUIPMENT	26.6	11.5	6.5
H-1 ENGINES	10.1	8.1	5.2
J-2 ENGINES	13.5	6.7	.9
VEHICLE SUPPORT	61.3	69.7	53.4
TOTAL	$ 274.8	$ 236.6	$ 156.2

NASA HQ MP67-5437
1-15-67

FIGURE 130

Stages (S–IB and S–IVB)

We are requesting $30.5 million for the Chrysler-produced 1st stage (S–IB) and $37.1 million for the Douglas-produced 2nd stage (S–IVB) in fiscal year 1968. These funds support completion of the eighth through twelfth flight stages, which are currently phased into manufacturing, assembly, acceptance testing, or checkout.

In terms of the 1st stage requirements, the FY 1968 funds requested support delivery and pre-launch checkout of the eighth and ninth flight stages; acceptance test, and shipment of the tenth and eleventh stages to Kennedy Space Center; and final assembly, in-factory checkout, acceptance test, and delivery of the last stage.

The FY 1968 funding for the Saturn I/S–IVB supports delivery of the last five flight stages for Apollo missions to the Kennedy Space Center. The eighth and ninth will arrive at the Center and undergo pre-launch checkout; the tenth and eleventh will complete acceptance testing at Sacramento and will subsequently be shipped to the Kennedy Space Center. The twelfth flight stage is scheduled to be through assembly, in-plant checkout, acceptance testing, and post-static checkout in preparation for shipment.

Instrument Unit

Fiscal year 1968 funds in the amount of $22.6 million are required for the Instrument Unit—the "nerve center" of the launch vehicle, which contains the all-important primary guidance, control, measuring and telemetry systems. The Instrument Units are produced by the International Business Machines Corporation in Huntsville, Alabama. The FY 1968 funds provide for completion of

assembly, checkout, and delivery of the remaining five Instrument Units required for Apollo Saturn I vehicles.

Ground support equipment

The automatic checkout system used to verify the launch readiness of the vehicles is designed to maximize the level of reliability and efficiency and to minimize the time and cost involved in checking out the hardware. Engineering support is provided by the General Electric Company for the electrical support equipment and by the Chrysler Corporation Space Division for the mechanical support equipment.

We are requesting $6.5 million in fiscal year 1968 to cover operation and updating of stage and vehicle ground support equipment to meet specific mission requirements. Operational requirements for the Marshall breadboard facility, which is used to validate the computer programs for each mission, are also included.

H–1 and J–2 engines

The fiscal year 1968 request includes requirements of $5.2 million for H–1 engines and $.9 million for J–2 engines. The liquid oxygen-refined kerosene H–1 engine is used in a cluster of eight to power the first stage of the Saturn I, and a single hydrogen-fueled J–2 engine is used in the second stage. Both engines are produced by the Rocketdyne Division of North American Aviation, Canoga Park, California.

Fiscal year 1966 was the last full year of funding the H–1 contractor field and engineering support under the "Engine Development" project. Following completion of H–1 qualification in June 1966, funding of the contractor's work on flight evaluation and problem-solving, maintenance of test engines in a configuration for rapid response to problems encountered during flight, and periodic verification on flight worthiness was transferred to this account.

The FY 1968 funds required for the H–1 and J–2 engines cover continued support of the flight program, evaluation of flight results for use in subsequent missions, and rapid response to flight problems that may arise.

Vehicle Support

The final line item under the uprated Saturn I project is Vehicle Support, which provides for studies, services and equipment that are common to more than one stage of the vehicle. Our FY 1968 requirements are $53.4 million, covering the support requirements during a period of intensive launch activity. During FY 1968, heavy emphasis will be placed on uprated Saturn I prelaunch and launch support and postlaunch pad refurbishment at the Kennedy Space Center. The funds also cover component and subsystem failure analyses, postflight reliability reports, and guidance and control system studies. In addition, the requirements include transportation of stages and instrument units via barge or aircraft.

Saturn V

Next we come to the fiscal year 1968 funding requirements for the most powerful of the Saturn family of launch vehicles—the three-stage Saturn V. We are beginning to come down the curve on Saturn V funding, as shown in this chart (fig. 131, MP 67–5436). In addition to the intensive ground test program that has been underway, FY 1967 marks the peak year for Saturn V hardware production to meet the scheduled flight missions. The funding requested for FY 1968, amounting to $1,108.5 million, is critical to sustaining the production rate, consistent with hardware need-dates at Kennedy. Equally important is the funding that provides for vehicle support activities, including static test support at our Mississippi Test Facility, checkout support at the Kennedy Space Center, systems integration to assure proper interface control, and reliability and flight evaluation programs. Fiscal year 1968 will be a decisive one in moving us closer to the immediate goal of manned lunar landing and return.

Let me go into the detail of the Saturn V requirements for FY 1968, beginning with the 1st Stage (S–IC).

1st stage (S–IC)

We are requesting $174.7 million in fiscal year 1968 to carry forward the manufacture, test, and checkout of Saturn V 1st stages on a time-scale consistent with the planned flight schedule.

MANNED SPACE FLIGHT

RESEARCH AND DEVELOPMENT
SATURN V
FY 1968 BUDGET ESTIMATE
(MILLIONS OF DOLLARS)

	FY 1966	FY 1967	FY 1968
1st STAGE (S-IC)	191.9	184.9	174.7
2nd STAGE (S-II)	256.2	248.6	245.9
3rd STAGE (S-IVB)	162.0	154.0	151.2
INSTRUMENT UNIT	67.8	72.9	75.1
GROUND SUPPORT EQUIPMENT	107.6	60.9	35.8
F-1 ENGINES	66.2	92.3	105.3
J-2 ENGINES	67.2	83.5	78.5
VEHICLE SUPPORT	216.0	238.5	242.0
TOTAL	$ 1,134.9	$ 1,135,6	$ 1,108.5

NASA HQ MP67-5436
1-15-67

FIGURE 131

This stage, which generates approximately 7.5 million pounds of thrust, is the most powerful developed by this country to date. The S–IC is powered by five liquid oxygen-kerosene F–1 engines, each developing about 1.5 million pounds of thrust. At launch, the S–IC will be lifting a total space vehicle weight of 6 million pounds. During flight, the stage burns for 2½ minutes, consuming about 15 tons of propellant a second.

The Marshall Space Flight Center, with the assistance of the Boeing Corp., manufactured the structural test components, the first ground test stage, and the first two flight stages at Huntsville, Alabama. Manufacuring of the first flight stage began at Huntsville in July, 1964. Boeing was awarded the contract to manufacture two other ground test stages (dynamic and facilities checkout) and 13 flight stages at the Government-owned Michoud Assembly Facility near New Orleans, Louisiana.

Activity in FY 1967 has been highlighted by the delivery of the first flight stage to the Kennedy Space Center. The second flight article has completed post-static checkout and the third has passed its acceptance test firing at Marshall. The fourth flight stage will be delivered to the Mississippi Test Facility to inaugurate acceptance testing at this location. The fifth and sixth are scheduled to complete manufacturing, and the remaining nine will be phased into manufacturing or long-lead procurement by the end of FY 1967.

The FY 1968 funds support completion of the S–IC structural test program and continuation of assembly, in-plant checkout, acceptance testing, and shipment of flight stages to the Kennedy Space Center. The fourth, fifth, and sixth stages will be put through post-static checkout at Michoud, and delivered to the Kennedy Space Center. The seventh and eighth 1st stages are scheduled to complete assembly, in-plant checkout, and static testing; and the ninth and tenth are scheduled to be through manufacturing and checkout at Michoud. The five remaining stages will be in manufacturing during FY 1968.

2nd stage (S–II)

Moving down to the next line item, our FY 1968 Saturn V requirements, include $245.9 million for the 2nd stage (S–II).

This stage—powered by a cluster of five liquid oxygen-liquid hydrogen J–2 engines—produces a total thrust of approximately 1 million pounds at altitude. It is the Nation's largest liquid-hydrogen powered stage. The aluminum alloy skin on the initial stages is only .153 inches thick and will be reduced to .128 inches in subsequent stages. Starting off on the launch pad, its gross weight, including engines, is about one million pounds—90 percent of which consists of propellants. During flight, the stage burns for 6½ minutes and must be capable of withstanding temperatures ranging from about +400 to −400 degrees Fahrenheit. The component qualification requirements for the S–II are particularly stringent because the stage stretches to the utmost existing hydrogen propulsion technology and related manufacturing techniques.

The prime contractor, North American Aviation Space and Information Systems Division carries out manufacturing, assembly, and factory checkout at government-owned facilities at Seal Beach, California. North American conducts developmental ground testing at its Santa Susana Static Test Laboratory. Flight stages are shipped through the Panama Canal to the Mississippi Test Facility to undergo acceptance firing before being delivered to the Kennedy Space Center.

Fiscal year 1967 activity to date has been marked by intensive ground qualification testing, acceptance testing of the first flight stage at the Mississippi Test Facility, delivery of this stage to Kennedy in preparation for the first Saturn V launch, and continued production of flight stages for subsequent missions.

Fiscal year 1968 activity will continue to emphasize production of hardware in support of the Apollo Saturn V flight requirements. The third, fourth, fifth, and sixth flight stages are scheduled for completion of acceptance test, poststatic checkout, and shipment to the Kennedy Space Center. The tempo of hardware production for the following flights must also be sustained. The stages for the seventh through twelfth Saturn V vehicles will be in an intensive period of manufacturing, assembly, in-plant checkout, or acceptance firing to support the planned launch rate. In addition, procurement activity will be underway on the three remaining flight stages.

3rd stage (S–IVB)

The next line item on the chart shows the funding estimate for the 3rd stage of the Saturn V—the S–IVB. We are requesting $151.2 million to cover these requirements in fiscal year 1968. Basic development costs for this stage, which is also used as the upper stage of the Saturn I, are funded in this line item. The S–IVB was developed and is being produced and tested by the Douglas Aircraft Company's Missile and Space Systems Division. The stages are manufactured at the Douglas Space Center, Huntington Beach, California; acceptance testing is conducted at the Sacramento Test Operations Site.

Fiscal year 1968 activity will focus on continued production and delivery of flight stages to support the Apollo Saturn V schedule. The fourth flight stage will be shipped from the West Coast to the Kennedy Space Center for prelaunch checkout. The next two flight stages are scheduled for completion of fabrication and in-plant checkout, as well as acceptance testing and post-static checkout, in preparation for shipment to the Kennedy Space Center. Fabrication, assembly, in-plant checkout, and acceptance testing of the seventh and eighth flight stages are planned, and the ninth and tenth will be through fabrication and assembly in preparation for acceptance firing at Sacramento. The remaining five flight stages will be in various phases of manufacture and assembly.

Instrument Unit

Our fiscal year 1968 funding requirements for the Saturn V Instrument Unit total $75.1 million. These funds will maintain the necessary delivery rate of flight units during FY 1968. The fourth, fifth, and sixth Saturn V Instrument Units will be checked out and delivered to Kennedy, and assembly, inspection, and checkout of the seventh unit will be completed. Work on the remaining Instrument Units will also be underway at IBM, Huntsville, during the fiscal year.

Ground support equipment

We are requesting $35.8 million for the Saturn V ground support equipment in FY 1968. This equipment consists of electrical and mechanical support equipment required to test and check out the stages, instrument units, and associated hardware. The checkout procedures developed for the Saturn V are based on the concept that improved vehicle reliability and minimum time at the launch site can be attained by using a computer-controlled system in which the operational soundness of components is automatically verified.

The General Electric Co. is under contract for design, fabrication, checkout, and logistic support of the Saturn V electrical support equipment, and the Boeing Co. is responsible for the integration and logistic support of all mechanical support equipment. The Radio Corporation of America is providing the computer system and Sanders Associates the display systems.

Fiscal year 1968 funds support preparation and verification of computer tapes for Saturn V missions. In addition, these funds cover completion of Saturn V-related ground support equipment for the third launch umbilical tower, high-bay, and firing room at Launch Complex 39.

F–1 and J–2 engines

The FY 1968 Saturn V engine requirements are $105.3 million for the F–1 and $78.5 million for the J–2. Produced by the Rocketdyne Division of North American Aviation, a cluster of five F–1 engines powers the Saturn V 1st stage; a cluster of five J–2 engines is used to power the 2nd stage; and a single J–2 engine, with re-start capability, powers the 3rd stage.

The last full year of funding the contractor development effort under the "Engine Development" project line item was FY 1966. After completion of qualification (October 1966) for the F–1 and January 1967 for the J–2, the contractor effort for field and engineering support was transferred to this account.

Fiscal year 1968 funds provide for continued delivery of F–1 and J–2 flight engines required for the Saturn V stages. A total of 34 F–1 engines and 36 J–2 engines are scheduled for delivery during this period. The FY 1968 funds also support flight evaluation, maintaining test engines in a configuration for quick analysis and solution of problems, component and engine system testing, and periodic verification of flight worthiness.

Vehicle support

As I indicated earlier, the Vehicle support line item covers studies, services, and equipment that are common to more than one stage of the vehicle. In the case of the Saturn V, the fiscal year 1968 funding requirements, amounting to $242.0 million, provide for an intensive support effort at the test and launch sites. These funds cover a wide range of activities that support test, checkout, transportation, launch readiness, and post-flight analysis. Included are systems integration, engineering services, quality control and inspection services, reliability assessments, and contract administration. Major emphasis will be placed on support of static testing at our Mississippi Test Facility, where we will be heavily involved in acceptance testing of Saturn V 1st and 2nd stages. In addition, the workload at the Kennedy Space Center will increase in support of the Saturn V launches.

Engine development and mission support

My last chart on Apollo funding includes engine development and mission support (fig. 132, MP67–5439). We are requesting $24.5 million in fiscal year 1968 for Engine Development, a significant drop from FY 1966 and 1967 requirements, since all three of our major vehicle engines are now qualified. Upon completion of engine qualification, funding of contractor effort was transferred to the respective engine account of the Saturn launch vehicles.

The FY 1968 funds requested will provide for government-furnished propellants, reimbursement to the Department of Defense for contract administration and quality assurance services, and a continuing program of evaluation and analysis of engine hardware. The major activity in this area is the J–2 engine environmental test program conducted at the Air Force Arnold Engineering Development Center, Tullahoma, Tennessee.

Mission support requirements for FY 1968 are $281.0 million and reflect the increasing tempo of flight activity, since this line item provides for the overall

MANNED SPACE FLIGHT
RESEARCH AND DEVELOPMENT
ENGINE DEVELOPMENT & MISSION SUPPORT
FY 1968 BUDGET ESTIMATES
(MILLIONS OF DOLLARS)

	FY 1966	FY 1967	FY 1968
ENGINE DEVELOPMENT	$ 133.2	$ 49.8	$ 24.5
MISSION SUPPORT	$ 164.3	$ 243.9	$ 281.0
OPERATIONS	112.9	196.9	229.0
SYSTEMS ENGINEERING	20.0	20.0	20.0
SUPPORTING DEVELOPMENT	31.4	27.0	32.0

NASA HQ MP67-5439
1-15-67

FIGURE 132

launch, flight, crew and recovery operations; program-wide systems engineering; and supporting development necessary for the successful accomplishment of manned space flights.

The Operations area accounts for the major share—$229.0 million, and includes activities at the Kennedy Space Center and the Manned Spacecraft Center that support the launch, flight, and recovery phases of Apollo missions. For Kennedy, it includes the operation of checkout, launch, and instrumentation facilities; contractor services; equipment and supplies; and reimbursement for services provided by the Air Force. At Houston, it includes mission control for Apollo flights; support of astronaut training and flight crew requirements; mission planning and analysis; remote-site operations; and recovery equipment and operations, including reimbursement to the Department of Defense for recovery forces.

Systems engineering, for which $20 million is requested, provides for integrated technical support, review, and analysis of manned space flight missions. These services include the development of functional and performance standards for the program, consistent with mission objectives; mission planning; test objectives and integration; program and systems specifications; trajectory analysis; checkout effectiveness; and technical documentation.

The $32 million for supporting development will continue activities which involve selected engineering efforts to eliminate potential deficiencies in Apollo and to provide a firm base for hardware decisions related to extensions of the program. This category also includes the development of improved hardware or manufacturing, test, and evaluation techniques to reduce cost and enhance reliability and efficiency.

APOLLO APPLICATIONS

Now I want to discuss Apollo Applications, for which we are requesting $454.7 million (fig. 133, MP67-5725). This is now a program line item, comparable to Apollo and Advanced Missions. Funding shown for fiscal years 1966 and 1967 was carried under Apollo and in the Space Sciences budget.

MANNED SPACE FLIGHT
RESEARCH AND DEVELOPMENT
APOLLO APPLICATIONS
FY 1968 BUDGET ESTIMATES
(MILLIONS OF DOLLARS)

	FY66	FY67	FY68
SPACE VEHICLES	$ 8.5	$ 38.6	$ 263.7
EXPERIMENTS	40.3	35.6	140.7
MISSION SUPPORT	2.4	5.8	50.3
TOTAL	$ 51.2	$ 80.0	$ 454.7

NASA HQ MPR67-5725
2-2-67

FIGURE 133

Apollo Applications builds upon the strong base of flight experience, ground facilities, and trained manpower developed in past and current programs. Each mission is designed to take full advantage of the Apollo Saturn system to make significant contributions to a wide range of objectives. Missions are planned to concurrently gain experience, test theory, perform experiments, and collect data. By establishing multiple objectives for each flight mission, a program limited to a minimum economical launch rate can achieve rapid progress and make great gains at low cost. Planning includes the decision to use, modify, and expand present Apollo systems capabilities rather than move toward whole new developments, the strategy of reusing basic hardware for many missions by storing it in orbit and returning later with fresh crews and expendables, and the approach of designing experiments that will gather important data while at the same time testing the experimental concepts themselves.

The program of investigations and development to be carried forward in the Apollo Applications program will meet two basic objectives; to make unique contributions to practical applications, operational capabilities, science, and technology; and, at the same time, to place the nation in a position to assess, on the basis of valid scientific experimentation and actual experience, the value and feasibility of future space flight and the interrelated roles of manned and unmanned systems.

In support of these objectives, the principal areas toward which the fiscal year 1968 effort will be directed are the development of an extended flight capability, the conduct of manned astronomical and earth observations from space, and the continued exploration of the moon.

Specific program elements have been selected for initiation in FY 1967 and 1968 that, in combination, provide the greatest contribution to the Nation's space objectives at the lowest cost. These are:

The spent, orbiting 2nd stage of an uprated Saturn I will be converted into a habitable, 10,000 cubic foot orbital workshop. Provided with an airlock, the workshop will provide in 1968 an economical long duration manned shelter for many experimental activities and will be revisited and reused during the course of the program.

The support systems of the basic Apollo Command and Service Modules will be modified for long duration operations.

The Lunar Module will be modified to serve as a base for manned lunar investigations of up to two weeks.