LUNAR BASE MODULE

The Lunar Base Module (LBM) provides the largest habitable volume for lunar surface operation; it retains the basic LM ascent stage structure. The ascent propulsion system has been removed, and the cabin enlarged to 450 cubic feet. The LBM, like the LM Shelter, is designed to land unmanned on the lunar surface, remain stored for 60 days, then support two men for as long as 14 days. Two beds provide maximum comfort for sleep. The LBM is used in conjunction with the LM Taxi in the dual mission mode.

Cabin volume is increased by enlarging the midsection diameter, moving the rear bulkhead back against the aft equipment rack, and removing the ascent propellant and helium tanks.

The Environmental Control Subsystem water sublimator has been replaced by a radiator, and solar panels have been added to the Electrical Power Subsystem. Both of these changes were made to support the 14-day mission with a minimum-weight vehicle.

MOBILITY AIDS

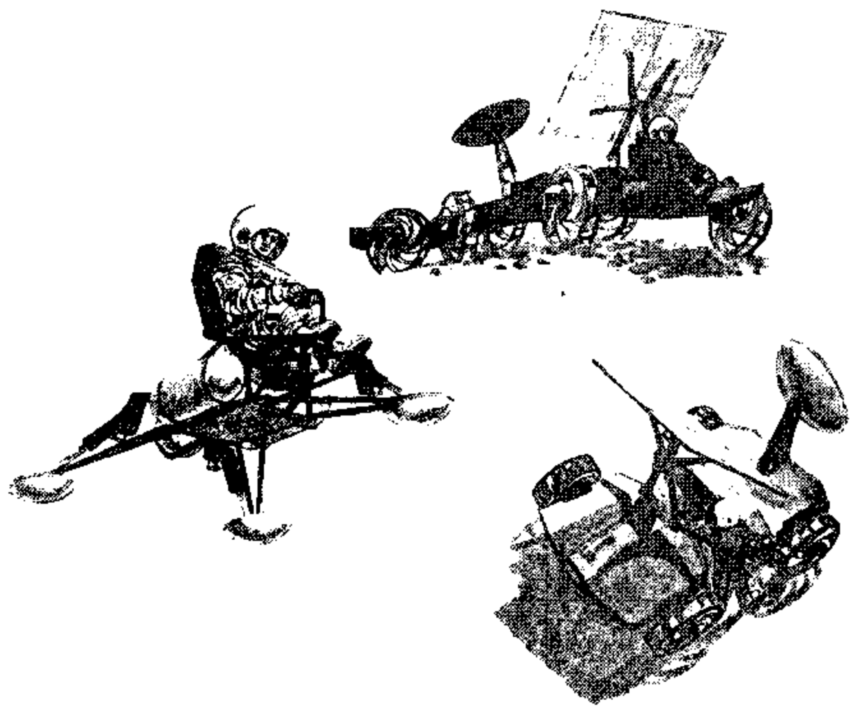
Flying and roving vehicles are being developed to support advanced lunar surface scientific exploration. Typical mobility aids that can be carried on the LM derivatives are:

Medium Duty: Lunar Roving Vehicle (LRV)

Capable of carrying 500 pounds, including an astronaut, the LRV is small enough to be carried on a single-launch mission. Although its radius of operation is limited to 3 nautical miles by backpack communications restraints, its battery power permits an 18-nautical-mile sortie before recharging is necessary. The basic vehicle weighs 500 pounds, including 100 pounds of scientific equipment; it may be converted for unmanned remote control by adding appropriate equipment.

Light Duty: Lunar Flying Vehicle (LFV)

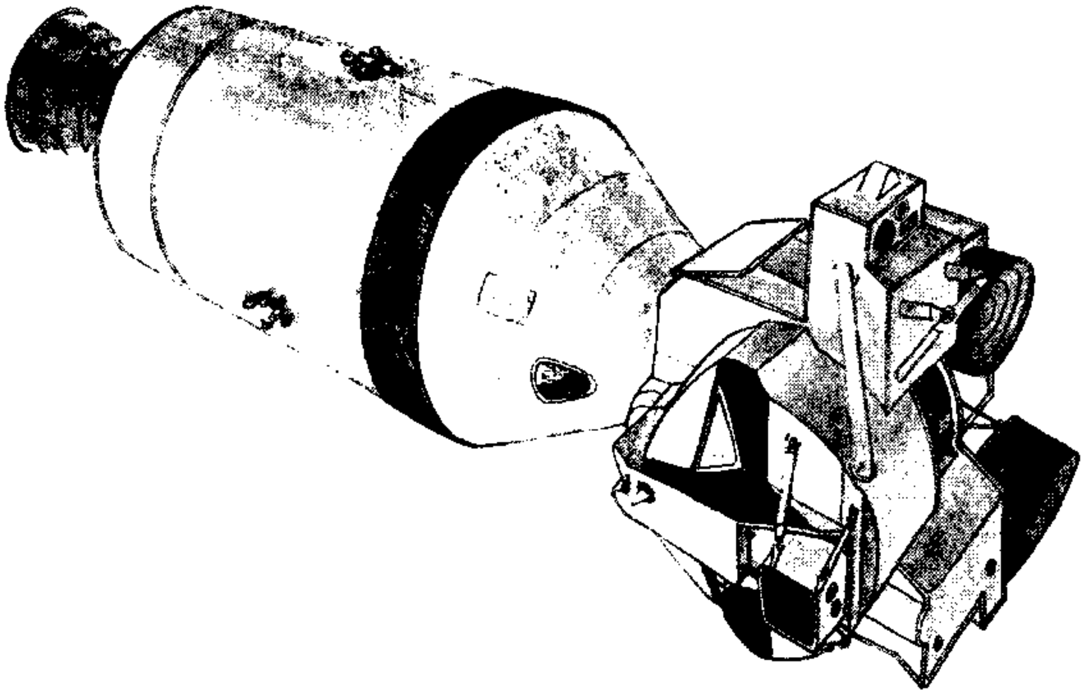
This vehicle can be carried on a single-launch mission. It weighs 180 pounds dry and carries 300 pounds of the same propellant used by the LM descent engine; therefore, LM residual propellant can be transferred to the LFV after landing. The LFV can carry one man with approximately 370 pounds of scientific equipment or, on a rescue mission, two men without the equipment.



R-146

Heavy Duty: Dual-Mode Lunar Roving Vehicle (DLRV)

The DLRV is a 1,000-pound vehicle, including 350 pounds of scientific equipment; it has a growth capability to 1,750 pounds of which 750 pounds is scientific equipment. In the manned mode, the DLRV has a 6-nautical-mile radius of operation; in the unmanned mode, controlled remotely from earth, it can traverse more than 600 nautical miles. The DLRV would be carried on an Extended LM or on an unmanned logistic spacecraft such as the LM Shelter or Truck.

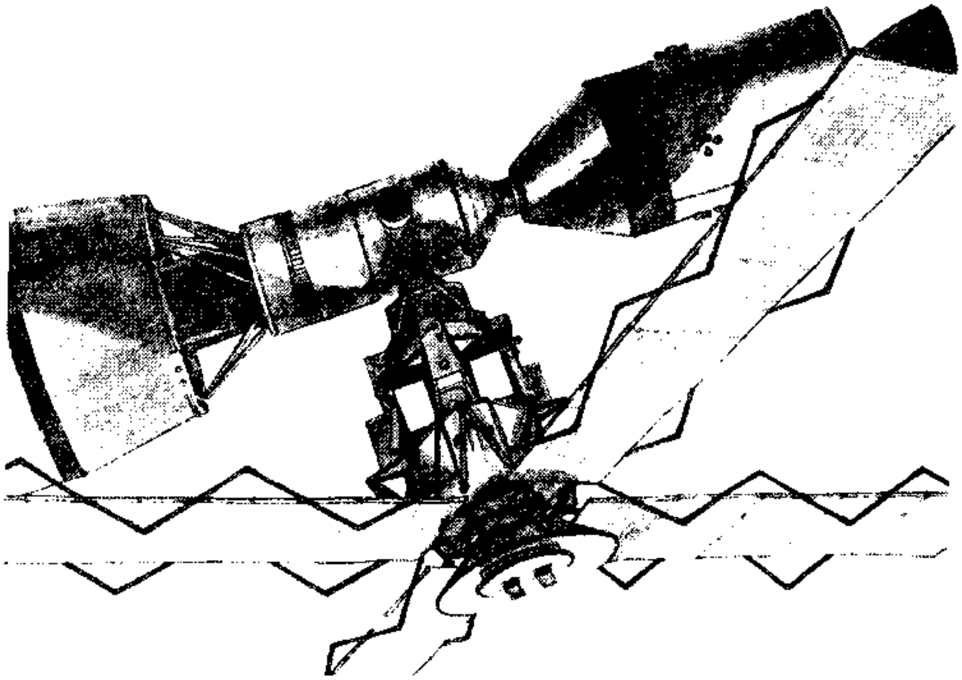


R-147

LM LABORATORY

Heavily equipped with experiment instrumentation, capable of operation in earth or lunar orbit, and provisioned to sustain two astronauts for 45 days in space, the LM Laboratory is an exciting science-oriented offshoot of the LM. Its experiment sensors include radiometers, spectrometers, a stellar camera, a terrain camera, multispectral cameras, X-ray sensors, a day-night camera, and an IR imager. Experiment categories in which these devices are used include meteorology, astronomy, earth resources, lunar survey and mapping, bioscience, and engineering technology.

The laboratory is compatible for docking with the CSM. It can be launched by the Uprated Saturn I or Saturn V vehicle.

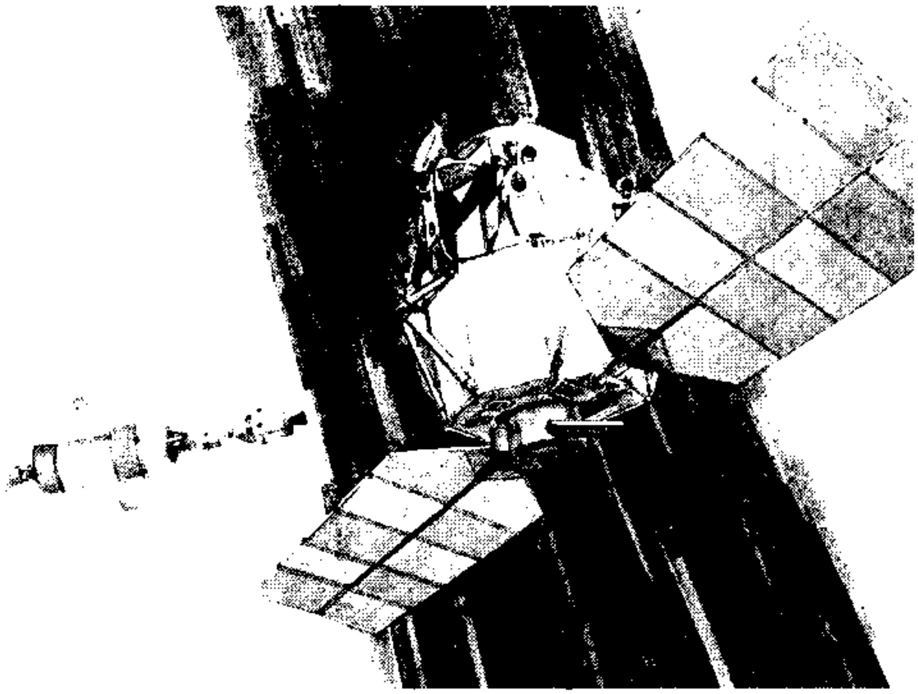


R-148

LM/APOLLO TELESCOPE MOUNT

The LM/Apollo Telescope Mount (ATM) spacecraft is being designed for an earth-orbit mission. In this LM modification, the descent stage is replaced by the ATM structure. Among the major items attached to the structure are solar astronomy experiment equipment, solar arrays, and control moment gyroscopes. Besides gathering data on the physical characteristics of the sun, the spacecraft will be equipped to perform an unmanned rendezvous and docking with an orbital Assembly (OA), and operate in orbit for as long as 51 days in an open-ended mode. The LM may also be modified to deliver supplies or other experiment modules.

The LM/ATM and OA are shown in the picture. Fully assembled, the OA will comprise a CSM, the LM/ATM, an Airlock Module, a Multiple Docking Adapter, and a spent S-IVB stage converted to an orbital workshop. The OA is, in fact, a small space station.

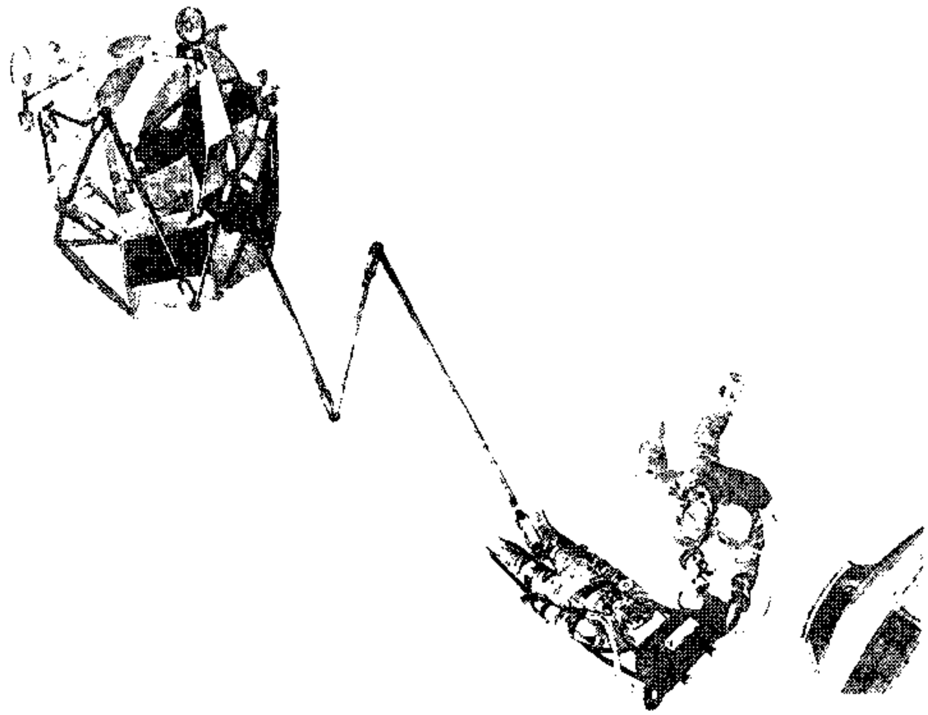


R-149

LM/STELLAR ATM

One of the purposes of the LM/ATM mission is to evaluate performance essential to the development of advanced manned orbiting solar and stellar observation systems. The experience gained on the LM/ATM mission may be applied to other observatory missions by replacing the solar telescope with a large-aperture stellar telescope. The Stellar ATM could then be used to collect scientific data on celestial objects in the ultraviolet spectrum. Such a configuration could be operated in a manned or man-attended mode of operation.

Periods of unmanned free flight away from the main orbital assembly would fall into the category of man-attended operation; such operation may be desirable because of the longer stabilization periods and higher pointing accuracy required with stellar targets. Such a configuration is shown in the artist's rendering. The solar array depicted is gimbaled to permit orientation with the sun, independent of the line of sight of the experiment package. The LM guidance, control, and propulsive capability, used in a manner similar to that of the LM/ATM mission, is of particular use in this mode of operation.



8-150

RESCUE LM

The LM's highly efficient Main Propulsion Subsystem, combined with the fully redundant Reaction Control Subsystem and versatile guidance and navigation capability, offers an in-orbit maneuvering, manned vehicle of unique capability. A LM with very limited modifications will permit application of this capability to effect in-orbit interception of, and rendezvous with, other space vehicles for such purposes as personnel rescue (as shown) and spacecraft inspection or repair.

THE MOON

R155

NASA PHOTO

APOLLO 10 VIEW OF MOON – This photograph of the moon was taken after transearth insertion when the Apollo 10 spacecraft was high above the lunar equator near 27 degrees east longitude. North is about 20 degrees left of the top of the photograph. The terminator is near 5 degrees west longitude. Apollo Landing Site 3 is on the lighted side of the terminator in a dark area just north of the equator. Apollo Landing Site 2 is near the lower left margin of the Sea of Tranquility (Mare Tranquillitatis), which is the large, dark area near the center of the photograph.

It has been said that if it were not for the Moon, many facets of our life on Earth would differ from what they are today. For example, all moon songs would be about the satellites of Mars or Jupiter, since there would be none closer to write or sing about. Such catchy phrases as "moon glow" or "once in a blue moon" would be unknown. And imagine the plight of the lone coyote, limned against an evening desert sky, muzzle pointed toward the stars, but no moon to sing to!

More fundamental is the fascinating fact that if it were not for the Moon, life, that tenacious, complex, and irresistible force which swarms across the face of this planet in a million different forms, might not exist; and its highest product, Man, would not be poised upon the threshold of the greatest adventure since his ancestors' rejection of the sea, the Journey to the Moon!

The Moon is unique. This solar system, the sun and the nine known planets orbiting around it, contains at least three dozen satellites. Only Earth and its moon, however, have a size relationship to each other of four to one: Earth is 7,910 miles in diameter, the Moon, 2,165. All other planets are much larger in comparison with even their largest satellites or "moons." Because of this unusual closeness in planet and satellite diameters, the Earth-Moon system has been called essentially a "double planet," the only such system we know of.

It is this unusual similarity in size which first marks the earth and moon as unusual, but there are other observations. The moon moves around the earth in what is called an "elliptical" orbit; that is, it can be as near as 221,463 miles, or as far away as 252,710 miles. This raises another fascinating point. Of all the planets, Earth is unique in having a major satellite (and you have to call any satellite as big as the moon, major), orbiting about 30 diameters away. If one lists the characteristics of the other planets and their major moons, one usually finds an orbit distance of only 10 diameters away, compared to the primary planet.

A third highly illustrative observation of the Earth-Moon system can be made with regard to density. All density measurements—that is, how much material is contained within how much volume—are based on water as a standard. For instance, the density of a globe of water the size of the earth, with due allowance for certain physical effects, would be about equal to "1." The actual density of the earth—the average, that is—is really about 5.52. The earth, then, has a mean density about 5.52 times that of an equal volume of water. This figure, the mean density of a planet or a moon, can give valuable information as to chemical composition if used with care along with other physical characteristics.

The density of the Moon is 3.34. The Moon, therefore, is less dense than the earth, but denser than an equal sphere, 2,165 miles across, of water. It must be remembered, however, that these figures refer to the *average* density of the earth and moon. For the earth, we know the density increases with depth because the heavy elements, iron and nickel, have separated during the lifetime of our planet and have collected to form the core. According to Surveyor data, something similar, at least in principle, seems to have happened to the Moon. This last fact is extremely important in deciding between various theories concerning the origin of the Moon.

Thus, to an objective observer, the Earth-Moon system is quite an intriguing planet-satellite pair. The planet measures four times (approximately) the diameter of the satellite, which orbits roughly once a month at an average distance of 240,000 miles away. If the mass of the planet is taken as "1," then the mass of the moon which orbits it can be expressed as 1/81 that of the planet, or, it would take 81 moons to make an earth! This very unusual pair, spinning through space around a tiny yellow star which the inhabitants of Earth call "the sun" is, when compared with all the other planet-satellite combinations known in this solar system, unique. A logical question—considering that the inhabitants of Earth having set first foot upon their satellite—Where and when did it originate?

There are as many theories as to the origin of the Earth-Moon system as there are theorists, but, practically speaking, most fall somewhere within three main avenues of research: the moon originated from the earth; Earth and Moon formed jointly at the same time in close proximity to each other; or Earth at some time "captured" the Moon from some distant solar orbit.

To understand the formation of the earth and its moon, one really has to understand the origin of the entire solar system, as the one is obviously but a part of the other. Unfortunately, there are several internally consistent but mutually conflicting ideas on the latter, and it is in determining how this planet and the Moon originated that, strangely enough, will allow eventual resolution between them. Ergo, the often heard phrase: ". . . When we get to the Moon and can analyze a piece of it, firsthand, we'll not only find out where the Moon came from, but how this entire solar system originated." This is true. In science, it is called serendipity. *Any* information about the physical and chemical composition of the solar system can't help but provide additional information about its origin, or the origin of parts of it, because the system is precisely that,-- a System! It is extremely fortunate that Earth has a Moon. If it did not, answers to these questions would have to wait until Man, provided he existed, could reach Mars or the asteroids. Analysis of the first truly uncontaminated extra-terrestrial material, the lunar samples,—in addition to shedding light on the age-old question of where the Moon comes from—will inevitably tell us something about where this planet and its satellite fit into the greater framework of the evolution of the solar system; and that makes the lunar landing but a Twentieth Century answer to a curiosity as old as Man himself: Where has he come from?

A star is being born. Gas and dust, swirled in great confusion, veil the fiery center of a solar system in formation. A series of lesser condensations, knots along the lanes of colliding atoms and solid grains, moves in spiral paths around the glowing proto-sun. Down there, coalescing out of the primeval interplanetary medium,—Earth. A flattened cloud, a rain of slushes: Ammonia, Methane, Water, and the like. Dust, debris and molecules, Hydrogen and Helium, a growing, spinning body . . . a planet. And nearby, according to prevailing thought, five billion years beyond this time, another object—a lesser eddy, also sweeping up material; lighter, smaller, destined to become a moon, a satellite forever of the other. Soon, in about a billion years, when the interplanetary skies are clear, and the nuclear fire of the central star burns steadily against the interstellar night, life will put in its appearance in the soupy, primeval mists of this young earth. The constant gravitational war, the conflicting fields of Moon and Earth down through the megayears, when the Moon is closer than she will be in 1969, raise huge tides, dwarfing those which Man will be familiar with; tides of "solid" earth, magma, molten rock, water, and even the primeval atmosphere of Hydrogen and Helium, race around the Earth. More megayears pass. Several fascinating results of this suspected close proximity of Earth and Moon are evident today. Earth's atmosphere is markedly different than it would have been if the Moon had not been near the earth at the time of its formation. As proof of this, we have only to look toward the brilliant "Morning" or "Evening Star," Venus, a sister planet about the size of Earth, but orbiting closer to the sun. Since Venus is about the same size, and our Mariner fly-bys have told us that its gravitational field is about the same as Earth's (close enough for this comparison), we would expect a comparable atmosphere, both in composition and in quantity. This is not the case! The atmosphere of Venus appears to be composed mostly of carbon dioxide at an atmospheric pressure at least one hundred times that found on Earth. An intriguing possible explanation of this discrepancy would be the earth and moon proximity during those early formative years. As the earth and its abnormally large, lone satellite whirled around each other across those megacenturies, the overlapping and constantly shifting gravitational fields inexorably stripped away the atmospheres of both new worlds, leaving a silent, rocky moon exposed to space, and a virgin planet, Earth, for volcanic action to mantle with new gasses,—nitrogen and carbon dioxide—in preparation across a billion years for Earth's first living cells; and later—much, much later . . . Man. According to our latest information, there is the distinct possibility that, without the presence of the Moon, there would have been no life on Earth.

Perhaps this is the "Why" of Man's fascination with the Moon, and our pilgrimage to her silent plains and wasted hills the repayment of a debt three billion years in age. But even in more recent history, from just two million years ago to Now (but a blink against the cosmic calendar), Man has worshipped Luna. In every language, the Moon . . . Selene . . . Luna . . . is personified as the Queen of the Night, Friend of Man, the Hunter, the Provider. If all the words in prose and verse and song were strung end to end,—and this is just a guess—they'd probably reach halfway to the Moon. Farmers around the world throughout recorded time have planted crops beneath her "correct" phase. Today, the tides she lifts, pale shadows of her former influence, govern fishing, sailing, and trade around this liquid planet. Science has even found a strange, but physical, connection between her waxing and waning face and our terrestrial rainfall. This is the lore and the lure of, as Shelly said it best, "That orbed maiden, with white fire laden, Whom mortals call the Moon . . . "

The waiting is almost over. The span of time remaining before Man's footprints mark forever the silent face of Luna can be measured now in hours. What will we find?

The Moon has not escaped unscathed her sisterhood with Earth. In 1969, she orbits our planet with an average speed of 2,287 miles per hour. At her present distance of 240,000 miles, this means a period of revolution of a little over 27 days; and, as you gaze at the Moon on clear evenings across that rift of space, you will notice the same features patterning the lighted aspect of her face. Luna keeps one side facing Earth, the other side eternally averted . . . the Earthside and Farside of the Moon.

This came about when our satellite was much younger, probably because of its then much closer orbit to Earth. If the Moon raised the gigantic tides which it must have, on our planet, then Earth, with a mass eighty-one times that of the Moon, raised tides upon that body sufficient to cause a slowing of her spin until, today, five billion years after the presumed beginning of this double planet system, the Moon swings unceasingly around the Earth, her rotation locked in synchronization with her period of revolution.

Upon the side that Man could see across the centuries he noted, first with the naked eye and later with the telescope, that the face of Luna is divided into two distinctly separate areas: *Maria*, or the "Seas," and the land, *Terrae*. The Seas are dark, the highlands lighter, but the average reflectivity or albedo of the lunar surface is only about seven per cent. Full moonlight for earthmen is only about one millionth as bright as sunlight, but even this, biologists are beginning to suspect, is responsible for many intriguing aspects of Earth's ecology.

It was the invention of the astronomical telescope by Galileo Galilei, in 1609, that was to start a controversy which still rages 360 years after. Galileo described a series of " . . . ringed, walled plains, many of them perfectly circular, upon the Lunar Surface." The origin of the over 30,000 visible craters of the Moon was to become one of the most dramatic astronomical arguments of all time. Resolution must await manned exploration.

Time has stopped. This must be the first impression of the Apollo crew as they descend the ladder on the front leg of the LM and become the first men to stand upon the surface of the Moon. For a billion years, nothing has changed—the rounded rocks, the dead grey ground, the pitch black sky. The sun, a blinding, searing circle of white-hot liquid fire, will seem to hang motionless above the eastern horizon. Harsh contrasts, the glaring sunlit rocks, the long shadows of early morning on the Moon, will be filtered by the gold-plated visors of these first Earthmen to explore the surface of another planet. Above a stark horizon, prostrate before unfiltered rays of our parent star, the sun, a planet will slowly spin—a blue-green jewel, a swirl of atmosphere cloud and desert sands as Africa slowly rotates her vast expanse across the lighted side of Earth, Man's home, a quarter of a million miles away. Sixty-seven degrees above the sunlit western limb where lunar landscape meets the dark infinity of space, this cool, ocean-covered world is suspended by the Moon's eternal, synchronous rotation, a swirl of natural color visible above this vast, forbidding wilderness.

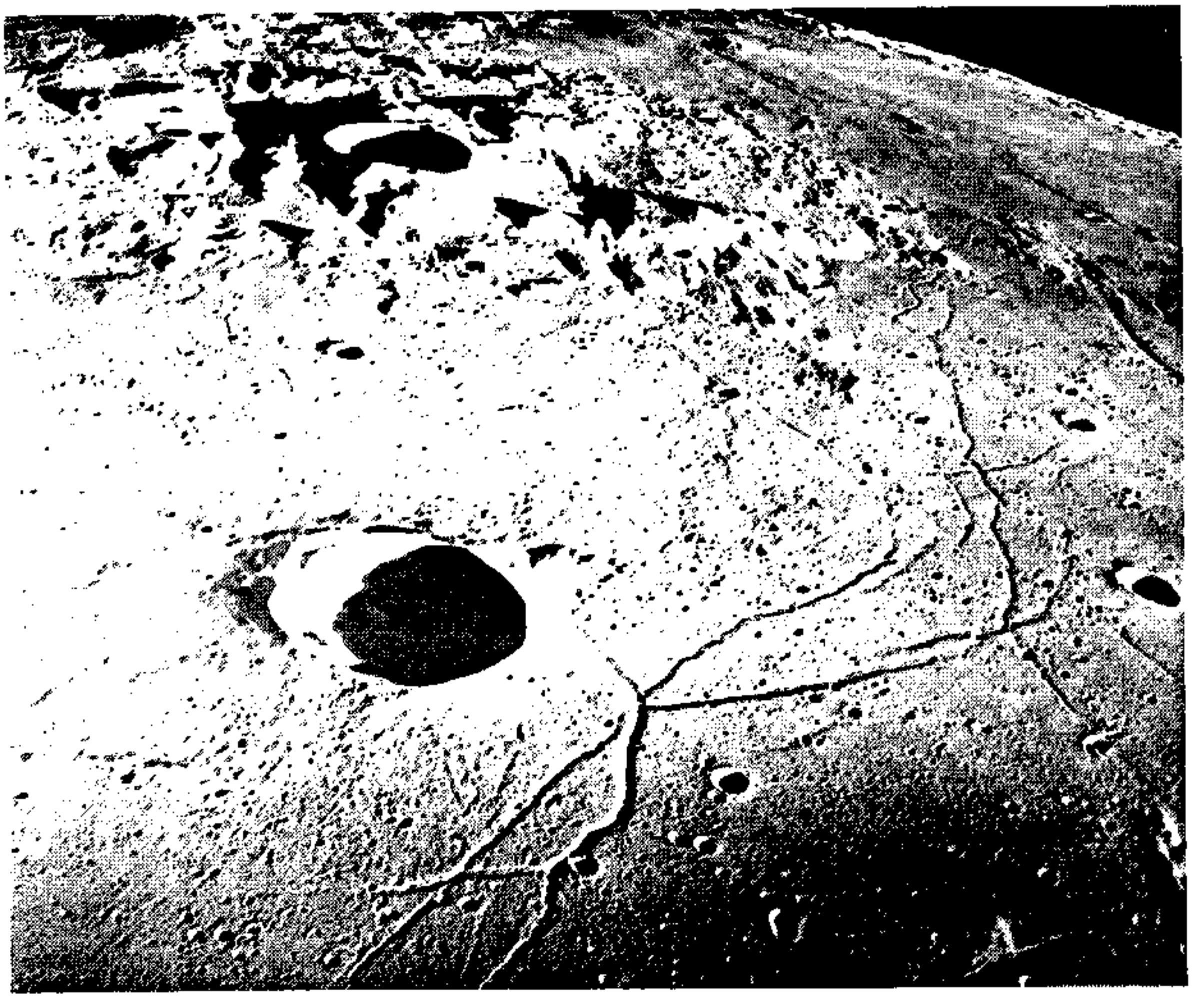
The Moon has paid her price for close association with the earth. Her small size and mass, resulting in her 1/6th gravitational pull upon her surface, as compared to Earth's, have doomed her to a life exposed to interplanetary space. Any atmosphere she might have had, collected during her formation, or released by subsequent activity from the interior, has vanished—lost forever because the molecules' and atoms' average speeds exceeded the small velocity needed to escape the clutches of her gravity.

This lack of atmosphere, this exposure to all radiation from the sun, the absence of wind, or waves, of rain or snow, is the single most important factor in determining conditions which Man will find upon the Moon. For unimaginable time, four billion circuits of our world around the sun, and more, the Moon and Space have met. The daily rain of particles, mostly small, sometimes large, debris left over from the dawning of the solar system, continually molds the surface of the Moon. At speeds never less than two miles per *second*, and sometimes as high as 100 miles per second, a constant flux, a meteoric rain, bombards the Moon, smashing, exploding, pulverizing the exposed surface of our only natural satellite. And what this "hailstorm" cannot do, our star's far-reaching atmosphere and radiation finish. The solar wind, that superhot, 100,000-degree extension of the sun in which our Earth and Luna orbit, sprays the surface of the Moon with atoms, nuclei, and ions. Its ultraviolet radiation, prevented from reaching the surface of Earth by oxygen miles above our heads, illuminates the constantly eroding rubble on the surface of Selene and, during periods of violent storms upon the sun, when tortured matter is ionized and flung at speeds near that of light, itself, into the vast abyss of space, these particles and before them, X-rays, bathe the surface of the Moon with high intensity, ever-changing radiation, both particle and wave. Is it any wonder, then, that across those megayears, this treatment has produced the pulverized, crater-strewn, lifeless, dead grey ground on which Man will soon be standing?

There are 14,600,000 square miles of barren lunar isolation. Apollo 11, Mission G of Project Apollo, in fulfillment of the national goal set forth by then President of the United States, John F. Kennedy, will accomplish the lunar landing on 36 square feet of lunar surface. Where?

There were many constraints upon the choice of a lunar landing site. In, roughly, the order of their effect upon the final decision, these were: The site must be somewhere within 5 degrees north and 5 degrees south of the lunar equator, and it must not be more than 45 degrees east or west of the Moon's prime meridian. These two factors became obvious when it was decided to go to the Moon via what is called a "Free-Return-Trajectory," one that insures that if something happens to your motive power en route, gravity at the Moon will swing you around and back toward Earth.

The Moon is divided into two main terrain types, the highlands, mountainous, upland areas of the Moon, and *Maria* the misnamed "seas,"—vast, relatively level plains which appear more and more to be internal lava flows across the lunar surface, triggered perhaps by collisions of several small asteroids, 100 miles or less in diameter. Craters cover the lunar surface everywhere, but appear heavier on the highlands than on the seas. For these reasons, it was immediately apparent that Man's first Lunar Landing should take place on relatively level ground in an area where the local crater density was low and, if such a site could be found, near some intriguing surface feature; in other words, upon a *Mare*. The Ranger Program, on July 31, 1964, with the success of an 800-lb. unmanned spacecraft called Ranger 7 began a survey of several potential landing areas via live television as the spacecraft swept in toward a crash landing on the Moon at 6,000 miles per hour. These regions were, respectively, upon the western side with Ranger 7, on the eastern side with Ranger 8, and almost exactly in the center, in an ancient and scientifically interesting crater called Alphonsus, with the flight of Ranger 9. It was through the results of this successful Ranger series that we first became aware of the tremendous erosion caused by the constant exposure of the surface to interplanetary meteoric particles. This was possible due to the tremendous increase in resolution available from the Ranger television cameras over that attainable from Earth. The best resolution acheived from Earth-based telescopes before the advent of lunar-bound spacecraft was about 1,000 feet. This meant that if a structure comparable to the U.S.S. Enterprise were to exist on the Earthside of the Moon, Man would never have been able to detect it through the constantly shifting atmosphere of Earth. It also meant that designers of the landing vehicle and trajectory planners could not know anything about the hazards or scientifically interesting features under 1,000 feet across. Ergo . . . Ranger.



R156 NASA PHOTO

APOLLO 10 VIEW OF MOON – An Apollo 10 northwestward oblique view of Triesnecker crater, centered near 3.6 degrees each longitude, and 4 degrees north latitude. This picture, taken from the Command and Service Modules, shows terrain features typical of northeastern Central Bay and the highlands along the northern margin of Central Bay. Beyond the highlands, the smooth floor of the Sea of Vapors extends almost to the horizon some 600 kilometers (375 statute miles) from the spacecraft. Triesnecker crater, approximately 27 kilometers (17 statute miles) in diameter, was 135 kilometers (85 statute miles) northwest of Apollo 10 when the picture was taken. The intersecting linear features to the right of the Triesnecker crater are the Triesnecker Rilles.

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Ranger photography made it possible to count craters on the lunar surface as small as five-tenths of a foot; but because of the nature of the missions, the area surveyed was obviously small and could only be observed for one "instant" in the history of the Moon. Something designed to simulate a manned landing, with cameras, was needed for the second phase of lunar exploration. This spacecraft, called Surveyor, would tell us if the Moon would bear the weight of a landing vehicle, or doom such a mission to disaster in jagged rocks or deep, smothering dust.

On June 2, 1966, with the Western Hemisphere of Earth in shadow, Surveyor I became the first terrestrial artifact to achieve a true soft landing on the surface of Selene. Its landing, in the extreme western edge of the previously described "Apollo Landing Zone" marked a fantastic "first" for Man and the United States. As Luna swept around the earth; from its vantage point on the Moon's Oceanus Procellarum, Surveyor became an extension of Man, watching the lonely and airless plain before its camera as the sun rose toward the zenith, then descended in the West, finally to set, plunging the spacecraft into the numbing two-week night upon the Moon. It saw, and sent to its creators, the panorama of a surface turned and battered, of blocks and rubble, and of rounded mountains, the eroded remains of an ancient crater rim beyond the east and north horizons. Surveyor photographed the stars from the surface of the Moon and, after sunset, watched the breathtaking view of our sun's own atmosphere, its corona, visible to earthbound astronomers only in eclipse, sink slowly beneath the western limb, the line separating Moon from starry space. And finally in the early hours of a night that would last fourteen days, sixteen hours, and fifty-one minutes, Surveyor sent to Man across the quarter million miles separating him from his explorer, his first view of earth-light from the Moon.

Surveyor I proved that, at least in the Moon's Ocean of Storms, Man could land and walk upon our satellite. There was no deep dust. Rocks and craters there were, but these should not prove especially troublesome to a manned landing, since the final landing site would be determined by the pilot of the LM, and the spacecraft was being designed with some hover capability. The Moon seemed very near in the early morning hours of June 2, 1966.

Concurrent with the Surveyor unmanned soft landings, another program was to become operational, the unmanned Lunar Orbiters. These spacecraft were designed to fill the gaps between the Ranger series and Surveyor, by providing extensive orbital reconnaissance of all proposed Apollo landing sites, as well as orbital photography of Surveyor landing sites, actual and potential. In this way, information obtained by the Surveyor series could be extrapolated to include the vast areas Surveyor couldn't see or sample.

The final Lunar Orbiter, Number Five in the series, completed picture readout of its last lunar photograph August 27, 1967. The Orbiters, as contrasted to Ranger and even Surveyor, did not take pictures via a direct television process, but, through an ingenious 150-lb. orbiting photographic camera/laboratory system. All photographs, taken directly on special high resolution film, were developed as the spacecraft orbited the Moon, then read back to Earth after a conversion of the film information to electronic signals. On Earth, these signals were used to run equipment which did the reverse, converting the electronic analogs back into light and dark areas on film. The same technique was first tried around the Moon when the U.S.S.R. sent its Lunik III looping around our only satellite, but the state-of-the-art used in Orbiter was vastly improved over the early Russian attempt.

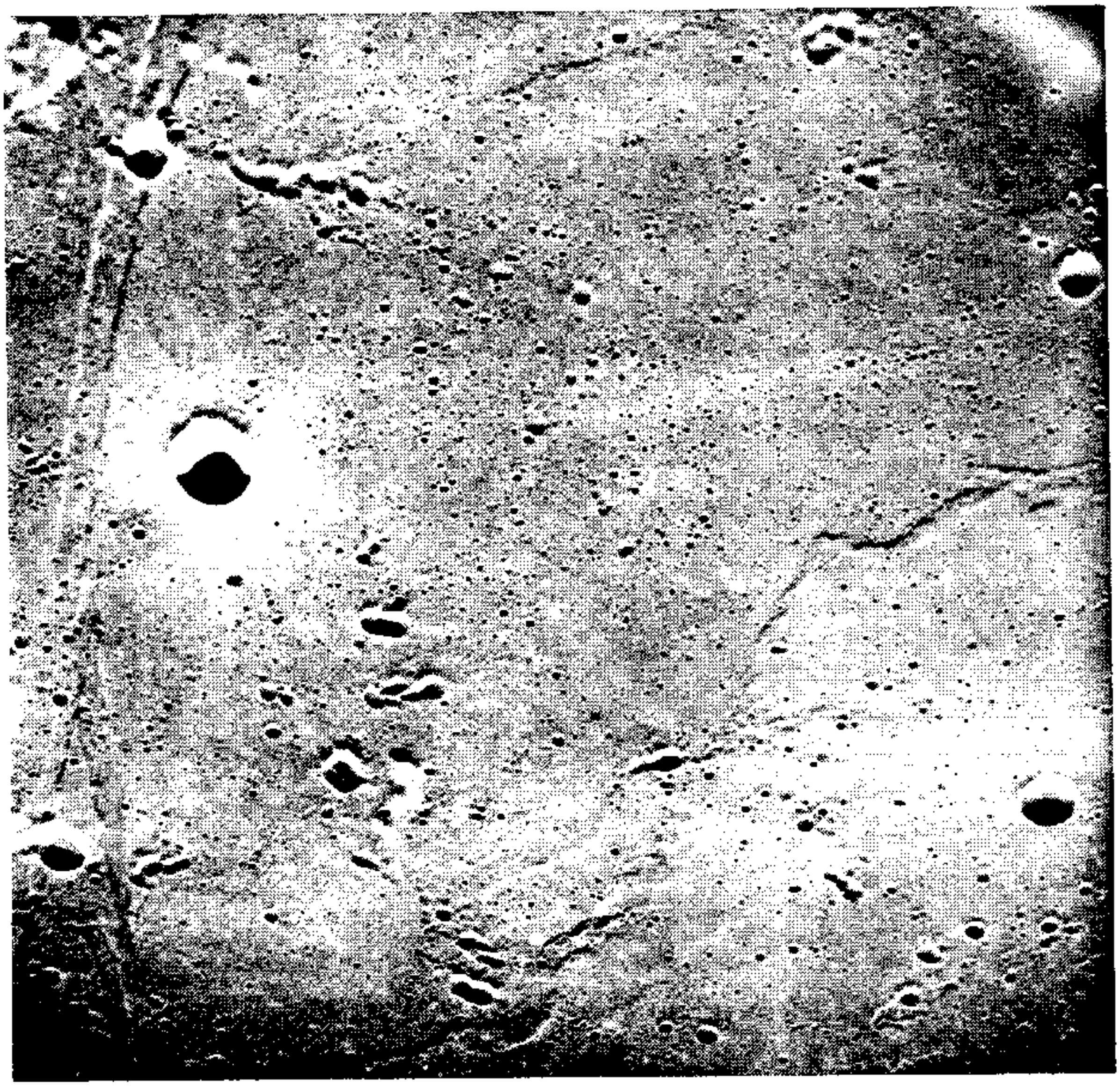
In all, five Lunar Orbiter spacecraft were sent into various orbits around the Moon. The first three were used expressly to scout the potential Apollo landing sites along the lunar equator. Because of the eminent success of these three, the remaining two were used to go after areas of scientific interest not directly concerned with the immediate goal of an Apollo landing before 1970. These spacecraft were injected into very highly inclined orbits, lunar polar orbits in fact, and made Man's photography of the entire Moon, including those areas never seen from Earth, ninety-nine per cent complete.

It was the Orbiter series that was also to make a very important discovery, from both engineering and scientific points of view, concerning the lunar interior. As the spacecraft, especially Orbiter 5, orbited the Moon, tracking was accomplished via the established ground stations of NASA's Deep Space Instrumentation Facility. With this data from all five spacecraft, it was hoped, a much better idea would be obtained concerning the nature of the lunar gravitational pull and how it behaved, in fine detail, as this would reveal information about the distribution of the Moon's mass in its interior.

From tracking data obtained during the mission of Lunar Orbiter 5, two investigators, Paul Muller and William Sjogren, of Cal Tech's Jet Propulsion Laboratories, revealed a series of denser parts of the Moon, "Mass Concentrations" or Mascons, discovered as the spacecraft, in polar orbit, traveled over five of the circular *Maria* visible on the Earthside. The irregular *Maria*, on the other hand, had much less effect on the spacecraft orbit.

While these results are fascinating from an astrophysical point of view and shed new information on theories of *Maria* formation, they also presented Apollo with a problem. As the Lunar Module is making its final descent from 50,000 feet to the lunar surface, it must fly over the Mascon areas, thereby falling prey to their perturbing effect on its trajectory. Apollo 8, orbiting men for the first time around a celestial body other than the earth, demonstrated the effect of these Mascon areas on a manned spacecraft in lunar orbit. Apollo 10, capable of accomplishing a lunar landing, but not equipped to make one, provided exact gravitational analogs by orbiting at similar heights and ground tracks as the mission to follow—Man's First Lunar Landing.

At the completion of the Orbiter program, the initial Apollo landing sites had been narrowed to five, scattered from east to west across the "Apollo Belt." The selection process at this stage of the game had excellent, high resolution photography with which to map the local terrain, analyze crater density, the heights and depths of terrain features, and areas of scientific and geological interest for the initial landing. Because of the long, very shallow descent profile followed by the LM as it rifles in toward the target area, special care had to be taken to insure the proper approach terrain along the ground track some sixty miles east of the actual landing site. This was due to the necessity of certain radar returns, which give the LM its velocity of descent as well as its height above the surface. Mountains, ridges, or large craters would cause anomalous readings, thereby "misinforming" the guidance computer of the spacecraft's actual position during those critical minutes. Many otherwise acceptable landing sites had to be discarded because this constraint made it impossible to "get there, from here, this way."



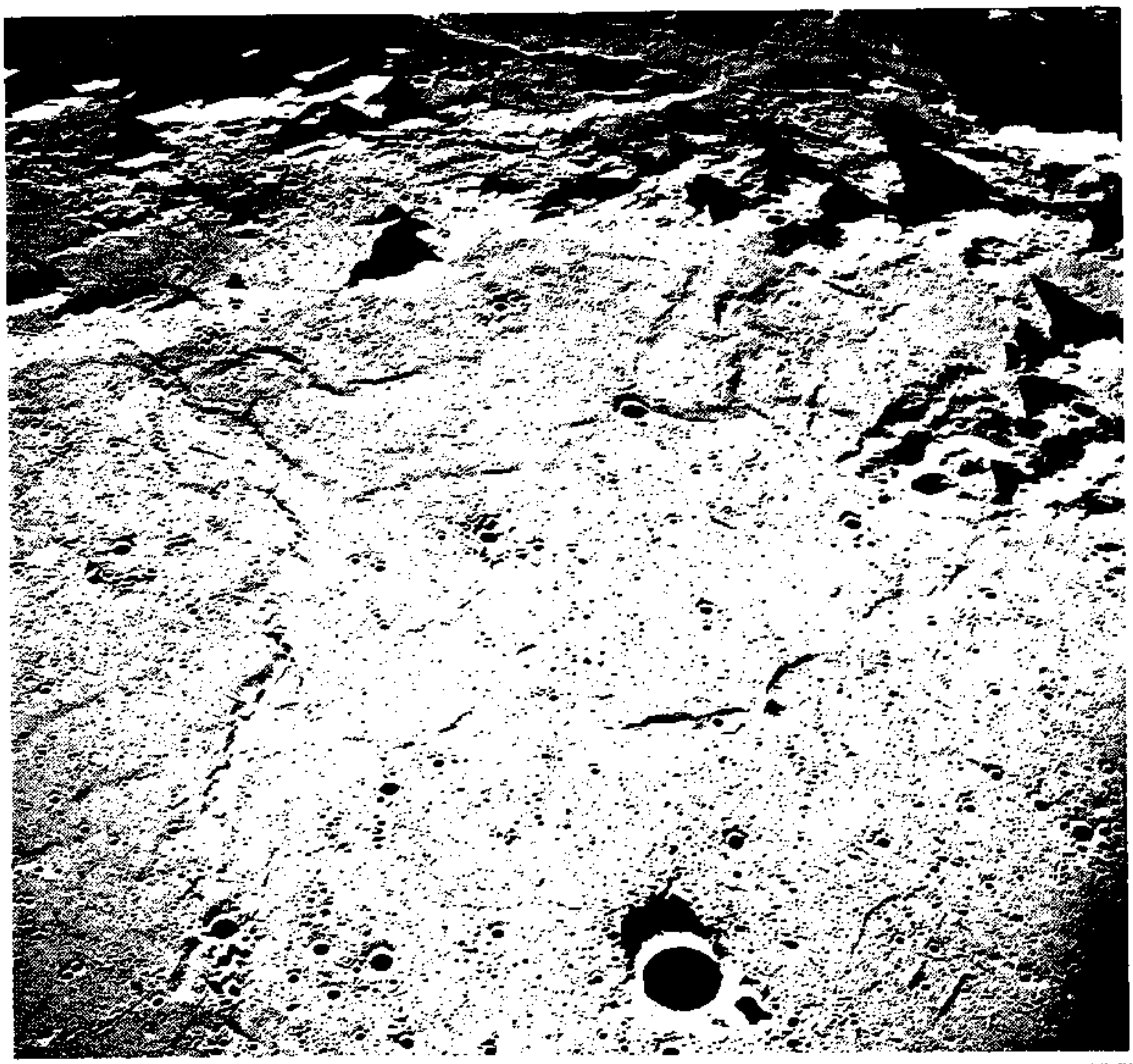
R157

NASA PHOTO

APOLLO 10 VIEW OF MOON – This near vertical photograph taken from the Apollo 10 Command and Service Modules shows features typical of the Sea of Tranquility near Apollo Landing Site 2. The proposed landing area for Apollo 11 (Lunar Landing Site 2) is a relatively smooth maria area in the upper right quadrant of the photographed area. Apollo 10 traveled from the bottom to the top of the picture. The prominent linear feature on the left is Hypatia Rille (called "U. S. 1" by the Apollo 10 crew). The prominent crater centered in Hypatia Rille at top left is Moltke AC (code name "Chuck Hole"). Moltke, the prominent crater to the right of Hypatia Rille, is centered near 24.2 degrees east longitude, and 0.6 degrees north latitude.

Even at the landing site, an area, not a point, had to be chosen. The actual spot at which the first men set foot on the Moon will be somewhere within an ellipse 4.5 miles long by 3.2 miles wide. This wide spread in the actual landing area is due to unavoidable errors in the instrumentation and in our imperfect knowledge of the effect of the Moon on the landing descent trajectory. It is an excellent maxim to remember, that the more we land on the Moon, the better we'll become.

At this writing, the most probable point on the lunar surface where men will first stand is somewhere within that ellipse, 4.5 miles long by 3.2 miles wide, centered at 23 degrees 37 minutes east



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APOLLO 10 VIEW OF MOON – An Apollo 10 westward view across Apollo Landing Site 3 in the Central Bay. Apollo Landing Site 3 is in the middle distance at the left margin of the pronounced ridge in the left half of the photograph. Bruce, the prominent crater near the bottom of the scene, is about six kilometers (3.7 statute miles) in diameter. Topographic features on the surface of the Central Bay are accentuated by the low sun angle. Sun angles range from near six degrees at the bottom of the photograph to less than one degree at the top of the photograph.

longitude, zero degrees 45 minutes north latitude. It lies in the southwest corner of *Mare Tranquillitatus*, the Sea of Tranquility. It is an old *Mare*, a lava plain formed about four billion years ago, and pounded and overturned to a depth of almost thirty feet. It will be flat, not too cratered, old, and weathered by the megacenturies' exposure to a vacuum more perfect than any possible beneath our atmospheric sea. The landscape will be grey, dead, lifeless. Across the horizon to the north, not 40 miles away, lies a crater in the wilderness, a fresh new scar upon the ageless face of Luna. Here, at 6,000 miles per hour, a part of history flashed silently into oblivion. In the sunlight, a few twisted metal fragments glint in testimony to the pioneer that was Ranger 8.

To the northwest, sixteen miles across another part of this flat and featureless horizon, is another monument to the genius that is Man. This artifact stands tall and proud upon the silent plain, its panels flashing in the sun, its golden valves and painted blocks a colorful display against the ashen surface. This is Surveyor V, and from it, gently resting on the crater rim, a box, lustrous and golden by the yellow glare of Sol. With this instrument Man made his first direct chemical analysis upon another world and found the Moon to be made, not of cheese, but of basalt, of once-molten lava, pulverized by time and exposure to the elements which rain upon this unprotected plain across eternity. Not too far from here, two men will stand, quite soon now, beneath a canopy of sun and earth and stars, emissaries to this hostile alien world from the cool green hills of earth, a quarter of a million miles across the sky.

The reasons for Man's Journey to the Moon are elegant in their simplicity. Man is going to the Moon because he can. To do otherwise would be a refutation of his past 2,000,000 years upon this planet. The history of Man has been the history of Man's life-long struggle for better understanding and control of his environment, of its utilization for his economic progress through better information and advancing technology. Man has now attained the capability to live anywhere upon the face of this third planet of the sun—this Earth—that he may choose to live. His vessels can descend into the deepest rifts of any ocean. His stations, powered by the fissioning of atoms, stand amid the ice of both the polar caps. Surveillance satellites, powered by the radiation of the sun, sweep around the planet, photographing weather in detail. As evidenced by history, the acquisition of knowledge and the control of energy have been the two most important factors governing the dominance of Man upon the earth. When viewed in this perspective, the Journey to the Moon is only the beginning of a future in which Earth's satellite and all the solar system will have been acquired for the betterment of Man, both on and off his home.

It has been said that the Moon is the most valuable piece of real estate man has yet acquired, and that exploring it will answer many questions: the origin of Earth and Moon, the solar system, even Man,—questions that today are only dimly phrased from the confinement of this sphere. If only for its intrinsic value as a chronicle, the Moon is priceless. Time is a terrestrial destroyer. The only universal constancy—Earth has guarded jealously the secrets of the past. Forces deep inside the earth, convection currents within the plastic mantle of the world, constantly give rise to mountains while dooming others to extinction. Upon the surface, the constant interplay of air and sea, the never ending cycle of the oceans, from waves to evaporated molecules, to droplets, and thence to rain and hail and snow, sluice away the record of the ages, wearing down the rooftops of the earth and carrying the silt back to the ocean floor. Life, in the form of plants and microbes, animals, and even Man, destroys each yesterday forever in pursuit of each tomorrow. The earth is a seething cauldron of hurricanes and tidal waves, geologic change, earthquakes and erosion, wind and pounding surf against the shores of every continent and island. And what these forces cannot grind away to dust, the atmosphere will slowly oxidize and change through combination. Mountains rust away, acids eat at geologic strata, and the layer of sediment buries everything as the planet, youthful still, evolves across the aeons.

In the midst of this inconstancy, Man has tried to piece together fragments of his heritage, to find a clue to the origin of worlds and suns, and of himself. The wonder is that he has done so well, in spite of the annihilation wrought by Mother Earth on artifacts of planetary history. Even a matter as basic as the abundance of the cosmic elements cannot be learned from study here. Through the process of formation, Earth effectively concealed this record: the heavy metals sank, because of gravity, to form the iron core of this, the sun's third planet. There they stay, locked, perhaps forever, beyond the probe of instruments. This makes any counting of the atoms in the crust hopeless for determination of the original distribution of the elements that formed our planet and the system, as a whole.

It is on the silent face of Luna, amid the desolation that has never known the fall of rain or the pounding of the sea that these clues to a yesterday removed forever from this earth will be discovered. There, too, change has left its mark: volcanic and external, the flow of lava from within and the explosive blast of meteoric impact from without.

But this change is of a different quantity and kind than that which has shaped and shaped again the surface of our world. Geology upon the Moon will tell a fascinating story of its formation and the forces which have made it what it is today. The surface rubble, from its depth and consistency, will disclose the frequency of objects orbiting the sun that had rained upon that surface, and the radiation character of every excavated inch will reveal the flux of cosmic rays and solar storms across the megacenturies our satellite has swept around the earth, waiting for the day when Intelligence would bridge the gap between these worlds, the planet and its satellite, and ponder its discoveries.

For the next several centuries, Man will be learning from the Moon. There is even speculation that beneath her bone-dry plains—ironically, the "seas" of Galileo—Man will find the molecules that in the liquid seas of Earth, began the spark of life. Perhaps, upon the Moon, suspended since the time of their formation four billion years ago, these complex organic compounds have remained, waiting for discovery by descendants from across 40,000,000 centuries of time and a quarter of a million miles of space. The discovery of proto-life, the step just before the creation of that first, simple, self-replicating cell, would undoubtedly rank as the greatest scientific discovery of this century, just short of the discovery of extraterrestrial life itself. In all the solar system, after due consideration for the environments of all the other planets and their satellites, this discovery of pre-organic molecules preserved against the ravages of time, is only possible amid the isolation and the silence of the Moon.

But even if it weren't for her intrinsic value, as the Rosetta Stone that will unlock the mysteries of Time, the Moon would still become a cherished gift to Man, as the foundation for exploration of the Universe.

Astronomy and astrophysics cannot help but benefit from the establishment of an observatory on the Moon. Earthbound astronomers for centuries have seen " . . . but through a glass, darkly," their view of space only a distorted glimpse through the thick, shimmering, absorbent veil of Earth's dynamic atmosphere. The limitations imposed by observation through this interfering gaseous mixture are almost too numerous to mention. It, first of all, absorbs most of the energy emitted by objects in the Universe: stars, galaxies, and quasars—just to name a few. What energy does finally filter down to the surface of the earth is then distorted through refraction imposed upon this radiation by our "transparent" air. This effect, the cause of "twinkling" of the stars, limits the fineness of detail that can be seen or photographed, be it of an object a million light-years distant, or right next door, such as the Moon.

Sometimes, on nights when skies are cloudy, the only radiation from the heavens reaching Earth is the delicate whisperings of radio emissions from the stars. The observatory on the Moon, with an array of telescopes covering the spectrum,—optical, X-ray, infrared and radio—will advance Man's knowledge of the Universe at least a thousand years. Anchored deep inside the lunar crust, these instruments will have the capability of seeing all of space in a period of time (27 days) equal to the rotation of Selene, if placed at the equator. Their gaze will span a distance back across the light years to the Dawn of Time itself, when the Universe was born. Time exposure photographs, measured not in hours, but in days, will image for the eyes of Man the details of the birth of stars and galaxies impossible to view from Earth observatories.

From that airless lunar plain, totally exposed to all the silent radiations that flash across the interstellar night, Man will first attempt to photograph the planets of the nearby stars. With telescopes at least six times as large as any ever built before, the light of other suns will be collected. By careful screening of their glare, a search in their vicinity for tiny, planetary points of light will then commence. It is thought that almost all stars form planetary systems as the natural function of their origin. Detection of these worlds in actuality,--a feat impossible except from space--would lead to great advances in our understanding of the Solar Family. It would also provide us concrete targets for our probes across the dark light-years, and may even lead to detection of a second "Earth," somewhere, orbiting an alien sun.

Sometime within this century, as Man explores and develops the resources of the Moon, there will be established upon the Moon's Farside, an additional observatory. This will be done in desperation as an increasingly technical society on Earth broadcasts its presence to the stars. The electromagnetic interference from television, radio, aircraft, surface transportation, and the like, is now, in 1969, a roar. In future years, this din will rise at an increasing rate until it drowns all radio reception from the Universe beneath a sea of electronic noise.

Radio astronomers, searching desperately for a solution, will plan and implement a research station on the Moon's Farside, forever out of sight of Earth; for even across the intervening quarter of a million miles, terrestrial electronic interference with delicate detection of intersteller radio emissions cannot be tolerated. A radio observatory on the Farside of Selene, with at least a thousand miles of solid rock screening it from Earth's electromagnetic clamor, will scan the heavens unhindered, mapping the natural song of hydrogen, hydroxyl radicals, water, ammonia, and a dozen other compounds, deciphering the death throes of a star or the birth-pangs of the Universe, itself. And from the isolated silence of the Moon's Farside, this observatory could become the first receiver of a signal *not* of natural origin, but one sent by Intelligence in search of a reply across the sea of stars which forms the Milky Way.

If utilization of the Moon is important, astronomically, to science, then so will be discoveries that are to come from basic research conducted in her physically unique environment. The basic properties of matter, the structure of the nucleus, even the laws governing the existence of Space and Time themselves can be discovered through the proper questions asked upon the surface of our satellite. When laboratories are constructed in the space environment upon Selene, physicists will have available for interaction with selected target materials, the most powerful radiations known in all the Universe, primary cosmic rays. These particles, ejected from the star-rending explosion of a sun, are accelerated to velocities near that of light. By studying their impact, science will come ever closer to an understanding of the forces which have shaped Creation, under conditions unattainable on Earth.

In laboratories on the Moon, research will also center on the effect of space on matter. Here, for mile after mile, is a more perfect vacuum than can ever be economically attained beneath our Terran atmospheric sea. On Earth, each cubic inch of "nothing" must be paid for dearly through the use of complex seals and pumps and power. On the Moon, all the vacuum Man will ever use is there, as free as air on Earth.

Scientific exploration of the Moon implies survival on the Moon; a base, with a variety of personnel, supplies, and means of manufacture and construction amid the Moon's environment. The philosophy whereby one transports everything,--men, equipment, food and water,--to the lunar surface must someday give way to means of utilizing those available resources on the Moon itself to sustain tomorrow's colonists upon her airless plains.

Apollo will determine, on a *Mare*, what the Moon is made of; but this determination will be essentially confined to scattered points on the top-most layer of a planet having an area almost as great as North and South America combined. It is obvious that a detailed inventory of the Moon's resources must await much more extensive exploration than the initial landings.

In areas of volcanism,—and from Orbiter photography, these are almost certain to exist,—those environmental factors favoring the establishment of a self-sustaining Lunar Base are most likely to be found. There will be lava tubes, allowing structures to be inflated underground, away from the 500 degree extremes of temperature encountered on the surface, as well as the eventuality of meteoric impact. Given enough energy (either the sun which shines full-force upon the Moon, or nuclear sources), Man can extract those vital elements of life, oxygen and water, from the surface of Selene. According to Surveyors 5 and 6, over half the atoms present in the surface were revealed as oxygen. Water was not detected in these historic findings, but should exist, especially if volcanism plays a part. In certain geologic forms, water should form as much as ten per cent by weight, allowing economical extraction through the use of energy derived from reactors or the sun.

This will be the key to the development of all the Moon. If mining and, through the use of energy, the subsequent extraction and refinement of essential air and water is possible upon the Moon, then, before the year 2,000 the Moon will be acquired for the betterment of Man. Colonies of scientists and engineers, of businessmen and manufacturers, of pioneering families, will transform Selene into a vital necessity to the people of the earth. Industries impractical forever here on Earth will flourish on the Moon where instant vacuum, temperature extremes, and 1/6 gravity lead to technological discovery. In the electronics field, alone, these conditions will inevitably lead to the growth of a whole new era of ultra-pure, solid-state components. With abundant energy, sophisticated treatment of the Moon's raw materials may lead to entirely new metals, plastics, glass, to say nothing of the manufactured products built around these new discoveries.

The once barren lunar surface will be transformed; clusters of domes rising from the airless ground in places the names of which have rung through history: *Copernicus*, the *Apennines*, the northern shores of *Mare Imbrium*. Monorails, gleaming in the two-week sun, will flash silently along, ferrying passengers and freight from the Observatory to manufacturing complexes, from tourist centers to the spaceport, across the wilderness, the *Mare*, and *Terrae*, from pole to pole, and even to Farside. Whole cities, peopled by the citizens of Luna, will grow beneath the surface of Selene. Before the turning of the century, amid the brisk development of this *entire* double-planet system, children, many never to set foot upon Man's green oasis, Earth, will be born upon the Moon. They and their descendants will make the Moon and other planets of this solar system a vital part of Earth's economy, feeding, housing, and supplying the people of the sun's third planet with many of their needs.

Realization of the Moon's potential, its resources and environment, must include a study of its effect on spaceflight as a whole. Escaping from the Earth, against its gravity, is an expensive operation which will deter efficient use of space until a way is found to overcome the inefficiencies of present rocket systems.

Todays massive vehicles, the Saturn 5's, the Titans and those similar, will soon—*must* soon give way to vehicles designed to be reusable; vehicles that will leave the surface of the earth, attain orbit just outside the atmosphere, and then return, landing like an aircraft of today. These ferry systems, carrying passengers and cargo into low orbit of the earth, will rendezvous with cities in the sky, space-stations orbiting the planet at altitudes around 500 miles. There, equipment, personnel, and vital luxuries unobtainable on the Moon, will be transferred aboard a Lunar spacecraft, a vehicle designed in the pattern of the LM, never to make a planetfall upon a world with atmosphere. Using fuel manufactured on the Moon, this transport system will follow its return trajectory to Luna and in three days will land its cargo upon the airless surface of our satellite. Man will learn, even if he does not realize it now, how unfortunate it is that Earth has a satellite located as it is. Rich beyond belief in minerals, information, and environment, it will someday become more economical to transport products, men, and even food from the surface of the Moon, a quarter of a million miles away, than it is or will be then to travel from the earth into an orbit of the earth. This will be possible because of the Moon's small mass, its lack of atmosphere, and its position.