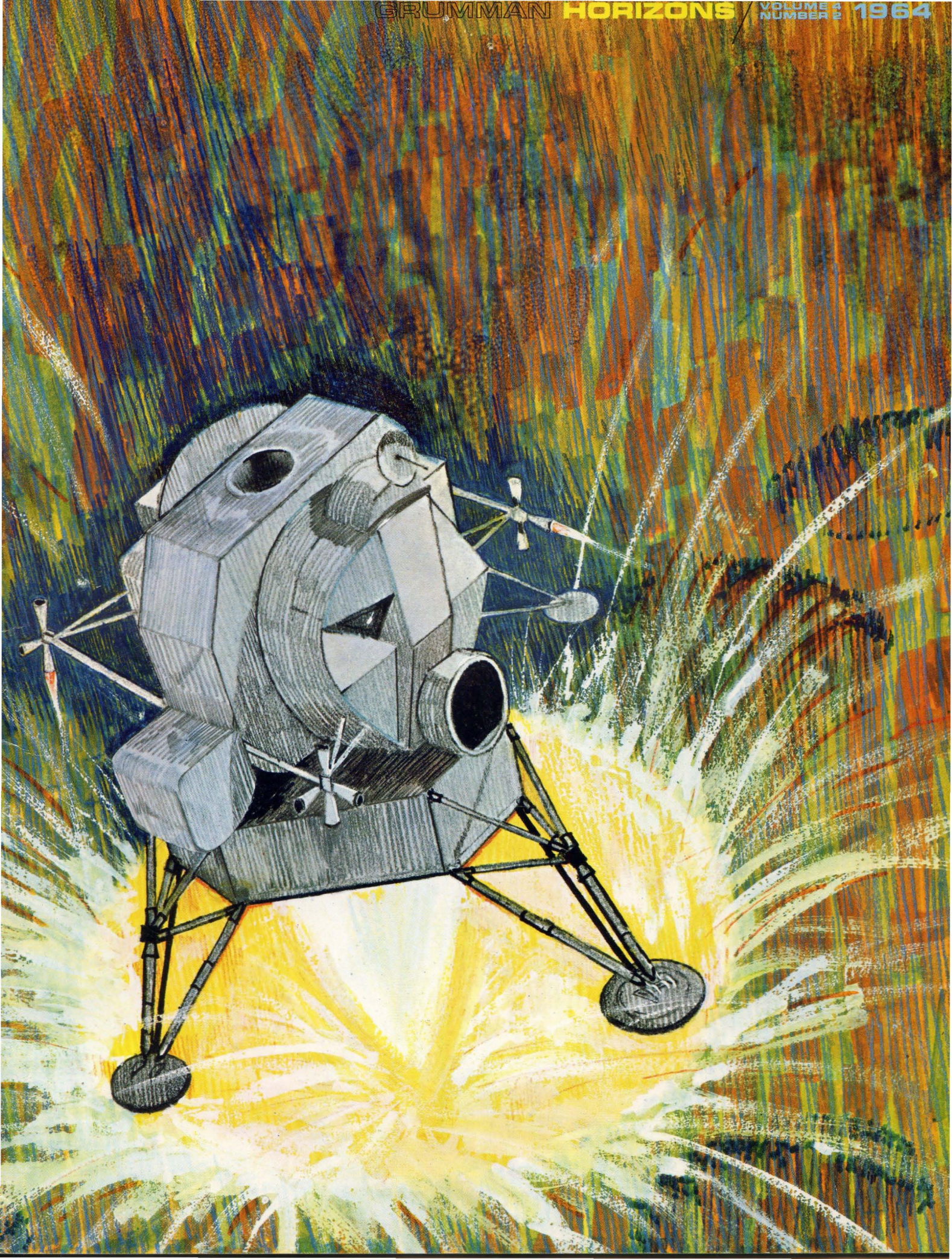
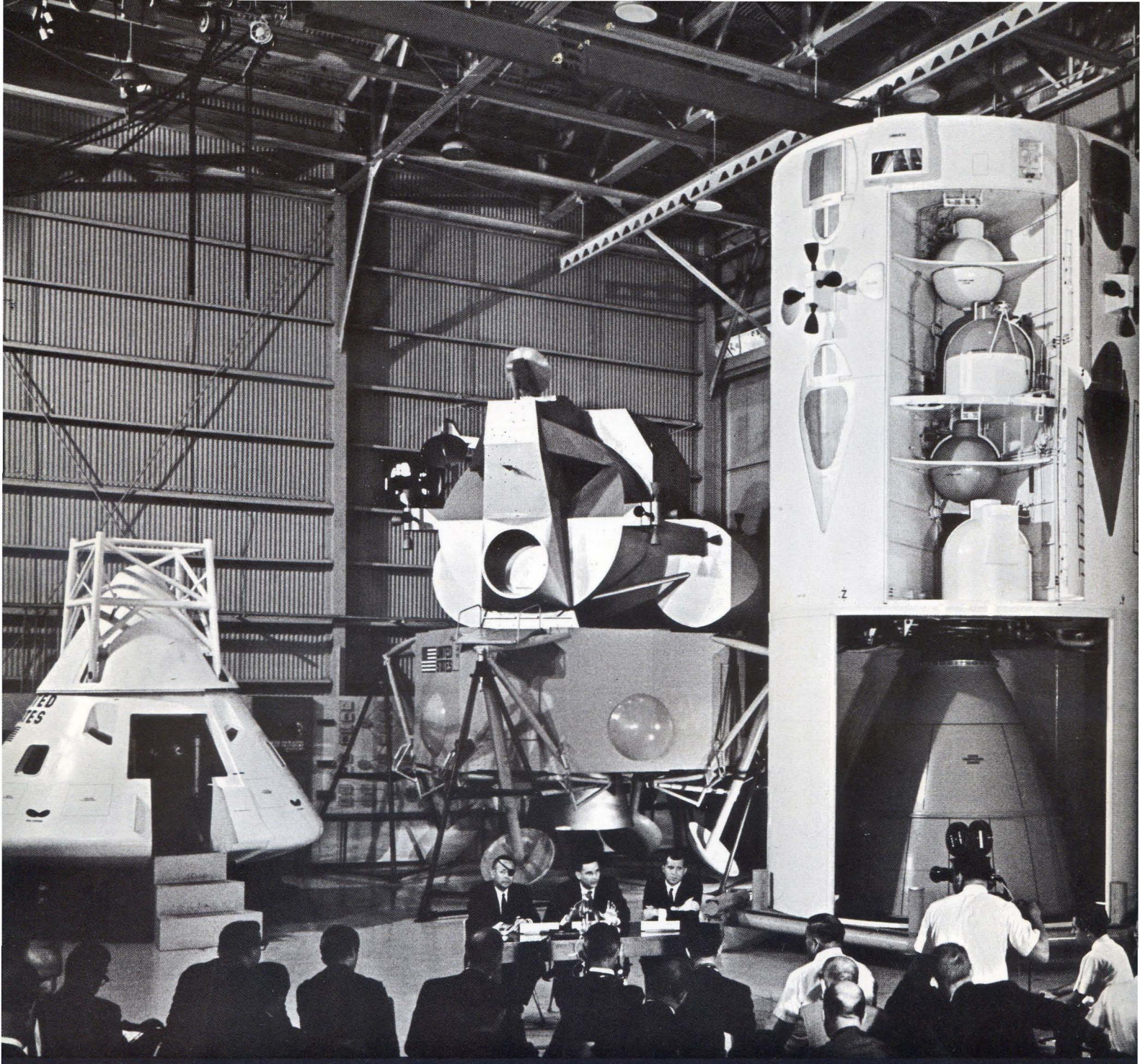
GRUMMAN HORIZONS / VOLUME 4 NUMBER 2 1964



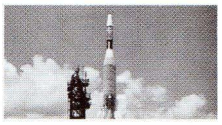


West Coast press get their first look at all three Apollo module mockups together at North American, Downey, Calif. Answering newsmen's questions about Command, Lunar Excursion, and Service Modules (left to right) are Dale Myers, Vice President–Command and Service Modules, North American Space Information Systems Div.; Dr. Joseph Shea, Apollo Program Manager, NASA; and Robert Mullaney, LEM Program Manager, Grumman. LEM M-3 mockup was shipped to Downey to enable engineers to check compatibility of LEM with adapter connecting Service Module and S-4B stage of Saturn launch vehicle. NASA says Ranger 7 spacecraft photos of moon's surface indicate that no major changes are necessary in LEM landing gear design. "Pregnant Guppy" is shown at Grumman taking aboard LEM mockup for flight to Downey.

LANFORD

2

THIS SPECIAL ISSUE ON APOLLO, our man-on-the-moon program, is introduced by James E. Webb, Administrator, National Aeronautics and Space Administration: we're well on the way to spacefaring leadership.

4 

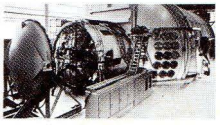
HOW SOON TO THE MOON?...DR. GEORGE E. MUELLER. NASA's Associate Administrator for Manned Space Flight documents a noncrash program which could cost $1 billion extra for each year of stretch-out.

12

THE MOON SHIP...DR. JOSEPH F. SHEA. NASA's Apollo Manager says "No technological breakthroughs are required . . . almost by definition . . ." we can accomplish a manned lunar landing by the end of this decade.

18

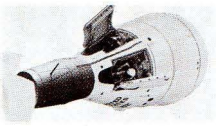
THE ENGINES...DR. WERNER VON BRAUN. NASA's Director of the Marshall (Huntsville, Alabama) Space Flight Center assesses rocket progress and potential for both manned and unmanned space exploration.

22 

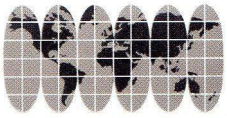
SPACE ON EARTH...BERNARD KOVIT. Heretofore, most vehicle and systems testing was done in natural environment—flight test. Today we must simulate vacuum, temperature, low gravity, and other space extremes.

26

EARTH IN SPACE...BURNHAM M. LEWIS. Exposed to the vacuum of space and moon, man would boil to death in minutes. But encased in his moon suit, he'll have at least some of the comforts enjoyed on earth.

29 

GEMINI...CHARLES W. MATHEWS. NASA's manager of the Gemini two-man program explains our current transition from one-man Mercury shots to long-duration flights, rendezvous and docking, and extravehicular tests.

32 

NEWS IN BRIEF... A roundup of late developments in the Apollo Program.

OUTSIDE COVER: Symbolic of the goal of our Apollo Program, to which this special issue of HORIZONS is devoted, is the Lunar Excursion Module (LEM), pictured about to land on the moon. The painting was done for HORIZONS by G. W. Michas, Jr., who also did the illustrations on pages 3, 19, 22, and 31. OTHER PICTURE CREDITS: Front inside cover, North American, Van Wallendael; 2, 4-9, NASA; 10, North American; 11-13, NASA; 14, NASA, North American, Grumman; 15, NASA; 16-17, Urrutia and Michas; 18, NASA; 20-21, NASA; 23, Hamilton Standard; 25, Burns and Roe; 26, Smithsonian, Hamilton Standard; 27, Urrutia; 28, NASA, Hamilton Standard; 29-30, NASA; 31, Michas, NASA; back inside cover, Harry Prodromides-Grumman.

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From Man-On-The-Moon to World's Leading Spacefaring Nation

NASA Administrator James E. Webb introduces this special issue on Project Apollo

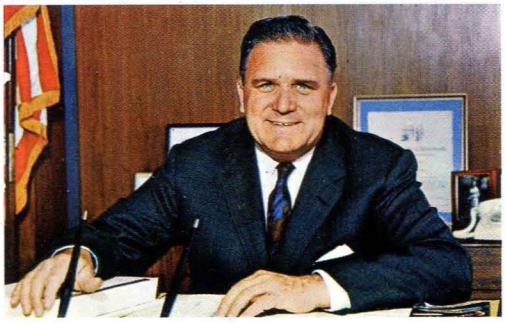
Three years ago, President John F. Kennedy stirred the imagination of men everywhere by delineating a new goal for the United States in the decade of the 1960s—the landing of a team of American explorers on the surface of the moon, and their safe return to earth.

Since this bold and forward-looking program was proposed as the focal point for nearly every aspect of space-related science and technology this nation must master to become preeminent in all major aspects of operating in near and deep space, the National Aeronautics and Space Administration has made good progress toward the goal.

This focal point is the well-known Project Apollo. It involves many disciplines of science and engineering; it requires the expenditure of billions of dollars; and it demands the energies and skills of hundreds of thousands of men and women in the government, in the nation's scientific community, and within the aerospace industry. This massive undertaking will help this nation acquire across-the-board space competence.

The pages that follow report on various phases of Project Apollo and describe where we stand today in some detail. Satisfactory progress has been and is being made.

Three years after Congress endorsed President Kennedy's acceleration of the National Space Program, the major contracts have been signed with industry. Work is well underway or nearing



completion on the ground facilities needed, not only for Apollo, but for other advanced missions in the future. A team of 29 astronauts has been selected and is undergoing training. The gigantic Saturn 5 launch vehicle, which will generate 7.5 million pounds of thrust at takeoff, is under development.

The three modules of the Apollo spacecraft which will be needed for the lunar mission have been designed and are now being built.

A worldwide tracking and data acquisition network has been established, and is undergoing refinements.

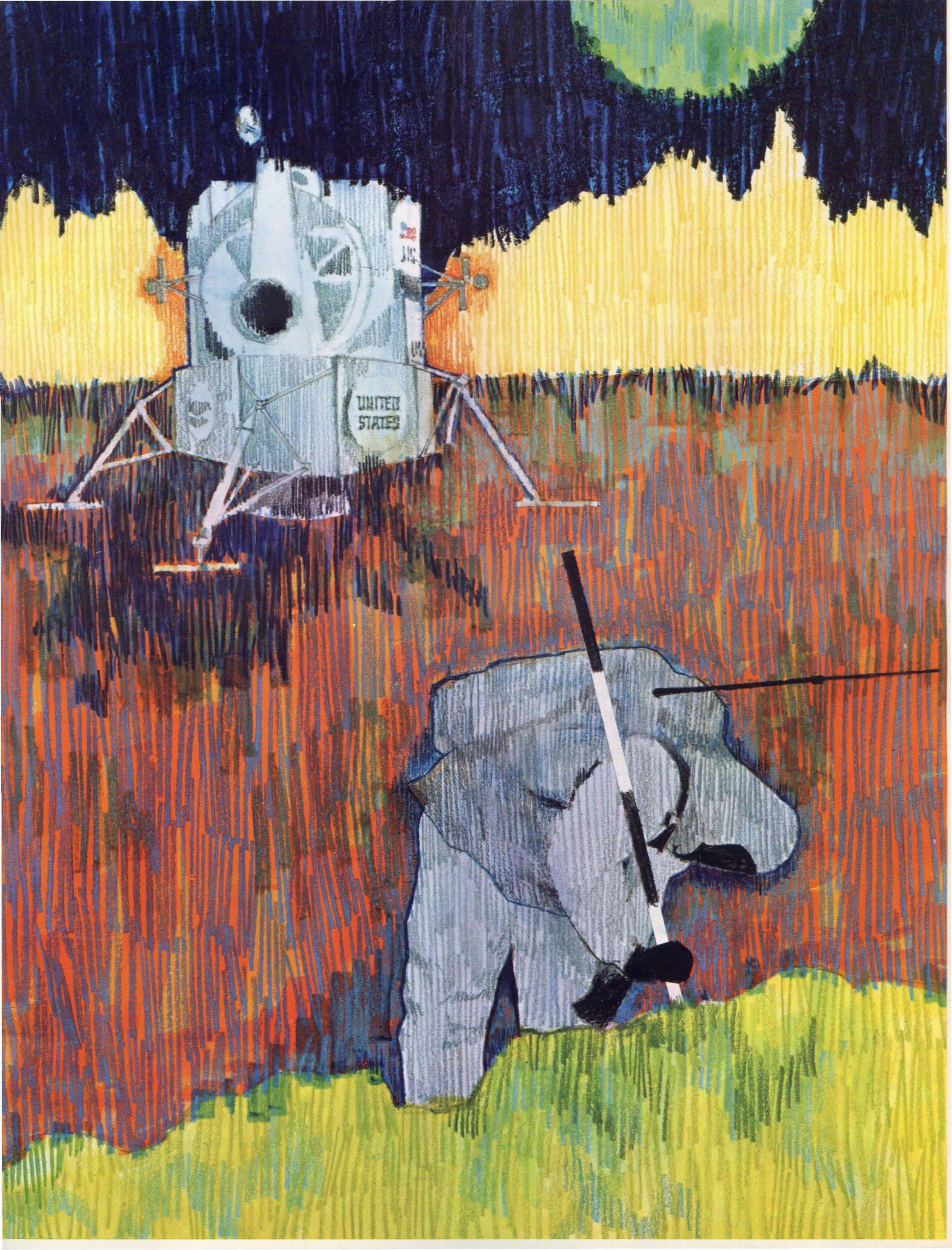
Research and development centers have been established, staffed with skilled and experienced personnel, and set to work finding solutions to the myriad problems inherent in a manned lunar landing mission, working in close cooperation with their counterparts in industry and the nation's leading universities.

Apollo began with Project Mercury, in which six successful manned space flights were accomplished. Project Gemini, the next logical step, is now underway. A full-scale model of the Gemini spacecraft was successfully tested in orbit this year and the sixth Saturn booster flight put the first full-scale model of the Apollo spacecraft into orbit.

These and other test flights set the stage for the first two-man Gemini mission scheduled for late this year. Gemini will increase the nation's competence in manned space flight, and will be of inestimable value in teaching our astronauts the skills of rendezvous and docking techniques. Such techniques must be perfected before we undertake the more difficult manned space flight tasks essential to the success of Project Apollo. Altogether, some 2,000 spacecraft hours and 5,000 astronaut hours are scheduled to be logged before the lunar mission takes place.

Scientific satellites and space probes are continually adding to the fund of knowledge concerning the environment of space, and the hazards which men will face beyond the earth's atmosphere.

Under the leadership of President Lyndon B. Johnson, one of the chief architects of the National Space Program, work on Project Apollo goes forward. With determination, with dedication, this nation can become, as John F. Kennedy said it must become, "the world's leading spacefaring nation" through the achievement of success in Project Apollo.


UNITED
STATES

How Soon to the Moon?

By Dr. George E. Mueller, Associate Administrator for Manned Space Flight, NASA

The Apollo program time schedule calls for a manned lunar landing by 1969. So far as cost is concerned, we have consistently stated to the Congress and the American people that we will accomplish this objective at a cost of about $20 billion.

Experience in the past year has demonstrated anew that neither of these tasks will be easy to achieve. The sheer magnitude of the job ahead has emerged with much greater clarity upon the completion of the detailed negotiation of major industrial contracts.

Technologically, we are confident that the lunar goal can be achieved. However, we are encountering the expected number of technical problems. Even with part of our $141-million supplemental request granted by the Congress, we will be living with a budget for the current fiscal year that is lower than we had proposed. Nevertheless, our best estimates at this time are that manned lunar exploration will begin in this decade.

Yet, from time to time in the last year, a subject of some public discussion has been the desirability of stretching out the program into the 1970s in the interest of economy.

Recently we made a detailed review of the factors affecting the time/cost relationship as part of our budget planning. We compared the time phasing of the Apollo program with other major United States research and development programs. We examined the effect on total cost of the overall pace of the program. We also reviewed the possible impact upon the schedule of the effect of the space environment. In this latter area, we have made studies of such technical factors as meteoroids, radiation, and the matter of a lunar landing site.

We have concluded from these reviews and studies that the pace of the program is efficient. It is compatible with economy. Solutions to the hazards of space flight are available with present technology. I shall describe in detail how we reached these three fundamental conclusions.

Noting "some public discussion on the desirability of stretching out the Apollo Program into the 1970s in the interest of economy," Dr. Mueller weighs the pros and cons. He concludes that a three-year deceleration would increase program costs about 15 percent—a six-year stretchout, 30 percent.

I. How does the time phasing of Apollo compare with other major research and development programs?

The development of the Apollo program has been planned in an orderly manner and a "crash" type of effort is not required to meet the program goal of a manned lunar landing within this decade. The Apollo spacecraft and launch vehicle are largely based on present state-of-the-art design approaches and do not differ greatly in principle from previous major developments of a similar nature.

The Saturn 5 launch vehicle, for example, embodies the same design approach that was recently demonstrated in the flight of the Saturn 1 vehicle, and the Apollo spacecraft uses more highly developed versions of the same general kinds of equipment that were used in Project Mercury, the X-15, and the Titan 2 launch vehicle.

Let's compare the overall development phasing for the total Apollo program—including the spacecraft, the Saturn 1B, and Saturn 5 launch vehicles and major subsystems—with the development cycles for similar major research and development programs which have been successful in the past.

Comparing the Apollo spacecraft development cycle with those of the Mercury spacecraft, the B-58 bomber, and the X-15 in terms of readiness for mission capability, we find that the Apollo development cycle allows one to four years longer than the cycles for the other three.

In general, the spacecraft development cycle parallels but is slower than those for the B-58 and the X-15 aircraft. It is appreciably slower than for the Mercury spacecraft. About seven years is allowed for development of the Apollo spacecraft to mission capability status.

Now let's compare the development cycle for the Saturn 5 and 1B launch vehicles with those for the Polaris, Minuteman, Titan, Atlas, and Saturn 1. Inasmuch as the Polaris and Minuteman missiles utilize solid propellants, the Atlas and Titan are the more pertinent. The total development time allowed for Saturn 5 is one to two years greater than that required for development of the Atlas and Titan. The Saturn 1B and 5 programs are a direct progression from the Saturn 1, using similar techniques and procedures.

Major subsystems for the Apollo spacecraft and Saturn 5 launch vehicle are the guidance system and the launch vehicle engines. Compare the development cycle for the Apollo guidance system with comparable past developments, the Polaris, Minuteman, and Titan 2 systems. The Apollo guidance system is an outgrowth of the Polaris system and benefits appreciably from the Polaris program. The time allotted for the Apollo system development is one to one and a half years greater than that required for the other systems. This increased time allows for orderly development and qualification of this

No crash program, the man-on-the-moon landing would cost an estimated one billion dollars extra for each year it is delayed beyond the 1969 target date.

system for its manned rating application. Again, however, it is apparent that a "crash" effort is not required and is not being followed.

A comparison of the development cycle for the F-1 and J-2 engines with previous major liquid engine developments shows that adequate time has been allotted for orderly development of these engines to the high state of reliability desired for the Apollo program. The engine development for Atlas did entail a "crash" type of activity because the first flight preceded the completion of the preliminary flight rating tests (PFRT). Although the F-1 and J-2 engines are significantly larger than predecessor engines, they do not represent departures from principles already demonstrated in the Pratt & Whitney RL-10 engine and in the Atlas and Titan launch vehicle engines.

How does the planned Apollo program duration compare with actual times required for previous major United States research and development programs? The overall time allotted for Apollo of about eight years is significantly greater than that for any of the comparable programs. It's apparent that the overall Apollo program and its major components are not planned on a "crash" basis.

The progression in the Apollo development cycle is phased in a logical manner without the need for major state-of-the-art breakthroughs. The various missile programs were the first of their kind in many instances. Yet they were accomplished at a more rapid rate than is planned for the Apollo program.

The Apollo program benefits immeasurably from the major missile, spacecraft, and high-performance aircraft programs which have preceded it. Its development cycle as currently planned is conservative.

II. Should we stretch out the Apollo program? Let's examine the cost aspect.

In recent months, we have taken a fresh look at the pace of Apollo in the light of the thorough cost information that has just become available upon completion of detailed contracts with our present development schedules. We have compared the total cost resulting from these requirements with the total cost that would result if we were to stretch out the program over a longer time span, or if we were to accelerate it.

We considered the real situation facing us, not a series of hypothetical conditions based upon different decisions that might have been made in the past. We limited our analysis to practical decisions that could be made from this time forward. The ground rules for this study are:

- Present development plans, program elements, and contractors were to be the base for the study.
- Delayed schedules are to assume a stretch-out of the current program without major revision of program elements.
- Three different schedules, two stretched out and one accelerated, were analyzed in relation to the present schedule.

We found some evidence that a very slight acceleration might result in savings. Certain costs would increase, but some of the fixed operating costs would be reduced. On the other hand, a six-month acceleration would increase costs by $1 billion.

We found that deceleration, stretching the program into the 1970s, would increase rather than decrease cost. A three-year deceleration would increase program costs about 15 percent; a six-year stretch-out, 30 percent. The dollar increases, respectively, are $2 billion and $5 billion. In other words, for each year the program was stretched out, the total cost would increase by about a billion dollars.

The starting point for the analysis is the program status as of today, involving Fiscal Year 1964 authorized funding plus our 1964 supplemental. It has been assumed that program continuity would be maintained for all schedules, that is, for the slower schedules; a stop now, start again later approach would not be followed. The program content for all four schedules has been assumed to be the same, or a total of twelve flights on the Saturn 1B, and a total of fifteen flights on the Saturn 5. The Gemini and Saturn 1 schedules have been assumed to be unchanged.

Included as a part of the overall Apollo program is the Gemini program, which will provide essential data for Apollo. These major elements in general are handled by prime contractors who, in turn, utilize subcontractors. In analyzing the cost of the program, a detailed analysis of each of the prime contractor and associated subcontractor efforts is made. In analyzing the cost of each element of the program, the costs are categorized in terms of direct and indirect costs.

The direct costs consist of manpower and material. Manpower can be broadly separated into manufacturing labor and engineering labor. Material consists of purchased raw material and supplies, minor subcontract items, and major subcontractor costs. The indirect costs are those required to directly support the engineering, manufacturing, planning, and material-processing efforts, and the overhead and general administrative costs which are required for maintaining the physical plant and providing administrative supervision, clerical support, and the like.

In estimating the prime contractor costs, a step-by-step analysis of the man-hour requirements for engineering and manufacturing tasks that must be performed is first made. Then the subcontractor items are similarly analyzed with

How Soon to the Moon?

assistance from major subcontractors involved. Once the direct costs have been estimated, then the burden and overhead costs required to support that direct effort are applied. The amount of overhead, of course, does not decrease in proportion to a decrease in direct labor; just to keep the factory open and running costs some minimum amount of money, whether any directed effort is applied or not. The overhead also varies with the total amount of company business at a given time.

Adding these costs for the three schedules shows that the present Apollo spacecraft program costs less than any of the other alternatives studied. The cost of the spacecraft program is calculated to increase from almost $5 billion for the present schedule to $7 billion for the six-year stretched-out Schedule C. The accelerated Schedule A would increase the total spacecraft cost slightly.

A major factor in this cost picture is the fact that our present spacecraft development effort will have been under way for 30 months by the start of Fiscal Year 1965. It has been organized to deliver a complete flight spacecraft by the end of that year. Any stretch-out of a development effort this far down the line inevitably results in increased total cost.

Similar calculations are made for the launch vehicles and engine programs. The total cost for the launch vehicle program would increase from almost $8 billion under the present schedule to approximately $11 billion under the stretched-out Schedule C. For the accelerated schedule, total cost would increase slightly.

For the launch vehicle engine program, costs increase relatively less with program stretch-out—from $1.24 billion for the present program to $1.53 billion for Schedule C—because the engines can be developed almost wholly by ground test, and only a relatively small staff need be maintained throughout the stretched-out flight program.

Analysis indicates that program acceleration would not increase total cost for the engines because the present schedule does not fully utilize the potential development and production capability for the engines, and a faster development and production rate would be feasible with minimal overtime.

Let's look at individual cost elements for the program, starting with the command and service module contract with North American Aviation.

An initial period in the program involves basic design. Much of this already has been accomplished for most of the elements of the program, and we see very little stretch-out, even in Schedule C. Most of those funds already have been spent.

As a complicated research and development program develops, many design changes become necessary as development data feed back from ground and flight tests. As the flight program is stretched out, then the design period must correspondingly be stretched out. For Schedule C, the design period for incorporating changes would actually stretch out to be almost three times as long as for the present schedule. This means that a minimum staff of design engineers must be kept on board to accommodate these changes for that period of time. Inasmuch as the design work requires many different disciplines, a minimum level of capability is needed in these different areas.

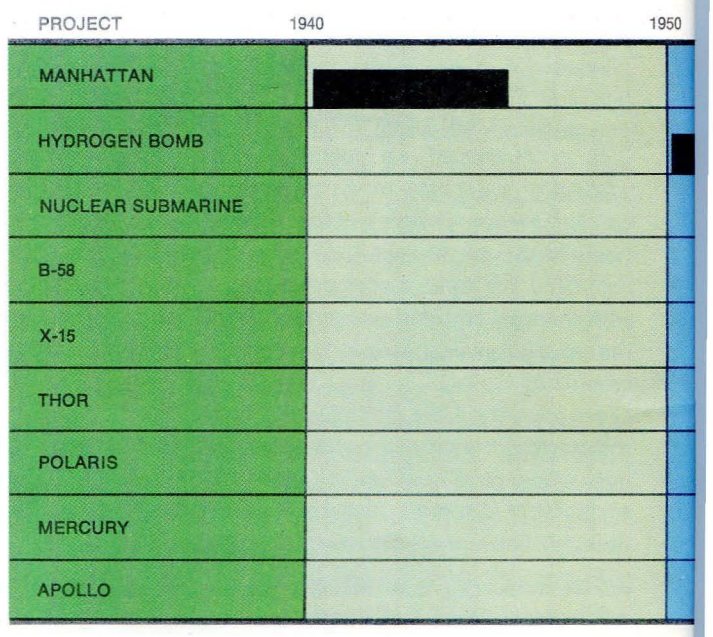
There is a minimum-sized engineering staff required for the ability to respond to all kinds of changes that may be necessary as the flight program proceeds. This staff is approximately the same whether the flight rate is of the order of two a year or four a year. Slowing the program down beyond the point where these personnel are fully utilized results in less efficient use of their abilities.

In manufacturing, several kinds of spacecraft must be built. These are called boilerplates, prototype spacecraft, and production or operational spacecraft. At this time, most of the boilerplate activity has been completed, and there is little difference in phasing for the remainder of the boilerplate manufacture. We are about halfway through the prototype spacecraft manufacture on the present schedule. For the slower schedule, this effort would be stretched out somewhat.

The main stretch-out in activity would be in the fabrication of production spacecraft. The direct production effort is more suitable for efficient stretch-out than is the direct engineering effort. The direct man-hours required for manufacture of production spacecraft are close to constant regardless of the schedules. Overhead increases significantly, however, for the stretched-out manufacturing period.

In the test activity, we divide our program into four major phases: subsystems development, subsystems qualification,

Duration of our major R & D programs



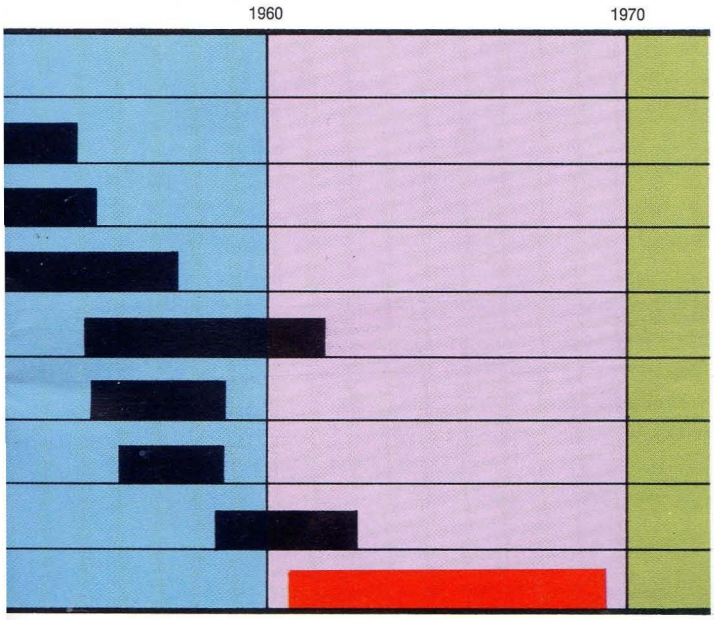
systems ground tests, and systems flight tests. The subsystems development activity is stretched out relatively little, even for Schedule C. Similarly, subsystems qualification activity is stretched out relatively little because this activity is gauged primarily to make ready for the first flight date, and most of the subsystems activity has already been completed. The systems ground test activity and the systems flight test activity, however, do have significant stretch-outs for the different flight schedules.

Schedule stretch-out of three and six years will increase total command and service module cost by about 16 and 49 percent, respectively, and the accelerated schedule would increase total cost by about seven percent.

The total subsystems cost variation with schedule is relatively less than for the overall command and service module because a relatively larger amount of the development and fabrication activity for the subsystems has already taken place. Their phasing comes appreciably earlier than that for the overall spacecraft because they must be built into that system. Therefore, only a minimal engineering effort must be maintained over the increased period of time associated with the stretched-out schedule.

Similar cost analyses have been made for the other cost elements of the Apollo program. Adding these together, it was found that the total program cost is nearly a minimum for the present schedule. The overall program cost would increase $2.6 billion for Schedule B and $5.9 billion for Schedule C. The accelerated schedule is estimated to cost about one billion more than the present schedule.

The moonship benefits immeasurably from the major missile, spacecraft, and high-performance aircraft programs which have preceded it. Yet its orderly development program is, conservatively, much longer than theirs were.



It is apparent from this technical analysis that certain fixed operating, personnel, and facilities costs mainly account for the increase under a decelerated program. For example, many thousands of skilled engineers, scientists, and technicians are needed to support the flight and ground test activity that is required throughout the total development program. These include propulsion, electronics, structures, thermodynamics, astrodynamics, and guidance and control specialists, as well as supporting technicians, plus the clerical and management staffs required by each industrial contractor to remain in business. Certain work must always be done and certain facilities constructed and maintained.

All these costs remain practically the same regardless of program pace, whether launches occur every three months as now planned or every nine months as would occur under a stretch-out. Because they accumulate in almost direct proportion to the time required for program completion, a stretch-out would substantially increase them. It would also reduce useful output and require maintenance of a technical-industrial base in low-gear operation over a longer period of time.

It should be pointed out that a considerable portion of the physical plant required for the Apollo program has been completed or is being constructed. The industry-Government team is largely assembled. Consequently, one element of the cost of stretching out the program would be the maintenance of these facilities and the waste inherent in the cutback of major contracts.

A minimum cost program is one in which funds expended for fixed costs and costs for overtime parallel development, and the purchase of hardware and facilities beyond those required for a slower paced program is in balance. We feel that we have achieved this in our present program. The pace is not so slow that operating costs absorb an undue share of total expenditures, as would occur were the program stretched out.

An orderly buildup of effort in the Apollo program has occurred in the more than two and a half years since 1961, when Congress endorsed the United States program calling for manned lunar exploration in this decade.

Following the Congressional endorsement, NASA selected major sites, began marshalling the needed industrial support, and carried on with the Department of Defense (DOD) a joint study on the nation's launch vehicle requirements. This study resulted in December 1961 in the NASA-DOD decision to begin the development of the Saturn 5 launch vehicles.

In July 1962, following a million man-hours of engineering studies, NASA announced a tentative decision to select the lunar orbit rendezvous mode of lunar flight and, following additional studies, that decision was confirmed in November 1962. During all this time, the buildup of effort proceeded rapidly but efficiently.

Apollo is not a crash program. This term is reserved for programs in which cost is not the major consideration, in which multiple approaches are taken for the solution of each

major problem, and in which overtime and multiple shifts are utilized without stint. None of these conditions exist in the Apollo program. In general, the amount of overtime and double shifts authorized in the Apollo program are quite limited. The great bulk of the effort is proceeding on a normal work-week basis except when people are donating their time because of enthusiasm for the job.

The Apollo program, in summary, is an effort paced in a manner compatible with current technology in a time frame consistent with minimum cost. A delay to the mid-1970s, calling for a change of pace, would cause a serious loss in stride and would cost more money in the long run. The economic considerations support the maintenance of the present schedule.

III. What effect does the space environment have on the Apollo schedule?

We have been particularly concerned as to whether there are environmental conditions that will inhibit us in our scheduling of manned lunar exploration in this decade.

The space environment is frequently described as hostile, forbidding, and perilous to man. But is it any more so than the earth on which we live? Certainly man has had to learn to protect himself from unfavorable conditions in the earth environment—extreme temperatures, epidemic and natural calamities.

Six years of intensive space exploration, both manned and unmanned, have contributed much to man's understanding of the space environment. Potentially adverse conditions have been identified, and it appears that solutions of the problems involved are possible within the present technology. In short, we know of no natural conditions that will interfere with our scheduling of Apollo missions.

Let's examine the potential effect of three space environmental conditions: meteoroids, radiation, and the lunar surface.

On the lunar mission, the Apollo spacecraft will encounter large numbers of meteoroids—small particles traveling freely in space. Most of these are so small that they are called space dust and do not contribute to the hazard of puncture of the spacecraft or space suit. Larger meteoroids, weighing in the range of a pound or more, are so rare that the danger from them can be disregarded.

The meteoroids about which some concern exists are tiny pebbles, having diameters less than 1/100th of an inch, which weigh a few 100,000ths of an ounce. Some of these, in orbit about the sun, enter the earth's atmosphere at speeds of 25,000 to 150,000 miles per hour. Their energy of motion at such speeds is greater than the explosive yield of an equivalent weight of TNT. A large number of smaller particles may also be in orbit about the earth. However, because of their tiny size, they do not present a hazard.

Present information on the frequency of meteoroids comes mainly from two sources—the Explorer 16 satellite launched by NASA on December 16, 1962, and visual and radar ground observations of meteor arrivals in the upper atmosphere. Further information will become available when larger meteoroid-detecting satellites are orbited on the eighth and ninth flights of the Saturn 1.

The results from Explorer 16 indicate that the rate of puncture of very thin metal by meteoroids is considerably less than had been anticipated on the basis of indirect information from ground observations. Estimates based on the combination of Explorer 16 and ground observations indicate that the hazard within the command module is extremely small, even if the most pessimistic estimates are made concerning the meteoroid environment. We will continue to review this matter very carefully.

The Apollo spacecraft service module, larger than the command module, presents a better target for meteoroids. However, most penetrations of the outer surface of the service module by meteoroids would be harmless because the surface would slow the speed of the particles and the vital components in the interior would present relatively small targets.

We are dealing with the matter of meteoroids in accordance with the conservative design philosophy of the Apollo program. Margins of weight are being held in reserve in the command module and the service module to deal with contingencies that may occur. If it should be determined that further insurance against meteoroids is required, these margins are available for this purpose.

Regarding the hazard to the astronaut in his space suit during the time he is on the surface of the moon, present information indicates that the chance of puncture is also negligible. Even if future measurements should indicate greater numbers of meteoroids than present estimates, the hazard could be held to an insignificant level by the addition of a lightweight protective cape.

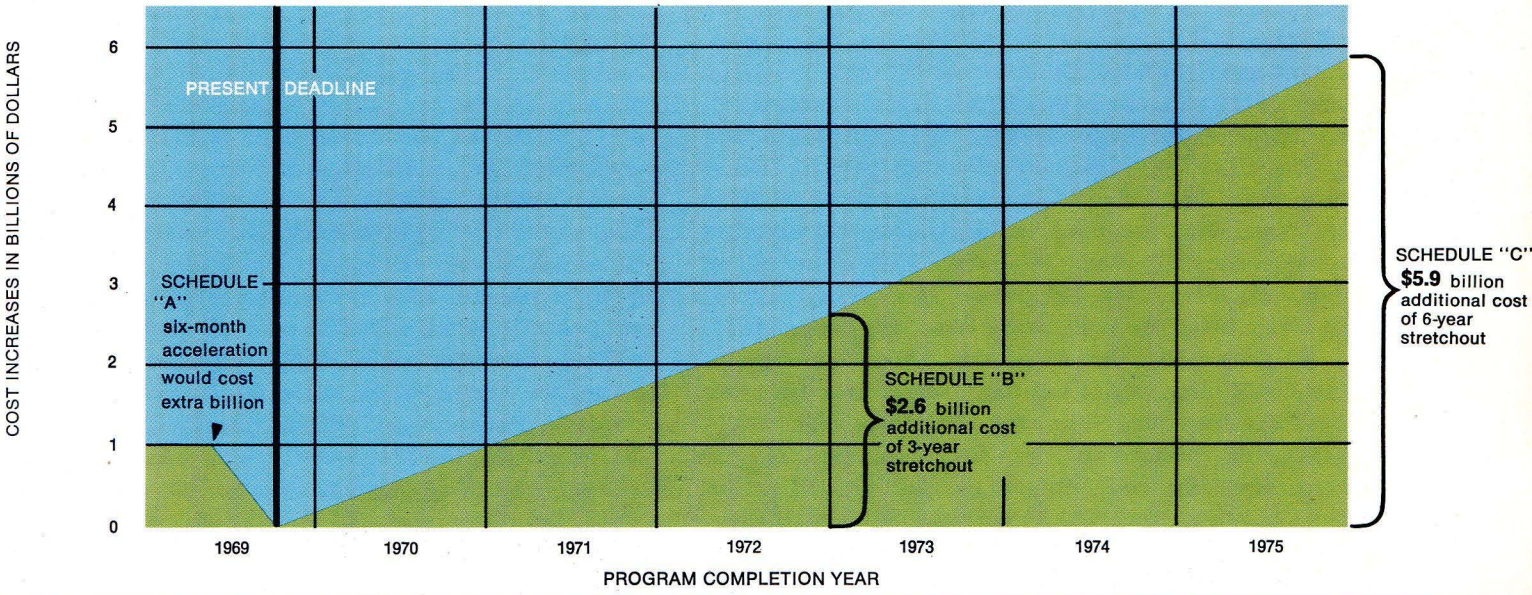
About a quarter of all the meteors observed visually belong to major showers, which reach the earth periodically. In some showers, such as the annual Perseids, the frequency of meteoroids may increase by five times. In a few cases, this temporary multiplication may be as much as 1,000. Apollo missions, however, can be scheduled around such showers, which last for only a few days.

Prudence will require careful study of the results of the meteoroid experiments on Saturns 8 and 9, as well as other future developments in this field. However, it is not anticipated at this time that meteoroids will constitute a major problem in the planning or scheduling of the first manned lunar exploration.

In space, three forms of radiation contribute to the hazard of manned flight: cosmic rays originating elsewhere in the galaxy, charged particles trapped by the earth's magnetic field in the Van Allen radiation belts, and high-energy radiation emerging from the sun.

Even though the cosmic rays from elsewhere in the galaxy may be highly energetic, the hazard from them is negligible because of their rarity. In a typical two-week flight, less

Slowing down the Apollo program to a lunar landing at the end of 1972 (three-year stretch-out) would add an extra $2.6 billion to the $20 billion estimated for a 1969 landing. A six-year stretch-out would add nearly $6 billion.



than one percent of the allowable dose is experienced. In the case of the Van Allen belts, if a spacecraft flies through them rapidly, the amount of radiation that comes through its walls is quite small and can also be disregarded. For the Apollo mission, it again amounts to an integrated dose of 1/10 of one percent of that considered safe.

The only material risk to manned flight is that a flare from the sun may eject a cloud of protons which will envelop the spacecraft during the time it is outside the earth's atmosphere and magnetic field. Solar-flare protons are largely diverted by the earth's magnetic field and do not reach below the Van Allen belts. Therefore, except in regions near the poles, solar flares do not present a hazard to orbital flight below the Van Allen belts.

Only July 10, 1962, the Space Science Board of the National Academy of Sciences reported findings as to acceptable radiation dose limits for emergency exposures in manned flight. These were approved earlier in that year by a Working Group on Radiation Problems set up by the Board's Man in Space Committee. The overall plans for the Apollo program, both in the design of hardware and in the scheduling of missions, are based on limits lower than those approved by this group.

Radiation is measured in various units, depending upon the nature of the consideration. I will speak of radiation in rads, a measure of the rate at which radiation is absorbed in a given material.

The Apollo permissible emergency dose limits in rads are: skin of whole body, 500; blood-forming organs, 100; feet, ankles, and hands, 700; eyes, 25. The permissible emergency dose is, of course, safely below the lethal dose.

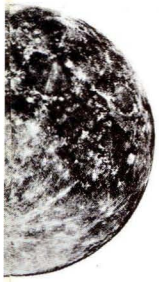
In the Apollo program, the command module effectively shields the astronauts from radiation. The spacecraft walls provide considerable protection. In addition, equipment and water supplies are placed along the exterior walls as much as possible.

During the passage through the Van Allen belts, the astronauts will receive a dose on the skin amounting to less than five rads and probably less than one rad. The shielding provided to the blood-forming organs by the body tissue itself will further reduce the dose on those organs to a number no more than a tenth as large. Therefore, the passage through the Van Allen belts does not present a significant problem.

What about solar flares? A few times a week, the whirling, boiling surface of the sun erupts in a large flare that can be seen from the earth's surface. These flares are usually associated with sunspots or groups of sunspots. Some of the flares result in the ejection of clouds of protons and other charged particles into the space between the sun and the planets. These proton clouds travel along paths that curve in accordance with the effect of the magnetic fields in interplanetary space. A few of these proton clouds reach the region of the earth and the moon.

Since 1956, between 50 and 60 solar events resulted in the arrival of high-energy protons in the vicinity of the earth. The initial manifestation is the occurrence on the sun's surface. The first substantial numbers of high-energy particles arrive near the earth several hours later and increase steadily to a maximum one to two days after the flare. Then a gradual decrease follows for several days.

These solar events have been studied intensively in recent years with the aid of satellites and space probes, high-altitude balloons and rockets, ground-level detectors, and radio



How Soon to the Moon?

systems which measure the effect on the ionosphere, which consists of levels of ionized atmosphere that reflect radio waves and make long-range transmission possible.

The largest events observed since 1956 have taken place on four occasions—in July 1959, November 1960, February 1956, and May 1959. The size of these events has been measured in the number of protons per square centimeter having energy higher than 30 million electron volts. Only particles having energy above this level could penetrate into the interior of the Apollo spacecraft command module. In fact, the minimum energy required by a proton to penetrate the thinnest portion of the module is 36 million electron volts.

Let's consider the radiation dose within the command module that would have been caused by the four largest events if an Apollo lunar mission had been in progress at that time.

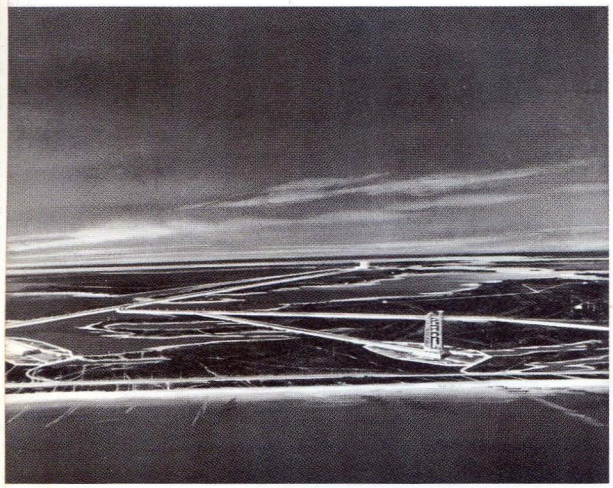
The maximum skin dose received during the July 1959 event would have been 160 rads. This compares with the level of 500 rads set on the basis of the National Academy of Sciences' report as to the maximum permissible emergency dose. The shielding effect of the body itself upon blood-forming organs would have reduced their dosage to 15 rads, compared with 100 rads set as maximum permissible.

These estimates may be too pessimistic. Very recent estimates of the size of all four events indicate that they may have been no more than half as large as indicated here. If so, the dose to the astronauts would have been reduced comparably.

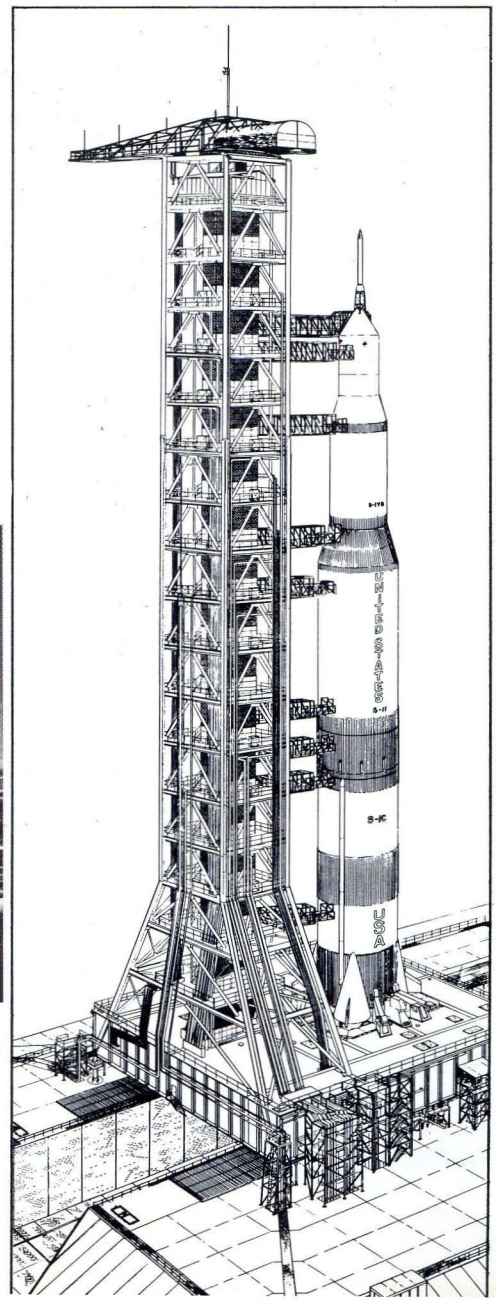
Because the eyes are so sensitive to radiation, special protective goggles, which would be donned in an emergency, will be used. These goggles, weighing a few pounds, would have reduced the dose from the July 1959 event to a perfectly safe level.

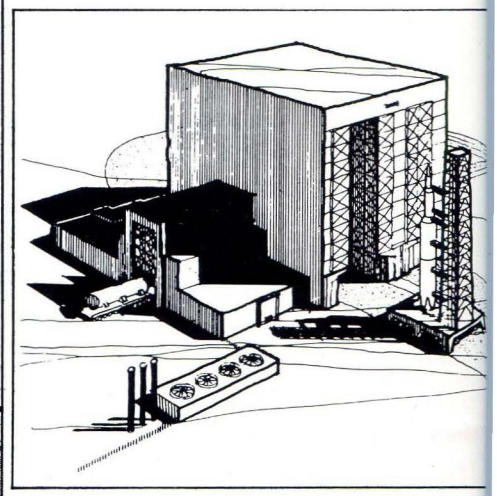
Altogether, the present evidence indicates that radiation does not present a hazard that would prevent manned lunar exploration in this decade. Indeed, we have encountered no serious evidence indicating that radiation would be a factor in scheduling our first lunar mission. Of course, it is necessary to continually review all information that becomes available from the various NASA unmanned satellite projects, which will yield a great deal of data on solar radiation.

The third environmental matter is the selection of the lunar landing site. One of the maneuvers critical to the success of an Apollo mission is the landing on the surface of the moon. To assure the success of this maneuver, the landing gear of the Lunar Excursion Module (LEM) must be designed to cope with surface conditions. These design efforts require detailed knowledge about the lunar surface. If it were possible to design the LEM to cope with any foreseeable lunar surface condition so that it could land anywhere, knowledge about the surface would not be needed in advance. On the other hand, if surface conditions were known in detail, a very promising site could be selected and the landing gear designed merely to meet the conditions imposed by that site.



Apollo moonship will be launched from Merritt Island Complex 39 at Cape Kennedy, Fla. In foreground of artist drawing is Apollo and launch pedestal; in background, Vertical Assembly Building.





Saturn 5 launch vehicle boosters will be assembled in Vertical Assembly Building (above), which will have 1½ times the volume of Pentagon. Moonship then will be moved erect to launch pedestal, at left.

This article is based on statements by Dr. Mueller before the Senate Committee on Aeronautical and Space Sciences and the House Committee on Science and Astronautics.

Present information about the surface of the moon is based on Ranger 7 photos and observations from the earth, which include telescopic observations, analysis of radar echoes, analysis of the rate of arrival of meteors, and analogies to the earth. Study of this information gives ground for confidence that it will be possible to find many suitable sites for landings on the moon within this decade.

The present design of the LEM landing gear is conservative. As can be seen here (NASA M64-1062), it is required to withstand a touchdown on the surface of the moon at speeds up to seven miles an hour vertically and three and a half miles an hour horizontally. It must remain stable following landing upon a surface tilted as much as 15 degrees from the vertical. It will have four legs that must provide minimum clearance of two feet.

Each foot will measure about 1,000 square inches, providing a total of about 4,000 square inches of surface. Any one of these feet will provide sufficient surface to hold the pressure on landing to a maximum of 12 pounds per square inch. Resting on the moon, the spacecraft will weigh about 2,000 pounds, the lunar equivalent to its 12,000 pounds of earth weight. Landing sites need not be selected until late in the program —probably only months before the actual mission.

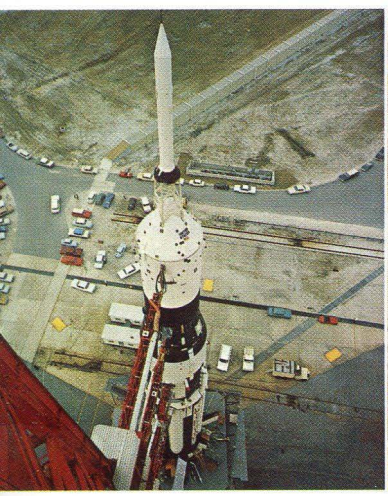
For this purpose, valuable data will be obtained from the unmanned lunar exploration programs. The first unmanned lunar program is Ranger, in which television pictures provide very detailed information on the slope and roughness of parts of the surface. At first, they show very large areas of the moon in small scale. Then, as the spacecraft falls toward the moon, the area covered grows steadily smaller and the scale grows steadily larger.

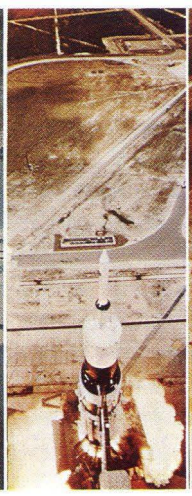
In the Surveyor program, the next phase of unmanned lunar exploration, unmanned spacecraft will make soft landings on the moon. The Surveyors will provide further information concerning the roughness of the surface. In addition, they will supply data on the bearing strength of the surface—its ability to support the spacecraft without its sinking.

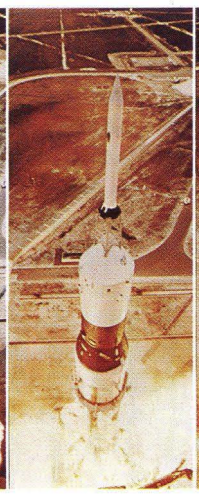
The Surveyor data could lead to decisions in either of two directions. Like the Ranger program, Surveyor could also lead to findings, contrary to present assumptions, that only about 10 percent of the surface is satisfactory for landings and that a lunar reconnaissance mission is required. The Surveyor program could also verify that 90 percent of the moon's surface is satisfactory—in which case no further surface investigation would be necessary.

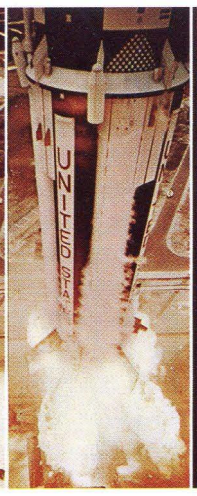
If neither of these two findings results, a third round of unmanned investigation will shed further light. The Atlas-Agena Orbiter and follow-on Surveyor missions should make possible a selection of one to three suitable landing sites, or may confirm that it is possible to land anywhere in the accessible regions of the moon. Studies are of course being carried out on the use of the Apollo spacecraft itself for detailed mapping and reconnaissance of the lunar surface.

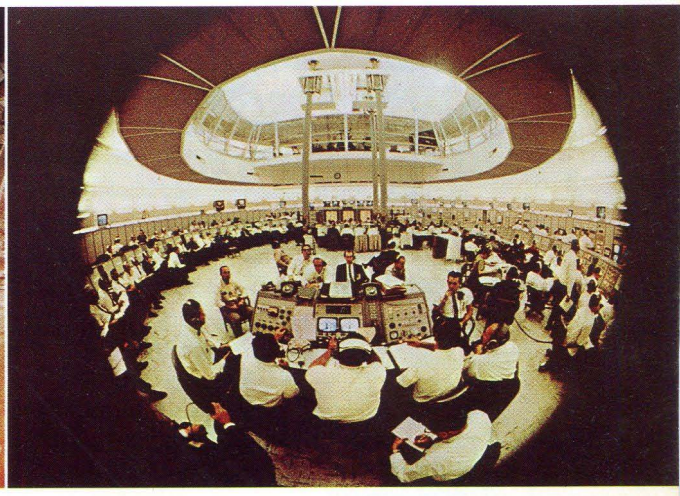
Under our present assumptions regarding the moon's surface, consistent with the information available from Ranger photos and by observing the moon from earth, many accessible sites exist for lunar landings. With unmanned lunar exploration programs—Ranger, Surveyor, Lunar Orbiter, and follow-on Surveyor flights—NASA is conducting a careful effort to expand upon this knowledge and to verify these assumptions. Apollo plans are proceeding on the assumption that the unmanned lunar exploration programs will provide all the information needed for site selection.







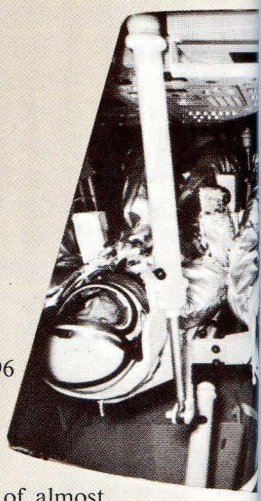




Saturn 1 SA-6, much smaller than Saturn 5 Apollo launch vehicle still being built, lifts off from Complex 37B at Kennedy with boilerplate Apollo spacecraft. Dramatically shown are ignition and flame pattern of first-stage Rocketdyne H-1 engines. Photos were taken May 28 by remote-controlled camera atop umbilical tower. Blockhouse (right) from which launch was controlled also is shown as white mound in upper right of two launch photos. This Saturn 1 is one of the largest operational space vehicles in the world. Purpose of test was to check compatibility of spacecraft shape with launch vehicle and to measure stresses it must survive as it passes through atmosphere.

The Moonship

By Dr. Joseph F. Shea,
Apollo Program Manager, NASA



"The landing of a United States citizen on the moon in this decade is the most challenging technical program ever undertaken by this country."

This sentence has been used innumerable times since May 1961 to describe the enormity of the task to which we now turn. Such a statement gives those of us working on the program a comforting sense of pride, and at the same time justifies to our fellow citizens the large investment required to achieve the goal.

There is a danger, however, to those of us in the program if we concentrate our thoughts only on the difficulty of the task. Despite the overlay of glamour associated with man's first visit to one of his neighbors in space, the job is the same type of technical development which has been the task of our Government-aerospace-industry team in aircraft, missile, and space programs for the last three decades. The work is hard, demanding, detailed, and very often mundane. In many cases, individual subsystems differ only in detail from those developed for other programs. The factor that makes this "the most challenging technical program" is really the total number of systems which must be brought to a mature development status at the same time, and the reliability which must be achieved by each system to provide adequate safety for our human cargo.

Focusing on the difficulty of the task can lead to a state of mind in which we excuse ourselves for lack of performance —be it in schedule, cost, or function—because, after all, this is "the most..." and "how can we be expected to predict accurately when we are working so close to the fringe of the state of the art?" Such thoughts are not only dangerous, they are not true. The program is the sum of its parts, and the individual parts are not "the most..." No "technological breakthroughs" are required to complete the Apollo mission. Each subsystem can, I am sure, be developed within our present cost, schedule, and functional requirements. The question of whether they will be can be answered only by the competence and management discipline with which we attack the task. And if the individual parts are done "on time, within spec." the whole program will, almost by definition, meet its goals.

I have come to the conclusion that "the most difficult" part of this "most challenging" program is really the problem of assuring that all responsible elements within the program understand what their jobs are, and that these many, many tasks are executed with competence and integrity. The Apollo team has been carefully chosen. It can and, I am convinced, will do the job.

Most of us know the lunar mission. Sometime before the end of the decade, the mission pictured in the accompanying diagrams [*pages 16 & 17*] will be flown—although some of the details may change as we gain further insight into the interaction between the mission and our evolving hardware. The astronauts will be away from the surface of the earth for about 196 hours, and the Lunar Excursion Module (LEM) will have operated around and on the moon for more than 30 hours.

The mission itself will be the climax of almost a decade of development activity which today is not yet at the halfway mark.

The program, which will move through several phases before we will be ready for the first mission, was defined in 1961 and 1962. In 1962 and 1963 came detailed design of the spacecraft and its many systems, as well as development of the facilities which will be used to test the equipment [*pages 22-25*] —to seek out on the ground the design weaknesses which otherwise would be found in flight.

Now, in 1964, we are in the year of development test on the individual systems which together will provide the capability to perform the mission.

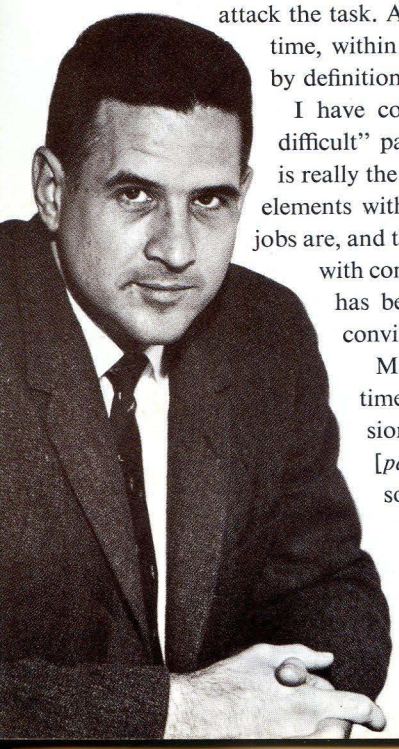
Two important developmental flight tests took place during May. At White Sands, N. M., we tested the launch escape system and the parachutes. The test conditions simulated the aerodynamics of an abort during the most critical phase of the launch environment. The spacecraft did not contain all the systems needed to go to the moon—only the ones actually being tested—mounted on a simple, heavy structure (boilerplate) with the necessary ballast.

A week later, another boilerplate spacecraft was launched from Cape Kennedy atop Saturn 1—one of the largest space vehicles in the world—to test compatibility of spacecraft shape with the launch vehicle and to measure the stresses it must survive as it passes through the atmosphere.

These two important milestones marked the gradual transition of Apollo to a flight test phase where the progress, and problems, will be more apparent to the country.

However, there is still much ground testing to be done. Next year we will be testing full spacecraft with all systems on board, initially on the floors of our laboratories and later in chambers which reproduce the environment of space, including vacuum and temperature extremes.

First flight of the complete command module will take place in 1966, with the LEM flying a year later. The initial



Dr. Shea

No technological breakthroughs are required to complete the Apollo mission. If the individual parts are done on time, within specifications, the whole program will, almost by definition, meet its goals.

flights will uncover those design defects which we were unable to discover in ground tests—either because our facilities could not reproduce the space environment with sufficient rigor or because we were not smart enough to design the proper tests.

Operational practice in earth orbit should begin in 1968, with the first lunar mission coming as soon as all techniques and hardware have been certified.

Although I have described our nominal program plan in a general way, it is literally impossible to predict from our present vantage point exactly when any individual test will be attempted, or even how many times we will have to repeat a given test before we are satisfied with the results.

We believe that the space age has advanced to the point where the designs can be accomplished and tested almost entirely on the ground. We expect the problems encountered in flight to be significantly fewer than in the recent past when we were learning how to design for the rigors of the space environment. Even so, we cannot be sure of the number of Saturn 5 flights, for instance, which will be required before the booster is developed to the point where it can be trusted to carry a human cargo.

Estimates of the number vary from a pessimistic high of 40, based on early ballistic missile experience, to an optimistic low of two, based on our recent Mercury and Saturn experience. Considering that we can fire between four and six vehicles a year, you can get a feel for the band of uncertainty possible in our time estimates.

Actually, recent experience tends to confirm our optimistic predictions. The two-stage Saturn 1, which last January injected into orbit what was then the largest payload launched from the earth's surface, was completely successful, as were the second and third tests in May and September. Its significance lies not alone in the size of its payload—although at long last the United States is second to none in payload capability—nor in its demonstration of a working hydrogen propulsion system, but equally in the fact that it *was* completely successful in its first three launches.

This data point, added to the four successful launches of the one-stage Saturn 1, and the six successful manned Mercury missions, is another strong indicator of the probability that today's optimism will be tomorrow's realism.

But even if every shot were completely successful, it would still be almost impossible to predict the exact date of any given mission, because success in flight comes only at the price of rigor in the ground program. Every failure, every anomaly in our test data must be analyzed, understood and corrected at the expense, if necessary, of meeting any given flight date.

There seems to be no efficient way to circumvent this. If we attempted to provide sufficient contingency time to assure every flight date, our schedules would be much longer than they are, we would not be in a position to capitalize on success, and there would be an attendant increase in total program cost.

With the inevitable uncertainties just discussed, our scheduling becomes, in effect, a tool with which we can establish our earliest practical flight dates, the rate at which we can deliver systems from our factories, and the rate at which we can perform flight missions. In a sense, this determines the capability we have to carry out the program, and these are the quantities against which our performance can be measured. We schedule hardware availability so that we can take advantage of success and so that any individual failures do not necessarily affect follow-on test objectives.

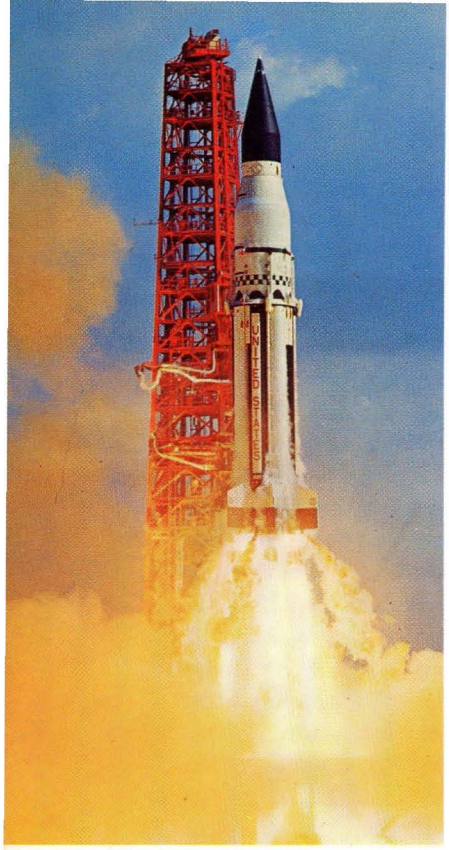
From the capabilities and the number of test objectives which must be met, we can develop an estimate of the most probable date for completing the lunar mission—allowing for what we consider the number of contingencies which will be encountered. We can also estimate an earliest probable date—the optimistic estimate which results from very few problems. There is also a latest probable date—and this can be several years later than the most probable date.

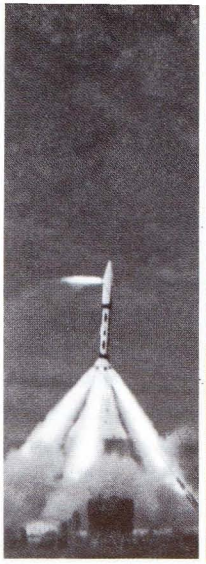
At the present time the most probable date for accomplishing the goal of Project Apollo is late this decade. However, this date is critically dependent on continued financial support from Congress at the levels we have requested. The program will reach its funding peak in fiscal 1965, and is almost at the peak rate now. Any serious curtailment of funds will mean adjustment of our initial launch dates and our capability, thus shifting all our estimates. However, at the present time, we still have more than a fighting chance to meet our initial goals.

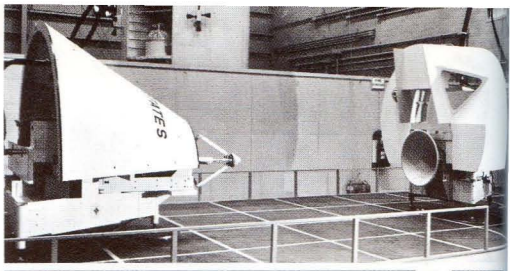
The exact reasons why NASA chose the name Apollo for the lunar program may have been mere happenstance but, considering the events of the past three years and the state of the program today, it was a remarkably apt choice.

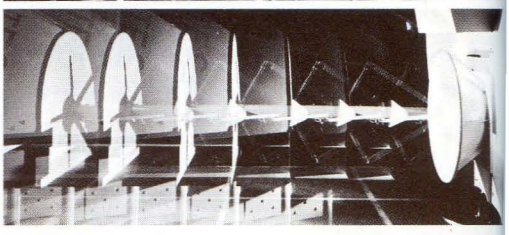
The justification of the program relates to its origin, character, and functions. Larousse, in the *Encyclopedia of Mythology*, points out that "uncertainty surrounds Apollo's origin. Some authorities believe he came from Asia . . . others, that he was brought by the Greeks from the north in the course of their migrations. It is difficult to decide between these two opposing schools of thought because, though both advance plausible arguments, neither can actually prove its case."

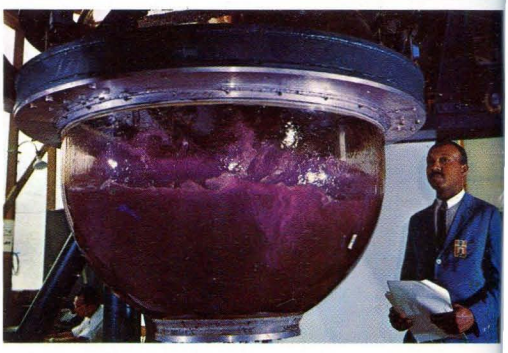
The similarity of today's debate over the lunar program shows that mythologists are not much different from scientists











First three launches of two-stage Saturn 1 were completely successful. Last January, SA-5 (left) injected into orbit largest payload in history. In May and September, SA-6 and SA-7 successfully tested boilerplate Apollo Command and Service Modules. Also in May, another important Apollo milestone: Little Joe rocket pulled Command Module free from launch vehicle (above) and parachutes lowered boilerplate spacecraft "without a scratch" to earth. Test conditions simulated aerodynamics of abort during most critical phase of Apollo launch.

and legislators. We continue to argue whether the lunar program should be of Asiatic origin, that is, purely a response to the Soviet space program—a national status symbol tied to the nuances of international politics and cocktail party talk in Moscow—or whether it is truly a sound national program, rooted in our nation's heritage of exploration, motivated by the conviction that we must continue to expand into every new frontier to reap the benefits it holds for both the enhancement of our economy and the insurance of our defenses.

Unfortunately, only when this national need for the lunar program is understood and accepted will it enjoy sufficient stability to ascend to a secure position in the firmament.

Larousse goes on to point out that Apollo's "functions are so multiple and complex that it is often hard to connect one with the other"—and this, of course, is one of the difficulties in the lunar program debate. As with any major national undertaking, there are a number of reasons which, all taken together, justify the commitment of so large a total resource.

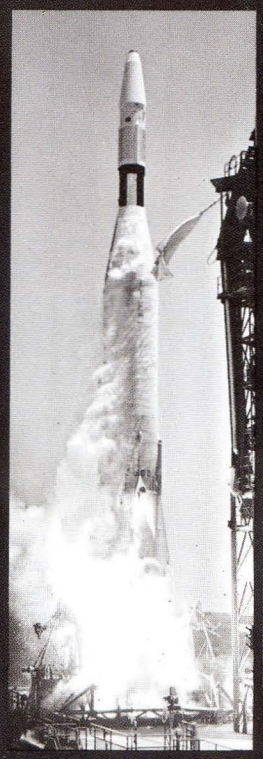
To the Greeks, Apollo "was first of all a god of the light, a sun god—without, however, being the sun itself, which was represented by a special divinity."

From our technologically parochial point of view, the "special divinity" today is the development of the nucleus of a national space capability with both peaceful and defensive potential. The lunar landing is not an end in itself. It does, however, provide an essential focus to the development of our national capability to operate in space—to obtain the skills we might some day need for defense—without prejudging the military uses of space and perverting, perhaps unnecessarily, the one environment in which men do not carry arms against each other.

The Greeks apparently could accept this duality of function without feeling it was self-contradictory—perhaps Mount Olympus was not organized into as many agencies as Washington. Larousse states that "as a solar god, Apollo made the fruits of the earth to ripen...in addition, he protected the crops..." He was "the god of sudden death; but also a healer god who drove away illness," as well as "the god of divination and prophecy."

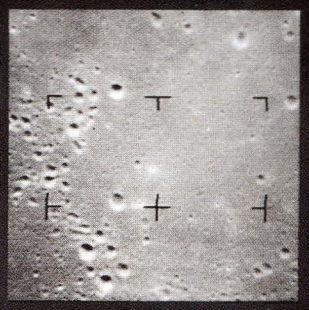
"He was a musician god, the god of song and lyre; a builder and a colonizing god who, as Callimachus says, 'delights in the construction of towns of which he himself lays the foundations.' "

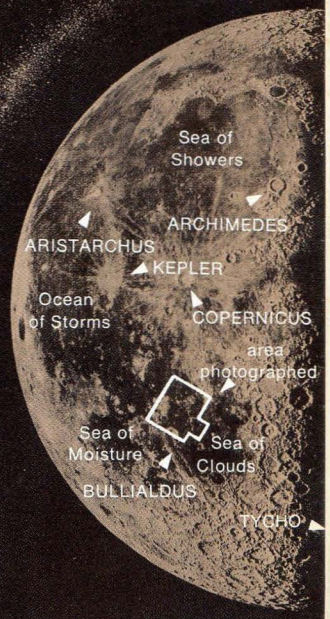
Although the analogies are occasionally slightly strained, this litany of Apollo contains the seed of the many-faceted justification of the program; the economic fallout which is an inevitable consequence of so broad a development program; its potential contribution to both offensive and defensive military space applications; the increased ability to heal which may result from our extensive aerospace medical research; the prophetic implications of mankind's release from the fetters of gravity to achieve the lunar heights; the implications



Closeups of moon augur well for LEM landing gear design.

Atlas-Agena (left) lifts off with Ranger 7 (below), July 28. Ranger transmitted 4,316 pictures of lunar surface back to earth before hitting the moon. Scientists called photo resolution 2,000 times greater than that of earth-based telescopic photos of moon—vastly exceeding expectations. New knowledge of lunar surface is not expected to require major design changes in LEM landing gear.





North American's partial mockups of Command and Lunar Excursion Modules (upper left) are used for simulated docking of two spacecraft. Grumman engineers (left) are studying effects of sloshing, swirling, and vortexing—caused by spacecraft vibrations—of propellants in LEM ascent and descent (half-shown) fuel tanks.

of Apollo's role in colonizing either a lunar base or a space station; and, finally, the lyrical Pied Piper effect the program has on the youth of our country and the consequent beneficial effect on their motivations and education.

However, the *Apollogetica* [to coin a word] is somewhat more than mythical. The most important point is that Apollo acts as a natural focus for the development of a national capability which will bring to mankind mastery of this new environment. The range of possible uses of space is really the listing of the things we can think of now. There is tremendous potential for science, for the civilian economy, and for defense—which actually will prove important. What new uses will arise, we are not smart enough to predict. And this, I believe, is the crux of the problem.

In the limit, the commitment to space is based on an intellectual belief that it will prove important—just as adventuring out on the oceans, exploring our own West, developing the airplane, and understanding the atom have been fantastically important to our present civilization.

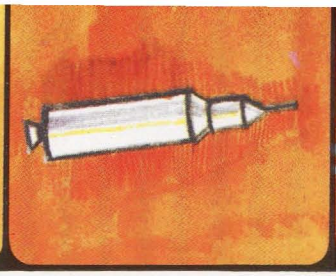
But it is hard to sustain an intellectual conviction in the face of political and budgetary pressure. The reality of today crowds in on the promise of tomorrow. And this, I believe, is why this country, which prides itself on being farsighted and pioneering, can, upon occasion, grossly underestimate the impact of technological change—as in the case of the ballistic missile and the early days of space—and even underestimate the need for defense, as has been the case before many of our previous wars.

In 1961, when the lunar program goals were established, the landing date was set within this decade and the program cost estimated at less than $20 billion. The program goals are still the same, and the schedule and the budget are equally valid today. The question is whether this country can maintain an "intellectual conviction" for a decade. If we can, then sometime before 1970 the astronauts who travel the long miles to their rendezvous with history may well have the thoughts expressed by C. S. Lewis in his *Out of the Silent Planet:*

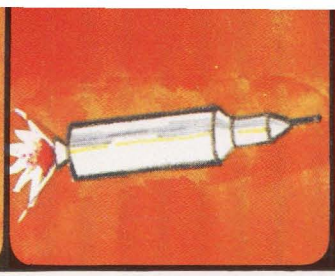
"He had read of 'Space'; at the back of his thinking for years had lurked the dismal fancy of the black, cold vacuity, the utter deadness, which was supposed to separate the worlds. He had not known how much it affected him till now—now that the very name 'Space' seemed a blasphemous libel for this empyrean ocean of radiance in which they swam. He could not call it 'dead'; he felt life pouring into him from it every moment. How indeed should it be otherwise, since out of this ocean the worlds and all their life had come! He had thought it barren; he saw now that it was the womb of worlds, whose blazing and innumerable offspring looked down nightly even upon the earth... No, 'Space' was the wrong name. Older thinkers had been wiser when they named it simply 'the heavens.'"

1 Apollo, three astronauts aboard, is launched with 7.5 million lbs. thrust

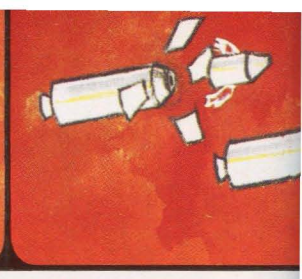
2 Second stage J-2s burn 6½ minutes, fall away; third stage ignites



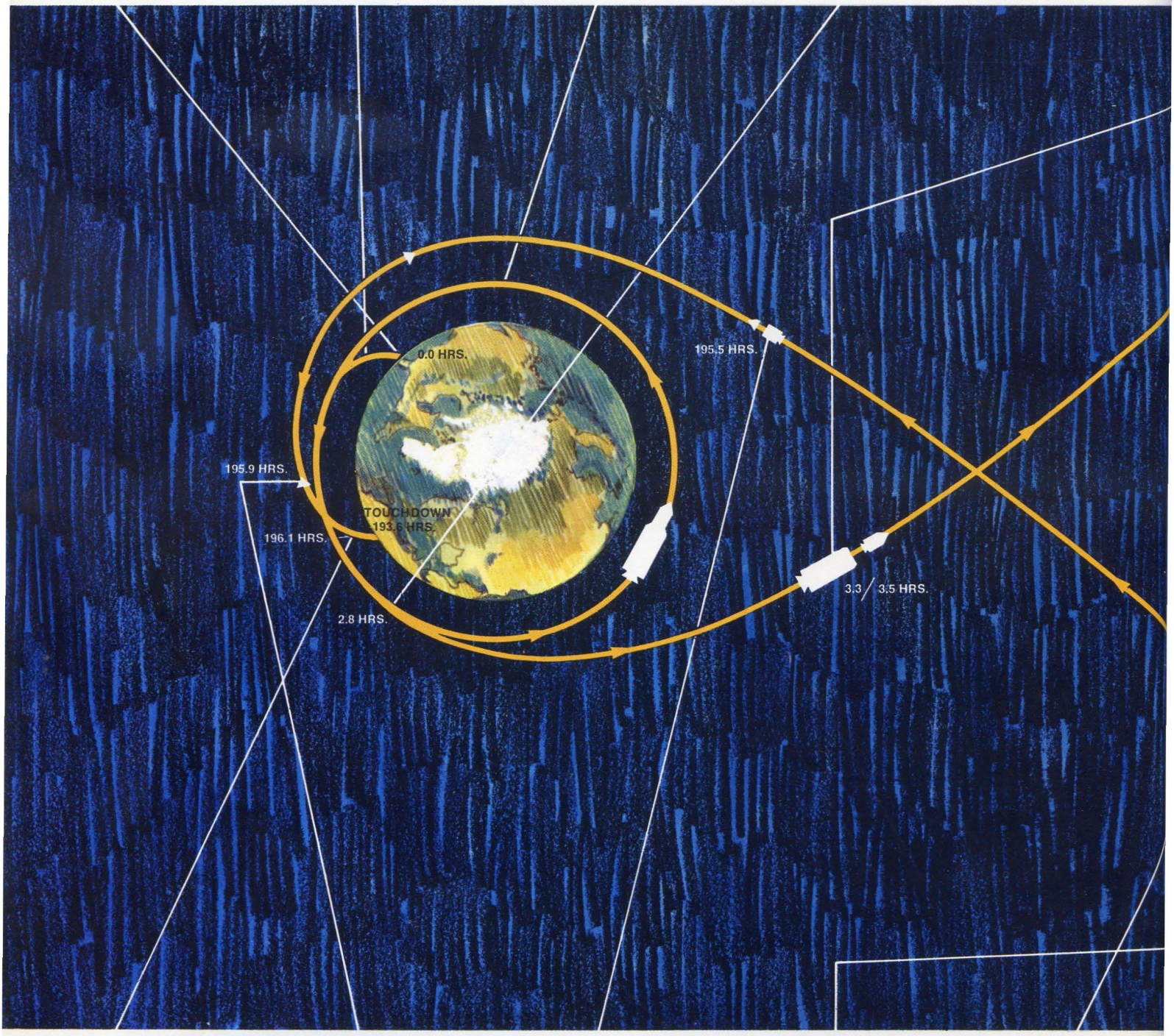
3 J-2 third stage shuts down, Apollo orbits earth 1½ times for checkout



4 J-2 re-ignites, boosts spacecraft into trajectory for the moon



5 LEM adapter separates; Command and Service Modules separate from

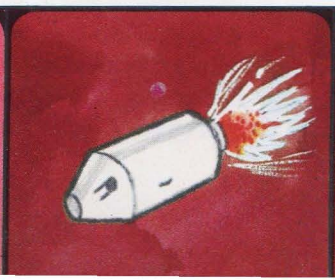


18 Spacecraft slows below sonic speed, three chutes lower it to earth

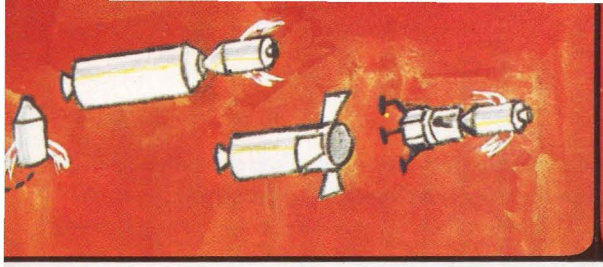
17 Three astronauts hurtle back into earth atmosphere in Command Module

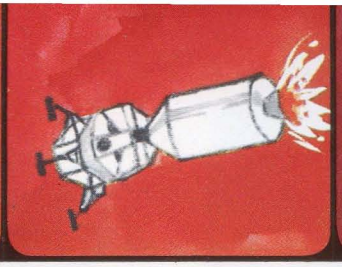
16 A 40-mile-wide earth re-entry corridor lined up, Service Module is discarded

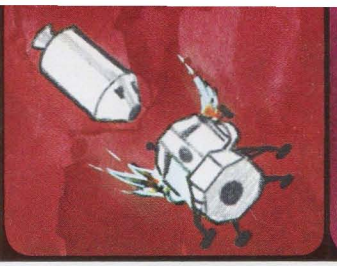
15 Spacecraft accelerates from 4,000-mph lunar orbit into 6,000-mph earth course

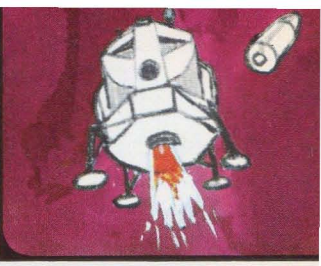


14 Two astronauts crawl into Command Module; cast-off LEM keeps orbiting moon







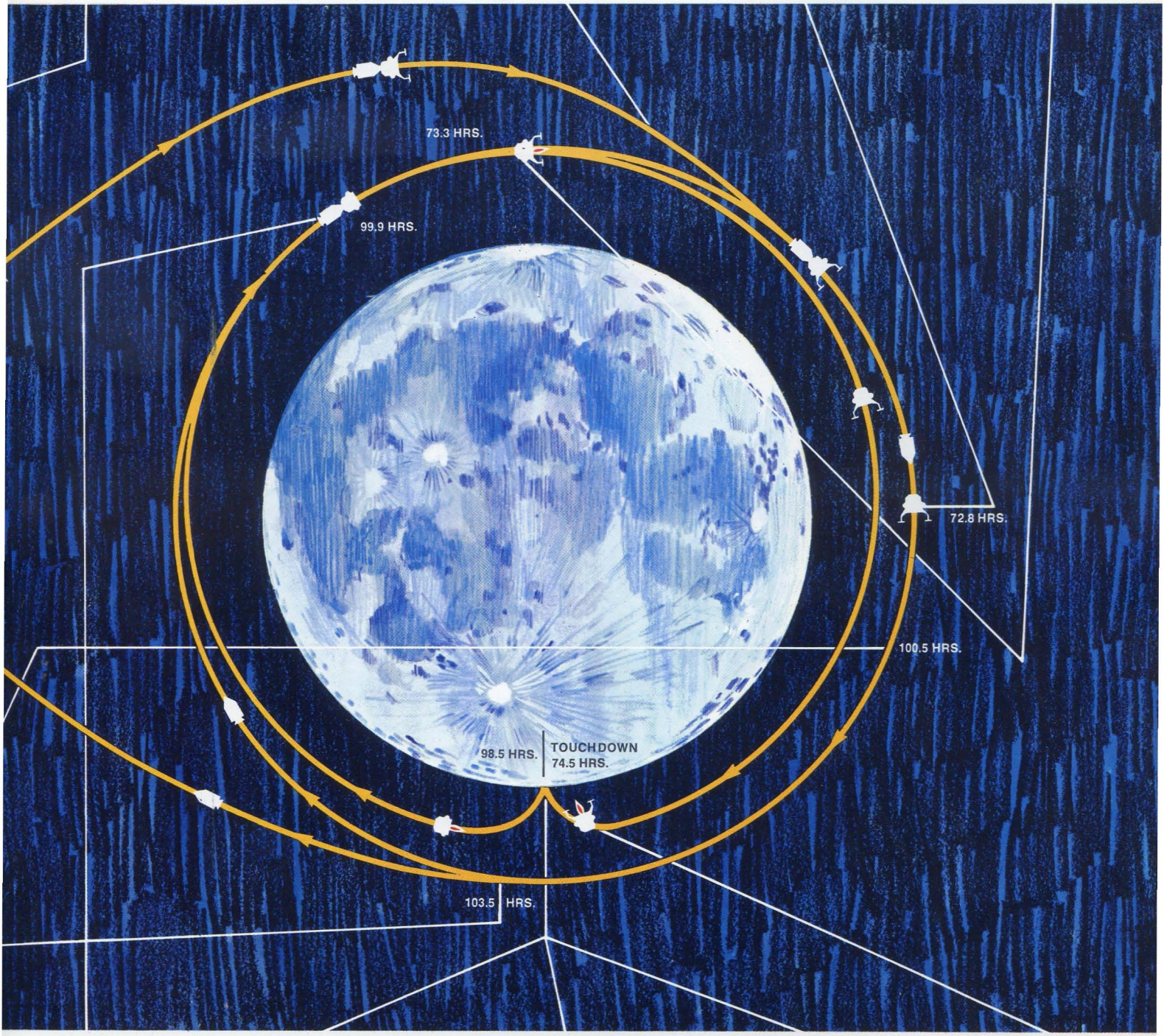


d stage, turn around, l dock nose-to-nose with LEM, whose fairing then falls away. Service Module pulls LEM away from abandoned third stage

6 Nearing moon, Service Module slows LEM enough for 100-mile-high orbit

7 Two astronauts crawl from Command Module into LEM and vehicles separate

8 LEM's 8,800-pound-thrust landing engine fires about one minute



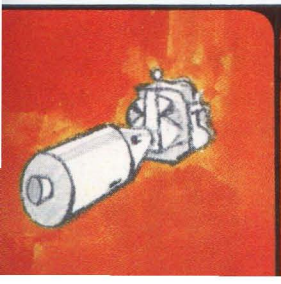
3 LEM and Command Module coast halfway around moon, then dock

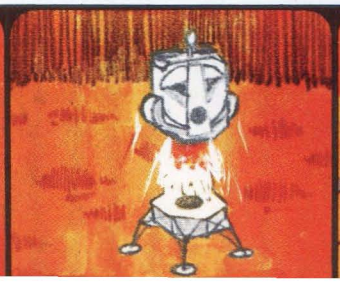
12 After 24-hour stay, LEM blasts off, leaving behind landing stage

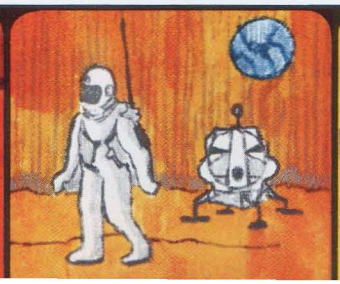
11 Astronauts take four-hour turns exploring the moon's surface

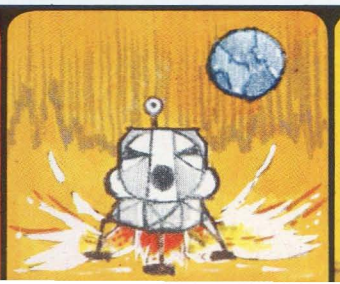
10 After hovering 300 feet above moon, LEM lands at less than 7 mph

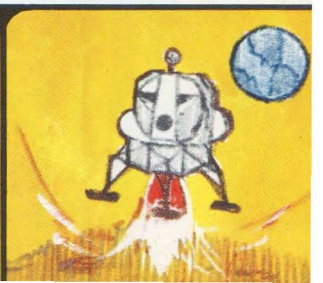
9 LEM orbits 4,000 mph to 10 miles above moon, re-ignites engine











The Engines

First generation Apollo propulsion already has won payload and reliability records. Second generation, to fly in 1966, is being followed closely by the third—the huge Saturn 5 that should do the job.

by Dr. Werner von Braun, Director, Marshall Space Flight Center, NASA

Giving a status report of the Saturn launch vehicle family can be compared roughly to describing the action in a three-ring circus—minus popcorn and clowns—where three new and daring acts are underway by highly skilled performers.

Three separate members of the Saturn family are being developed under the direction of the Marshall Space Flight Center at Huntsville, Ala., for NASA's manned space flight program. The high point of the Saturn program will come when the Saturn 5 launches the Apollo spacecraft with its three-man crew for an epic voyage to the moon and back to earth.

While the advancement of launch vehicle technology and the achievement of manned lunar landings in Project Apollo are the initial aims of the Saturn program, these versatile launch vehicles are capable of numerous other missions—both manned and unmanned. The Saturns will help provide the United States with the broad capability to explore space that is NASA's ultimate goal.

After four years of steady expansion, the Marshall Center, home of the Saturns, has reached a plateau in growth. Our annual budget is about $1.5 billion—93 percent of which is spent on contracts with industry. To supervise this tremendous work volume and to carry out the related in-house engineering and research work, in addition to other currently assigned projects, our Civil Service personnel has risen to 7,500. Our laboratory, test, and support facilities at Huntsville have been expanded, and are now valued at a quarter-of-a-billion dollars. New construction includes a $50-million test area for static firing of F-1 and J-2 engines and the booster, or S-1C stage, of the Saturn 5. Almost completed, it will be operational within the next six months.

In addition, the Marshall Center operates NASA's 845-acre Michoud site in New Orleans, where contractors are now fabricating and assembling the first stages of all three Saturns. Employment at Michoud totals 10,000.

Thirty-five miles northeast of Michoud by Intracoastal Waterways, NASA is building a test site on 141,950 acres of land in Mississippi and Louisiana. Cypress and pine trees have been pushed aside, and some 1,500 construction workers are now building a $270-million complex for testing the first and second stages of the Saturn 5 moon rocket. By the time the construction workers leave in 1966, some 2,500 permanent employees will have arrived to conduct static testing programs.

The bulk of the 93 percent of the Marshall Center's current budget spent in industry goes to contractors for stage and engine development. Manufacturing, test, and other support facilities have been provided in numerous contractor plants, many of which are in California. But since a high percentage is passed on to a legion of subcontractors and component vendors, there is hardly a state in the Union that is not benefiting from the Saturn program.

Saturn 1, the first generation vehicle, continued an unbroken string of flight tests when SA-7 provided another successful launch from Cape Kennedy in September. Its middle-sized brother, Saturn 1B, will be ready for launching early in 1966, and Saturn 5, its big brother, will be ready for a countdown in 1967.

The Saturns are handled as separate projects at the Marshall Center, and yet all three are interconnected in an obvious blood relationship. The Saturn 1 is the test bed for large launch vehicle technology and a host of vital systems and subsystems. The booster for the Saturn 1B is essentially a lighter, improved version of the booster for the Saturn 1. The Saturn 1B and 5 make common use of the S-4B stage. All three Saturn launch vehicles use a cluster of engines that burn kerosene and liquid oxygen in the booster stage, while liquid oxygen and liquid hydrogen are used as propellants in all upper stages. The most striking family trend among the three vehicles can be seen in the instrument units which house the electronic brains of the Saturn. Each is a planned outgrowth of its predecessor, modified and expanded as the Apollo space missions increase in complexity and sophistication.

Only a relatively small number of Saturn rockets are being flight tested, compared with previous vehicle development for military purposes. The costs in both time and money for such large and complex launch vehicles prohibit extensive developmental flight testing. To offset this limited launch schedule, heavy reliance is placed on extensive quality and reliability assurance programs and thorough ground testing [*see article beginning on p. 22*]. For this purpose, we build several versions of each stage that never fly for structural, dynamic, and static testing and for facilities checkout.

When Saturn 1 went to the launch pad the first four times, only the first stage was live. In a stepped-up schedule, the first launches of the Saturn 1B and the Saturn 5 will be in an "all up" condition—all stages will be live and the instrument units will be capable of flying the entire spectrum of space missions involved in the Saturn/Apollo program.

While the primary mission of the Saturn 1 is the advancement of launch vehicle technology, as secondary missions it is placing into orbit boilerplate versions of the Apollo command module and three meteoroid detection satellites.

SA-7 continued the overall mission of launch vehicle development. Just like SA-6, it orbited a boilerplate Apollo command module, jettisoned the launch escape system after ignition of the second, or S-4, stage, and tested the engine-out capability of the eight-engine booster after the flight was well underway.

Meteoroid detection satellites are scheduled as payloads for SA-8, SA-9, and SA-10. The final Saturn 1 flight is expected in mid-1965. The first four Saturn 1 flights were launched from Complex 34 at Cape Kennedy, while flights SA-5 through SA-10 utilize Complex 37B.

Present plans call for 12 Saturn 1B vehicles to be launched, including two for launch vehicle development and command module re-entry tests at superorbital speeds. If these tests confirm adequate launch vehicle reliability, the following six 1B launches will support a series of manned orbital experiments involving the Apollo command, service and lunar excursion modules. The remaining four Saturn 1's are projected as backups or will be assigned to other space missions.

Saturn 1B launches should begin early in 1966 and the currently approved number of launchings should extend through mid-1968.

The Saturn 5 launch series will overlap the 1B series with 15 flight vehicles originally scheduled for Project Apollo. As in the Saturn 1B program, early manned flights will be determined by the success of vehicle development launches. Here's a rundown on the Saturn launch vehicle family:

S-1 Stage of Saturn 1—The Saturn 1 booster is a cluster of nine propellant tanks and eight H-1 engines produced by Rocketdyne Division of North American Aviation, Inc. Each engine produces 188,000 pounds of thrust in the S-1. By mid-1964 Marshall had received 160 tested H-1 engines of a 180-total to be delivered through 1964.

All ground test versions and eight flight S-1 stages were designed, produced, and tested at the Marshall Center. The Chrysler Corporation is producing two S-1 stages at Michoud. Chrysler's first booster has been static tested at MSFC (Marshall Space Flight Center, Huntsville, Ala.), and will be delivered to Cape Kennedy for launching.

S-4 Stage of Saturn 1—Designed and developed by Douglas Aircraft Co. in Santa Monica, Calif., the S-4 stage was successfully flight tested for the first time last January 29 on SA-5, and again on SA-6 and SA-7. It is powered by six RL-10 engines, each having 15,000 pounds of thrust, developed by the Pratt and Whitney Division of United Aircraft Corp. at West Palm Beach, Fla.

The S-4 stage is pioneering in the Saturn programs in the use of the cryogenic oxygen/hydrogen propellant combination. While this exotic fuel gives us 40 percent more thrust per pound than kerosene, it presents greater difficulties in handling.

S-1B Stage of Saturn 1B—Chrysler is producing S-1B stages at

Michoud. While it is essentially the same as the S-1 booster, refinement in design and engineering has resulted in weight reduction of several tons.

The H-1 engines in this stage are uprated to a 200,000-pound thrust level, giving the S-1B stage a total thrust of 1.6 million pounds.

Fabrication of the first S-1B stages is underway at Michoud. The S-1B ground test program is concentrated in the 1964-65 period in preparation for the first launch early in 1966.

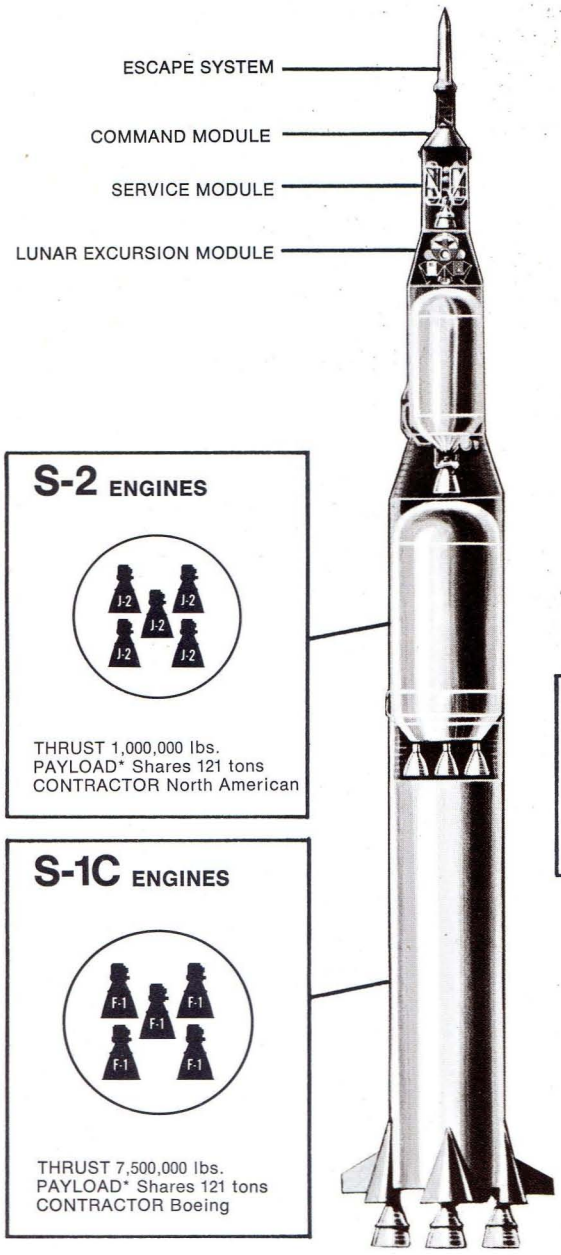
S-4B Stage of Saturn 1B and Saturn 5—Designed and developed by Douglas at Santa Monica and Huntington Beach, Calif., the versatile S-4B will perform first as the second stage of Saturn 1B and then as the third stage of Saturn 5. On the Saturn 5, it will have restart capability.

The stage uses a single J-2 engine which burns liquid hydrogen and liquid oxygen to produce 200,000 pounds of thrust. The J-2 is produced by Rocketdyne at Canoga Park, Calif.

The battleship static test firing program and structural testing for the S-4B stage are now in progress, and the all-systems stage was to be completed in November. The dynamic test stage will be ready in December, and fabrication will begin by year's end on the first flight stage.

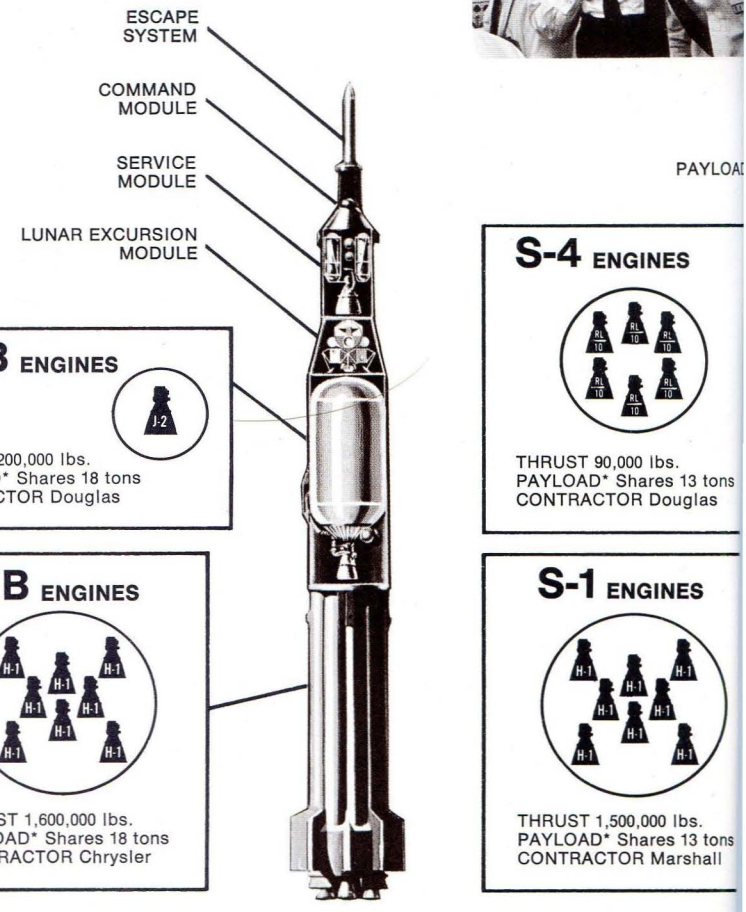
The Saturn 1B lends itself extremely well to carrying a third stage. With Centaur as a third stage, the Saturn 1B could launch 12,000 pounds on a lunar mission or send 9,000 pounds on a planetary mission. This flexible vehicle will prove to be a reliable workhorse for space exploration.

S-1C Stage of Saturn 5—The huge booster stage for the Saturn 5 was designed and is being developed jointly by the Marshall Center and The Boeing Co. The Marshall Center will build two ground test stages for structural and all-systems testing, and the first two flight stages at Huntsville. Boeing will



SATURN 5

Flanked by George Mueller and Eberhard Rees, von Braun's deputy director, author watches booster performance plot boards moments after SA-6 launch. Minutes earlier, von Braun is shown peering through middle periscope (center of three dark columns).



SATURN 1B

*into 100-nautical-mile orbit.

build the dynamics test stage and facilities checkout stage, as well as the remaining flight stages at Michoud.

More power will be harnessed in the S-1C than any other stage or entire launch vehicle under development in the United States. It clusters five F-1 engines, developed by Rocketdyne at Canoga Park, Calif. Burning kerosene and oxygen, all five engines produce a total of 7.5 million pounds of thrust.

The first production F-1 was accepted by the Marshall Center in October 1963, and the second engine was delivered in April.

Static testing of all five engines will begin at Marshall in early 1965. The new S-1C test stand built for this purpose was turned over to us by the contractor in May, and instrumentation is now being installed.

Structural testing of the S-1C stage has been underway at Huntsville for some time, and assembly of the first flight stage began in June.

S-2 Stage for the Saturn 5—This stage is being designed and built by North American Aviation, Inc., at Seal Beach, Calif. Clustering five J-2 engines, it provides a total thrust of one million pounds.

The first ground test S-2 stage will come off the line before the end of this year. Work is underway on all five ground test versions of the S-2, and the buildup of the first flight stage began this summer.

Static testing of a battleship S-2 tankage with a cluster of five J-2 engines will begin at Santa Susana, Calif., late this year. Buildup of the first flight stage was to begin in early fall. It will be delivered to Mississippi Test Operations early in 1966 for acceptance testing on static stands, the foundations of which are now under construction.

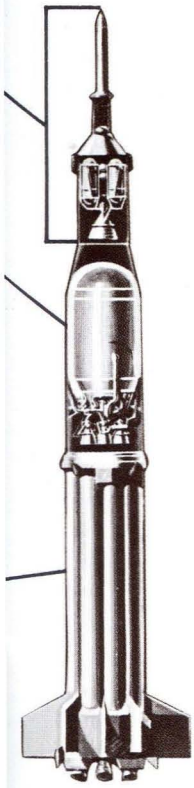
Instrument Units—The first operational Saturn instrument unit was flown on SA-5 in January. The instrument units will be operational on all future Saturn launches, including the first firings of the Saturn 1B and Saturn 5.

The instrument unit for the first 1B launch will contain several significant changes and additions over the Saturn 1 instrument unit, because of its more complex mission. Further changes for the Saturn 5 missions will not be as far-reaching.

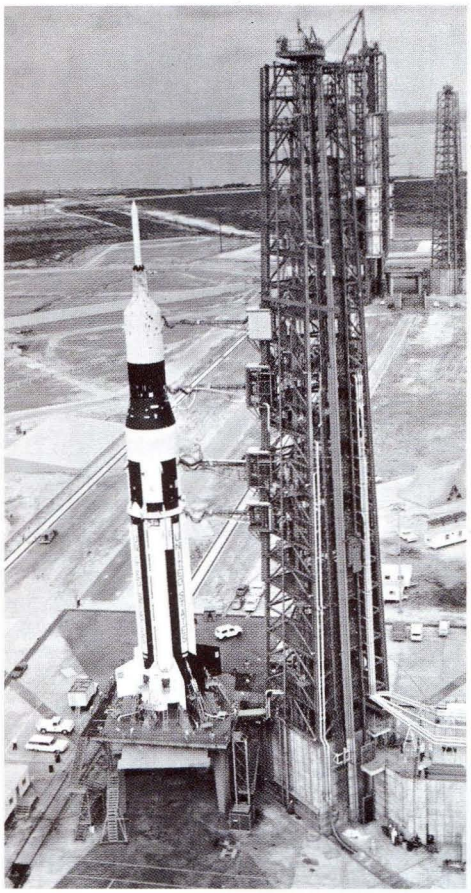
Instrument units are produced jointly by the Marshall Center and International Business Machines.

Saturn progress can be summarized in one brief sentence: It is a going concern. The first generation Saturn is flying. The second and third generations are following close on its heels.

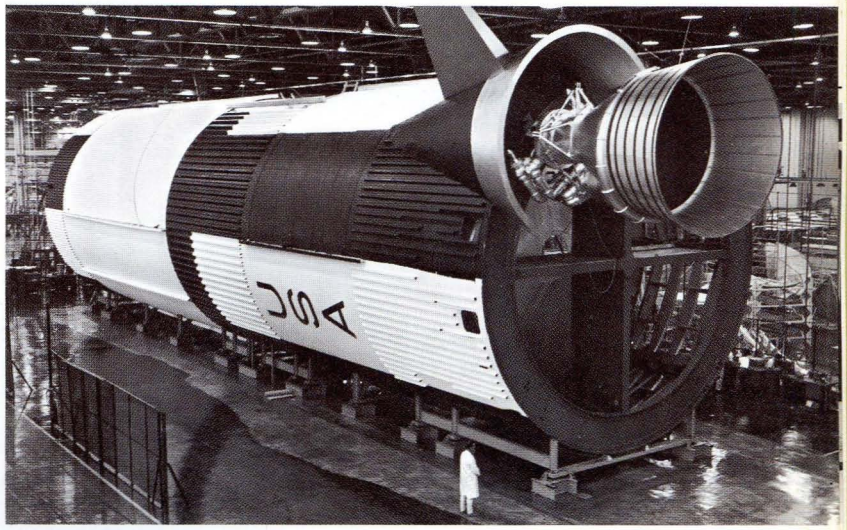
The Saturn vehicles are opening the gates to a bright, new frontier on the ocean of space.



SATURN 1



Saturn 1 (left) may still hold world's weight-lifting record. But Saturn 5 (partial mockup below), actual man-on-moon launch vehicle, is designed to lift more than nine times as much into 100-nautical-mile orbit, towers nearly 2½ times taller. Bottom engines of Saturns 1, 1B, and 5 burn liquid oxygen and kerosene; upper stages burn liquid or cryogenic oxygen and liquid hydrogen.



Space on Earth

By Bernard Kovit, Associate Editor,
SPACE/AERONAUTICS magazine

All is in virtual readiness for the greatest ground and flight test program man has yet undertaken—to put the Apollo spacecraft through its moon-bound mission paces. The chips are down. The design will either prove itself or spoil a dream. A fantastic array of R&D test devices, miracles of modern technology, has been set up at centers across the nation. And the early Saturns have already begun to hurl boilerplate Apollo hardware into orbit. If man's ingenuity has its way, we will soon have a man-rated moonship.

We were not long into the age of spaceflight before it became clear that man's expeditions beyond earth's atmosphere would require construction of strange earthbound vehicles and contrivances—the massive space chambers and flight-operations simulators in which man first tried his new space "wings." We now have been left many such ingenious mementos from Mercury and Gemini, but they are as museum pieces compared to the flight simulation and full-scale systems test facilities rapidly taking form at various NASA bases for the pioneering Apollo spacecraft.

The kind of testing that will be done on the moonship hardware will, in most cases, involve simulated space and lunar conditions, because most of the modular craft will see service only in space. For example, the service module will power the ship to and from the moon and will be abandoned on the final leg of the return trajectory. The LEM (Lunar Excursion Module), which is our first true spacecraft, will operate as a ferry between lunar orbit and lunar surface and will be left circling in lunar orbit after bringing the lunar explorers back to the orbiting Apollo. Then, after the moonship has been accelerated along the return trajectory, only the manned capsule itself will re-enter to make an intact earth landing.

Since so many crucial Apollo designs and mission operations can be truly proven only out in space, and since this nation will never take any undue risks with human life in space, our only recourse has been to undertake one of the most extensive flight and ground test programs in technological history. The flight test phase has already been underway for nearly a year, using the first of the giant Saturn family of space boosters, Saturn 1, to fire boilerplate Apollo hardware into orbit.

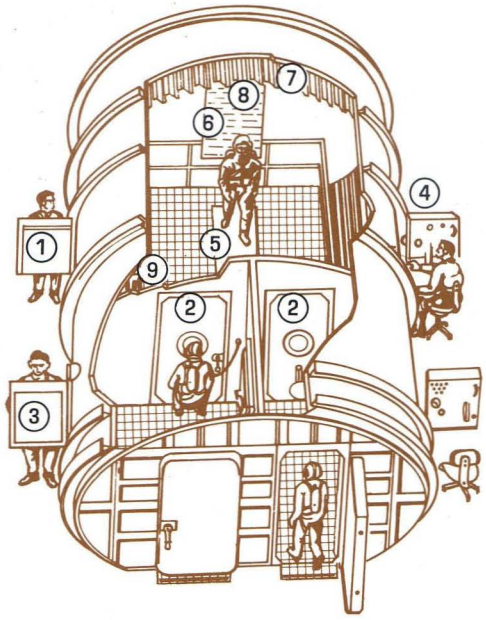
Seven straight successes have already been notched in these Saturn test flights, the latest having been the SA-7 which went up in September. Later, in early '66, the more powerful, next-generation Saturn 1B booster will begin putting into orbit active "all-up" Apollo systems for tests and maneuvers simulating what will have to be done en route and in lunar orbit. Saturn 5 operations should get underway around mid '67 and Apollo astronaut training and equipment performance will be perfected in earth orbital flights as well as during the first of several planned manned and unmanned circumlunar test flights.

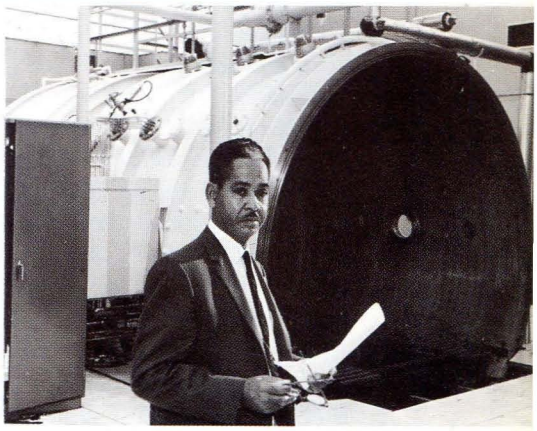
Perhaps not as spectacular but certainly no less important, the vast Apollo ground test program will be conducted in a far-flung network of NASA installations sprawling across this nation from such places as a barren patch of badlands desert at the southern end of the legendary *Jornada del Muerto* (Journey of Death) at White Sands, New Mexico, to the table-flat Clear Lake region near Houston, Texas, and the lush tidal lowlands near Hampton, Virginia.

At Manned Spacecraft Center's White Sands facility, which has been the site of successful Little Joe 2 tests of the Apollo pad-abort and launch escape system, a group of large hangar-like buildings and gantry structures are nearing completion for static testing Apollo spacecraft powerplants. Easily the most impressive buildings at NASA's Propulsion Systems Development Facilities—as the 10-mile-long chunk of the missile range is called—are the twin Preparation Buildings, one of which will be used to check out the 21,900-pound-thrust service module engine. The other will serve the same purpose for the LEM's 10,500-pound-thrust lander and 3,500-pound-thrust takeoff engines.

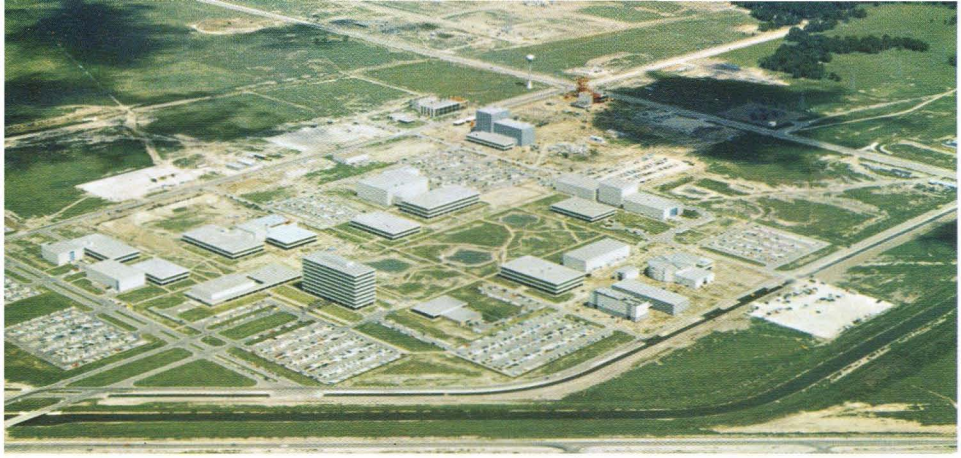
About 2,000 yards away from the preparation buildings, the black asphalt ribbons that extend from them pass fences of blinking warning lights that define the safety perimeter of the static firing area and connect with Service Module Test Stands No. 1 and 2. The control center forms a triangle with the two stands, its banks of computers and data recording/processing units linked by miles of coax cabling to the two engine test stands. Nearly 600 channels of engine-performance data will be taken from each test firing.

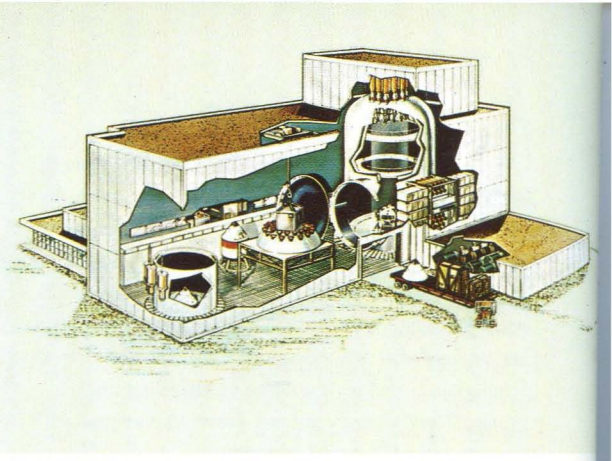
Engineers and technicians from MSC's WISMR Operations Office (already joined by hundreds of NAA and Grumman personnel) have completed the plumbing installations for the service module engine at test stand No. 1. The first engine, which was flown into White Sands earlier this year,





Man, as well as machine, must be "guinea-pigged" under space conditions unnatural to earth. This man-rated space chamber at Hamilton Standard simulates vacuum, thermal, and solar heat flux conditions of cold, black space. In emergency, pressures in main and one antechamber are equalized at 3.5 psi in three seconds, permitting observer to enter. A minute later, all chambers are at atmospheric pressure, astronaut subject can be removed to adjacent medical room.





has been installed in the 45-foot-high stand and mated to the propellant system. Initial firings have begun.

In yet another area, separated from the service module test stands by a typical badlands strip of arroyos (almost suggestive of a moonscape), are three more static test structures and the concrete and steel ribs of a rapidly rising control center. These facilities are designed for testing the LEM's ascent and descent stage propulsion and its attitude control thrusters.

Stands No. 3 and 5 [*photos page 25*] incorporate large steel cocoons which will enclose the LEM engines and allow them to fire under conditions simulating the rarified lunar atmosphere. Stand No. 4 will be for firings at ambient, or local atmospheric, pressure.

Plans are to exercise the Apollo propulsion units in as realistic a manner as possible. In testing the LEM propulsion, for instance, it would be given the same kinds of commands it will receive from the astronauts manually, or from the on-board guidance computer automatically during its lunar mission. The critical throttleable power ratio (10:1) of the lander engine will be tested and retested, as will the service engine's ability to restart and cut off instantly.

As with any piece of highly sophisticated equipment—and doubly so for equipment that has to operate with clockwork precision the very first time it's called upon in space—there is a vast number of unpredictable variables that must be ferreted out. The alternative is to put the system up in space, which obviously can't be done because the risk would be too great and the cost too high.

So the only feasible approach is to simulate at the ground firing stand an environment that permits checking the engine's performance at near-altitude conditions. Doing this is no mean feat because, while it is one thing to build a fairly large environmental test chamber that will reproduce space conditions, it is quite another to get a device that will both do this and swallow the particle-ridden exhaust of a rocket engine.

This will be done at White Sands by a system of diffuser-ejectors at the exhaust end of the steel engine enclosure. Steam injected into the diffusers at high velocity will vent away from the enclosure, and it and the downdraft created by the rocket exhaust itself are expected to evacuate the enclosure.

Present plans call for the initial test firings to begin early in '65 and to continue through mid '66. The myriad data that will come pouring in from both the LEM and service module engines will be plowed back into the final engine development programs to give the utmost assurance of successful performance during early flight tests.

Even more impressive are the size and number of Apollo laboratory and test facilities at MSC-Houston. For example, the Space Environment Simulation Lab [*photo page 24*], when completed, will include two huge man-rated space simulation chambers, one of them the world's largest.

This mammoth Chamber A is 65 feet in diameter, a stainless steel vessel towering 120 feet. In it, MSC plans to exercise spacecraft up to 75 feet high and 25 feet in diameter. Here is where the Apollo spacecraft will be given its maiden systems test checkout.

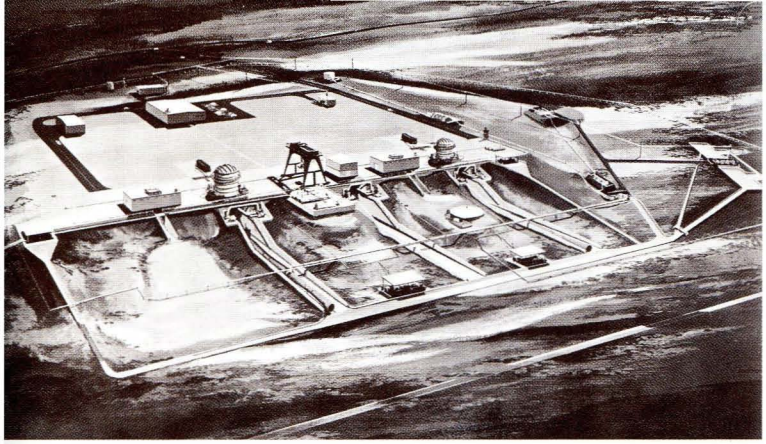
Inside the cavernous chamber is a large, 45-foot-diameter rotating platform that MSC engineers call the "lunar plane." This huge disc will be able to support a spacecraft weighing up to 150,000 pounds. It can be made to rotate ±180 degrees, either manually or automatically, at rotational speeds of up to nearly 1.7 rpm.

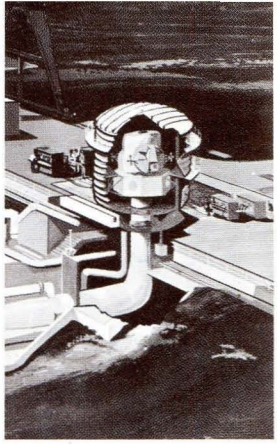
While the spacecraft is rotating on this plane in the way it would in space, it will be bathed in simulated solar radiation streaming in from units in the circular chamber walls and dome. Thus, the "sun's" position relative to the moonship can be changed as it would on a typical lunar trajectory. The carbon-arc simulators have a range of 60-140 watts per square foot and are packaged in modular groups.

To simulate thermal conditions of the mission profile, the interior of the chamber is lined with heat-sink panels, coated black and nitrogen-cooled at around 80 degrees K. It will be up to the ingenuity of the chamber designers to see that, to the maximum extent possible, the rotating space vehicle will see only heat-sink surfaces in the chamber in order to give it a constant radiation environment.

In all, the moon will be able to chill the vehicle at temperatures as low as —315 degrees F and sear it at up to +297 degrees. The chamber simulates part of this range. Its fantastic vacuum-pumping system, comprised of mechanical and diffusion pumps and a —423 degrees F cryopump, will allow the big chamber to be pumped down to 1×10^{-5} torr (vacuum conditions at 300,000 feet above earth) in just under 19 hours.

The smaller chamber B, a 35-foot-diameter, 43-foot-high steel upright cylinder, will be able to do nearly everything the giant can do, but on a lesser scale. Its fixed lunar plane will support a spacecraft module measuring up to 13 feet in diameter and 27 feet in height and weighing up to 75,000 pounds. It will have a top-positioned "sun" only, which would be an adequate arrangement for testing in discrete spatial and lunar conditions.





At MSC (Manned Spacecraft Center, Clear Lake, Houston, Texas) (extreme left), two man-rated space chambers are nearing completion (center), the taller to be world's largest. All Apollo spacecraft propulsion engines (Service and Lunar Excursion Modules) will be tested at MSC-White Sands (near left).

Other nearby buildings in this huge MSC complex will house many other smaller space chambers, test and checkout facilities, and astronaut training devices. But probably the next most imposing structure is the Flight Acceleration Facility, which will boast still another "world's most"—the most powerful centrifuge [*painting page 22*].

The big spinner will be housed in a circular structure over 150 feet in diameter and four stories tall. Able to swing a 3,000-pound payload on the end of a 60-foot arm at 42 rpm, the centrifuge is designed to generate a maximum force of 30 G for more than three minutes, if necessary.

On the end of the horizontal arm, a gimbal-mounted, 12-foot gondola will have accommodations for three men, their acceleration couches and other gear, and a mockup of the command module's control panel. The gondola interior can be pressurized to simulate the actual interior of the flying spacecraft and will be used for biochemical and engineering studies of various gravitational forces on the astronauts and their support equipment. At times, the crew will be able to manipulate the gondola as they would a spacecraft during launch and re-entry.

Construction of the advanced machine is now about 60 percent complete at Houston. The Apollo ground test schedule calls for it to be ready for use by March 1965.

Still another simulation facility at MSC will capture much interest when it's completed. A simulated area of the moon's surface will be made of tons of slag, big chunks of lava rock, and a stadium full of rubble and pumice. Plans are for the area to be roughly the size of a football field, or about 328 feet in diameter.

Several large, 15-foot-deep craters will dot this little bit of the moon, which is a scaled-down model of the Kepler Crater in the Oceanus Procellarum region. The map was made from the best available observation data on that part of the lunar surface. The aim is to provide one area only in the simulated region that would be suitable for landing a spacecraft, and here a LEM mockup will be set up to give the astronauts practice in getting in and out of their ship.

The primary purpose of the bizarre facility, MSC engineers report, is to have a realistic lunar surface that will allow them to make time-and-motion studies of the lunar explorers in their space suits. It will also help in perfecting the design of the scientific tools and equipment the LEM's crew will use. As better data on the actual surface come in, as from the recent Ranger shot, MSC's moonscape will be altered accordingly.

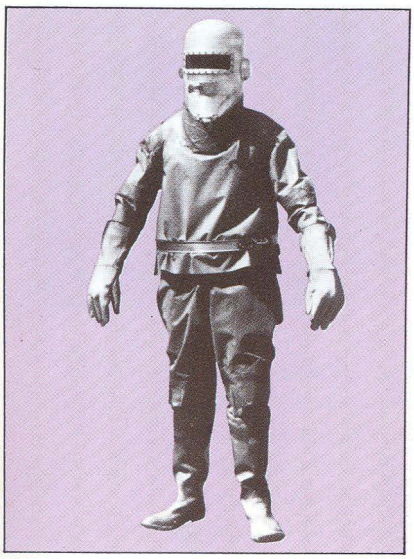
Some 1,500 miles to the northeast of MSC, at NASA's Langley Research Center, another fantastic facility is rapidly going up that will simulate the actual landing performance of ferry vehicles in the lunar environment. The Lunar Landing Research Facility is an enormous outdoor laboratory using a gigantic steel structure that allows a tethered lunar landing research vehicle to simulate the final phases of the landing approach and touchdown on the moon's surface.

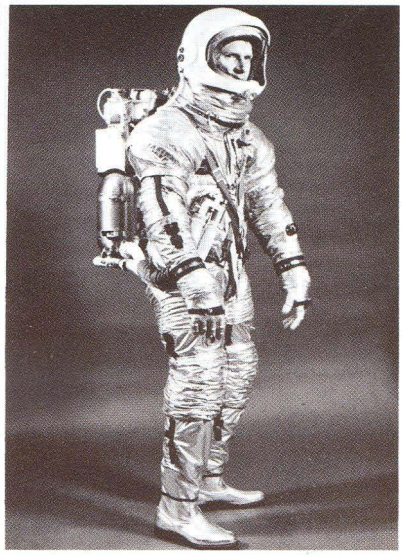
From a distance, the steel-girdered structure stands out against the sky like some monstrous six-legged creature, straddling a good part of the Virginia landscape [*painting page 22*]. The huge gantry-like device is more than 250 feet high and 400 feet long. A crane rolling along the upper length of framework, held up by three squared-off A-frames, will suspend a 20,000-pound LEM simulator. The latter resembles a helicopter bubble mounted on a lander stage.

Though testing will, of course, be done under normal sea-level outdoor conditions, the moon's gravity (one-sixth that of earth) will nevertheless be simulated fairly closely. The crane's suspension will be used to support five-sixths of the vehicle's weight and one-sixth will be supported by controlled firing of two clusters of five hydrogen-peroxide monopropellant motors. The latter will generate a total thrust of 6,300 pounds. This full thrust will be mainly needed for lift-off maneuvers.

Multiple gimbals in the suspension apparatus will give the research vehicle the same freedom of movement as it would have near the moon. Controls and displays in the two-man pilot's compartment are designed to give the crew angular (pitch, roll, and yaw) and linear (back and forth, up and down, and translational) motion cues. Auxiliary attitude-control jets will permit the pilots to make detailed corrective maneuvers while bringing the ship down.

Considering the enormity and cost of all these lunar test facilities, one might well wonder what their future might be after the program is completed. Actually, NASA has keyed many of its future planned programs to existing space environment laboratories. Once the actual lunar mission is accomplished, the big landing gantry will certainly not lose its usefulness, nor will the other ground test facilities—the space rocket firing stands in New Mexico, the huge environmental chambers, centrifuges, and lunar simulators in Texas, or the other Apollo test facilities at other NASA centers. Already in the works, new and more advanced lunar and planetary spacecraft and systems will be coming along for development testing, as man sets his sights on the vast expanses that stretch beyond the moon.





First known pressure suit in this country was awkward deep-sea diver's type rig of rubberized canvas and metal helmet. Wiley Post wore it in 1934 in a vain attempt to climb his Winnie Mae above Italian record of 47,000 feet. Apollo suit is at right.

Earthman in Space

by Burnham M. Lewis, Editor

The moon suit is by far the most complicated set of haberdashery man has attempted—and the most fascinating since knights in armor.

In engineering effort, it is absorbing more than all the preceding pressure-suit development man-hours spent by NASA, the Defense Department, and industry since Wiley Post's tinkering—plagued by mechanical failures—with a high-altitude "diver's" suit (*above*) in the early 1930s.

Significantly, the Hamilton Standard Division (Windsor Locks, Conn.) of United Aircraft Corporation helped power those first flights in which Post tried to maintain normal atmospheric pressure and oxygen for his body at high altitudes.

Hamilton Standard made the propeller that pulled Post above the 40,000-foot mark. In the 30 years since, Hamilton Standard has gained vast experience in moving masses of air. As aircraft moved faster and higher, this division branched into techniques for keeping man alive and comfortable at higher and higher altitudes (F-86 Sabrejet air conditioning in 1950, on to the environmental control systems for the B-58, 880, 990, and B-70 aircraft, regenerative CO_2 systems, zero-G water separators, evaporative heat sinks, and a variety of control devices).

These demonstrated capabilities in life support led NASA to award Hamilton Standard the contract for management, development, and integration of the Apollo space suit program and the design of the life-support backpacks the astronauts will use on the moon. Grumman also named the company subcontractor for the LEM (Lunar Excursion Module) ECS—Environmental Control System.

Experience in designing the Mercury and Gemini suits provides inputs for Apollo suit design. Our astronaut will first brave extravehicular space environment in the Gemini suit—floating outside his vehicle at the end of a tether. In the moon suit, he'll take his first space footsteps away from his vehicle. His suit will become his primary life-sustaining shell as man begins his first exploration on terra firma away from earth.

Besides comfort and mobility for working on the lunar surface, pressure protection for astronaut safety is a primary consideration, with a reliability factor of 99.9. Reliability of one failure in a thousand can be attained in such hardware as suit fittings and connectors—and approached in zippers and other closures. But it's far more difficult to design out the possibility of losing pressure integrity through accidental tears or punctures in the suit.

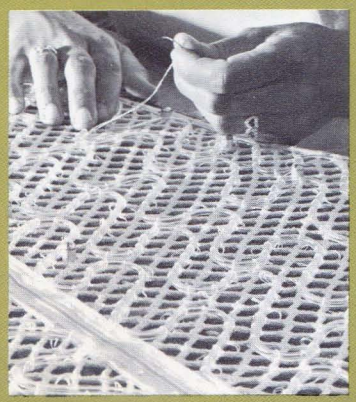
As shown in the cutaway drawing on page 27, the astronaut's skin will be in direct contact with loose-weave cotton-nylon underwear combined with a network of plastic tubes through which cool water is pumped when he braves the minus-250-to-plus-250-degree-F temperatures of the lunar surface. Next comes a thin nylon liner and a network of ducts, supported in the open position by metal spiral wires to keep the air conditioning (not water cooling) he'll use inside the spacecraft from being restricted by any pinching of the tubes.

Now comes a layer of heavy, tight-weave neoprene-coated nylon twill. It has convoluted neoprene rubber joints at the shoulders, elbows, thighs, and knees. The advantage of these constant-volume bellows is that in bending the joints the astronaut doesn't waste energy compressing the 100 percent oxygen with which his suit is pressurized.

The final outer "restraint" is lighter nylon coated on the outside with aluminum. This layer is attached to the primary pressurization layer at the joints and at the pressure glove and boot connectors. Boot design will remain even more flexible than the suit, itself, until more is learned about the lunar surface, according to International Latex Corporation, Dover, Delaware, major subcontractor in the suit development.

Pressure gloves and fiber glass helmet are attached to O-rings and bearing seals to prevent pressurization leakage. The gloves have such "finger dexterity" that an astronaut can pick up a coin while they're pressurized. The entire suit, in fact, has sufficient mobility to permit the astronaut to crawl through narrow hatches, climb up and down the outside of the LEM (Lunar Excursion Module), and kneel down and chip away at the surface of the moon. Should he find himself lying on his back on the surface, he can—with some effort

1. Water-cooled long-johns
Switch from air conditioning of astronaut on lunar surface to water cooling was recently made by Hamilton Standard, which says new system removes body heat 70 percent faster. Backpack pumps cool water through plastic tubes sewn to undergarment, whose net weave permits air cooling of astronaut without backpack inside spacecraft.



2. Thin nylon layer

3. Air cooling duct

nylon fabric with Tri-loc "hair curler" fillers

4. Pressurization layer

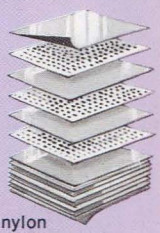
heavy, tight-weave, neoprene-coated nylon bladder

convoluted neoprene rubber joints at shoulders, elbows, thighs, and knees

5. Outer restraint layer

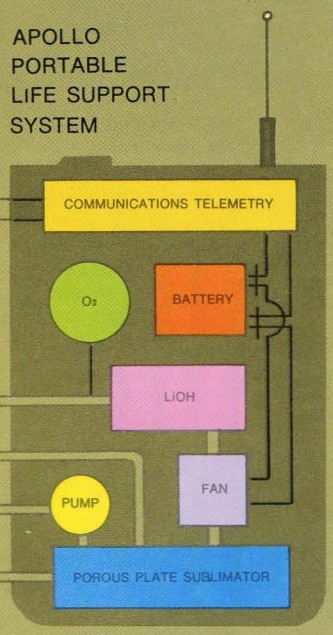
nylon aluminized on the exterior

6. Outer thermal garment



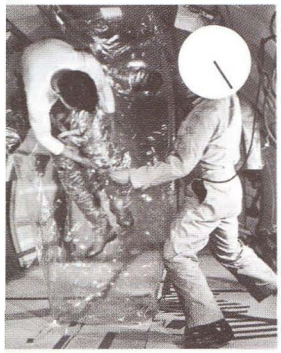
14 layers of lighter nylon and aluminum-coated Mylar

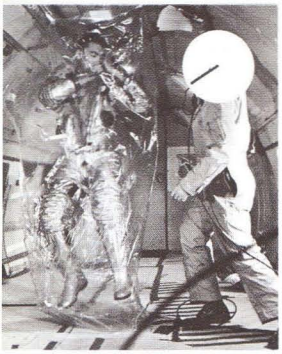
APOLLO PORTABLE LIFE SUPPORT SYSTEM

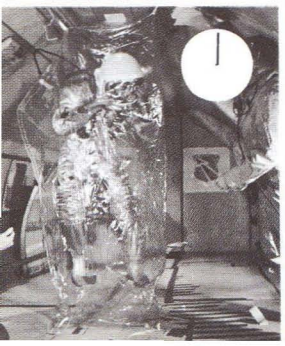


On moon's surface, backpack will give astronaut four hours of oxygen, body comfort, and communications. Porous plate sublimator cools water forced through plastic undergarment tubes.

Moon suit actually is a one-man spacecraft in which astronaut, with life support backpack, can maneuver in space outside and independent of any vehicle. On lunar surface, hooded thermal garment of aluminized mylar and nylon and mittens [p. 3] will be worn over suit and backpack.







—roll over and get to his feet unaided.

This is a far cry from the suit which, when pressurized, forced Wiley Post into a rigid sitting position with his arms stiffly extended toward the controls. Even the Mercury suit forced the astronaut into a semifetal position on his couch, permitting only limited leg and arm movements.

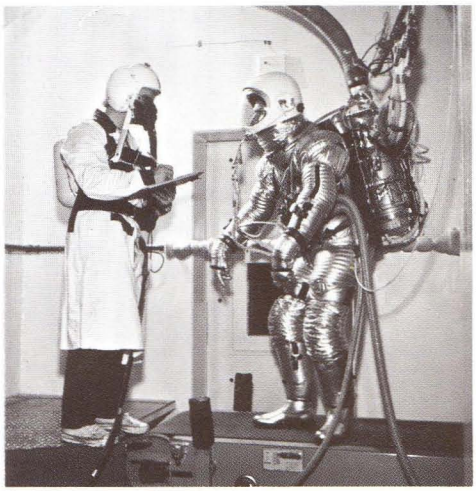
Hamilton Standard's helmet can be adjusted to any size head, simply by turning a knob on its exterior. This permits the astronaut to adjust helmet pressure against his head and to elect to swivel his head while the helmet remains stationary or to rotate head and helmet together. The face plate gives him 100-degree vision to either side.

Before he steps out onto the moon, the astronaut will don a "pants-and-parka" ensemble [*see page 3*]—loose-fitting aluminized mylar and nylon for temperature and solar radiation safety.

This thermal garment is contoured to fit over the life support backpack, which will provide four hours of oxygen, body comfort, and communications on the moon. A porous plate sublimator in the backpack cools the water running through the astronaut's undergarment—a method about 70 percent more efficient than a blown-air system.

During lift-off from Cape Kennedy, the three Apollo astronauts will wear the suits hooked into the command module's environmental control system. They'll be receiving 100 percent oxygen for cooling—but cabin, not suit, pressurization. The suits will automatically pressurize at 3.5 pounds per square inch if the spacecraft's 5 psi pressurization fails. After the LEM has been positioned on the front of the command module on the way to the moon, the two astronauts who will make the landing will remove their suits, donning them again just before entering the LEM for the descent to the moon.

For extra safety, one crewman may be required to wear this "one-man spacecraft" for the whole mission. Several astronauts have commented privately that that might not be a bad idea.



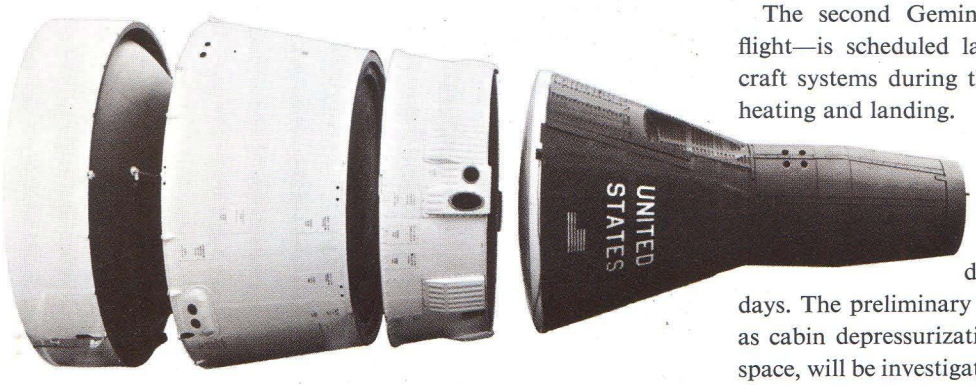
With backpack, Hamilton Standard test subject has flown suit up to test chamber altitude of 130,000 feet, walking on treadmill and using arms with reasonable ease. Now tests are being held in new chamber [p. 23] which simulates lunar temperature extremes.

In addition to increasing man's biomedical knowledge and techniques, moon suit project already has resulted in such "commercial fallout" as this water-cooled undergarment worn by race car driver Paul Goldsmith during 125-degree-F competition. Hamilton Standard engineer in this underwear drove 1¾ hours in 143-degree-F auto interior without perspiring. Garment has other product potentials for protection against intense heat (firefighters, foundry workers, etc.).

Weightless inside "doff-and-don bag," Air Force Lt. Edwin H. Sasaki manages to don Apollo suit, up to point of fastening neck ring, in about two minutes. Experimental bag can be pressurized for astronaut protection in event of spacecraft pressure loss emergency.

Besides permanent faceplate, helmet has two removable ones. One filters out ultraviolet and infrared rays. Other, nearly opaque, serves as sunglasses.

Gemini: Eager Spacechild in Search of Apollo Manhood



By Charles W. Mathews,
Gemini Program Manager, NASA

Few people realize how strongly Gemini supports Apollo, the real support lying in operational experience and personnel training—both for astronaut teams and ground crews.

Project Mercury, our nation's first manned space flight program, is already history. Four years, eight months, and one week after Mercury started, it was officially and successfully concluded. Mercury proved that our fundamental space flight concepts were accurate. A major step in a national commitment to manned space exploration, it gave us the firm foundation necessary for reaching far out into the universe.

The Gemini program will further man's ability to work and live in the environment of space, as well as reduce the number of Apollo flights before the lunar mission. Apollo then will lead—via manned lunar landing and exploration—to more advanced programs dealing with the exploration of earth's nearer planets.

With the Gemini program, whole new vistas open up for man as he develops, refines, and practices the advanced concepts and ideas which should serve as a basis for all future manned use of space.

Gemini flights began last April 8, the first mission being unmanned to check overall launch vehicle performance and aerodynamic loads on a structural shell spacecraft during launch.

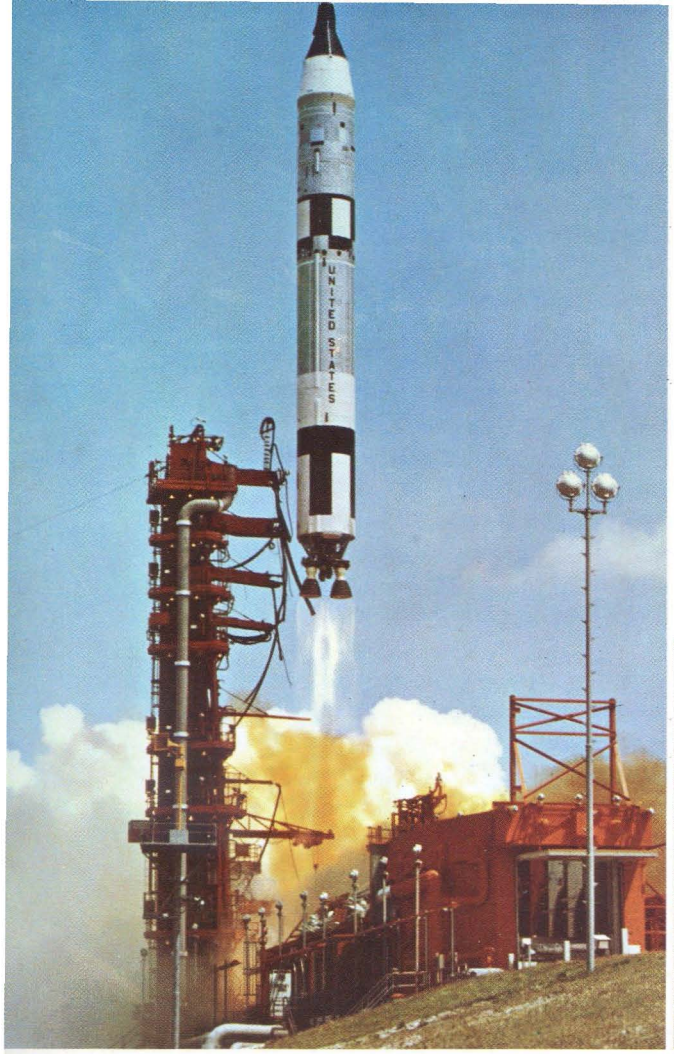
The second Gemini mission—an unmanned, suborbital flight—is scheduled late this year; this will test all spacecraft systems during the launch phase and through re-entry heating and landing.

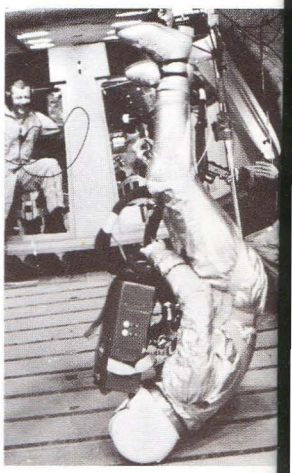
The first manned Gemini flight, GT-3, will establish man-spacecraft compatibility in a planned three-orbit mission. GT-4 will be the first long-duration mission—up to possibly four days. The preliminary phases of extravehicular activity, such as cabin depressurization and opening of the hatch while in space, will be investigated. GT-5 will be another long-duration flight—up to as many as seven days. Rendezvous evaluation exercises will be conducted with a rendezvous pod during this mission in preparation for the first rendezvous missions scheduled to begin with GT-6 in 1965.

As the intermediate step between Mercury and Apollo, the major Gemini objectives are to:

1. Provide long-duration manned-flight experience by studying the effects of weightlessness; determine physiological and psychological reactions to long-duration missions; and develop performance capabilities of the flight crews. Long duration means up to two weeks to see if the astronauts *can* actually remain in weightless orbit for that time length. If they cannot, then man's stay on the moon in the Apollo craft will have to be greatly reduced. A lunar flight and landing requires a minimum of seven days. Gemini, in accord with NASA plans, *will* determine if the men can remain in space flight without ill effect.

2. Provide early manned rendezvous capability by developing rendezvous techniques; assess pilot functions; develop propulsion, guidance, and control; develop pilot displays; and train pilots and provide them with rendezvous experience. After





GT-1, first Gemini flight last April 8 (left), was powered by Titan 2 and checked overall launch vehicle performance and aerodynamic loads on structural shell spacecraft during launch. McDonnell Aircraft engineer-pilot (above) tests weightless egress from McDonnell Gemini spacecraft mockup flown in Air Force KC-135. Each parabolic maneuver of jet aircraft provides 22 seconds of weightlessness. First astronauts to make Gemini flight, Virgil Grissom and John Young (left), probably will blast off in February on three-orbit GT-3 mission.

the Agena D target vehicle is in orbit and is found to be operational, we will send up two men in Gemini; they will give chase, catch and latch onto the Agena, then use its engine for greatly increased spacecraft maneuver capability. If this earth-orbit rendezvous method encounters difficulties, then we must develop and perfect new techniques so that the ultimate goal of Apollo can be completed. This development can be done safer, in less time, and at very much lower costs with Gemini hardware than with the larger Apollo vehicles. Lunar orbital rendezvous is scheduled for Apollo; the LEM (Lunar Excursion Module) must land the two men, then be launched back into lunar orbit for rendezvous with the Apollo command module for crew transfer and return to earth. Without Gemini-gained knowledge of rendezvous, we would not be certain that rendezvous in lunar orbit is practical. We must know first before attempting it around the moon. Gemini provides the means.

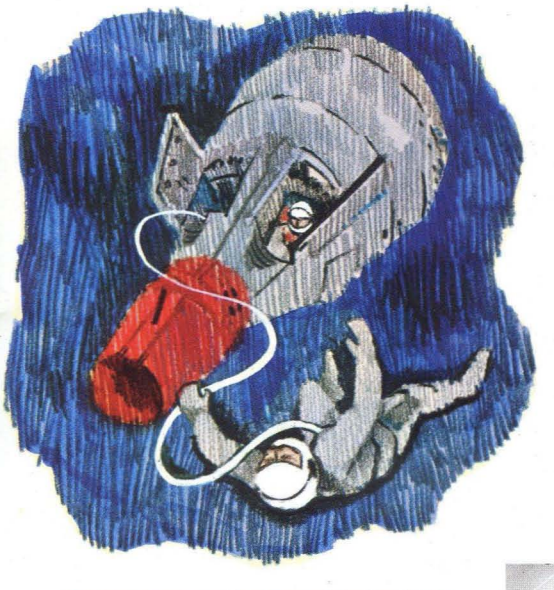
Training for ground crews includes at least four new areas of flight technology:

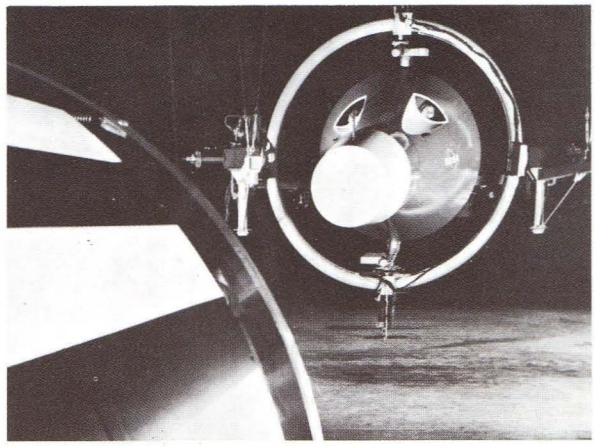
1. Preparing and checking out two space vehicles simultaneously for a combined launching or for launching both within short time periods of each other—for Gemini, the spacecraft and target vehicle; for Apollo, the command module and LEM; for planetary flight, the spacecraft and a booster for interplanetary flight.

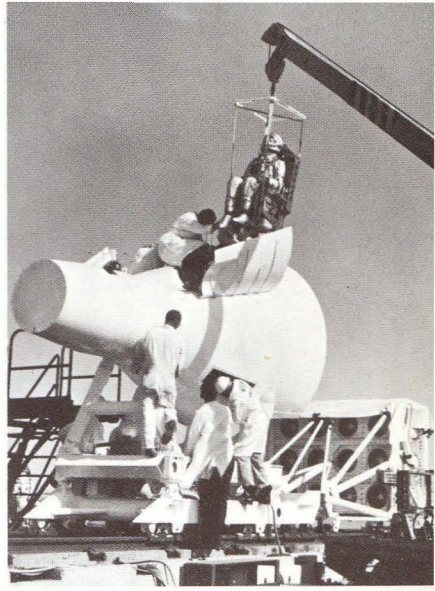
2. Launching vehicles within a critical time period and in accurately controlled but constantly changing launch directions: for the Gemini spacecraft to catch the target vehicle in a minimum of time when the launch azimuth (horizontal angle) continually changes as each second after the optimum launch instant ticks by; for LEM to rendezvous with the Apollo command module (the astronauts must continually make minor flight path corrections to be in good docking position as the orbiting Apollo spacecraft passes overhead). When we fly to the planets, there are optimum days in the month and in months of the year to make the time in flight as short as possible to attain our goal. Further, the launch angles are changing constantly as the minutes pass because of the earth's rotation, and because the earth and target planet are orbiting around the sun at different speeds.

3. Tracking and controlling the flights of more than a single space vehicle from the ground with high degrees of accuracy in order to put them in position to rendezvous. In the Apollo program, the flights of LEM and the Apollo spacecraft will be watched carefully by monitoring radio signals over great distances in space.

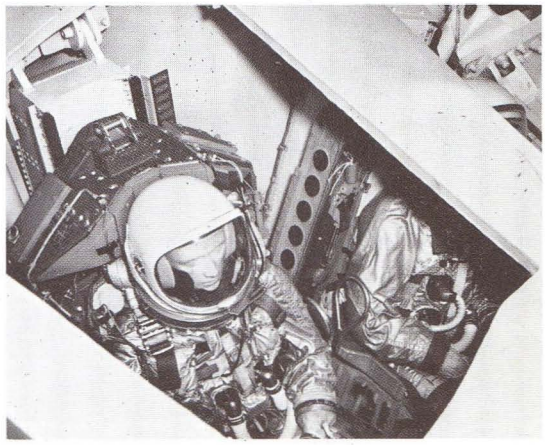
4. Directing space flights over long periods of time. Resolving problems of developing techniques for rotating shifts for







Our astronauts will get out of their vehicle into space for the first time late in the Gemini program. Artist's drawing shows astronaut working on outside of Gemini. Extravehicular experiments with chest life support pack are scheduled for GT-8, and with maneuvering backpack for GT-9 and GT-12, the final Gemini flight scheduled for 1968. Docking of two orbiting spacecraft, another planned "first" in Gemini program, is practiced on earth with NASA's Langley simulator (middle photo). Lifelike Grumman-Alderson dummies are used to check out ejection seat escapes from Gemini during launch or recovery emergencies. They're ejected from mockup on rocket sled at Supersonic Naval Ordnance Research Track, China Lake, Calif.



the straining tasks of uninterrupted surveillance or coping with ground equipment failures and deficiencies, and of handling varied contingencies such as spacecraft systems failures, solar flare storms, emergency abort precedures, and inclement weather developing in planned recovery areas.

Thus, it becomes obvious that a major purpose of the Gemini program is to gather a fund of operational experience in critical manned space flight areas to successfully accomplish future missions—in particular, the manned lunar landing and exploration program. We must evaluate the behavior of man-spacecraft systems and further develop the philosophy of safety and reliability.

Both long-duration flight experience and rendezvous procedures will be applied to many other spacecraft mission plans; this includes the resupply of space stations with crews and equipment, plus the gathering of equipment in earth-orbit in preparation for future long journeys to the near planets. Gemini will obtain rendezvous information before the need for accomplishing this maneuver in connection with the lunar and planetary missions. Again, the lunar landing requires considerable maneuvering both to and from the moon as well as upon the moon. The precision control of the firing of large engines in space, therefore, is an important aspect of our flight experience.

Extravehicular operations of man also need exploration and development. The self-sustaining Gemini spacecraft with its two-man crew and quick-opening hatches is suited to this activity.

Gemini spacecraft and launch vehicle are far less expensive than their Apollo counterparts. So, we can flight-qualify many new hardware systems on Gemini before they are needed in Apollo—new systems never before flown. Digital computer, radar, and fuel cells are examples. For the crews, the effects of cleanliness, eating, sleeping, working, waste control, and systems operations will have been thoroughly researched and developed prior to lunar flights.

Finally, there is a strong desire to conduct many space experiments; each of these will be enhanced greatly by man's presence as an aid in the conduct of these experiments. A lot of good work of this nature was accomplished in the Mercury program, but payload and space limitations as well as flight duration limitations precluded many experiments in which research agencies were interested. Gemini considerably increases capabilities in these respects.

The current status of the Gemini program is a healthy one, and the objectives and flight plans as outlined will provide much-needed information for future space operations in a timely fashion.

News in Brief

Astronauts and other NASA personnel attended an Inspection Review at Grumman in early October of the metal M-5 mockup of the Lunar Excursion Module (LEM). The formal session on recent and proposed changes to the LEM was to be preceded by two days of astronaut tests in the M-5, which represents a final version of the spacecraft. Tests were to include mobility demonstrations with the Peter Pan hoist system, which simulates the moon's 1/6-G conditions. Manned Spacecraft Center officials were to review all LEM changes and progress since the TM-1 mockup review at Grumman last March.

A new simulator is being built to help define more fully the ascent, descent, rendezvous, and docking problems associated with the LEM. Ultimately, it will help train LEM astronauts.

Grumman awarded a $2.78 million contract to the Farrand Optical Company of New York City for design, development, and production of two external visual displays for the LEM Mission Simulator.

The Farrand displays will generate and display images that astronauts in the LEM will see while orbiting, descending to, landing on, and ascending from the moon, as well as while rendezvousing and docking with the Command Module. The images will be generated by spherical mirrors, beam splitters, and relay lenses.

Although NASA's technology utilization program began only in 1962, NASA Administrator James Webb says innovations to meet the demands of the space program already are proving valuable to the general economy.

Among innovations cited is development of frangible (crushable) tube impact energy absorbers for the LEM landing gear which, he says, "may be translatable into elevator and automotive safety devices and helicopter struts."

NASA is negotiating with Grumman for fabrication of a third Orbiting Astronomical Observatory (OAO) and an option for a fourth and fifth.

Contract value is expected to exceed $20 million if only the OAO C (the third one) is acquired and more than $50 million if the D and E models also are bought.

The C spacecraft will have the same basic design as the OAO B now being built by Grumman as prime contractor for the current OAO program. Contract effort is expected to extend over three years if the C is purchased, for five years if the D and E also are bought.

The NASA Goddard contract will provide for testing, spare parts, field support, and design efforts required for differing payloads and continued refinement of the basic design. An incentive-type contract is being considered.

"Oh—about here, I should think."

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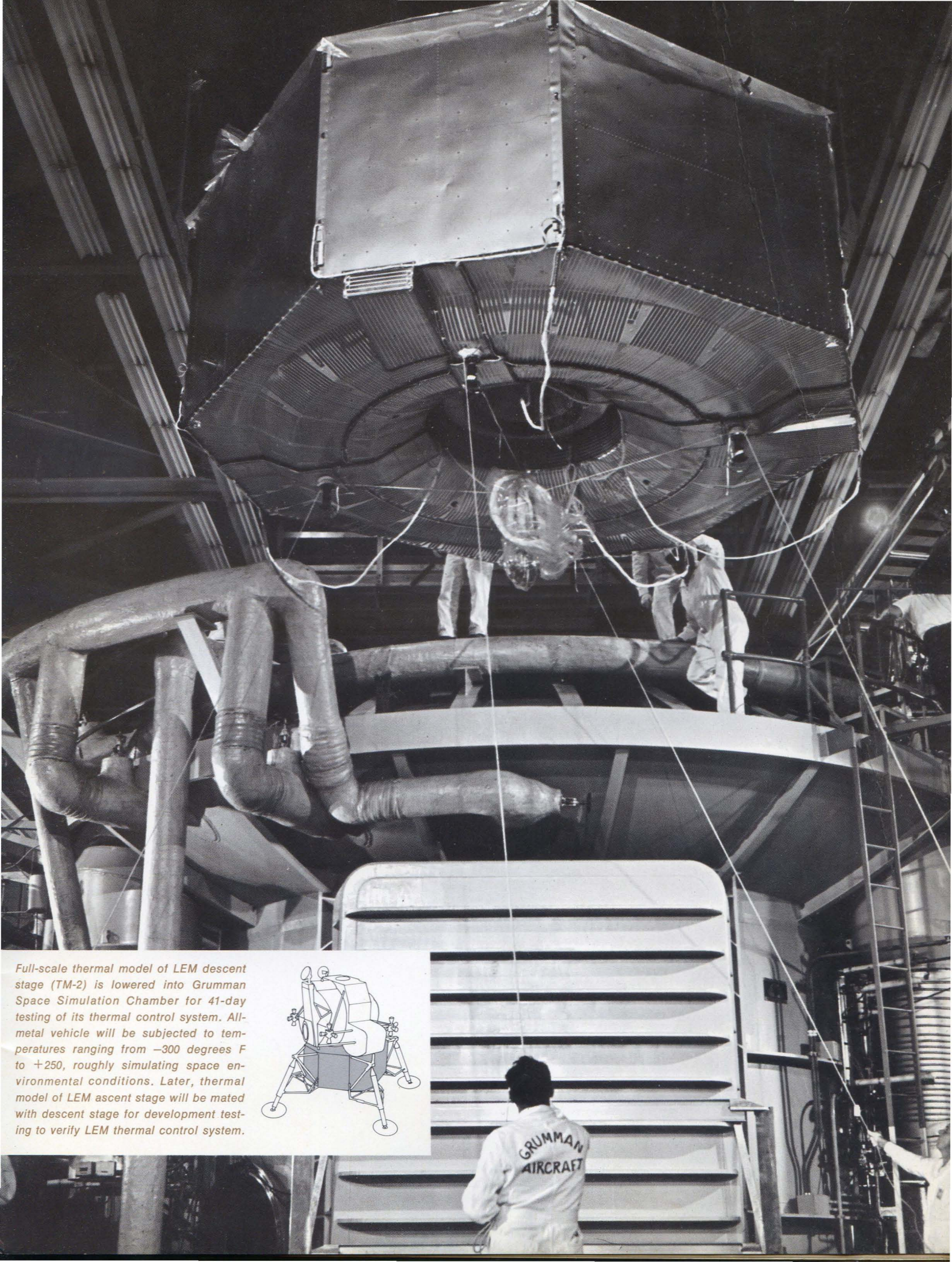
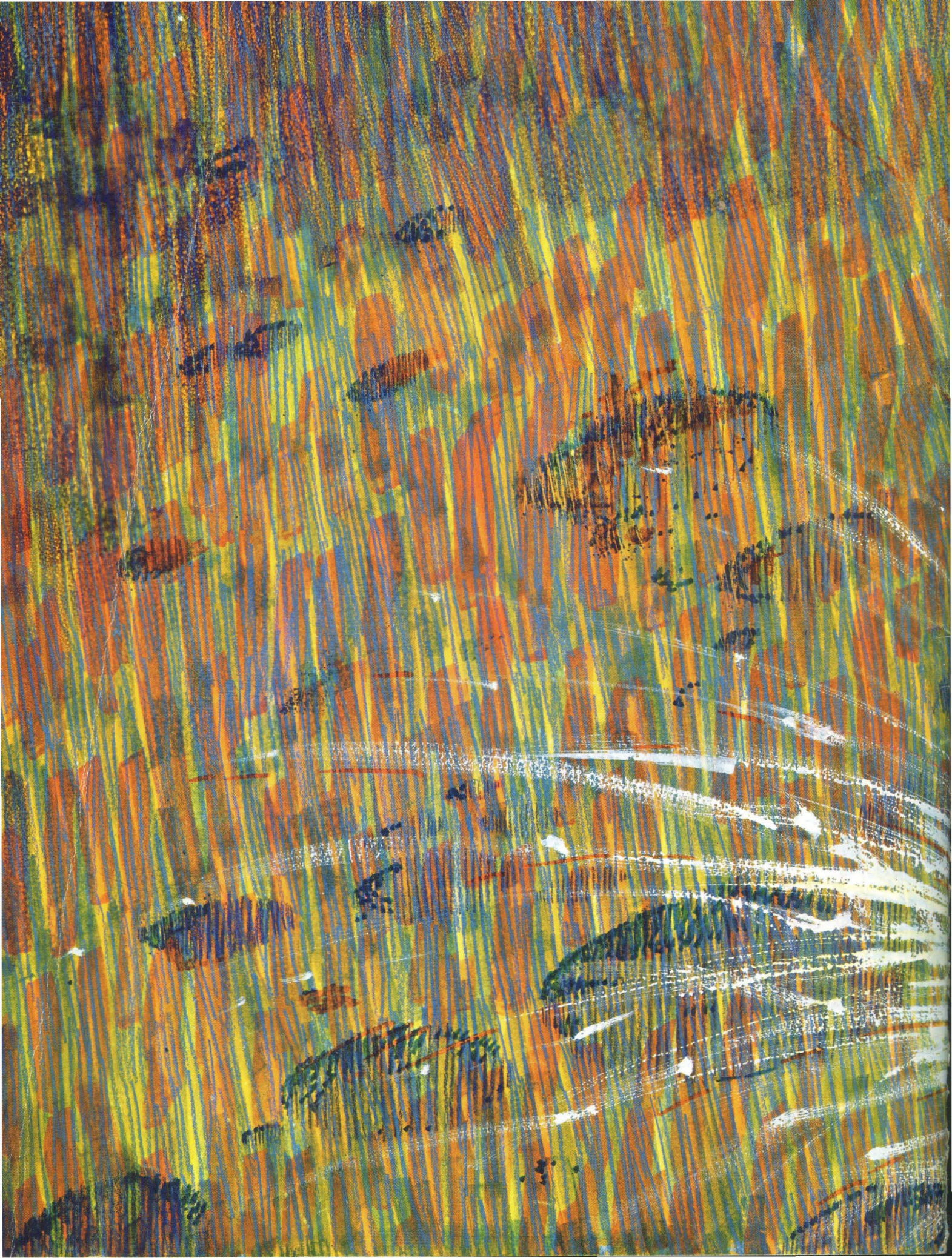
Full-scale thermal model of LEM descent stage (TM-2) is lowered into Grumman Space Simulation Chamber for 41-day testing of its thermal control system. All-metal vehicle will be subjected to temperatures ranging from −300 degrees F to +250, roughly simulating space environmental conditions. Later, thermal model of LEM ascent stage will be mated with descent stage for development testing to verify LEM thermal control system.