The Apollo developed Lunar Mapping and Survey System will be used to complete the cartography of the moon.

The Command Module will be modified to carry up to 6 men for short duration ferry and resupply missions and will be provided a land landing capability, thereby reducing costs and increasing operating flexibility.

Specialized payloads will be developed for operation in various orbits and on the moon, including multispectral earth and weather sensors, biological and biomedical experiments, mobile lunar vehicles, and communications systems.

A manned solar telescope system, forerunner of long-lived orbital astronomical facilities, will be flown during the peak of solar activity.

Space vehicles

Fiscal year 1968 funding requirements for space vehicles total $263.7 million, of which $167.4 million is for the first three line items (fig. 134, MP67–5709). This request provides for continued incremental funding of the follow-on uprated Saturn I procurements initiated in FY 1966 and 1967 and for the initial funding for follow-on Saturn V vehicles and Command and Service Modules (CSM). The first follow-on uprated Saturn I will be delivered in late 1968. The delivery of the first follow-on CSM is planned late in 1969. The first follow-on Saturn V will be delivered in mid-1970.

The remaining requirements, totaling $96.3 million, support the continuation of the design and development efforts, begun in FY 1966 and FY 1967, required to furnish modified Apollo spacecraft systems for the planned missions. Apollo spacecraft systems, including the electrical power, life support and environmental control systems, are currently being subjected to extensive tests to determine their ability to operate in the environments and for the durations proposed for the Apollo Applications missions. To minimize the cost of this phase of the program, the plan is to incorporate only those changes required by the planned missions.

Fiscal year 1968 funding also includes the initiation of development of a land landing capability for the Command Module, which will allow elimination of water landing as the primary recovery mode, thereby providing greater operating

MANNED SPACE FLIGHT

RESEARCH AND DEVELOPMENT

APOLLO APPLICATIONS

FY 1968 BUDGET ESTIMATES

(MILLIONS OF DOLLARS)

	FY 66	FY 67	FY 68
SPACE VEHICLES	$8.5	$38.6	$263.7
CSM PROCUREMENT	-0-	-0-	43.3
UPRATED SATURN I PROCUREMENT	1.0	24.0	78.5
SATURN V PROCUREMENT	-0-	-0-	45.6
SPACECRAFT MODIFICATION	7.5	14.6	91.3
LAUNCH VEHICLE MODIFICATION	-0-	-0-	5.0

NASA HQ MP67-5709
1-15-67

FIGURE 134

flexibility, allowing refurbishment and reuse of command modules, and reducing recovery and new procurement costs. The changes to the spacecraft that permit incorporation of the land landing capability will also allow the interior of the Command Module to be rearranged to accommodate up to three additional astronauts for short duration ferry and resupply missions. Limited development of a Lunar Module (LM) shelter/taxi to extend lunar surface exploration time beyond that planned for the Apollo program will also commence in FY 1968.

Experiments and mission support

My next chart (fig. 135, MP67–5708) shows the remainder of the funding being requested for Apollo Applications—$140.7 for experiments and $50.3 million for mission support.

Experiments

Of the experiment funding, $33.7 million is for definition and $107 million is for development. Apollo Applications experiments cover a wide range of objectives in the fields of space medicine, science, applications, technology, and engineering. The definition and development of experiment payloads to meet these objectives will include activity by elements of NASA, other government agencies, and the scientific and industrial communities.

Effort in FY 1966 and FY 1967 was primarily confined to definition of experiments and experiment hardware for use in the early Apollo Applications missions. Included in these efforts were studies which led to the Apollo Telescope Mount (ATM) and the spent-stage S–IVB orbital workshop, now under development.

The fiscal year 1968 effort will continue the development of the Apollo Telescope Mount and the orbital workshop and will define and develop other experiment payloads for follow-on Apollo Applications missions. These experiments have already been discussed in considerable detail.

MANNED SPACE FLIGHT
RESEARCH AND DEVELOPMENT
APOLLO APPLICATIONS
FY 1968 BUDGET ESTIMATES
(MILLIONS OF DOLLARS)

	FY 66	FY 67	FY 68
EXPERIMENTS	$40.3	$35.6	$140.7
DEFINITION	34.4	12.0	33.7
DEVELOPMENT	5.9	23.6	107.0
MISSION SUPPORT	$2.4	$5.8	$ 50.3
PAYLOAD INTEGRATION	.1	4.4	40.0
OPERATIONS	2.3	1.4	10.3

NASA HQ MP67-5708
1-15-67

FIGURE 135

Mission support

Payload integration, for which $40 million of the $50.3 million requested for mission support is earmarked, includes the system analysis and development effort required to assemble experiments into mission compatible payloads, and the effort required to physically install and qualify them for flight readiness. This activity includes definition, design and development, modification, and installation. The definition phase of payload integration was initiated during FY 1966 and will be essentially completed by the end of FY 1967. Design and development includes control documentation, interface, qualification and acceptance test specifications, and testing plans. Modification and installation provide for changes to space vehicles and experiment carriers to accommodate experiments and physical installation of experiments into applicable carriers. The FY 1968 effort will provide for the analyses of payloads to determine detailed payload integration requirements and the implementation of design and development activities for the initial Apollo Applications flights.

Operations will require $10.3 million and include efforts at the Kennedy Space Center and the Manned Spacecraft Center that are directly concerned with launch, flight, crew, and recovery activity. Basic support is provided in the Apollo program for those missions currently scheduled as alternate Apollo Applications flights. FY 1968 funding will also provide for initiation of operations support for missions including the augmentation of the mission control center located at the Manned Spacecraft Center required to support the increased data demands resulting from the enlarged experiment and operational activity associated with the Apollo Applications program.

ADVANCED MISSIONS

The Advanced Missions program, for which we are requesting $8.0 million in fiscal year 1968, allows us to investigate advanced manned space flight concepts. The studies examine logical extension of the NASA space capability through analysis of the growth potential of present hardware systems; assesses requirements for future systems; furnish guidance for research and technology activities; provide technical information and cost data upon which future program decisions can be based; and permit initiation of the definition, preliminary design, and specification of probably future missions.

By conducting these advanced studies, we build a solid base for planning and selecting future manned space flight missions. Specific areas of investigation include manned earth orbital, lunar, and planetary missions and launch vehicles. Fiscal year 1966 and 1967 studies provided support for the evolving Apollo Applications program, including the definition of experiments and other mission payloads and analysis of the cost-effectiveness of alternate flight equipment approaches. The FY 1966 and 1967 studies also examined the feasibility of a long-duration space station module. In addition to considering various earth orbital applications, the space station study includes analysis to identify features common to manned planetary flight requirements.

In the area of Earth Orbital Studies, we have been analyzing a one-year earth orbital workshop which could evolve into a continuous-operation space station. Alternate approaches for an eventual one-year workshop included module configurations utilizing the third-stage structure of the Saturn V; a Saturn V-launched module containing all expendables for a one-year duration; and a system based on a flexible subsystem module. We are also defining rescue concepts and space station resupply and logistic systems, and continuing work on the selection and definition of candidate experiments. The potential economic benefits that can be derived from space station operations are also being assessed. Based on the results of the conceptual studies, preliminary definition of a one-year workshop module will be initiated, together with the preliminary definition of a modular spacecraft to allow us to carry out earth resources experiments and astronomical observations. The FY 1968 studies will concentrate on the definition of a versatile space station designed for earth applications, astronomy, and biomedical research, as well as interplanetary exploration.

We are also conducting Planetary Mission Studies, examining various mission modes and systems concepts for manned Mars and Venus reconnaissance, sample retrieval from the Martian surface and, ultimately, Mars landing missions. These studies have established the practicability of using Apollo space vehicle hardware for sample retrieval or reconnaissance missions, and have provided us with spacecraft concepts for manned Mars landing missions in the future.

The fiscal year 1968 study program will focus on continued definition of technology requirements and concepts for a Mars sample-retrieval mission. This type of manned mission offers the unique advantage of bringing samples of the Martian surface and atmosphere back to earth for scientific analysis. The manned spacecraft, which would also allow for scientific research and observations on the way to and returning from the planet, would be used to aim, launch, and retrieve an unmanned sample return probe. During FY 1968, the study effort will include preliminary definition of the mission spacecraft, and the associated propulsion stages, in addition to the onboard experiments that could be conducted by the crew members during the mission. The studies will define the total system for Mars sample retrieval in enough depth to permit definitive planning of the funding requirements, the technological development program required to support this mission, and the total program support required within NASA.

Fiscal year 1968 Lunar Mission Studies will provide for updating the current plan for lunar exploration so that the accompanying conceptual designs can be developed. This integrated exploration plan will review the basis for a continuing series of manned and unmanned missions.

Finally, Launch Vehicles Studies to support earth orbital, planetary and lunar missions will be continued during fiscal year 1968. These studies will stress preliminary definition of improved Saturn vehicles, analysis of reusable reentry vehicles, and determination of the facilities and support requirements.

Conclusion

Now, in conclusion, why does the manned space flight program merit support at this time? I believe there are many reasons.

It 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.

To summarize, I have reviewed the major activities of the manned space flight program. As you recall, I began by citing our general objectives in manned space flight. These are the broad objectives that have motivated our efforts in specific programs. We have worked for the establishment of man's capabilities; for development of a national competence for manned space flight as represented by an industrial base, trained personnel, ground facilities, launch vehicles, spacecraft, and operational experience, for the exploration of space; and for United States leadership in space. Now we propose we move forward and use this national capability.

In Apollo Applications I have presented the program which resulted from the study effort authorized by this Committee in fiscal year 1966. This careful planning was further supported by this Committee in FY 1967 when funds were authorized to keep the options open one more year. We are now asking you to exercise these options. The Apollo Applications funds you provided last year defined a follow-on effort to the Apollo program that resulted in an effective program to capitalize on the investment this country has made in space. This program has been reviewed and endorsed by the Bureau of the Budget, the President's Science Advisory Committee and the President. They recommend that we press onward in the investigation of man's role in space, the interrelationship between man and machine in space exploration, scientific experimentation and operational systems. They recommend the Nation not be deprived of the ultimate benefits to mankind this capability offers.

In this presentation in support of our budget request for fiscal year 1968, we are asking that you approve the continuance of our efforts toward these national objectives.

I believe the example I have shown in the development of the Powercel as a potentially new household item to produce power, reduce pollution, and provide a better way of life for mankind ties in closely with not only the reasons for supporting manned space flight activity but also to the gist of the Fortune magazine article just quoted.

Mr. TEAGUE. For your information and the information of the committee, the hearings will start each morning at 10.

Thank you.

(Whereupon, at 12 p.m. the subcommittee adjourned until 10 a.m. on Wednesday, March 15, 1967.)

1968 NASA AUTHORIZATION

WEDNESDAY, MARCH 15, 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. WAGGONNER (presiding). The committee is in order.

Proceed, Dr. Mueller.

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

Dr. MUELLER. This morning I would like to review the Apollo program and the progress that has been made in the past year on Apollo. I will not discuss the accident further since we will have a considerable discussion of that later when the results of the Accident Review Board are in.

With your permission, however, I will discuss all of the other aspects of the program for the past year.

Turning to the first viewgraph (fig. 1, MA 66-9411); the Apollo program, itself, involves not just the spacecraft and the launch vehicle, but a complex of launch facilities, manufacturing facilities, and test facilities that stretch across the Nation. It involves the logistic support for making those facilities useful and it involves the worldwide tracking network that provides the information to the Mission Control Center that permits the safe control of the flight. It involves the support fleet and it involves the crews and their training. It involves many things that have to be coordinated and brought to focus and made to operate together effectively if the program is to succeed.

The Apollo program itself is divided into seven phases (fig. 2, MA66-10,262). We have completed the first phase, the unmanned flight program on the uprated Saturn I and completed the unmanned flight of the command and service module. The next phase that we will be entering later this summer is the unmanned flight of the lunar module. From there we expect to qualify the command and service module for manned flight and to carry out open end missions for periods of up to 2 weeks. From there we plan to go to combined operations. The Saturn V unmanned flight program will test both the

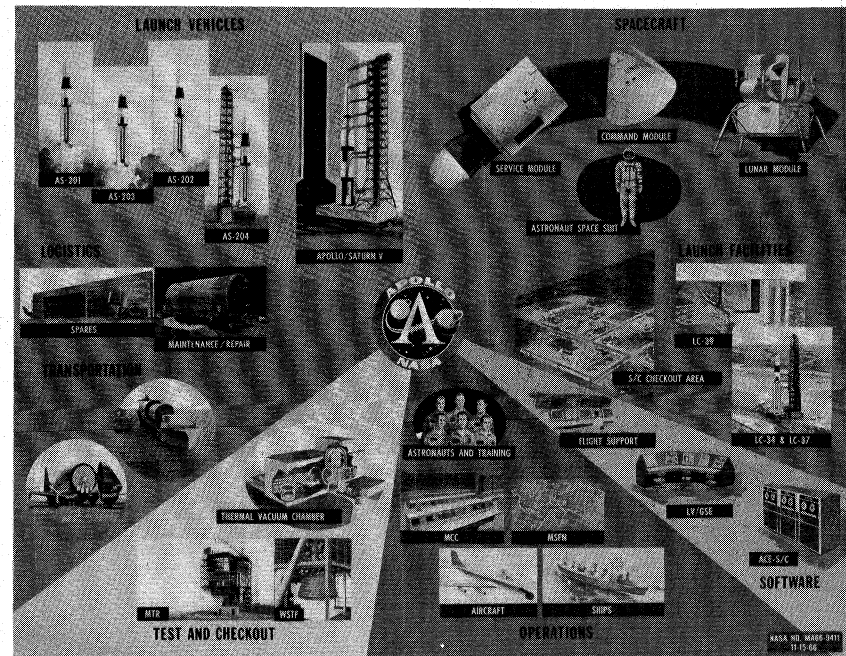


FIGURE 1

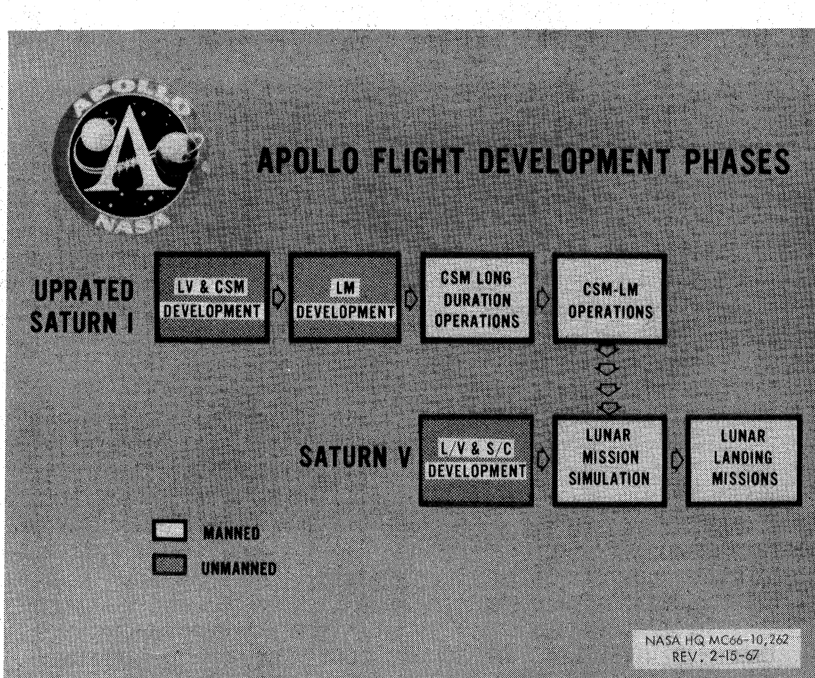


FIGURE 2

launch vehicle and the reentry heat shield of the spacecraft as well as its control systems during this year leading to the first manned flights on Saturn V in Earth orbit in the next year.

We will be carrying out simulations of the lunar missions on the Saturn V and Earth orbit until such time as we develop the procedures and verify the operations of the equipment so that we can proceed to the final lunar landing mission.

Turning to the next pair of viewgraphs (figs. 3 and 4, MA66-9171 and MC66-10263), I would like to review just briefly the results of the flights of the Apollo/Saturn 201, 202, and 203 which took place during 1966. The first of these, 201, and the third, 202, were tests of the launch vehicle with its new second stage, the SIVB and tests of the reentry heat shields. One of these flights was designed to provide us with information concerning a peak heat impulse, the peak heating rate that will occur coming back from the Moon. The other, a flight profile, which provided a maximum total heat input which again was equal to that which we will experience coming back from the Moon. It was necessary to divide the test into those two parts because of the limited velocities that we can attain with the uprated Saturn I. These were passed successfully and the design certification preview board in November and December declared the command and service module and the launch vehicle ready for manned flight. The hydrogen experiment carried out on AS203 last summer was also a completely successful test of what was and is a relatively new field of engineering which is the distribution and control of liquids in a zero gravity environment. Now, although we speak of a zero gravity environment there is enough air drag in the upper reaches of the atmosphere so that there is some deceleration of these vehicles when they are traveling around the Earth. In order to counteract that and to provide enough countergravity or counteracceleration to keep the liquids at the bottom of the tank, we introduced a new concept. This was to use the normal vent gases of the hydrogen to provide thrust in a forward direction thus more than counteracting the drag in the atmosphere and keeping the fluid at the bottom of the tanks. It was questionable whether you could actually control the thrust to the degree required to keep the fluid settled. We are talking about something on the order of a thousandth of a G which is a thousandth of the gravitational pull of the Earth. At these very low levels, it was just not understood what would happen to large quantities of hydrogen in that kind of environment. In fact, it settled nicely. The importance of the test was that this is the method we had planned to use with the third stage of the Saturn V and we had need of being sure that it would in fact work before we committed the Saturn V to it. That experiment again was completely successful.

Mr. FULTON. Could you submit in a short statement as to how it works?

Dr. MUELLER. I will be pleased to.

(The information requested follows:)

LIQUID HYDROGEN EXPERIMENT

A main point of concern in the orbital use of hydrogen is assurance that the fuel can be settled to the lower bulkhead or bottom of the fuel tank and kept there, covering the engine pump inlet and ready to supply the engine pump with fluid—not gas—when it is time to restart the main engine.

FIGURE 3

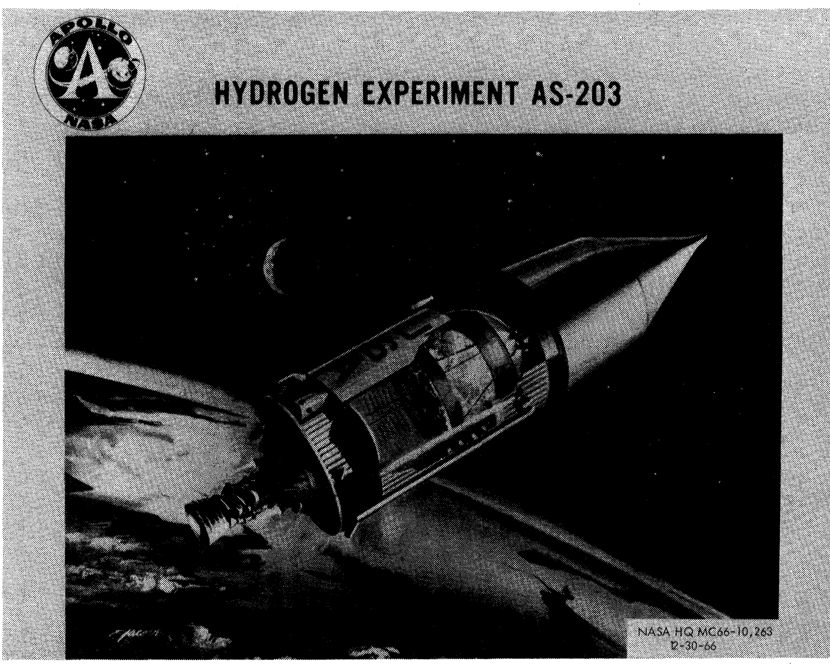


FIGURE 4

A second aspect of this is the necessity of keeping the gas produced by boiloff of the liquid in the top portion of the tank, so that gas alone—not liquid—will be vented overboard. In space there is no natural force to seat the propellant and keep it in place.

To maintain the hydrogen in a settled condition—as if the vehicle were standing upright on earth—designers must create an artificial gravity for the orbiting vehicle. The simplest way to do this is to accelerate the vehicle slightly, continuously, in its orbit. This acceleration must be sufficient to keep the hydrogen settled once the stage's small ullage rockets have settled it initially but must not use up too much fuel or accelerate the vehicle enough to change its orbit appreciably. The most promising way of providing this small continuing thrust is by venting the hydrogen tank itself—expelling beneficially the gases created within the tank by evaporation due to the heat input.

Boiloff gases expelled through two small nozzles pointing rearward gives the stage a minimum of about six pounds forward push which helps maintain the proper condition in the tank. This constant forward thrust keeps the propellants essentially settled. In the Saturn V mission, two 70-pound thrusters will fire just prior to restart of the main engine to "finish the job" and assure a completely acceptable state within the tank.

The LH_2 orbital experiment conducted on the A/S 203 flight verified the adequacy of the liquid hydrogen continuous propulsive venting system. The hydrogen fuel tank was instrumented to report to ground stations. Among the instrumentation was a television camera which sent pictures to four ground stations. Engineers observing TV monitors at the stations were able to see to what degree the fuel management techniques were successful.

In February, after the accident, we made several decisions. One of those was to proceed with the unmanned flights of the lunar module and the Saturn V Command and Service Module in the year 1967 (fig. 5, MC67–5782). Those decisions then are reflected in our planning.

The next slide shows the mission objectives of the AS–206 flight, which is an unmanned Lunar Module development flight (fig. 6, MC67–5779). There are three primary objectives, one is to verify the ascent and descent propulsion system and the Lunar Module structure. The second is to evaluate the staging. Here we have a basic kind of a

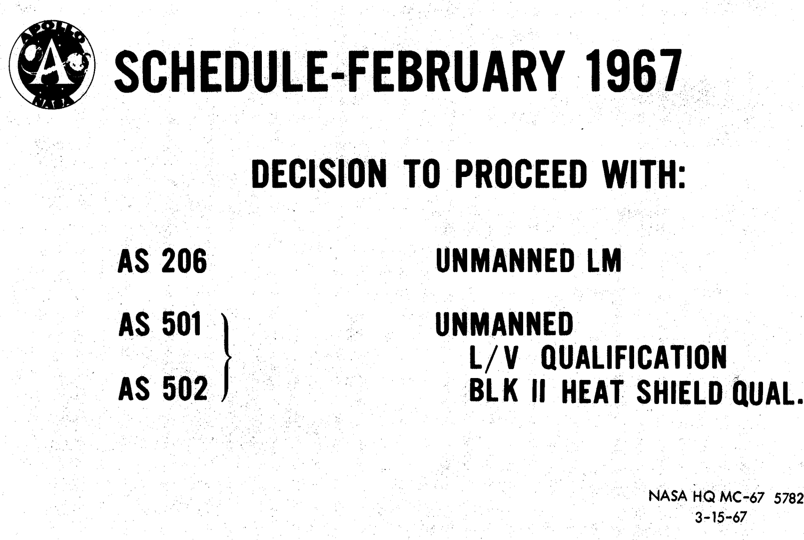


FIGURE 5

physical phenomena that occurs when you fire an engine into a closed or essentially closed volume as we do when the ascent stage takes off from the lunar surface. We want to verify in fact that the engine would work properly under those conditions. The third is to verify that the uprated H–1 engine, where we have gone from 200,000 to 205,000 pounds of thrust, will yield the performance on the uprated Saturn I that we expect.

The mission sequence is shown on the right-hand side (fig. 7, MC67–5793). It begins with the insertion into an 85 to 120 nautical mile elliptical orbit and then use the descent engine to achieve a circular orbit. There are actually two burns of the descent engine followed by an ascent burn which places the ascent stage into a higher elliptical orbit. In addition to that, you have an elliptical orbit with a higher apogee and it provides us with a test of an ascent burn.

It results in a larger orbital altitude. The problem that we have in designing this mission profile is to provide that the burns take place over places where we have tracking stations on the ground. There is a fair amount of work that has been done to be sure that we make the burns which resemble as closely as we can, the burns that are going to be used in carrying out the lunar mission itself. Also, that those burns occur over places on the Earth where we have tracking stations. Generally we prefer to have these burns take place over the United States. You can't do all of them over the United States because you have to fire both at perigee and apogee to control it.

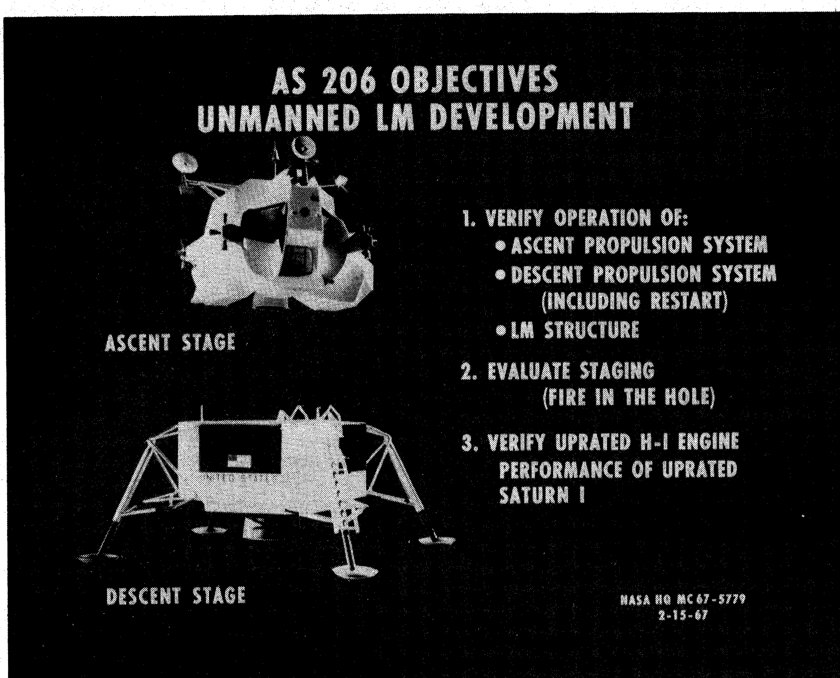


FIGURE 6

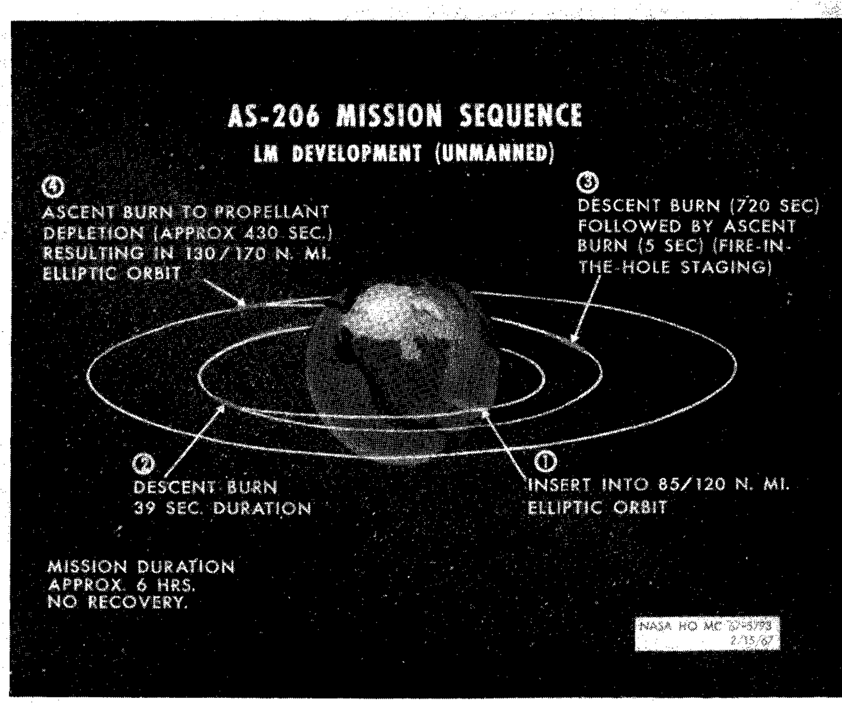


FIGURE 7

Turning to the next set of missions (fig. 8, MC66-10266A) those flights have five primary objectives, one is to demonstrate the structural and thermal integrity of the launch vehicle and spacecraft during the launch environment and reentry.

The second is to demonstrate that the stage separations occur properly.

The third is to verify the operation of the critical subsystems, the fourth is to evaluate the performance of the emergency detection system. That is a system that measures how well the launch vehicle is doing. It is a system that, if it is not doing well, tells the astronauts that they should abort. In fact, during the early phases of the launch, it automatically aborts.

The last is to demonstrate mission support facilities capabilities. That involves both the network and launch ships themselves. The AS-501 and AS-502 missions are similar. I will use the AS-501 as an example (fig. 9, MC 67-5794). One of the major objectives of it is to test the reentry heat shield. Much of the flight path is determined by that requirement. The original launch is into a 10-nautical-mile circular orbit. We inject into a 9,000-nautical-mile apogee and that is followed by another Service Module burn which raises the apogee to 9,900 nautical miles.

We then burn the Service Module for a long burn to give us both a test of the long duration burning of the service module and build

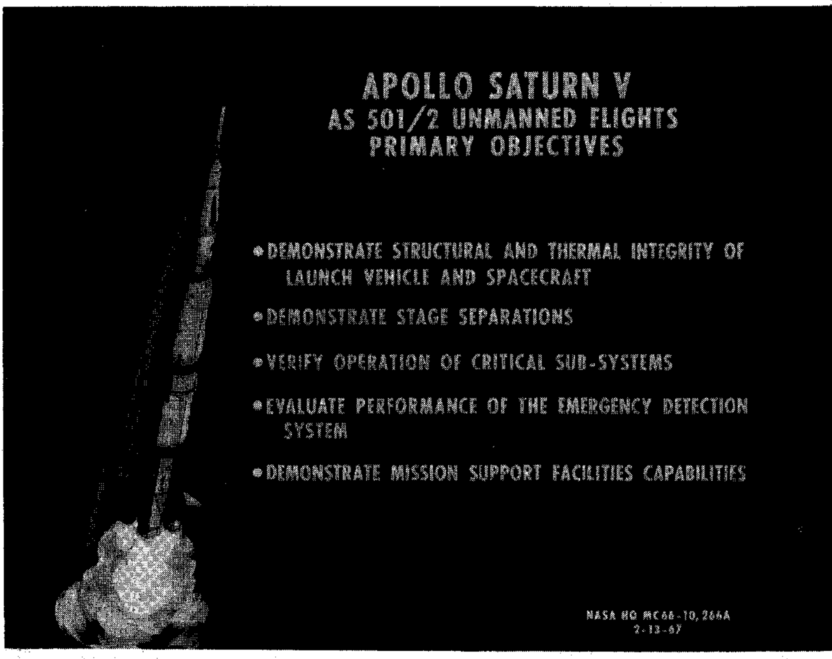


FIGURE 8

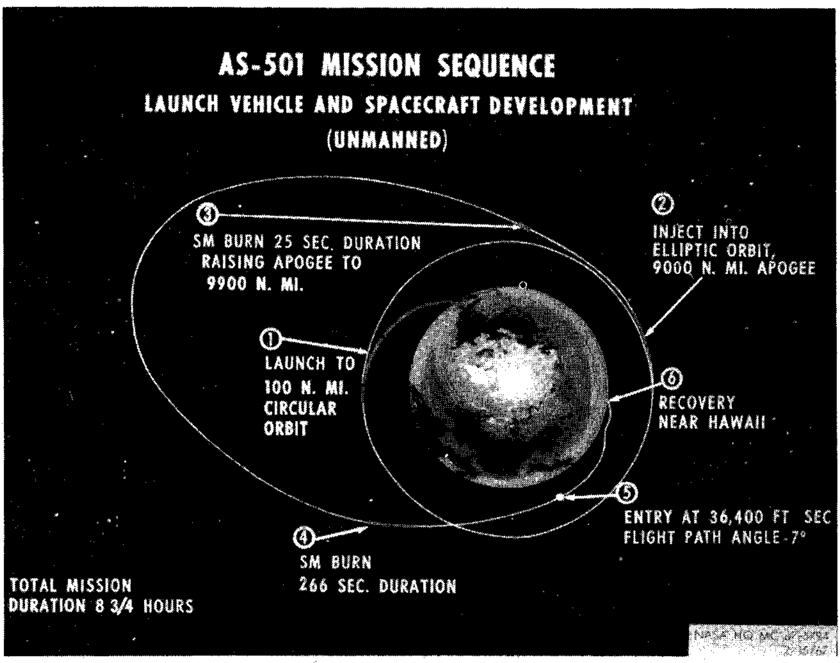


FIGURE 9

up the velocity that is required for reproducing the reentry conditions. Obviously, we have to provide more velocity during the reentry phase of the mission in order to simulate the effect of coming back from the 240,000 miles of the lunar distance.

The final Service Module burn provides an entry velocity of 36,000 feet per second which is the equivalent of the reentry velocity from the Moon. Recovery will take place in the Pacific Ocean near Hawaii.

Mr. FULTON. When we approach the Moon on the Apollo manned mission, we will be doing it for the first time. Why don't we have a mission that has a long elliptical orbit that includes both the Earth and the Moon as focal points and perform some of these operations in the vicinity of the Moon to see how these experiments work under real conditions rather than under simulated Earth conditions?

Dr. MUELLER. Mr. Fulton, we have examined that as one of the alternatives. The basic constraint we have is we have to operate the spacecraft unmanned and that requires the addition of supplementary equipment that takes the place of the men, which adds to the complexity of the equipment. In applying the mission as we have outlined it we have about an 8- to 9-hour mission. If we went the full distance to the Moon, we would be going to a mission that had a duration of several days, something like a minimum of 4 days, going that far and having to operate that far would require a different kind of a programing device. This can be self-timed so that it does not require, except in an override instance, commands from the ground. Basically it is a self-operating programer. On a 4-day mission the discrepancies in time become such that you would have to depend upon ground command.

Mr. FULTON. Does the Russian booster have a big enough power booster to do that? Do we? For example, I felt possibly that the U.S.S.R. would have a manned mission in a long elliptical orbit that would circle the Moon and return to Earth. Can they do it? Can we?

Dr. MUELLER. We do not have that capability at the present time.

Mr. WAGGONNER. Dr. Mueller, have you given any consideration to a manned flyby before the actual landing itself?

Dr. MUELLER. The way our missions are planned, once we have verified the equipment will operate satisfactorily for the lunar mission, we will establish a set of decision points that will allow us to go as far as the equipment and the procedures that we have developed will permit.

What that means is that the first step will be a commitment to actually take off from Earth, orbit and then go to the Moon. During the course of the mission we can in fact fly by it in the event that our service module propulsion engine malfunctions in some way. If we do fly by we will automatically fly around the Moon and come back to the Earth. If the service module is working we will use it to go into lunar orbit. At that point in time we can either stay in lunar orbit or we can commit to the lunar landing itself. That will depend upon whether or not the Lunar Module at that time is ready to carry out the landing phase itself. So we make a conscious decision in each step as to whether to proceed to the next step, it may very well be that the first flight will circle the Moon. Our planning says we will go as far as it is safe to go.

Mr. ROUDEBUSH. Why don't we plan to recover the first unmanned shot?

Dr. MUELLER. We do.

Mr. ROUDEBUSH. I thought on our first unmanned shot we didn't intend to recover it?

Dr. MUELLER. No, sir.

Mr. ROUDEBUSH. I understood we were going to. I understood you said we were not.

Dr. MUELLER. No, sir, we plan to recover near Hawaii. And the second unmanned will be recovered also.

Mr. ROUDEBUSH. Both are being recovered?

Dr. MUELLER. Yes.

Mr. ROUDEBUSH. I misunderstood.

Dr. MUELLER. We are exercising the full recovery fleet at the same time. We will have a complete test of the whole system.

Mr. WAGGONNER. Dr. Mueller, for future reference, is there going to be any change in the numbering of these follow-on flights as a result of the accident or do you intend to continue as you had planned prior to the accident?

Dr. MUELLER. We don't plan to change the numbers because of the accident. There may be some shifting of launch vehicles and spacecraft numbers. Also, because of the complexity involved in the phrase Apollo/Saturn 206 flight and the difficulty of CAPCOM, communicating with the spacecraft, we are looking at the possibility of changing the nomenclature to call it perhaps Apollo II, Apollo IV, Apollo V, or something like that, just to make it simpler for the public to know what is going on.

Mr. FULTON. Why are you using oxygen for stationary ground capsules used for astronauts practice? Why would you not do as well with normal air pressures?

Dr. MUELLER. We don't as a rule use pure oxygen. The only time that we use it is where we are trying to simulate exactly what we are going to do in the actual flight itself. Actually there are three tests up to the launch that use pure oxygen in the capsule. One is an unmanned test in the vacuum chamber; the second is a manned test in the vacuum chamber; and the third is a plugs-in plugs-out test on the pad.

Mr. FULTON. Will you make a statement on these proposed tests as to their purpose and duration, the type of atmosphere used and whether there is a mixture of oxygen, hydrogen or helium?

Dr. MUELLER. That is under review.

Mr. FULTON. I am saying for the future.

Dr. MUELLER. So with your permission, I would like to ask if we could delay that until we have completed the studies that will lead to a recommendation in this area

Mr. FULTON. That is perfectly all right.

Dr. MUELLER. Turning now to what we have planned in 1966 versus what we have accomplished. On the left-hand chart (fig. 10, ML 66–10,399) you will see that we have, in the case of the launch vehicles

APOLLO PROGRAM

MAJOR 1966 PLANNED ACTIVITIES

LAUNCH VEHICLES — **ACCOMPLISHED**

UPRATED SATURN I

- COMPLETE QUALIFICATION TESTING PROGRAM — DEC.
- COMPLETE VEHICLE GSE FOR LAUNCH COMPLEX 37B — FEB.
- BEGIN UNMANNED FLIGHT PROGRAM — FEB.
- COMPLETE ALL STRUCTURAL TESTING OF THE FIRST STAGE — MAY
- START ASSEMBLY OF THE TWELFTH FLIGHT ARTICLE OF THE FIRST AND SECOND STAGES — AUG
- COMPLETE 205K H-1 ENGINE QUALIFICATION — JUNE
- DELIVER FIFTY 205K PRODUCTION H-1 ENGINES — AUG.
- COMPLETE H-1 FIRST FLIGHT WORTHINESS VERIFICATION — OCT.

SATURN V

- DELIVER FIRST FLIGHT STAGES TO KSC — JAN. 67
- DELIVER GSE AND PROGRAM TAPES REQUIRED FOR LAUNCH AS-501 — DEC.
- BEGIN CHECKOUT OF FIRST POSITION OF FIRST STAGE ACCEPTANCE TEST STAND AT MTF — DEC.
- ACTIVATE BOTH SECOND STAGE ACCEPTANCE TEST STANDS AT MTF — MAR. '67
- COMPLETE F-1 ENGINE QUALIFICATION TESTS — SEPT.
- COMPLETE J-2 ENGINE 205,000 POUND THRUST QUALIFICATION — AUG.

NASA HQ ML66-10,399
REV. 2/15/67

FIGURE 10

and the uprated Saturn I, completed the qualification testing program, and we have completed the vehicle ground support equipment for launch complex 37B. We have begun our unmanned flight program, and have completed all structural testing of the first stage. For the benefit of those that are new to the committee, I might point out that what we have tried to do is identify our major planned activities for the coming year. Then the following year see how well we did with respect to that plan.

We did complete the structural testing of the first stage. We did start the assembly of the 12th flight article of the first and second stages. We did complete the 205,000 pound thrust engine qualification for the first stage (fig. 11, MA66–9215). We did deliver some 50 of these production H–1 engines which completed our order for those engines. We did complete the H–1 first flightworthiness verification.

In Saturn V we delivered our first flight stages to KSC (fig. 12, MC67–600). We were late with the second stage. Instead of that being done in October and November as we had planned, it came in January. We did deliver the ground support equipment and program tapes required for the launch of AS. 501. We did begin the checkout of the first position of the first stage acceptance test stand at Mississippi and, as a matter of fact, at this point in time, the first test firing has been completed (fig. 13, MC67–5737).

I don't know that I have a view of that at this point here but that was done just about a week ago. We did activate both second stage acceptance test stands at Mississippi. We were behind schedule on the second one and it is activated at this point in time. We did com-

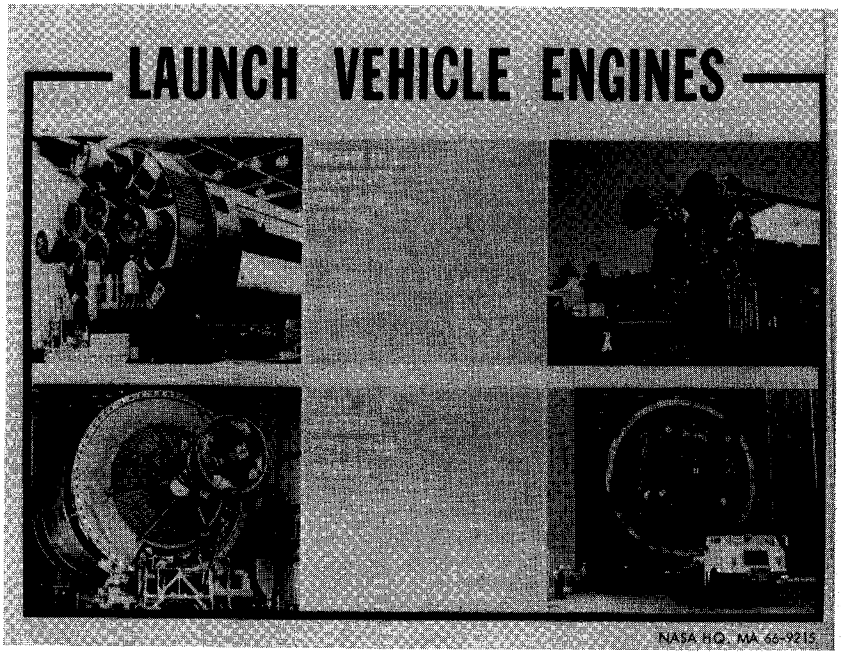


FIGURE 11

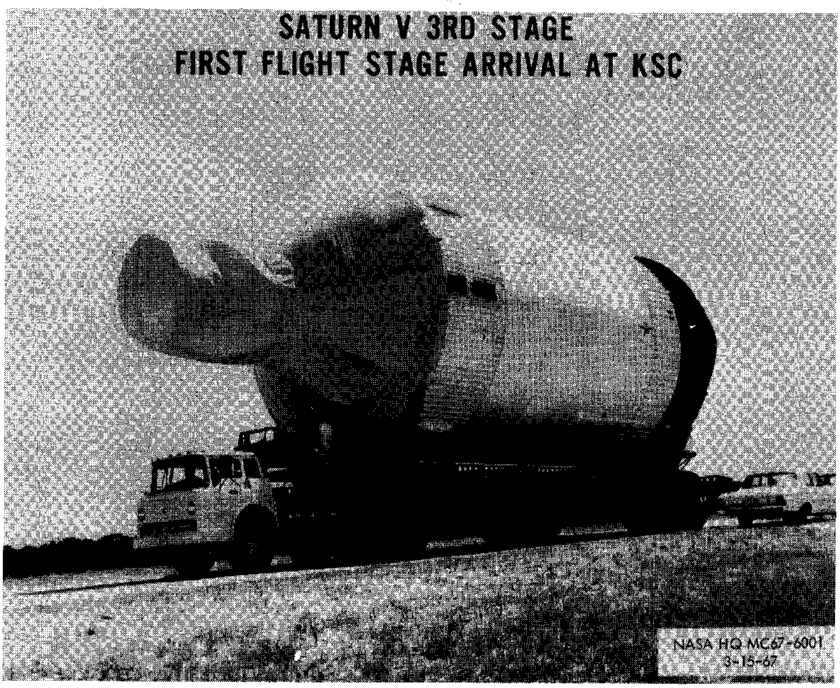


FIGURE 12

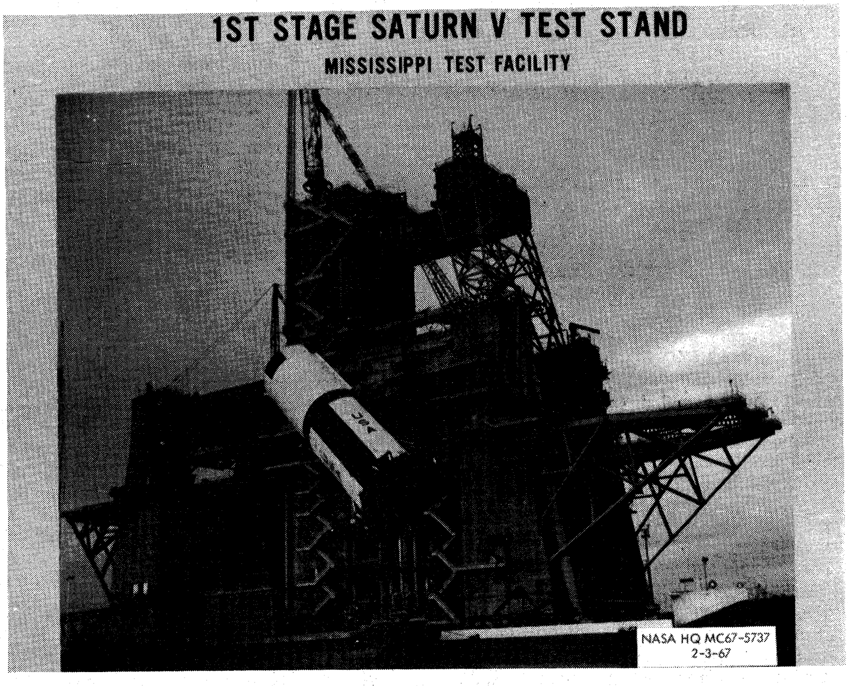


FIGURE 13

plete the F–1 engine qualification test and the J–2 engine, 205,000-pound thrust qualification.

Mr. WAGGONNER. Hasn't the J–2 been uprated?

Dr. MUELLER. Up about 5,000 pounds. It has developed a higher specific impulse so instead of being at the lower end of its specification, it is near the upper end which results in higher performance.

Mr. WAGGONNER. Is this higher performance essential?

Dr. MUELLER. Yes, as the spacecraft design has been completed, we found that there have been increases in the weight and we have been able, by virtue of the fact that the performance of the launch vehicle was improved to accommodate those increases in weight.

Mr. WAGGONNER. Was this 5,000-pound increase in the J–2 engine, was this a fractional increase that was necessary for the mission performance?

Dr. MUELLER. No, actually it is part of our normal experience in these engines as they mature, it is relatively easy to raise their performance as a normal course of evolution.

Mr. FULTON. There was an article appearing in the Sunday Washington Post to the effect that there were 20,000 mistakes in the Apollo program already. I would like to have in the record your comments in answer to some of those statements. I think it shouldn't go unanswered.

Mr. WAGGONNER. I think you will find that in yesterday's record.

(The information requested follows:)

The Washington Post article was a quotation taken from the Apollo News Media symposium which was held at MSC Houston, December 15 and 16, 1966. The statement represented a small portion of a more comprehensive discussion. This discussion which places the statement in context is as follows:

"Those subsystems, not the ones that are going to fly but the ones like the ones that are going to fly, are put through a series of qualification tests, which involve, to the best of our ability to estimate environments, the environments that the hardware is going to see, either singly or combined. And we have invested a fair amount in facilities around the country to improve our ability to do that kind of environmental testing. You see a whole bunch of them here, you see them at White Sands, you see them at Mississippi, you see them at the Cape, and you see them at the contractor plants. We also, in addition to the subsystem testing, we do testing at the system level. Now, whether we like it or not, that testing frequently shows up problems, a surprising large number of problems. To give you some idea of the magnitude of this, we keep book on every failure that occurs in the program. The inspector that notes the failure and the engineer that sees the failure has to fill out a form. That form goes into the data processing system so that we can trace the failures. The reason we are doing this isn't so much to keep book, because we believe that the way we are going to get reliability in the system is by rooting out the failure. In other words, take every failure, force somebody competent to understand it and take whatever corrective action is necessary to remove that as a possible cause of failure. But through the Block I program, on the command service module alone, we have logged something like 20,000 of these kind of failures. That is a relatively large number of things. All of them aren't hard failures, some of them are failures associated with something being out of specification, and we then have the problem of judging literally how good is good enough? If you think of the world of failures, you can break it into these two parts, those that obviously have to be fixed, and those that represent, for instance, a piece of instrumention being out of spec by a few percent."

In examination of these failures, it was found that the number 20,000 more accurately represented the failures at that time in all of the Apollo spacecraft. The comparable number for the CSM alone was 15,100.

As mentioned in the testimony, the complexities between Apollo, Gemini and Mercury must be considered in using this type of data and on this basis Apollo represents a significant improvement over the Gemini and Mercury programs. For example, on the CSM, 21,600 drawings of parts and assemblies are required for the 1,500,000 parts as compared with 6,100 drawing for 268,000 parts on Gemini.

Mr. FULTON. I would like to have listed in the record these companies who have a high rating on meeting time deadlines, qualification tests, and conforming to the programing that you have set out and, if you will, I would like to have the major deadlines the companies have not met so that some other means that have not been devised yet may provide for that.

(The information requested follows:)

The complexities of the Apollo project, design and fabrication, support to the contractors by NASA advancement in the state of the art, etc., makes a comparative rating of companies subjective rather than objective.

For purposes of incentive fee settlement, we do rate the contractors in terms of performance, cost and schedule. The relationship of these three factors varies from contractor to contractor depending upon our judgment of the difficulty the contractor will experience in meeting the milestones for performance, cost and schedule.

Additionally, we assess each major hardware element to determine the status at various times throughout the development cycle. These ratings have been provided the Subcommittee on NASA Oversight for use in their study of the Apollo Program Pace and Progress in 1965 and 1966, respectively.

Enclosed as attachment No. 1 is the status of hardware provided the Subcommittee on NASA Oversight on July 10, 1966. This data is organized to reflect the hardware status and in meeting the major MSF Apollo milestones that is, first unmanned Saturn IB

first manned Saturn IB

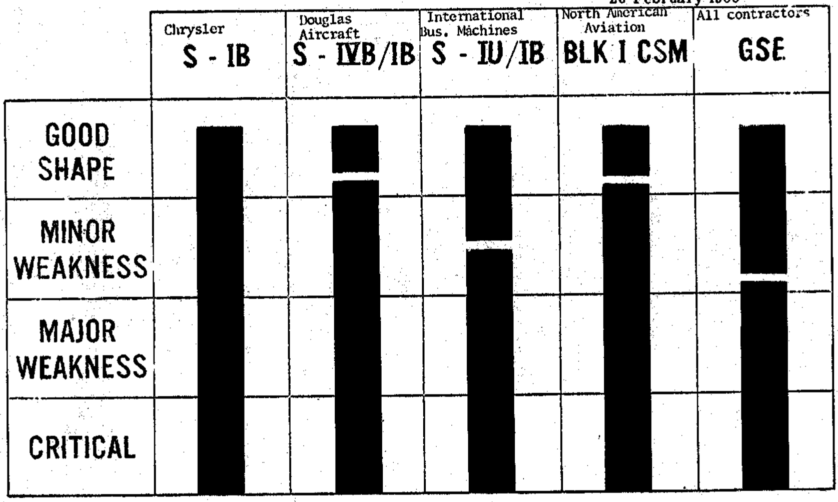
first manned Lunar Configuration Spacecraft

first manned Saturn V Apollo Lunar Landing

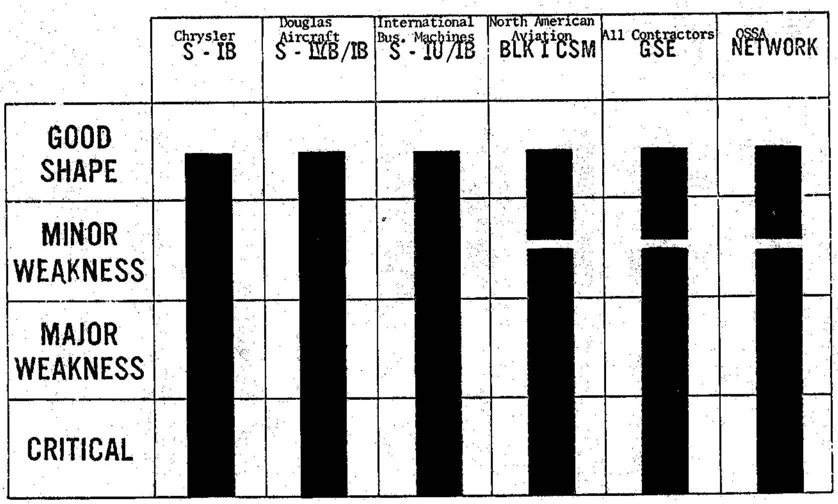
ATTACHMENT I

FIRST UNMANNED SATURN IB
1966

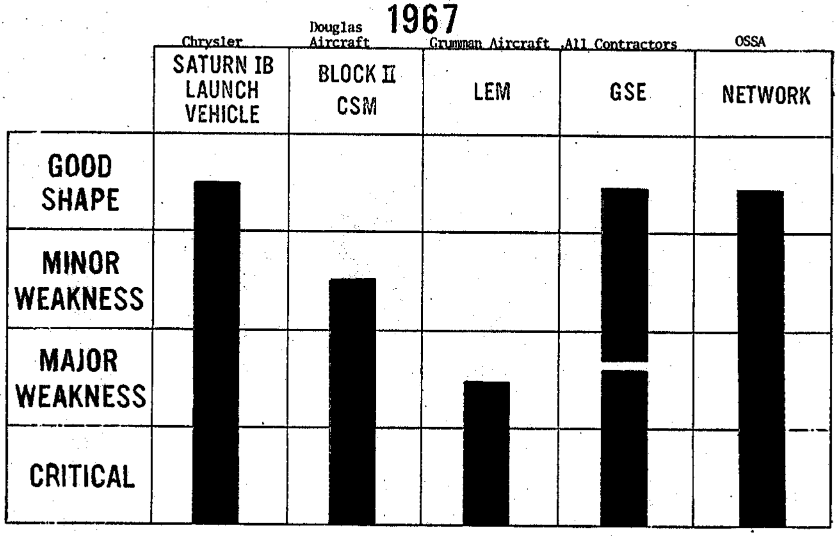
SUCCESSFULLY LAUNCHED
26 February 1966



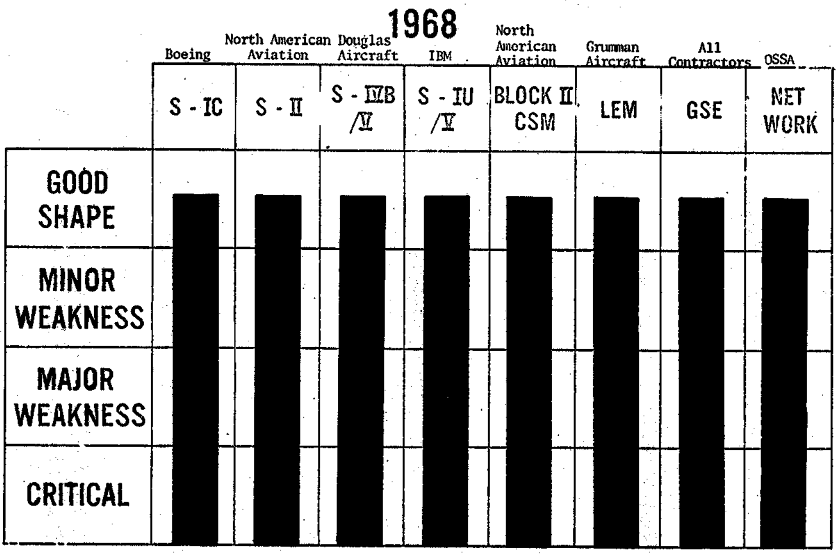
FIRST MANNED SATURN IB
1967



FIRST MANNED LUNAR CONFIGURATION SPACECRAFT (SATURN IB) 1967



FIRST MANNED SATURN V 1968



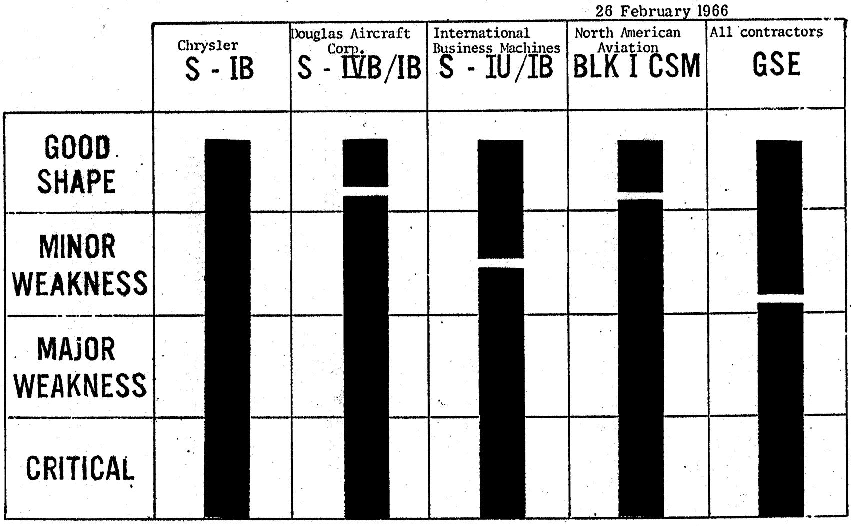
The chart (MA5–9143) dated 7/66 shows that the Block I Command Service Module was in a minor weakness as reported in July 1965 but was in good shape as of July 1966. The break in the bar represents the report provided to the Subcommittee on NASA Oversight 1965. The portion above the break represents the status as of July 1966.

Attachment No. 2 contains charts showing the same data as of November 1966. Again, locating the Block I, Command Service Module, first manned Saturn IB the bar indicated as of that date a minor weakness.

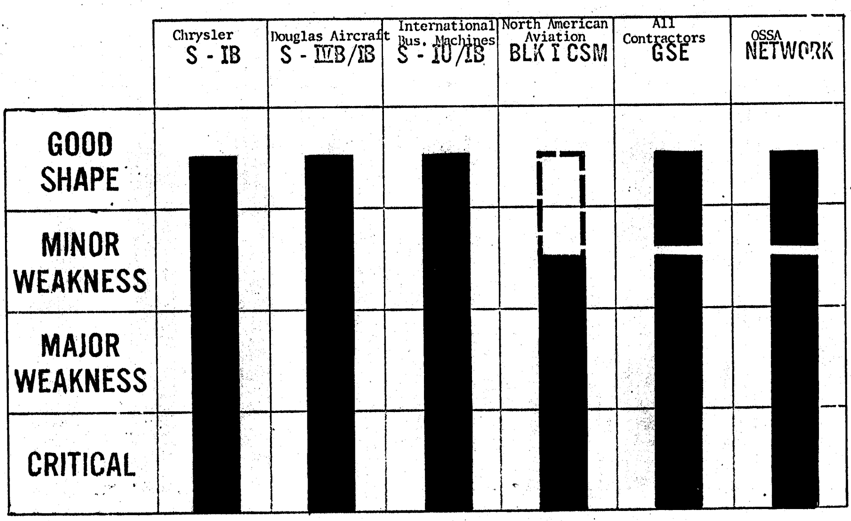
ATTACHMENT II

FIRST UNMANNED SATURN IB
1966

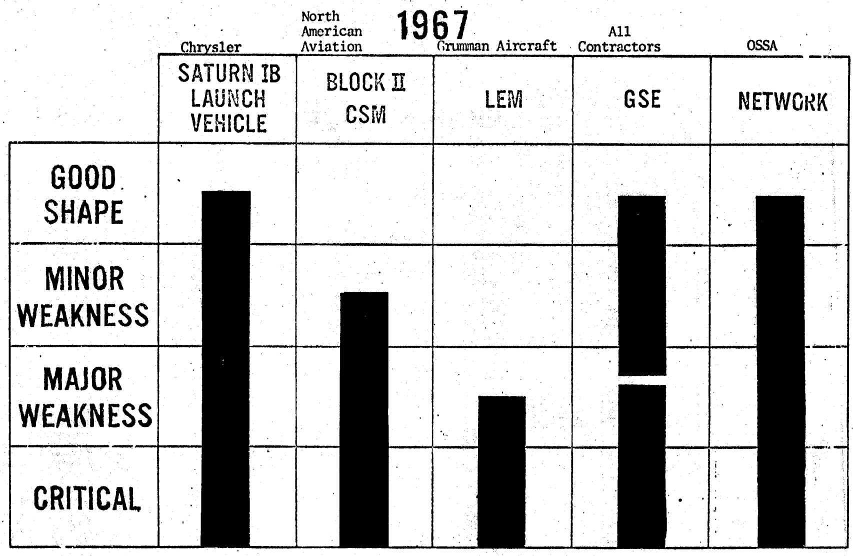
SUCCESSFULLY LAUNCHED
26 February 1966



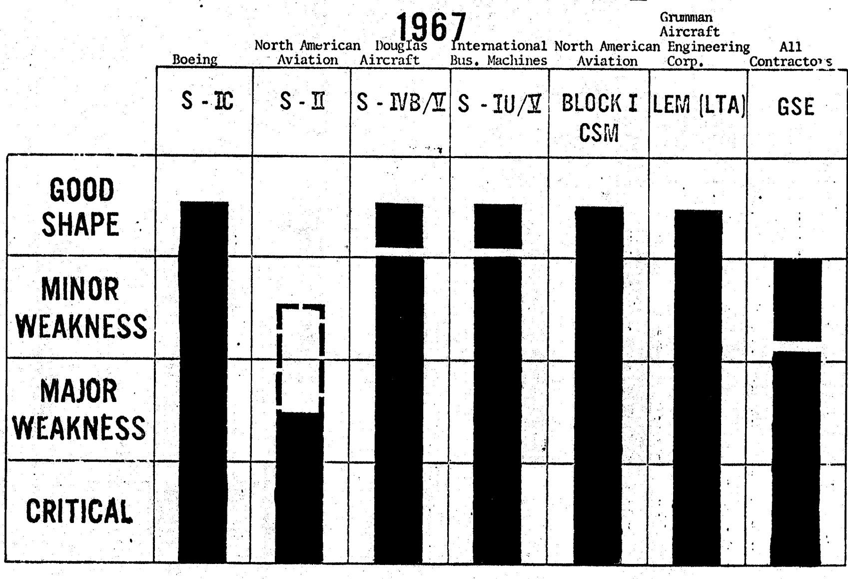
FIRST MANNED SATURN IB
1967



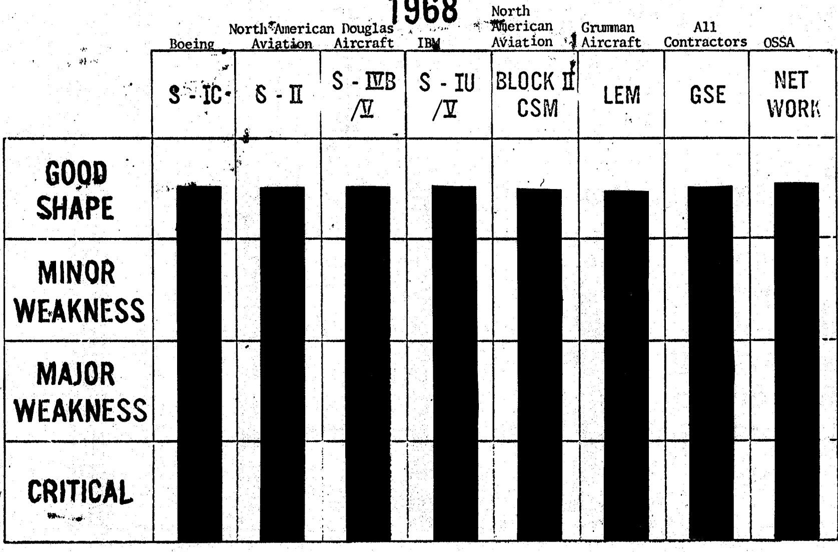
FIRST MANNED LUNAR CONFIGURATION SPACECRAFT (SATURN IB)



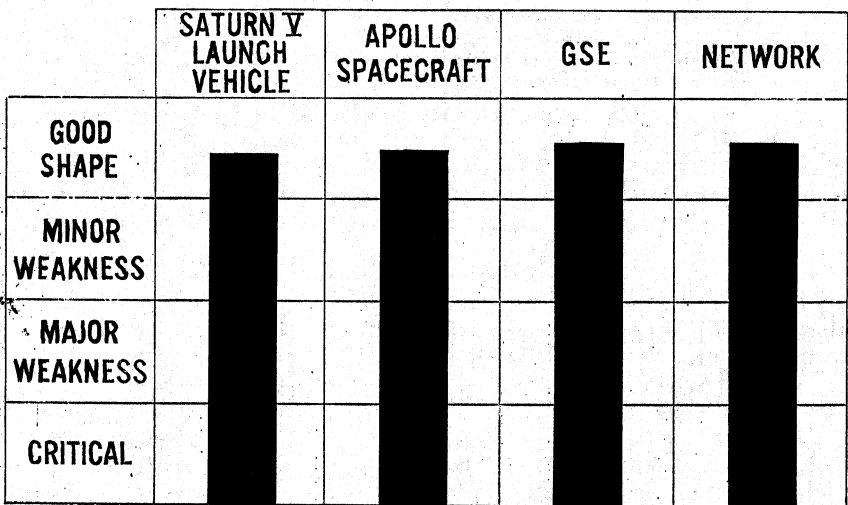
FIRST UNMANNED SATURN V

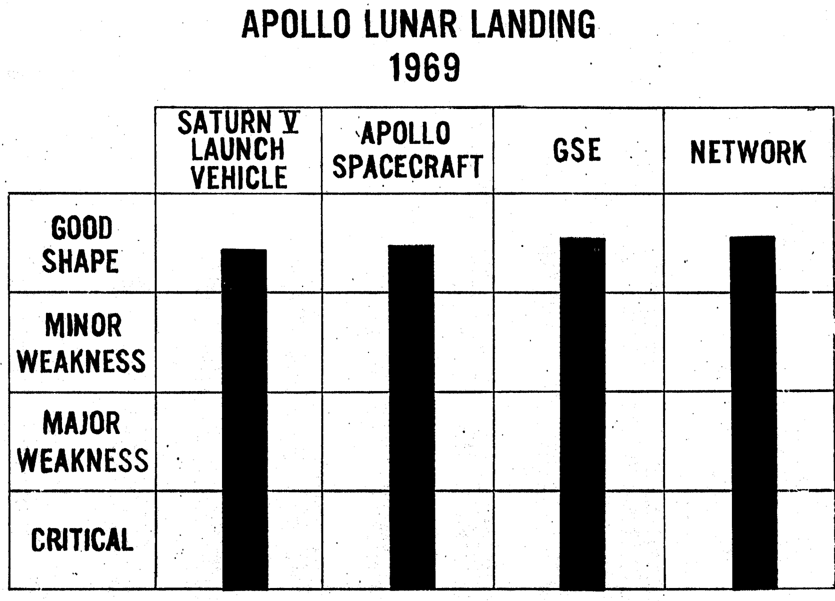


FIRST MANNED SATURN V
1968



APOLLO LUNAR LANDING
1969





The dotted line represents the location of the bar in the previous report July 1966.

As I mentioned the charts show the condition of the major Apollo elements and thus reflect the overall performance of the contractors, his subcontractors, venders, and suppliers.

It also demonstrates that the status of individual hardware elements can vary from month to month depending upon the many conditions outlined in the first paragraph of this statement. The status is also dependent on the phase the particular program element is going through at the time, i.e., ground testing, flight testing, qualification testing, etc.

Mr. BELL. I assume you have read this article a hundred times; is that true?

Dr. MUELLER. I have read it but not a hundred times.

Mr. BELL. I was rather curious at the comments supposedly made by one of the astronauts, Grissom. Had you heard of the comments he made?

Dr. MUELLER. We did discuss that yesterday, Mr. Bell, to some extent. I had not heard before the article that it was a lemon. I had discussions with Gus Grissom and some of the other crewmembers and got their views on the spacecraft.

Mr. BELL. Were these views unsatisfactory and were they displeased with the operation?

Dr. MUELLER. They were pleased with the spacecraft before it was delivered. When they first went aboard the spacecraft and participated in the testing, they found things that they were not satisfied with; those were carefully considered and carefully worked off.

Mr. BELL. What were some of those things?

Dr. MUELLER. Well, they had to do with the procedures and how they were being carried out. Some of the practices with respect to the testing itself, the rigor with which the inspection of the components were carried out, those kinds of things. The astronauts tend to be quite critical in their evaluation of the performance and do, in fact, serve a very effective role in causing the people that are working on the spacecraft to find solutions, and in this case they did better and Gus Grissom was pleased with the spacecraft when it was delivered. There is a second thing that the article referred which is our trainers. As I said yesterday, the trainers follow behind the spacecraft by several months in the development cycle and each one, of course, is enough different so that you have to get it into operation. Gus and his crew went through the development cycle of the trainer at Houston and then they were going through it again down at the Cape. In this particular case, Gus had a very good working relation and a very real appreciation of the work that the crew was doing. The occurrence, as I understand it, took place after about a period of some 12 successful runs of the trainer and was sort of an anticlimax in the sense that they had trouble earlier; they finally got the troubles fixed. It was working well and my understanding was that it was sort of a private joke between him and the test conductor on the trainer to highlight the fact that he had now solved the problems.

Mr. BELL. I am already starting to hear from my constituency on some of these things mentioned in this article. I also note that the article states that there was not any firefighting equipment or personnel for the specific purpose of handling an emergency, like a fire. Is that true?

Dr. MUELLER. There were people on deck.

Mr. BELL. I mean on the same level, the same location ready to help out in case of an emergency.

Dr. MUELLER. There were people who were ready to help out in case of an emergency. They were not, however, prepared for this particular emergency and that, of course, goes back to the fact that this test was not regarded as hazardous.

Mr. FULTON. When you go visit the field installations and talk to the people on the spot, have you uncovered how many change orders or engineering deficiencies were pasted on that particular equipment when it arrived at the test stand? What were these deficiencies? Will you put that in the record? I heard that on some equipment there have been as many as two or three hundred deficiencies by the contractor prior to acceptance. With the chairman's permission, we would like to have a general statement on that.

Dr. MUELLER. We will put a statement in the record. I also would say that we try to balance the workload in the various places that we carry out work. There is a certain amount of work that is always done after a stage arrives at the test stand.

(The information requested follows:)

S-IC-T was sent to the Mississippi Test Facility in November of 1966 to determine the readiness if the S-IC test stand to accept the S-IC-4 stage. Upon arrival at MTF 198 man-hours of open work was required:

Remove 4 GSE fittings from Actuator Arms	12
Install Actuator Heat Shield Support at Structural Fins A & B	40
Install Actuator Heat Shield Panel at Fins A & B	60
Install 4 Boot Assemblies at Fins at A & B	40
Remove Fuel Emergency Drain Cover	2
Remove 2 LOX tank Module Covers	2
Remove Module Assembly Cover (Connect to GSE)	4
LOX Emergency Direct (Connect to GSE)	8
LOX Emergency Drain Valve (Connect to GSE)	9
Install Coupling	3
Install Timer Distributor	8
Install Environmental Duct Adapter	6
Install LOX Fill & Drain Line	4

Mr. FULTON. We all realize that is what the contractor has not done. When they have the change orders pasted on the side, you didn't expect them?

Dr. MUELLER. That is what I was going to say. We do make delivery decisions to transfer work from one plant to another.

Mr. FULTON. That is what I am asking about.

Dr. MUELLER. But that is not a contractor that does that. It is the Government itself that does it. That is the point I am trying to make.

Mr. FULTON. Will you give us some little history about it?

Dr. MUELLER. We will be pleased to.

(The information requested follows:)

In the spacecraft and launch vehicle areas, a series of NASA board actions precede the turnover of the item vehicle to NASA. The contractor identifies to the board, in writing, the known changes or deficiencies that are outstanding at the time of turnover. The board, with the assistance of working groups evaluates the documentation, the physical vehicle and test results. A decision is made to accept the vehicle with certain "open" work to be accomplished later or make the contractor bring the vehicle up to an acceptable level of completion before acceptance. For the spacecraft this turnover action occurs at the contractor's facility since the spacecraft is then delivered to KSC. For launch vehicles, the turnover point is usually after acceptance testing at a facility such as SACTO or MTF since acceptance firing cannot be conducted at the contractor's plant. In either case, the turnover is formally documented with known outstanding work positively identified.

In the case of launch vehicles, the move from the contractor's facility to the acceptance test facility is preceded by a formal review board but there is no written acceptance by the government of the stage. The vehicle still belongs to the contractor and tests are conducted by the contractor with supervision and assistance by NASA to insure the tests are run in conformance of government requirements. The demonstration of the launch vehicle is a prerequisite for government acceptance. For spacecraft, there are a series of in-plant tests that represent this same demonstration of performance.

There are several reasons for accepting a piece of hardware with known open work still to be performed. We, of course, refer only to items of a relatively minor nature. Were a discrepancy of a major nature to appear, it is held for correction where it can best be handled, schedules not withstanding. During the early part of a program where time is a factor, initial production overlaps, to an extent, the later phases of the ground test and verification effort. Refinements and modifications which result continue even through delivery dates of these earlier units. Discrepancies found by inspections just prior to delivery must be accommodated. Discrepancies are uncovered during testing which follows manufacture. In all cases the modifications which are dictated by these occurrences are evaluated by both the contractor and NASA on the basis of schedule impact versus work complexity to determine the best place in the total vehicle flow to make the change or correct the fault.

There is a certain amount of work that is always done after a stage arrives at a test stand or a vehicle arrives at KSC. Any deferred or added work is also scheduled into the flow. Neither we nor the contractor like to defer work.

We would both prefer to do this work in the normal manufacturing sequence of a vehicle. Moreover, we are acutely aware of the potential for this deferral of work to grow. We have taken definite management actions to decrease this growth so that we can establish normal test cycles at the field test sites and at KSC. Due to the nature of a development program, the first vehicles have transferred work due to the phase of design, testing and manufacturing. There is a significant downward trend in the amount of open work transferred with each succeeding vehicle. We have included a clause in our incentive contracts that allows us to deduct fee for discrepancies or open work existing at the time of turnover of hardware to the government. We are never satisfied with any amount of transferred work. We have and will continue to exert NASA and contractor emphasis to reduce the level.

Mr. WAGGONNER. Isn't this one of the reasons you have contractor personnel on the scene at these facilities to do last-minute things that can better be done there than at the point of fabrication?

Dr. MUELLER. Yes.

Mr. WAGGONNER. These pastings are to point out what remains to be done. for safety purposes.

Dr. MUELLER. And there are, of course, things that are picked up when you go to the new place. That is why we static fire these vehicles, and carry through the complete inspection at the far end, to find those things that are incompatible in the design.

Mr. FULTON. The point of my question is whether the contractor is meeting the requirements on vehicles and components.

Dr. MUELLER. Yes.

Here is one of the problems we encountered last year. On the left you see the second stage, the second or third firing of the all-systems stage at the Mississippi Testing Facility (fig. 14, MA66-9226). Fol-

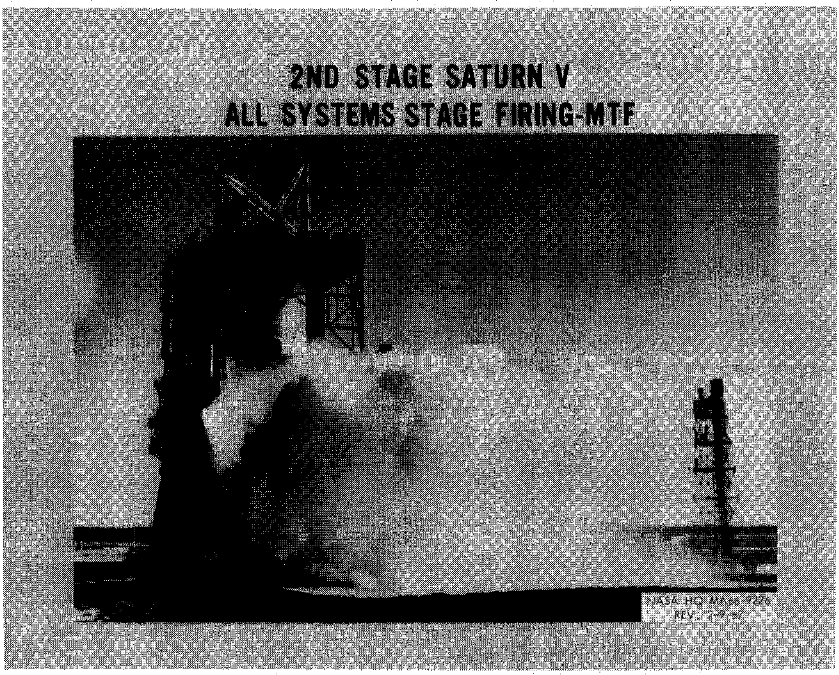


FIGURE 14

lowing the completion of the firing testing down there, we had planned to take the stage down and move it to Marshall for use in the dynamic test vehicle. We successfully completed the firing of the all-systems stage and were in the course of the dismantling of it from the test stand. Certain things had happened during static firings and they were being repaired and tested before shipping them to Marshall. There was an accident caused by overpressurization of the second stage and that, in turn, resulted in the destruction of the stage (fig. 15, MA-66–9250). That had several consequences, the principal one was that we had to divert our structural test stage from the testing down at the cape to the dynamic test vehicle at Huntsville. That meant that we had to make one stage do the work of several stages.

Fortunately for us, it had completed its firings and therefore it had provided us with the information we needed to go forward with the flight stage itself.

Mr. Fulton. Is that a personnel error or equipment failure?

Dr. Mueller. There was a report prepared by the Accident Review Board. They attributed the failure to a combination of personnel error and also to an overstressing of the stage itself, so it was a combination of two errors, if you will.

Mr. Fulton. Do you mean the personnel error was an error in planning or an error in real-time operations?

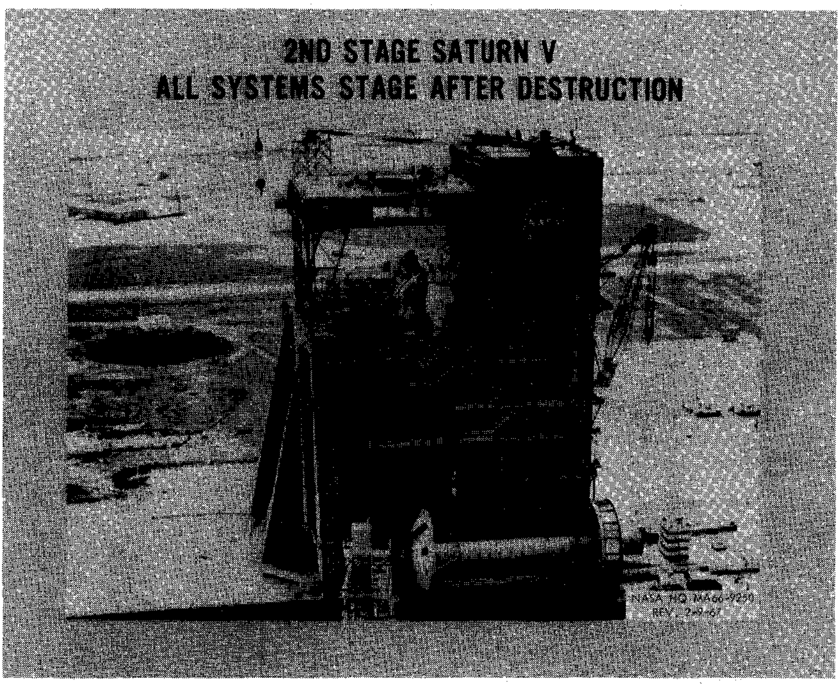


Figure 15

Dr. MUELLER. It was an error in real-time operations. The pressure gage on the stage was not operating, the test conductor continued to pressurize the stage without an operating pressure gage, and the result was destruction of the stage.

Mr. FULTON. Why wasn't the pressure gage operating? That looks like an equipment failure of a small routine nature.

Dr. MUELLER. The pressure gage was inoperable because it had been, as I understand it, disconnected.

Mr. RUMSFELD. You said that the Accident Review Board looked into this. What accident review board? A board created just to look at this accident?

Dr. MUELLER. Yes, headed by Dr. Kurt Debus with membership from other centers who reviewed in some detail the complete sequence of events.

Mr. RUMSFELD. There is no way this board could be described as an independent review board? They were NASA people or contractor people?

Mr. MUELLER. There were NASA people on the board, although they were from different centers, and were not associated with the actual test or the carrying out of the test. The test itself was under a contractor's supervision at the time. The stage had been turned back to the contractor to prepare for shipment and in this particular case there was not a NASA test supervisor. It was in a repair-rework cycle.

Mr. RUMSFELD. For the sake of definition when I use the word "independent", I would not include other NASA personnel even though they may not have been involved in the project. That is what I mean by the word. Also, did the President's Scientific Advisory Board take a look at this?

Dr. MUELLER. I don't know the answer to that, Mr. Rumsfeld. My timing is a little vague today. I don't know whether they actually looked at that particular failure or not.

Mr. WAGGONNER. This isn't a proper function of the Board, is it?

Dr. MUELLER. No.

Mr. RUMSFELD. I am trying to understand the general procedure. You indicate it is not a function of the President's Scientific Advisory Committee. That was my understanding. Yet your response yesterday led me to believe that you considered this body somewhat of an independent review board over NASA.

Dr. MUELLER. I said that they did review the Apollo program, Mr. Rumsfeld, from end to end. They did review the various failures. I don't know whether this failure occurred after the time that their review was completed or not. I believe it occurred after their review was complete. They do not serve as a case by case review board.

Mr. WAGGONNER. Will you yield?

Just before you came in, Mr. Fulton asked the same question on review boards for the same purpose, did he not?

Mr. FULTON. I asked about practices and procedures and I asked that it be put in the record.

Mr. RUMSFELD. I am aware of that. I asked a number of questions on it yesterday. I am still interested.

Mr. WAGGONNER. Proceed.

Mr. RUMSFELD. Did you agree with Mr. Waggonner that this was not a function of the President's Scientific Advisory Committee?

Dr. MUELLER. It is not their function to review accidents per se. They reviewed the Apollo program including our failure history before arriving at a conclusion about both the management and progress.

Mr. RUMSFELD. How would you describe this failure or accident, as a major one?

Dr. MUELLER. In terms of when it occurred, it would not have a major impact on the program, so I guess I would describe it as not of major significance. The reason I am not saying it is a minor accident is that I don't regard any accident or any failure in the program as minor and we treat each and every incident of this sort with a great deal of care, with a great deal of attention, so that we can understand the causes of the failure and be sure that it doesn't occur again.

I would like to say one word about independence of our accident review boards. Although they are composed of NASA personnel in large part, they, nevertheless, are carefully selected to bring new viewpoints, but also a good understanding of the actual problems to the review.

In such complex systems as these, it is essential that people understand what the system is, how it should work, and be able to identify what was wrong in order that corrective actions can be taken.

Mr. BELL. Mr. Chairman?

Mr. WAGGONNER. Mr. Bell.

Mr. BELL. You say major or minor. How do you measure that? Financewise or whether it slows the program?

Dr. MUELLER. That was my point. I regard all accidents as major.

Mr. BELL. When you say it is not of major proportion, do you mean because of the cost?

Dr. MUELLER. We did not have to add substantial cost to the program to compensate for this failure because it had completed the major part of the work we planned to do with it in the program.

Mr. FUQUA. Dr. Mueller, in the review of this accident, what recommendations did this review board make so that this type of thing does not happen again? What do you do about the personnel who continued with pressurizing, when it was obvious that the pressure gage was not working?

Is there any disciplinary action involved?

Dr. MUELLER. There are specific actions that are taken in each case. It depends on the circumstances as to whether or not there is disciplinary action taken. It is not always the best thing to do to just fire the individual because he isn't likely to pressurize the stage again without having a pressure gage working. Clearly, however, he is disciplined. In this particular case several actions were taken including a change in our own procedures to be sure that we did have proper supervision of all the operations in the test stands and to be sure that the responsible people were supervising the tests on the contractors side, so there are specific actions taken in every case.

In some cases the board recommends a set of actions. In every case the center involved carries on an independent review and takes additional actions.

Mr. FUQUA. You try to take corrective action so that this same individual will not go to sleep at the switch again, so to speak?

Dr. MUELLER. Yes, sir.

Mr. FUQUA. Because this can get rather expensive.

Dr. MUELLER. So far, we have not, to my knowledge, repeated an accident in the program. We have learned from each one, we have learned enough to avoid doing that again.

Now, it is not, however, true that we haven't had the same or similar kinds of accidents in various contractors plants because there are different ways of doing things and, occasionally, we will have a similar accident occur in a different contractors plant for different reasons.

Mr. FUQUA. In short, you try to take corrective action so that this same type of situation will not develop again?

Dr. MUELLER. We take very positive corrective actions and we have had good experience in this regard.

Mr. FUQUA. Thank you.

Mr. GURNEY. I would like to bring to the attention of the subcommittee that, on the trip of the subcommittee to California this year, this accident was gone into at great length in our hearings with the contractor involved and it will be in the report of the hearings.

One of the interesting things was the fact that the contractor itself, on its own initiative, pinpointed the cause of this accident almost within a matter of hours after its own investigation into the accident in great detail, and also has revised its procedure to see that nothing like this occurs again.

I think that should be brought out in the hearing at this time.

Mr. RUMSFELD. Dr. Mueller, you made the statement that you never repeated an accident. This, of course, is good. On the other hand, if an overall procedure is defective and therefore permits new and different accidents to occur from time to time; this, in essence, is equal if not more serious than repeating a specific accident.

The point I am raising is this question of the possibility of a truly independent review board. My thought is that if one existed—and it does not now exist, and there seems to be no inclination to create one—this type of mechanism could, over a period of time, help to pinpoint potential difficulties before they lead to accidents and thus would be very useful.

You made a comment on this subject which interested me. You indicated the importance of having people who understand the system well enough to serve on these accident review boards with respect to this one you mentioned.

Are you suggesting that there are not people who are not NASA employees or contractor employees who have sufficient competence in these areas to serve on such a board?

Dr. MUELLER. Well, no, I wouldn't say that at all. The problem one finds, of course, is that the number of people with experience in this kind of development program, with this kind of equipment and this kind of operation is quite limited. You can't draw on a very large number of people in universities, for example, because this is a different thing than universities are accustomed to.

You can draw on the Air Force for competence in this area because they have had experience in ballistic missiles but then to a very large extent, we are already drawing on the Air Force for this. I think you have to recognize that we are developing a new technology, and I think, in all honesty, you also ought to recognize the people involved in this development process in the Government and among the contractors are probably among the most objective and dedicated people that you will find anywhere.

Our progress is determined by their willingness to examine objectively the things that they did wrong and take corrective action. It is always true that looking back you can say "Well, gee, this guy shouldn't have done that," and that is right, 20/20 hindsight is just marvelous. But in terms of your overlook at the procedures, you must determine, is our general attack on the problem proper? That is something that the President's Science Advisory Board did look at very carefully and tried to evaluate whether or not our approach was a sound one.

The result of that investigation was a clear feeling on their part that we were using the best practices that they could conceive of. They didn't rubberstamp it. They are a group that has competence in this field and are outside of our organization completely, but they did feel that we were doing everything that they thought one could do in this kind of an area.

Now, that doesn't say that you couldn't do better and we are striving very hard to find ways to do things better. I would only point out that independent review boards of specific accidents of the sort we have here are unlikely to be able to contribute effectively in a short time to curing the problem.

That is not because I am against an independent review board. I am enthusiastic about it. One has to get the proper people to serve, the proper amount of time, and it does take a fair amount of time, as you know, to know enough about these systems to be able to do something constructive.

Mr. RUMSFELD. You mentioned that these men are dedicated. Certainly I don't question in any way their dedication. You also mentioned the word "objectivity" and this is the area that I am probing in. You also mentioned that it is nice to have 20/20 hindsight, and I am not raising that question at all about the advance of hindsight in knowing that the pressure gage should have been working, but I am talking about this broader question of a review board.

You indicate that the President's Science Advisory Committee has tried to evaluate whether this program makes sense from a safety standpoint. I have trouble understanding the extent to which they went into the safety question in view of the fact that, according to you, they did not make any recommendations in the area.

It raises the question in my mind, was this even a minor part of their interest, let alone a major part? I am not referring to an independent review board with respect to specific accidents. I am thinking of an independent review board that would not have the problem that you mentioned of becoming knowledgeable enough to do a competent job after a specific accident. I am talking about an independent review board that would look at the overall picture, as you proceeded, to prevent accidents and to ask the hard questions that someone possibly too close to it isn't asking.

I think maybe one of the ways I can better understand this would be if I could see the number of accidents you have had that resulted in a cost of excess of $100,000 and the type of people that were on the boards that investigated those accidents.

Dr. MUELLER. I will be glad to find that. We are going to put together some material in this area that Mr. Fulton has asked for. We will try to do just that.

Mr. RUMSFELD. I don't understand how the Navy and the AEC can do it with respect to the Polaris submarine, how they could get this independent review and why it couldn't and shouldn't be done by NASA. I want to see what the differences are. At some point we better understand this problem.

Mr. WAGGONNER. The chairman wants to finish Apollo today. Will the gentlemen agree that any other questions he may have will be given to Dr. Mueller in writing?

Mr. RUMSFELD. I have written to Mr. Webb. Since the first 50 pages was on the accident, I thought it would be appropriate.

Mr. TEAGUE. Mr. Rumsfeld, the investigation hearing on the accident will be broad, and you are invited to attend. Safety questions might better be asked there.

Mr. RUMSFELD. I am not privileged to serve on the Oversight Committee.

Mr. TEAGUE. You will be invited to attend whether you serve on it or not.

Mr. RUMSFELD. Fine.

Dr. MUELLER. Turning to the second stage, we also have problems on it with respect to getting the first flight stage down to Mississippi.

To put this in perspective, you have to recognize that the second stage is perhaps the most difficult technical development in the Saturn V vehicle. It represents a step forward, a rather considerable step forward in that it is the largest cryogenic stage we have yet developed.

We did, in order to proceed with the program, substitute in our initial checkout of the Saturn V, at Cape Kennedy, a spacer (fig. 16, MA 67-5796) that permitted us to check the ground support equipment, the electrical support equipment of the first stage, third stage, the instrument unit and the spacecraft while waiting for the initial second stage to complete its firing at the Mississippi test facility.

That was successfully completed at the end of 1966 (fig. 17, MC 67-5998) and the complete vehicle is now being stacked up in Florida.

Another problem that we ran into was the loss of the third stage for AS-503 at Sacramento during its static firing test (fig. 18, MC 67-5707).

We found here a problem that occurred in a vendor's plant, a substitution of a pure titanium welding rod for the right kind of welding rod which caused the pressure vessels in the stage to burst. These are titanium tanks that contain high pressure helium and over a period of time there was sufficient growth of a titanium alloy hydride in the joint of the weld to cause a fracture and this resulted in the loss of a stage.

We were able to trace it all the way back to the manufacturing process that failed and again it turned out in this case to be a human error. The inspector said it was the wrong welding rod and the welder

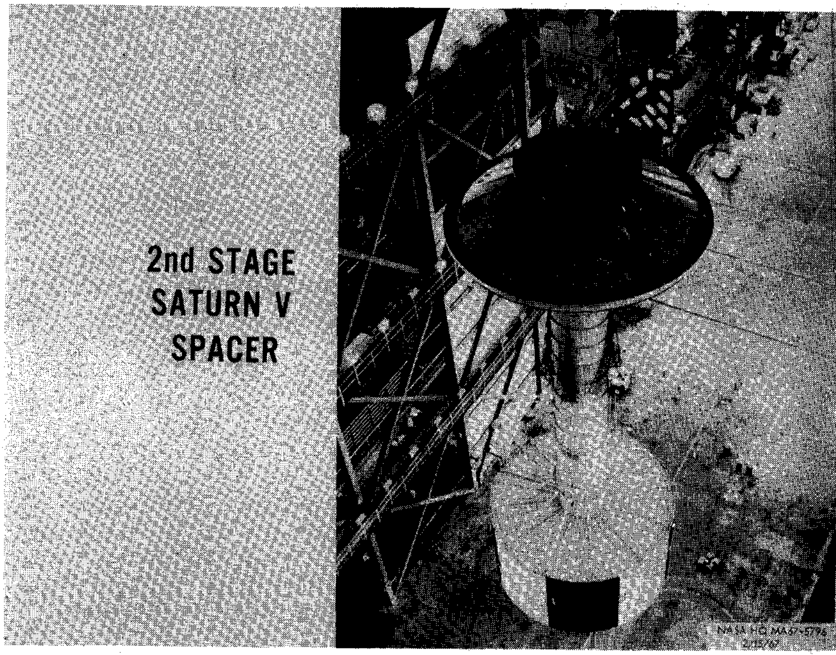


FIGURE 16

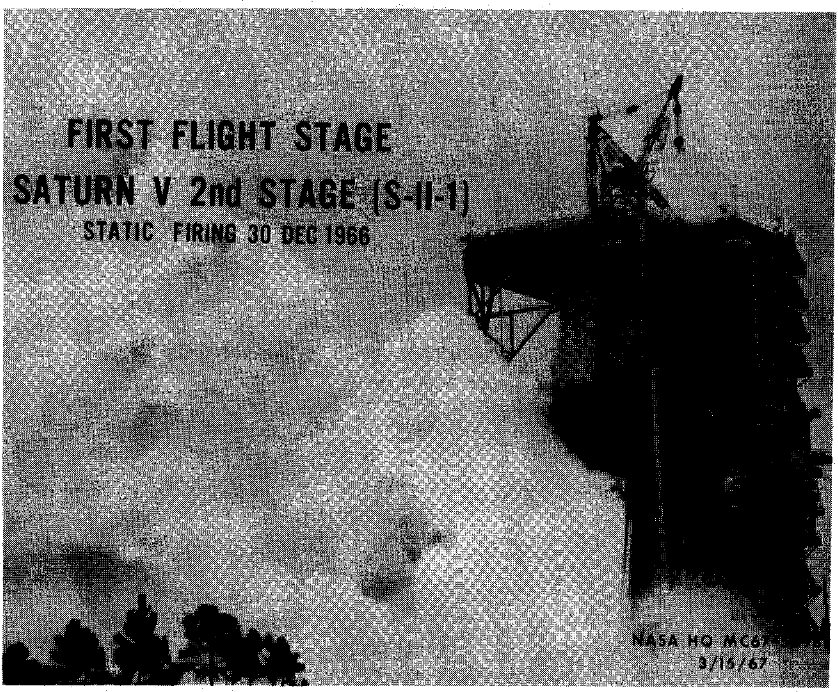


FIGURE 17

welded it again. We have gone back through and we have found techniques for detecting the use of the wrong welding rod. We replaced all the pressure vessels that had the basic problem and we are proceeding with the testing of the next stage in line.

There is a monetary impact on the program because of this failure. It is, however, in a stage that has been ahead of its basic schedule over the past several months, so that the stage, the third stage for AS–504 which is now in test on Beta 1 at Sacramento is able to maintain the schedule (fig. 19, MC 67–6002).

I think this is an illustration of the fact that we have tried, throughout the program, to provide some flexibility by establishing our contract structure in a way that provides stages early, spacecraft early, where it is possible because of the development cycle to do so.

In this particular case we were sufficiently far ahead of schedule in this third stage delivery so that we are able to maintain the basic Saturn V schedule without an impact.

Our status on the launch vehicles can be summarized by looking at these next two charts (fig. 20, MA66–9694A). The gray area represents the amount of the stage that is completed and as you can see, we have begun working and are about a fourth of the way through the last stage of manufacturing on AS–212, the last of the present Apollo Saturn ones.

In the case of the Saturn V (fig. 21, MA66–9694B), we have the first two vehicles completely manufactured and as you can see, the

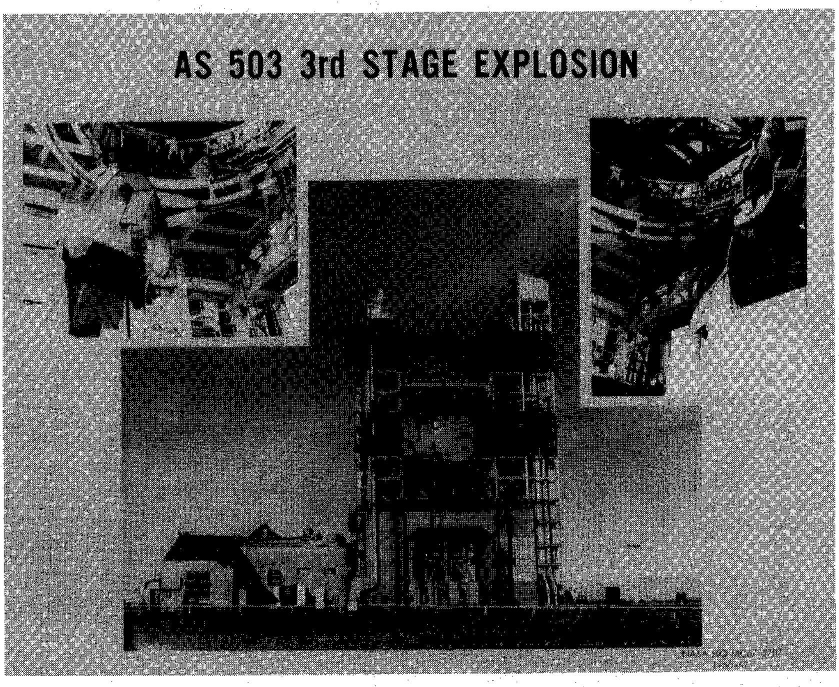


FIGURE 18

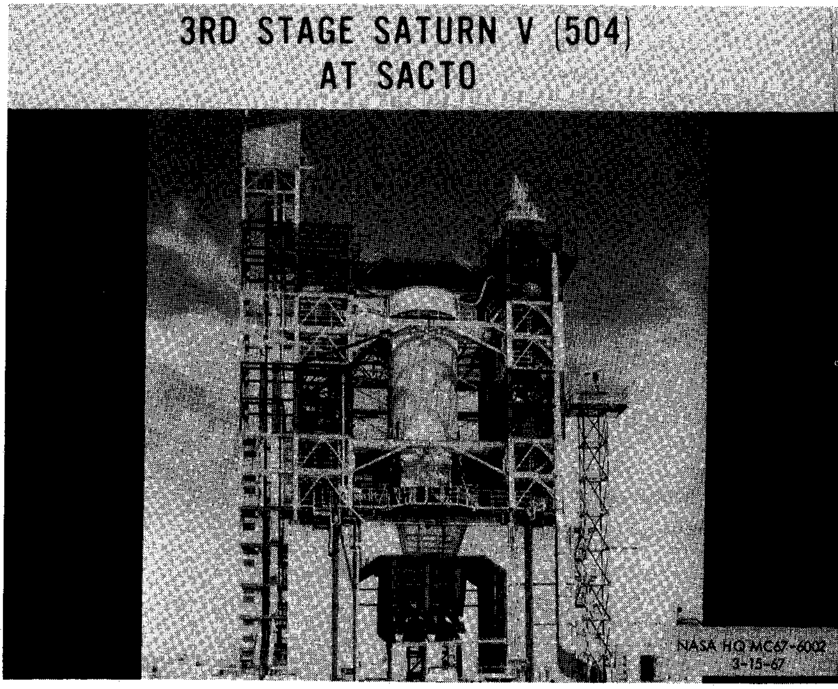


FIGURE 19

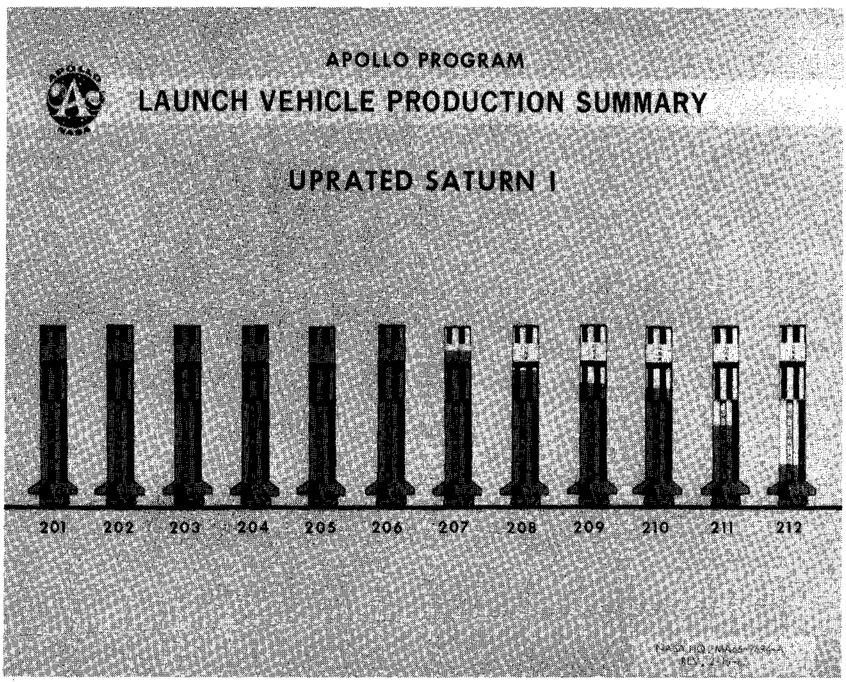


FIGURE 20

others are in some stage of manufacture or long leadtime procurement. The last three are in the process of long leadtime procurement.

Mr. FULTON. When we see a whole group of Saturns such as that, is that a covey? An array? What is it? What is the technical term?

Dr. MUELLER. That is our complete contractual commitment.

Mr. FULTON. If you see quail, it is a covey of quail or a pride of lions. What is it of Saturns?

Dr. MUELLER. Mr. Fulton, they haven't developed it——

Mr. WAGGONER. A bevy of boosters would do, wouldn't it?

Dr. MUELLER. Turning to the planned activities and accomplishments in the spacecraft area (fig. 22, MC66-10398). We did plan to initiate flight tests of the block I spacecraft.

We did plan to activate the Houston thermal vacuum chamber and carry out tests on CSM 008 in support of CSM 012 and this was accomplished; as you can see on the right, the thermal vacuum test model CSM 008 is in the chamber at Houston (fig. 23, MC 67-5414).

We expected to complete the Service Module and subsystem tests in support of CSM 011 and CSM 012. That was done.

We did complete the block I Command and Service Module structural and thermal test. We began the initial testing of the block II spacecraft.

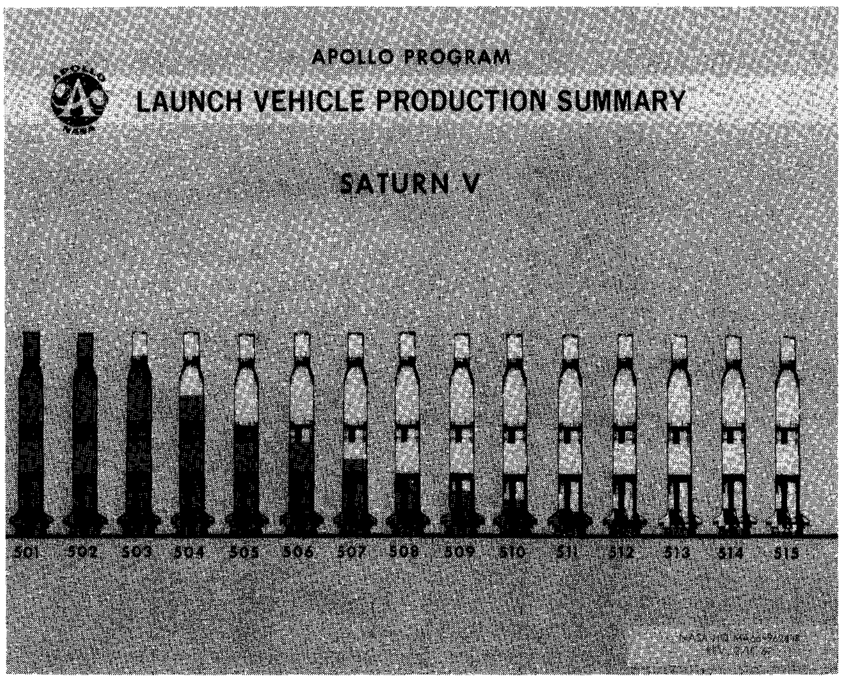


FIGURE 21

APOLLO PROGRAM

MAJOR 1966 PLANNED ACTIVITIES

SPACECRAFT	ACCOMPLISHED
CSM	
• INITIATE FLIGHT TEST OF BLOCK I SPACECRAFT	FEB.
• ACTIVATE THE HOUSTON THERMAL VACUUM CHAMBER	MAY
• COMPLETE 008 TESTS IN SUPPORT OF 012	AUG
• COMPLETE SERVICE MODULE-001 SUBSYSTEM TESTS IN SUPPORT OF 011, 012	JUL
• COMPLETE BLOCK I COMMAND AND SERVICE MODULE STRUCTURAL AND THERMAL TESTS	JUL
• BEGIN INITIAL TESTING OF BLOCK II SPACECRAFT	JUL
LM	
• STRUCTURAL LOAD TESTS	JUL 66-NOV 67
• CONTINUE PROPULSION TESTS	
• DELIVER FIRST FLIGHT VEHICLE TO KSC	
FLIGHT TEST ARTICLE	SEPT
FLIGHT VEHICLE	MAY 67
CHECKOUT	
• ACTIVATE FIRST TEST STAND FOR INITIATION OF FIRST BLOCK II SPACECRAFT CHECKOUT	SEPT
• SPACE ENVIRONMENT SIMULATION LABORATORY AT MSC OPERATIONAL	MAY

NASA HQ MC66-10,398
REV. 3-1-67

FIGURE 22

In the lunar module area we began structural load tests (fig. 24, MA66-9114). We expect to complete them later this year. We are continuing our propulsion tests and we have delivered the first flight test article to KSC, but not the flight vehicle. We are several months behind in the first flight Lunar Module.

Checkout. We did activate the first test stand for initiation of the first block II spacecraft checkout.

We do expect the Space Environment Simulation Laboratory at MSC to be operational. It is. That was completed in May.

One of our problems in the Service Module (fig. 25, MA66-9169) was, in fact, a form of stress corrosion. We found it in the test of Service Module for the CSM 017 which was the Service Module to be flown on AS501, the first unmanned flight of the Saturn V.

We were using methyl alcohol as a fluid to pressure test the Service Module tanks and had been doing this for a number of vehicles.

At the time that this explosion occurred, we went into, again, a rather intensive investigation. The investigation was carried out by the contractor since this was an early stage of the manufacturing process of the Service Module. We found that methyl alcohol, under

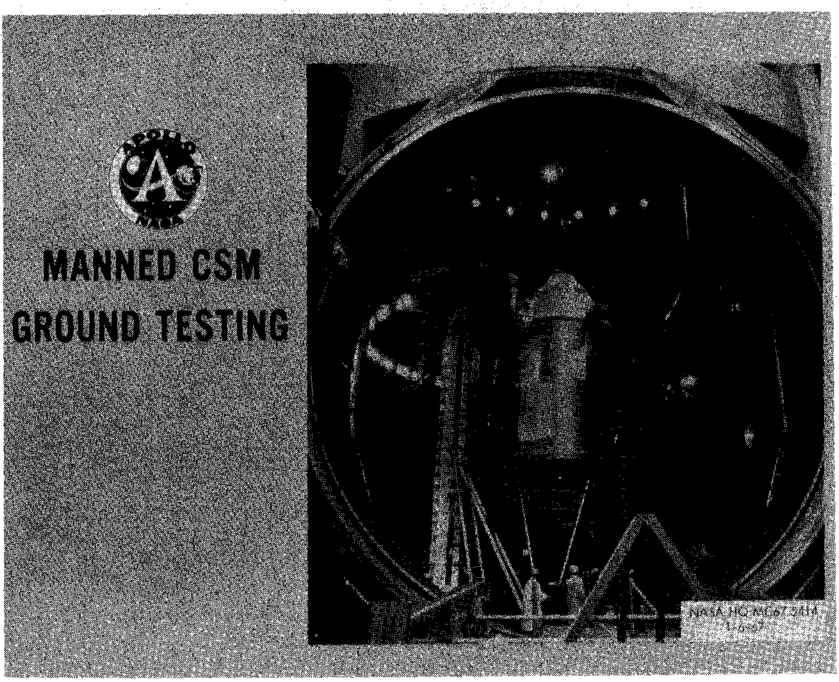


FIGURE 23

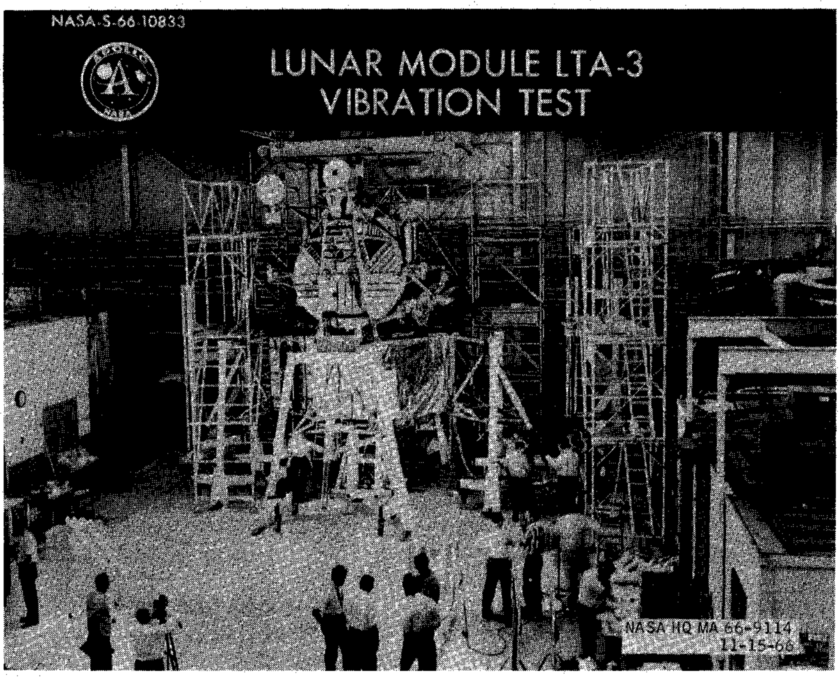


FIGURE 24

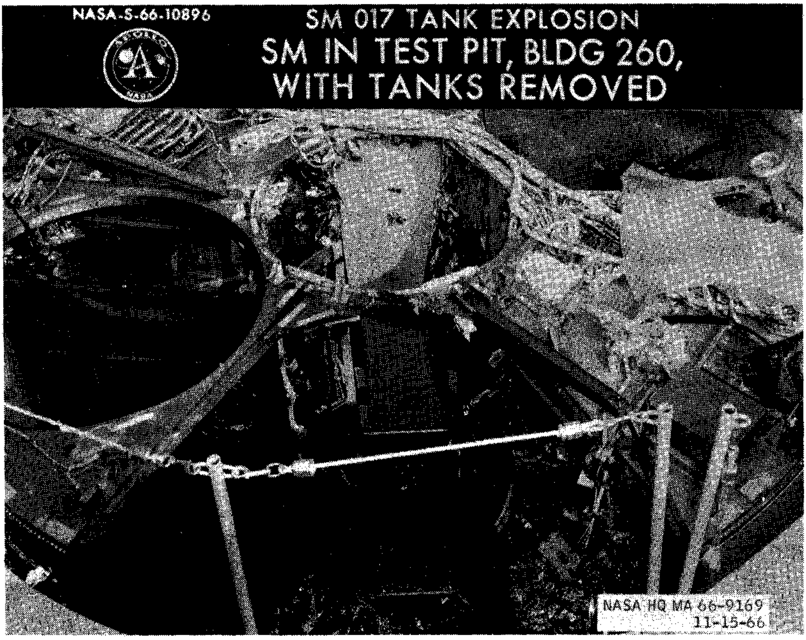


FIGURE 25

pressure will, in fact, induce stress corrosion in titanium. We found that we had to change the Service Module tanks on all of our spacecraft that had gone through this test cycle in order to be sure that they were safe.

Mr. FULTON. On the possible or probable change of insulation, couldn't you almost judge that you should get started on changing to the fiberglass insulation which is, of course, really flame resistant? In the tests we saw at Houston, there was a world of difference between that type of insulation and the type currently used. My point is when you can see that you are going to have to make some sort of change in insulation, why aren't we getting started so there will be no further delay on this equipment?

Dr. MUELLER. Mr. Fulton, there are studies being made of the changes that are required in order to make the spacecraft safe. Those studies are underway and we have felt that it would be better to understand the total problem before beginning to solve it piecemeal. Now, that doesn't say that we aren't going forward with the development of fiberglass replacements. It just, however, takes time to develop sources and to carry through the qualification testing of these sources. We would expect to be able to report to you again on that some time after the end of this month.

Mr. FULTON. When I saw that Rube Goldberg complex of wires in this particular illustration, it certainly pointed up to me the amount of change and the amount of time that might be necessary.

Dr. MUELLER. I understand and it is of concern to us. I might point out that this is an example of the kinds of things you learn in the course of the development program. The accident that we had with the CSM 017 tank has contributed to our knowledge of titanium and its characteristics; it has triggered a rather extensive test program that will permit us to have a good understanding of the various forms of stress corrosion to which titanium is subjected. I think this is an example where we are adding to knowledge by doing.

Mr. WAGGONNER. Proceed, Dr. Mueller.

Dr. MUELLER. Looking at our production situation on the spacecraft (fig. 26, MA66-9695B), we are essentially complete with the block I; the block II spacecraft are in test at Downey, now, and in various stages of production in the factory. We do have a long-lead-time procurement on all spacecraft of both the command and Service Module and the Lunar Modules.

Our major planned activity in 1967 in the spacecraft and launch vehicle areas are shown in figures 27 and 28 (MC66-9695A and MC67-5148).

In the case of the spacecraft (fig. 29, MC67-5149), we expect to complete the block I and block II CSM ground test program, we expect to complete the Block II CSM subsystem certification and, of course, we still are finishing out the certification process because we are still flying two of the unmanned Block I spacecraft. We will expect that to be complete some time this summer.

We will complete the qualification of the Block II extra vehicular Mobility Unit. That is the space suit. Extensive changes have been introduced that will give us more mobility.

We will activate Apollo mission simulators, complete delivery of five spacecraft adapters to KSC and complete delivery of Block I CSM to KSC. In the case of Lunar Modules, we expect to complete LM

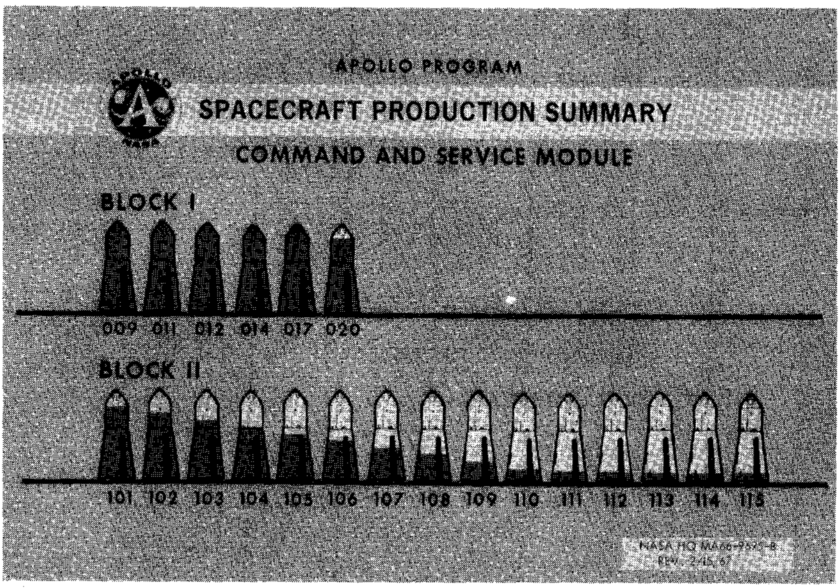


FIGURE 26

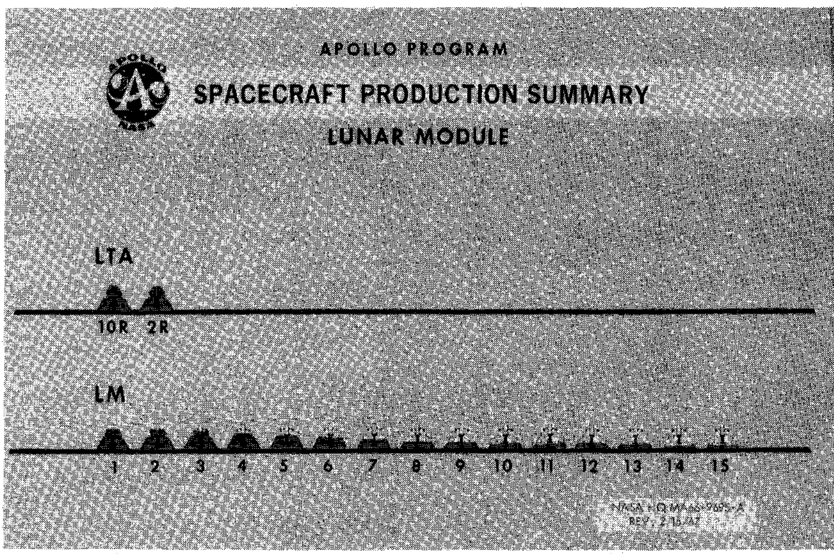


FIGURE 27

1967 PLANNED MAJOR ACTIVITIES
LAUNCH VEHICLES (L/V)

UPRATED SATURN I

- DELIVER STAGES FOR FOUR L/V TO KSC
- COMPLETE FABRICATION, ASSEMBLY AND FACTORY CHECKOUT OF STAGES FOR LAST THREE L/V'S IN PROGRAM
- DELIVER LAST J-2 ENGINES

SATURN V

- COMPLETE DELIVERY OF FIRST L/V TO KSC
- DELIVER STAGES FOR NEXT THREE L/V TO KSC
- COMPLETE DYNAMIC TEST PROGRAM
- ACTIVATE 1st STAGE ACCEPTANCE TEST STAND AT MTF
- ACTIVATE SECOND POSITION 2nd STAGE ACCEPTANCE TEST STAND AT MTF
- DEMONSTRATE 3rd STAGE RESTART CAPABILITY

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1967 PLANNED MAJOR ACTIVITIES
SPACECRAFT (S/C)

COMMAND AND SERVICE MODULE (CSM)

- COMPLETE BLOCK I AND BLOCK II CSM GROUND TEST PROGRAM
- COMPLETE BLOCK II CSM SUBSYSTEM CERTIFICATION
- COMPLETE QUALIFICATION OF BLOCK II EXTRA-VEHICULAR MOBILITY UNIT (SPACE SUIT)
- ACTIVATE LAST APOLLO MISSION SIMULATORS
- DELIVER FIVE S/C ADAPTERS TO KSC
- COMPLETE DELIVERY OF BLOCK I CSM'S TO KSC

LUNAR MODULES

- COMPLETE LM GROUND TESTING CONSTRAINING EARTH ORBITAL AND LUNAR MISSIONS
- COMPLETE PRODUCTION HARDWARE QUALIFICATION TESTS
- DELIVER LAST REFURBISHED GROUND TEST VEHICLE FOR SATURN V L/V QUALIFICATION FLIGHT

NASA HQ MC 67-5149
REV. 2-15-67

FIGURE 29

ground testing constraining earth orbital and lunar missions, we expect to complete the production hardware qualification tests and deliver last refurbished ground test vehicle for the Saturn V launch vehicle qualification flight.

We do not have a schedule for delivery of flight Lunar Modules to the cape, depending upon what, if any, changes are required.

Turning to the experiments program (fig. 30, A66–9770), we have a number of experiments being developed for Apollo. The in-flight experiments include medical, scientific, technological, and a few DOD experiments. These, in turn, however, are few in number as compared to the Gemini and Apollo Applications program. We are tending to shift experiments that aren't directly related to the lunar mission itself into the Apollo Applications program. In the case of the Apollo Lunar Surface Experiments Package (fig. 31, MA66–9806), we do have six experiments being developed. As you can see in the right-hand chart, the general concept consists of a central data gathering and transmitting system with outlying sensors to provide the information that is then transmitted back to earth. It is designed for operation for about a year on the lunar surface, both night and day.

We are also developing equipment for geological survey of the lunar surface; they include handtools, sample containers, and, of course, the mapping and survey system.

APOLLO PROGRAM

THE APOLLO EXPERIMENTS PROGRAM

- **IN FLIGHT EXPERIMENTS**

  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
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FIGURE 30

With respect to the present position of the Apollo R. & D. program (fig. 32, MC66-10, 277), our costs per month have been decreasing in fiscal year 1967 and we project a continuing decrease through fiscal year 1968.

As you can see, in terms of the cost, we hit a peak in April and May of last year and have been going down fairly rapidly ever since. That, of course, is due to the manpower curves that you see on the right-hand screen. These are total Manned Space Flight employment figures, about from this point on, almost all of that is Apollo.

There are only a relatively few people involved in things other than the Apollo program (fig. 33, MC67-5724). We went through our peak of about 300,000 people in May of last year and we have been going down rapidly since then. You can see that that decrease will continue on the basis of the Apollo program from now on. In fact, we are going down at a rate which is about as precipitous as you can go and still maintain the basic integrity of the contractors' structure. If you go too fast, then the organization tends to react.

Now, if I may turn to the budget book, I would like to, Mr. Chairman, very briefly, summarize the material in the book.

First let me turn to the fiscal year 1968 funding required to maintain the Apollo program. If you turn to volume V, pages RD 1 and

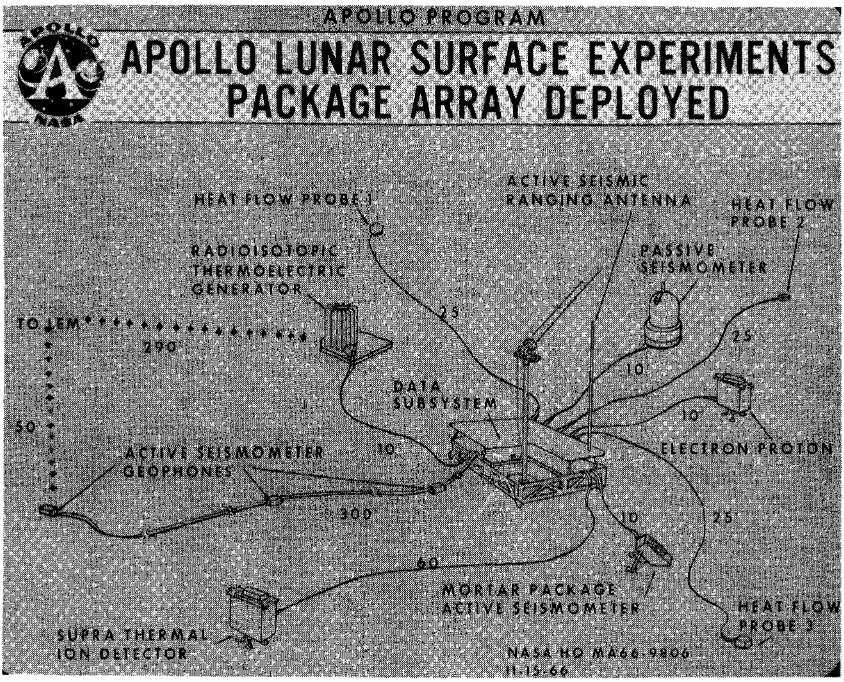

FIGURE 31

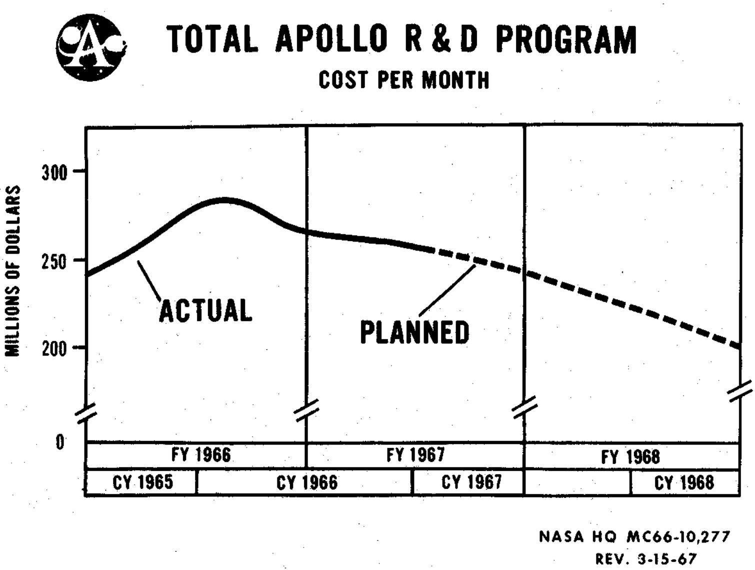

FIGURE 32

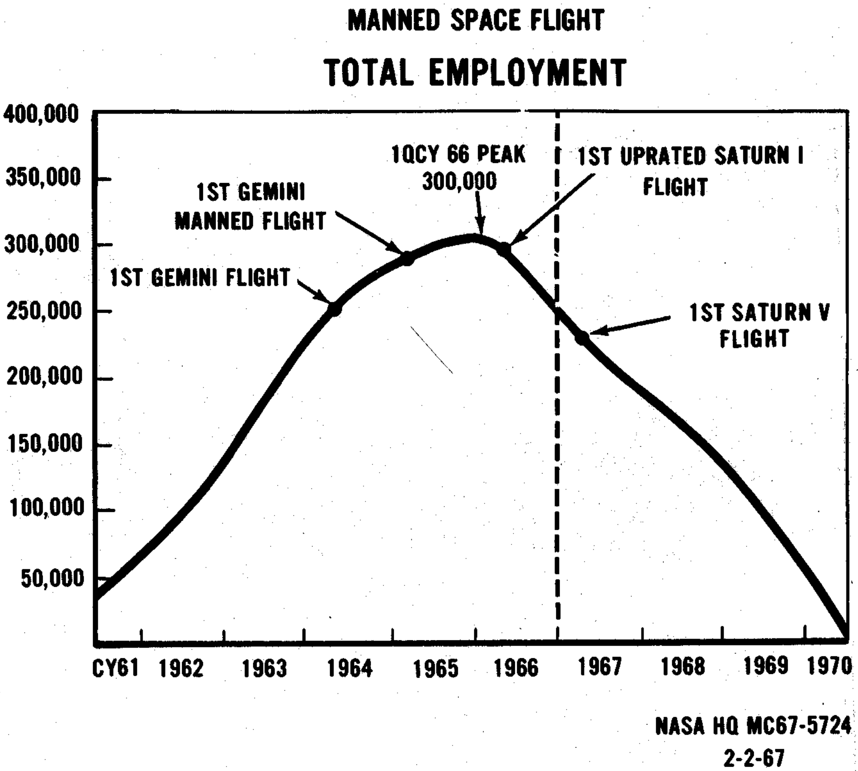

FIGURE 33

2 of the budget estimates you will see that 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. 34, MP67–5441), the fiscal year 1968 Apollo budget is divided into five line items: Spacecraft, Uprated Saturn I, Saturn V, 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.

We feel that we will be able to continue our Apollo program within the total resources detailed in the fiscal years 1967 and 1968 budgets.

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 fiscal year 1968, we will be heavily involved in assembly, checkout, and launch operations at the Kennedy Space Center, mission control activities at the Manned Spacecraft Center, and reimburse-

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 34

ment 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. 35, 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 continued 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.

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 35

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, Calif., plant, followed by shipment to Kennedy in preparation for uprated Saturn I 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 Corp., Bethpage, N. Y., 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 fiscal year 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. The five Lunar Modules will be delivered to KSC, depending on the changes that are required as a result of our ongoing assessment.

Guidance and Navigation.—Moving down to the next item, we are requesting $55.4 million for the Apollo spacecraft guidance and navigation system in fiscal year 1968.

During fiscal year 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 mission the fiscal year 1968 activity will focus on spacecraft hardware verification, mission planning and analysis, and postflight documentation.

Fiscal year 1968 funds also cover the operation, maintenance, and updating of the 12 ACE stations to meet mission requirements, located at key Apollo spacecraft sites across the country.

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 fiscal year 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, Tenn., and altitude chamber tests at the Kennedy Space Center.

The fiscal year 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.

Uprated Saturn I.—Moving on to the Saturn-class launch vehicles, the next chart (fig. 36, MP 67-5437) 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 fiscal year 1968 request for the uprated Saturn I is $156.2 million—a decrease of $80.4 million from the fiscal year 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. Four additional launch vehicles are scheduled for

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 36

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 fiscal year 1967 level.

Stages S–IB and S–IVB: We are requesting $30.5 million for the Chrysler-produced first stage (S–IB) and $37.1 million for the Douglas-produced second stage (S–IVB) in fiscal year 1968. These funds support completion of the 8th through 12th flight stages, which are currently phased into manufacturing, assembly, acceptance testing, or checkout.

Instrument unit and GSE: Fiscal year 1968 funds in the amount of $22.6 million are required for the instrument unit. The fiscal year 1968 funds provide for completion of assembly, checkout, and delivery of the remaining five instrument units required for Apollo-Saturn I vehicles.

We are also requesting $6.5 million in fiscal year 1968 to cover the operation and updating of stage and vehicle ground support equipment to meet specific mission requirements. Operational requirements for the Marshall breadboard facility, which is also 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 $0.9 million for J–2 engines.

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 of flight worthiness was transferred to this account.

The fiscal year 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 fiscal year 1968 requirements are $53.4 million, covering the support requirements during a period of intensive launch activity. During fiscal year 1968, heavy emphasis will be placed on uprated Saturn I prelaunch and launch support.

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 on this chart (fig. 37, MP 67–5436). In

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

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FIGURE 37

addition to the intensive ground test program that has been underway, fiscal year 1967 marks the peak year for Saturn V hardware production to meet the scheduled flight missions. The funding requested for fiscal year 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.

Let me go into the detail of the Saturn V requirements for fiscal year 1968, beginning with the first stage (S–IC).

First stage (S–IC): We are requesting $174.7 million in fiscal year 1968 to carry forward the manufacture, test, and checkout of Saturn V first stages on a time-scale consistent with the planned flight schedule.

The fiscal year 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 poststatic checkout at Michoud, and delivered to the Kennedy Space Center. The 7th and 8th first stages are scheduled to complete assembly, in-plant checkout, and static testing; and the 9th and 10th are scheduled to be through manufacturing and checkout at Michoud. The five remaining stages will be in manufacturing during fiscal year 1968.

Second stage (S–II): Moving down to the next line item, our fiscal year 1968 Saturn V requirements include $245.9 million for the second stage (S–II).

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 7th through 12th 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.

Third stage (S–IVB): The next line item on the chart shows the funding estimate for the third 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 Uprated Saturn I, are funded in this particular line item.

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 poststatic checkout, in preparation for shipment to Kennedy Space Center. Fabrication, assembly, in-plant checkout, and acceptance testing of the 7th and 8th flight stages are planned, and the 9th and 10th will be through fabrication and assembly in preparation for acceptance firing at Sacramento by the end of the year. 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 fiscal year 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 fiscal year 1968.

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 fiscal year 1968 Saturn V engine requirement are $105.3 million for the F–1 and $78.5 million for the J–2.

The last full year of funding the contractor development effort under the engine development project line item was fiscal year 1966. After completion of qualification in 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 fiscal year 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 postflight 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 first and second 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. 38, MP67–5439). We are requesting $24.5 million in fiscal year 1968 for engine development, a significant drop from fiscal year 1966 and 1967 requirements, since all three of our major vehicle engines are now

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

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FIGURE 38

qualified. Upon completion of engine qualification, funding of contractor effort was transferred to the respective engine account of the Saturn launch vehicles.

The fiscal year 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, Tenn.

Misssion support requirements for fiscal year 1968 are $281.0 million and reflect the increasing tempo of flight activity, since this line item provides for the overall launch, flight, crew and recovery operations; programwide 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 $20.0 million is requested, provides for integrated technical support, review, and analysis of manned space flight missions.

The $32.0 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.

Mr. WAGGONNER. Thank you. Any questions?

Mr. RUMSFELD. Yes; on page R.D. 1–2, is it correct that the $60 million shown there is your estimate of unobligated funds as of June 30, this year?

Mr. LILLY. No, sir. The President imposed a restriction on all agencies and pulled back certain moneys which are not available to us this year. The amount pulled back from NASA was $60 million, which is subsequently being made available to cover our cost in fiscal year 1968.

Mr. RUMSFELD. Where is the figure for any sums previously authorized and appropriated, not including that $60 million you anticipate will remain at the conclusion of this fiscal year?

Mr. LILLY. We do not anticipate there will be any unobligated balance in the Apollo program in fiscal year 1967. Our history in the prior years has been that we have always obligated about 99.8 percent of our Apollo funds.

Of course, you will always have a balance of a few hundred thousand in many different elements. However, this amounts to less than two-tenths of 1 percent.

Mr. RUMSFELD. That doesn't show up in the budget book?

Mr. LILLY. That is correct.

Dr. MUELLER. We have used every dollar that the committee has given us for Apollo in the last several years. We have adopted the philosophy that you gave us this money to carry out the program and we are using it as effectively and as efficiently as we can.

Mr. RUMSFELD. If it doesn't come out, then you make a reprograming request?

Dr. MUELLER. We do shift funds within the reprograming authority provided to us by the Congress in order to support the areas where we have problems.

Mr. WAGGONNER. Any further questions?

If not, the committee is adjourned until 10 a.m. tomorrow morning.

(Whereupon, at 11:50 a.m., the subcommittee adjourned until 10 a.m., on Thursday, March 16, 1967.)

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1968 NASA AUTHORIZATION

THURSDAY, MARCH 16, 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.

We will go to the Apollo Applications program this morning.

Please proceed Dr. Mueller.

FURTHER STATEMENT OF DR. GEORGE E. MUELLER, ASSOCIATE ADMINISTRATOR FOR MANNED SPACE FLIGHT, NASA; ACCOMPANIED BY WILLIAM E. LILLY, DIRECTOR, MANNED SPACE FLIGHT PROGRAM CONTROL, NASA; ROBERT F. FREITAG, DIRECTOR, MSF, FIELD CENTER DEVELOPMENT, NASA; CHARLES W. MATHEWS, DIRECTOR, SATURN APOLLO APPLICATIONS, NASA; AND JOHN H. DISHER, DEPUTY DIRECTOR, SATURN APOLLO APPLICATIONS, NASA

Dr. Mueller. This morning I would like to provide an outline of the Apollo Applications program. As you know, the Apollo program will itself by the end of this year have developed two sets of space flight vehicles (MPR66-7783, fig. 1) the first of these is the Apollo Saturn I and by the end of 1967 all elements of the Apollo Saturn I vehicle including the first and second stage, the lunar module and the command and service module should be qualified for manned flight.

By the end of 1967, we also expect to qualify for manned flight the Apollo Saturn V. Sometime in 1968 we can begin manned flights on that vehicle. Schedules for the development and qualification of these vehicles are shown on the slide on the right and this slide and its schedules have remained constant for the last several years (MC66-5438A, fig. 2). This is essentially the same chart that I showed you in early 1964. You will note here that Apollo Applications uses the hardware that has been developed in the Apollo program to apply to missions other than the manned lunar landing and, in particular, we would expect during 1968 to begin the use of the uprated Saturn I for manned orbital missions in the area of astronomy and in the area of long-duration flight.

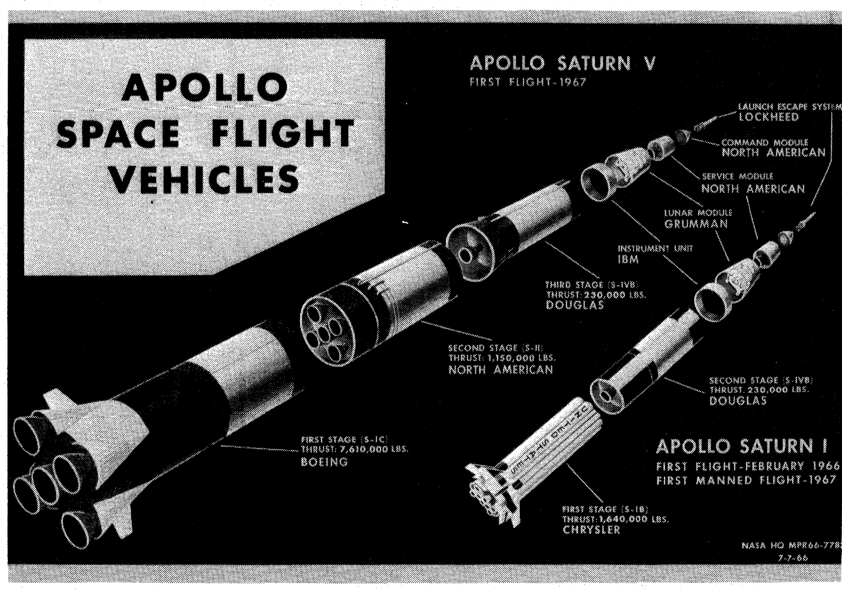

FIGURE 1

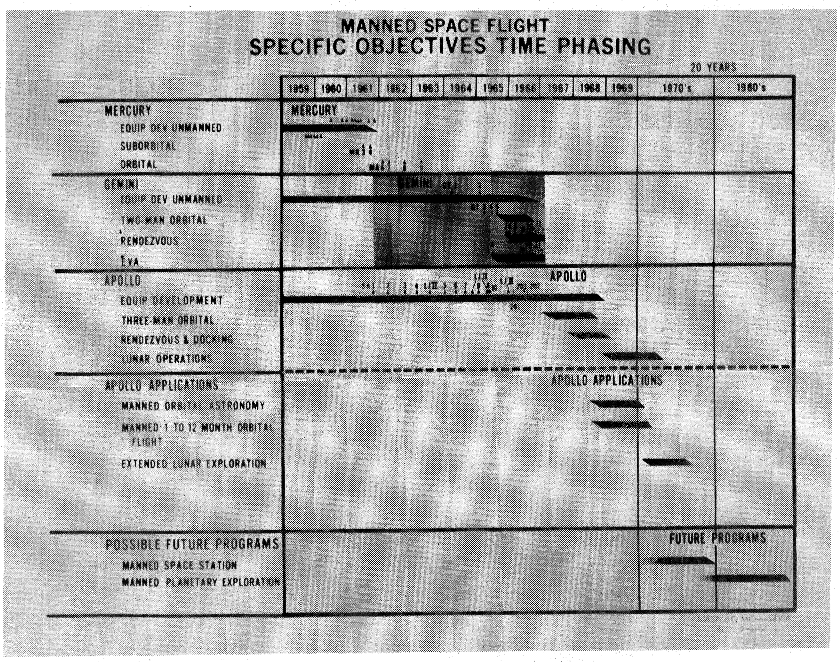

FIGURE 2

We would expect following the manned lunar landing to begin extended lunar exploration using this basic hardware but with modifications beginning in the 1970's.

In addition to the Earth orbital applications, one of the objectives of the Apollo Applications program is to lay a foundation for other future programs so that we do not come to the end and not establish a foundation for further manned and unmanned space flight activities. Apollo Applications does represent a bridge or transition from the Apollo hardware developed for the manned lunar landing and its use for those future programs which may be developed as a result of or experience in space activities.

There are two basic mission concepts that we use in the Apollo Applications program (MC 66–5173, fig. 3). As you know, we may be able to use some of the launch vehicles and some of the spacecraft that are in the basic Apollo program for missions other than the manned lunar landing. Whether or not these vehicles will become available depends upon our progress in the basic Apollo program. We believe that it is to the Nation's best interest to make most economical use of the hardware and equipment by providing alternate missions for the basic Apollo hardware. This will permit us to utilize these vehicles and these trained launch operational teams to carry out certain missions that apply the basic equipment to operations other than the lunar landing if this basic equipment becomes available from the basic Apollo program.

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 3

The second class of missions that we have are follow-on missions and here we do expect to use the basic hardware of the Apollo spacecraft and standard launch vehicles with certain modifications in order to permit them to work for long periods of time in Earth and lunar orbit and on the lunar surface.

The major Apollo Applications objectives (MC 67–5412, fig. 4) for each of these classes of missions are, first of all, to determine the usefulness of man in space. The Apollo developed equipment, our experience is showing, is applicable, versatile enough to be applied to missions other than the Lunar landing itself and one of the most important things to determine from our national point of view is how useful man can be in space, what it is you can best use him for and one of the primary objectives of our Apollo Applications program is to determine just how best to use man in space and whether or not it is worthwhile to have man engaged in these activities.

A second major objective and one which has obtained almost universal recognition from the scientists and other people who have looked at the possible use of man in space is the use of man to conduct astronomical observations. One of the major objectives of the Apollo Applications Program is not only to determine the range of astronomical observations that can be carried out in the space vehicles adapted from the basic Apollo hardware but also to determine the usefulness and how best to use man in this set of observations.

Now, the third major objective is to develop the capability for economical space flight through hardware reuse and long duration

MAJOR APOLLO APPLICATIONS OBJECTIVES

- USE APOLLO DEVELOPMENT TO:
  - DETERMINE USEFULNESS OF MAN IN SPACE.
  - CONDUCT ASTRONOMY OBSERVATIONS.
  - DEVELOP CAPABILITY FOR ECONOMICAL SPACE FLIGHT THROUGH HARDWARE REUSE AND LONG DURATION FLIGHT.
  - EXTEND LUNAR EXPLORATION.

NASA HQ MC67-5412
1-9-67

FIGURE 4

flight. Our studies to date have shown that the cost of having men in space is inversely proportional to how long they can stay in space. The major increment in cost is involved in getting into orbit and coming back down again. The expendables required to keep the man in orbit are a relatively small fraction of the total weight requirement and thus for most economical manned flight, one finds that the longer one can stay on a single flight, the more cost effective the use of man becomes.

In turn, of course, the ability to do that depends upon the development of the equipment for long duration flight. Our studies thus far have indicated that again the basic Apollo hardware is capable of extensions with minor modifications. Another important thing that we are studying is the reuse of the Apollo hardware. The Apollo spacecraft is a relatively expensive part of the equipment and we are studying the development of a land landing capability which would facilitate the reuse of this relatively expensive element of the total space vehicle.

Finally, the fourth objective is extended lunar exploration and I will spend some time later on that.

We have initiated the development of a piece of experimental apparatus called an airlock. This airlock is being developed by the McDonnell Corp. and parts of it actually are being built at the Marshall Space Flight Center. The airlock is under the supervision of the Manned Spacecraft Center, but the overall integration of the orbital workshop is under the direction of the Marshall Space Flight Center. This is the picture on the left. (MG 66–8987, fig. 5.)

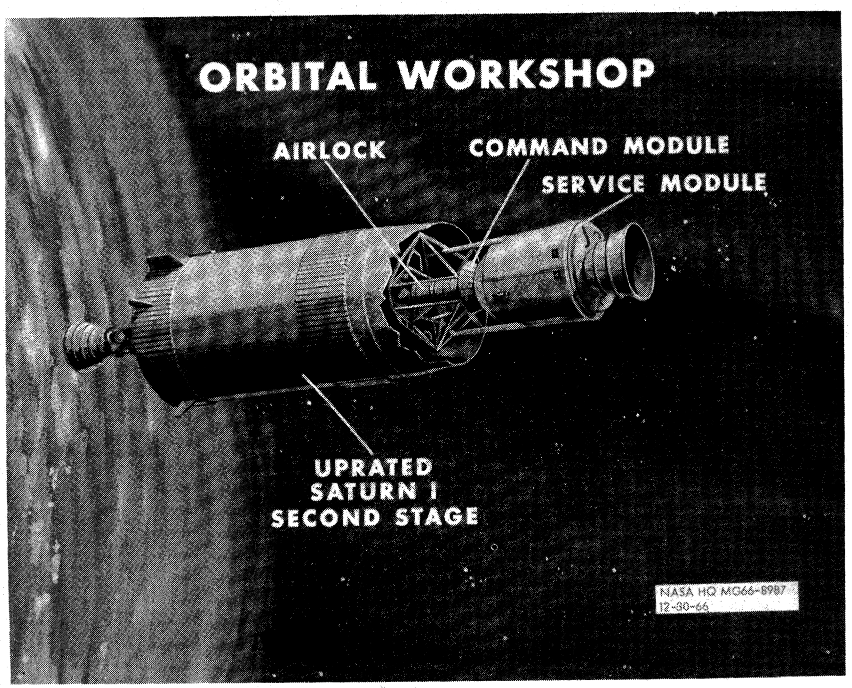

FIGURE 5

The basic concept here is one of making use of the hydrogen tank of the uprated Saturn I which is normally left in orbit to provide a pressurized volume in space, pressurized through the airlock, it provides us with some 10,000 cubic feet of space of pressurized volume and with the airlock we have the ability to both enter this pressurized volume, attach it to the command and service module in which the crew comes up and goes down again and also provides for docking other experimental modules as time passes. Included in the airlock itself is also a power supply, the equipment for making the internal part of the S–IV B hydrogen tank habitable, that includes the addition of floors, ceilings, walls and so forth. All this is carried up on one flight of the Saturn I.

A second flight brings the crew up with certain supplies.

Mr. GURNEY. May I ask a question?

Mr. TEAGUE. Mr. Gurney.

Mr. GURNEY. Do you use the engine and fuel in the second stage to get it up there?

Dr. MUELLER. That is correct. The second stage is filled with hydrogen and oxygen. It is placed in orbit by burning. When it is emptied and in the right orbit, the hatch is opened into the hydrogen tank. First of all the tank is vented and the hydrogen is let out into the vacuum of space. Then the hatch is removed, the airlock is opened and the crew enters and begins to build these floors and walls and install the equipment in very much like building a ship in a bottle except it is a very large bottle. (ML 66–9611, fig. 6.)

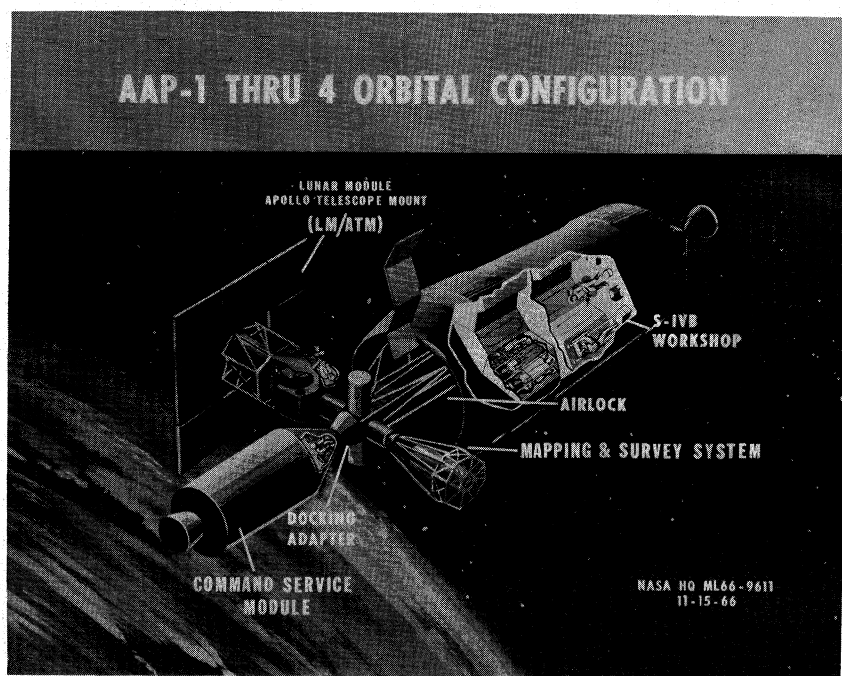

FIGURE 6

Mr. GURNEY. What boosts that?

Dr. MUELLER. There is another Saturn I-B that actually lifts the command and services module in the same orbit.

Mr. GURNEY. Thank you.

Dr. MUELLER. If you look on the right you can see some of the equipment that is being developed for experimental use inside the workshop (ML 67–5537, fig. 7). The interior of this S–IV B is a two-story arrangement (ML 66–9611, fig. 6). One floor is set up to be used as a living quarters for the astronauts and the second story is designed to be used for the maintenance area, laboratory area that is the second function of this workshop. On the right-hand side (ML 67–5537, fig. 7) you can see the heat exchanger experiment where principally you are looking to ways of developing maintenance capabilities, the ability to service this kind of equipment in orbit. There is a high-pressure gas experiment. Some of the things we don't know about are the changes that occur when you try to expand gas very rapidly through a small nozzle in a zero g environment as contrasted with the one g environment condition on Earth.

One of the interesting things that we can't really do here on Earth is to measure the rate of flame propagation in zero gravity.

Mr. ROUDEBUSH. Will the interior of this workshop be zero g? You are not going to simulate gravity in there?

Dr. MUELLER. No, we will not. There will be essentially zero gravity inside.

Mr. ROUDEBUSH. Thank you.

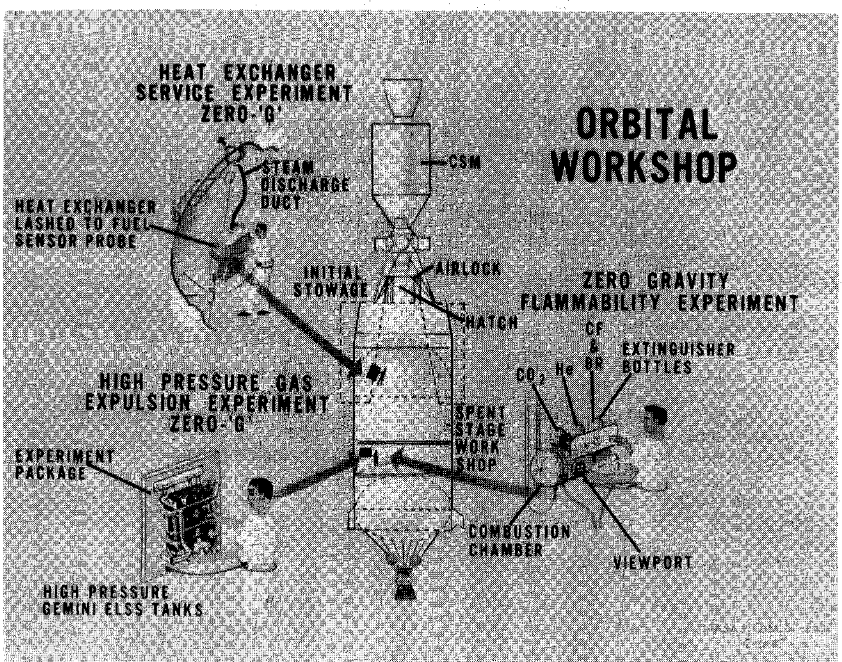

FIGURE 7

Dr. MUELLER. If we go forward, I would like to go through some of the experiments that are presently being planned for the orbital workshop. (ML 66–9785, fig. 8.) This is the list that is so far approved and, interestingly enough, we have sufficient experiments now so that we are beginning to have to shift the operation of the experiments from one mission to another. We may carry them up on the first mission, but we have to shift the actual operation or carrying out of the experiments downstream because we are running out of astronaut time even though they will be up a month if all goes well on this first flight.

In the area of engineering, we do have experiments on space suits and here we are particularly interested in learning how to design these suits using them so we can get time and motion studies in the zero g environment since that is an important element in the design of the restraint systems and how they actually work outside the spacecraft as well as inside. In the case of the workshop we can work in a relatively safe atmosphere because we can simulate being outside the spacecraft by increasing the suit pressure three and a half pounds per square inch above the ambient atmosphere. We can take pictures of what the astronauts are doing while using the suits and trying to do certain tasks in an area which is relatively safe and perfectly confined and it should improve our knowledge of extravehicular activities by intravehicular operations.

Mr. FULTON. When you are talking about difficulties of zero gravity,

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

DEPARTMENT OF DEFENSE

- D018 INTEGRATED MAINTENANCE
- D019 SUIT DONNING AND SLEEP STATION EVALUATION
- D020 ALTERNATE RESTRAINTS EVALUATION
- D021 EXPANDABLE AIRLOCK TECHNOLOGY

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

TECHNOLOGY

- T017 METEOROID IMPACT AND EROSION
- T020 JET SHOES
- T021 METEOROID VELOCITY
- T022 HEAT PIPE

NASA HQ ML66-9785
REV. 2-7-67

FIGURE 8

why don't you do something to change it then. Why don't you have the capsule have a slight spin and magnetism or even have a pressure system where a flow of some sort of an atmosphere goes by and holds them in some position?

Dr. MUELLER. Mr. Fulton, those are various things that we do want to look at in the development of our ability to operate in space. We are looking toward the development of experimental equipment to do each one of these things. And we don't really know at this time just which is the best way to proceed, but this is one of the major results that we anticipate from carrying out the work in the orbital workshop.

Mr. FULTON. You are having experiments along those lines going ahead just as you are with the zero gravity?

Dr. MUELLER. Yes, sir. We are trying to find adequate substitutes for the gravity that we have here on Earth for comfortable living in space and effective working in space. You are quite correct, so we are going to do both. We are going to find out what the trade-off is between working in a zero gravity environment and creating an artificial gravity environment and the problems that are associated with that. You recognize that one of the important products of being in space is that you are in an inertial environment. It makes it convenient to point telescopes and large antennas at particular points and if you do introduce artificial gravity by such things as spinning, then you find that you have to find some way of designing the instruments so you can continue to point in a particular direction.

Mr. FULTON. You have all these new adhesives that you could stick wherever you want. Could you just use that?

Dr. MUELLER. True. But you would then have to unpoint them for the operational aspects of a mission.

Mr. FULTON. My feeling is if you are going to a place that is going to be one-sixth gravity, why don't you have them start in a thing that is one-sixth gravity and learn everything that way so when they come to the Moon that transition has been made and not make that transition when you come down on the Moon. When you have all this new environment you give them a new gravity so why don't you do it ahead?

Dr. MUELLER. We have looked quite carefully at producing a sixth gravity in this orbital workshop. There are, however, problems associated with that because the only way that we have yet thought of to get a sixth of a gravity is by a rotational scheme. The rotational scheme in turn introduces coriolis forces which create some difficulty in reproducing the environment of the Moon.

Mr. FULTON. What are coriolis forces?

Dr. MUELLER. Those are forces that result from moving linearly in a rotating system.

Mr. FULTON. I find myself doing that on some legislation. (Laughter.)

Dr. MUELLER. One of the things in an engineering sense that we are going to try to do is to take one of the inertial platforms out of the instrument unit and disassemble it. We are going to try to learn how to maintain equipment in space. We are looking at zero g flammability and astronaut EVA equipment. We are interested in habitability and crew quarters.

On the right-hand screen there are a number of different approaches to providing beds, sleeping quarters, help for donning suits and so on. (ML 67–5547, fig. 8.)

There are interesting problems that are associated with how one sleeps in space that have not been solved yet. As a matter of fact, in looking at the crew sleeping system that we have here, one has a feeling that we still have to do a fair amount of inventing of more comfortable sleeping quarters than we have today. One thing you don't need however, is springs. Because at least in the zero g environment you are floating all the time.

Going on to some of the other experiments in the medical area we are trying to develop a fairly comprehensive set of medical measurements, particularly for these longer duration flights in order to determine just what does happen to the human body as a function of time in the weightless environment.

In terms of our long-range manned spaceflight operations, it would appear desirable to be able to stay in the zero g environment. For most of the activities, on the other hand, we have to be sure that the man can operate effectively under these conditions and he doesn't degrade his performance. These medical experiments are aimed at determining the changes and also determining how one can avoid changes that are not good for the men.

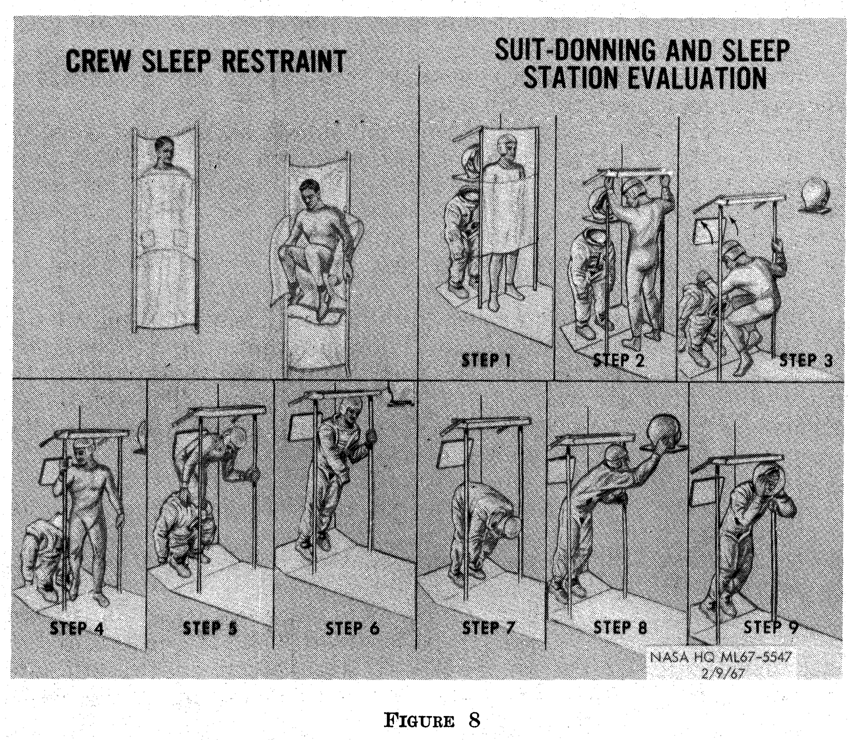

FIGURE 8

We are carrying several Department of Defense experiments including an integrated maintenance station, a suit donning and sleep station evaluation, some alternate restraints evaluation, and expandable airlock technology.

Some of these are multiple experiments: one for example is a test of a molecular sieve for taking the carbon dioxide out of the atmosphere and at the same time using it to circulate the air in the cabin.

In the area of technology, one of the interesting things that we are looking at is the use of jet shoes. This is different from the back pack with jets on it that we have been studying in Gemini. We are looking at different ways of achieving mobility in space.

Going forward to one of the next major experimental configurations that we have shown here is the Apollo Telescope Mount. (ML66–9610, fig. 9.) It includes, as you can see, a lunar module ascent stage. The descent stage is replaced by a rack which carries with it a solar cell array and in the center of that rack you will see a tube which is some 82 inches in diameter and 130 inches long which contains the instruments for observing the sun during 1969 and 1970, the course of the solar maximum. These solar instruments weigh about 2,000 pounds. The tube is gimballed and it has axles by which it can turn by about five degrees in either plane. It also can be rotated around its own longitudinal axis in order to permit pointing to any particular area on the Sun and stay pointed there.

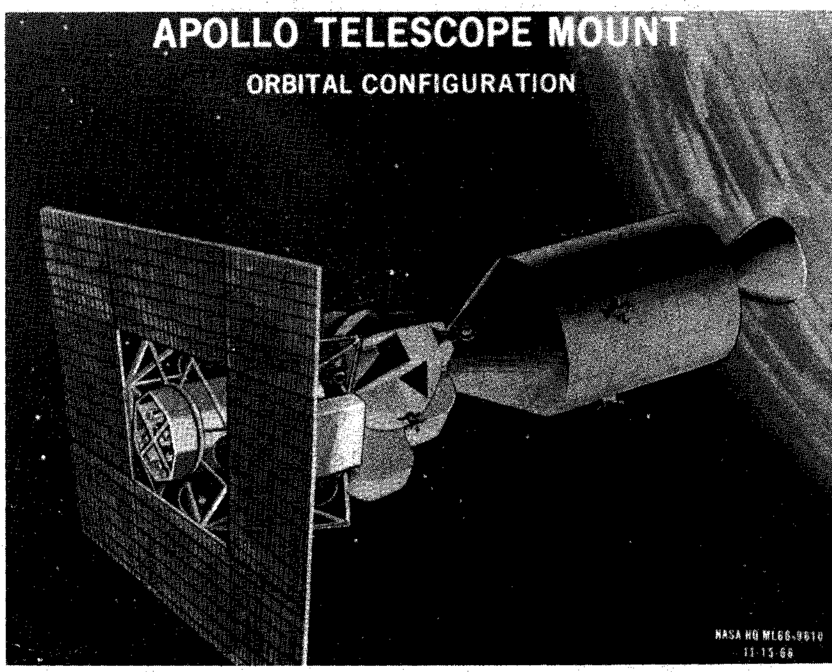

FIGURE 9

The basic rack also contains a set of gyroscopes. They provide you with the coarse pointing accuracy required for pointing the whole assembly toward the Sun and the ascent stage provides the cockpit for the astronauts. It also has a reaction control system aboard which permits you to carry out docking maneuvers, and so on. This configuration we see on the left-hand screen (ML66–9610, fig. 9) is one possible configuration, and this is the way it would work in the event that we wanted to fly a telescope mount with a command and service module.

The man carries out some five functions in this Apollo Telescope Mount (MC66–9678, fig. 10). The first is that of sensing and, in particular he does carry out the initial operation of pointing and the fine alignment and trimming of the system.

The second is that of computing. The man here is responsible for trimming and stabilizing during the drift mode periods. He is computing the drift and correcting for it by his manual control of the pointing. He sets and controls the camera exposure sequences.

The third thing that he is responsible for is maintenance. In this he monitors the experiment operation and he insures the proper functioning of the ATM, taking such corrective actions as are necessary depending upon the problem.

In the fourth area, he is responsible for data acquisition. He recovers the exposed film and magnetic tapes and makes sure that they are operating correctly.

MAN IN APOLLO TELESCOPE MOUNT

1. SENSING	• INITIAL ACQUISITION AND POINTING • FINE ALIGNMENT AND TRIM
2. COMPUTING	• TRIM FOR STABILITY DURING "DRIFT MODE" OBSERVING PERIODS • SETS AND CONTROLS CAMERA EXPOSURE SEQUENCES'
3. MAINTENANCE	• MONITORS EXPERIMENT OPERATION • INSURES PROPER FUNCTIONING OF ATM
4. DATA ACQUISITION	• RECOVERS EXPOSED FILM AND MAGNETIC TAPES
5. SCIENTIST	• DETERMINES SOLAR EVENTS OF INTEREST AND DIRECTS SYSTEM TO OBSERVE

NASA HQ. ML66-9678 1-5-67

FIGURE 10

Finally, he serves as a scientist, to determine which solar events are of interest and to direct the system to observe these events.

There are a number of scientific experiments that have been adopted.

Mr. GURNEY. How does that telescope compare in size or magnification to these telescopes we are now using?

Dr. MUELLER. The largest optics in this particular instrument is a 12-inch mirror. Now, I would hasten to point out that this telescope tube has in it some 13 major instruments, so that it really is a complete observatory housed in this telescope tube and they are all pointed with the same tube at the Sun and they make some five different kinds of measurements that permit you to observe what is happening during the course of the solar events, the major flares, and so on, at different frequencies, and wavelengths of light that you just couldn't observe here on Earth.

It will be the first comprehensive examination of the solar phenomena during a peak period of solar activity. There is no comparable system here on Earth.

Mr. GURNEY. In other words this will give us an opportunity to increase our knowledge very considerably over what we gain from telescope observation.

Dr. MUELLER. We expect this will result in a new breakthrough in our understanding of the solar system. It may lead to a better understanding of how the Sun works which in turn will provide us with information as to how this tremendous source of energy operates. Then it may lead to a better understanding of energy here on Earth.

The releasing of energy is the most important single thing that determines the course of all of mankind's progress.

Mr. GURNEY. Many fields will benefit from this sort of astronomical observatory?

Dr. MUELLER. I am sure the scientific community as a whole is expecting a great deal to come from this and it is strongly supporting it.

Mr. TEAGUE. Mr. Fulton.

Mr. FULTON. My question would be, looking at the corona, its spots and the Sun—what is the purpose of the telescope?

Dr. MUELLER. Let me go through the instruments themselves.

Mr. FULTON. Why don't you use the same type of instrument in space that is being used in Kits Peak at the high altitude observatory in Arizona where you have a long focal length of about 300 feet and up here you would have no weight so that you would have no trouble getting a very large screen that probably by TV pictures would be taken back to Earth rather than use a 12-inch glass?

Dr. MUELLER. In particular, some of the optics have an effective length which is several times 150 inches but generally the kinds of experiments that we are doing here don't require a tremendously long focal length. Most of them are spectrographic measurements in areas of the spectrum which are not available on the Earth at all because of the atmosphere.

Mr. FULTON. Is there a temperature range as well as light? Are you going through the various spectrums of light?

Dr. MUELLER. Yes, we are looking through the whole spectrum from X-rays through visible light.

Mr. FULTON. Put it in the record.

(The information requested follows:)

This figure (fig. 11, SG66-299) shows the solar emission spectra from cosmic rays thru radio waves. The absorption effect of the earth's atmosphere is also shown. The Apollo Telescope Mount will examine the solar emission spectra from x-rays through visible light.

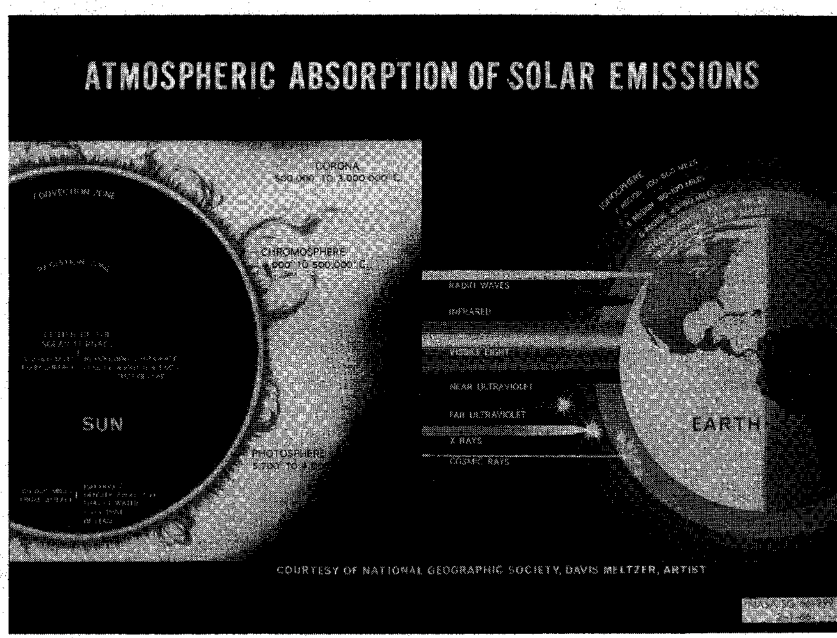

FIGURE 11

Dr. MUELLER. All right. To further answer your question, Dr. Newkirk of the High Altitude Observatory is one of the experimenters and he will have and is developing a coronagraph for our use. The purpose is to monitor the form and brightness of the solar corona in bright light.

Mr. Purcell of the Naval Research Laboratory has two experiments, one is the coronal spectroheliograph which makes high-spatial resolution monochrometric solar images in the 160–650 angstrom range and a chromosphere spectrograph which goes from 800 to 3,000 angstroms and records the solar spectra in that region.

Mr. FULTON. Just put a statement in the record. I will read it and I think some of the others will.

(The information requested follows:)

This figure (fig. 12, ML67-5554) lists five basic experiments designed to obtain solar data during the period of maximum solar activity. The principal investigators, the scientific instruments, and the purpose of each experiment is shown. The combination of instruments involved in these five experiments will 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 as shown in figure 13 (SG66-245).

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

NASA HQ. ML 67-5554
-25-67

FIGURE 12

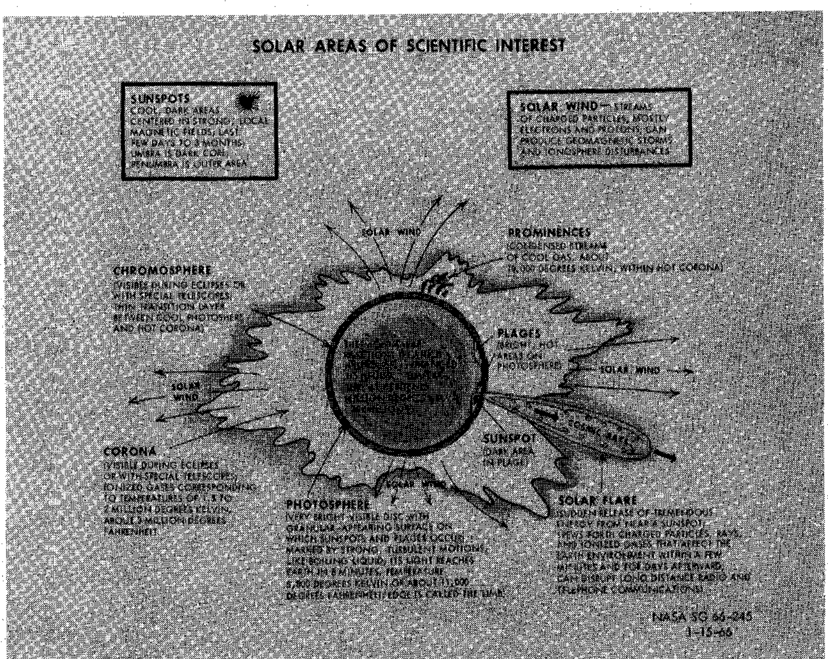

FIGURE 13

Dr. MUELLER. Very well. We have here a set of instruments which are at least as good as any of the instruments that have been developed.

Mr. FULTON. How much better resolution do you get than the Earth's best telescope?

Dr. MUELLER. In terms of resolution, we will not have very much greater angular resolution. In terms of the spectral resolution, itself, we are actually making measurements in areas not available to earth-bound telescopes so it is infinitely better than Earth telescopes.

Mr. GURNEY. Will you transmit it back to Earth via radio or will the astronauts bring it back?

Dr. MUELLER. Most is stored on film. Some comes back on radio. It comes back when the astronauts come back. In addition to the major scientific instruments there are a number of supporting instruments that make it possible to use these instruments and provide location which are shown on the right chart (ML67–5555, fig. 14). They make up a total of 13 instruments.

The package which you see on the left (ML67–5558, fig. 15) is a fairly complex integration task. It is complicated by the fact that these instruments themselves have to maintain alignment to something like a second of arc. I guess a second of arc is an amount that is subtended by about 1 mile on the Moon as measured from the Earth so that you are pointing quite accurately and the relative alignment of these instruments has to be held to something of that order of magnitude.

So the thermal problems associated with this, an instrument that points toward the Sun for 45 minutes, is a real challenge to our designers.

In turn, we expect to learn a great deal from the design effort required here in terms of knowing better how to build such precise instruments in future missions.

If you will look at the right, you will see a cross section through the

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 14

Apollo Telescope Mount (MC67–6003, fig. 16). Particularly you can see the ascent stage over there on the left. We will use that stage both for docking as we shall see in a moment and for maneuvering with the reaction control system and we use the forward section for working quarters of the astronaut and we have access through the floor where the ascent engines used to be through the telescope tube so we can remove film from inside and replace it without having to go outside of the cabin for almost all of the instruments.

You can see the location of this telescope too, the diameter of the tube is 82 inches. You can see the solar panels deployed. You can see where the control gyroscopes are mounted. Those are the little spheres located on the rack.

Mr. FULTON. Why isn't this an experiment that we could have other countries or other foreign associations, that are interested in space, join with us?

Dr. MUELLER. As a matter of fact, the President has spoken to the German Chancellor last year with respect to joining in the development of some of these experiments. Mr. Webb has had various discussions with the scientific groups in each of the European countries exploring with them the possibility of participating in these experiments. They require a fairly long development time. We have invited cooperation from foreign countries in their use.

There is one other point, although the instruments themselves represent considerable engineering development, the data that is gathered

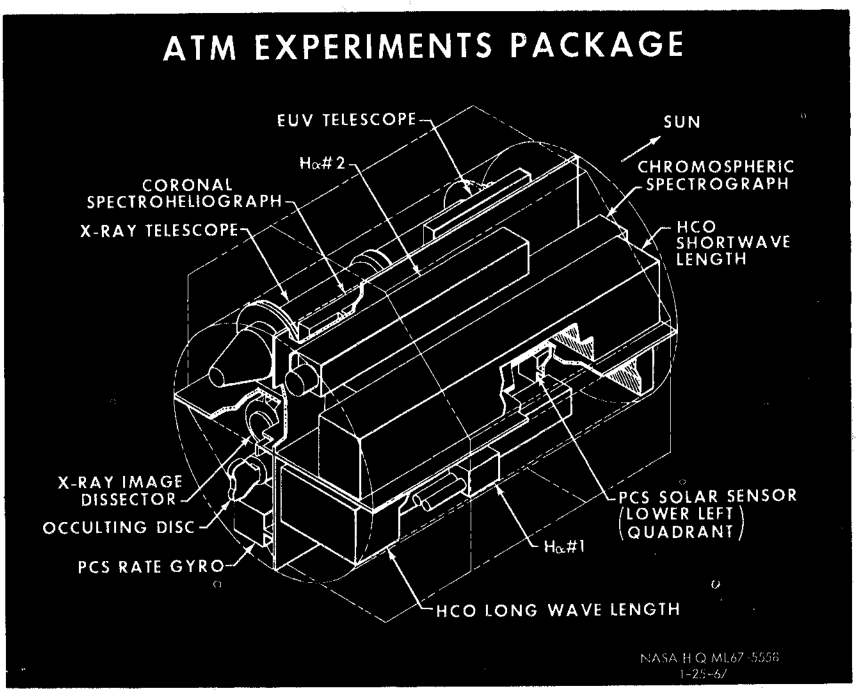

FIGURE 15

LUNAR MODULE/APOLLO TELESCOPE MOUNT

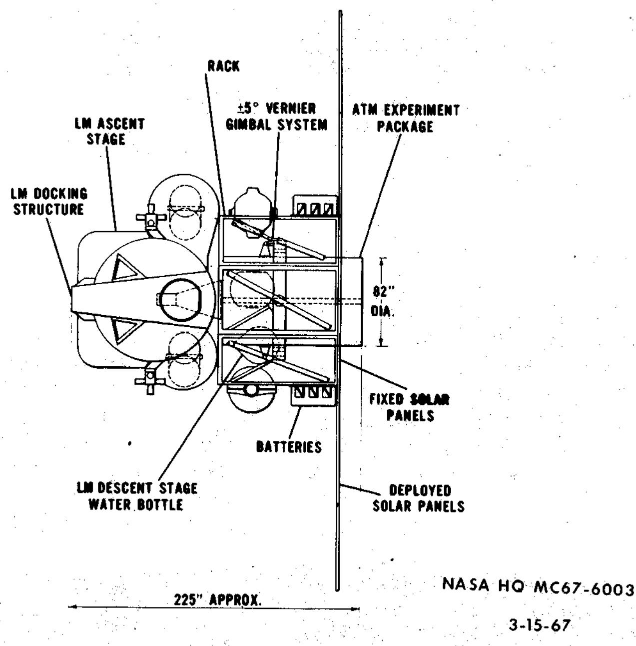

FIGURE 16

by these instruments will be made available to all the scientists in the world. It is in fact the analysis and understanding of this data that provides the real scientific return from the equipment and that will be made widely available.

Mr. FULTON. I was wondering about the European nations who are building the new telescope 50 miles away from ours.

Have they been contacted? There is no use in our paying the full expense if others are working in the same field and they can be joined.

Dr. MUELLER. You are quite correct. They were invited to examine the possibilities here. They are interested principally in a large optical telescope for stellar observations and this is a fairly specialized instrument for solar observations.

Mr. ROUDEBUSH. Has there been a determination as to when this telescope will be built and who will be the contractor?

Dr. MUELLER. This particular telescope system is being assembled by the Marshall Space Flight Center; in order to be in a position to carry out each of these experiments a major fraction of this work is being done in-house at MSC and at Marshall Space Flight Center.

There is of course, a considerable amount of contractor work. The Ball Bros., I believe, are building about six of the instruments that are involved in the mount itself and other contractors are working on the integration; the Lockheed and the Martin companies are in basic competition for an integration contract with Marshall.

Mr. FULTON. Because of distortion factors and heat, have you considered using a metal disk?

Dr. MUELLER. A metal disk?

Mr. FULTON. Mirror; yes.

Dr. MUELLER. As a matter of fact, the X-ray mirror is a metal disc.

Mr. FULTON. They are experimenting with those at the University of Arizona and they seem to be quite successful and active. I wondered if you looked into that phase.

Dr. MUELLER. The experimenters that we have are responsible for the development of the instruments themselves. They are aware of the development of the metal mirrors. There is a problem, however, with the grinding of them in terms of the techniques that are now available generally.

Mr. GURNEY. The orbiting solar observatory, was that built in-house?

Dr. MUELLER. That was built by Ball Bros. in Colorado. The Orbiting Astronomical Observatory is being built by Grumman. Some of the control systems are built by General Electric, for example. The system being assembled and integrated in-house but the various components and experiments are being built in industry.

Mr. GURNEY. Isn't this a departure from our previous method of operation?

Dr. MUELLER. It is. We have done this both ways in the past. For example, Goddard has built satellites in-house and has contracted for satellites.

Marshall has in the past developed the initial parts of equipments and then turned them over to industry. The first stage of the Saturn V is an example of that. This is not a departure from past practice. It does, however, represent two things. One is that as the Apollo program is phasing out, people are becoming available in the manned spaceflight centers to do other work.

In order to use their talents and develop their talents in this new area of technology, it has seemed to us important to have them do some of these things that are on the forefront of the technological developments of today otherwise they, in turn, will not be capable of directing other people. The second aspect is that we have had some limited funds in the past years and the only sources for this work were literally the people in our centers.

Mr. GURNEY. It seems to me that is not in keeping with our national policy which is to do as much of this work as we can in private industry, and I know that some private industry is very unhappy about this because they have expressed their feelings to me personally.

Why couldn't we do this by private industry? Why do we have to do it in-house?

Dr. MUELLER. I think there are two answers to that. At the present time, we need to maintain the capability and the talents that we have at Marshall and at the Manned Spacecraft Center. In order to provide the kind of direction, the kind of ability to solve problems that are needed in these centers. We are doing the same thing of course elsewhere in industry where we have special talents that are required for the on-going Apollo program.

In the long run, there is a need for competence and understanding and skill in the Government organizations that monitor contractors and, in fact, the National Aeronautics and Space Administration represents one of several sources of considerable technical talent within the Government that the Government has available to it, and I think that in order to manage properly, it is essential that the Government have a competent group of technical people. This is the only way I know to keep technical people competent with an understanding of current technology, that is, to have them do a certain amount of actual technical work themselves.

I don't think that one can otherwise, in the long term, manage to understand the real technical problems that are associated with these complex developments.

Mr. GURNEY. I follow that argument but if you follow it to its logical conclusion, then you would have to say that it would be necessary for the Government and NASA to build Surveyor and Lunar Orbiter and Voyager and any one of these programs. The argument is exactly the same if you follow it through to its logical conclusion and we completely defeat the purpose that we have expressed to do as much as possible through private enterprise.

Dr. MUELLER. Mr. Gurney, one can carry this argument to any of these extremes. One could just as well carry it to the other extreme where all the work was done by private enterprise and there were no governmental laboratories at all. That is, of course, a possibility.

I think that the balance that we have achieved in NASA is a sound one where certain things are done in-house and the majority, some 90 percent or more of the work, is done by private industry.

When we are talking about these two particular items, we are talking about something on the order of $45 to $55 million worth of work. All of that money is being spent in industry and we are talking about perhaps half that much in terms of in-house effort.

Mr. GURNEY. How many people will be employed in this particular effort of putting together the observatory?

Dr. MUELLER. In terms of industrial contractors?

Mr. GURNEY. I mean NASA people.

Dr. MUELLER. We have something on the order of 400 or 500 people working on this. We have something like a thousand or more people in industry.

Mr. GURNEY. I am not sure this is the correct place to inject this question, Mr. Chairman, but I think we ought to develop some evidence here at these hearings of NASA manpower in comparison with industrial manpower.

For example, industrial manpower we know peaked here a year or so ago and now it has gone down very considerably in this space program.

I am wondering where Apollo shows a corresponding increase? Is it proper to go into it?

Mr. TEAGUE. At Huntsville we went into this. All the details are in the hearing. I think we covered it very thoroughly.

Dr. MUELLER. Let me add just one thought, Mr. Chairman, if I may, and that is that the manned space flight organization has increased slightly.

In the case of the Apollo program, there is a role that our manned spaceflight organization is playing that is a quite important role in carrying out the actual Apollo program. That role is being responsible for the integration of all of these pieces, the stages, integrating them together into a launch vehicle, the spacecraft, integrating them together into a space vehicle and then the integration of the systems as a whole.

This is a responsibility that the NASA center and headquarters have undertaken. It represents the overall system engineering and it represents the kind of thing that persists through the whole development cycle so that in fact the workload is increasing on our centers while the workload on our contractors is going down, so we are just now at the point where we are putting all of these things together having to make them work as a total system.

Mr. GURNEY. I realize that. My real question and the thing that troubles me is that I hope that the Government isn't trying to retain all of its people that are necessarily in the space program just to make work for them in a project like we are talking about here, doing the in-house work rather than in private industry.

Dr. MUELLER. First of all, we have not changed our policy of doing as much as possible in private industry. There are, however, things that are of considerable importance to recognize in this kind of an operation.

When you do an experiment development of the sort we are talking about here, it is a one-of-a-kind thing. There isn't any production involved in it. You need a certain cadre of competent people to do it, and one has to use the resources one has in order to accomplish this.

I don't think that we are in a sense competing with industry in this case. We clearly would not have the capability with the funding levels we have available to, in fact, put out anything more in industry than we have done now.

Mr. FULTON. In order to relate the telescope planned in this program to practical use, would you say this might help us in the future on weather prediction, on radio receptivity, on determination of solar wind effects because we are finding the source?

Can you make a practical prediction for this particular experiment that might help justify it?

Dr. MUELLER. All of these things and more will come from a basic understanding of the physics of the Sun. This is, of course the major source of energy in our solar system. Understanding it and learning how it operates will in turn tell us much about its effect on our own life here on Earth.

Mr. FULTON. Will modification of the Voyager program help us learn basic facts?

Dr. MUELLER. Yes, sir.

By the end of 1968, if all goes well on the basic Apollo program, and if all goes well in the Apollo Applications program, we will have carried out the set of maneuvers that you see on the right-hand side (ML66-8975, fig. 17), we will have placed in orbit the orbital workshop; we will have tested the mapping and survey camera which will eventually be used for mapping and surveying the Moon. We will have had some 28 days of exposure to weightlessness in our flight of the workshop. We will have gone back to the workshop and revisited it and have carried up to the workshop the Apollo Telescope Mount and have assembled in space the Apollo Telescope Mount and the workshop together with the command module and the crew and we will have begun to stay there for 56 days so we will have built up our exposure.

They will experiment with the Sun and carry out experiments in the workshop and they will test various techniques for the use of the Apollo telescope itself.

In particular, you will note that one of the views in this chart (see ML66–8975, fig. 17), shows the Apollo Telescope Mount tethered to the workshop. We hope to be able to study this as a possible method of operation in order to isolate the Apollo Telescope Mount from the workshop.

We will also be carrying out operations with the Apollo Telescope Mount coupled or docked to the workshop, and if our control system works well enough, it will be possible without going into pressure suits to travel from the Apollo Telescope Mount to the workshop using the airlock and docking adaptor.

We will have then really an embryonic space station available to us for carrying out additional observations of the Sun and additional experiments throughout 1969 by using additionally the follow-on command and service modules to resupply and revisit.

By the end of 1969 we would expect to have reached, by doubling the weightless exposure, the ability to stay in orbit for as much as a

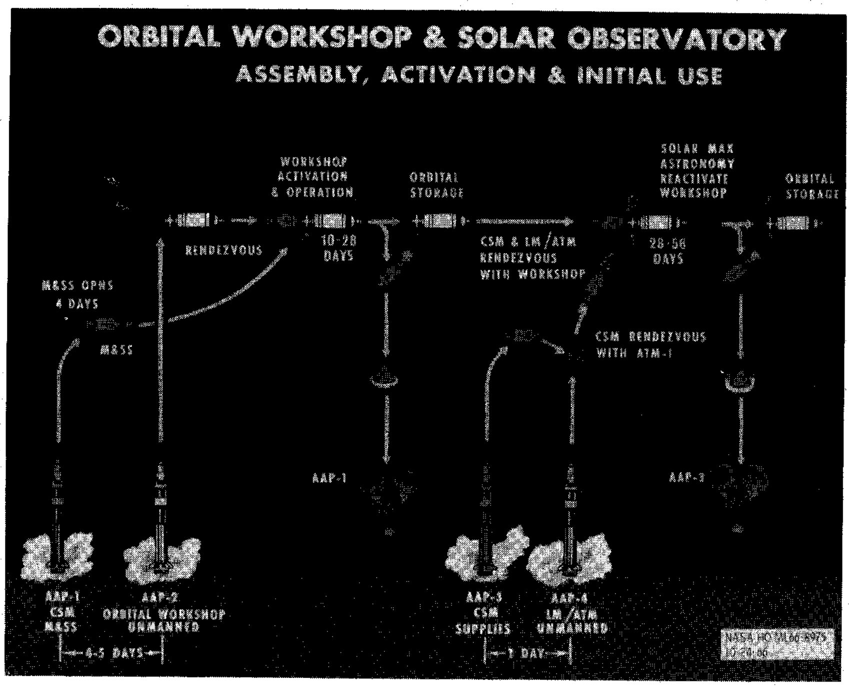

FIGURE 17

year. That is with the proviso, of course, that the workshop and its equipment is still operating.

Mr. FULTON. I am amused by the difference in titles. I could never understand the difference between a manned orbital workshop and a Manned Orbital Laboratory.

In the Air Force you get a laboratory. In NASA you get a workshop. If you could explain that, I would like to see that there is no overlapping of function and that you aren't both doing the same thing in competition.

Dr. MUELLER. As a matter of fact, the workshop is available in a time scale that permits us to help by developing techniques and equipment that will be used by the manned orbiting lab in the Air Force program.

Mr. FULTON. You are correlating the programs rather than duplicating?

Dr. MUELLER. Yes; and careful coordination is being carried on as I mentioned, yesterday. The Department of Defense participates in it. All the agencies coordinate. We design the program to provide the maximum amount of information to the Department of Defense.

Mr. FULTON. Secretary McNamara made the "big steal" of the decade when he got the Manned Orbital Lab away from NASA. I don't want any comment on that.

Dr. MUELLER. In the Apollo alternate missions (MC 67–5409, fig. 18), we will use the basic Apollo space vehicles which may become available from the manned lunar landing program to acquire the maximum yield of solar data during the solar maximum; we will place in orbit, operating modules for reuse, we will provide early capability

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 18

for large environmentally controlled volume in which to evaluate human performance, engineering concepts and technology leading to a space station. We will demonstrate up to a 3-month orbital flight capability.

As we go further, we will expect to continue several major areas; one of these is long-duration flight (MC 67-5410, fig 19). As I said, I expect to build up by the end of 1968 a system that will permit us by proper reuse to acquire the experience that we need for determining whether man can stay in space for periods of a year or more and that in turn is an essential understanding if we are ever to carry out manned planetary explorations. We are laying the foundation that will provide us with the knowledge that we need for determining whether manned planetary travel is feasible at the present time.

The major benefits we expect (ML 66–9790, fig. 20) include the astronomical observations, the determination of man's effectiveness as an astronomical observer in space and the test of alternate operating modes for future large manned telescopes. The development of the capability for reuse of space hardware will reduce program costs and we will determine the effects of extended duration flights in space on men and systems. The determination of the effects of artificial gravity in space on men and systems is one of the long-term objectives and we plan to develop more complex manned extravehicular capabilities.

Now, I would like to take just a moment, if I may, to show a film. This film represents the testimony of some six outstanding scientists, doctors, and engineers, in establishing the requirement that they see in the future for manned space operations.

(Whereupon, a film was shown, and an accompanying text was provided by Dr. Mueller as follows:)

Dr. Charles H. Townes, Massachusetts Institute of Technology: "The NASA Science and Technology Advisory Committee, of which I am Chairman, is a committee of Scientists and Engineers formed to advise the National Aeronautics and Space Administration on Manned Space Flight.

"We've been quite interested in the possible uses of the Apollo/Saturn hardware—the scientific and engineering missions, in earth orbit, lunar orbit, and on the lunar surface. Its boosters and other important units will also be valuable in exploration of the planets and interplanetary space.

"It is important for the scientific community to be familiar with the program now getting underway for utilizing the Apollo/Saturn space vehicle, because capabilities of the Apollo/Saturn hardware are far enough beyond what has previously been available for space science before this that scientists can think in terms of quite new types of experiments, much more extensive experimentation, and new modes of operation."

Dr. Charles A. Berry, Manned Spacecraft Center: "It's now time that we expand our observations from determining whether a man can indeed function in this environment and now look at what we can learn that we can apply in general to medicine wherever it is practiced. What can we gain, or what do we need to know as medical scientists in using the space systems which can be provided for us which will allow adequate volume and time to expose the human being.

"We can look at the cause of the changes which have been observed thus far in exposing man to a space flight environment.

"It's terribly important that we define what is the cause of these various changes in order to protect against them. We can also work at adaptive mechanisms. We can apply the information obtained in this manner to man adapting to environments of other types here on the surface of the earth. We also ought to look at basic biochemical mechanisms. And this is a time when we can help to determine what really happens to substances in the body, because we can look at them as they occur in normal human beings in a very unique environmental situation.

APOLLO APPLICATIONS
LONG DURATION FLIGHT OBJECTIVES

- MEASURE EFFECTS OF LONG DURATION FLIGHTS ON MEN AND SYSTEMS.
- ACQUIRE OPERATIONAL EXPERIENCE.
- DEVELOP SYSTEMS REQUIRED FOR NEXT GENERATION OF MANNED SPACE FLIGHT.
- PERFORM EXPERIMENTS

NASA HQ MC67-5410
REV. 2-7-67

FIGURE 19

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 ML66-8790
1-5-67

FIGURE 20

"The vestibular system offers us a very interesting sense organ which can be studied in this particular environment and take advantage of the laboratory situation which exists nowhere in the universe. Because this system was designed to function in gravity with one "G", in other words, with gravity as it exists on the earth's surface. We can now look at this system as it functions without gravity and thus learn a great deal of basic physiology. In addition, the information obtained in this manner is applicable to future systems where we might have to try and provide gravity so that man could work in this space situation for very long periods of time, in planetary missions or just orbiting the earth.

"To do these various things we need a laboratory. We can no longer ride piggy-back on operational science missions, but we must have a laboratory with adequate volume so that we can conduct these experiments.

"This means that it could perhaps be supplied by a system like Apollo Applications. For such a system would allow both medical scientists and the astronauts to perform a number of experiments and to make observations which would be extremely helpful to us from the medical point of view here on the surface of the earth and as we plan our future exposures of man to unique types of environments.

"This information is valuable then, not only as we try to protect man in unusual environments or extend his stay, but also to medicine wherever it's practiced here on the surface of the earth."

Astronaut James A. Lovell, Manned Spacecraft Center: "To capitalize fully on the advantages of having a man in space, we must now increase the length of our flights, first to a month, then to several months, and, ultimately, to indefinite periods. Not only must we investigate the physiological factors, we must learn much more about how to live and work in space on a day-to-day basis.

"Of course, in the small Gemini spacecraft, which had about as much room as a typical sports car front seat, we proved that man can operate effectively in space for up to two weeks. To achieve this, we incorporated special provisions, for instance, a light-weight pressure suit which could be doffed or donned with reasonable facility.

"And in the Apollo spacecraft, which has somewhat more room for flight crews, we again have a two-week mission capability.

"But for missions of much longer duration, there are still many questions about how to live and work most efficiently in space.

"We expect to find many answers in the early Apollo Applications missions.

"To establish a base of operations in space, we will launch an uprated Saturn I second stage into earth orbit, and then convert it into quarters for living and working.

"In the stage, we will investigate things such as . . . how much cubic footage do we need for routine functions of life, experiments for science, maintenance of equipment?

"What is an optimum floor plan for crew quarters and work stations?

"What is the best way to sleep in the zero gravity of space?

"What forms of exercise are most effective in keeping a crew physiologically fit?

"We will investigate methods of food preparation, types of food, care of personal hygiene, management of human wastes, ways of "keeping house."

"We can learn the best means of moving from place to place under zero "G" and restraining ourselves at work stations. Here we will be able to build on our earlier experience during similar work in Gemini, but in a controlled environment.

"The data from our studies will be used in planning and developing both the later flights in Apollo Applications and the flights for future programs. And it will be instrumental in making the most effective use of man during long-duration missions in space."

Dr. Lloyd V. Berkner, Southwest Center for Advanced Studies: "Now that we have moved such a long way in this first decade of the space age, we have the opportunity to intensify the work of determining and measuring the benefits that can be provided to man here on the earth. It's time that we capitalized on this opportunity.

"As populations increase and as there is a rising concern with the problems of living in a crowded world, we have greater need to make effective use of the earth's resources. To do this we need to measure their totals, and the depletion and the contamination that man's activities produce.

"A satellite is at a vantage point at which comprehensive mapping and accurate measurements over really broad areas are possible for the first time.

"The earth's resources are in the four states of land, sea, the atmosphere and the magnetosphere.

"On the land, we can inquire into how effectively observations from space can help us find ores, fuels, and mineral deposits.

"I have here a picture taken from the Gemini of Central Australia, which was an important aid in finding an oil deposit (figure 1).

"We can pursue the possibility of aiding agriculture and forestry with repeated measurements of changes in the states of forests, of range land, and cultivated areas. Agricultural specialists have found that the infrared camera is an excellent analytical tool for determining the plant and the soil temperatures and assessing the energy budget of the earth surface.

"We can determine how well observations from space can provide useful information about such things as land uses in human populations. I have here perhaps one of the most densely populated areas of the earth, the Nile Delta, Figure 2 which goes back to man's earliest history, in which one can study in detail the concentrations of these populations as taken from the Gemini.

"With respect to the earth's water, much information of value related to hydrology can be obtained. The fresh water supply and the extent of pollution. We use this photograph on the cover of our annual report for the Southwest Center for Advanced Study (figure 3).

"It was taken in infrared and it shows the waters of the Cascade range very clearly; as you can see here, the peaks, which are clearly outlined, the faults and the structure which would aid in hydrological study.

"In particular, about 5/6 of our planet surface is covered by the sea. Complete coverage of the oceans from its surface, of course, is very difficult. The ocean-

FIGURE 1

ographer finds that he can see a great deal from space, and here I have a photograph taken from near the coast of Africa looking over almost the entire Indian Ocean, from one of the Gemini studies (figure 4).

"There are many opportunities to learn much more about the weather from space.

"Sometimes the meteorologist would like to have greater detail which can be supplied from actual color film or the record of observations of other otherwise invisible portions of the electromagnetic spectrum.

"Here we have a photograph of the Indian sub-continent which shows, I believe, quite clearly the influence of the convective action of the atmosphere as it approaches the continent itself, and you will see the clouds are held away from the continent by this action. Certainly an observation that could only be made in space.

"At very high altitudes an orbit synchronized with the earth's rotation, the view from this vantage point can encompass a much wider area and follow step by step, minute by minute, the life history of a developing storm.

"I have here three pictures taken from the Advanced Technology satellite in quick succession, and you can see in each of these three pictures the development of a storm system of over almost half of the whole earth's surface.

"One problem in our atmosphere, of course, is the effects of man's activity upon it. As we become increasingly aware, air pollution is a major and increasing problem in heavily populated and industrial areas.

"Of course, this problem can extend far from the most populated areas and here is an interesting picture of two forest fires which are creating heavy pollution in the area of development in the Gulf of Mexico, near Tallahassee and Apalachicola.

"In all such research, it will be important to measure carefully the costs and the benefit's to be obtained by alternative methods of obtaining data. In some cases, the needed information can be obtained with aircraft, or with sounding rockets, or simple unmanned spacecraft. In others, the presence of a man in space to do such things as selecting the targets, calibrating and directing instruments will justify the additional cost.

"But space offers the opportunity to do many things that just cannot be done in any other way. I'm reminded for example, of the fact that on my first expedition to the Antartic with Admiral Byrd in 1928, we flew some six hours to discover the Rockefeller Mountains only a short distance from Little America One.

"I look forward with pleasure to the day when a Polar orbiting Apollo will be able to sweep and map the whole continent in a single orbit."

Dr. Eugene Shoemaker, U.S. Geological Survey: "The Geological Survey is carrying out a major program of Geologic investigation of the moon. The first step in this program is Geologic mapping of the moon from earth-based telescopes. You see here on this frame the one-to-one million Geologic maps which have been prepared for the lunar equatorial belt. The next step in the investigations will be the detailed Geologic investigation of Ranger impact sights for Ranger 7, 8, and 9 from the very high resolution pictures obtained on the Ranger missions. Next we will be studying in great detail the lunar equator from high resolution pictures obtained from the unmanned lunar orbiter. The Apollo Applications program will offer us the opportunity to extend these studies over the entire sphere of the moon, and to study in even greater detail areas of special interest such as the Crater Alphonses and the Crater Copernicus which may be the targets for Manned Lunar Landing.

"Our first detailed information obtained directly from the Lunar surface will come from the unmanned spacecraft Surveyor. From the pictures obtained from the two cameras, it will be possible to prepare very detailed maps of a region extending out about 100 feet from the spacecraft, which is an area about the size of this model.

"In the first manned lunar landing, it will be possible to extend these observations to distances of about a thousand feet, and in the Apollo Applications program, we will have the opportunity to look at features several thousand feet across.

"Finally, we are studying the methods by which this information is to be transmitted to the earth and the techniques for reducing this information primarily by photogrammetry and photometry. Our objective in studying the moon is to compare the Geology and History of the moon with the Geology and History of the earth. And by this comparison, we hope to solve some of the age-old questions of Geology."

FIGURE 2

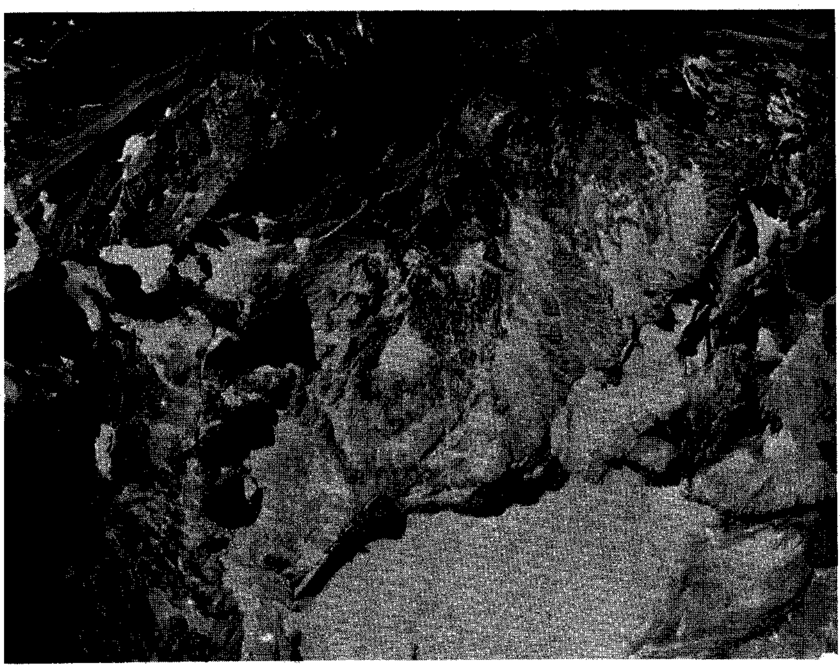

FIGURE 3

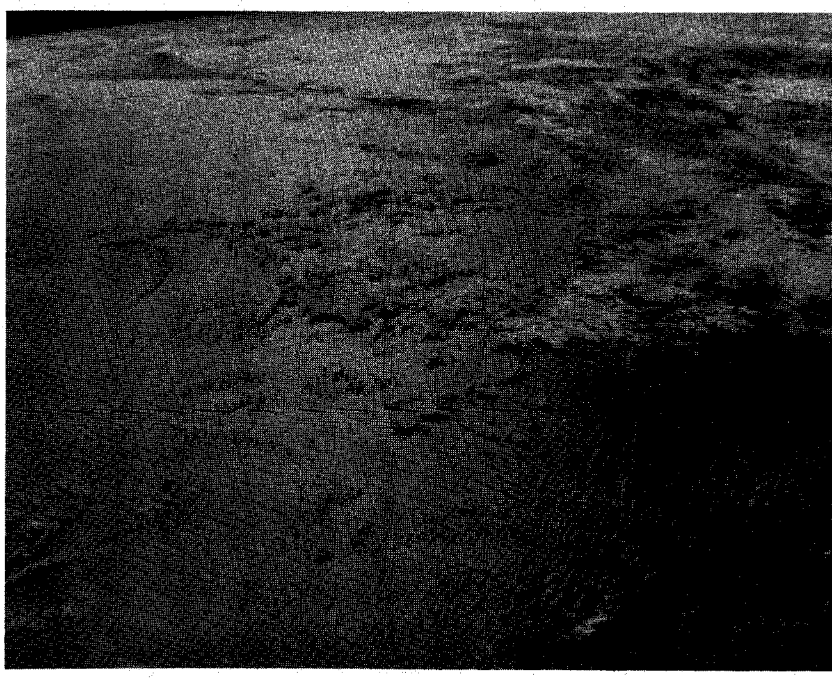

FIGURE 4

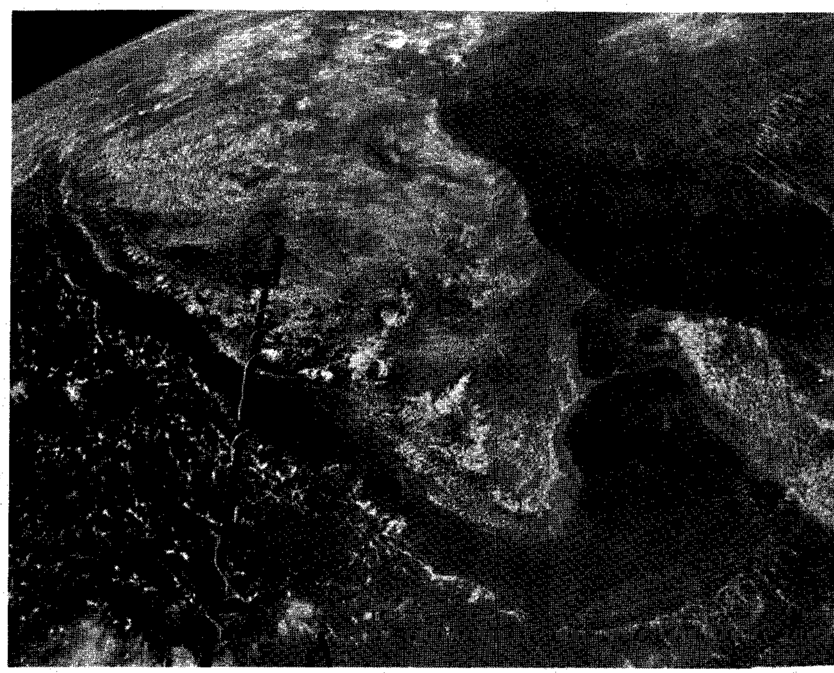

FIGURE 5

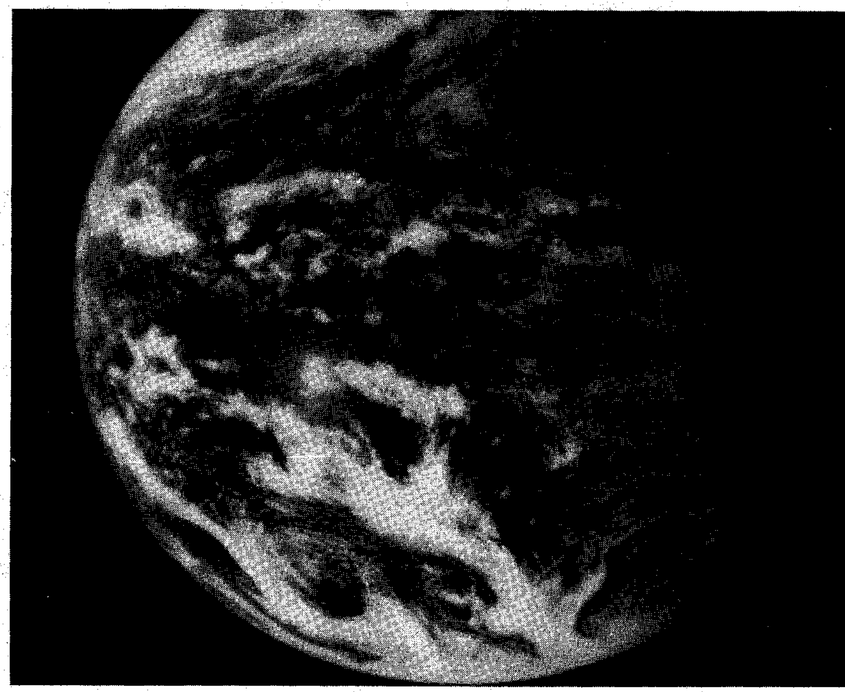

FIGURE 6A

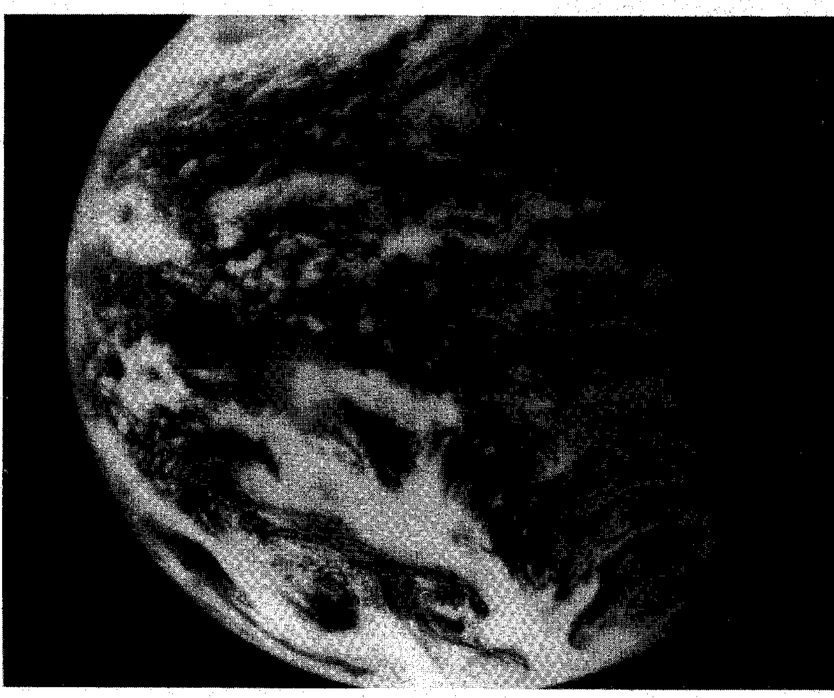

FIGURE 6B

76-265 O—67—pt. 2——19

Dr. James Arnold, University of California: "Here at the University of California at San Diego, scientists are using the techniques of modern chemistry and of structural analysis to try to answer the question of the origin of the solar system.

"Now to do analyses we need samples. We have the crust of the earth but the crust of the earth has had such a colorful history that most of the traces of its origins have been lost. We have the meteorites and a very rich field has grown up here. We've used modern instruments such as mass spectrometers, low level counters, to learn a great deal from these objects. We've learned such things as the age of the solar system—4.6 billion years—most of what we know about the origin of the elements, and much more. But we don't know exactly where the meteorites come from. We do not have these samples in context. So we look elsewhere.

"Now there are many controversies about the moon, but there is one thing about which I think we all agree, and that is that the surface of the moon is very old. The processes of erosion which take place on the earth do not take place there to the same extent. We should be able to find clues, fingerprints of the moon's origin. Now Apollo will bring us back samples of the moon and the importance of this is so great that the scientists concerned have assigned sample return the highest scientific priority on the Apollo missions.

"The Apollo Applications program can bring us samples from the moon in context, in a known relation to the lunar environment. We can bring these samples back to our laboratories; we can study them with our instruments; we can make discoveries and apply those discoveries and further measurements on similar samples. We can, in fact, do generations of work on the samples from a single mission. Perhaps, we can even give firm answers to the question of the origin of the solar system itself."

Dr. Leo Goldberg, Harvard/Smithsonian Astrophysical Observatory: "Here in this laboratory, we assemble, test, and calibrate astronomical instruments used in observing the sun from rockets and satellites.

"Observations from space are of fundamental importance to astronomy, which has long been retarded by the restrictions imposed by the earth's atmosphere and

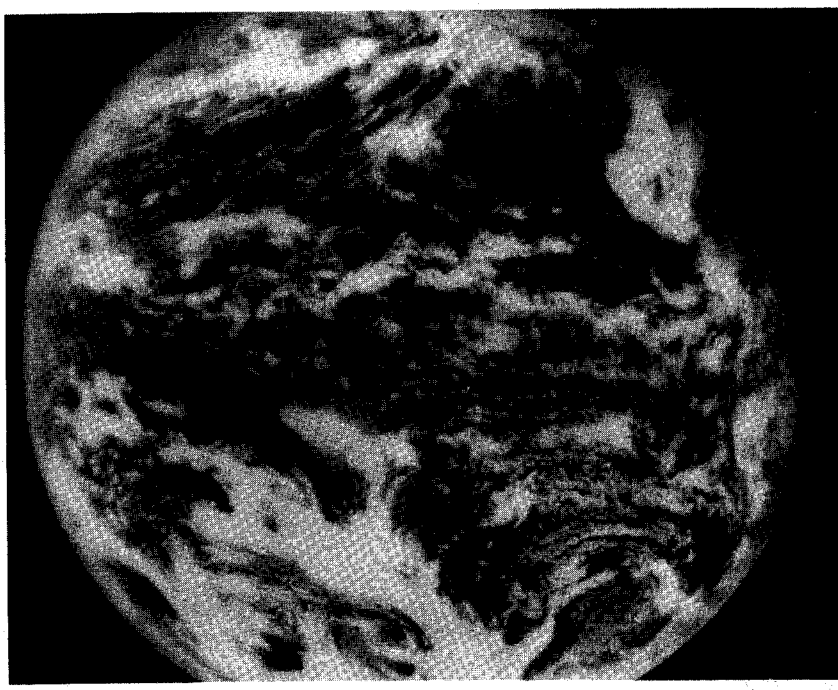

FIGURE 6C

gravity. We have, in effect, been looking at the universe through a screen that is opaque to both ultraviolet and infrared radiation, as well as to x-ray, gamma rays, and many types of high speed particles. Moreover, the atmosphere causes the stars to dance and twinkle, against a background glare, of scattered sunlight by day and of airglow by night. The removal of these restrictions promises to extend our observational reach by many many times.

"Our own efforts, and those of other groups elsewhere, are devoted to the investigation of the sun. And more specifically, towards getting an understanding of the origin of magnetic fields, of the source of the sun's spot cycle and solar activity, of the origin of the solar wind and solar flares, and the production of high energy particles and photons.

"At present, we are pursuing these studies with relatively small telescopes and spectographs, such as this instrument, which we have designed to fly in the unmanned OSO-Orbiting Solar Observatory-series of spacecraft, as illustrated by this model, and here the left-hand box is designed to represent our instrument.

"While much valuable ground work is being laid by observations with these small instruments, the questions we are asking about the sun, can only be answered through the use of much larger telescopes. Much valuable experience in manned operation of solar telescopes and also much valuable preliminary data will be gained during Apollo missions in low-earth orbit, with an installation like this one, called the "Atom."

"In the Atom concept here you see the Apollo spacecraft, with the astronauts in their places, controlling the pointing of a battery of solar telescopes toward the sun. Later on, the Apollo Applications program will make it possible for us to put the large telescopes into operation in space. For example, telescopes up to 60 inches in diameter, with which angles as small as a tenth of a second arc, can be resolved. Telescopes so large that they will undoubtedly have to be assembled in orbit by astronauts, who would then also play an important part in the operation of the telescopes. By making required major changes in the observational equipment, by performing instant analysis of output data, and then modifying subsequent observations, for example, by reacting to the outbreak of a solar flare, by performing maintenance and repair, and finally, by returning

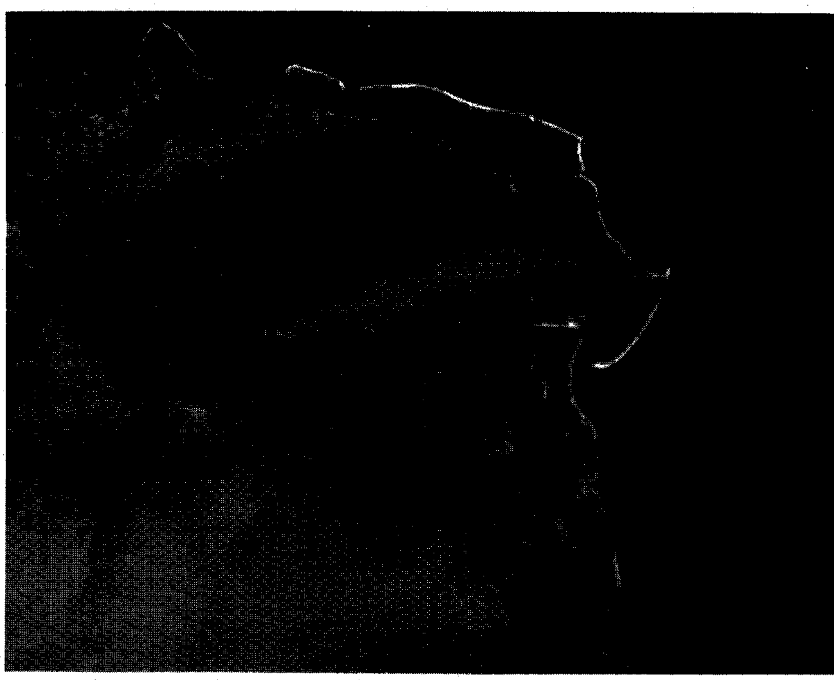

FIGURE 7

photographic data to earth. Through such efforts, we may hope to get answers to many of the most fundamental questions about the universe—the nature and number of x-ray and radio sources, the origin of cosmic rays, and finally, the origin and evolutionary history of the stars and galaxies, themselves."

Dr. MUELLER. Mr. Chairman, I thought that it would be worthwhile to have these requirements stated by some of our leading scientists. I wonder if it would be your desire to place them in the record.

Mr. TEAGUE. Yes, sir. We would like to have them in the record.

Dr. MUELLER. Going on to the use of the Apollo hardware in the follow-on program, in particular in carrying out extended lunar exploration, there are two major courses that we expect to follow, one is the development of a mapping and surveying system which is capable of providing high resolution multispectral pictures utilizing a wide electromagnetic spectral range to cover the lunar surface. The system to be used here is, as you see, in the left-hand view (ML 66-9782, fig. 21), the mapping and survey camera, which is now under development in the Apollo program. We expect to fly it in lunar orbit and leave it in lunar orbit for a period of 28 days and thus permit a complete mapping of the lunar surface in a single mission (ML 66-8965, fig. 22).

Mr. FUQUA. Would this be a manned mission?

Dr. MUELLER. Yes. The man is essential to maintain the equipment to keep it operating and to change films. We would hope also to obtain both stereo coverage and color as well as high resolution photographs of the lunar surface. That is one of the types of missions.

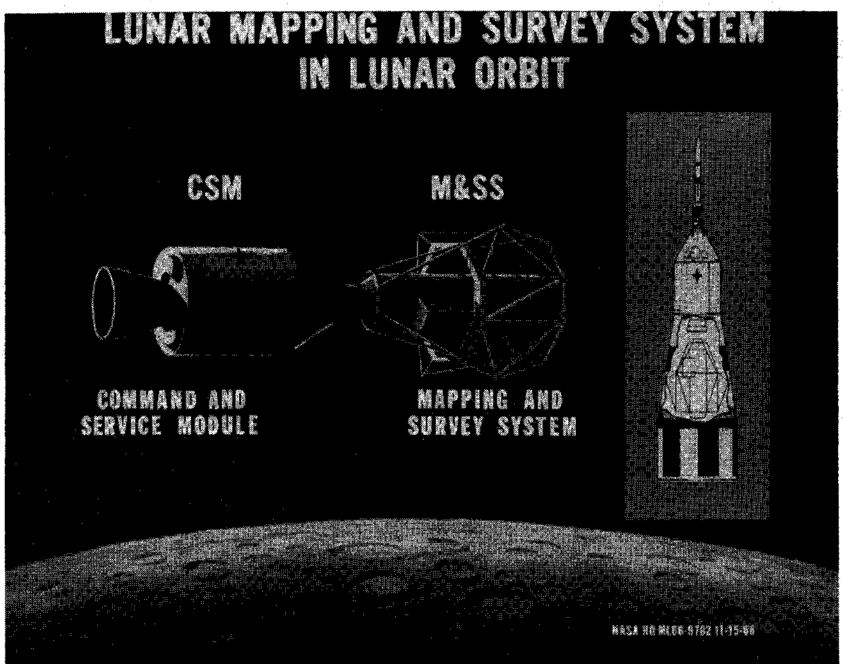

FIGURE 21

Mr. FULTON. Before you go on, when the new treaty on space goes into effect and it will probably be ratified very soon, there will be a number of missions of the Department of Defense in space that are automatically banned and I, for one, would like to see a program looked into on transferring those missions to NASA where they come within the jurisdiction of NASA on aeronautics and space. We are planning a lot of military operations in space and therefore the Department of Defense will have no particular specific program for such operations and I certainly hope that NASA will look to its jurisdiction and pick up some of the programs which can just as well be done by NASA.

Dr. MUELLER. I will call Mr. Webb's attention to your remarks, Mr. Fulton.

Turning to the extended lunar surface exploration, we would expect to develop a capability to extend the stay time on the lunar surface to approximately 2 weeks in the course of our developments. In the time that we spend on the surface, there are several types of experiments that we would like to carry out (MT 66-8685, fig. 23). One is a drill that will drill as deep as 100 meters, 300 feet or so, and with that drill, then, we have the ability not only to collect samples but also to use a probe similar to the probes that are used in the development of oil wells and other geologic investigations to determine the composition of the subsurface of the Moon, and what its history was.

We also expect to carry on extended surveys of the lunar surface and to emplace various scientific stations that will permit us over a

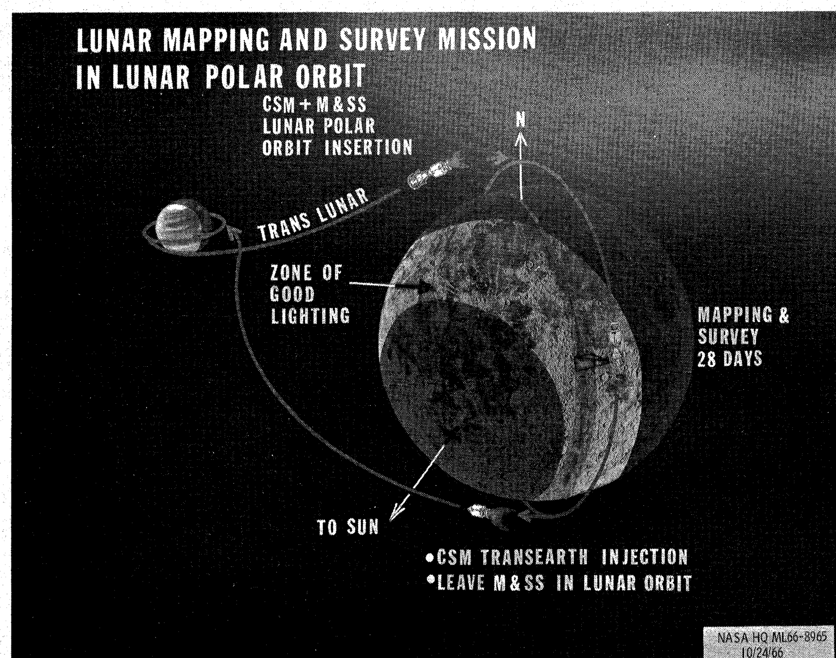

FIGURE 22

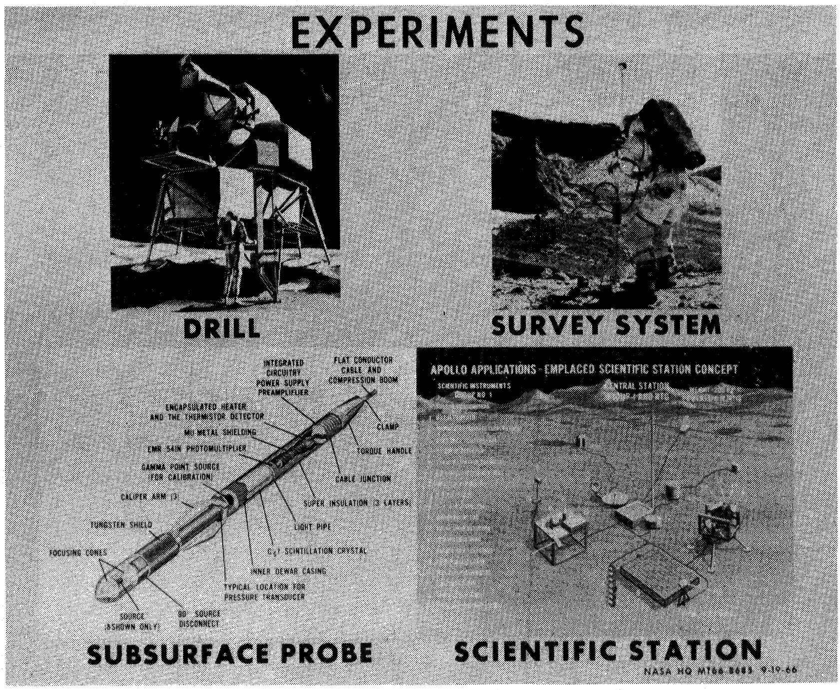

FIGURE 23

rather wide area to measure the deep characteristics of the moon itself, through seismic observations, and also to measure the environment on the surface through careful and extended observations (MT 66–10142, fig. 24).

Mr. RUMSFELD. May I interrupt there? What you are describing, to some extent, is very similar to the types of activities that will be undertaken in the portion of the budget that is being funded under the Apollo program, the samples and checking the surface and this type of thing. Is this correct?

Dr. MUELLER. Well, in the Apollo program itself, we are limited rather markedly in the payload that we can deliver to the lunar surface so really we are only collecting surface samples in the case of the Apollo missions. That is the only capability that we have. This represents not just small extensions, but significantly greater extensions.

Mr. RUMSFELD. Isn't it difficult to know exactly what you want to do in this Apollo Application without taking a look at some of the samples from the first Apollo missions?

Dr. MUELLER. I think that our present knowledge of the lunar surface is such that we know that it represents a "garden" surface, a surface that has been worked over by meteorites over a long period of time.

We have been led to those conclusions from the photographs. That describes a clear need for some method of drilling. There is no question about the need for a drill.

FIGURE 24

Mr. RUMSFELD. My question was, Is there a possibility that after the first manned lunar landing that you would have to or desire to change your plans substantially?

Dr. MUELLER. I think we have examined that question pretty carefully as well as the question, Is it desirable really to continue this lunar exploration? After we look at the first samples, will we find that is all we are interested in? There is a uniform opinion of those people who have worked on the subject in the scientific community, and we did have a major study during the summer of 1965 at Woods Hole of this particular area; the consensus was that we ought to plan on extending the capabilities of Apollo, and we ought to develop the capability both for drilling and extensive observations on a single site, and the ability to move a mobile system so you can move some distance across the terrain. The geologists say that the thousand feet which is the maximum range that an astronaut can go from a landing point in Apollo is not going to be sufficient to do anything other than preliminary observations.

Mr. TEAGUE. Mr. Gurney.

Mr. GURNEY. If you go ahead with the part of the Apollo program, what are we going to use for boosters?

Dr. MUELLER. These are Saturn V's, it takes two to provide enough payload in order to have a 2-week stay and in order to carry enough experimental equipment.

Mr. GURNEY. I though you were skating on thin ice with the payload already.

Dr. MUELLER. We use one of the Saturn V launches to land a lunar module descent stage without any ascent propulsion on board and that provides us with several tons of capacity.

Mr. FUQUA. Will it be possible to leave certain equipment on the Moon and set up some type of outpost or station there?

Dr. MUELLER. One of the things that we are looking at is the possibility of going back to a site, for example, where we have a drill emplacement. We haven't determined whether that is the best way to utilize an expensive set of apparatus. The scientists are divided, whether they want to go to a single site and explore it in depth or go to different spots. That will have to wait until we get some experience.

As we go further downstream, we see two types of payloads which have been developed in concept and on which the principal experiments have been identified, one is a meteorology payload package (ML 66–9876, fig. 25), and in this particular case, we are carrying out a set of experimental observations of the earth's atmosphere, but using equipment that we would hope eventually to understand well enough to determine whether or not it should be flown in an unmanned mode or a manned mode. Particularly, one of the objectives is to find that kind of equipment and to develop that kind of equipment using a man, that could be used most economically for extended meteorological observations. That is one of the principal objectives of this total package. The other is an Earth resources package (ML 66–9873, fig. 26). It is used for observing the Earth's surface and the manned mode is desired so that we can develop the range and the scale of the instruments to be used for future missions. These are both initial

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 25

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 26

missions and we will establish the kind of equipment that is useful and the limitations and they will be flexible enough to permit adjustment so as to modify them while in flight and to get the maximum amount of information.

These are the kind of experiments that are being planned in the Apollo Applications program. Funding for both of these programs is included in the budget.

A further extension of the Apollo telescope mount has interesting possibilities (ML 66–9875, fig. 27). I do believe that the combination of the workshop and the Apollo telescope mount represent a major step forward in our capability and our ability for man to operate in space, a major step forward that can be taken with a relatively small expenditure of funds and yet which will lay the foundation for future space operations. I personally am convinced that this program provides an opportunity that is of incalculable value in the long term to our progress in space flight.

In particular, the same basic equipment that is used for the solar observations can be used to mount a telescope, a telescope that might be some 40 inches in diameter, but also be associated with a visible light telescope and probably would be associated with some X-ray telescopes as well. This array could be used for carrying out stellar observations. One of the basic requirements for this kind of a system is the ability to take long exposures of film so that you can photograph faint stars.

The combination of time of exposure plus the aperture provides you with the faintness of the star that you can identify and in particular,

MANNED PHOTOGRAPHIC TELESCOPE

SCIENTIFIC OBJECTIVES

- UV PHOTOGRAPHY OF GALACTIC EMISSION AND REFLECTION NEBULAE AND OF BRIGHT GALAXIES AND QUASARS
- SPECTROGRAPHY OF PLANETARY AND DIFFUSE EMISSION NEBULAE AND QUASARS

INSTRUMENTATION

- 38-INCH APERATURE f/5 ULTRAVIOLET TELESCOPE
- 1000 POUNDS
- 48-INCH DIAMETER BY 10 FEET LONG

REQUIREMENTS

- ± 1 ARC SECOND POINTING
- MANNED OPERATION
  - TARGET RECOGNITION AND SELECTION
  - COARSE GUIDANCE
  - CHOICE OF PHOTOGRAPHIC AND SPECTROGRAPHIC MODES
  - ALIGNMENT AND FOCUS
  - SELECTION AND CHANGING OF FILM
  - EXPOSURE AND PROCESSING FILM
  - EXCHANGE OF FILM

FLIGHT READINESS

- 1971-1972

NASA HQ ML66-9875
11-15-66

FIGURE 27

then, we would want to place this thing in a high enough orbit so that first of all the earthshine is not a problem and, secondly, we can take long exposures without being occulted by the Earth. A synchronous orbit is what most of the studies suggest (ML 66–8977, fig. 28).

We would use the basic ATM equipment and place a workshop with it in Earth orbit, assuming the first flights work well, and then we will establish, if you will, a manned orbital telescope using the same basic equipment that we are developing for solar observation in lower orbits.

Mr. RUMSFELD. Have you rejected plans or the possibility of an unmanned lunar observatory that would be put on the surface of the Moon? There was some talk of this.

Dr. MUELLER. Unmanned lunar observatory?

Mr. RUMSFELD. That would be on a fixed position on the Moon as opposed to an orbiting observatory.

Dr. MUELLER. There is the possibility of a manned and unmanned observatory. I don't know of a serious study on the lunar surface unmanned because of the difficulty of controlling and pointing it. The work done indicates that probably the decision will be to go to an orbiting telescope rather than one placed on the lunar surface, and all of the people are agreed that that ought to be attended by man. Whether or not there is a full-time man operating it or not is still a question that needs to be determined as a result of our carrying out the work with the Apollo telescope mount.

Mr. RUMSFELD. I remember talking to some people from the Lindheim Observatory in Illinois some years ago that they desired to undertake such an effort prior to the first manned lunar mission. Their thought was that it would be a simpler operation. They thought the information would be of greater interest before the first manned flight.

Dr. MUELLER. The complexity of that is greater when you get down to designing it than it is in concept and there were some studies made several years ago in this area, but when you really figure out what you actually have to do in order to do it, it turns out to be a pretty complex mission.

Mr. RUMSFELD. So there are no plans for it to be unmanned?

Dr. MUELLER. That is right; on the lunar surface.

Another area of great promise is the land landing capability in the Apollo Applications program (ML 67–5763, fig. 29). What we are talking about is the development of a capability to reuse the command module. We hope at the same time to be able to increase the crew complement hopefully to as many as six rather than three using the basic Appollo capsule. We would expect, therefore, to be able to reduce the water recovery forces and, of course, to increase our landing flexibility.

Now, the development required in order to do this is first of all a development for a gliding parachute (ML 67–5516, fig. 30) which we

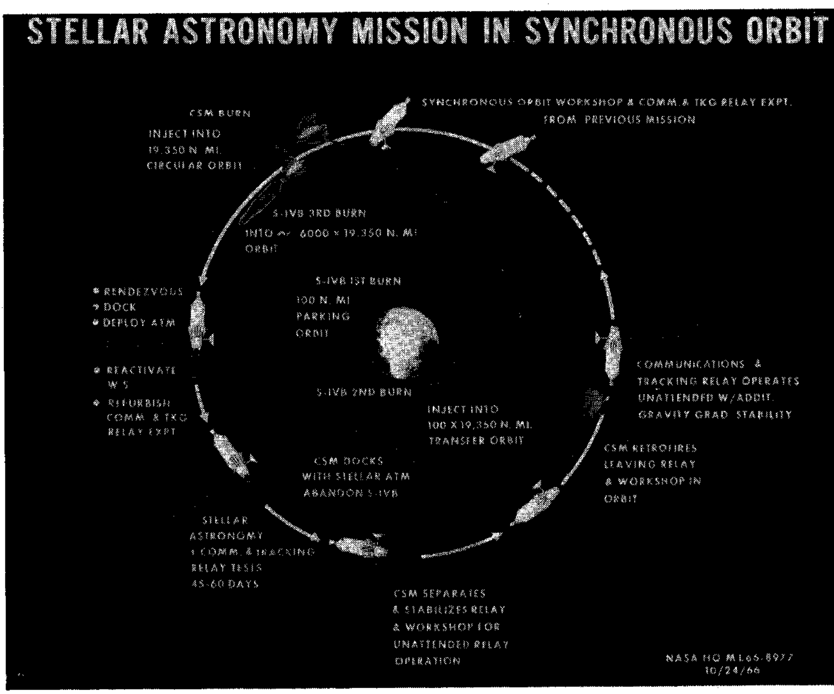

FIGURE 28

APOLLO APPLICATIONS

LAND LANDING

- DESIGN OBJECTIVES
  - COMMAND MODULE REUSABILITY
  - INCREASED CREW COMPLEMENT
  - REDUCED WATER RECOVERY FORCES
  - INCREASED LANDING FLEXIBILITY

- DEVELOPMENT REQUIREMENTS
  - GLIDING CHUTES
  - MANEUVERABILITY CONTROLS AND DISPLAYS

NASA HQ MC67-5763
2-21-67

FIGURE 29

call a parasail and the requisite controls and displays to cause this to be useful. I ought to add one other thing and that is the development of capability for retrorockets at touchdown.

This is under study at the present time and does have a great deal of promise in reducing the cost of operations for the manned space flight program in the future.

Now, where we stand in the course of procurement and where we have to go forward this year with the Appollo Applications program if we are to avoid a shutdown of the factory lines that are producing the equipment and a corresponding hiatus and dissipation, if you will, of the launch teams and the test teams and the whole fabric of the organization is shown in these two charts (ML 67–5906, fig. 31; ML 67–5907, fig. 32).

In the case of the command module, we have under procurement in one fashion or another all of the systems. In the case of the surface module and the lunar module, the same thing holds true. In the case of the Saturn launch vehicles, Uprated Saturn I, we have progressed to where all the vehicles are in fabrication and assembly at the present time. In the case of the Saturn V, we have long-lead-time procurement on all the vehicles, 10 of them are in various stages of fabrication and assembly so we are well along in the actual production of the hardware that is to be used in the basic Apollo program. In order to avoid a hiatus in production and to continue at least some

FIGURE 30

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.

NASA HQ MC66-5906
2-27-67

FIGURE 31

level of production, it is necessary to reorder the equipment at the present time. The leadtimes are shown on the next chart on the left-hand side (ML 67–5917, fig. 33) and in some cases we are past the long-lead procurement point, in fact. We have, in fact, placed orders for portions of the Apollo and Saturn I vehicles. We are in the process of having to place orders for long-lead-time procurement on Apollo-Saturn V, and the command and service modules, in order to provide the opportunity, if you approve the President's budget, to proceed on the production of these vehicles.

Now, in conclusion, I would like to say something about the Apollo Applications program and particularly to try to answer where the Apollo Applications program merits your support at this time (ML 67–5971, fig. 34). I believe there are many reasons, but some of them are as follows: It 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.

I think that both of these points were made in a different way by the Vice President last evening. He did stress the importance to the Nation of a vigorous space program. It will maintain the forward momentum that space technology has given our competitive position in the world marketplace.

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 space capability assembled in painstaking fashion over a period of a decade. It will hold open the opportunity to return direct benefits to man on earth in the next phase of space activity, maintaining the momentum achieved thus far.

APOLLO SPACECRAFT PROCUREMENT

STATUS AS OF FEB. 25, 1967

SPACECRAFT	BLOCK DESIGN-ATION	USED	ASSEMBLY COMPLETED	IN FABRI-CATION AND ASSEMBLY	ORDERED BUT NOT YET IN FABRICATION	LONG LEAD PROCURE-MENT	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 32

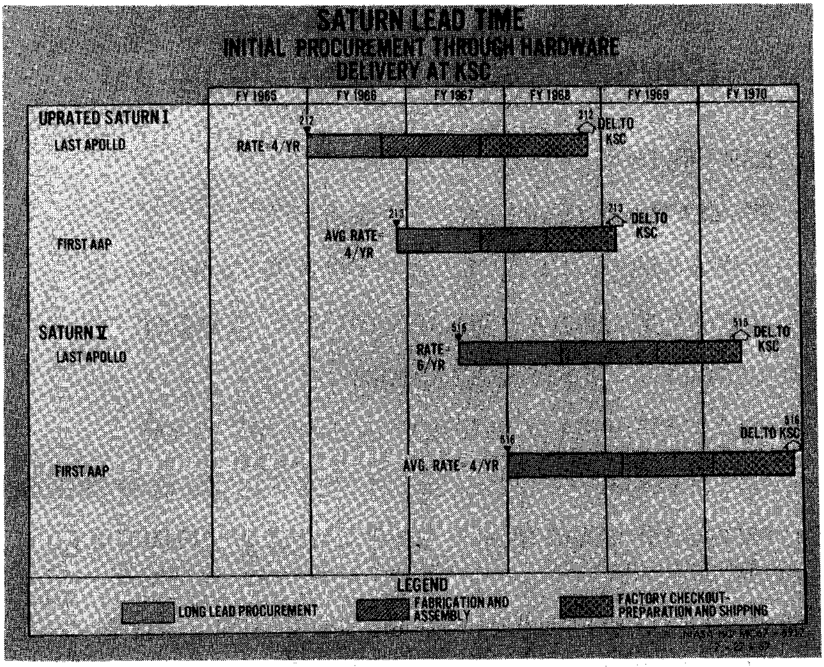

FIGURE 33

It will take advantage of the opportunities for expansion of knowledge when space-age technology shows promise of breaking through into an era of real discovery. I think most of the scientists who have been involved in our program in the Apollo Applications program are really looking forward to the fact that they ought to make discoveries that will be such that some of them will win Nobel Prizes.

It will provide the means to meet the challenge of future in space at relatively modest cost. Our peak year was in fiscal 1966 when NASA expenditures totaled 0.83 percent of the gross national product. In the current fiscal year we are down to 0.73 percent and in the budget for fiscal 1968, the total would be only 0.67 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 be insured because this proposed program would keep the space team together and in a position to respond to economic developments in the national scene.

I have presented the program which resulted from the study effort authorized by this committee in fiscal year 1966. This careful planning was further supported by this committee in fiscal 1967 when funds were authorized to keep the options open for one more year, and we are now asking you to exercise these options. The Apollo Applications funds you provided last year defined the follow-on effort to the Apollo program that resulted in an effective program to capitalize on the investment this country has made in space. This program has been reviewed and endorsed by the Bureau of the Budget, the

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

NASA HQ MC67-5971
3-7-67

FIGURE 34

President's Science Advisory Committee, and the President. They recommend that we press onward in the investigation of man's role in space, the interrelationship between man and machine in space exploration, scientific experimentation and operational systems. They recommend the Nation not be deprived of the ultimate benefits to mankind this capability offers.

In this presentation in support of our budget request for fiscal year 1968, we are asking that you approve the continuance of our efforts toward these national objectives.

Mr. TEAGUE. Any questions?

Mr. GURNEY. Dr. Mueller, how are you handling the procurement for these? You mentioned you place orders for Saturn I–B hardware.

Dr. MUELLER. That is correct.

Mr. GURNEY. How have you handled this in view of the fact that we haven't authorized them yet?

Dr. MUELLER. The funds were authorized for those on long-lead-time procurement in the fiscal 1967 budget.

Mr. TEAGUE. $41.9 million.

Dr. MUELLER. $41.9 million and those are the funds we are using.

Mr. TEAGUE. Any questions?

The committee will be adjourned until Monday at 10 a.m.

(Whereupon, at 12 noon, the subcommittee adjourned to reconvene at 10 a.m., Monday, March 20, 1967.)

1968 NASA AUTHORIZATION

MONDAY, MARCH 20, 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., Hon. Olin E. Teague (chairman of the subcommittee) presiding.

Mr. Teague. The subcommittee will come to order.

We will begin with advanced missions this morning.

STATEMENT OF DR. GEORGE E. MUELLER, ASSOCIATE ADMINISTRATOR FOR MANNED SPACE FLIGHT, NASA; ACCOMPANIED BY WILLIAM E. LILLY, DIRECTOR, MANNED SPACE FLIGHT PROGRAM CONTROL, NASA; CHARLES MATHEWS, DIRECTOR OF THE SATURN APOLLO APPLICATIONS, NASA; ROBERT F. FREITAG, DIRECTOR, MSF, FIELD CENTER DEVELOPMENT, NASA; AND EDWARD Z. GRAY, ADVANCED MANNED MISSIONS PROGRAM DIRECTOR, NASA

Dr. Mueller. That is correct, Mr. Chairman.

With your permission, I will talk about the advanced missions programs and then go through the budget books for both the Apollo Applications and Advanced Missions.

Mr. Teague. Do I understand it will take you until about 11:20 on Advanced Missions?

Dr. Mueller. I would hope that we would be finished by then. I will move rapidly.

Turning to the first chart (MT66-10,256, fig. 1) we have developed over the past year using the funds provided by the committee, several baseline programs. What we have tried to do is to define the steps that are required to continue manned space exploration and manned space utilization. In the left-hand chart, you see the normal sequence of a development cycle. The development phase that we are in at the present time or that we are just entering on involves man's capabilities and requirements for operating in space. We are now going through the phase of just figuring out how man can survive and how he can be supported in space.

We would expect, as the next major step in the manned part of this program, to begin the development of equipment and procedures for long duration manned research, flight, and operations. As we go

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further into the future, we eventually expect to begin to develop and improve equipment and procedures for Manned Space Flight.

Now, in terms of a capability, this provides the development of the capability of staying for long periods of time in orbit so that we can measure the effects of the environment on man and also so we can develop the equipment to support him effectively for long periods of time. We will want to develop the equipment for continuous operations in space, first resupplied and then continuously operating on its own supplies so that we eventually reach the capability for interplanetary travel.

This baseline kind of advanced program is one of many that we have looked at and the dates here aren't necessarily any that would be met and, of course, the progress in this kind of a program depends upon the funding made available. Nevertheless, this is a baseline program that could be done providing it was found desirable to proceed in this direction and providing resources could be made available. Another way of looking at it is shown in this chart (MC66–5358A, fig. 2) which is one that we have used in the past. It represents a probable kind of a program evolution for manned spaced activities beginning with Gemini and going through Apollo, to Apollo Applications plus the experiments program. All of which leads to the conclusion that the next major module that will probably be required on the next major development will be a manned space station. A manned space station can, if the design constraints are proper from our studies, be designed so that it could be useful for a number of different end objectives. Because it is a major investment, it is probably desirable to have as flexible a design as possible and this is the area in which our advanced missions program is working. From

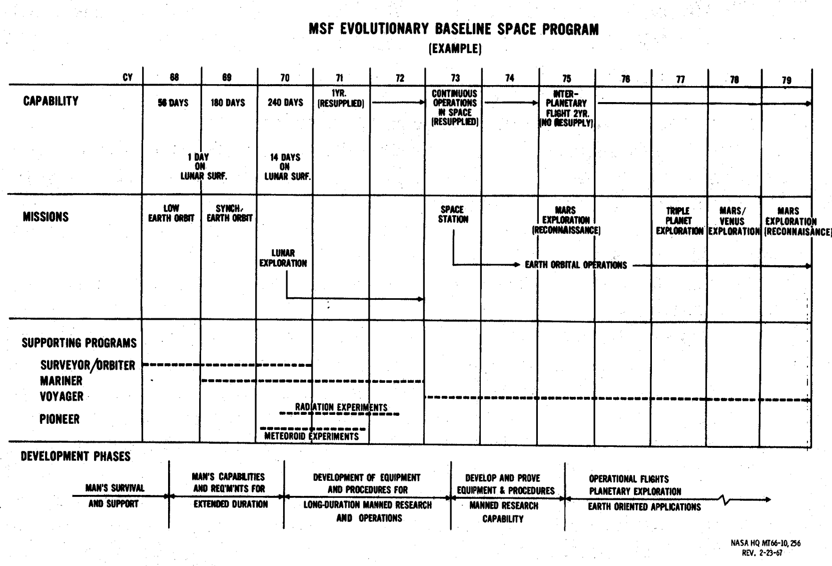


FIGURE 1

there we could go to manned planetary reconnaissance and finally to a manned planetary landing. That is the kind of evolutionary program that we have been studying.

Next we have the manned earth orbital advanced studies. (MT66-7996, fig. 3.) They have as primary objectives the development of earth orbital program planning alternatives to support the major objectives of identifying the important manned earth orbital missions. They also explore systems concepts for these kinds of missions to evaluate and define logical program alternatives; to evaluate the supporting ferry, logistics and rescue concepts; and to identify such R. & D. technology and development that might be required to support these mission objectives.

At the present time, we have a fair knowledge of the space environment (MC66-5361, fig. 4). We do have a considerable amount of Manned Space Flight experience. We have developed the basic technology for operation of spacecraft and we have a large booster capability that is coming into being, so that at the present time we have a space flight capability that is good enough for us to begin to define what man's capabilities are. This, of course, is the objective of the Apollo Applications program. From that experience and using this equipment, we expect to be able to define what man's usefulness will be in the future and how one needs to support him in order to make him most useful.

Mr. DADDARIO. You will recall, Dr. Mueller, that during the course of the preliminary hearings before the full committee I asked you a question involved in the PSAC report which although supporting manned activity in the future was somewhat critical of the way in which NASA had prepared itself for future activities. As I understood it the question was to the way you have come to judgment on nonmanned as against manned missions and the facts they believed

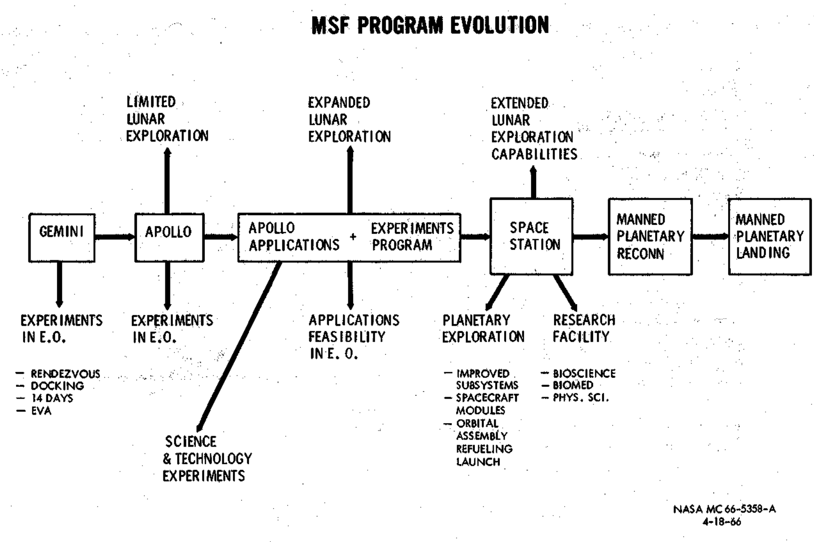


FIGURE 2

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 3

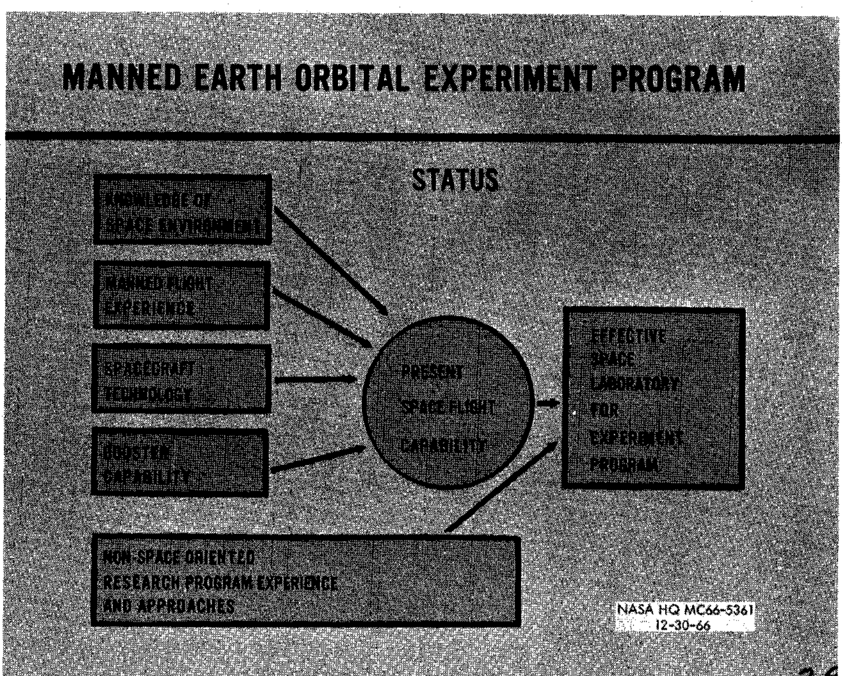


FIGURE 4

supported the idea that this was not properly synchronized. I referred you exactly to the point in the PSAC report. I wonder if you might enlarge on that a bit since we didn't have an opportunity to do so at that time.

Dr. MUELLER. I would be pleased to. I believe you are referring to the passage on planetary exploration.

Mr. DADDARIO. Yes, because you just touched that. I thought at this stage of the game that question would again be appropriate.

Dr. MUELLER. Let me say that the PSAC report, in general, has supported the immediate plans of NASA. I am thinking of the manned orbiting telescope work and the long duration flight activities.

Mr. DADDARIO. Yes; there is no question about that. I agree with the idea that we ought to be involved with a man in these missions. I was concerned because they showed an agreement with that principle but concern about the way you had programed your plans for the future with some criticism about the lack of synchronizing the manned and unmanned missions. I recall that the major reason you could not make a decision at this time was because you did not have available to you the information which you would some year or two later as you develop activities of this kind. To make such decisions at this time would be, as I understand it, premature and might lead you to misjudgment.

Dr. MUELLER. Precisely. The basic organizational structure of NASA has been set up to provide for coordination of our planning activities. The PSAC report reflects the fact that we have all agreed that we ought to go forward with Voyager at this point in time in order to provide for early information about the environment of first the near planets and then the far planets.

At the same time we are continuing in our planning studies to examine alternatives between continued use of the Voyager and the use of a manned vehicle, first in a flyby mode and then eventually leading to a manned landing. We have carried on a fairly extensive study effort in the past year in this area and that study effort has been quite well coordinated. We have some five or six coordinating panels in NASA. Mr. E. Z. Gray, is our representative. Mr. Cortright is the OSSA representative, Mr. Eggers is the representative of the OART. We do coordinate our planning. In order to have meaningful alternatives one has to define the alternatives and then examine the tradeoffs between one set of missions and another set of missions so we have a meaningful basis for judgment between the alternative of a manned flyby and an expanded Voyager program. This will enable us to understand what it costs and what can be gained from each one of these approaches.

We are still at that point in time when we have to define these two approaches clearly and then make the tradeoffs. We do expect and plan to make those tradeoffs as our knowledge improves both as to what man's capabilities are and what his usefulness is as our studies define clearly just how to go about doing these very complex missions. They are very complex whether they happen to be manned or unmanned. I think that all of the groups that have been examining the future of manned space flight have concluded one thing. They are sure that man will eventually want to carry out planetary explorations for a number of reasons. Each group may have a different reason, but they all conclude that manned planetary exploration is a desirable and necessary thing that man will do in the course of time.

With that as a basis then one needs to define a program that optimizes one's getting there. You could make a different asumption and then you would have a different set of results. Since there is almost universal agreement among those people that have examined the course of development that man will eventually be needed to explore the planets, then the question is what is the most economical way of arriving at that objective.

The other thing is to define what is possible and what is desirable.

Mr. FULTON. When you are talking about planetary exploration, I have always been interested in the asteroid belt, which as you know, lies between Mars and Jupiter. One of these asteroids is going to approach Earth very closely. Why don't we try to see what it is going to be doing in the next couple of years; why don't we have an effort of this type in the program and see what an asteroid is?

Dr. MUELLER. Dr. Newell has had under consideration probes to comets as they pass Earth in order to get some closeup views and some idea of their trail. The asteroids are somewhat beyond Mars and tend to be in orbits that don't interest our orbit directly. One of the interesting possibilities as well as problems of a Mars flyby, for example, is in coming past Mars you also come out in the asteroid belt before you return. You might not be able to avoid a major asteroid. The advantage is that it gives you an opportunity for close and detailed observation of a number of asteroids as one spends some time out there.

Mr. FULTON. With 50,000 asteroids strewn in your path, it would certainly be worthwhile for you to learn about them ahead of time.

Dr. MUELLER. Yes, sir.

Mr. FULTON. Secondly, when the Manned Space Flight Subcommittee flew in from Arizona we saw that tremendous crater where some sort of an asteroid hit. So when I hear that within the next couple of years, there is a one chance in a billion that a particular asteroid will actually hit the Earth or go into orbit around us, I believe we ought to be looking into it. I don't want to be in the position of my great aunt living in Erie who was 80 years in age and was always freightened to death because Niagara Falls was going back 37 feet a year. This particular asteroid may be too far out to be of danger. However, it would give us a chance to see what these asteroids are, particularly if we are going to Mars. We might conceivably acquire another moon in the next couple of years or might possibly be in the path of the asteroid.

Dr. MUELLER. That is a possibility.

Mr. FULTON. So we may have to go up and hitch a rocket to it.

Dr. MUELLER. But it is, of course, fortunately an extremely remote possibility.

Mr. FULTON. In astronomy, one chance in a billion isn't too remote.

Dr. MUELLER. Turning to one of the major applications of Earth orbital applications, we have carried out some studies of optical telescopes (MC66–5366, fig. 5) in Earth orbit and have looked at some comparisons between various kinds of telescopes (MC66–5597, fig. 6). For example, the 200-inch Mount Palomar telescope has a resolution

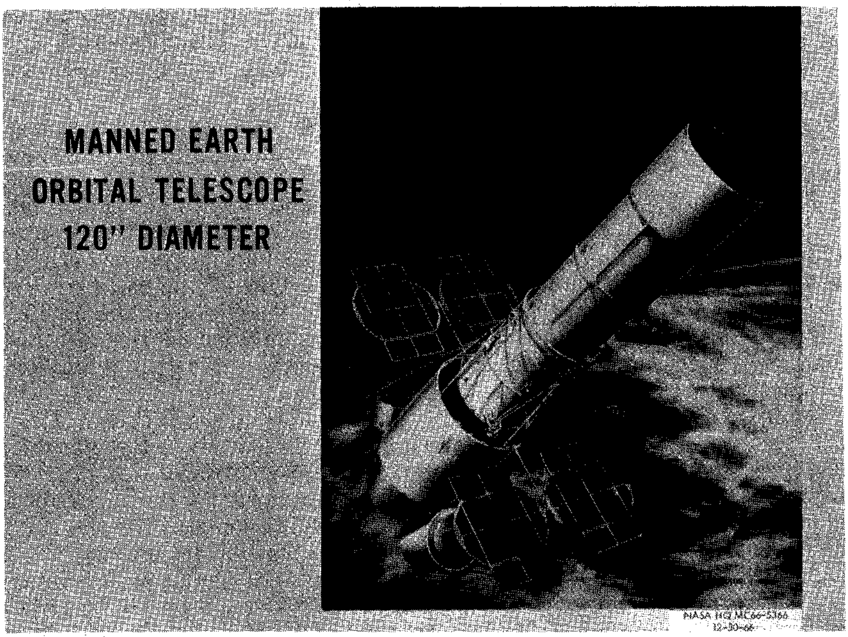


FIGURE 5

OPTICAL TELESCOPE COMPARISONS

	GROUND-BASED		IN ORBIT			
	200" (MT. PALOMAR)	16"	16"	38"	60"	120"
EFFECTIVE RESOLUTION (MILES)						
MOON	.3	.3	.3	.14	.09	.05
MARS	50	50	50	20	13	7
DETECT STAR PLANETS	NO	NO	NO	NO	?	POSSIBLY
SPECTRAL RANGE	←VISUAL→		←VISUAL PLUS INFRA-RED AND ULTRAVIOLET→			
REQUIRED STABILIZATION (ARC-SEC)	±0.1–0.2	±0.2	±0.2	±0.1	±0.05	±0.025
APPROXIMATE WEIGHT OF TELESCOPE (LBS)	1,000,000		500	1000	4000	30,000

FIGURE 6

on the Moon of about three-tenths of a mile. A 16-inch telescope in orbit has about the same resolution. This is also true of Mars where we have about a 50-mile resolution. If you look at the improvements achievable in orbit, you see that the 16-inch in orbit is about the same for Moon and Martian observations as that on the ground, but you get successively better resolution as you go to larger diameters.

Finally, at 120-inch diameter, you get something like a 0.05 miles resolution on the Moon and something like 7 miles on Mars. With the 120-inch in orbit and perhaps even with the 60-inch in orbit, it might be possible to detect planets, and other stars. One of the basic things that one can do in orbit that one can't do on Earth is to extend the spectral range of operation and extend the regions of the electromagnetic spectrum over which one can observe. That is a unique characteristic of being in orbit.

There are increased requirements in technology to reach these. One is developing the capability of pointing quite accurately. By the time one gets to a 120-inch telescope one has to have a stability of plus or minus .025 arc-seconds. The approximate weight of the telescopes increases as one goes up in size and the present estimates for the 120-inch telescope is that it might weigh as much as 30,000 pounds.

Another area that we have looked at in terms of near Earth orbital operations is the way one might resupply or carry out periodic trips to space stations in orbit (MT65-9715, fig. 7). We have looked at a

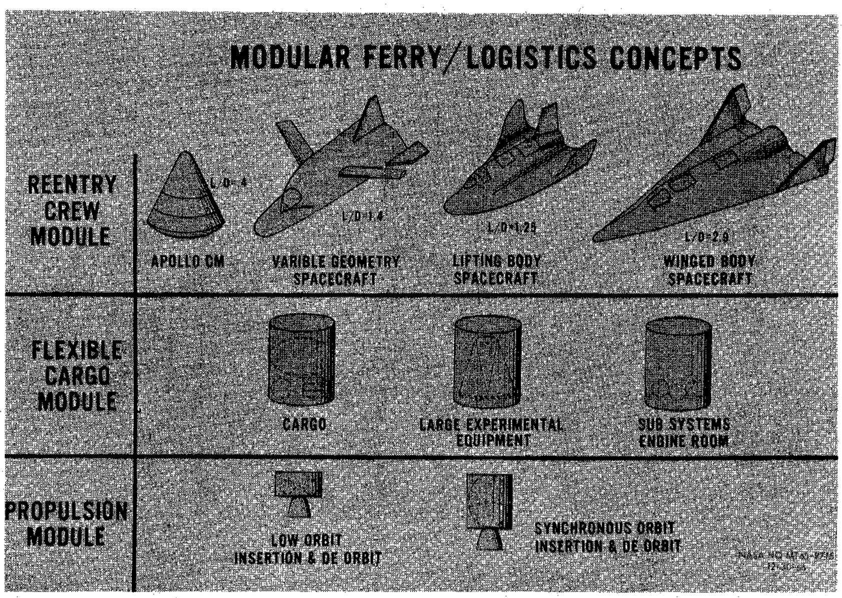


FIGURE 7

range that starts with the Apollo Command Module and goes on to finally reaching something like a winged body spacecraft with an engine as you can see, on the far right, which is capable of flying. You will also find that there are various ways of carrying cargo and we have been examining these various means to try to find the most efficient way of carrying the cargo to orbit. We have also been looking at various propulsion modules. These are the kind of studies that lead us to an understanding that permits us to make sound decisions in times to come.

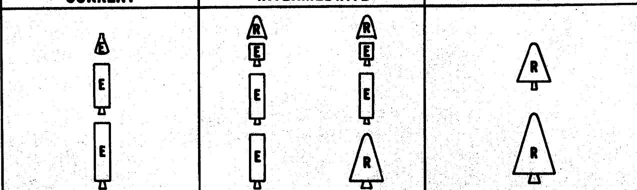
Turning to the trend of the transportation systems (MT66–8032, fig. 8) that we will be using, we have been looking at various general kinds of vehicle concepts including such things as improving the present systems and then those systems where we can begin to reuse part of the system, beginning with the reusable spacecraft and then considering some form of reusable booster systems. In this case the first stage is proposed as being reuseable time after time.

Finally we are working toward a concept of fully reusable vehicle systems so that we would have a fully reusable launch vehicle and spacecraft.

Mr. DADDARIO. In the area of manned Earth orbital telescope activity, Dr. Mueller, will you briefly sum up those members of the astronomical community who have advised you in this and supported this?

Some of them have made the point that by spending less money on

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

NASA HQ MT66-8032
12-30-66

FIGURE 8

Earth activities we could accomplish a great deal which is included in this kind of astronomical activity at what they consider to be a much greater cost.

Dr. MUELLER. Of course we have the space-sciences groups who have reviewed our programs and have approved them as well as recommended them. There is the Harvard observatory group. There is a group at the University of California's Lick Observatory; just to name a few who have specifically looked at manned orbital telescopes.

Mr. DADDARIO. We are curtailed for time. Might you be able to provide that for the record?

Dr. MUELLER. I would be pleased to do that. The other point which I would like to make now is that there isn't a conflict between the resources used for ground based telescopes and those used for space telescopes.

(The information requested follows:)

SPACE SCIENCE BOARD

The proposal for a 120 inch optical telescope was made by the Space Science Board of the National Academy of Science in its recommendations for Space Research: *Directions for the Future* made as a result of the 1965 studies at Woodshole, Massachusetts. The particular astronomers associated with this recommendation were:

Lyman Spitzer, Chairman, Princeton University Observatory.
A. D. Code, Washburn Observatory, University of Wisconsin.
L. W. Fredrick, Leander McCormick Observatory, University of Virginia.
F. J. Low, Lunar and Planetary Laboratory, University of Arizona (until recently, National Radio Astronomy Observatory).
N. U. Mayall (Coordinator, Astronomy Working Groups), Kitt Peak National Observatory.
A. B. Meinel, Steward Observatory, University of Arizona.
Guido Munch, Mt. Wilson and Palomar Observatories.
H. J. Smith, McDonald Observatory, University of Texas.
W. G. Tifft, Alternate, Steward Observatory, University of Arizona.
F. L. Whipple, Smithsonian Astrophysical Observatory.

NASA has conducted an advanced study to examine the major technological implications of such an instrument when orbited in conjunction with a manned orbital facility (c.f. A System Study of a Manned Orbital Telescope. NAS 1-3968, The Boeing Company). The detailed characteristics of such a large telescope in orbit are not defined now, however, as a result of our studies such a telescope appears feasible towards the end of the 1970's.

PRESIDENT'S SCIENCE ADVISORY COMMITTEE (PSAC)

The Space Science and Space Technology Panels of the President's Science Advisory Committee in the PSAC report "The Space Program in the Post-Apollo Period" indicate that they have "studied the Space Science Board recommendations concerning earth orbital astronomy as well as other proposals that a major effort be concentrated on a very large orbiting telescope (of perhaps 120-inch aperture): While we feel that ultimately—perhaps in the late 1970's—the very large orbiting telescope will be feasible and may command a high priority, we believe that it would be a serious mistake to embark on this single objective now to the exclusion of a more "evolutionary" approach. For scientific as well as technical reasons, we urge an immediate start on simpler instruments which can more dramatically exploit the new access to unknown regions of the spectrum—such as X-ray and gamma-ray telescopes, and relatively inexpensive submillimeter instruments. In addition, a reflecting telescope for the ultraviolet, visible and infrared of 40-to-60-inch aperture should be placed in orbit at the earliest practical date if diffraction-limited resolution can be obtained with available technology. The argument for this evolutionary approach follows directly from the great scientific impact which we expect these new facilities to have. If we are corect in this expectation, it is essential that the program be planned in such a way that the most expensive and ambitious instruments profit in their conception and design from the discoveries made using smaller ones which are more quickly deployed. The possibilities of large optical interferometers, X-ray telescopes, low-frequency telescopes, and other instruments never used on a large scale before are such that it is unwise to attempt to predict at this time the nature of the highest priority large instrument for the program in the late 1970's".

The membership of these panels is as follows:

Dr. Franklin A. Long, Chairman, Cornell University, Ithaca, N.Y.
Dr. Lewis M. Branscomb, Co-Chairman, Joint Institute for Laboratory Astrophysics, Boulder, Colo.
Dr. William R. Adey, University of California, Los Angeles, Calif.
Dr. Hendrick W. Bode, Bell Telephone Laboratories, Whippany, N.J.
Dr. Robert W. Buchheim, The RAND Corp., Santa Monica, Calif.
Dr. Melvin Calvin, University of California, Berkeley, Calif.
Dr. Loren D. Carlson, University of California, Davis, Calif.
Dr. Joseph W. Chamberlain, Kitt Peak National Observatory, Tucson, Ariz.
Mr. Allen F. Donovan, Aerospace Corp., Los Angeles, Calif.
Dr. Howard W. Emmons, Harvard University, Cambridge, Mass.
Dr. George Field, University of California, Berkeley, Calif.
Dr. Herbert Friedman, U.S. Naval Research Laboratory, Washington, D.C.
Dr. Thomas Gold, Cornell University, Ithaca, N.Y.
Dr. Lester Lees, California Institute of Technology, Pasadena, Calif.
Dr. Gordon J. F. MacDonald, Institute for Defense Analyses, Arlington, Va.
Dr. Frank T. McClure, Applied Physics Laboratory, Silver Spring, Md.
Dr. Bruce Murray, California Institute of Technology, Pasadena, Calif.
Dr. Edward M. Purcell, Harvard University, Cambridge, Mass.
Dr. J. Barkley Rosser, Mathematics Research Center, Madison, Wis.
Dr. Jack P. Ruina, Massachusetts Institute of Technology, Cambridge, Mass.
Dr. Martin J. Schwarzchild, Princeton University Observatory, Princeton, N.J.
Dr. Irwin Shapiro, Lincoln Laboratories, Lexington, Mass.
Dr. Nathan W. Snyder, Georgia Institute of Technology, Atlanta, Ga.
Dr. Charles H. Townes, Massachusetts Institute of Technology, Cambridge, Mass.

The recommendation of PSAC is consistent with the planning for Apollo Applications. The ATM is the first step in the evolutionary approach suggested by PSAC. In the Advanced Manned Missions Study area concept data is being obtained for a comprehensive manned Astronomy/Astrophysics experiment program. This activity is described in the statement of work "Orbital Astronomy Support Facility" attached.

NASA AD HOC ADVISORY COMMITTEE (RAMSEY COMMITTEE)

The following are the members of an ad hoc committee appointed by Mr. Webb in the spring of 1966 and chaired by Professor Norman Ramsey who have advised and supported NASA in our planning on a variety of topics, including large astronomical facilities in space:

Dr. Norman F. Ramsey, Chairman, Harvard University.
Dr. George W. Beadle, University of Chicago.
Dr. Leo Goldberg, Harvard University.
Dr. Jessee L. Greenstein, California Institute of Technology.
Dr. Harry H. Hess, Princeton University.
Dr. Howard W. Johnson, Massachusette Institute of Technology.
Dr. Gordon J. F. MacDonald, University of California at Los Angeles.
Dr. Horace W. Magoun, University of California at Los Angeles.
Dr. Nicholas U. Mayall, Kitt Peak National Observatory.
Dr. Colin S. Pittendrigh, Princeton University.
Dr. Martin Schwarzchild, Princeton University.
Dr. Charles Townes, Massachusetts Institute of Technology.
Dr. James A. Van Allen, University of Iowa.
Dr. Homer E. Newell (NASA Rep.), Associate Administrator for Space Science and Applications.
Dr. John E. Naugle (NASA Rep.), Deputy Associate Administrator for Space Science and Applications (Sciences).
Dr. Henry J. Smith (NASA Rep.), Deputy Director, Physics and Astronomy Programs, Office of Space Science and Applications.
Mr. Robert J. Gutheim (NASA Rep.), Program Planning Officer, Office of Space-Science and Applications.

SCIENCE AND TECHNOLOGY ADVISORY COMMITTEE FOR MANNED SPACE FLIGHT (STAC)

STAC in a letter to Mr. Webb of November 22, 1966 concerning NASA's program and planning for the coming years states that "while *Exploration of the Solar System* should be a general and continuing goal of NASA, it does not encompass all important missions. There are also a number of scientific experiments to be done in space which do not involve examination of the solar system or any astronomical object. From a scientific point of view, astronomical observations of objects outside our own solar system from the vantage point of space vehicles, and hence without interference of the earth's atmosphere, represent one of the most rewarding applications of space technology, and should be an important and continuing part of the space effort."

Also, it continues:

"Major parts of the manned space effort which we envisage as a minimum reasonable program are as follows:

1. * * *

2. * * *

3. Manned space stations will be needed for a variety of purposes. By a space station we mean an earth satellite maintained in orbit over a period as long as about one year, and furnishing the necessities of life for man continuously or from time to time over a comparable period with the possibility of his doing useful work in orbit. Such a station will be needed to test man's ability to operate in space for the time periods required for interplanetary travel. In addition, use of a space station, at least on an intermittent basis, seems worthwhile for an orbiting astronomical observatory, for some other varieties of scientific experiments, and for engineering testing."

Members of the STAC who signed the above letter are:

Luis W. Alvarez, University of California, Berkeley, Calif.
Stanley Bennett, University of Chicago.
Francis H. Clauser, University of California, Santa Cruz, Calif.
Lee A DuBridge, California Institute of Technology.
Leo Goldberg, Harvard University.
Gordon J. F. MacDonald, Institute of Defense Analyses, Arlington, Va.
William G. Shephere, University of Minnesota.
William B. Shockley, Stanford University.
William H. Sweet, Massachusetts General Hospital, Boston, Mass.
Charles H. Townes, Massachusetts Institute of Technology.
John R. Whinnery, University of California, Berkeley, Calif.
George D. Zuidema, Johns Hopkins Hospital, Baltimore, Md.

Dr. MUELLER. The funding for ground based telescopes has traditionally been supplied by the National Science Foundation. The need for ground based telescopes is one that is being met. It is not an area in which we attempt to make a judgment. We rather rely upon the advice of our scientific colleagues in that field to make these judgments.

Mr. DADDARIO. This question having been put to you and having been examined, I believe it would be helpful if we could have that for the record.

Mr. TEAGUE. Yes.

Dr. MUELLER. Thank you. We will be pleased to provide you with a detailed example of the kind of study we are doing in advanced missions.

(Information requested is as follows:)

NASA is currently studying orbital astronomical support facility concepts in order to identify those that will allow us to take advantage of the opportunities for astronomical observations outside the earth's atmosphere for the advancement of scientific knowledge. In defining these concepts we are examining the requirements for a broad program of observations, the potential instruments involved, flight missions and the interactions among these requirements. A copy of the work statement follows:

STATEMENT OF WORK: ORBITAL ASTRONOMY FACILITY, APRIL 4, 1966

ADVANCED SYSTEMS OFFICE, RESEARCH AND DEVELOPMENT OPERATIONS, GEORGE C. MARSHALL SPACE FLIGHT CENTER, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, HUNTSVILLE, ALABAMA

I. Scope

This work statement covers a 9-month study to derive an Earth Orbital Astronomy Support Facility concept that will enhance performance of a comprehensive, manned Astronomy/Astrophysics experiment program. The systems discussed in this work statement do not necessarily represent approved programs and this study will not necessarily lead to hardward projects; however, the results will provide technical information upon which management decisions can be based.

II. Background

Advanced mission and systems studies to date have established that the national manned space flight capability can significantly enhance a broad program of space research and experimentation. Specific analyses have delineated the scope and nature of such a manned experiment program and have identified the potential contribution to be gained by use of Earth orbital research laboratories in various scientific/technical areas.

Experimentation leading to the enlightenment and resolution of key scientific questions in Astronomy and Astrophysics is of major significance in the Earth orbital program in view of the unique opportunities for observations conducted from the vantage point of space. Earth-based observations are limited by atmospheric absorption of much of the electromagnetic spectrum; all but a few narrow bands in the visible, IR and radio regions of the spectra emitted by cosmic bodies are blocked and even in these narrow "windows" through the atmosphere, resolution capability of existing equipment is impaired by atmospheric turbulence. From a space-based observatory, the astronomer may observe uninhibited the emissions of interest with optical, UV, radio, x-ray, and Gamma-ray telescopes, and will also have the unique opportunity to make simultaneous, correlated observations with different sensors. Utilization of an Earth orbital research facility for continued and coordinated intestigations into the fundamental questions of Astronomy/Astrophysics promises to increase by an order of magnitude man's knowledge and understanding of the universe.

The virtual absence of gravity in orbit permits less massive telescope structures and promises pointing accuracies of 0.01–0.02 seconds. It is visualized that the Earth orbital facility will eventually attain the flexibility and multi-use that a ground facility would provide.

Many separate and independent experiments and instrumentation related to Astronomy/Astrophysics have been proposed, particularly for the Apollo Applications Program. Studies have identified special areas of interest in this scientific discipline and have provided preliminary concepts of the instrumentation necessary to investigate each. Building on these efforts, this study will analyze the needs of a comprehensive manned Astronomy/Astrophysics experiment program and will delineate specific concepts of an Orbital Astronomy Support Facility that enhances the program's potential value by capitalizing on man's participation.

III. Objectives

The objectives of this study are:

1. To develop a logical and evolutionary plan for Earth-orbital facilities for Astronomy/Astrophysics observations and to derive the criteria and direction for the conceptual design of an Orbital Astronomy Support Facility.
2. To develop system concepts for a flexible Orbital Astronomy Support Facility(ies) which fully exploits man's presence and participation and which enhances equipment simplicity and flexibility.
3. To define the capability of each facility concept to satisfy the needs of a comprehensive, manned Astronomy/Astrophysics experiment program and the manner in which the program's objectives can be pursued.

IV. Guidelines

The following guidelines are provided. Where warranted, the Contracting Officer's Representative (COR) may revise the guidelines during the course of the study. Additional information and guidance will be provided at the contractor orientation meeting and during the course of the study as required.

1. The single purpose of the Orbital Astronomy Support Facility(ies) is to capitalize on the established manned space flight capability in advancing the objectives of a comprehensive Astronomy/Astrophysics experiment program in Earth orbit.

2. NASA will provide the contractor with manned Astronomy/Astrophysics experiment program planning documentation, and, to the extent available, with equipments/instruments and instrument packages identified as being required by these objectives and experiments. This material will guide and aid the contractor in establishing a suitable reference frame within which the Orbital Astronomy Support Facility(ies) concepts and configurations can be derived.

3. To the extent that it is practical and desirable, the facility concepts will utilize the spacecraft currently envisioned for the Apollo Applications Program (AAP) and the Manned Orbital Research Laboratory for housing the equipments/instruments. If for best overall results the OASF should be housed in a spacecraft different from those currently envisioned, the facility housing will be such that it will be capable of operating with the AAP or MORL during the time periods specified in paragraph IV–6.

4. The facility concepts, particularly those for the earlier time periods, should allow for modular addition of equipment and accessories, thus further enhancing the facility's flexibility. This equipment may consist of items that become available after initial operation of the facility or items that may become necessary due to the refinements of experiments based on feedback from the initial phases of manned experimentation. Manned assembly, calibration, or modification with subsequent unmanned periods of operation, manned and unmanned data return, crew rotation, and resupply requirements, shall be considered where appropriate in this study.

5. The facility will capitalize on man's appropriate participation as a research and operator in the experiments, observations, assembly, maintenance, calibration, and other activities.

6. For initial guidance purposes the spacecraft to be assumed to be available for the Orbital Astronomy Support Facility, or for operation with it are:

a. For 1969–70: Basic Apollo and AAP spacecraft including LEM laboratory; Saturn S–IVB spent stage.

b. For 1972–74: Extended-life Apollo CSM with laboratory module in adapter; Saturn spent stages.

c. For 1976–78: Manned Orbital Research Laboratory with Saturn spent stages.

7. The facility concepts may include units that require several manned launches and/or unmanned launches. The facility concepts will be compatible with the Saturn IB and Saturn V launch vehicles.

8. Orbital characteristics to be considered should include those of greatest interest to the scientific community and are limited only by the Saturn IB and V capabilities launched from Cape Kennedy and man's presence during all or portions of the experimentation/observations.

9. Emergency escape is to be provided at all times for all personnel.

10. Results of current research projects, data of existing equipment/instruments and those under development will be used wherever possible. Possible use of existing ground-based instrumentation and equipment that could be modified for space operations should be considered. In particular, for the 1969–70 time period, the optical telescope available is expected to be an adapted and modified 38-inch diameter GEP type telescope. For 1972–74, the optical telescope is expected to be a minimum of 40-inches in dameter with technology moving towards 60-inches. For 1976–78, the minimum diameter is expected to be 60-inches with technology moving towards the 120-inches diameter telescope.

11. Use shall be made of ground tracking, instrumentation, and data acquisition facilities currently planned or being developed.

12. The National Academy of Sciences' 1965 Woods Hole summer study shall be considered a major source of astronomical ideas and "directions for the future" in space astronomy research.

13. The contractor will consider and build upon the results of previous studies, particularly the analysis of the scientific goals of Astronomy/Astrophysics, and the assessment of equipment requirements and their adaptation to space-borne experimentation. These studies include, but are not limited, to the Douglas MORL Study (NAS1–3612), the Boeing Manned Orbital Telescope Study (NAS1–3968), the IBM study of the ORL Experiment Program (NASw–1084

and NASw-1215), the Kollsman study of adapting the GEP-38" telescope to lunar surface missions (NAS8-20132) and the North American Aviation study of radio astronomy experiments on the lunar surface (NAS8-20198). Portions of this documentation are required during the course of this study but are not required in preparation of the contract proposal.

14. Spacecraft and launch vehicle performance and schedules will be made available by NASA as well as data from other appropriate NASA studies and facility and equipment development funding guidelines.

15. Dimensionless parameters shall be used wherever practical and appropriate. The "International System of Units (SI)" shall be used in addition to the "English Gravitational System" in final presentations and reports, where appropriate.

16. The division of effort of this study will be approximately as follows:

Task A: 10 to 15%.
Task B: 20 to 25%.
Task C: 60 to 70%.

V. Contractor's tasks

The objectives of this study are to be achieved by proceeding sequentially from the requirements of a comprehensive Astronomy/Astrophysics program to the development and systems analysis of manned astronomy support facility concepts. This study will consist of three distinct tasks:

Task A: Astronoy/Astrophysics Experiment Program Baseline and Associated Equipment and Mission Requirements.—It is the purpose of Task A to provide an updated, comprehensive Astronomy/Astrophysics research program baseline with correlated scientific objectives and requirements. The general criteria, direction and guidance for developing the subsequent analysis will be based on the results of this task.

1. The contractor will review, refine, and fill-in, to the extent required by this study, the NASA provided time-phased research objectives, experiments and requirements of the manned Astronomy/Astrophysics experiment program. Thus, the contractor will establish an up-dated baseline program and reference frame for the study. In this review and refinement the contractor will not limit his time frame to the 1969-78 time period and will pay particular attention to the interrelationships among objectives and among experiments. The program baseline will be submitted to NASA for review and approval. The Work Statement Addendum, which is a general discussion of an overall astronomy program, is provided to help outline the astronomy program scope for contractor consideration.

2. The contractor will identify and relate to the Astronomy/Astrophysics objectives the equipment requirements needed to conduct the research program.

3. Further, the contractor will review, analyze and define the types of missions, including orbital parameters and duration, which are required or desired for conducting the observations of the Astronomy/Astrophysics research program.

Task B: Establishment of Equipment Meeting Astronomy Program Objectives.—The purpose of this task is to identify equipment capabilities and availabilities as a function of time that can meet the needs of the Astronomy/Astrophysics Research program.

1. The contractor will analyze the equipment requirements established in Task A and assess the commonality among the requirements of the various program objectives and time-ordered activities.

2. The contractor will review the basic instrumentation and equipment packages provided by NASA and those developed by other NASA studies, specifically under the IBM Experiment Program and Boeing MOT studies. Furthermore, the contractor will relate the instruments/instrument packages to the common requirements; he will assess the adequacy of these instruments/instrument packages and identify additional instruments that are required by the program.

3. The contractor will assess equipment designs, providing conceptual designs where they are not available and establish as a function of time, considering the three time periods indicated in IV-6, the equipment that best meets the requirements of the program objectives and specific experiments. The contractor will especially assess the advantages to be gained in equipment simplicity by man's participation in the erection, operation and servicing of the specific equipments/instruments.

4. The contractor will delineate the requirements of the major equipments, including operating regimes, stabilization, fine guidance, isolation, work space, photographic and data recording and other ancillary equipment.

5. The contractor will establish development times and order of magnitude costs. The costing should be done only to the level possible on the basis of engineering estimates, not detailed cost accounting techniques.

Task C: Development of an Orbital Astronomy Support Concept.—It is the purpose of this task to establish specific orbital astronomy support facility concepts that best satisfy the Astronomy/Astrophysics program objectives in the given time periods (indicated in paragraph IV–6). The overview purpose of this task is to define a logical evolutionary plan of Earth orbital facilities and capabilities to satisfy Astronomy/Astrophysics program objectives. The impact on the astronomy equipment/instrumentation requirements will be assessed when they are made to operate within specific spacecraft and in conjunction with the spacecraft indicated in paragraph IV–6. It is also the purpose of Task C to consider and analyzé the operational interfaces and relationships of the instrumentation, related equipment and total operations in conjunction with specific spacecraft and launch vehicles.

1. The contractor will delineate, using the results established in Tasks A and B, specific facility concepts for the time periods indicated in IV–6. These concepts will be so structured that they satisfy the Astronomy/Astrophysics program objectives, the requirements imposed by the equipments, their operation and their integration including peripheral equipment, combined operation, crew/time allocation and work space requirements. Each concept will include the capability to be shut down in orbit and then reactivated at a later date by man.

2. The contractor will determine the effects on the spacecraft and launch systems of the Astronomy/Astrophysics equipment and instrumentation. Specifically, the contractor will consider the systems indicated in paragraph IV–6.

3. The contractor will recommend specific configurations of the Astronomy/Astrophysics facility after analyzing and selecting the basic operations modes. The modes of operations could be, but is not restricted to:

a. The facility(ies) being docked and permanently coupled to an AAP or MORL or spent stage spacecraft.

b. The facility(ies) coupled to the specific spacecraft for experiment setup but decoupled operation.

c. The facility(ies) and the specific spacecraft completely decoupled.

4. The contractor will perform and analyze the trade-offs in integrating the instrumentation with the facility. This will include attitude control and stabilization distribution considerations among the equipments, the facility(ies), and the spacecraft with which the facility may be operating; power source; altitude of operation; and thermal/visibility problems.

5. The contractor will perform conceptual designs of the facility concepts finally selected for the time periods as indicated in IV–6. The designs should give sufficient detail to show how they respond to the requirements of the Astronomy/Astrophysics program and how and over what time period they help to accomplish the objectives.

VI. Expected results

This study will include, but will not necessarily be limited to, the following results:

1. An updated, comprehensive Astronomy/Astrophysics research program baseline with time-ordered Astronomy/Astrophysics objectives and experiments.

2. Determination of the relative effectiveness of each type of scientific equipment in contributing to the program objectives, presented within a meaningful and easily read format showing the relationship of Astronomy/Astrophysics program objectives and the required scientific equipment/instrumentation.

3. Definition for each major Astronomy/Astrophysics program objective and for each associated major scientific equipment the following:

a. Technology Requirements: technology advancement, experimental verification, prerequisite ground-based research and necessary flight testing.

b. Mission Requirements: preferred orbital characteristics, duration and number of missions (consistent with the time frame of interest), crew participation and size, specialized crew training, logistic support.

c. Operational Requirements: operational development, ground facility support, data management, launch support.

d. System and Subsystem Requirements: volume, weight, controlling dimensions; power, environment control; stabilization control and accuracy; special handling; reliability and accuracy.

4. Development of a time ordered sequence for each major scientific instrument shown to be required with consideration of technology advancement requirements, funding development periods and prerequisite accomplishments.

5. Identification and assessment of the applicability of adapting present-day ground equipment and instrumentation for use in an Orbital Astronomy Support Facility.

6. Specification of the appropriate combination of scientific equipment that best satisfy the Astronomy/Astrophysics program objectives into three facility concepts.

7. Recommend configurations of the OASF for the time periods indicated in IV-6 that can operate with specific spacecraft, and assess the capability of each configuration for conduct of the Astronomy/Astrophysics program.

VII. Period of performance and reviews

A. *Period of Performance.*—All work required herein shall be completed within nine (9) months from date of contract.

B. *Reviews.*—1. The contractor shall visit MSFC, before beginning work, to discuss details of the work to be accomplished and the contractor's method of approach.

2. At the completion of approximately one-third of the contract period, the contractor shall give a presentation (at a location to be determined) on the work completed, and the work remaining, including the planned approach to be taken. Special emphasis should be placed on the work to be accomplished during the next reporting period. The purpose of this presentation is to inform MSFC personnel of the work being done by the contractor and to allow MSFC to comment on the approach being taken to insure that the desired results will be obtained.

3. At the completion of approximately two-thirds of the contract period, the contractor shall give a presentation (at a location to be determined) on the work accomplished, work remaining, and approach to be taken for the remainder of the study.

4. The contractor shall make final presentations at MSFC and NASA Headquarters at the completion of the study on dates agreed upon by MSFC and the contractor. These briefings will outline all work accomplished during the contract period, giving the study results and conclusions, as well as recommendations for further study.

VIII. Reports and visual aids

A. *Reports Required.*—1. The contractor will prepare a study plan developing in further detail the sequence of investigation to be conducted during the study. Each major step defined in this more detailed sequence will include objectives, expected results, approach to the solution, allocated man-hours, and data required from other sources. After approval of this plan by the COR, detailed analysis may begin.

2. Upon completion of the study, the contractor shall prepare and distribute, in accordance with a distribution list to be furnished by the COR, approximately 100 copies of the final report. This report shall consist of a minimum of two volumes: a "summary technical reports" limited to 20 pages and a "detailed technical report." The length of the detailed technical report should be proportional to the complexity of the study. The report should be comprehensive, i.e., include all significant data, but should also be concise. Include only significant and useful information; e.g., working papers, detailed calculations, etc., should not be reproduced in the report. This does not preclude referencing significant supporting data. Illustrations should be reduced as much as possible without sacrificing clarity and should be integrated into the text.

3. Upon completion of the study, the contractor shall prepare and distribute, in accordance with a distribution list to be furnished by the COR, approximately 100 copies of a "research and technology implications report" limited to 20 pages. It shall include a brief summary of the study covering the objectives and results. This report shall reflect the contractor's concerted effort to delineate those areas of research and technology wherein further efforts would be desirable based on

the results of the study. The recommendations should be listed in the following categories, where appropriate:

a. Instrumentation
b. Biotechnology and Human Research
c. Electronics and Control
d. Materials and Structures

4. At the time of each presentation, the contractor shall deliver to MSFC 50 copies of a brochure containing reproductions of the slides or charts used in the briefing, supported by a short description on the facing page.

B. *Reports Approval Requirements.*—1. The contractor shall submit a detailed outline of each volume of the final report to the COR for approval prior to a preparation of the report.

2. Before final publication, draft copies of each volume of the final report shall be submitted to the COR for review and approval. The number of draft copies required shall be determined by the COR.

C. *Printing Requirements.*—1. The requirements outlined in paragraph 35 of Government Printing and Binding Regulations, Joint Committee on Printing, Congress of the United States, April 1, 1964, concerning contract printing, are waived in accordance with the Committee's Authorization No. 21985.

2. Printing of reports resulting from this study shall be in accordance with the following general specifications:

a. Method of Reproduction—offset;

b. Finished Size—8½" x 11";

c. Paper—60-litho cover stock;

d. Pages will be printed on both sides, blank pages will be avoided when possible;

e. Oversize pages will be avoided when possible, but if necessary will be folded to 8½" x 11":

f. Additional color shall be used only upon prior approval by the COR;

g. Binding shall be the most economical method commensurate with the size of the publication and its intended use.

3. The cost of printing the final reports shall be a line entry on the financial reports (NASA Form 533). The cost includes composition, platemaking, presswork, and binding. Composition includes typesetting or final copy preparation by any method used as a substitute for typesetting.

D. *Visual Aids Required.*—The contractor shall deliver to MSFC two sets and one set to NASA Headquarters (MTE) of 2" x 2" slides of all charts used in the final presentation and one set for the mid-term presentation. The slide mounts shall not be more than 3⁄32" thick.

IX. Program management

A. *Technical.*—1. This contract will be administered and monitored by Marshall Space Flight Center (MSFC) of the NASA. The MSFC will monitor all technical activities of the contractor, provide technical direction and coordination and expedite the resolution of problem areas. The scope of the task requires that a number of NASA centers, contractors, and other organizations be involved in its implementation. The MSFC will be the focal point for this coordination activity.

2. The contractor shall assign a competent study program manager, free of other responsibilities, and staff to provide maximum continuity to the study effort.

3. The COR and other NASA representatives will visit the contractor's facility periodically to evaluate technical progress. The COR may also call periodic meetings to resolve problems when required.

4. During the performance of the study, the Contracting Officer or his authorized representative may redirect the study as required for maximum benefit to NASA.

5. It will be necessary for the contractor to coordinate the exchange and integration of all pertinent information with other NASA elements, other Government agencies, and contractors performing on studies or programs that are in progress or that may be initiated during the life of this contract. This integration and and coordination activity will be as specified by the Contracting Officer or his authorized representative, and will include reports, both written and oral, presentations conferences, and special meetings.

B. *Administrative.*—The contractor shall submit to the Contracting Officer and to the COR financial data on NASA Form 533 (Five (5) copies) monthly, on or before the 15th day of the month succeeding the period covered by the report. The line entries for subdivisions of work and elements of cost to be reported shall be determined by MSFC. Separate curves, showing programmed man-hours vs. actual manhours expended, and programmed dollars vs actual dollars expended, shall be submitted on or before the 15th day of the month succeeding the period covered by the report. These curves will be forwarded directly to the COR and prepared in accordance with his instructions.

WORK STATEMENT ADDENDUM—ORBITAL ASTRONOMY/ASTROPHYSICS, APRIL 4, 1966

A BROAD REVIEW OF AREAS TO BE CONSIDERED

Introduction

Advanced mission and system studies to date have established that the national manned space flight capability can significantly enhance a broad program of space research and experimentation in various scientific/technical areas. Space astronomy/astrophysics is one of the areas being pursued. The Orbiting Solar Observatory was the first true spaceborne astronomical observatory. Information gathered by this observatory indicates that continued studies with more advanced orbiting laboratories could contribute much more significant data and further enhance advancement in space sciences. For example, the ultraviolet solar spectrum has only been partially studied.

Research in space would allow full utilization of the light gathering and resolving power of sensing instruments in virtually all spectral regions. By fully exploiting the capabilities of even the current instrumentation we would be able, for example, to separate into componets close binary systems, to obtain more accurate parallaxes and proper motions (much wanted for the sub-dwarf, white dwarf, and SS Cygni stars), and to obtain more planetary details. Space astronomy/astrophysics experimentation will bring a broad perspective to research in various aspects of the knowledge which is needed for the understanding of the universe.

Astronomy/Astrophysics is concerned with the understanding of the nature and evolution of the universe. Among the outstanding problems of current interest we may mention the angular dimensions of the quasi-stellar radio sources or quasars the structure of the nuclei of galaxies, the resolution of galaxies into starts to refine the distance scale, the study of the faint end of the population of clusters of galaxies and stars the source and acceleration of cosmic rays, and the mechanisms of energy generation.

Structured key questions in the area of Astronomy/Astrophysics have been generated in the study of ORL Experiment Program (NASw–1084 and NASw–1215) by IBM.

The number of important astronomical problems requiring the highest achievable resolution in space is very large. Indeed, every one of the outstanding astronomical problems of our time requires high resolution for further understanding.

Celestial objects

The following section reviews some of the main categories of celestial objects, and to point out what yet needs to be observed to find the answers to the key questions and to extend our knowledge of the universe. The following identified objects should not be considered to be all inclusive and should be used only as a guide.

Solar system

1. All Planets: Of top priority is high resolution direct photography and spectrophotometry of all objects in the solar system, including the Sun, its corona, the Earth and its suspected cometary tail, planetary aurora, comets and astronomy of other possible planetary systems.

2. Earth: It is of importance to determine more accurately the shape of the Earth's gravitational field, its "pear shape", plus higher harmonics, from accurate tracking of Orbiting Geophysical Observatories (OGO). An Earth orbiting satellite equipped with a precision gyroscope to measure relativistic geodetic effect and the precession resulting from Earth's rotation. A very accurate Earth orbiting satellite could be used for the determination of ephemeris time

(or gravitational time) to be compared with atomic time at two different epochs. It is of cosmological interest to know whether the ratio of these two kinds of time varies from epoch to epoch. This requires tracking of the satellite to $0''.1$ or better.

3. Moon: It is desired to do high resolution mapping of the Moon in the UV, visual, and IR in various wave bands.

4. Mars: All types of observations of Mars are needed to prepare for unmanned exploration as recommended by the National Academy of Sciences. The unmanned exploration would in turn prepare for manned exploration. Most especially needed is a better knowledge of the Martian atmosphere for the design of spacecraft. Observations in the UV, visual, IR, radio wavelengths, together with the use of radar is required.

5. Venus: Needed are sub-millimeter measurement of the continuum radiation for the selection of suitable models of surface and atmosphere.

6. Jupiter and other large planets: Radio observations of the larger planets, especially on either side of the radio window, will provide information leading to an improved knowledge of their magnetic fields, Van Allen Belts, internal structure (core and upper layers). Measurements of total heat flux are needed. A determination of the abundance of D, He^3, Li^7 relative to H and He would aid in unraveling the physical processes on Jupiter, Saturn, Uranus, and Neptune.

7. Sun: In addition to high resolution photography and spectrophotometry, radio observations of the solar corona and interplanetary plasma are needed.

Stars

1. Bright Stars: Observations of luminosity and spectral energy distribution over the complete range of wavelengths for a comparison with Planck and other theories is needed for an understanding of stellar structure and stellar evaluation. The Hertzsprung-Russell relation (spectral-luminosity function) should be extended into the UV and IR (and perhaps X-ray region) for much wider range in stellar temperatures. High resolution spectrophotometry should be carried out for all wavelengths for better understanding of stellar atmosphere and ultimately the dynamic of stellar evolution and abundance analyses. This will lead into the nature of stellar chromospheres and coronas. Direct photography will result in the improvement of stellar paralaxes; if ever this can be done at great distances from the Sun, the larger base-line will produce even more improvement.

2. Faint Stars: Broad band filter photometry and low dispersion spectroscopy of fainter stars, especially those of large proper motion, will statistically augment the program outlined in the first paragraph; the sampling in this case will largely be in favor of the *cool stars*. But also to be included will be the more distant *hot stars* (blue and UV). Direct photography (including the use of filters) will ultimately result in a revised "Palomar-National Geographic Sky Survey." Accurate determination of astrometric coordinates of most stars down to a selected magnitude would then result in a new general catalogue of star positions unaffected by atmospheric refraction, and includes accurate proper motions.

3. Binary Stars: Observations from beyond the atmosphere will especially include those binary stars whose spectra are difficult to separate in the visible region. This will expand our knowledge of the masses of stars and other dynamic properties of binary systems. Search for close companions is of importance.

4. X-ray Stars: The existence of X-ray stars (i.e., point sources) is yet to be proved. The only X-ray source identified with an optical source is the Crab Nebula; it appears to be an extended X-ray source. Improved large equipment (by collimation directed equipment, and by focusing with grazing-incidence optics) needs development. Perhaps the most accurate coordinates of X-ray sources can be obtained on the lunar surface from occultations by lunar mountains. This should bring about refinements of "neutron star" theory, and perhaps the theory of *proto stars*, and wherein non-thermal effects play a role.

5. Gamma-Ray Stars: This might be considered an extension of the X-ray observations noted in the preceding paragraph. To date no isolated sources, point or extended, have been identified. Large-area spark chambers, geiger counters, and other special devices have yet to be fully developed. Longer wavelengths and cosmic rays must be eliminated by filters and anti-coincidence equipment.

6. Special Stars: Radio observations of stars at either side of the radio window for thermal and non-thermal effects are needed for *flare stars*, *variable stars*, and *peculiar stars* as well as a number of those noted above. *Incipient planetary nebulae* and *old novae* should be given attention.

Our Galaxy, its structure, interstellar matter

1. Survey of Galactic regions, its gaseous nebulae and clusters, with high-resolution diffraction-limited optics. Fainter objects and more detail. Detailed observations in all wavelengths are of great interest. IR studies of central regions, for extinction and distribution of hydrogen. Abundances of other elements relative to H; e.g., C, N, O. Also emission in UV, especially in Lyman alpha. How much emission is thermal and how much non-thermal. IR for total extinction, UV for size distribution.

2. Special attention to Galactic center, photos of filamentary structure, determination of motions of gasses—turbulent and systematic.

3. Distribution of *gas and dust*. Magnetic fields (from polarization measures) associated with interstellar material, because of theoretical implications with regard to cosmic ray accelerations. Observations of interstellar absorption lines in ultra spectra of distant stars. Primary source of excitation of emission nebulae thought to be Lyman alpha and other lines in series.

4. *Supernovae* and their remnants, include X-ray observations, and UV observations, and gamma ray observations if latter sensors can be pointed with sufficient accuracy.

5. A sky survey in X-radiation and gamma-radiation at many wavelengths is needed to determine sky background and discrete sources, and their diameters. Until now, the gamma radiation appears to be all due to background. Only about 10 X-ray sources are known, and only one of these (Crab Nebula) has identified with an optical object and is not a point source. Only imaging has been done on Sun: first with a pin-hole device, later with grazing incidence optics. For objects fainter than the Sun, collimating systems may be required in order that very large collecting areas are possible.

6. Large orbiting radio antennas may be needed for exploring the Galactic center and arms of the Galaxy, in wavelengths on either side of the radio window. The longer wavelengths (longer than optical) penetrate absorbing features more easily than shorter wavelengths.

Galaxies and Intergalactic Space

1. Direct high-resolution photographs and spectrophotometric observations of the nearer galaxies, together with polarization measures will give improved knowledge of the largest groupings of stars and gas clouds. This will include radio observations and X-ray source observations. Galactic nuclei deserve special attention since there is evidence of ejection of large gaseous masses. With high resolution (e.g., 0.″1, 0.″01″ or better) it will be possible to identify much smaller components of galaxies, including brighter stars, star clusters, gaseous nebulae, and filaments for many more nearby galaxies than the dozen or so now studied in detail from ground observations. Some of these special features should be easier to detect against a blacker sky—beyond the airglow of the atmosphere.

2. Distance criteria for nearer and more distant galaxies will improve the Hubble velocity-distance relation (or redshift versus magnitude). This in turn should lead to the selection of cosmological model(s) of the universe, and more reasonable explanations of the apparent expansion of the universe of galaxies. Is there a relation between a "neutron star" as proposed by theory), and an "X-ray star" (also theoretical, and perhaps yet observable), and the QUASAR (observed as a "radio star" and photographed as a bright star-like object)? Observations of these objects outside the Earth's atmosphere, together with the efforts of the theorists may shed light on this question.

3. Observations of the most distant objects, such as the galaxies themselves, and the QUASARS (quasi stellar radio sources) may indicate important differences between the universe as it is now, and as it was, say, 5 to 10 billion years ago. It is important to correlate energy received from the galaxies in wavelengths observable outside the atmosphere with energy received at the Earth's surface through the optical and radio windows. Will there be found good evidence of aging of galaxies the farther out one observes? (i.e., Are distant galaxies appreciably younger, or at least, different from nearer galaxies?)

4. Quasi stellar galaxies (QSG) emit excessive amounts of light in the ultraviolet range and not radio detectable as sources. Although only a few of them have been studied, they appear to be much more plentiful than quasars. Further discovery and study of these QSG's will provide much more information for studying the outer limits of the universe.

MAN IN SPACE

An Apollo Telescope Mount (ATM) will point telescope up to 3 meters in length at the Sun with a precision of about 5 sec of arc. In some experiments, astronomers will need to achieve a resolution of 1 sec of arc, and eventually 0′.′1′ 0′.′0′.′ or better. Not only must telescopes be pointed with that precision, but more significantly, considerably larger telescopes are required, as well as corresponding refinement of component specifications, alignment, etc. Two consequences of this desired high-resolution performance of space telescopes are of special importance to the question of man's potential role. First, the data collection rate of large telescopes may be greater than that of small telescopes. Second, those telescopes and their accessories must be specialized as to functions, wavelength of operation, etc., so that versatility is achieved only by major subsystem interchange or adjustment. All of these factors must be considered as part of the question of man's usefulness in performing astronomical observations from a satellite.

It is clear that men can perform many useful functions in connection with the assembly and operation of large instruments in space. Perhaps other advantages of manned operation will appear as man gains experience in space work. In the operation of large telescopes, man has several potential functions. First, he can perform major configuration changes—for example, converting a spectrograph into a spectroheliograph, altering the wavelength setting of a solar monochromator, inter-changing gratings of different rulings, etc. During individual observational projects, man provides the ability to perform rapid analysis of the output data in order to modify the subsequent observations. An example would be to monitor an active region, and to start a series of high-rate spectral or cine observations at the inception of a flare. Automatic equipment to do the job accurately and reliably probably cannot compete with human judgment, since the complex activities of time correlation, field search and event localization, and very sensitive threshold judgments must be made simultaneously, and both accurately and quickly sometimes under conditions of low signal-to-noise ratio.

SPACE OBSERVATIONS AND SENSING

As a matter of convenience, ofttimes dictated by the types of detection equipment employed, it might be well to divide the total electromagnetic spectrum into a number of wavelength intervals. The names of these intervals, as tabulated below, are generally accepted; the boundaries of these intervals, however, vary from one investigation to another. If man's environmental and biological history had been quite different, perhaps wavelength intervals of a completely different character would have resulted.

1. Gamma Rays	Shorter than 1.0 A
2. X-rays	1.0 A to 100A
3. Ultra-Violet (UV)	100A to 3000A
4. Visible	3000A to 7000A or 0.3μ to 0.7μ
5. Infrared (IR)	0.7 to 100
6. Microwave	100 to 10,000 or 0.01 cm to 1.0 cm
7. Radio	1.0 m to 10.0 km and greater
8. "Radio Window"	0.1 cm to 10 m

All except the visible range of wavelengths correspond to five or more octaves of frequencies. The amount of light which we see through the Earth's atmosphere covers a little bit more than one octave of the electromagnetic spectrum. When we add the narrower slots in the optical window and the somewhat larger radio window, the coverage from the ground still does not cover some very important regions of the total spectrum which NASA should cover in order to obtain a satisfactory knowledge of the universe.

The series of spectrum wavelengths, then, gives us one of the important parameters for making observations in outer space, and beyond the turbulent and absorbing layers of the Earth's blanketing atmosphere. Another parameter is the intensity of this radiation, and another is its variation with time for particular coordinates. Inasmuch as it is, perhaps, an impossible task to cover each and every coordinate in the sky to the nearest 0'.' or 0'.'0001, the astronomer concentrates on special astronautical objectives of particular interest. The parameters of importance, then, are:

1. Celestial object: spherical coordinates, distance.
2. Intensity of radiation, polarization.
3. Wavelength.
4. Time, date.

The amount of accurate data for each of these parameters, of course, varies with the type of sensing and recording. For example, a direct photograph of a portion of the sky normally covers only a very narrow range of wavelength and time; however, properly interpreted the intensity date is very good for a very wide range of spherical coordinates. A spectrophotometric scanning device, on the other hand, gives excellent and detailed intensity data for many wavelengths; but generally applies to a particular set of coordinates for a particular instant of time. The problem of the astronomer is to obtain all the data for all time (or a reasonable fraction of this), and to interpret these data according to presently known physical laws, and to theorize how these laws can best be modified and extended.

Dr. Mueller. We assume that first of all the Voyager program is going to go forward and now we are looking at what comes after the initial Voyager flights. We looked at a specific mission in some detail and the objectives of this particular mission (MT66–10,201, fig. 9) of manned Mars-Venus reconnaissance would be the return of a Martian or a Venusian surface sample. Another objective would be reconnaissance and mapping of Mars and Venus. It would make

OBJECTIVES OF MANNED MARS/VENUS RECONNAISANCE

- RETURN OF MARTIAN SURFACE SAMPLE
- RECONNAISSANCE AND MAPPING OF MARS AND VENUS
- ASTRONOMICAL OBSERVATIONS OF THE PLANETS, SUN AND OTHER BODIES
- MANNED PLANETARY SYSTEMS DEVELOPMENT AND PROOF TESTING
- MANNED PLANETARY OPERATIONAL EXPERIENCE
- UTILIZATION OF PRESENTLY EVOLVING TECHNOLOGY TO EMBARK ON MANNED PLANETARY EXPLORATION
- ACQUIRE ENGINEERING DESIGN INPUT DATA FOR APPLICATION TO FUTURE SYSTEMS
- ENHANCEMENT OF NATIONAL PRESTIGE

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Figure 9

astronomical observations of the planets, Sun, and other bodies while in transit.

It would look at the development and proof testing of manned planetary systems. It would give us some experience on manned planetary operations. It would utilize our presently evolving technology to embark on early manned planetary exploration. It would acquire engineering design input data for application to future systems, and it would provide enhancement of our national prestige.

Mr. FULTON. On Mars and Venus it would give you two reference points in which to determine the effect of the Sun and Earth, so that you would then have some method of calculating other than just have one reference point when we are on the Earth?

Dr. MUELLER. That is correct.

Mr. FULTON. It would have an application to better life on Earth and possibly better man's existence?

Dr. MUELLER. It would be our first opportunity to observe the total operation of the Sun.

Mr. FULTON. It would be very interesting.

Dr. MUELLER. Turning to the actual profile of a typical Mars mission (MT66–10,212, fig. 10) we would launch as we approach the target planet a series of probes; one would be an Orbiter; another would be a Mars Surface Sample Return probe.

There are also some Lander probes which would provide us with information about the atmosphere and the surface on a continuing basis. All of this would be done in a matter of a few days while one was in the vicinity of the planet.

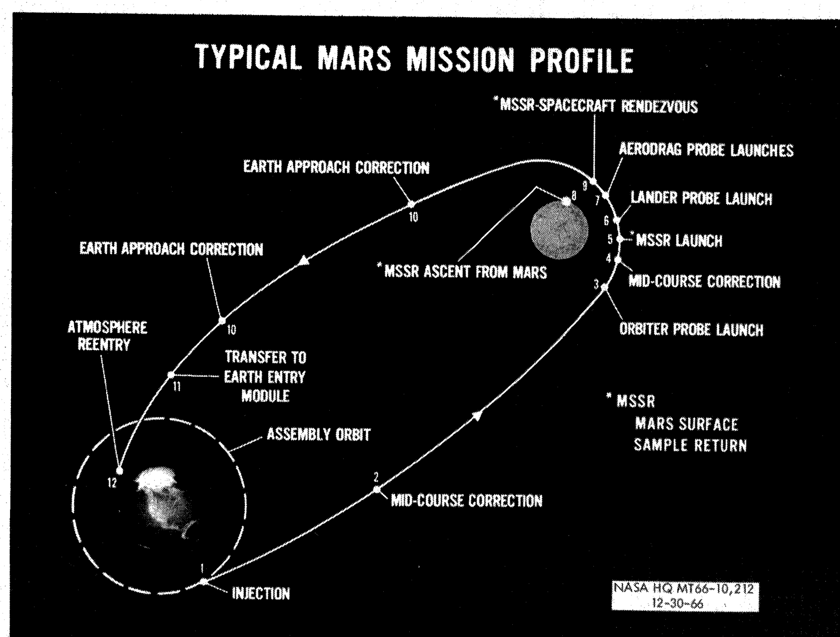

FIGURE 10

We would also be carrying out observations of the local environment and conducting an extensive solar observation program and a planetary observation program from the various vantage points one attains from an orbit that is far removed from the Earth.

Mr. FULTON. Why couldn't you put an instrumented capsule in orbit that was a long elliptical orbit that would have two focal points, the Earth and Mars, and leave it there and man it from Earth?

Couldn't you do something like that rather than just a one-shot program?

Dr. MUELLER. That is possible. The major problem associated with that is that we are talking about a sizable telescope, at least 40 inches in diameter. It is a quite difficult task and we are reaching a level of complexity where man becomes an essential part of the system. The use of man becomes mandatory as the system complexity increases beyond a certain point, and for this kind of a mission it is clearly one that would have to be manned.

Mr. FULTON. So you really need a manned Mars mission as well as an unmanned flight?

Dr. MUELLER. That is right.

Mr. FULTON. That is all.

Dr. MUELLER. Now, the flight opportunities (MT 66–10,222, fig. 11) for such a flyby are relatively frequent in the 1970's, they run from

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 11

September of 1975 through November of 1979 for a Mars mission. In the case of Venus, they run from June of 1975 to April of 1980. Those are the launch dates. They will come back a year or 2 years later depending upon the mission program.

One of the most interesting missions is a Venus-Mars-Venus flyby in February 1977. That permits you in some 700 days to fly out past Venus, go around Mars, fly back past Venus and then return to the Earth. The time is very comparable to that of the other flight times; the reentry velocity is low as is our projection velocity and it is an interesting case of billiards in space.

Mr. Gray informs me this is a unique event. It won't happen again in this century.

Mr. FULTON. Wouldn't it be interesting to pick up a piece of this asteroid, Icarus, that is expected to come within 4 million miles of the earth and compare it to whatever landed in Arizona, I understand that its size is estimated at between several kilometers and several miles and that its orbit will be between one-fifth of an astronomical unit (putting it inside the orbit of Mercury) and two astronomical units (putting it outside the orbit of Mars). You may have an asteroid in being. If so we could have our own laboratory.

Why don't we take over the tourist center in Arizona where there has been an impact from an outerspace object of some size.

Why doesn't the United States take that over as a national asset? Wouldn't that help?

Dr. MUELLER. I don't feel that I know enough about the problem, Mr. Fulton, to answer that.

Mr. FULTON. Go ahead with your report.

Dr. MUELLER. Significant results (MT 66–10,203, fig. 12, MT 66–10,202, fig. 13) that we would expect to obtain from manned Mars reconnaissance missions include returned surface samples, photography, measurements of the atmosphere and the solid body properties; we would expect also to carry out a number of en route experiments which, as we have looked at them in some detail would rather fully occupy the crew. Then in addition we have certain technological developments that will markedly affect the future of our own technology since for the first time we have to have equipment that will last for 2 years and in return there will be a certain amount of prestige associated with a first manned planetary flight.

Mr. DADDARIO. I assume those samples would be brought back to the lunar receiving laboratory?

Dr. MUELLER. That is correct. The samples would be returned to our lunar receiving laboratory where they would be processed. The interesting thing about such a reconnaissance program is that many of the major components can be modified from the existing Apollo Applications hardware so that it would appear that we do have at least the major elements of technology available to us for carrying out such a program (MT 66–6708, fig. 14). There are certain areas where we have to extend our technology and it would not be wise to embark on a program of this magnitude without in turn expecting to extend our technology because that is one of the major benefits that comes to our society here on Earth.

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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FIGURE 12

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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FIGURE 13

MARS/VENUS RECONNAISSANCE PROGRAM FEATURES UTILIZATION AND MODIFICATION OF PRESENT SYSTEMS

MAJOR COMPONENTS	DEVELOPMENT BASE
EARTH ENTRY MODULE	MODIFIED APOLLO COMMAND MODULE
MISSION MODULE	GROWTH FROM EARTH ORBITAL ACTIVITIES
SPACECRAFT PROPULSION	APOLLO SERVICE MODULE AND LEM
EARTH ORBIT ESCAPE STAGE	MODIFIED SATURN S-II OR SATURN S-IV B STAGES
PROPELLANT TANKERS	MODIFIED S-II
LAUNCH SYSTEM	SATURN V
LAUNCH FACILITIES	SATURN V
MISSION CONTROL CENTER	APOLLO
COMMUNICATION AND CONTROL NET	APOLLO + DSIF

TECHNOLOGY EXTENSIONS

ELECTRIC POWER SYSTEMS	HYPERBOLIC ENTRY
LIFE SUPPORT SYSTEMS	LONG-TERM RELIABILITY CONCEPTS
ASTRIONICS (GUIDANCE, COMMUNICATIONS, ETC)	LONG TERM SPACE STORABLE PROPELLANTS
ORBITAL OPERATIONS	STERILIZATION TECHNIQUES

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FIGURE 14

We have the development base and we have the major components reasonably well defined.

Mr. DADDARIO. Your remarks indicate that you don't give one target superiority over another. You seem to indicate that both the Mars and Venus programs offer you a choice without discriminating one as against the other. Your charts sometime refer just to Mars and you never have a Venus chart. You have Mars charts and Mars-Venus charts which seems to indicate that you do, in fact, tend to indicate at this time that your objectives will be more toward Mars than Venus, is that so?

Dr. MUELLER. I think they are both equally interesting objectives. We have a limited amount of resources so that we have had to concentrate on one.

Mr. DADDARIO. At this point in time it is Mars.

Dr. MUELLER. It is also true that we have a much greater knowledge about the Martian environmental characteristics than we do about Venus so therefore we can do better planning.

Mr. DADDARIO. Did we make the choice of Mars over Venus because of certain observations that come back to us from our satellite activity and then find as we examine that information, we have some question about its accuracy? Have we then come to some other judgment that perhaps we have made the choice too soon to operate for Mars rather than Venus?

Dr. MUELLER. I believe the scientific community has fluctuated between Mars and Venus being the most desirable planet for study for the past 25 years. There seems to be some vacillation between the two. I think they are equally interesting. I think that the scientific community does tend to be divided.

My own expectation is that these Mars and Venus missions will provide us with two quite different understandings of the development and operation of our solar system.

Mr. DADDARIO. Would it be fair to say even though it seems to indicate that we would be aiming more of our efforts toward Mars, that if the information on Venus spells itself out with more accuracy than is now available, we would not have any problem adjusting to take advantage of Venus as a target if it is proven to be a better one.

Dr. MUELLER. That is correct. We are trying to design the apparatus and the missions themselves to be flexible enough to use either planet or for that matter other planets as targets.

Mr. DADDARIO. Thank you.

Dr. MUELLER. Now, turning to another example of advanced missions we show here (MA66–10245, fig. 15) the possible evolution of lunar exploration. The steps that are involved begin with Apollo, go through Apollo Applications. Here we have quite a few plans under development for carrying out extended lunar surface and lunar orbit operations.

Then we go forward from that to a next major step which involves much greater mobility than we can accommodate in the Apollo Applications program and the ability to stay and carry out extensive observations. Each one of these steps depends upon the knowledge that we gained from the preceding one, so that we are trying hard now to develop the various alternatives, but not to make firm decisions

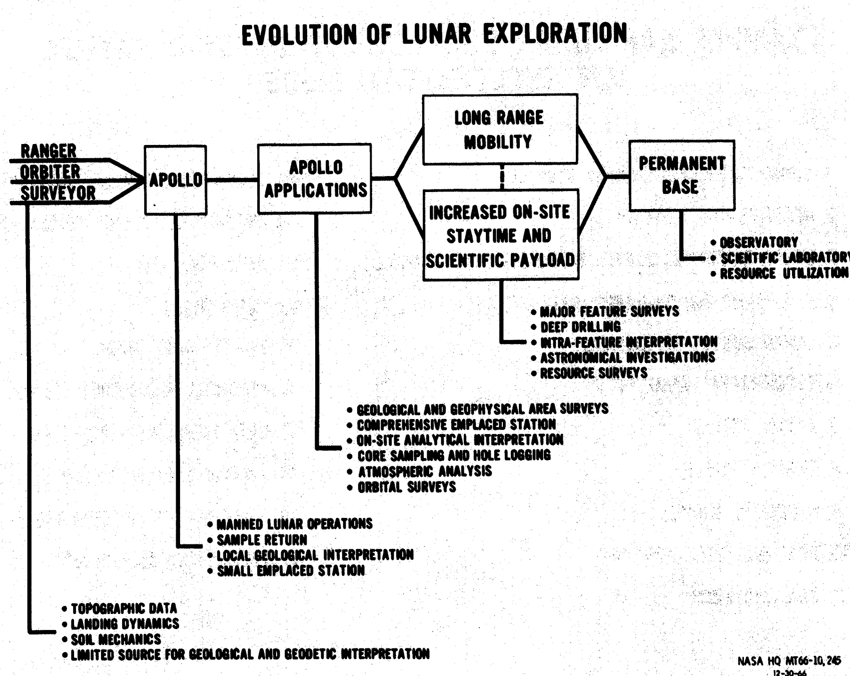

FIGURE 15

as to the course that we are going to follow. This is an evolutionary process. We learn from each step as to what can and should be done in a scientific sense at the next step.

Some examples of the lunar surface exploration payload can be seen on this chart (MT 66–10246, fig. 16) and there are a number of extended lunar surface explorations.

One thing in particular that is of interest to the scientific community equipments that need to be developed and can be used to carry out is the ability to move around on the lunar surface. We have looked at several modules that can carry out extended traverses on the Moon and on this chart (MT 66–9608, fig. 17) you see one example of such a vehicle. A summary of the objectives of such a mobile lunar exploration is shown here (MT 66–10247, fig. 18).

The classes of vehicles that will be useful for transportation beyond Earth orbit (MT 67–5865, fig. 19) include the current Saturn V which is capable of putting something like 100,000 pounds on a trajectory to the Moon. We would expect that the next major step would be the development of a nuclear upper stage which would roughly increase this from 50 to 100 percent depending upon the actual characteristics developed in such a propulsion system.

If we look forward to the future, it is possible to envisage the fact that NERVA can grow and be capable of larger payloads in these missions. The Saturn V also is capable of growth. One way would be to strap on solids. Another way would be to improve the basic

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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FIGURE 16

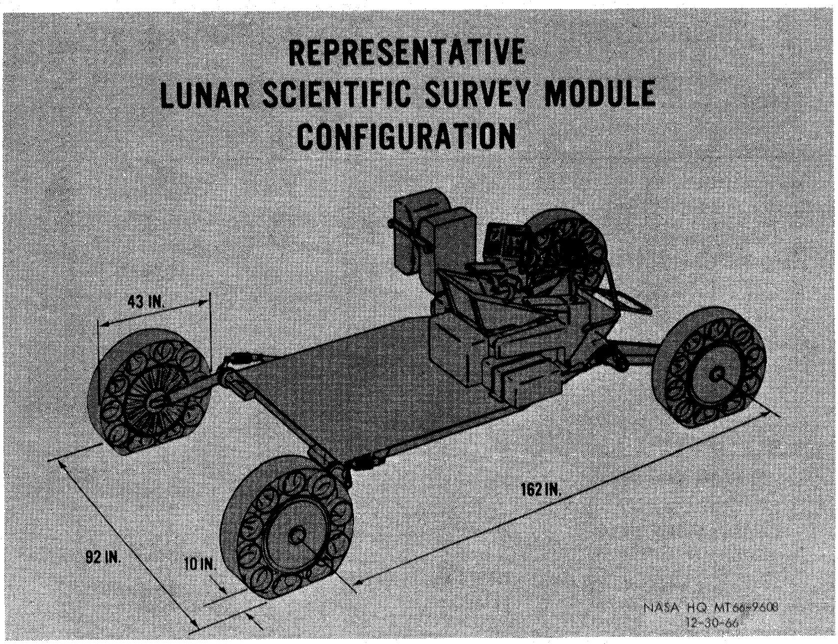

FIGURE 17

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.

NASA HQ MT66-10,247
12-30-66

FIGURE 18

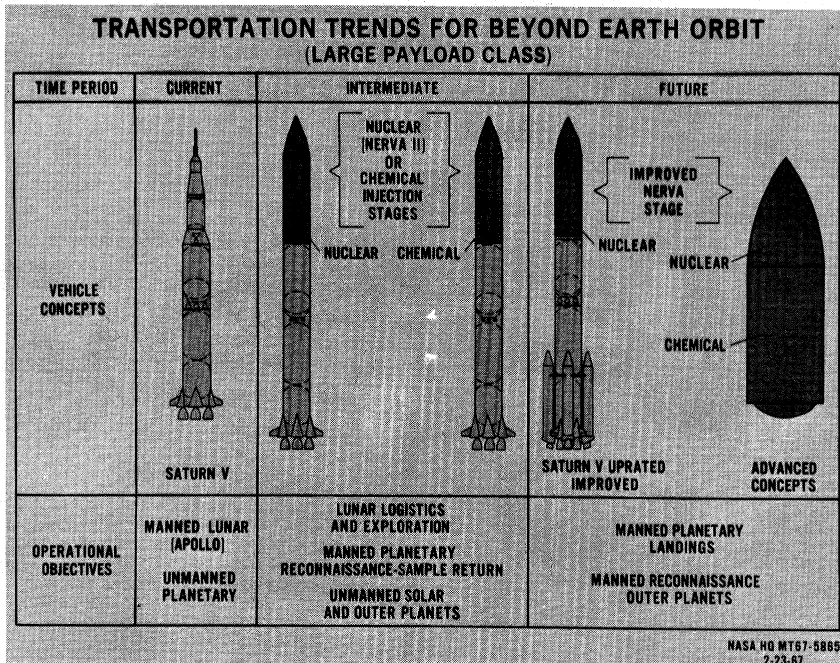

FIGURE 19

engines of the vehicle and, finally, of course, one can go to a new advanced launch vehicle.

I would say at this point in time it would look to us as though the combination of the Saturn V plus NERVA would satisfy our immediate needs for planetary exploration.

Mr. FULTON. Mr. Chairman?

Mr. TEAGUE. Mr. Fulton.

Mr. FULTON. As you remember some time ago the members of this manned spaceflight committee strongly opposed the concept and proposed the building of the NOVA rocket type booster. It would appear that this concept has been completely dropped and NASA is now moving toward the NERVA concept and the high-energy fuel concept, liquid or the large solid concept; is that correct?

Dr. MUELLER. We are advocating the NERVA engine in the 200,000-pound class and we believe that that is the next and needed step toward our launch vehicle capabilities.

Mr. FULTON. You have dropped the NOVA which is as big as the Capitol dome?

Dr. MUELLER. Yes, sir.

Mr. FULTON. Thank you. If I could just say to our chairman, that is one bird that this subcommittee shot down.

Dr. MUELLER. With your permission, I would like to turn to the fiscal year 1968 budget book for Apollo Applications and go through that beginning with volume V, pages RD2–3 and RD2–4.

Turning to Apollo Applications (MP67–5725, fig. 20) for which we are requesting $454.7 million in fiscal 1968, this is now a program

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 20

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.

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 ex-

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tended 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 fiscal year 1967 and 1968 that, in combination, provide the greatest contribution to the Nation's space objectives at the lowest cost.

I go further and say in my judgment they represent an absolute minimum funding for the program in terms of meeting these objectives.

Mr. FULTON. Can you divide those figures between Venus and Mars?

Dr. MUELLER. As a matter of fact none of these are devoted to either Venus or Mars. They are devoted to developing the basic capability for long-duration space flight and the utilization of those for astronomical observations and for extended lunar exploration.

Mr. TEAGUE. I would hope on Apollo Applications you would spell out in much more detail for our hearings than what we have in our backup books, for the ordinary layman to know what the vehicles are you are using and what the experiments mean and that type of explanation.

Dr. MUELLER. I will try.

Mr. TEAGUE. Not now but for the record.

Dr. MUELLER. Yes, sir.

(The material referred to follows:)

APOLLO APPLICATIONS

The following is a description of the Apollo Applications planned missions, equipment, experiments and funding requirements. This description supplements and further defines the material contained in the FY 1968 Budget back-up books submitted to the Congress and reflects the status of program planning.

FIRST APOLLO APPLICATIONS MISSION—AAP-1 AND AAP-2

The end objective of the AAP-1 and AAP-2 flights is to establish in orbit the Orbital Workshop. The Orbital Workshop is an important new concept for an embryonic space station. It is economical because it involves minimum new hardware development and is reusable, thus allowing basic exploration of space station requirements with a reasonable funding level.

For the short term, the Orbital Workshop provides an *early* capability for a large, controlled environment to evaluate human performance and secure engineering data for future subsystem design for both manned and unmanned spacecraft.

Ultimately in the workshop or any successor space station where man will be assembling apparatus, antennae, structures, etc. as well as operating instruments, cameras, electronic equipment and other devices he will need to know the most efficient and effective means of operating and living.

The first two Apollo Applications missions will provide for further economies in space flight by developing techniques for the resupply and reuse of hardware that is left in orbit. The Orbital Workshop concept will also provide for the early development of a long duration flight capability, which is a key requirement for most of the possible significant advances in manned space flight.

The experimental payloads included in the AAP-1 and AAP-2 flights 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. In addition, there are included scientific and applications experiments.

MISSION MODE AND RELATED EQUIPMENT

The initial AAP mission, which could be as early as 1968, consists of 2 launches, AAP-1 and AAP-2. The following equipment will be required for these launches:

For AAP-1, a manned flight, the launch vehicle will be the uprated Saturn I. Spacecraft equipment will include the Command and Service Modules and a Lunar Mapping and Survey System.

For AAP-2, an unmanned flight, the launch vehicle will be the uprated Saturn I. Spacecraft equipment will include the Airlock Module and Multiple Docking Adapter.

AAP-1 will have a 3 man crew in the Apollo Command Module. The crew will perform several days of operations in low earth orbit for qualification of the Lunar Mapping and Survey System which is launched in an adapter of the Saturn space vehicle (Figure 1). The Lunar Mapping and Survey System will be used in later AAP operational missions for mapping and geological survey of the lunar surface from lunar orbit.

After these tests, AAP-2 (Figure 2) will be launched unmanned into a higher, circular orbit about 300 statute miles altitude where the orbital lifetime will be greater than 1 year. The crew from AAP-1 will transfer the Command and Service Module and the Lunar Mapping and Survey System to the higher orbit and rendezvous with and dock to the Multiple Docking Adapter from the second launch (Figure 3). The spent S-IVB stage from AAP-2 will then be activated into an Orbital Workshop. Through use of the Airlock Module, the crew will transfer equipment into the workshop and erect the crew quarters (Figures 4 & 5). Orbital Workshop operations and experiments will be performed for a period of up to four weeks, when the crew will deorbit in the Command Module, leaving the Orbital Workshop, Multiple Docking Adapter and Airlock Module in orbit in a gravity gradient stabilized condition for later usage.

OBJECTIVES FOR FIRST APOLLO APPLICATIONS MISSION

In summary, the five objectives of the first Apollo Applications mission are (1) to test the Lunar Mapping and Survey System photographic equipment and spacecraft subsystems in earth orbit for subsequent lunar mapping and survey missions; (2) to determine feasibility of operating the Orbital Workshop as a habitable space structure for a period of up to four weeks; (3) to evaluate

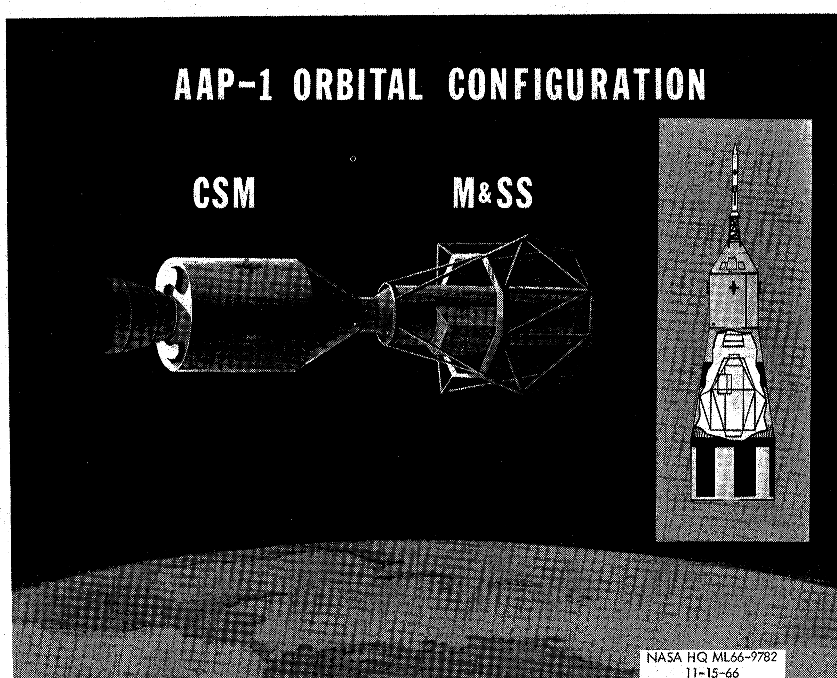

FIGURE 1

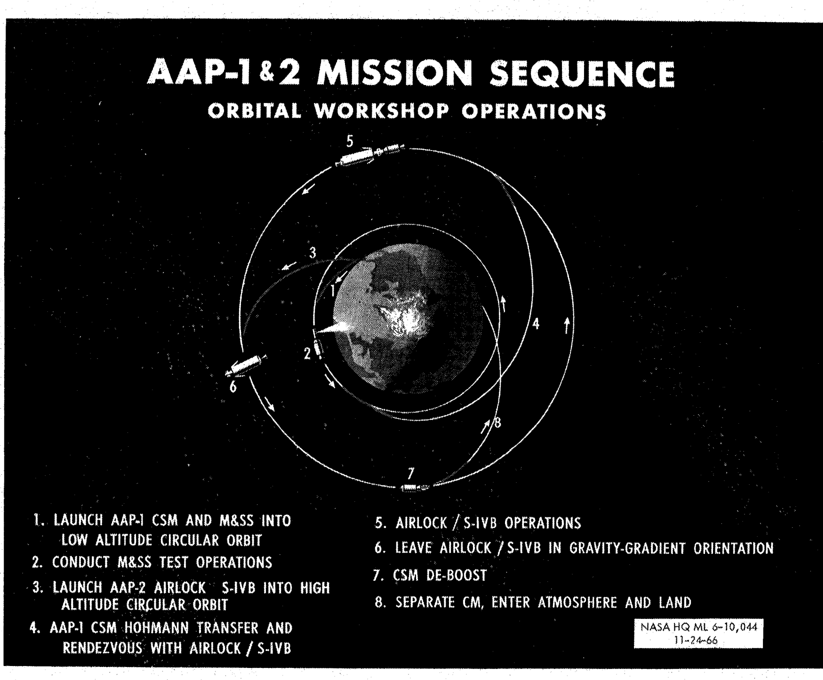

FIGURE 2

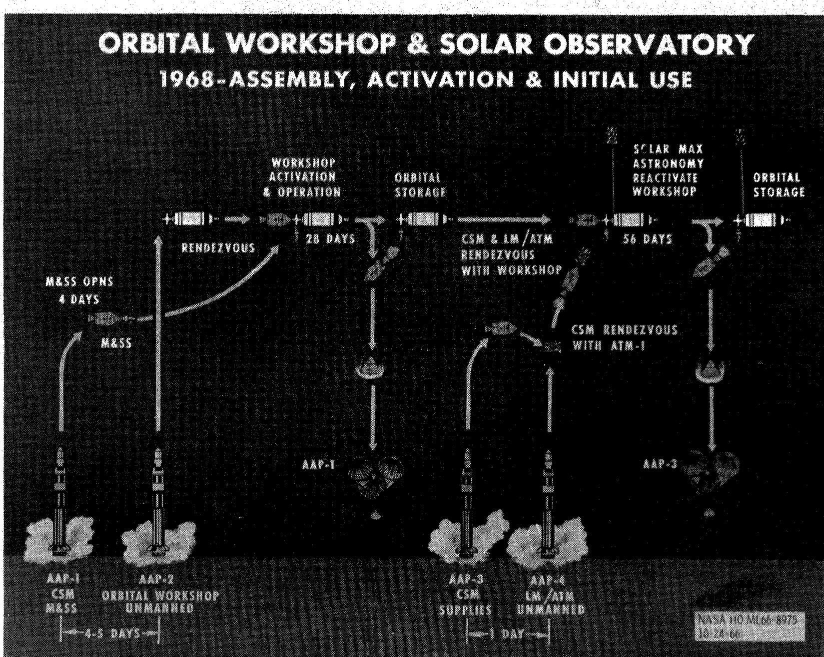

FIGURE 3

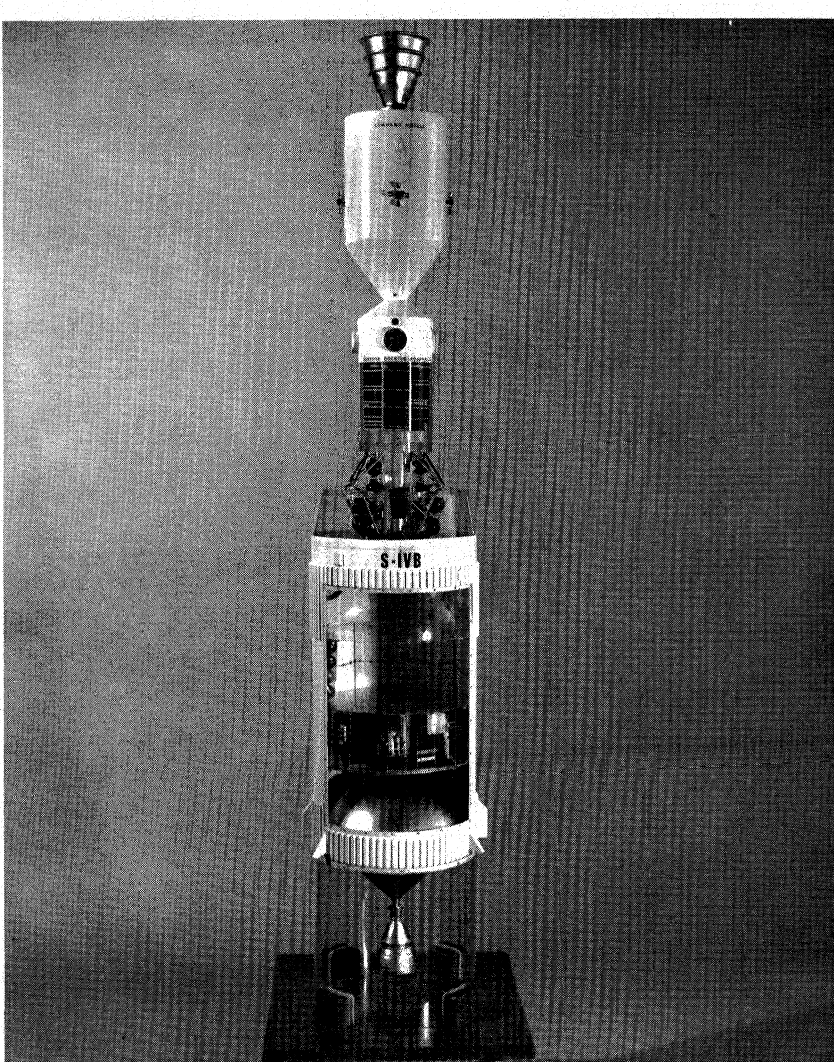

FIGURE 4

space flight environmental effects on the crew of a mission duration up to four weeks; (4) to conduct approximately 40 other experiments; and (5) to leave the Orbital Workshop and associated equipment docked in orbit for reactivation and reuse during subsequent AAP missions.

HABITABILITY

To completely exploit the advantages of having a man in space, we must increase the length of our flights, first to a month, then to several months, and, ultimately, to indefinite periods. Not only must we investigate the physiological factors, we must learn much more about how to live and work in space on a day-to-day basis.

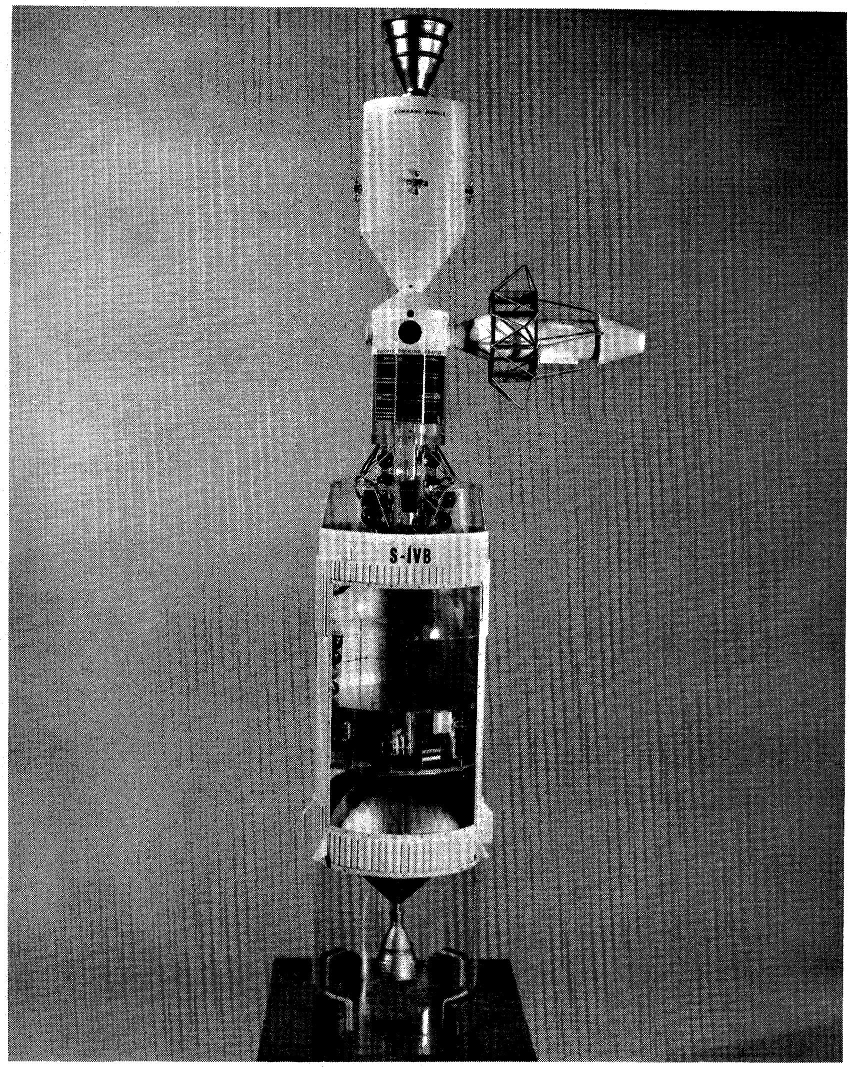

FIGURE 5

In the confined quarters of the Gemini spacecraft, providing about as much room as the front seat of a small car, we proved that man can operate effectively in space for up to two weeks. To achieve this, special provisions were incorporated such as a light-weight pressure suit which could be doffed or donned conveniently.

In the somewhat larger flight crew quarters of the Apollo spacecraft, we also will have a two-week mission capability. But for missions of much longer duration, many questions must still be answered about how to live and work most effectively in space. The Apollo Applications missions are designed to find many of these answers.

In order for man to operate successfully in the workshop where man will be assembling test apparatus, antennae, structures, etc., as well as operating instruments, cameras, electronic equipment and other devices we will study and develop efficient and effective means of living and operating in this orbital environment.

In the Orbital Workshop, we will investigate questions such as how much cubic footage do we need for routine functions of life, experiments for science, maintenance of equipment.

What is an optimum floor plan for crew quarters and work stations? What is the best way to sleep in the zero gravity of space? What forms of exercise are most effective in keeping a crew physiologically fit?

We will investigate methods of food preparation, types of food, provisions for personal hygiene, management of human wastes, ways of "keeping house."

We can learn the best means of moving from place to place under zero gravity and restraining ourselves at work stations. Here we will be able to build on our earlier expeirence during similar work in Gemini, but in a controlled environment.

The data from our experiments will be used in planning and developing both the later flights in Apollo Applications and the flights for future programs. Our experiments will be instrumental in making the most effective use of man during long-duration missions in space.

In effect, the Orbital Workshop may be considered an embryonic space station. It increases our useful habitable workspace volume by a factor some 30 times greater than provided by the Apollo Command Module Spacecraft. This Orbital Workshop can be exploited to make many contributions in the major fields of space science, earth-oriented applications, and support for space operations.

Experiments

Five types of experiments will be flown on flights of the first Apollo Applications mission: Scientific, Technological, Medical, Engineering. Some of the experiments support Department of Defense studies.

SCIENTIFIC EXPERIMENTS

The scientific experiments are designed to take advantage of space operations to learn more about the universe, the space environment, and the phenomena that exist in the solar system that affect the environment of man on earth.

Scientific experiments and their objectives are as follows:

(1) *Synoptic Weather Photography.*—Obtain selective, high quality, color cloud photographs for studying the fine structure of the earth's weather system.

(2) *Nuclear Emulsion.*—Investigate the physical and chemical characteristics of cosmic radiation in near earth space.

(3) *X-Ray Astronomy.*—Study X-ray sources originating beyond our system to determine source position and strength.

(4) *Micrometeorite Collection.*—Collect and study composition and flux rate of small micrometeorites in near earth space.

(5) *Ultraviolet Steller Astronomy.*—Obtain ultraviolet spectrum photographs of stars to determine their temperature and composition.

(6) *Ultraviolet Airglow Photography.*—Photograph and study the airglow band surrounding the earth to determine its characteristics and composition.

(7) *Multiband Terrain Photography.*—Photograph the earth's surface in four different spectral regions to determine earth's characteristics and resources.

(8) *Ultraviolet/X-Ray Astronomy.*—Obtain detailed information about the sun in the ultraviolet and X-ray emission regions.

TECHNOLOGICAL EXPERIMENTS

The technological experiments are designed to learn more about the space operational environment to improve man's ability to operate effectively and perform useful work in space.

Technological experiments and their objectives are as follows:

(1) *Manual Navigation Sightings.*—Evaluate the ability of a navigator to accurately measure the angle between celestial bodies with a hand held sextant.

(2) *Frog Otolith Function.*—To determine the adaptability of the otolith or balance system to weightlessness and acceleration due to rotation.

(3) *Meteoroid Impact and Erosion.*—Obtain data on the flux of micrometeoroids and their effect on optical surfaces.

(4) *Jet Shoes.*—Determine the feasibility of using reaction-jets mounted on shoes for astronaut maneuvering in space.

(5) *Meteoroid Velocity.*—Measure the impact velocity and penetration depth of meteoroids in soft aluminum.

(6) *Heat Pipe.*—Study the feasibility of transferring heat from one place to another during weightless flight by means of a fluid circulating through pipes.

MEDICAL EXPERIMENTS

In addition to biomedical and physiological studies, the medical experiments will provide information and knowledge necessary to improve living conditions for man in space and enable him to live and work comfortably in space for long periods of time.

Medical experiments and their objectives are as follows:

(1) *Vectorcardiogram.*—Measure the electrical activity of the astronauts' hearts to determine any effects due to weightless flight.

(2) *Metabolic Activity.*—Measure changes in man's metabolic effectiveness during space flight.

(3) *Cardiovascular Function Assessment.*—Determine weakening of man's blood circulation system due to weightless flight.

(4) *Bone and Muscle Changes.*—Assess alteration in man's bone and muscle systems during orbital flight.

(5) *Human Vestibular System.*—Investigate the effects of weightlessness on man's balance system.

(6) *Time and Motion Studies.*—Make time and motion studies of astronauts performing tasks in orbit.

(7) *Habitability/Crew Quarters.*—To evaluate the habitability of large crew quarters as compared to the more restricted quarters of previous spacecraft.

ENGINEERING EXPERIMENTS

Engineering experiments and their objectives are as follows:

(1) *Mapping and Survey System.*—Conduct comprehensive photographic study of the lunar surface from lunar orbit.

(2) *Space Suit Evaluation.*—Evaluate several different types of space suits in terms of mobility, comfort, etc.

(3) *ST–124 Stable Platform Removal.*—Remove components of the Guidance and Navigation system from the Instrument Unit during orbital flight to obtain experience in space maintenance.

(4) *Zero Gravity Flammability.*—To determine the propagation of flames along the surface of combustible materials and the relative effectiveness of several extinguishing agents.

(5) *Astronaut EVA Equipment.*—To evaluate the effectiveness of various tethers, restraints, and hand hold devices.

(6) *High Pressure Gas Expulsion.*—To determine the liquification characteristics of high pressure gas during prolonged blow-down in zero gravity.

(7) *Heat Exchanger Service.*—Formulate acceptable heat exchanger servicing procedures for use in extended missions of the future.

(8) *Tube Joining Assemblies.*—Develop and demonstrate tube joining maintenance operations during space flight.

(9) *Electron Beam Welding.*—Develop and demonstrate plate welding maintenance operations in space flight.

DEPARTMENT OF DEFENSE EXPERIMENTS

Experiments conducted for the Department of Defense and their objectives are as follows:

(1) *Carbon Dioxide Reduction.*—Determine the operational capabilities of a solid electrolyte carbon dioxide reduction system in a zero gravity space environment.

(2) *Integrated Maintenance.*—Evaluate factors of equipment maintainability in-orbit including tools, crew restraints, illumination levels, and the timelines and procedures for performing specific maintenace tasks.

(3) *Suit Donning and Sleep Station Evaluation.*—Evaluate the time required and techniques for pressure-suit donning starting from the restrained sleeping position.

(4) *Alternate Restraints Evaluation.*—Evaluate various crew restraint devices for use in both operating and maintaining equipment.

(5) *Expandable Airlock Technology.*—Demonstrate the feasibility of expandable structures in an earth orbital environment and evaluate the functional characteristics of an airlock design based on this technology.

(6) *Expandable Reentry Structures.*—Demonstrate the ability of an astronaut to deploy and lock or rigidize an expandable reentry capsule structure.

Typical Experiments

SCIENTIFIC

The X-ray Astronomy experiment is a typical scientific experiment. The purpose of the X-ray Astronomy experiment will be to continue the study of X-ray sources outside our solar system. These sources cannot be studied from the earth's surface because of the influence of the atmosphere on absorbing the X-rays. Specific objectives will be to determine the positions of the known X-ray sources very accurately to within less than a tenth of a degree; to measure the X-ray spectrum of the stronger sources; and to observe discrete objects of astronomical interest such as strong radio emission centers, the galactic center and nearby galaxies for evidence of X-ray emission.

These scientific data will be gathered by using a high sensitivity, high resolution detection system. The system will shed light upon the nature of these sources and provide experimental observations for comparison with theoretical predictions.

TECHNOLOGICAL

The Jet Shoes experiment is a typical technological experiment. The potential importance of extravehicular activity (EVA) in space operations such as repair, rescue, multiple rendezvous, refueling, etc., makes it desirable that the astronaut be provided with a natural, simple, and reliable means of mobility. The Jet Shoes concept shows promise of providing the desired type of mobility in a manner closely related to walking.

The Jet Shoes concept involves placing jets on the soles of the astronaut's shoes. These jets are activated on demand by using the toes to depress a switch, and the more or less instinctive movement of the feet and legs is used to direct the jets and produce locomotion in the desired direction. Because the jets are directed and controlled by the feet, both hands are free for any tasks that are required.

Utilization of the large enclosed volume of the S–IVB Workshop is ideal for a safe yet practical evaluation of the Jet Shoes concept. The experiment involves having an astronaut perform a series of maneuvers within the confines of the Workshop to demonstrate the feasibility of the concept and to gain experience and confidence in the use of the jet shoes. The maneuvers will first be performed without a space suit in a shirt sleeve environment, and later, in a pressurized space suit for a realistic evaluation of the concept under the identical conditions of true "space walking".

MEDICAL

A typical Medical Experiment is the Metabolic Activity experiment. The purpose of the Metabolic Activity experiment is to determine man's metabolic effectiveness in doing mechanical work under exposure to the space environment; and comparing this effectiveness with identical physical activities under the influence of earth's gravity. A great deal is known about the relationships between the rate of doing work utilizing muscular effort. However, this wealth of information pertains to measurements done on the earth's surface and under the influence of the force of gravity.

To obtain this comparison of work in space and on earth, it is planned to measure man's metabolic rate as related to his work output in space. This can best be done by measuring his metabolic rate for various work outputs using a calibrated device similar to a bicycle exerciser to provide reproducible levels of work.

Importance of AAP-1 and AAP-2

For the long term, the AAP-1 and AAP-2 flights will provide a test bed for the systems and subsystems required for future unmanned and manned space stations and for long duration manned planetary exploration flights.

The AAP-1 and AAP-2 flights are designed to take full advantage of the Apollo/Saturn system to make significant contributions to a wide range of objectives.

The major benefits to be derived from the AAP-1 and AAP-2 flights are (1) to develop capability for reuse of space hardware which will reduce program costs; (2) to determine effects of extended duration space environment on men and systems; (3) to conduct a large number of important experiments; and gain operational experience with manned space systems to put this nation in a position to define and evaluate further manned and unmanned exploration and operational space systems; and (4) to develop effective manned extra-vehicular capability.

If the AAP-1 and AAP-2 flights are not accomplished, there would be an indefinite hiatus in achieving the benefits mentioned above. The timing of the AAP-1 and AAP-2 flights will have a most important effect on the future of our space program. Use of the Apollo developed hardware for the AAP-1 and AAP-2 flights, as now scheduled, will give the United States the means to operate effectively and economically in space for long periods of time at an early date and in an orderly fashion.

Our Advanced Manned Mission planning involving future earth orbital manned space station operations and manned planetary flights relies heavily on tests, experiments and operational data to be gained from these Apollo Applications flights.

Cancellation or postponement of the AAP-1 and AAP-2 flights will disrupt the orderly pace of our progress in space and would dissipate a capability assembled in painstaking fashion over the period of a decade.

RESOURCES

The fiscal year 1967 and 1968 increments of funding required for the AAP-1 and AAP-2 flights are tabulated as follows:

Apollo Applications program—Resources summary

[In millions of dollars]

	Fiscal year 1967	Fiscal year 1968
Apollo Applications:		
AAP-1	2.6	10.0
AAP-2	19.6	19.9
Subtotal	22.2	29.9
Basic Apollo hardware: [1]		
AAP-1	58.5	14.3
AAP-2	24.1	6.7
Subtotal	82.6	21.0
Total	104.8	50.9

[1] Apollo procured equipment for alternate use by AAP.

Second Apollo Applications Mission—AAP-3 and AAP-4

In the short term, the AAP-3 and AAP-4 flights will provide three major benefits: (1) solar astronomical observations will be obtained during the period of maximum solar activity; (2) man's effectiveness as an astronomical observer in space will be determined; and (3) alternate operating modes for future large orbital telescopes will be tested.

In the long term, the AAP–3 and AAP–4 flights will provide a significant initial capability that can be enhanced over the years to conduct comprehensive and detailed studies of the sun. There are many reasons to conduct these studies, but the two principal ones are emphasized below.

First, variations of the sun are the major cause of environmental changes to the earth. Further knowledge of how these environmental changes occur could permit man to control them for his own benefit or learn to better adapt and make use of them.

Secondly, the sun is a valuable astrophysical laboratory which may be viewed by scientists of many disciplines and is considered a virtually untapped reservoir of new and different facets for exploration in extending the knowledge of the respective scientific fields. The effect of the sun on the environment of our planet is especially important since the sun's energy ultimately impacts on every living organism, including all plant and animal life. Evolutionary effects may certainly be said to be tied up with this environment. The effects of the sun's environment on agriculture are obvious. The field of meteorology is intimately concerned with the study of solar physics as a means of predicting and possibly even controlling the earth's weather. Communications are also involved because of the sun's effect on the earth's ionosphere with subsequent disturbing 'blackouts" of world wide radio nets.

Mission Mode and Related Equipment

Apollo Applications flights 3 and 4 comprise the second mission. The equipment for the flights will consist of the following:

For AAP–3, the launch vehicle will be the uprated Saturn I. Spacecraft equipment will consist of the Command Service Module.

For AAP–4, the launch vehicle will be the uprated Saturn I. Spacecraft equipment will consist of the Nose Cone, the Lunar Module Ascent Stage, and the Apollo Telescope Mount (ATM).

The Command and Service Module and crew from AAP–3 will be placed in a low altitude parking orbit and AAP–4 will be launched unmanned into a higher parking orbit (figure 6). The Command and Service Module will transfer to

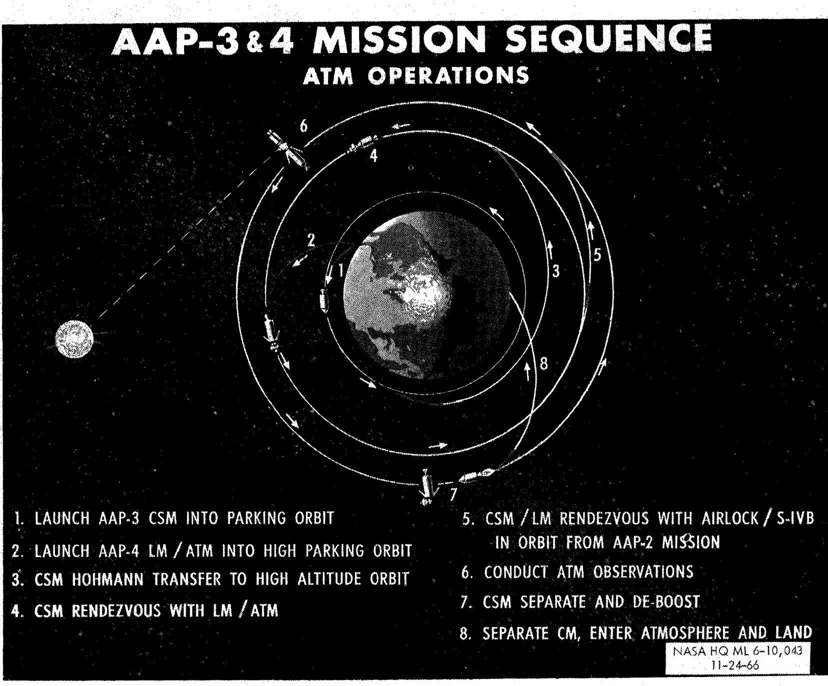

Figure 6

the higher orbit and rendezvous and dock with the Lunar Module/ATM. The Command and Service Module will then transfer the Command Service Module/Lunar Module/ATM combination to the orbit of the Orbital Workshop stored from AAP–1 and AAP–2 and rendezvous and dock, forming an embryonic space station (Figures 7 and 8). The crew will reactivate the Orbital Workshop, install and perform additional experiments, including solar astronomy observations through use of the Apollo Telescope Mount. The Command and Service Module from the AAP–3 flight will carry sufficient expendables to reactivate and resupply the entire orbital cluster for a period of up to eight weeks. Upon completion of this mission, the crew will return in the Command and Service Module, leaving the remainder of the early space station in a gravity gradient stabilized condition for later usage (Figure 8).

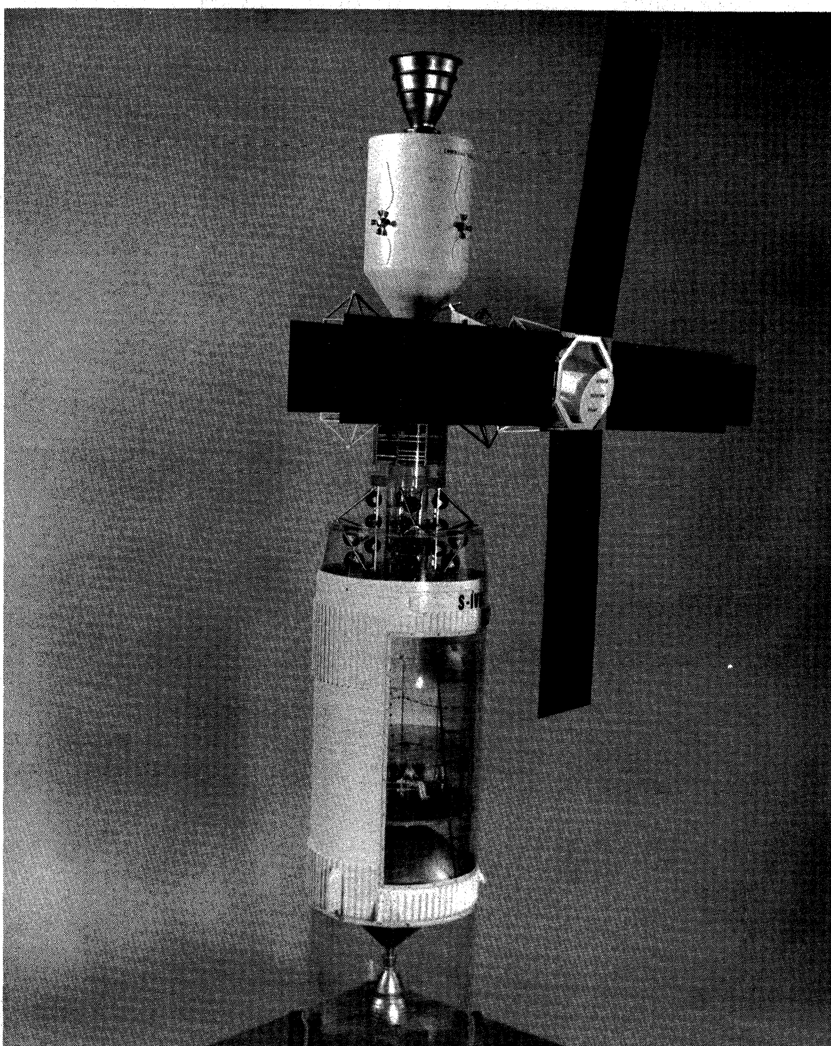

FIGURE 7

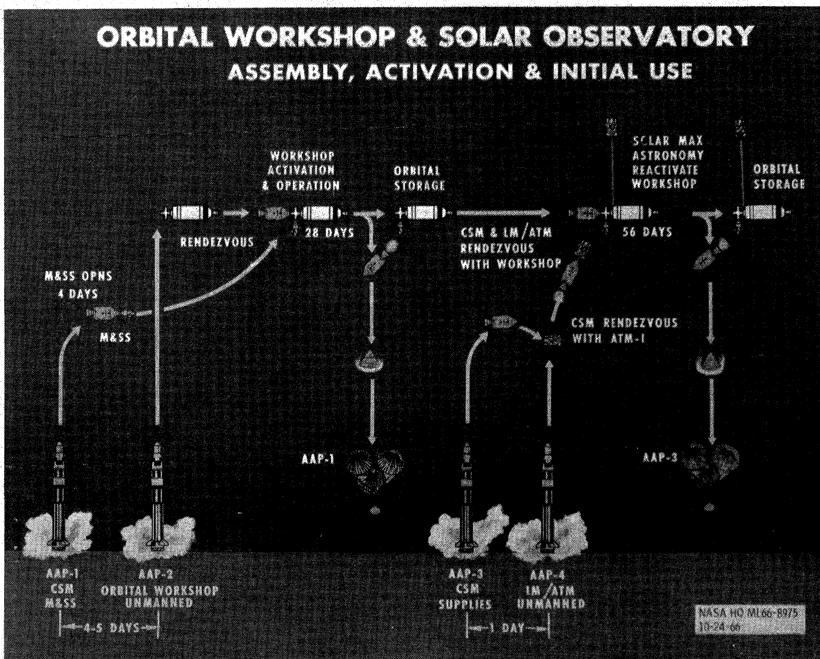

FIGURE 8

OBJECTIVES OF SECOND APOLLO APPLICATIONS MISSION

In summary, the objectives for the second AAP mission are (1) to obtain scientific data on the characteristics of the sun through observations of the entire electromagnetic spectrum made with the ATM instruments; (2) obtain engineering data for selected modes of operation of the Lunar Module/ATM to support development of an advanced manned astronomical observatory; (3) to determine effects of long-duration space flight on crew and space vehicle subsystems up to eight weeks; (4) to leave the Lunar Module/ATM and Orbital Workshop docked in orbit for reactivation and reuse during subsequent Apollo Applications missions; and (5) to conduct approximately five other experiments.

The primary objective of the AAP–3 and AAP–4 flights is to place the Apollo Telescope Mount into operation supported by the Orbital Workshop.

The Apollo Telescope Mount, a significant part of the Apollo Applications program, is essentially a manned solar laboratory being designed and developed to study the sun, its evaluation, structure and behavior. It represents the first use of manned scientific telescopes in space. It provides the capability of carrying large scientific instrumentation to study the sun, having increased spatial and spectral resolution over and above that of similar instrumentation being flown in space today.

Observations from space are of fundamental importance to astronomy, which has long been retarded by the restrictions imposed by the earth's atmosphere. We have, in effect, been looking at the universe through a screen that is partially opaque to ultraviolet, x-rays, gamma rays, and many types of high speed particles. The removal of these restrictions promises to significantly extend our observational reach.

APOLLO TELESCOPE MOUNT

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 (Figure 7). The ATM provides a stabilized platform which can be carried on Apollo Applications missions to accommodate experiment instruments having a requirement for finely controlled pointing.

The ATM includes scientific instruments and supporting sub-systems mounted in a structural rack attached to the ascent stage of an Apollo Lunar Module. It 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 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. 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 as early as 1969, to obtain data during the next period of maximum solar activity (1968 through 1970).

Five basic experiments to obtain solar data during the period of maximum solar activity have been selected for development for the initial ATM launches (Figure 9). Supporting instruments are also being developed to make the scientific experiment instruments more effective (Figure 10). The combination of instruments involved in the overall ATM experiment platform will 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.

The forthcoming period of maximum solar activity is expected to range from 1968 through 1970. This period is probably the most interesting period of the eleven-year solar cycle, however, there is still much to be learned about the sun's behavior during the remaining portion of the cycle. Scientific returns from the ATM experiments package mission during the 1970 portion of solar maximum, and on into the period of degrading activity would be extremely beneficial to the scientific community.

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 SPECTROHELIOGRAMS 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

NASA HQ. ML 67-5554
1-25-67

FIGURE 9

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

NASA HQ. ML 67-5555
1-25-67

FIGURE 10

EXPERIMENTS

APOLLO TELESCOPE MOUNT EXPERIMENTS

The primary focus of experiments for the AAP-3/AAP-4 mission centers around the Apollo Telescope Mount. The five major experiments planned for ATM are described below:

(1) *White Light Coronagraph.*—To monitor the brightness, form and polarization of the solar corona from about 1.5 to 6 solar radii from the center of the sun.

(2) *Ultraviolet Coronal Spectrographs.*—To obtain high resolution pictures of short-time variations in the solar atmosphere such as flares.

(3) *X-Ray Spectrographic Telescope.*—To study solar flare emissions in the soft X-ray wavelengths of 2–10 angstroms.

(4) *Ultraviolet Spectrometers.*—To accomplish vacuum ultraviolet solar astronomy from above the earth's atmosphere utilizing the participation of the astronaut in the observing sequence.

(5) *Dual X-ray Telescopes.*—To map the X-ray emission from the solar corona in various wavelength bands and to measure the total flux and crude spectral shape of the solar X-ray emission in two bands.

OTHER SCIENTIFIC AND ENGINEERING EXPERIMENTS

Other scientific and engineering experiments to be performed include reactivation and reuse of experimental equipment in the Orbital Workshop. In addition, among the other experiments that would be conducted are:

(1) *Star Horizon Automatic Tracking.*—To validate the definition of a horizon based on scattered visual light, and the measurement techniques for on-board horizon position during flight and to provide a worldwide check of the horizon model.

(2) *Zero G Single Human Cells.*—To study the influence of zero gravity on living human cells and tissue cultures and try to determine whether or not the absence of gravity has a significant effect on isolated human cells.

(3) *Galactic X-ray Mapping.*—Survey a large portion of the sky for X-ray sources of very low flux and gather spectral data of limited resolution of the sources.

(4) *Potato Respiration.*—To determine whether sprouting potatoes will change their rhythmic biological processes when subjected to a zero gravity environment.

IMPORTANCE OF AAP-3 AND AAP-4

In the long term, a well-planned and adequately supported program of astronomy using orbital telescopes can contribute significantly to the resolution of important scientific problems. By extending the range of accessible wavelengths and the levels of faintness, it can clarify the problem of stellar evolution and the origin of the universe. By permitting an increase in the sharpness of images attained, it can permit an attack on the existence of remote planetary systems, some of which may harbor life. And by increasing the power and spectral bandwith over that obtainable on the ground, it can push even further the studies, of remote objects initiated with ground-based instruments. It is worth noting that many of the general philosophical questions for which such a program has great implications have great interest for the general public.

The sun is the ultimate source of all energy on the earth, and natural conversion of this energy has provided us with such resources as oil, coal, and wood. It has been estimated that in the last 100 years, the world has used an amount of energy approximately equivalent to the quantity consumed in the previous 1800 years. In the last century, the increase in energy used has been tenfold and the rise in increased consumption is continuing.

A major and largely untapped source of energy is that obtained directly from te sun in the form of solar energy. Approximately 32,000 times as much energy as the human race is currently using reaches the earth's surface each year. Were we able to efficiently harness a sizeable portion of this energy, our energy source problem could be solved. Therefore, a better understanding of the sun, its activities, and its influence upon the earth is basic to practical applications.

The ATM, with its improved capabilities and techniques, will provide major contributions toward a better understanding of these questions. Initial steps are being taken by NASA to develop an optimized space astronomy program. Studies have been made in this regard and others are currently in process. NASA is working with the National Academy of Sciences and with some of the leading astronomers to develop the best approach to a space-borne general astronomical observatory.

Additionally, ATM will establish the basic technological advances, enabling us to achieve a large space-borne astronomical observatory. It is expected that it would be man-tended in that man would maintain it, focus and repair instruments, replace parts as required and change and return film. The ATM and OAO are current development steps being conducted in parallel, leading toward this objective. In gathering data regarding solar phenomena, the ATM incorporates man into the data gathering loop and also provides for the use of photographic film for obtaining high resolution data at a high data rate. The OAO, being an automated spacecraft carrying instrumentation to study stellar astronomy, provides experience in long term operation of astronomical scientific instrumentation in a space environment. The combination of these two programs provides the logical development know-how to obtain the currently viewed optimum astronomy program.

The Apollo Telescope Mount experiment has been endorsed by the President's Science Advisory Committee. The Committee has stated in its February, 1967 report that astronomy is an appropriate choice as a primary objective in our National Space Program. In addition, the Committee envisions an evolutionary development of earth orbiting astronomical facilities designed to take advantage of the unique opportunities which are offered by observations from space. The ATM will provide the basis for future work in stellar astronomical observations as well as expanded capability for solar astronomy studies. To not accomplish the AAP-3 and AAP-4 flights within the concepts described herein will seriously curtail long duration astronomical observations in space by man. Without AAP-3 and AAP-4, the maximum time available for manned experiments of this type would be limited by the present Apollo capability which is 14 days maximum.

The continuous gathering of solar data by such equipment as the ATM and the ultimate large space laboratories of the future, will provide man on earth with fundamental information on which to base practical applications which will benefit his own welfare.

RESOURCES

The fiscal year 1967 and 1968 increments of funding required for the AAP–3 and AAP–4 flights are tabulated as follows:

Apollo Applications program—Resources summary

[In millions of dollars]

	Fiscal year 1967	Fiscal year 1968
Apollo Applications:		
AAP-3	6.0	13.1
AAP-4	12.2	34.8
Subtotal	18.2	47.9
Basic Apollo hardware: [1]		
AAP-3	55.4	24.2
AAP-4	38.3	22.2
Subtotal	93.7	46.4
Total	111.9	94.3

[1] Apollo procured equipment for alternate use by AAP.

APOLLO APPLICATIONS MISSIONS FOR CALENDAR YEAR 1969

The first two Apollo Applications missions will demonstrate the ability to employ a concept of revisitation and reuse of major equipment stored in orbit. This capability will then be extended to approach continuous operations in the late 1969 time period. In this way new experimental packages can be ferried to the workshop to carry out more detailed observations of the earth and sun. Emphasis will be placed on weather observations, with man evaluating new scientific instruments and techniques to better comprehend the factors affecting the earth's weather as an aid to improved predictions and leading eventually to possible control of storm systems and general climatic conditions.

A significant aspect in the utilization of the revisitation and reuse concept is the ability to sustain men in this orbiting observation post. Can man perform effectively and usefully in the space environment for periods up to a year? The ferry and resupply concept as planned for the 1969 period will allow crews to be sustained and to operate in the embryonic space station for such periods of time. If man is ultimately to journey to his neighbor planets this ability must be demonstrated.

Preliminary investigations are also necessary to design and improve instruments and devices required for orbital observations of the earth's resources. These investigations in 1969 will provide better information on overall resources existing on the surface of the earth and will lead to more complete earth resources surveys beginning in the 1970's.

MISSION MODES AND RELATED EQUIPMENT

As now planned we would revisit and reuse the embryonic space station, placed in orbit by Apollo Applications flights 1 through 4, through additional flights, beginning in calendar year 1969. These flights will be of increasing duration and open-ended for up to 90 days for each mission. We would thus build up to nearly a continuous manned operation of the Orbital Workshop and Apollo Telescope Mount.

With appropriate overlapping of succeeding Apollo Applications flights using the uprated Saturn I and Apollo Command and Service Modules, we can interchange crews and can build up operational and biomedical data approching one year's duration on a given crew member. By overlapping 3-man crews, we can also provide up to 6 crew members for short periods of time working in the Orbital Workshop or with the ATM.

The equipment planned for the missions starting in calendar year 1969 will support four launches approximately 90 days apart, each consisting of an uprated Saturn I launch vehicle, and Command and Service Module spacecraft with resupply provisions.

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In the event that the orbital configuration of the Orbital Workshop, Apollo Telescope Mount and associated equipment are in some way inoperative or not usable, we have planned for a second Orbital Workshop and Apollo Telescope Mount to be available as back-up for flights in the calendar year 1969 time period. Our funding request for FY 68 includes the increment of obligational authority required to support this back-up hardware.

Experiments

During the course of these missions, we will perform various scientific, technological, engineering, medical and applications experiments.

The scientific experiments will include areas of astronomy, space physics and bioscience for flight in low earth orbit.

The technological and engineering experiments will deal primarily with evaluation of advanced technology associated with future planned space stations or planetary missions.

The medical experiments include apparatus to test and record human response during long duration flight to various stresses. Among such stresses are physical exercise, variable gravity, and the performance of complex other human tasks.

The applications experiments are planned to develop techniques for measuring the effectiveness of man's participation in orbital meteorology. A large portion of the meteorology experiments is contained in a package of experiments known as Applications A (APP–A) (Figure 11).

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 11

Applications A (AAP–A)

The Applications A experiments are planned to develop techniques for, and to measure the effectiveness of man's participation in orbital meteorology. Meteorological investigations will afford the opportunity to evaluate a number of instruments, establish their flight worthiness, and to examine man's capability to control or modify the experiments.

This experiments package affords an excellent opportunity to investigate space concepts for orbital flight before they are applied to long-life, unmanned meteorological satellites for continuous worldwide weather forecasting. In this respect, the use of manned missions will materially assist in accelerating the development of key experiments and techniques for a worldwide observation system.

Significant improvements in weather predictions depend upon data which better define initial state weather conditions on a global scale. All the data which are necessary for determining this initial state condition are not attainable through conventional weather forecasting networks because of the relative spacing of weather reporting stations.

These early investigations will lead to more advanced systems which will result in more accurate prediction of violent weather conditions; improve length and accuracy of weather forecasts; and provide greater understanding of the air pollution problem, leading to the development of air pollution countermeasures.

RESOURCES

The initial FY 1968 plan that went forward to the Bureau of the Budget is shown on the Figure 11A. Column 2 reflects the revised amounts that were requested in the President's Budget to Congress. Column 3 reflects the difference between Columns 1 and 2. Column 4 is a statement of the impact of each of the funding reductions from Column 1. (The information presented in Figure 11A is the same as the material provided on page 362 to answer Mr. Daddario's question "I would like to request for the record that Dr. Mueller provide us with those programs eliminated after having gone to the Bureau of the Budget.")

The fiscal year 1967 and 1968 increments of funding required for the Apollo Applications missions are tabulated as follows:

[In millions of dollars]

	Fiscal year 1967	Fiscal year 1968		Fiscal year 1967	Fiscal year 1968
Basic hardware	24.0	167.4	Experiments	1.0	11.7
Mods for long duration	13.5	66.8	Land landing and 6-man capability	1.1	18.5
Science	(20.1)	(86.7)	Synchronous orbit capability	----------	5.0
ATM	11.7	36.9	Medical	.8	18.3
APP-A	----------	13.5	Habitability	14.2	30.0
APP-B	----------	17.0	Mission support	5.3	50.3
Extended lunar	----------	5.0	Total	80.0	454.7
Other earth orbital	----------	1.7			
Definition	8.4	12.6			
Technology	(2.1)	(35.2)			

FY 1968 BUDGET PLAN
(Millions of Dollars)

APOLLO APPLICATIONS	INITIAL	REVISED	Δ	IMPACT
SPACE VEHICLES	309.9	263.7	- 46.2	Reduce rate of buildup of long duration and re-use capability. Defer development of extended lunar capability one year.
EXPERIMENTS	235.0	140.7	- 94.3	Reduce effort related to definition of experiment payloads (stellar astronomy, medical, meteorological, earth resources) for Calendar Year 1970 and beyond. Defer development of synchronous flight. Defer development of extended lunar exploration, experiment payloads one year.
MISSION SUPPORT	81.8	50.3	- 31.5	Reduced requirements based on reduced experiments. Delay mods to Mission Control Center at Houston relating to real time experiment readout.
APOLLO APPLICATIONS TOTAL	626.7	454.7	-172.0	
APOLLO	2,706.5	2,606.5	-100.0	
SPACE STATION	100.0	-0-	-100.0	

ATTACHMENT IV

FIGURE 11A

Apollo Applications Missions in the 1970's

In the early 1970's, Apollo Applications missions can be expected to fall into three broad and, to some extent, overlapping groups:

(1) In some cases, they will be a continuation and extension of those activities that previous experience has shown to be valuable.

(2) A second class will still be aimed at the questions—"What can man do and what is worth doing in space?"

(3) A third group may be more specifically oriented to the development and flight testing of components, subsystems, techniques, and operations leading to an expanded capability in manned space flight.

Taken altogther, these missions will tell us when we are ready to take the next major step in space, and whether it should be aimed at the planets, the moon, the earth, or some combination of these. When such a step has been decided, Apollo Applications missions may play a further role as a test bed for such subsystems as power, life support, communications, guidance and navigation, or even for whole spacecraft modules.

Objectives

Extended Flight Capability

In the area of extended space flight capability, we will be looking for pragmatic data to answer such questions as:

(1) What must be provided beyond subsistence to make space livable for prolonged periods?

(2) How can space flight be made simpler and less expensive?

(3) How can we repair and maintain spacecraft in flight for extended periods?

(4) How can we best insure astronaut safety?

(5) How can we streamline our operating procedures?

(6) How can return to earth be simplified?

(7) How can we get greater mobility in extravehicular operations to permit safe and easy construction of large assemblies in space?

(8) What crew size should be planned for planetary missions of one to two year duration?

(9) What living and recreation facilities are needed?

(10) Is artificial gravity worth the price, or is it an absolute need?

(11) How big should a space station be, and what facilities should it provide?

(12) What is the best way to use man in support of the mission objectives?

Lunar Exploration

In the area of lunar exploration, we will be accumulating data to help answer questions such as:

(1) What is the surface structure of the moon?

(2) Is there a core?

(3) Are there active volcanoes?

(4) How was the moon formed?

(5) What does it tell us about the earth?

(6) What does it tell us about the solar system?

(7) Are there traces of living organisms?

(8) What does it take to support a man on the moon and allow him to do effective exploration?

(9) What kind of lunar vehicle is needed?

(10) Can he make use of materials found on the moon?

(11) Is there anything worth exploiting on the moon?

(12) What exploration is best done by men? By robot?

(13) Is the moon a good base for an astronomical observatory?

(14) What can we learn from photography and other remote sensing from lunar orbit?

(15) Are the polar areas essentially the same as the equatorial?

ASTRONOMY

In the area of astronomy, we will be attacking such questions as:

(1) What can be learned about the fundamental nature of the sun, using observations at wavelengths that are obscured by the earth's atmosphere?

(2) What can we learn about other planets, using the greater detail observable from space?

(3) What is the nature of the celestial sources of x-ray radiation that have been observed by rocket born sensors?

(4) Are there other sources of high energy radiation (e.g. gamma rays)?

(5) What can be learned from low frequency radio waves that do not penetrate the ionosphere?

(6) It is practical and worthwhile to operate a large astronomical observatory in space?

(7) How can man's presence best contribute to astronomy in space? As an observer? As a mechanic?

(8) Do the benefits of astronomy from synchronous orbit outweigh the additional cost?

EARTH OBSERVATION

In the area of earth observations from space, we will look for answers to such questions as:

(1) Can more accurate weather prediction be made using more detailed observations from space?

(2) How well can the remote measurement of wind velocity, moisture content, temperature, pressure, etc., be made?

(3) What altitude is best for different kinds of observations?

(4) How does solar activity interact with the earth's atmosphere to effect weather? Crops? Communications? Magnetic activity?

(5) Can the observation of rainfall and snow cover lead to better water management?

(6) Can the observation of crops and forests from space help in improving the production and distribution of food?

(7) Can observations from space help to control the pollution of air and water?

(8) How much detail is needed for useful observations?

(9) What wavelengths or groups of wavelengths yield the most valuable data?

(10) How frequently should observations be made?

(11) What is man's proper role in observations of the earth from space?

WEIGHTLESS ENVIRONMENT FOR EXPERIMENTATION

In addition to the above major areas of activity, Apollo Applications will provide a facility in which scientists can conduct experiments which exploit the weightlessnes and other attributes of the space environment. These will attach such questions as:

(1) How are the growth and activity of plants and animals affected by weightlessness?

(2) How are the daily life rhythms of plants and animals affected by removing them from their normal environment and 24 hr. daily cycle?

(3) What is the behavior of fluids and gasses in a weightless condition?

(4) How is the sense of balance affected by weightlessness?

(5) How do animals adjust to gravity after a prolonged period of weightlessness?

(6) How are the functions of the bodily organs affected by weightlessness?

(7) Will observations of biological specimens under weightlessness provide better understanding of their normal function?

(8) Are there beneficial effects of weightlessness that could be exploited?

MISSION PLANNING

Mission assignments for Apollo Applications in the 1970's are of necessity tentative and still under study. Early AAP missions are contingent on events in the Apollo program. Many problems that might arise in the Apollo program would not impact AAP. For example, a problem associated with the Saturn

V/Apollo flight may not impact Saturn I/Apollo hardware used by AAP for early missions. As a matter of fact, the AAP planning and scheduling is consistent with and would not be changed by moderate difficulties or moderate success in the basic Apollo program.

In the event that Apollo hardware is not available for AAP usage, the AAP payloads for the early missions will be stored for later usage on follow-on missions. The alternative schedules for AAP will be determined after analysis of the situation at that time. The storage and maintenance of the AAP hardware will involve increased cost. However, the AAP payloads will be available for modifications and improvements while in storage, thus permitting the experiments in the payload package to be kept abreast of the state of the art. Thus the experiments will be maintained in a configuration to obtain the quality and quantity of data consistent with the latest scientific and engineering techniques.

Definition is underway for a large module which could be placed in orbit by a Saturn V vehicle and provide the capability of one year's manned operations in earth orbit. Early concepts of this one year module include an Advanced Orbital Workshop or prototype Manned Space Station. Sufficient experiments and equipment would be provided for a one-year duration, with periodic resupply missions (both crew and expendables) being provided by additional flights of the uprated Saturn I with Command and Service Modules. The configuration of systems involved with this one year module represents an initial validation of the types to be used in manned planetary missions.

Another Saturn V Apollo Applications mission is a mission in lunar orbit to perform mapping and survey operations which will provide accurate mapping and high resolution stereo photography in the polar areas of the moon, which will not have been covered previously. Subsequent Saturn V flights are planned for extended lunar surface exploration. Our planning for these lunar surface missions requires 2 Saturn V flights per year beginning in 1970. Present planning also includes additional lunar mapping and survey operations from lunar orbit at a rate of 1 per year.

One of the results expected from this extended lunar exploration will be information relating to the origin and evolution of the moon with possible significance to the understanding of the origin and evolution of the earth.

Operations utilizing the Saturn V launch vehicle in the 1970's also include extended manned operations and stellar astronomy from synchronous earth orbit. A manned earth orbital telescope in synchronous orbit offers large potential returns in terms of determining the dimension and origins of the universe. Such an instrument, utilizing up to 120-inch 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. Such a discovery would be an initial indication of solar systems similar to ours and, therefore, the possible presence of life forms existing beyond our solar system.

Applications Experiments

The experiments planned for Apollo Applications missions in the 1970's are now being defined. A funding increment is included in the FY 1968 budget to support this definition activity. The categories of experiments are: (1) Communication and Navigation experiments; (2) Meteorological experiments; and (3) Natural Resources experiments.

COMMUNICATION AND NAVIGATION EXPERIMENTS

The objectives of the Communication and Navigation experiments will include:

(1) Control and coordination of all air traffic while flying over the ocean.

(2) The development of position fixing data to provide for all weather global navigation by sea and by air.

(3) The development of improved air-sea emergency, search and rescue aids.

(4) The development of techniques to broadcast voice and television directly to home receivers, on a global basis.

(5) The development of improvements in spacecraft to ground communications and space vehicle tracking aids.

METEOROLOGICAL EXPERIMENTS

Meteorological experiments in the 1970's will be extensions of the experiments carried out in the 1969 missions. There are two basic purposes for the continued research and development in meteorology. One is the basic scientific pursuit to explore and understand the nature and behavior of the atmosphere. The second results from the impact of the weather on daily operations, private and public, and upon the economy of nations.

NATURAL RESOURCES EXPERIMENTS

The Natural Resources experiments cover specific applications to agriculture/forestry, geology/hydrology, oceanography/marine technology and geography.

The following principal fields associated with agriculture/forestry will be explored in order to determine if useful data is obtainable from space for identification and management of available resources.

(1) a better understanding of the emission and reflectance properties of biological and physical materials through spectrophotometric analysis in the laboratory, on the ground, and from low altitudes.

(2) Identifying the single or combined wavelengths in the electromagnetic spectrum that will yield unique and consistent imagery as it is acquired from progressively higher altitudes.

(3) Specifying the minimum accuracy standards and quality requirements of data for the various agriculture and forestry application areas.

(4) Identification and analyses of economic benefits of the application of space technology to agriculture and forestry.

The objective of applying space technology to the field of geology/hydrology will be to improve the utilization of the earth's land, mineral, and water resources through the use of repetitive global surveys. The principal fields of interest to be analyzed in formulating the manned earth-orbital experiment program are:

(1) Geology: Field mapping, economic geology, petrology and mineralogy, geomorphology and tectonophysics.

(2) Hydrology: Basins, streams and rivers, percolation and runoff, rainfall and, evapo-transpiration.

The objective of applying space technology to oceanographic purposes will be to improve utilization of the world's oceans through the use of repetitive global surveys. Repetitive surveys will include the following:

(1) Physical phenomena of the sea which vary markedly with time.

(2) Physical phenomena of the sea which are relatively invariant with time.

(3) Economic geography of the sea.

(4) Improved displays of global oceanographic information suitable for direct utilization by technical, commercial, and scientific communities.

The application of space technology to the field of geography will be used for repetitive global surveys. These surveys will provide the following:

(1) Compete multisensor coverage of the earth's surface, thus eliminating reliance on incomplete coverage of major portions of the earth.

(2) Current information of natural and cultural phenomena, thus eliminating reliance on old, incorrect and outmoded data.

(3) Seasonal coverage of the earth's surface which will enable analysis of the extent and rate of seasonal changes in the earth's geography.

(4) Comparative coverage which will be acquired from time to time to understand the extent and frequency of long term changes in the earth's geography.

LAND LANDING CAPABILITY

The Apollo Applications land landing capability, as planned, will present a major step in the advancement of a technology which will reduce the possibilities of crew injury and equipment damage during landings. It will provide flexibility in the accomplishment of Apollo Applications and future manned space flight missions. In addition, the land landing capability will facilitate reuse of Command Modules returned from space, with attendant cost savings. The system will be available for first flight tests in 1971. Follow-on Apollo Applications mission planning involves full use of the land landing system on all flights.

The land landing system technical objectives cover the capabilities of a descent system to provide a greater glide range. Maneuvering controls to provide the crew with the ability to make a controlled touch down is another technical objective (Figure 12). The system will provide decreased impact velocities while retaining the original water landing capability.

Many of the Apollo Applications program missions are of long duration and are open-ended. The capability to effect a land landing as well as a water landing thus increases mission abort flexibility. The lower impact velocities will lessen the chances of crew injury and provide greater assurance of crew safety.

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 (Figure 13). 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 retro rockets.

The reduced landing accelerations will minimize current crew seat requirements, resulting in more usable volume in the Command Module. Existing couches can be removed and replaced with storable light-weight net couches. This will provide a capability for carrying up to 6 astronauts for short duration resupply ferry flights (Figure 14). The net couches further provide more crew volume for experimentation and other mission required operations.

Studies are currently being conducted for refurbishment and reuse of Apollo Command Modules. Soft landing recovery and reuse provides potential savings in refurbishment costs over that of water recovered spacecraft because of the noncorrosive land environments.

APOLLO APPLICATIONS

LAND LANDING

- **DESIGN OBJECTIVES**
  - **COMMAND MODULE REUSABILITY**
  - **INCREASED CREW COMPLEMENT**
  - **REDUCED WATER RECOVERY FORCES**
  - **INCREASED LANDING FLEXIBILITY**

- **DEVELOPMENT REQUIREMENTS**
  - **GLIDING CHUTES**
  - **MANEUVERABILITY CONTROLS AND DISPLAYS**

NASA HQ MC67-5763
2-21-67

FIGURE 12

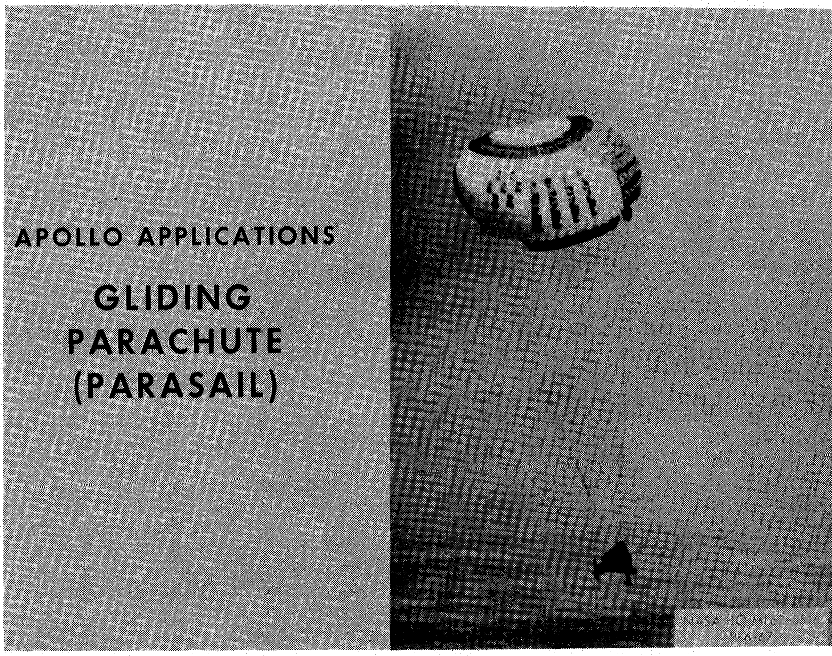

FIGURE 13

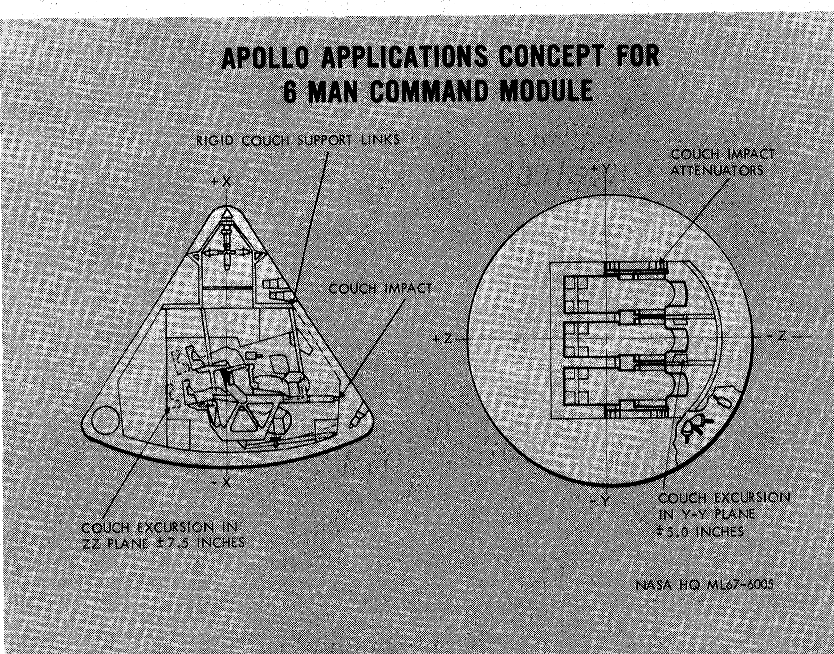

FIGURE 14

TIMING OF FOLLOW-ON PROCUREMENT

Another consideration regarding the Apollo Applications program is the procurement cycle for Apollo/Saturn hardware. Figures 15 and 16 summarize the status of Saturn launch vehicle and Apollo 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 provided by the Apollo program, 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 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.

Figure 17 shows the lead time relationship between the launch vehicles for the basic Apollo program and the follow-on Apollo Applications program. The various elements of the launch vehicles have slightly different lead times, but planning is such that all launch vehicle entities arrive at Kennedy Space Center at the proper time for integration and launch.

The lead time problems currently faced—maintaining continuity of the capability developed for Apollo—are evident. Similar situations exist for the spacecraft and other Apollo equipment.

This effort will permit accomplishment of significant results with the first follow-on Apollo Application Saturn V vehicles and it will provide a means of maintaining our national capability. It will also allow a 4 per year rate in the future to meet the follow-on mission goals. The President's Science Advisory Committee in its report published in February 1967 recommended an average 4 per year rate for the Saturn V which can be provided if the required funding is available.

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 15

APOLLO SPACECRAFT PROCUREMENT
STATUS AS OF FEB. 25, 1967

SPACECRAFT	BLOCK DESIGN-ATION	USED	ASSEMBLY COMPLETED	IN FABRI-CATION AND ASSEMBLY	ORDERED BUT NOT YET IN FABRICATION	LONG LEAD PROCURE-MENT	TOTAL
COMMAND MODULE	BLOCK I BLOCK II	3 —	3 2	— 7	— 3	— 3	6 BLOCK I 15 BLOCK II GRAND TOTAL=21
SERVICE MODULE	BLOCK I BLOCK II	3 —	3 2	— 7	— 3	— 3	6 BLOCK I 15 BLOCK II GRAND TOTAL=21
LUNAR MODULE		—	3	4	8	—	GRAND TOTAL=15

NASA HQ MC67-5907
2-27-67

FIGURE 16

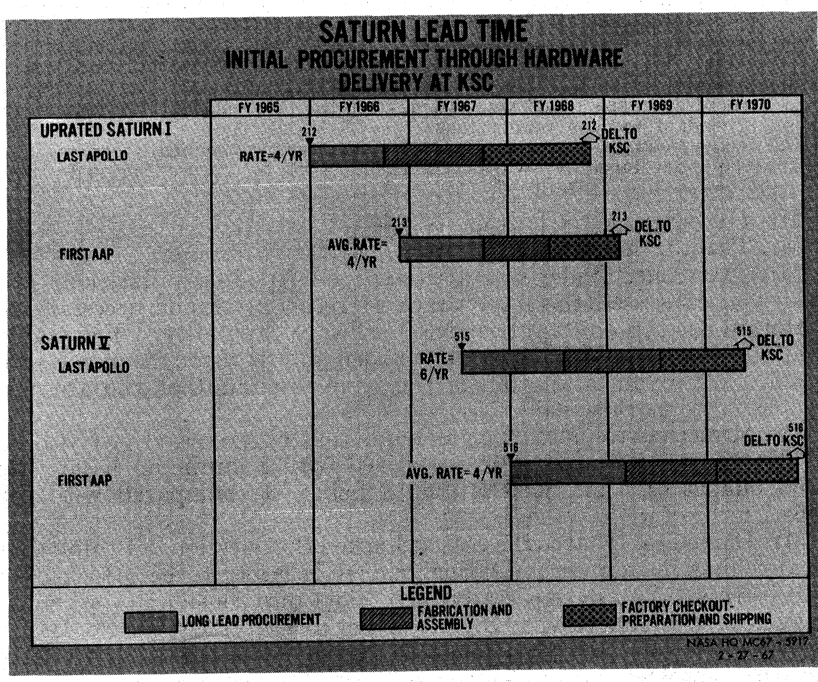

FIGURE 17

SUMMARY OF APOLLO APPLICATIONS BENEFITS

Manned and unmanned space activities present many exciting prospects for great benefits, not only for this nation, but for the entire world.

Such possibilities could include meteorological 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.

Research stations to map and study the earth's resources which could provide a better way of life for millions of people is another possibility. Astronomical observatories to conduct solar and stellar observations outside the filtering effects of the earth's atmosphere is a third possibility. A fourth is assembly, maintenance and operation of communication stations potentially capable of significantly increasing reliable world-wide communications and television coverage. Navigation and traffic control stations to achieve increased efficiency of transportation, particularly the operation of ships and aircrafts, is a fifth possibility.

Furthering space technology by developing and using man's ability to assemble, test, repair and maintain large space structures is a sixth possibility. 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 means to study these requirements and to do it economically are provided by the Apollo-developed hardware. The Apollo Applications program is designed to make use of this capability.

Mr. DADDARIO. Mr. Chairman?

Mr. TEAGUE. Mr. Daddario.

Mr. DADDARIO. When you discussed the Apollo Applications last year you expressed the importance of receiving funds necessary to maintain the Apollo Applications hardware capability. You stated that this year would be essential to then follow through on the program. Were you talking about the same amounts that you are now proposing to us this year?

Dr. MUELLER. No, sir. The amounts that we talked of last year as holding open an option were associated with a minimum fiscal year 1968 budget of some $626 million I believe as compared with the $454.7 million we have here.

Mr. DADDARIO. That is the reason I asked the question. I think that if anything in our authorization budget is going to be attacked, it will be this. You have already then taken into consideration knowledge now available to you which was not available last year. In the recommendations you then made to us you have been able to come up with a budget that recommends that is some $200 million less for this year than you thought it would have been at this time last year?

Dr. MUELLER. That is correct.

Mr. DADDARIO. Can you go into that? What did you do? How were you able to lower this amount of money and what effect does it have upon the program?

Is is going to be a stronger program or have you already lowered your sights? What is the whole background of that?

Dr. MUELLER. We have done several things. We have introduced a new program concept at an early date and that involved the development of the concept of the spent stage and the use of the Apollo Telescope Mount (ATM) using the Lunar Module attached to the spent stage or the S-IVB orbital workshop. This orbital workshop ATM concept permitted us to provide a single development of a set of complex instruments that we could reuse and it is that basic concept of reusing the hardware which has made it possible to save this $200 million.

In addition to that, however, we had to cut back on our basic development of experiments, cutback to the absolute minimum that Dr. Newell and Dr. Adams feel will sustain a meaningful scientific effort in years to come.

What we have done, therefore, is to do two things, basically. One is to invent a new approach to carrying out space activities in the Manned Space Flight program and implement that with the workshop and the Apollo Telescope Mount.

The second thing we have done is to reduce the funding in the experiment area to a minimum consistent with maintaining a viable utilization of this workshop and the Apollo Telescope Mount in Earth orbit.

Mr. DADDARIO. How did you do with the Bureau of the Budget with this proposal? Did you come out with what you asked for or did they reduce it?

Dr. MUELLER. We proposed $626 million for fiscal year 1968 for the Apollo Applications program. In addition to that, we proposed another $100 million for the beginnings of a development of a space station.

The Bureau of the Budget said under the circumstances, they could not support that level of funding. They asked us to eliminate the funding for the space station and to reduce the Apollo Applications program funding to an absolute minimum.

Mr. DADDARIO. When you went to the Bureau of Budget, you figured for this program some $600 million and you had an additional request for some $100 million to get going in space on your space station.

Dr. MUELLER. That is correct.

Mr. DADDARIO. The space station can be considered a separate program?

Dr. MUELLER. That is correct, separate from Apollo Application.

Mr. DADDARIO. One you can pick up at a later time?

Dr. MUELLER. That is correct.

Mr. DADDARIO. And that is what you intend to do?

Dr. MUELLER. Yes.

Mr. DADDARIO. Then this figure represents, if not a drastic cut, certainly a very large cut from your original request?

Dr. MUELLER. Yes.

Mr. DADDARIO. Do you believe, however, that it will still allow you to do the job that you need to do?

Dr. MUELLER. It is my belief that we will be able to do the job that we need to do. But you have to recognize that a program of this sort does not have built into it the ability to solve problems. It is, if you will, a high risk program, not a risk in terms of lives or safety, but a risk in terms of can we in fact meet these objectives that we have set out for ourselves.

Mr. DADDARIO. Are you saying that you will maintain this same objective within the $454 million rather than have stretched it out over the next few years?

Dr. MUELLER. We have not maintained the same objectives. We have, however, held onto the primary objectives that we had before, that is long duration flight and the use of the orbital telescope for solar observations in the beginning of the development of the manned orbital telescope program.

Those two major objectives we have held onto. We have had to shear off many desirable, in fact, essential experiments in terms of future developments. We have held onto those that appeared to have the most promise for immediate payoff in the area of applications experiments.

Mr. DADDARIO. I would like to request for the record that Dr. Mueller provide us with those programs eliminated after having gone to the Bureau of the Budget.

(The following is submitted for the record:)

The attached table (attachment IV) is in reply to Mr. Daddario and Mr. Fuqua who posed the above questions for the record. Column I of Attachment IV shows the initial fiscal year 1968 plan that went forward to the Bureau of the Budget. Column 2 reflects the revised amounts that were requested in the President's Budget to Congress. Column 3 requests the difference between columns 1 and 2. Column 4 is a statement of the impact of each of the funding reductions from column 1.

ATTACHMENT IV

Fiscal year 1968 budget plan

[Millions of dollars]

	Initial	Revised	Decrease	Impact
Apollo applications:				
Space vehicles	309.9	263.7	46.2	Reduce program assurance for long duration. Delay extended lunar capability 1 year.
Experiments	235.0	140.7	94.3	Reduces definition of experiment payloads (stellar astronomy, medical, meteorological, earth resources) for calendar year 1970 and beyond. Delay synchronous flight of cluster. Delay extended lunar exploration, experiment payloads 1 year.
Mission support	81.8	50.3	31.5	Reduced requirements based on reduced experiments. Delayed mods to Mission Control Center at Houston relating to real time experiment readout.
Total	626.7	454.7	172.0	
Apollo	2,706.5	2,606.5	100.0	
Space station	100.0	0	100.0	

Then I would like to ask one last question.

The Apollo Applications program is now presented to the committee in the amount of $454 million. If, in fact, it is low, would it then be worth, let us say, a $300,000 expenditure in order to accomplish Apollo Applications activities that you would like to have?

Do you reach the point somewhere where it is better not to go ahead and is the $454 million pretty much the low water mark in that regard?

Dr. MUELLER. There is nothing that I know of that one can do to reduce the costs on the space vehicles without eliminating a space vehicle in the future. You either have to give up the Saturn I or the Saturn V since you couldn't eliminate the spacecraft and still fly.

All of those are involved in the number under "space vehicles" as we will see in a moment. In the experiment area, we have cut back very drastically experiment developments, and I believe that we are already at a point where the scientific community feels that we are inadequately supporting the development of future experiments.

Mr. TEAGUE. Then, George, are we going to be sending vehicles half loaded with experiments?

Dr. MUELLER. No, we are not going to be sending vehicles half loaded in the years immediately ahead. The basic thing that we have had to cut out is the early development of extended lunar capabilities for example. That phase had to be deferred by a year.

We had to cut out the development of new kinds of Earth sensing experiments beyond the first packages. When I say we have a high-risk program, what I am really saying in this regard is that if our judgments are wrong and if we haven't made exactly the right set of decisions at this point in time in an area in which, after all, we aren't that sure that we are going to be right about, then we may not be able to stay up for 2 months. We may have to come back down after only 1 month or even 2 weeks. We don't have the alternatives that would permit us to go back. There is a considerable risk that the very desirable things that we are setting out to achieve using the Apollo Applications program, we may not be able to achieve because of the restriction on funding.

Mr. TEAGUE. It is the wise thing to do to have each one of our vehicles have the maximum number of experiments on when they fly?

Dr. MUELLER. I agree.

Mr. TEAGUE. Would you include for the record the request Mr. Daddario made of the items that were cut out?

Dr. MUELLER. Yes, sir.

Mr. FULTON. Along the lines that we have been speaking about, I would like to have estimates put in the record of the monetary result of a 1- or a 2-year postponement on the Apollo Applications program and also the effect on the program in view of the present installations which we already have.

I would like the cost put in and I would like an estimate on what would happen on the same factors if we put the Apollo Applications program temporarily in mothballs for an indefinite time and then tried sometime in the future to pick it up again, so that that would be an indefinite suspension.

One other point that I want to finish with. On the asteroid Icarus that is coming within 4 million miles of the Earth's surface by June 1968, this asteroid is a part of the asteroid belt between Mars and Jupiter and could give us an insight into what asteroids are and help understand this unknown danger for astronauts who are going to operate in this asteroid belt of some 50,000 asteroids.

So the question is: When this asteroid comes within 4 million miles, why don't we look at it? It is going to be several kilometers in diameter, so that we might be able to acquire a sample. We might try to put it in orbit.

Mr. FUQUA. What level of funding would be the optimum amount to have the maximum amount of experiments on each payload that we could take advantage of?

I agree with the chairman that we should not send half-loaded vehicles into orbit if at all possible. Where are we along in the program? What would be the level of funding that we could have for the optimum amount of experiments on each one?

Dr. MUELLER. Let me hasten to assure you and the chairman that we are not sending half loaded vehicles into orbit in the calendar year 1968 and 1969 time period. The optimum funding level for the experiments to provide some alternatives and some future experiment development would involve almost all of the $200 million reduction that I mentioned. Most of the $200 million that was cut out would appear in the AAP experiments line item and that is where the principal costs were taken out.

What we have essentially done is to do what Mr. Fulton has suggested, and that is defer as well as we could, everything that could possibly be deferred and still leave us with a viable program.

Mr. FULTON. How much did you ask for originally?

Dr. MUELLER. Roughly two and a half times the funds we have here in the experiments line item.

Mr. FULTON. That is all.

Mr. FUQUA. I think it would be helpful when you answer the question that Mr. Daddario asked about the breakdown, if you could break them down into the three line items, space vehicles, experiments, and mission support.

(Information requested is as follows:)

ATTACHMENT IV

Fiscal year 1968 budget plan

[Millions of dollars]

	Initial	Revised	Decrease	Impact
Apollo applications:				
Space vehicles	309.9	263.7	46.2	Reduce program assurance for long duration. Delay extended lunar capability 1 year.
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Total	626.7	454.7	172.0	
Apollo	2,706.5	2,606.5	100.0	
Space station	100.0	0	100.0	

Dr. MUELLER. Yes, sir.

Mr. FUQUA. I think this would be very helpful.

Mr. RUMSFELD. I thought you said two and a half times.

Dr. MUELLER. Mr. Fuqua asked me what the experimenters asked for.

Mr. RUMSFELD. I see. Is it possible to give us a breakdown; and I don't find it here in backup books on the cost per launch with the fact of experiments and mission support that go with each of the launches anticipated.

Dr. MUELLER. Yes. But that can be done for the basic launch vehicle, Mr. Rumsfeld. Each package has a different set of experiments. It is different in each case. We can provide that information.

(Information requested is as follows:)

Answer: We are engaged at NASA, not merely in landing an expedition on the moon, but in developing the whole range of technology to give the nation a rounded manned space flight capability. This development of itself has tremendous benefit for our whole country.

It helps to demonstrate our advanced position in science and technology before all the nations of the world.

It has an enormous impact on our educational system, challenging and stimulating our youth to new standards of excellence.

It creates basic new industries for our economy.

It is producing immediate benefits of direct use to people here on earth. Whenever a laboratory develops a new scientific concept or a piece of hardware for space purposes, the probability is high that the development will turn out to be useful somewhere in earth-bound life. Over the next 20 years, you will see an amazing parade of new products, improvements on old ones, and price cuts on expensive ones. In many cases, the origins of these new and revolutionary products will lie in research carried out as part of the national space effort.

Just as the necessities of World War II led to such lasting innovations as the jet plane and aerosol spray, the exploration of space has already started a beneficient fallout of commercial products and processes that promises profound effects on our economy and lives here on earth.

The list is a long one: lightweight plastics, developed for use in rockets, are being used in the construction of railway tank cars that weigh only half as much as their steel counterparts; new metals, developed by space researchers, are now being used in oil refineries where their resistance to corrosion is required; sealants, developed for the seams of spacecraft, are being used in caulking bathroom tiles and for sealing windows of automobiles; an alkali silicate paint that resists weather, solvents, and radiation, has been marketed commercially.

In addition to developing new products, space research has led to the discovery of new uses for old ideas and products. An example of this is the fuel cell, which was developed in the last century but found no marketable application until space researchers began to use it for supplying electrical power onboard the Gemini and Apollo spacecraft. Commercially, the fuel cell is now being used to power experimental golf carts, tractors, spot welders, fork-lift trucks, and smog-free, electric automobiles of superior efficiency.

In the field of medicine, we have already seen many benefits as a result of our space program. For example, the tiny bio-sensors used to monitor the astronauts' physical condition during flight are now being used in many hospitals to permit one nurse, seated at a central console, to monitor the condition of many patients at the same time.

Another medical device stemming from our space research is a tiny radio transmitter which is swallowed by the astronaut and suspended in the stomach without surgery. This enables doctors to monitor his physical condition, especially thermal stresses, gaseous conditions, and tensions. This device, which is only the size of a large vitamin capsule, also has extensive "earthly" application in the practice of medicine.

The future holds promise of many more benefits to medicine through space research. In the past we have used studies of patients during periods of long bed-rest as an analogy to determine the effects of prolonged weightlessness in space.

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Now, there is promise that the reverse analogy will prove useful, and that our studies of weightlessness may provide information of help to the practice of medicine here on earth in cases where patients are required to spend long periods of time in bed.

Perhaps one of the greatest benefits that will come to mankind through our space research is a better understanding of what the healthy human being is and what he is capable of doing. The ordinary physician looks at many sick people in a normal earth environment; our space medicine people, in their work with the astronauts, are able to monitor healthy people in the "abnormal" environment of space. By changing the environment, we are able to get a different view of the mechanism that is the human body, and we are able to gain a better understanding of just what a healthy human being is, and how he can be kept healthy.

The space program is thus in the forefront of a scientific and technological revolution that is changing radically our whole way of living here on earth. Any prediction of what will happen in the next 20 years is bound to be ultraconservative.

The Apollo Applications program proposed for initiation in the FY 1968 budget will meet two basic objectives. The program of investigations and development to be carried forward will make unique contributions to practical applications, operational capabilities, science and technology. At the same time, it will 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 flights and the interrelated roles of manned and unmanned systems.

(Mr. Rumsfeld's request is further amplified in reply to a question by Chairman Teague on p. 334.)

Mr. RUMSFELD. I can see it would be unwise to go ahead with the original number of vehicles if you were going to cut the mission support and experiments to a point where it wasn't worthwhile to buy the vehicles.

How many inseparable activities are involved here? How many vehicles are there, for example?

Dr. MUELLER. Actually, there are four launches of the uprated Saturn I which produce two missions. In other words, we need about 80,000 pounds of payload capability or a little more per mission in order first to set the workshop up and, second, to get the orbiting observatory up. We use a single launch in 1969 to resupply the workshop plus the telescope. Now, it is turning out, as our studies proceed, that if we can make these flights contiguous, it simplifies tremendously the problems keeping this cluster operating.

Mr. RUMSFELD. You basically have two separable missions?

Dr. MUELLER. That is right.

I think that it ought to be recognized that there is in fact a minimum rate at which we can launch these vehicles and still maintain a reasonable degree of competence in our launch crews and flight crews and in the ground support system. One of the constraints, actually, on the scheduling we have here is how few launches can we make a year and still have a viable operational team. One of the problems is that we are already at what in my view is below the rate of launching that provides for maximum safety, for maximum efficiency and for maximum effectiveness. We really are talking about an average rate of four launches of a vehicle a year. That would be one every three months except in the case of the Saturn I, which will be dual launches so there is one dual launch every 6 months and the trained crews don't maintain their proficiency. There is a forgetting cycle that goes with this, too. I am personally concerned as to whether or not we have an adequate launch rate to maintain a viable team.

Mr. RUMSFELD. How many missions, if there are two missions basically involved in the $454 million, how many were in the $626 million request which the Bureau of the Budget disapproved?

Dr. MUELLER. Actually the same number of missions was provided at the $626 million level. There were, however, different missions in 1969 than we have in 1968. There are two missions in calendar year 1968 that we are talking about. In calendar year 1969 at the $626 million level, there were additional apparatus carried up to the vehicle that we are not now carrying. We will reuse the old equipment in 1969. That provides a great savings providing the old equipment is equipment that you really want to use.

Mr. RUMSFELD. The figure, $454 million is five and a half times the $80 million for fiscal year 1967, yet when you compare the total expenditures for Apollo and Apollo Applications they are level. To combine them it is $2.99 billion in fiscal year 1966; $2.99 billion in fiscal year 1967; and $3 billion in fiscal year 1968. Is this just a coincidence?

Dr. MUELLER. In a sense it is a coincidence and in another sense, I am sure that the Bureau of the Budget in carefully looking at our activities has said to itself: Is there a level at which one can operate. I think though that it is not a coincidence in that sense. In fact, the Bureau of the Budget has allowed us an increase in the amount required in the fiscal year 1968 manned space flight R. & D. program because they felt that we do absolutely have to have this relatively slight increase. If my recollection is correct, we have actually gone up about $45 million in R. & D. in fiscal year 1968.

Mr. RUMSFELD. Combining the two?

Dr. MUELLER. In total the Bureau held back $60 million from NASA in fiscal year 1967, as part of the President's anti-inflation effort.

Mr. RUMSFELD. With the $60 million of prior years?

Dr. MUELLER. Yes. The $60 million was made available to us to cover fiscal year 1968 requirements. Literally the reason the Bureau of the Budget let us go up is that they couldn't find any way of bringing us down and still have a viable program.

Mr. RUMSFELD. If you take your NASA request of $626 million and reduce it to this figure you are recommending $454 million, we are increasing to a level of $263 million in vehicles but we have cut back in the other areas which in fiscal year 1969 would have given us the capability of possibly making greater use of that original investment from an experimental standpoint?

Dr. MUELLER. That is exactly right.

Mr. RUMSFELD. I would like to talk about the space station for a minute.

What were the specific goals that you set forth in the request to the Bureau of the Budget? What were the things that NASA hoped to gain? And to reverse that, what are we losing by not requesting, authorizing, and appropriating the $100 million for the beginning work on the space station?

SPACE STATION NEEDS AND REQUIREMENTS

The following statements summarize the potential objectives and requirements of the space station.

1. The prime justification for a manned space station rests in the potential it provides for undertaking with a single space vehicle broad-based research and

development programs in science and technology adressed to all of the space objectives of the United States as stressed in the National Space and Aeronautics Act of 1958.

2. In Earth Resources, a manned space station, with a discipline oriented staff onboard, can capitalize on the global synoptic overview to survey simultaneously many earth resources in hitherto inaccessible and undeveloped regions, and thus contribute greatly to the development of systems designed to alleviate growing world problems of production of food and consumable resources. Basic requirements are a low-altitude orbit at an inclination of from 50° to 70°.

3. In Meteorology, a manned space station with scientist/observers abroad could provide the potential for an unequaled opportunity for the observation and description of meteorological phenomena on global, regional, and local scales; for the conduct of experiments with new sensors that would hasten the development of the full-scale observational satellite system; and for exploring the capability and effectiveness of sustaining or modifying an unmanned observational satellites system. Much of the initial research and developmental effort can be conducted from an altitude of 200 miles at an orbital inclination of from 50° to 70°; however, in later phases of the program, observational opportunities in other orbits may be required to employ these potentials.

4. In Biology and Aerospace Medicine, a manned space station with trained observers and scientists affords an unexcelled opportunity to study the effect of long-term weightlessness on the physiology and human performance of man. It would provide a unique laboratory for studying basic life processes in a free gravity field which scientists believe will furnish insight into the basic laws governing life processes on earth. These programs can be conducted in a low orbit of any inclination. An onboard centrifuge capable of up to 1g is required for studying men and animals. A capability of simulating the reentry g profile is also desired.

5. In Astronomy, a manned space station affords the opportunity to make immediate contributions to our knowledge of the universe through the use of intermediate size telescopes sensing radiation throughout the electromagnetic spectrum. The experience gained from the use of these instruments, together with the capability to develop further techniques and procedures onboard a manned space station in low orbit, will lead to the ultimate very large instruments which are probably best located in synchronous or higher orbit.

6. For Orbital Operations and Advanced Technology, a manned space station would provide the needed laboratory for developing the enormous variety of skills, techniques, procedures, training, subsystems, and equipment required for efficient utilization of man and systems in space.

7. A manned space station affords an opportunity to make immediate contribution to qualifying man and systems for long-duration missions such as the exploration of the near planets.

8. As a guide to minimum requirements, it is suggested that programs of space systems research, development, and applications of tremendous significance to the national interest can be undertaken with a manned space space station capable of operation up to 5 years, either intermittently or continuously manned, in a low orbit (200 miles) of moderate inclination (50°), operated with a small station staff (8 to 12), and supplied by space systems derived from the existing manned space vehicle inventory.

THE NEED FOR A SPACE STATION

Table 1 identifies the fields of interest associated with the basic objectives of the Space Act. The disciplines of science and technology that have been found to be especially amenable to space exploitation are also shown. Specific programs in these disciplines have formed the nucleus of the unmanned and manned space programs of NASA since 1958. The activities shown in the last column include the objectives set forth for the present study and are indicative of activities for which the presence of man can be expected to contribute significantly or which cannot be undertaken at all without man's active participation.

It is noted that if a manned space station could be operated to support activity in the disciplines of Biology, Astronomy, Orbital Operations, Long-Term Flight, Advanced Systems, Meteorology, and Earth Resources, a singular space facility capable of supporting programs addressed to all of the objectives cited in the Space Act would exist.

The usefulness of space

The fundamental ways by which operations in space differ from those conducted on or near the ground are the guideposts to the manner in which space-based operations can be utilized for scientific and technological programs aimed at harnessing space for human welfare. Four highly useful and exploitable features of extended operations in space are these:

(1) *Comprehensive overview.*—Areas of the earth which are countrywide, continent-wide, or hemispheric in scope can be viewed for purposes of observation or communication. (Earth Resources, Meteorology)

(2) *Absence of atmosphere.*—Absence of atmosphere permits astronomical and astrophysical observations with a clarity and breadth not possible from earth. (Astronomy)

(3) *Weightlessness.*—The weightlessness in space permits new insights into matter, energy, and life processes through experiments and measurements not possible in earth's gravity field. It allows erection and assemblage of large structures without constraint of deflections due to weight. (Biology, Orbital Operations and Logistics, R and D in Advanced Technology, Long-Term Flight, Meteorology)

TABLE I.—*Space act objectives*

Space Act of 1958 objectives, sec. 102(c)	Field of interest	Activity or discipline	Activity for man in space
1. Extension of human knowledge.	Science	Physics, chemistry, biology, astronomy, medicine, planetary exploration.	Biology, astronomy, long-term flight, aerospace medicine.
2. Increased efficiency of spacecraft. 3. Development of capabilities of spacecraft.	Technology	Launch vehicles, ground support, orbital operations, long-term flight systems.	Orbital operations, R. and D. in advance technology.
4. Utilization of space. 6. Information exchange.	Applications	Communications, meteorology, cartography, resources, Earth sciences.	Meteorology, Earth resources.
5. U.S. leadership. 7. International cooperation.	International relations	Pioneering programs, international programs.	All.
8. Cooperation with Government agencies.	Economics	Department of Defense, Department of Commerce, Department of the Interior, Department of Agriculture, etc.	Do.

(4) *Long flight duration.*—Flight lifetime limited principally by ingenuity in providing reliable operation equipment. (Long-Term Flight)

These features of the space environment exploited, singly or in combination, using the unique capabilities of man as an onboard investigator in a spacecraft of adequate payload capacity, offer such potential benefit in so many fields of interest as to compel an examination of the requirements for a manned space station.

The Role of a Manned Space Station

The most important advantage of man in space is found in his capability to observe and act upon unforseen phenomena and events. Research is inherently oriented to the discovery of the unknown and unanticipated and requires the active participation of a staff possessing the necessary judgment, experience, and skills. Thus, man's role in an orbiting space station is similar to his role in a research laboratory on earth.

The active participation of a laboratory staff permits experiments and tasks to be undertaken that would otherwise be impossible or are so complex that the probability of successful completion with an automatic system is low. For example, man's potential ability to erect and assemble large equipment in orbit and maintain it for long periods of time affords a flexibility and reliability that is beyond reasonable attainment for an unmanned system. The ability to conduct experiments and correlate inputs from ground-based specialists with results from many observations and sensor measurements affords an opportunity for an onboard scientific specialist to adapt experimental procedures to real time and possibly to edit and select the most appropriate data for transmission to the ground.

Clearly, a manned space station should not be planned to perform functions or execute programs that can be done better or more economically on the ground or by unmanned satellites. On the other hand, it would be proper to undertake special tasks on a manned space station that would be excessively demanding in cost, time, and manpower if undertaken by unmanned space experiments. Furthermore, unmanned satellites are constrained to perform those functions for which the technology either exists or can be developed with reasonable certainty and for which the tasks can be defined in complete detail and are not so complex or intricate that the probability of successful completion is unattractive. Nevertheless, a manned space station utilized as a research laboratory can furnish the needed insight into the kind of meaningful measurements and observations that are required before unmanned satellites can be employed to provide large amounts of data on a routine basis.

SPACE STATION REQUIREMENTS

The detailed program requirements are summarized herein in such a manner as to indicate the general scope of a space station system which would effectively accommodate the initial activities of all the programs and the greater portion of all the long-term activities.

Performance Requirements.

Orientation, stabilization, and gravity are the most significant program requirements related to space station performnace. The requirements for each of these factors are sumarized in table II.

TABLE II.—*Space station program requirements*

Program	Instrument orientation	Instrument stabilization accuracy, degree	Gravity
Astronomy	Inertial	0.001	No instrument rotation.
Earth resources	Earth	0.05	Do.
Meteorology	do	0.05	Do.
Biology	Independent	Independent	10–5 and centrifuge.
Long-term flight	do	do	Nominal zero and centrifuge.
Research and development.	Inertial and earth	0.1	Nominal zero.
Orbital operations	Independent	Independent	Do.

Orientation and stabilization

Programs involving the use of optical and/or photographic instrumentation equipment dictate the orientation and stabilization accuracy requirements. For astronomy, inertial orientation is required and obviously the need is to look in the direction of space. Meteorology and earth resources programs obviously need to look at the earth and require continuous geocentric orientation. These requirements then are conflicting in both direction and stabilization modes, and on a single space station require that the astronomy programs be conducted sequentially with the earth observation programs when the astronomy instrumentation is operated attached to the station. During many portions of the astronomy program, it is desired to operate the instrumentation remote from the station, and under these circumstances the programs could be conducted simultaneously.

The stabilization accuracies required for the optical and photographic instrumentation most likely cannot be satisfied by the space station primary stabilization and control system. It is anticipated that the station system will achieve at least 0.5° stabilization and may achieve 0.1° stabilization. Separate stable platforms and/or gimbal mounts will be required for most of the program instrumentation. Those programs which are basically independent of station orientation or stabilization accuracy do require nominal zero gravity and this dictates the need for a high-quality space station stabilization system to minimize periodic and transient motions and angular rates.

Gravity

In discussions between the requirements committee and the design teams, it became evident that the most difficult problem to resolve is the matter of artificial gravity. If artificial gravity is made a firm requirement its implementation can have a very large impact on space station design. Zero gravity is a mandatory requirement for major portions of the experiment programs. There is however, apprehension in some quarters that personnel will not be able to carry out certain tasks satisfactorily in a zero-g environment. On the other hand, provision of artificial gravity by rotating the station complicates the experiment and station design tremendously and introduces other apprehensions about the capability of people to carry out tasks in a rotating station. The following comments on these problems are therefore offered.

Rotation of the space station cabin presents a serious problem in the execution of most experiments in all the areas studied. In astronomy, the need for accurate pointing of telescopes without disturbance from the station obviously calls for a support system that is as motionless as can be obtained. Photography and accurate pointing of sensors needed in meteorology and earth resources can be accomplished simpler and more reliably from a stationary platform than from a rotating one. Most orbital operations could be accomplished only with difficulty from a rotating station and all advanced technology experiments not directed toward the study of the effect of gravity are generally best accomplished in a nonrotating situation. Similarly, in long-term flight, most of the program is best suited to nonrotation and that portion of the program which requires a centrifuge is directed toward the effects of gravity (primarily biomedical effects). Plant biology is constrained to a gravity level less than 10^{-5} gravity units.

Even though the experiments and their apparatus are most suited to zero gravity, there still remains the question whether man can, in zero gravity, accomplish the experimental program conveniently. This problem is more than a question of man's health. It relates to his awkwardness in doing tasks that are quite simple in a normal earth environment but are complicated by the lack of a gravity force to keep things in proper place. Experience in the Gemini program tends to be a little discouraging in this respect. It must be realized, however, that we are still in the early stages of developing competence in operations at zero gravity and, furthermore, the Gemini cabin is so small that it provides a relatively cramped space for two people. With the development of suitable aids and provision of more commodious cabins, the defficulties in working in a zero-gravity field could certainly be alleviated. An argument has been advanced by some groups concerned with the operational feasibility of a space station that artificial gravity should be provided in any event for crew convenience. The validity of this argument can probably be determined from experiments in space addressed to this issue. In any event, whether this convenience is furnished or not, the space station crew must learn to operate in a zero-gravity environment in order to carry out most of the crew tasks associated with the research and development programs.

If the artificial gravity were obtained by rotation of the space station cabin with the rotating radius very large so that the angular velocity would be very low then the experimental program might be less severely affected. A radius of rotation of thousands of feet would be needed to get the greatest advantage of this approach and, of course, the practicality of providing it remains to be established.

More conventional schemes for rotating the cabin usually have a radius of rotation of the order of 50 to 100 feet. They offer the capability of living continuously in an artificial gravity field, but Coriolis effects and gravity gradients are expected to be problems for personnel in this type of environment. Naturally, the programs that cannot tolerate station rotation would have to be carried out in a nonrotating part of the station or in a nonrotating module separated from the station unless rotation of the station were stopped for the duration of such experiments.

Mission requirements

Orbit attitude and inclination and mission duration are the key factors considered as space station mission requirements. Table III shows a summary of the altitude and inclination requirements.

TABLE III.—*Space station mission requirements*

Program	Initial activity		Long-range activity	
	Altitude, nautical miles	Inclination, degree	Altitude, nautical miles	Inclination, degree
Astronomy	200–260	(1)	20,000	<60
Earth resources	125–200	50–70	125–200	(2)
Meteorology	200	50–70	20,000	0
			750–1500	(2)
Biology	(1)	(1)	(1)	(1)
Long-term flight	(1)	(1)	(1)	(1)
Research and Development	(1)	(1)	(1)	(1)
Orbital operations	(1)	(1)	(1)	(1)

1 Independent.
2 Near polar.

Programs other than astronomy, earth resources, and meteorology are independent of either orbit altitude or inclination and any convenient orbit will satisfy their needs. Biomedical experiments within the long-term flight program require a minimum flight duration of 2 years in zero gravity. This requirement represents the maximum duration experiment identified; however, it is highly desirable to operate the space station in orbit for about 5 years. During the 5 years it is not ncessarily required that the space station be continuously manned should unforeseen circumstances warrant a period of inactivity.

There is no requirement for altitudes much above about 200 nautical miles to accomplish the initial activity within most of the astronomy, earth resources, or meteorology programs. An answer to the question of what altitude must be a compromise between minimum orbit-keeping propulsive disturbance, desired optical resolution, desired range of view of the earth's surface, the radiation hazards, and light scattering effects in the astronomy program. An altitude of about 200 nautical miles is a reasonable compromise altitude for each program.

The earth observation and meteorology programs are most dependent on orbit inclination. Within the earth resources program there are significant reasons for having an overview of all the populated regions of the earth. An inclination of about 70° would provide such coverage. It is recognized, however, that such a high inclination for the first permanent-type space station is undesirable for many reasons and may even be impractical for early achievement. Therefore, a lower limit of 50° inclination has been established because an orbit nearer that inclination is realized to be more practical.

TABLE IV.—*Spacc station staff requirements*

Program area	Basic skills						Specialist skills								
	Electronics technician	Photographer/optical technician	Electrical/mechanical technician	Electronics engineer	Mechanical engineer	Medical doctor	Agriculturist	Astronomer	Biologist	Chemical engineer	Geologist	Medical technician	Meteorologist	Oceanographer	Physicist/physical scientist
Astronomy	X	X	----	X	----	----	----	X	----	----	----	----	----	----	----
Earth resources	X	X	----	----	----	----	X	----	----	----	X	----	----	X	----
Meteorology	X	X	----	----	----	----	----	----	----	----	----	----	X	----	----
Biology	----	----	----	----	----	----	----	----	X	----	----	----	----	----	----
Long-term flight	----	----	X	X	X	X	----	----	----	X	----	X	----	----	----
Research and development	X	----	X	X	X	----	----	----	----	----	----	----	----	----	X
Orbital operations	X	X	X	----	----	----	----	----	----	----	----	----	----	----	----

Moreover, the gamma-ray and X-ray portions of the astronomy program probably require the lower inclination. Any inclination less than 50°, however, would seriously compromise effective accomplishment of the earth resources program. The continental United States must be utilized to provide the calibration sources necessary to the program and, furthermore, it is highly desirable that the immediate information gained be most useful to the United States.

Within the meteorology program, it is, of course, desirable to see all of the earth's atmosphere. Much the same reasoning as was applied to the earth resources program must be applied to the meteorology program, however, and therefore an inclination range of 50° to 70° is indicated. There is a general consensus, fortunately, that considerable and meaningful portions of the meteorology program can be accomplished in that inclination range. Lesser inclinations would materially depreciate the value of the program.

The long-range activity envisioned within the astronomy and meteorology programs requires synchronous altitude orbits. However, it does not seem wise at this stage of development in manned space flight to consider long durations for man at synchronous altitudes. The benefits of low-altitude manned space flight should be realized before planning long-term synchronous orbits. Additionally, it is reasonable to expect that more sophisticated unmanned satellites will accrue from the space station activity and these satellites may satisfy a portion of the needs of meteorology at the very high altitudes. The needs for observations in the range of 750 to 1500 miles at sun-synchronous near-polar orbits may also be best served by unmanned satellites. The long-range activity within the earth resources program requires near-polar orbit for total earth observation. This requirement may ultimately be more closely related to the collection of operational data than to research and development activity and may be best satisfied by unmanned satellites once the research activity has been conducted aboard the low-altitude moderate-inclination space station.

It can be concluded therefore that an orbit altitude of 200 nautical miles and 50° to 70° inclination will satisfy most of the initial activities in each program area and will also satisfy a significant portion of all the long-term activities. The long-range astronomy and meteorlgy programs require much higher orbit altitude.

Space station staff skill requirements

The space station staff primary skills required to accomplish all of the programs are summarized in figure 9. Those six skills for which there is the greatest demand are indicated to be basic skills and may be required on a continuous basis. It is recognized that these are also the basic skills required to operate the space station. The remaining skills mostly represent scientific specialties which are not necessarily required on a continuous basis and may be phased or shared in accordance with program scheduling and demand.

Dr. Mueller. We have carried out during the course of the last year a rather comprehensive study of both the benefits to be derived from a space station and the characteristics that a space station might have.

I am sure that we can put a summary of that in the record if you would like. The principal things that the space station was going to provide for us and will not be provided as an early a time is a capability for extended stay time in orbit about the Earth, it would have developed the ability to carry out extensive observations on the Earth itself, in terms of at an earlier time having a thorough Earth resources evaluation capability, it would have provided us with the ability to carry out manned meteorological observations for extended periods of time, and it would have permitted us to provide a base for astronomical observations.

Now, essentially, the elimination of this has delayed by at least 1 year the availability of this capability.

Mr. Rumsfeld. Is there anything besides dollars that is causing a problem as far as the $100 million turndown on the beginning work of the space station? Is there any conflict, discussion, negotiation, or difficulty with the Department of Defense as to this particular activity?

Dr. MUELLER. No; we never had a problem in this area. That is an area where we are working with the Department of Defense to try to find a joint program. I would like to say one further word and that is in all honesty, we are, of course, trying to make the workshop do some of the things that we have planned on doing with the space station.

Mr. TEAGUE. Will the gentleman yield?

Mr. RUMSFELD. Yes.

Mr. TEAGUE. Is it not true, Dr. Mueller, that many of the experiments on this are for the benefit of defense, for their Manned Orbiting Laboratory that comes around in 1971?

Dr. MUELLER. That is correct.

Mr. TEAGUE. There are some definite agreements that the Defense Department wants in this program.

Mr. RUMSFELD. I know that. What program? The $100 million for the beginning of the space station?

Mr. TEAGUE. Yes.

Mr. RUMSFELD. They want NASA to do this?

Mr. TEAGUE. Yes.

Dr. MUELLER. They are asking us to do experiments in our workshop in support of their Manned Orbiting Lab.

Mr. RUMSFELD. I am confused by the chairman's answer. Are you saying that the Department of Defense went before the Bureau of the Budget and urged that they not cut out that money?

Dr. MUELLER. No, they asked NASA to do these experiments before they fly their Manned Orbiting Laboratory.

Mr. RUMSFELD. Which ones? The ones they are going to do or the ones they are not going to be able to do because of the cut?

Mr. DADDARIO. Would the space station—if that had been authorized this year and if that had been supported—would it include Defense Department experiments?

Dr. MUELLER. Yes, it would have, because we have a good working relation with the Department of Defense in developing experiments and I do anticipate that we will be working with the Department of Defense in this area of the space station's development.

Mr. TEAGUE. Mr. Rumsfeld?

Mr. RUMSFELD. I am through for the moment.

Mr. FULTON. The question on the $454.7 million in the fiscal 1968 figure, is that a tight figure? Is there any backup at all? If so, how much, in that figure?

Dr. MUELLER. Is there any backup? I don't know quite how to answer that, Mr. Fulton.

Mr. FULTON. Put it in the record.

Dr. MUELLER. I don't know how to answer it.

Mr. FULTON. Have you made the figure on the basis that 100 percent of the experiments will be correct and performed the first time? In Mercury, Gemini, and Apollo, we had a backup on everything.

In this figure on Apollo Applications, is there backup and if so, how much? A statement in the record will be fine, thank you, sir.

The 454.7 million dollars request is a tight figure. We proposed 626 million dollars to the Bureau of the Budget for Apollo Applications in FY 1968. The Bureau of the Budget stated they could not suppport that level of funding and requested NASA to reduce the Apollo Applications funding to an absolute minimum. The 454.7 million dollars figure is the NASA response to the BuBud request. This request contains no contingency funding. There are no back-up experiments planned with this level of funding. In terms of reliability and safety, however, these are back-up reflected in redundant systems on board the space vehicles similar to Apollo.

Dr. MUELLER. Thank you.

Mr. DADDARIO. As we proceed along this line of the discussion, I am looking ahead to some of the problems we have and I wonder where is it that the NERVA II proposal came up? Why was it not included in your original proposals? Was it because you just have not put your thoughts together or was it because you came upon it at a later date and it was not something you really wanted?

Dr. MUELLER. The President, as you know, has had to be very careful in the process of putting together the budget because of the real pressures that are involved in the Vietnam and other areas of the Government on the total resources of the Nation. The President included the NERVA II in the contingency portion of the budget message. Therefore funding for it was accounted for in his budget. It is my understanding that it was included this way to provide further time for consideration.

We had recommended the NERVA II very strongly in our initial presentation to the Bureau of the Budget and very consistently recommended it throughout the budget process.

Mr. DADDARIO. When you recommended NERVA II to the Bureau of the Budget, it was eliminated?

Dr. MUELLER. No. It was treated within the total President's budget as a case requiring special consideration.

Mr. DADDARIO. At that time?

Dr. MUELLER. That is correct.

Mr. DADDARIO. Was it in this same amount?

Dr. MUELLER. That is correct.

Mr. DADDARIO. Then at that stage of the game, taking everything into consideration, the Bureau of the Budget obviously felt and apparently it was supported by your arguments as well, that the Apollo Applications was a more important program at that time and place in consideration of the economics involved than was the NERVA II?

Dr. MUELLER. I believe the discussion centered around the fact that the Apollo Applications is really a continuation of an ongoing program and the NERVA II development is an extension of the present technology program leading to flight hardware in the 1975–77 time period. In one sense NERVA II is dependent upon a continuing space program. If you don't have a program aimed at continued flight of large payloads, there isn't really a need or requirement for the NERVA II development at as early a date.

Mr. DADDARIO. It seems curious to me taking the whole space program into consideration, would it not be better to use that additional part of the money which is some $90 million for a space station?

What suddenly caused the high priority or a higher priority for NERVA II versus the space station which seems to have some security implications involved?

Dr. MUELLER. Well, I can't answer that question. I can only offer my own opinion in this area, and that is that if we are to have a viable long-term space program, then we do need, as a nation, to continue examining alternative methods of propulsion.

One of the most—in fact, we have not really been pursuing new areas of technology in the past several years as vigorously as desirable because of the constraints of our budget. I think it is most important from our long-running posture to have more new developments, new technology under development in the years ahead and NERVA has such a long leadtime that there is always a tendency to put it off.

It has been put off for 2 successive years and one cannot put these things off indefinitely. One must proceed or else the basic technology will not be used in a timely fashion.

Mr. DADDARIO. I would agree with that and I would agree wholeheartedly with the importance of having nuclear power developments in our program and I wish we would have had it sooner than later. But the fact remains that there does come a time when you make a choice.

The choices in the Apollo Applications pained all of us in this committee because we had felt last year that there should have been greater support.

This is really an observation. I wonder if this is the same logic which has inclined you to establishing priorities in the past? It seems to me, and I may be wrong about that, that at this stage NERVA has jumped over something which a year ago you felt was more important, that is just an observation, Mr. Chairman.

Mr. FULTON. Mr. Chairman?

Mr. TEAGUE. Mr. Fulton.

Mr. FULTON. There is no doubt that maneuverability in space is dependent upon the ability to have space fuels which are first easily boosted, secondly, are space storable, and thirdly, available for extended times in space.

If there is anything in space that requires defense, then of course a high-energy fuel, either chemical, liquid, or a nuclear fuel, is vital to any operations, so if we are talking security, there is just as much security for a high-energy fuel as an element as there is for a space station and to me it means more.

In conclusion, unless we are going to go into a series of programs that are expensive, bulky, and have minimum payloads because of the necessity of putting second and third stages of liquid fuel into orbit, we are going to have to advance on a long leadtime to first reduce expense, and secondly, to increase geometrically the payload because of the less weight and the probable less cubic content for the nuclear fuels.

Likewise, when we move into the nuclear fuels, we get away from the tremendous amount of insulation load that we have between hydrogen and oxygen combinations.

For example, hydrogen boils at 123° below zero and the same temperature in space is going to run 200° to 220° below zero, so we have to have the insulation there anyhow and we couldn't afford to hang a coffeepot on the safety valve in space if the hydrogen is boiling.

I have for many years been urging that we get high energy, space-storable fuels that are operable in space and secondly have been pushing for the nuclear fuel development and may I say on that that the nuclear fuel development under NERVA II is simply an extension of the program of NASA and Atomic Energy in this field. That brings up the question, what do we do, break up the scientific teams and postpone it for 2 to 5 years or do we take advantage of the know-how which may be less expensive by continuing these programs?

Finally, and this is where I disagreed with NASA, I do believe we need the emphasis on the large, first-stage boosters of solid fuels so if I have any criticism of the fuel program, it has been that we aren't pushing that field as well as the nuclear.

That is all.

Dr. MUELLER. I do agree, Mr. Fulton and Mr. Daddario, on the need for and desirability of an increased emphasis on new developments. I do believe, though, when one has a very severe budget restriction in ordering them, I can't help but feel that the priority that was attached by the Bureau of the Budget to the President was a reasonable one.

Fundamentally, if we are going to have any future Manned Space Flight program, we must implement the Apollo Applications of the program this year.

Now I said "any," but I mean "any" in the context of really utilizing the resources we have already placed in this very large program. Clearly there are alternatives available that delay the Manned Space Flight program and shift its emphasis, but it would really lose the capabilities and team that we have developed.

We must go forward with the Apollo Applications program this year in terms of new developments. I do believe the NERVA is an attractive new development. I do believe the space station is something that we inevitably are going to need to develop if we are going to continue in the future in Manned Space Flight.

Continuing with the budget, the spent, orbiting second 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 2 weeks.

Now that is just in the very early phases of the operation. The Apollo developed lunar mapping and survey system will be used to complete the cartography of the Moon.

The Command Module will be modified to carry up to six men for short duration ferry and resupply missions and will be provided a land landing capability, thereby reducing costs and increasing operating flexibility.

Specialized payloads will be developed for operation in various orbits and on the Moon, including multispectra Earth and weather sensors, biological and biomedical experiments, mobile lunar vehicles, and communications systems.

A manned solar telescope system, forerunner of long-lived orbital astronomical facilities, will be flown during the peak of solar activity.

Space vehicles: Volume V, RD 2–4 fiscal year 1968 funding requirements for space vehicles total $263.7 million, of which $167.4 million is for the first three lines (MP67–5709, fig. 21). This request provides for continued incremental funding of the follow-on Uprated Saturn I procurements initiated in fiscal years 1966 and 1967 and for the initial funding for the follow-on Saturn V vehicles and Command and Service Modules (CSM). The first follow-on Uprated Saturn I will be delivered in late 1968. The delivery of the first follow-on CSM is planned late in 1969. The first follow-on Saturn V will be delivered in mid-1970.

Mr. FUQUA. Before we leave this page on delivery by various installations, you have $228.2 million for the manned spacecraft, the largest item in the procurement of space vehicles.

What is the justification for this large amount? I can recognize that many expenditures will be necessary at the Marshall Center.

Dr. MUELLER. It is roughly half and half.

Mr. FUQUA. You have $199.6 million at the Marshall Center?

Dr. MUELLER. Mr. Lilly, would you like to answer that?

Mr. LILLY. Mr. Fuqua is reading the distribution of program amounts by centers. You don't have that break on your chart. The amount identified for the Manned Spacecraft Center AAP effort is $228.2 million; $199.6 million for Marshall; $3.3 million is for Kennedy; and $23.6 million is for NASA Headquarters.

Dr. MUELLER. Then I understand. Included in those items distributed by centers is the experiment development and the majority

MANNED SPACE FLIGHT

RESEARCH AND DEVELOPMENT

APOLLO APPLICATIONS

FY 1968 BUDGET ESTIMATES

(MILLIONS OF DOLLARS)

	FY 66	FY 67	FY 68
SPACE VEHICLES	$8.5	$38.6	$263.7
CSM PROCUREMENT	-0-	-0-	43.3
UPRATED SATURN I PROCUREMENT	1.0	24.0	78.5
SATURN V PROCUREMENT	-0-	-0-	45.6
* SPACECRAFT MODIFICATION	7.5	14.6	91.3
LAUNCH VEHICLE MODIFICATION	-0-	-0-	5.0

NASA HQ MP67-5709
1-15-67

FIGURE 21

of experiments development funding it, the majority of experimental development funding is identified to the Manned Spacecraft Center. The $228.2 million for the Manned Spacecraft Center includes both space vehicle and experiments and definition and development funding.

Mr. FUQUA. Would the space vehicle development be at the Marshall Center?

Dr. MUELLER. Partly at Marshall and partly at Manned Spacecraft Center. Practically equal.

Mr. TEAGUE. Are they funded out of Houston?

Dr. MUELLER. All spacecraft are funded out of Houston—all launch vehicles are funded out of Marshall. The experiments carried out at Houston are different.

Mr. FUQUA. The work will not be carried out per se at Houston?

Dr. MUELLER. No, sir.

The remaining requirements under space vehicles totaling $96.3 million, support the continuation of the design and development efforts, begun in fiscal years 1966 and 1967, which are required to furnish modified Apollo spacecraft systems for the planned missions. Apollo spacecraft systems, including the electrical power, life support, and environmental control systems, are currently being subjected to extensive tests to determine their ability to operate in the environments and for the durations proposed for the Apollo Applications missions. To minimize the cost of this phase of the program, the plan is to incorporate only those changes required by the planned missions.

Limited development of a Lunar Module (LM) shelter/taxi to extend lunar surface exploration time beyond that planned for the Apollo program will commence in fiscal year 1968. The LM shelter, carrying scientific exploration equipment such as a lunar mobility vehicle and drill, is intended to be landed unmanned on the lunar surface where it will remain quiescent. The manned LM taxi combination and its equipment will be used as a base for lunar exploration for periods of up to 2 weeks.

That is the next major step forward. This is the area which we delayed for a year because of the reduction in the level of funding to $454.7 million.

Fiscal year 1968 funding also includes the initiation of development of a land landing capability for the Command Module which will allow elimination of water landing as the primary recovery mode, thereby providing greater operating flexibility, allowing refurbishment and reuse of command modules, and reducing recovery and new procurement costs. The changes to the spacecraft that permit incorporation of the land landing capability will also allow the interior of the Command Module to be rearranged to accommodate up to three additional astronauts for short duration ferry and resupply missions.

Experiments and mission support: Volume V, RD 2–6 and RD 2–8. My next chart (MP67–5708, fig. 22) shows the remainder of the funding being requested for Apollo Applications—$140.7 million for Experiments and $50.3 million for Mission Support.

MANNED SPACE FLIGHT
RESEARCH AND DEVELOPMENT
APOLLO APPLICATIONS
FY 1968 BUDGET ESTIMATES
(MILLIONS OF DOLLARS)

	FY 66	FY 67	FY 68
EXPERIMENTS	$40.3	$35.6	$140.7
DEFINITION	34.4	12.0	33.7
* DEVELOPMENT	5.9	23.6	107.0
MISSION SUPPORT	$2.4	$5.8	$ 50.3
PAYLOAD INTEGRATION	.1	4.4	40.0
OPERATIONS	2.3	1.4	10.3

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FIGURE 22

Mr. Chairman, in addition to this, we will provide you with some backup information, the details and the experiments and the breakdown of cost.

Experiments: Of the experiment funding, $33.7 million is for definition and $107 million is for development. Apollo Applications experiments cover a wide range of objectives in the fields of space medicine, science, applications, technology, and engineering. The definition and development of experiment payloads to meet these objectives will include activity by elements of NASA, other Government agencies, and the scientific and industrial communities.

Effort in fiscal year 1966 and 1967 was primarily confined to definition of experiments and experiment hardware for use in the early Apollo Applications missions. Included in these efforts were studies which led to the Apollo Telescope Mount (ATM) and the spent-stage S–IVB Orbital Workshop, now under development.

The fiscal year 1968 effort will continue the development of the orbital workshop and the Apollo Telescope Mount and will define and develop other experiment payloads for follow-on Apollo Applications missions.

The Orbital Workshop permits astronauts to work and perform experiments in the empty hydrogen tank of a spent second stage of the Uprated Saturn I. A 65-inch diameter airlock and docking adapter provides the connection between the Apollo spacecraft and the spent stage. A hatch in the airlock permits the astronauts to go into space without depressurization of the workshop or the spacecraft. In orbital flight, the Command and Service Module docks with the airlock and the crew activates systems to pressurize the workshop for habitation. The experiment equipment for use in the workshop is stored elsewhere and carried into the workshop for operation.

An extensive list of experiments is planned for operation within the Orbital Workshop. Some are directed at evaluating the habitability of the workshop for long duration flight, the work capability, and mobility of astronauts in zero-g, and the effect of long duration zero-g on man. Others are directed at engineering and technology experiments which utilize the large enclosed volume of the workshop.

The Apollo Telescope Mount provide a new capability for a variety of solar and stellar scientific experiments to be performed above the Earth's atmosphere, where the Sun and stars can be clearly observed without being obscured by the Earth's atmosphere. Film can be returned from a space astronomy mission, and for the first time the role of the astronaut in astronomical observations can be evaluated. The ATM provides a stabilized platform which will be carried on Apollo Applications missions to accommodate instruments requiring finely controlled pointing. The ATM will be mounted in a structural rack attached to a Lunar Module ascent stage.

Five experiments using 13 separate instruments to obtain solar data during the period of maximum solar activity have been selected for development for the initial ATM mission. These experiments are: Intensity of solar flares; ultraviolet spectrometer; X-ray telescope; solar atmosphere photography; and white light coronagraph.

Applications experiments are planned to develop techniques for, and to measure the effectiveness of, man's participation in such fields as orbital meteorology, communications, and remote sensing of Earth resources. Low-altitude orbits at medium and high inclinations have been studies for meteorology and natural resources missions during 1969 and 1970. An initial synchronous orbit mission is planned to test man and spacecraft operation in that operational mode. Also planned is a test of operational techniques for communicating between the low-altitude manned spacecraft, synchronous spacecraft, and ground control stations. Later synchronous orbit missions are under study for continued operational use, as well as for experiments in astronomy, space physics, meteorology, and advanced communications techniques.

The extended lunar exploration missions planned for Apollo Applications include both orbital mapping missions and extended lunar surface exploration. The objective is to extend knowledge of the Moon beyond that achieved in the earlier Ranger, Surveyor, Lunar Orbiter missions, and Apollo missions, and to provide the basis for the decisions on the establishment of semipermanent or extensive research facilities or manned stations on the Moon.

The lunar orbital missions are planned to acquire high-quality mapping and survey photography from polar or near-polar lunar orbits. This will allow the detailed study of the geologic features of the total lunar surface. Lunar surface missions are planned to provide up to 2 weeks staytime at selected lunar sites for extensive geological, geo-

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physical, and biological exploration. Experiments planned for these missions include small vehicles to perform traverses at moderate distances from the landed spacecraft; drills for subsurface sampling and vertical profile measurements; and deployed instrumentation for acquiring geophysical data to be transmitted back to Earth by radio frequency link for up to a year after departure of the astronauts. One extended lunar surface mission per year is planned, beginning in 1971.

Medical experiments during 1968 and 1969 will concentrate on the biomedical effects of long duration flight on man. A biomedical laboratory is planned for flight in 1970. This laboratory will consist of an Apollo spacecraft module equipped with biomedical and behavioral apparatus to test and record human responses during long-duration space flights, to various stresses such as physical exercise, variable gravity, and the performance of complex tasks.

Bioscience and biotechnology laboratories are planned to extend earlier investigations on various life forms ranging from simple cells to primates. In these laboratories, greater stresses can be applied to specimens than are normally planned for human subjects, and the results will benefit both the bioscience community and manned space flight technology.

Mr. DADDARIO. Included in these medical experiments, you have not included any animal experiments?

Dr. MUELLER. The bioscience experiments that I referred to are on animals and they run up to primates and one of the downrange or downstream experimental sets of apparatus is an experiment on primates, using man for the carrying out of experiments.

Mr. DADDARIO. You are talking about primates in orbit for what period of time?

Dr. MUELLER. Well, at this point in time, the experiment is in a definition phase and that has not been determined.

Mr. DADDARIO. But it is definite that we will be using animals in this time period?

Dr. MUELLER. Yes. But that time period is out in 1970, so it is several years away.

Mr. DADDARIO. Thank you.

Dr. MUELLER. The technology and engineering experiments planned for Apollo Applications missions are focused generally toward the development of equipment and techniques which are fundamental to the accomplishment of the next generation of space flight missions.

During 1968 and 1969, emphasis will be placed on conducting related experiments in and with the Orbital Workshop. Resupply and crew transfer flights are planned to extend mission duration, rotate crews, and to test orbital rescue operations. Orbital assembly of complex structures and in-flight maintenance of vehicles and experiment apparatus are also planned.

The fiscal year 1968 effort will continue the development of the Apollo Telescope Mount and the Orbital Workshop and will define and develop other experiment payloads for follow-on Apollo Applications missions. These experiments have already been discussed in considerable detail.

Mission support: RD2–8 payload integration, for which $40 million of the $50.3 million requested for mission support is earmarked, includes the system analysis and development effort required to assemble experiments into mission compatible payloads, and the effort required to physically install and qualify them for flight readiness.

This activity includes definition, design and development, modification, and installation. The definition phase of payload integration was initiated during fiscal year 1966 and will be essentially completed by the end of fiscal year 1967. Design and development includes control documentation, interface qualification and acceptance test specifications, and testing plans.

Modification and installation provide for changes to space vehicles and experiment carriers to accommodate experiments and physical installations of experiments into applicable carriers. The fiscal year 1968 effort will provide for the analyses of payloads to determine detailed payload integration requirements and the implementation of design and development activities for the initial Apollo Applications flights.

Operations will require $10.3 million and include efforts at the Kennedy Space Center and the Manned Spacecraft Center that are directly concerned with launch, flight, crew, and recovery activity. Basic support is provided in the Apollo program for those missions currently scheduled as alternate Apollo Applications flights.

Fiscal year 1968 funding will also provide for intitiation of operations support for missions including the augmentation of the Mission Control Center located at the Manned Spacecraft Center required to support the increased data demands resulting from the enlarged experiment and operational activity associated with the Apollo Applications program.

That is a summary of Apollo Applications.

Could I now turn to advanced missions to briefly go through that material, volume V, RD3–1.

The advanced missions program, for which (MC 67–5540, fig. 23) we are requesting $8 million in fiscal year 1968, allows us to investigate Advanced Manned Space Flight concepts. The studies examine logical extensions of the NASA space capability through analysis of the growth potential of present hardware systems; assesses requirements for future systems; furnish guidance for research and technology activities; provide technical information and cost data upon which future program decisions can be based; and permit initiation of the definition, preliminary design, and specification of probably future missions.

By conducting these advanced studies, we build a solid base for planing and selecting future Manned Space Flight missions. Specific areas of investigation include manned Earth orbital, lunar, and planetary missions and launch vehicles. Fiscal year 1966 and 1967 studies provided support for the evolving Apollo Applications program, including the definition of experiments and other mission payloads and analysis of the cost effectiveness of alternate flight equipment aproaches. The fiscal year 1966 and 1967 studies also examined the feasibility of a long-duration space station module. In addition to considering various Earth orbital applications, the space station

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

NASA HQ MP67-5440
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FIGURE 23

study includes analysis to identify features common to manned planetary flight requirements.

In the area of Earth orbital studies, we have been analyzing a 1-year Earth orbital workshop which could evolve into a continuous-operation space station. Alternate approaches for an eventual 1-year workshop included module configurations utilizing the third-stage structure of the Saturn V; a Saturn V launched module containing all expendables for a 1-year duration; and a system based on a flexible subsystem module.

We are also defining rescue concepts and space station resupply and logistic systems; and continuing work on the selection and definition of candidate equipments. The potential economic benefits that can be derived from space station operations are also being assessed.

Based on the results of the conceptual studies, preliminary definition of a 1-year workshop module will be initiated, together with the preliminary definition of a modular spacecraft to allow us to carry out Earth resources experiments and astronomical observations. The fiscal year 1968 studies will concentrate on the definition of a versatile space station designed for Earth applications, astronomy, and biomedical research, as well as interplanetary exploration.

We are also conducting planetary mission studies, examining various mission modes and systems concepts for manned Mars and Venus reconnaissance, sample retrieval from the Martian surface and, ultimately, Mars landing space vehicle hardware for sample retrieval or reconnaissance missions, and have provided us with spacecraft concepts for manned Mars landing missions in the future.

The fiscal year 1968 study program will focus on continued definition of technology requirements and concepts for a Mars sample retrieval mission. This type of manned mission offers the unique advantage of bringing samples of the Martian surface and atmosphere back to Earth for scientific analysis. The manned spacecraft, which would also allow for scientific research and observations on the way to and returning from the planet, would be used to aim, launch, and retrieve an unmanned sample return probe.

During fiscal year 1968, the study effort will include preliminary definition of the mission spacecraft, and the associated propulsion stages, in addition to the onboard experiments that could be conducted by the crewmembers during the mission. The studies will define the total system for Mars sample retrieval in enough depth to permit definitive planning of the funding requirements, the technological development program required to support this mission, and the total program support required within NASA.

Fiscal year 1968 lunar mission studies will provide for updating the current plan for lunar exploration so that the accompanying conceptual designs can be developed. This integrated exploration plan will review the basis for a continuing series of manned and unmanned missions.

Finally, launch vehicles studies to support Earth orbital planetary and lunar missions will be continued during fiscal year 1968. These studies will stress preliminary definition of improved Saturn vehicles, analysis of reusable reentry vehicles, and determination of the facilities and support requirements.

To summarize, I have reviewed the major activities of the Manned Space Flight program. As you recall, I began by citing our general objectives in Manned Space Flight. These are the broad objectives that have motivated our efforts in specific programs. We have worked for the establishment of man's capabilities; for development of a national competence for Manned Space Flight as represented by an industrial base, trained personnel, ground facilities, launch vehicles, spacecraft, and operational experience, for the exploration of space, and for U.S. leadership in space. Now we propose we move forward and use this national capability.

Mr. RUMSFELD. Before we wind the whole thing up, I have a couple of questions on this advanced missions section, Dr. Mueller.

How much did you request for this category of advanced missions at the Bureau of the Budget?

Dr. MUELLER. $26 million in our fiscal year 1968 preview budget.

Mr. RUMSFELD. $26 million?

Dr. MUELLER. Yes.

Mr. RUMSFELD. Now $8 million is a lot of money, but when you start enumerating all those things that you hope to try to undertake under advanced missions, $8 million isn't going to go very far. Possibly you could explain the relationship between advanced missions and the category of Apollo Applications. Isn't this a study category and a planning category that feeds into Apollo Applications in some cases and in some cases in other categories?

Dr. MUELLER. That is correct. In fact, the major part of the money that we spent in the last year was in the area of supporting Apollo Applications work.

Mr. RUMSFELD. How many studies were undertaken with the $6.2 million in fiscal year 1967? How many different areas were explored and how many do you anticipate with this $8 million?

Dr. MUELLER. The average cost of a study, Mr. Rumsfeld, that is, the money spent outside of NASA, which does not include the people inside NASA that are also working on advance studies is around $200,000. Therefore, there were a number of actual studies carried out. There were some 37 studies in 1966, and we are planning some 18 in 1967.

Mr. DADDARIO. Would you like those listed for the record?

Mr. RUMSFELD. I think it would be useful.

Dr. MUELLER. I would be pleased to.

ADVANCED MANNED MISSIONS STUDIES FOR FISCAL YEARS 1966, 1967, AND 1968

The FY 66–67–68 studies in the Advanced Manned Missions program are a progressive set of phased studies directed at providing in-depth technical and fiscal data required for major program decisions that are anticipated in connection with the FY 69 and 70 budget submissions.

FISCAL YEAR 1966

The 37 FY 66 studies were aimed at defining later flights in the Apollo Applications program, the requirements for an earth orbiting space station, a preliminary investigation of manned planetary missions, and studies of launch vehicle improvements.

Seventeen studies primarily cover activities in earth orbit and the definition of experiments in earth orbit. These include studies on satellite recovery, refurbishable spacecraft, artificial gravity, extravehicular activity, orbital astronomy support facilities, subsystem definition, spent stage utilization, space stations and observatories, emergency and rescue concepts, and economic benefits.

In the lunar area six studies cover experiment activities on the lunar surface and advanced concepts for delivery to the lunar surface.

Seven manned planetary studies cover electric propulsion, mission modes, and the use of Saturn/Apollo systems and their modifications.

Seven vehicle studies cover possible Saturn upgratings and facility requirements, large solid rocket motors, and advanced logistics systems.

FISCAL YEAR 1967

The FY 67 program totals 18 studies in the four areas of earth orbital missions, lunar exploration, planetary reconnaissance, and vehicle systems.

Six studies in the earth orbit area include the preliminary definition of a long duration space station, definition and integration of space station experiment modules for conducting experiments in astronomy, biosciences, and earth resources, and for studies of earth orbit emergencies, reentry and rescue systems.

Two lunar mission studies continue the effort in defining the objectives for continued lunar missions and includes studies on integrating lunar orbit missions with work stations on the lunar surface.

In the planetary area six studies of reconnaissance flights to Mars and Venus cover alternative mission modes, mission integration, contingency planning, spacecraft and several modules and probes for landing, orbiting, experiments, and sample return.

Four studies in the vehicle area encompass facilities and operational concepts for future programs, facilities and equipment for improved launch control, logistic systems for earth orbital missions, and orbital launch vehicles systems and operations for planetary missions. The studies of launch vehicles are directed toward a single set of vehicles that will accommodate requirements for the earth orbital, lunar, and planetary missions.

FISCAL YEAR 1968

Based on the results of the FY 66 and some of the FY 67 studies, planned FY 68 studies will continue the earlier studies emphasizing selected areas such as identifying common systems in the various spacecraft modules and with a view to reducing the number of distinct modules required for earth orbital, lunar, and planetary missions.

A better definition of the long duration earth orbital space station will continue to investigate the implications of artificial gravity requirements as well as to determine the feasibility of adaptation to planetary modules. Similarily, the designs of the experiment modules will be investigated for their applicability for planetary missions.

Planetary studies will continue to identify design requirements for the reconnaissance flights to assure maximum carry over to later manned planetary landings.

Studies in the lunar area include the preliminary definition and predesign of a direct flight lunar logistic vehicle identified in a FY 66 study. Additional studies will continue the investigation of lunar experiments for both fixed stations and long distance lunar traverses.

The vehicle studies will continue to determine in more detail the characteristics of the most desirable systems to support the areas of earth orbital, lunar, and planetary missions.

Mr. RUMSFELD. This category of advanced missions was cut down to less than a third of what you requested. Was there any other category that was cut down to less than a third?

Dr. MUELLER. Well, the space station was cut——

Mr. RUMSFELD. One hundred percent?

Dr. MUELLER. Yes; 100 percent and to some extent these tie together. We are delaying the work that could be done on a space program for at least a year. The advanced mission studies lay the foundation for the future course of our activities. When we cut those back, we essentially cut back our ability to determine the course of action that would be most economical and most effective in the future.

Mr. RUMSFELD. That is what my view is. It seems to me that it is rather foolish to pare down advanced missions to less than a third of what NASA thought would be reasonable when this does, in fact, lay the groundwork for making intelligent decisions as we proceed through the future months and years.

Let me put it this way. Why did NASA accept this?

Dr. MUELLER. Well, again, it goes back to the need to balance the total program. I think that what this represents is a decision on the part of the President and the Bureau of the Budget to go forward with an aggressive space program, but by no means to go forward with the most aggressive space program that we could undertake.

It represents a conscious decision to——

Mr. RUMSFELD. Isn't it true that these studies help you decide what should be undertaken?

Dr. MUELLER. Yes, sir.

Mr. RUMSFELD. By revising that to less than a third, aren't you cutting off your options for the coming months and years? Aren't you reducing the input that is going to be available to make intelligent decisions next year and the year after?

Dr. MUELLER. That is precisely the difficulty that one encounters. I do believe, though, that the funds here will support the program well enough, I think we will get the definition of those essential elements that will permit us to make the correct decision concerning the program that we have adopted. It does not provide us with the basic knowledge and facts we would need for an aggressive space station program. It does not provide us with the basic background and basic facts we would need to make a reasonable decision on a lunar base. It does not provide us with the background nor the studies that are needed in order to form a basis for a manned planetary exploration.

Mr. RUMSFELD. It doesn't provide you with the money you need to make intelligent decisions across the board as to where the space program should go in the coming years?

Dr. MUELLER. Essentially it provides us with the money we need to make intelligent decisions on the programs we have already decided on.

Mr. RUMSFELD. It strikes me that that is a rather poor place to be saving money. I will be happy to look at the list that will be submitted for the record of the studies undertaken in 1967 and those anticipated in 1968.

Mr. DADDARIO. There isn't much you can do about it if you go to the Bureau of the Budget and they cut it out. You have to decide on what they give you. I disagree with it.

Mr. RUMSFELD. I don't mean to leave the implication that I am criticizing Dr. Mueller.

Mr. DADDARIO. I know you are not. I agree with you. The arguments indicate that they put up a good fight for additional funds.

Dr. MUELLER. I must say that I agree with Mr. Rumsfeld and Mr. Daddario and on the other hand, being faced with a limitation on funds, I do believe this is the best balance that we can achieve.

Mr. DADDARIO. You are an executive agency, Dr. Mueller. I don't know how you can take any other position.

Dr. MUELLER. In this presentation in support of our budget request for fiscal 1968, we are asking that you approve the continuation of our efforts toward these national objectives.

Mr. DADDARIO. Any questions, gentlemen?

Dr. Mueller, I want to thank you for your statement today and your completely candid positions in answering our questions. We recognize, of course, the difficulties you have. These are things it is our responsibility to add or subtract from. We are looking forward to a continuation of these hearings which will begin tomorrow morning at 10 o'clock at the same time.

This meeting is now adjourned until then.

(Whereupon, at 12 noon, the subcommittee was adjourned to reconvene at 10 a.m., Tuesday, March 21, 1967.)

1968 NASA AUTHORIZATION

TUESDAY, MARCH 21, 1967

House of Representatives,
Committee on Science and Astronautics,
Subcommittee on Manned Space Flight,
Washington, D.C.

The subcommittee met, pursuant to adjournment, 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.

We will begin this morning on the construction of facilities and administrative operations.

Mr. Gurney, do you have any questions on what we covered yesterday?

Mr. Gurney. No.

Mr. Teague. Proceed, Dr. Mueller.

STATEMENT OF DR. GEORGE E. MUELLER, ASSOCIATE ADMINISTRATOR FOR MANNED SPACE FLIGHT, NASA; ACCOMPANIED BY WILLIAM E. LILLY, DIRECTOR, MANNED SPACE FLIGHT PROGRAM CONTROL, NASA

Dr. Mueller. Turning to facilities, at this time, Mr. Chairman, I would like to cover the status of our facilities, reviewing progress of the past year and our plans for the future.

Over the last 6 years an orderly buildup of these facilities has resulted in an investment totaling approximately $2.5 billion. The basic plant is now available to support a manned lunar landing, with sufficient built-in capability to accommodate follow-on programs at minimal cost. Most test and launch facilities, particularly those located at the Kennedy Space Center, Mississippi Test Facility and Manned Spacecraft Center are now operational.

This year the total request for facilities in support of manned space flight activities consists of nine projects totaling $27.9 million. During my discussion, I will review this year's request for each MSF Center and location, beginning with Kennedy Space Center.

The Kennedy Space Center is the site of major launch facilities for both manned and unmanned space flight. As of June 30, 1966, the investment at this location aggregated $808,549,000. By far the largest item is launch complex 39 (fig. 1, MC67–5745), where all three stages of the Saturn V launch vehicle will be assembled and mated with the Apollo spacecraft, undergo both individual and integrated checkout, and then proceed to one of the two pads (fig. 2, MC67–5742) for launch into space. The vehicle assembly building, which is 525 feet high, has a volume of 129.5 million cubic feet (fig. 3, MC67–5746). The structure will be fully outfitted and operational in three of the four high bays. In addition, two crawler transporters, three launch umbilical towers, one mobile service structure, and three fully instrumented firing rooms will make up the operational complex.

Mr. FULTON. Before you leave the vertical assembly building, I was down there about 3 or 4 weeks ago and it seems to me that you ought to have some arrangement for visitors. They took us clear up in an elevator and we looked over a rail which had no screen and we only had the rail to hold you. I think we ought to have a glass enclosure so you could take visitors where they can see the building. My suggestion is that there should be better visitor facilities.

Dr. MUELLER. Thank you, Mr. Fulton; we will look into that.

Mr. FULTON. They did a good job in showing us around. I mean for the general public. It ought to be set up particularly for visitors.

Dr. MUELLER. It isn't really set up for visitors at the upper levels at this point in time. We didn't plan to use it for the regular visitor tour. It would be most impressive but it adds to the cost and increases our problem of handling the people.

Mr. FULTON. I think there should be something for visitors and it should be separated from the workmen.

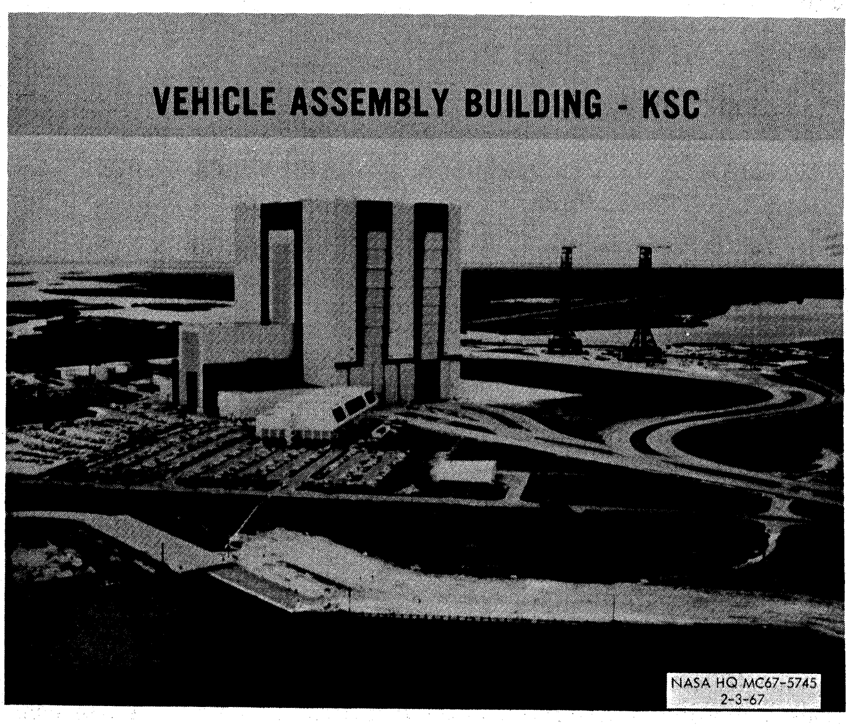

FIGURE 1

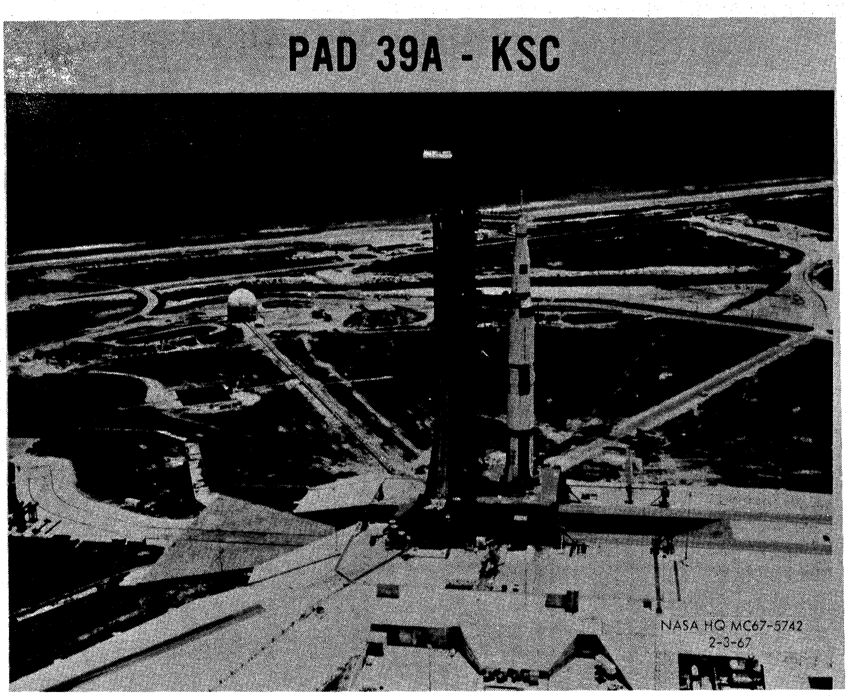

FIGURE 2

Dr. MUELLER. Incidentally, the VAB is going to be the largest volume building in the world for a relatively short period of time. Boeing Co. in Seattle is building a larger building than this one for the production of their 747.

Mr. FULTON. I understand the Boeing building in Seattle is the kind of building that the Government would build if it were rich. [Laughter.]

Dr. MUELLER. Last year saw the completion of construction and outfitting of high bay No. 3 and firing room No. 2 and the basic construction of launch area B (fig. 4, MC67-5743). During the coming year plans call for the second high bay launch umbilical tower No. 2, and pad B to become operational. This coming year will also see the completion of a visitors information center, a critically needed addition to the KSC headquarters building and an addition to the flight crew training building to house urgently needed additional simulators.

Two additional launch complexes at the Kennedy Space Center which play a major role in the Apollo/Saturn program are launch complexes 34 and 37 (fig. 5, MC67-5747). Both are now operational. Launch complex 34 already has undergone a major modification to launch the first uprated Saturn I flights, and will be used for the first manned Apollo/Saturn flight. Launch complex 37 also has undergone a modification for the uprated Saturn I vehicle. These complexes will continue to be modified in order to meet the needs of future programs.

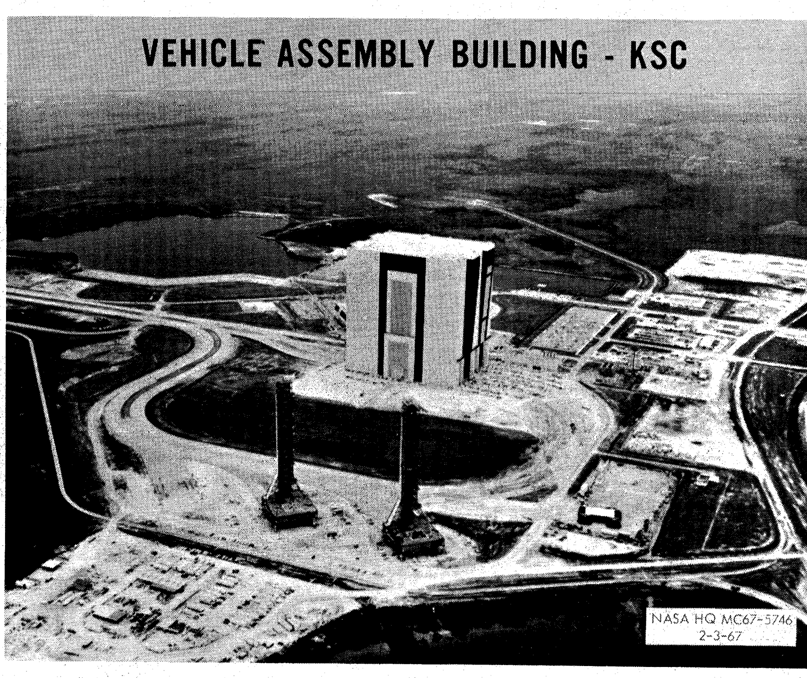

FIGURE 3

PAD 39B - KSC

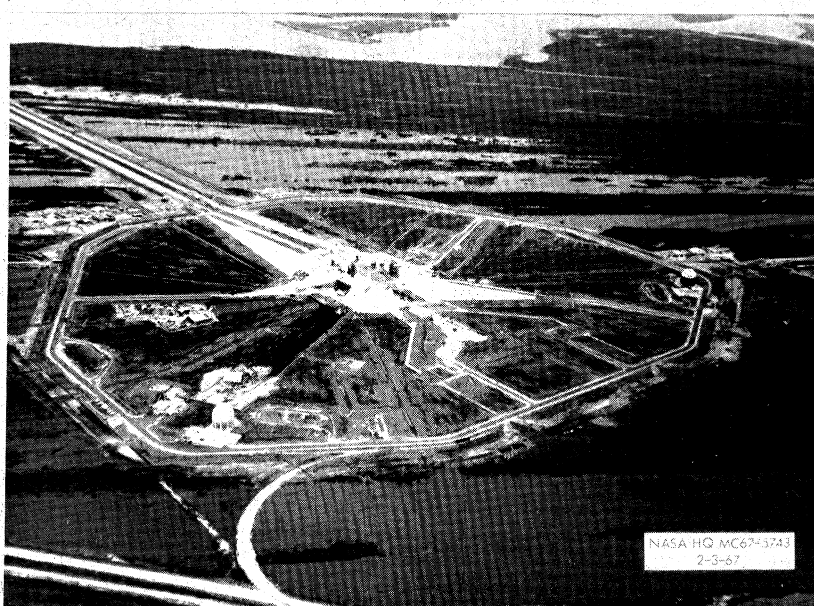

FIGURE 4

The launch complexes cannot function without supporting facilities for communications, data processing, testing of components, maintenance of facilities and hardware, and accommodations for engineers and administrative personnel. One of these is the central instrumentation facility (fig. 6, MC67-5749). Its major instrumentation elements act as processing stations for Kennedy Space Center wide telemetry, flight TV, prototype tracking data; facilities for computing and data reduction; and systems for data storage, presentation, and distribution.

Another key support facility is the operations and checkout building (fig. 7, MC67-5748). This facility is used for assembly and checkout of all manned spacecraft and provides for crew training and preflight operations.

The KSC headquarters building presently provides administrative space for about 1,890 personnel, with an addition currently underway which will house an additional 988 personnel. Maintenance facilities, shops, and warehouses as well as numerous laboratories and checkout facilities round out the support required for launch operations which will adequately support both current and presently contemplated future operations (fig. 8, MC67-5750).

The request for fiscal year 1968 includes a requirement for funds to complete outfitting of launch complex 39 and to provide for modifications required by changes in hardware. Also included is a request for funds to rehabilitate major elements of complexes 34 and 37 and,

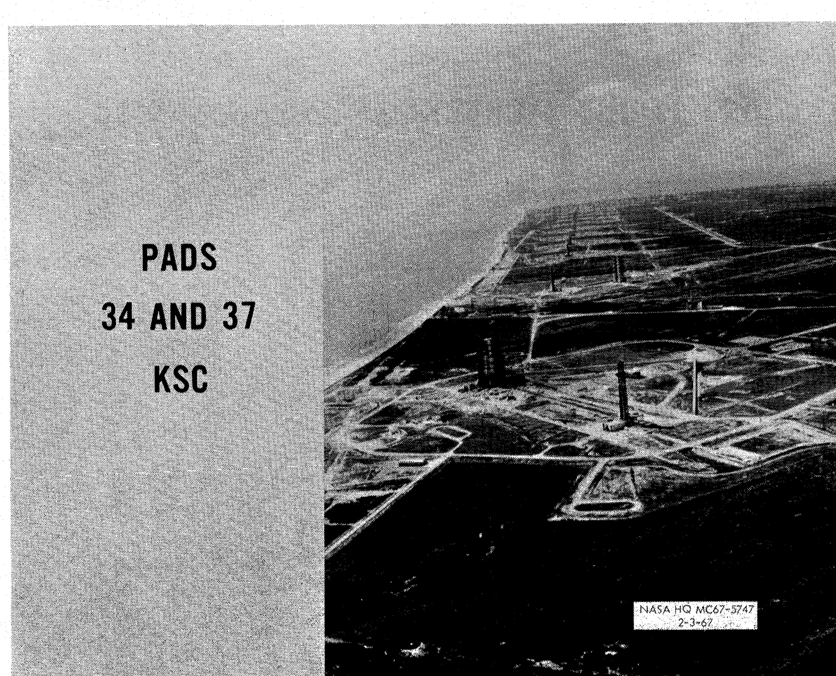

FIGURE 5

CENTRAL INSTRUMENTATION FACILITY - KSC

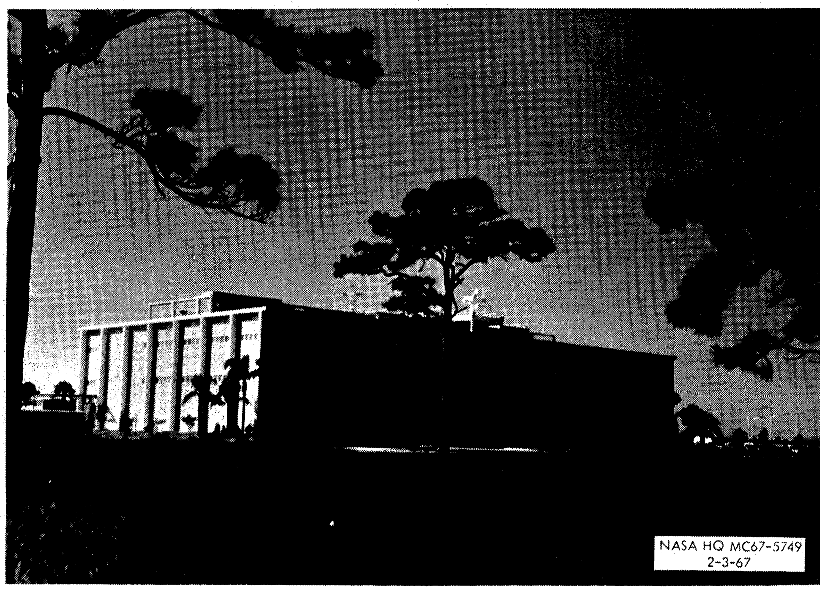

FIGURE 6

OPERATIONS & CHECKOUT BUILDING - KSC

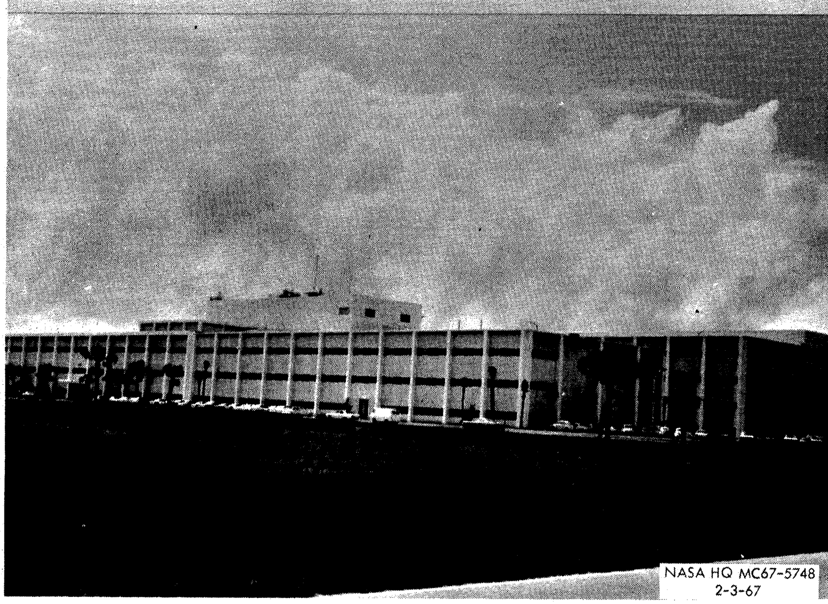

FIGURE 7

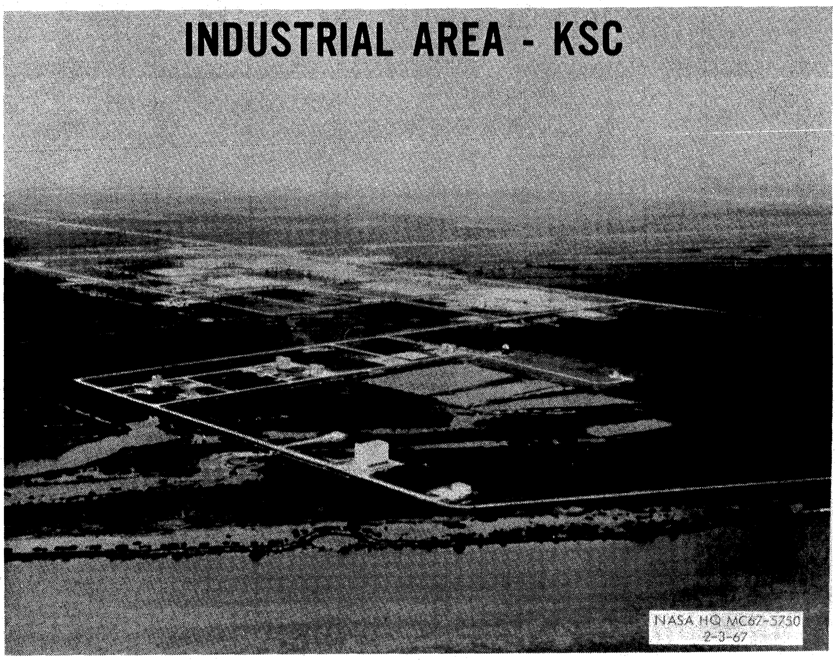

FIGURE 8

finally, a small extension of the Merritt Island industrial area high temperature hot water distribution which will provide increased reliability to the environmental control systems in key facilities located in this area.

The responsibility for the development of spacecraft for manned space flight programs and the conduct of manned flight operations, including astronaut training, is concentrated at the Manned Spacecraft Center, Houston, Tex. (fig. 9, MC67–5727). Since construction was started in 1962, the facilities investment has grown to $294,709,000 as of June 30, 1966.

The center is the site of the largest man-rated space environment chamber with solar simulation in this country (fig. 10, MC67–5756). This chamber can simulate an altitude of about 80 miles, and subject Apollo or larger spacecraft to the complete spectrum of environmental conditions which can be expected during a lunar mission. A large anechoic chamber is ideal for testing Apollo spacecraft communications (fig. 11, MC67–5754). These and other scientific laboratories provide a basic developmental capability contributing to both present and future missions.

The Mission Control Center at Houston became completely operational in 1965 (fig. 12, MC67–5771). This sophisticated facility makes available immediate tracking and telementry data as received from the ground network. It houses a large computer complex which can provide preplanned alternative courses of action for use in the

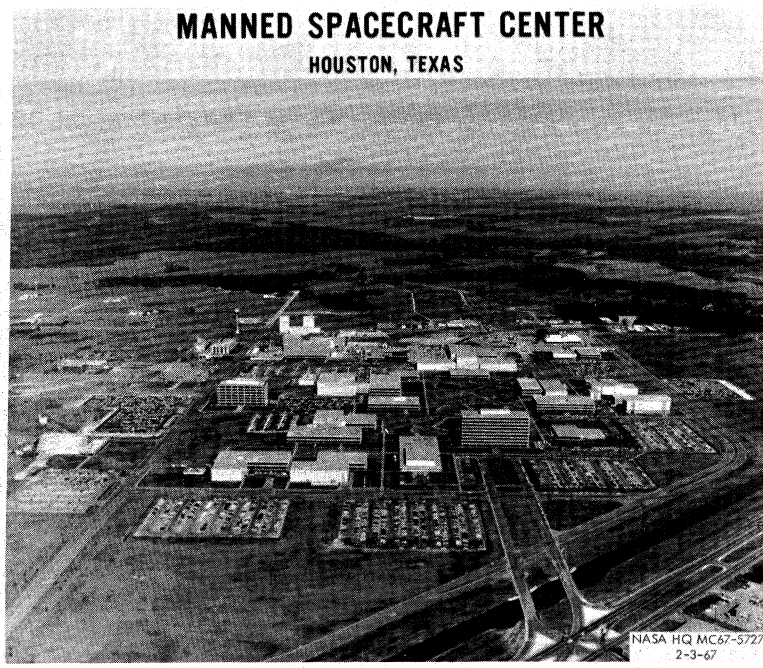

FIGURE 9

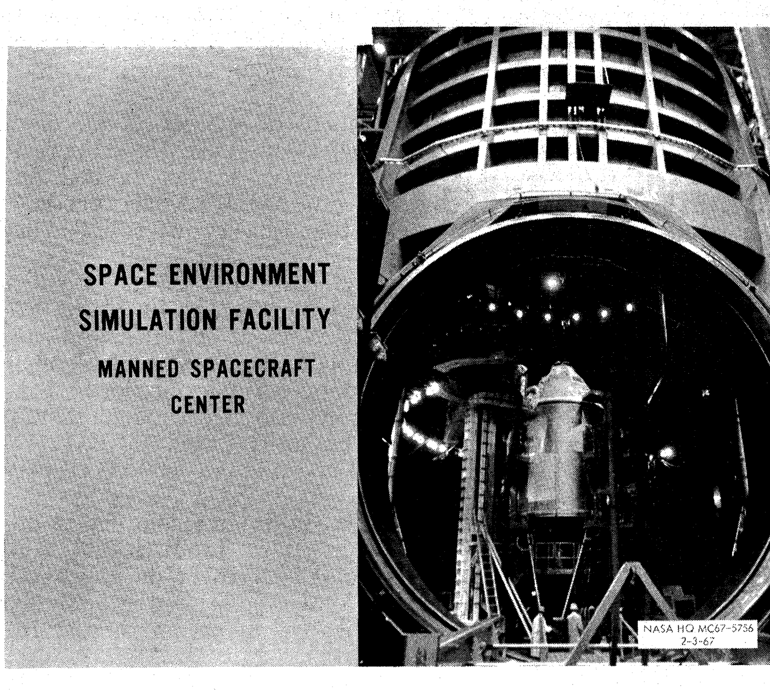

FIGURE 10