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III 3

MANNED SPACE AND LUNAR EXPLORATION

Less than five years ago the National Aeronautics and Space Administration (NASA) was given the clear-cut task of landing men on the moon before 1970. The major goals of Apollo, the name selected for this phase of our national space program, were also clearly defined as being to explore the moon first hand and in so doing to give our nation the managerial, industrial, and technological resources to do almost anything in space for years to come.

The George C. Marshall Space Flight Center at Huntsville, Alabama, the NASA field installation where I work, was assigned responsibility for development of space launch and carrier vehicles with payload capabilities large enough to accomplish both original goals of the Apollo program.

These heavy spacecraft transporters were dubbed Saturn and presently include three versions as shown in FIGURE 1--Saturn I, a two-stage vehicle capable of putting 10 tons in earth orbit; uprated Saturn I or Saturn IB, with a more powerful second stage which can orbit an 18-ton payload; and Saturn V, a three-stage vehicle capable of placing 125 tons in earth orbit, sending 47 1/2 tons to the moon, or lugging about 56,000 - 60,000 pounds into a planet Mars orbit.

Just three short years from now the Saturn V vehicle will transport three men and their spacecraft to an orbit close to the moon. The Apollo spacecraft, shown in FIGURE 2, and the third stage of its Saturn V launch/carrier vehicle will first be placed into an orbit around earth. While in this "parking orbit," the three-man crew will perform a complete checkout of all onboard systems. They will then align the vehicle and ignite the Saturn's third stage engine at the precise point of orientation, which will send them on the remainder of the three-day flight to an orbit around the moon. As shown by the mission profile in FIGURE 3, their path or "trajectory" will not be a straight line between the two orbits. They will travel an "S" shaped path which encloses the earth in its counter-clockwise loop and the moon in its clockwise loop. Carrying two of the three men, the Lunar Module, a special landing craft called "LEM" and shown in FIGURE 4, will detach itself from command and service modules (the other parts of the three-part Apollo spacecraft) in orbit and descend to the lunar surface.

After a short period of up to one day of surface exploration, these men will take off and rendezvous with the spacecraft modules left in the lunar orbit. They will then transfer into the Command Module for its 3-day return and reentry flight to earth. The return trajectory to earth will make a figure "8" out of the "S."

As formidable a task as this may seem, today I want you to realize that we have built into the Saturn-Apollo hardware the capabilities for even greater and perhaps more rewarding space missions. But before I elaborate on Saturn's capabilities and its future mission potential, let me briefly summarize for you the giant steps taken or now being taken in preparation for the eventual manned exploration of the moon and planets.

Most of the exploration of space has so far been accomplished by unmanned spacecraft. But instrumented spacecraft can alone do no more than man designs into them. The ability of man to make adjustments, to improvise, and innovate with the unforeseen makes it inevitable that he explores space in person. The Mercury program was planned primarily to test man's ability to live and control his actions in space, but also illustrated his singular capability for reasoning. FIGURE 5 is a photograph of the Himalayas showing with striking clarity details of snowy peaks, green valleys, lakes, and rivers. It was one of several such remarkable shots made by astronaut Gordon Cooper from his Mercury Capsule, Faith 7, with an ordinary 70 mm camera.

The two-man capsule Gemini flights were planned primarily to demonstrate man's ability to live under the no-gravity conditions of space for days and weeks without ill effects. This was certainly achieved but the more spectacular feats were the improvised ones: the extravehicular activity such as walking in space during Gemini 4 and 5 flights, shown in FIGURE 6, and the Gemini 7-6 rendezvous with only one foot separating the two craft. In addition, as shown in an artistic rendition in FIGURE 7, Gemini 8 achieved the first space "docking"--or linking up of two spacecraft--so important to the success of all future manned missions. The remaining Gemini flights will prove out the astronaut environmental control, maneuvering systems, and docking techniques; adding additional assurance of their success in future missions.

Since our solar system contains the sun, 9 planets, 31 moons, 30,000 asteroids or minor planets, and thousands of comets, we cannot hope to reach all of these celestial objects in the near future. So we will be concentrating our planetary explorations on the moon, Mars, and Venus.

The moon was selected for the first manned exploration simply because it is closer and, therefore, more easily reached. In support of the Apollo manned lunar exploration program, the Ranger, Surveyor, and Lunar Orbiter instrumented spacecraft were designed to provide us as much information as possible about the lunar surface before man, himself, lands there.

Last year saw the successful conclusion of the Ranger series of photographic probes of the moon. In all, the Ranger series provided 17,000 photographs to help astronomers and geologists check their concepts of the lunar surface. Ranger 7, shown in FIGURE 8, was the first total success of the series. It impacted on the lunar surface within the target area and provided 4,316 excellent photographs before impact.

Perhaps the most spectacular of all our successes in space so far occurred earlier this year when the first test of our approach or method for landing two astronauts in a 15-ton Apollo spacecraft on the moon occurred. The unmanned Surveyor spacecraft, shown in FIGURE 9, landed ever so gently after its quarter-million-mile voyage precisely on schedule, within feet of the exact spot planned on the lunar surface, and apparently undamaged. Apollo's spacecraft will distribute its weight more widely by its footpad design so that its load per square inch will be about the same as Surveyor's. Thus this extraordinary success of Surveyor's initial attempt at a "soft" landing on the moon almost obscured the otherwise perfect performance of its TV cameras and other instruments transmitting excellent pictures, like that of FIGURE 10, and data back to earth. You can better appreciate Surveyor's soft landing feat by comparing it with the Russians' first "soft landing" by their Luna spacecraft last year on its ninth attempt and utilizing a method believed to consist of tossing a simple capsule weighing only about 200 pounds from a larger craft just before impact--a technique we consider too crude or dangerous for depositing human beings on the moon.

The six more Surveyor probes planned will extend our knowledge of lunar conditions and verify suitability of Apollo landing sites.

To supplement the information about the lunar surface gained by the Ranger and Surveyor spacecraft and to aid in the final selection of the Apollo landing site, a total of five Lunar Orbiters are planned. The Lunar Orbiter spacecraft, as shown in FIGURE 11, are designed to fly within 28 miles of the lunar surface and take a series of high- and medium-resolution photographs of thousands of miles of surface. It is hoped that one of the Lunar Orbiters will be able to take a picture of a downed and operating Surveyor so that pictures from the ground-level cameras may be related to those covered by Orbiter.

As of now, the Jet Propulsion Laboratory (JPL) at Pasadena, California--the program administrant for the NASA--is moving rapidly along with preparations for the probe of Venus scheduled for next summer. This instrumented scouting voyage will utilize an improved Mariner spacecraft like the one shown in FIGURE 12. The objectives of the Mariner Venus '67 probe are to obtain more information relevant to that planet's origin and nature and to acquire information on the interplanetary environment during a period of increasing solar activity.

The fly-by of planet Venus by the instrumented spacecraft, Mariner 2, in 1962 revealed to us a very hot (above 750°F) surface temperature, disclosed no large openings in the thick clouds surrounding the planet, and detected no appreciable magnetic field or radiation belt at around 20,000 miles (Mariner 2 passed Venus at a distance of about 21,000 miles).

Most of you will recall the striking TV photos taken by Mariner 4 durings its fly-by of Mars last July 14. Moon-like craters ranging from 3 to 75 miles in diameter were shown pitting the Martian surface. But of greater interest to space engineers and designers, was Mariner's occultation experiment in which the density of the Martian atmosphere was estimated to be in the 4-7 millibar range instead of previous estimates of over 14 mb. The thinner-than-expected Mars atmosphere tells us that we must plan a more shallow approach path to provide adequate spacecraft deceleration before reaching the planet's surface. Although Mariner 4 and astronomers now paint a rather bleak picture of Mars' surface environment for higher forms of living things--65 to 80 degrees below zero temperature, an oxygen-free atmosphere containing carbon dioxide, a severe water shortage, and a landscape bombarded by cosmic rays and ultra-violet radiation--the possibility of any kind of life on Mars should be explored thoroughly because that planet appears to be the likeliest place in our solar system for life beyond the earth.

Although a full-fledged program for exploration of Mars' surface is not scheduled until the first Voyager spacecraft lands in 1973, at least one more fly-by of the planet will be made in 1969. For this probe JPL will develop two larger Mariners equipped for experiments designed to provide maximum preparatory information for the Voyager landings.

The Voyager program is defined as one for unmanned exploration of the solar system, but present plans call for flights only to Mars. Two Voyager spacecraft will be transported into a Mars orbit by one Saturn V launch/carrier vehicle on each probe, as shown in FIGURE 13. The first flight in 1973 will carry two Voyager orbiters; the kind of lander, if any, to be used on the first Voyager flight is still to be decided. Eventually, the total Saturn V-Voyager payload will be some 60,000 pounds (two Voyagers).

Because Voyager's primary experimental goal for the Mars probes is to search for life, an automated biological laboratory will certainly be included on the initial lander capsule. One of several proposals for such a laboratory is shown by the artist's rendering in FIGURE 14. Tests conducted by automated laboratories on Mars will be controlled from stations on earth. Line scanning photographic equipment such as that shown in FIGURE 15 will give science its first look at the Martian landscape. Other proposals for the Voyager landing package include a multitude of every conceivable type of roving surface vehicle capable of roaming many miles from the landing site.

Meanwhile, our preparations to land men on the moon move rapidly ahead. Shown in FIGURE 16 is the Saturn IB - Apollo space vehicle used for the first successful launching of the unmanned Apollo spacecraft on February 26. The uprated Saturn I (IB) stands 22 stories high and is four times as powerful as the Titan II used in the Gemini program. Two or more additional unmanned tests will precede the first manned flight, with three men aboard. The Saturn IB-Apollo vehicle will also be used during 1967 for perfecting moonflight components and techniques.

The cost of producing follow-on improved Saturn I-Apollo vehicles may be reduced as much as 30 to 40 percent from first production runs so space officials are considering a number of possible uses for the improved Saturn I, once its role as flying lab for the Apollo mission is fulfilled. Another mission studied is to have an improved Saturn I vehicle ready within hours to perform emergency orbital rescue missions--see artist's rendering of rescue operations in FIGURE 17.

A number of proposals have been made to use the improved Saturn I for launching large space stations into earth orbit. The operational vehicle will have a capability of putting at least 40,000 pounds of payload into orbit. By the addition of four strap-on solid propellant motors, its load capacity could be boosted to 78,000 pounds or more.

Today, with the Apollo program on or ahead of schedule, space officials, the Administration, and Congress are looking beyond the first moon landing. The next phase of our planetary exploration program following Apollo is called Apollo Applications. This 5 to 10 year program, if instigated, would start as early as 1968 using a step-by-step, yet flexible, procedure for sending one or two manned lunar landing missions and possibly some manned lunar orbital missions each year until sometime between 1973 and 1975. Each mission would have stay times of up to 14 days. Afterwards, The Apollo moon exploration program is the major mission so far approved and funded for the Saturn family of large space launch and carrier vehicles. The initial moon landing follow-up operations--Apollo Applications--could be completed in the mid '70s or shortly thereafter if the present rate of progress on the Apollo program is maintained during Apollo Applications. The Apollo program, though extremely important and constituting a major milestone in the conquest of space, barely taps the tremendous capabilities of the Saturn V which, as I mentioned before, we developed to give our nation the capability to do almost anything it chooses to do in space for several decades to come.

What happens after the Apollo programs will depend upon Administration decisions about future goals of the national space program and, as with any investor, Congressional satisfaction with current and potential dividends. In respect to the latter, let us briefly survey some of the more rewarding things that have been proposed for the post-Apollo period of planetary explorations beginning about 1975 or upon completion of Apollo Applications missions. The proposals that I will discuss fall well within the payload capabilities of the Saturn V launch vehicles now being built and tested for the Apollo programs. And to give yourself a better realization of the quantum jump that we have made in developing the Saturn vehicles for the Apollo programs please keep in mind the remarkable fact that one Saturn V alone can carry about twice as much payload as the entire NASA space program has flown to date. The weight of all Mercurys, Geminis, Rangers, Surveyors, etc., launched to date would fill the cargo hold of a single Saturn V to little more than 50 percent of its capacity.

In general, post-Apollo proposals for planetary exploration center around either missions for extended lunar exploration or missions aimed at excursions to the nearby planets.

Study contractors working on lunar exploration have proposed a modified and heavier version of the Apollo spacecraft's landing vehicle for extended landing missions in the post-Apollo period of moon exploration. The new LEM, as shown in FIGURE 20, is called a LEM Truck, could be carried by a Saturn V to a lunar orbit from which it would, in turn, carry a 7000-pound payload down to the surface of the moon. It could land a fixed shelter for astronauts and scientists to live in, a roving vehicle with a range up to 800 miles, or both.

One large such surface vehicle envisioned is called MOLAB, shown in FIGURE 21, a giant rolling laboratory (collapsible for delivery by LEM Truck) that could carry two or three persons in climatized comfort on 45-day excursions of up to 800 miles over the lunar terrain.

a similar mission rate would prevail until all missions are accomplished, but the astronauts would remain longer, possibly as much as two months, on the moon's surface or in a moon orbit.

Since only about one percent of the moon's surface can be covered by man during the planned landing excursions of this program, the major source of the lunar geologic knowledge and mapping data could be the manned orbiters, carrying remote sensors. In addition to camera subsystems for photographic coverage and mapping, the orbital missions will include such instruments as magnetometers, spectrometers, and gravity gradiometers and a variety of sensors capable of recording on magnetic tape or film the data obtained from microwave, radar, infrared, x-ray, gamma-ray and alpha-particle experiments. These orbiting experiments should shed light on the structure and composition of the lunar surface and sub-surface, on particles and fields in the vicinity of the moon and would help identify and select lunar areas warranting further investigation by manned surface missions.

The Apollo Applications manned surface missions during the first half of the program call for stay times up to 14 days and traverses of astronauts aboard roving vehicles, see FIGURE 18, up to nine miles from the point of landing. During the second half of the program, astronauts would be expected to remain longer on the moon's surface, possibly as much as two months. Early Apollo Applications landing missions would return lunar material samples (from dust to rock-size pieces) for analysis in laboratories on earth, determine topographic and geologic features, and make stereoscopic photographs in the vicinity of the landing site.

By emplacing several experiment packages on each landing mission, a small array of stations could be set in operation to provide a continuous flow of information on the internal properties of the moon.

Basic types of equipment to be carried on one or more of the landing missions include: automatic position-recording systems to relay to earth or to the LEM the movements of the astronauts and the roving surface vehicle; the roving vehicle, itself, capable of carrying one or two astronauts and a scientific payload of some 500 to 700 pounds; a manned lunar flying vehicle, see FIGURE 19, able to carry a 300-pound scientific payload about 10 miles to study features not accessible with the roving vehicle; and a one-inch drill capable of penetrating at least 10 feet in rubble or solid rock to assist heat flow studies and to provide samples of possible biological interest.

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The next big step in lunar exploration would be the establishment of a base where six-to-nine-man teams could live for several months. For this purpose, a Lunar Logistics Vehicle (LLV), see FIGURE 22, has been studied. The LLV could be launched by a Saturn V vehicle straight from earth to the moon's surface with a payload of about 30,000 pounds.

The need for a fixed-site lunar station is based on the scientific requirements for measuring geophysical phenomena that vary with time, for studying lunar surface processes, and for deep drillings (to about 1000 feet) for sub-surface materials that would enhance our knowledge of the moon's crustal composition and early history, and, perhaps, its origin.

While men are still exploring the moon in the late '70s or early '80s, the first manned landing on Mars could be made. By that time we will know a great deal more about both Mars and Venus from the unmanned probes that I have already described. And, though nobody seriously expects to find either Mars or Venus populated by little green men, the possibility that some form of life exists, especially on Mars, is still great.

My supervisor and Director of the Marshall Space Flight Center, Dr. Wernher von Braun, and another associate at Marshall, Dr. Ernst Stuhlinger, have studied in depth our capabilities for a manned Mars landing. Though their concepts for such a mission are different, both foresee the possibility by the mid '80s. Both concepts utilize the S turn V for launching the Mars spacecraft.

Though the Saturn vehicle developed for Apollo will be able to take Mars missions most of the way to their target, new kinds of navigation and guidance equipment and the landing vehicle (called Mars Excursion Module, or MEM, as envisioned in FIGURE 23) will be a major new development, as will life support equipment for extended stays. But parts of the Mars spacecraft, life support, and communications, micrometeoroid and radiation shielding, provision for artificial gravity on board the spacecraft, etc. will be developed during the Apollo Applications, post-Apollo lunar exploration, and advanced earth orbital missions.

The Mars spacecraft will consist of at least three separate modules, one for the crew, one for equipment, and one, the MEM, for landing. Because of its huge size, the spacecraft will have to be launched into earth orbit in several sections and assembled, see FIGURE 24, there for launching to Mars.

The crew's quarters would have a centrifuge to create artificial gravity, a heavily shielded compartment to protect the men from solar flares, and radioisotope thermal generators to provide power for subsystems.

Dr. Stuhlinger proposes the use of a nuclear-propulsion stage to accelerate the Mars spacecraft to escape velocity from its assembly point in earth orbit and electric propulsion to propel it to Mars' gravitational field (FIGURE 25). Stuhlinger's design study was based upon the performance achieved recently by electric thrusters, and upon the performance of nuclear-electric power supply systems anticipated within the next ten years. The nuclear-electric Mars vehicle design would require only five Saturn V's to put the components of one spacecraft (capable of carrying a four-man crew) into earth orbit for subsequent assembly.

The flight time to Mars on a direct trajectory is 145 days. Stuhlinger's vehicle would spiral into a low Mars orbit from which a chemically powered MEM descends to the Martian surface. A few weeks later, the excursion module returns to the orbiting electrically propelled spacecraft for the return voyage to earth. The minimum time required for the round trip is estimated to be about 440 days, of which some two weeks would be spent on Mars' surface.

Because the propulsion for the return to earth from Mars would weigh so much, life support equipment sufficient for only a few weeks on Mars can be carried on the early manned flights. However, Dr. von Braun has suggested in his study that if the first Mars astronauts were sent off without return propulsion, they could be equipped for a year-and-a-half visit on Mars (FIGURE 26). If this approach were taken, the astronauts could land on Mars with close to 200,000 pounds of equipment, housing and surface vehicles, and plenty of water, oxygen and food for up to 18 months in a Martian village of half a dozen or so MEMS. Two of the MEMS would have propulsion to carry the men into Martian orbit to meet a subsequent spacecraft sent from earth to pick them up and return them home immediately.

The major investments in programs such as Mercury and Gemini for a manned spaceflight capability and in Apollo for a transportation-to-the-planets capability have already been made. It is now a matter of simple investment principle that we should capitalize on those big investments in ways that will produce the greatest returns or dividends from our original investments.

The basic space vehicles (Saturns I and V) for landing men and equipment on the moon and possibly on Mars have been developed and they represent a large portion of our total investment in space. It remains now for us to protect that investment--avoiding the eventuality of a disastrous accident on one of our manned flight missions or the dismantlement of our present space capabilities--by continuing the so-far highly successful lunar and planetary exploration program and by providing every means available to us for the safe conduct of its manned flight missions.