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A PROPOSED HYPOTHETICAL EXPLORATION MISSION IN THE FLAMSTEED CRATER REGION OF THE MOON

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Space Flight Center,
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ABSTRACT

A hypothetical 14-day lunar surface mission is proposed for two astronauts to investigate the lunar terrain and larger features about a preselected landing site. Because the Surveyor I spacecraft soft-landed in the Flamsteed Crater region and demonstrated that an unmanned spacecraft can safely land in this particular area, this site will, for purposes of this paper, be considered a suitable site in which to carry out a proposed scientific exploration mission. The proposed mission will be supported by a lunar shelter (to be landed up to six months before the manned landing) which will serve both as a shelter and a communications center with the earth. A small roving vehicle will be used for manned traverses within a radius of eight kilometers about the shelter, and a flying vehicle will be used for flights up to 30 kilometers away. Scientific instrumentation will be provided for experiments in several disciplines. The geological and geophysical investigations include (1) sample collection, seismic, magnetic, and gravity surveys, and long-term tidal and quake measurements and (2) measurements of radiation, temperature, micrometeoroid flux, etc. An engineering investigation on the Surveyor I spacecraft and its components will also be conducted.

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AEROSPACE ENVIRONMENT DIVISION
AERO-ASTRODYNAMICS LABORATORY
RESEARCH AND DEVELOPMENT OPERATIONS

LIST OF ILLUSTRATIONS

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SUMMARY

A hypothetical 14-day lunar surface mission is proposed for two astronauts to investigate the lunar terrain and larger features about a pre-selected landing site. Because the Surveyor I spacecraft soft-landed in the Flamsteed Crater region and demonstrated that an unmanned spacecraft can safely land in this particular area, this site will, for purposes of this paper, be considered a suitable site in which to carry out a proposed scientific exploration mission. The proposed mission will be supported by a lunar shelter (to be landed up to six months before the manned landing) which will serve both as a shelter and a communications center with the earth. A small roving vehicle will be used for manned traverses within a radius of eight kilometers about the shelter, and a flying vehicle will be used for flights up to 30 kilometers away. Scientific instrumentation will be provided for experiments in several disciplines. The geological and geophysical investigations include (1) sample collection, seismic, magnetic, and gravity surveys, and long-term tidal and quake measurements and (2) measurements of radiation, temperature, micrometeoroid flux, etc. An engineering investigation on the Surveyor I spacecraft and its components will also be conducted.

I. INTRODUCTION

Discussed is a hypothetical lunar surface exploration mission developed by the author and based on considerable studies done by various contractors, NASA Headquarters, Marshall Space Flight Center, and the U. S. Geological Survey over the past few years. The engineering and scientific mission described is a proposed 14-day effort by two astronauts to investigate areas of interest about a pre-selected lunar landing site. Because the soft-landing of the Surveyor I spacecraft in the Flamsteed Crater region has demonstrated that an unmanned spacecraft can safely land there, this region is considered a suitable place in which to carry out such a mission. In fact, it is already being considered for an Apollo manned landing. Because it appears to be sufficiently geologically diverse to produce a great deal of scientific information, this site may also be included in the post-Apollo phase of lunar exploration. However, it must not be construed that the hypothetical mission described here will be the actual mission performed at that time.

The Crater Flamsteed, in southeastern Oceanus Procellarum (figure 1), is a bright crater about 20 km in diameter near the south rim of a discontinuous ring some 90 km in diameter. This ring appears to be a "ghost" crater flooded with a mare material. Within the rim, which is estimated to be as high as 50 meters on the south and as high as 400 meters on the northeast, are many internal craters, Flamsteed D and E being among the larger ones. The dark mare surface is covered with bright craters and rays. Because this site was photographed by Orbiter I in medium resolution and by Orbiter III in both medium and high resolution (8-meter and 1-meter, respectively), we now have enough information to produce very good geological and topographic maps of a large area of this site for the planning of an exploration (see figures 2, 3a and 3b). Because no final geological interpretation map has been prepared at the present time based on the Orbiter data, only those features which appear to the author to be of major geological interest will be visited during this hypothetical mission.

II. OBJECTIVES

The general objectives of this proposed surface exploration mission are as follows:

(1) To determine the geological and geophysical nature of the initial landing site and other selected areas nearby.

(2) To emplace scientific stations at the landing site and three selected remote sites.

(3) To survey, remove, and return selected samples from the Surveyor I spacecraft for engineering analysis which will be performed at the lunar shelter.

It is expected that these objectives can be achieved by performing a total of twelve sorties (six with the flyer vehicle concept and six with the rover vehicle concept).

The geological investigation will include determining the contacts between the major stratigraphic units, sampling of common and uncommon materials, and describing the structural and geomorphic features. If possible, craters of different sizes should be examined to determine the age and layer thickness of the mare material in the craters. In addition to the surface surveys, a 30-meter hole at the shelter site and a 3-meter hole at each of the three remote sites will be drilled, cored, and logged as part of the emplacement of the scientific stations.

The geophysical objectives will be to obtain data for the gravity and magnetic surveys of the landing area and to obtain seismic information about the lunar maria around the shelter. The objectives of the engineering survey of the Surveyor I spacecraft will be to obtain selected parts of the craft and other materials which have had long time exposure to the lunar environment (radiation, temperature cycles, micrometeoroids, etc.) for analysis at the lunar shelter. Although some of the objectives of each type of mission may not be achieved because of time and mobility restrictions, it is not expected that many pre-planned activities will require modification.

III. SUPPORTING EQUIPMENT

The support equipment required to perform these missions are as follows:

(1) A lunar shelter (figure 4) with a roving vehicle and a flying vehicle on board will serve as a base of operations (food, quarters, communications, and laboratory space). The shelter, to be large enough for a two-man crew, would have a quiescent six-month storage life and a 45-day operations capability including the extra life support equipment required for extravehicular activities.

(2) Either one of the roving vehicles shown on figure 5 might be used for transporting the astronaut and for carrying cargo. These vehicles, either of which could be remotely controlled or driven by the astronaut, would have a radius of action of about 8 kilometers about the site and could be driven at least 20 kilometers in each sortie. (This proposed mission, however, does not require that the vehicle be remotely controlled.)

(3) The flying vehicle (figure 6) has a 30-kilometer radius of action. For this proposed mission, two lunar flying vehicles are required, one to fly to the remote sites across difficult terrain or at ranges that would require too much driving time using the rover, the second to be reserved as a rescue vehicle for emergencies occurring at a remote site. This second vehicle (fully fueled) is delivered to the surface by the LM taxi during its initial landing. Thus, if the LM taxi on its initial landing misses its programmed landing site or, because of mission difficulties, is required to land at a site which is in excess of the astronaut's walking distance (approximately 1 km) to the lunar shelter, a mode of transportation is available to continue the mission. This technique also prevents further large-scale contamination of the lunar shelter area by a second LM-type descent engine.

The required scientific equipment and supporting tools for this mission consists of both standard and specialized geology laboratory equipment at the shelter, a 30-meter drill mounted on the shelter, already shown on figure 4, a 3-meter hand drill (figure 7), a lunar surveying staff (figure 8), special geophysical instrumentation (carried by the roving vehicle), four scientific stations (figure 9) capable of remote operation to obtain environmental and geophysical information, and equipment to support both the geological and engineering missions (figure 10).

IV. GUIDELINES AND CONSTRAINTS

In planning a lunar surface mission, it is necessary to establish ground rules and constraints based on the capabilities of the astronauts and their equipment. For this mission, these are as follows:

(1) Limit the astronaut to six hours away from the shelter during any one sortie.

(2) Alternate the astronaut assignments on the sortie and use only one astronaut on the sortie at any time.

(3) Stay within 8 kilometers of the shelter with the manned roving vehicle during a sortie.

(4) Stay within 30 kilometers of the shelter when using the flying vehicle.

(5) Carry the large scientific packages on the roving vehicle and small scientific packages on the flyer.

In considering the mission objectives, the following criteria were used in selecting the landing site:

(1) The area should have had a preliminary geological interpretation map completed so that certain assumptions can be verified or disproved.

(2) The location should be near the Surveyor I site or within the range of both the roving and the flying vehicle.

(3) A number of large features should be accessible from the site using the mobility aids provided.

(4) The site will be located in a mare which has been determined to have minimum slopes and roughness and which meets all requirements for minimum performance of the spacecraft and crew during the landing phase.

V. MISSION PROFILE

Considering the overall mission, the physical limitations of the astronauts, the support equipment, and the restrictions imposed by the lunar environment, twelve sorties will be required for the geological and geophysical investigations, for emplacement of the scientific stations, and for the examination of the Surveyor I spacecraft and its components. The two astronauts will land on the moon by a LM taxi within about 800 meters from the lunar shelter (landed up to six months before the manned landing). The astronauts will then proceed to the shelter and begin their mission. Figure 12 shows a typical set of the three types of sorties (geological, geophysical, and engineering) to be performed at or near the landing site. Typical investigations are as follows:

A. Geological Mission

One of the most interesting features observed on the Orbiter I and III high resolution photography has been the ridges or larger hills north and east of the Surveyor I site. John A. O'Keefe and his associates [1] believe that these ridges are a convex body of viscous lava (a surface manifestation of a ring dike) and that the finely divided material in the Surveyor I pictures is the surface of a lunar ash flow tuff of acid or intermediate composition. In addition, they argue that the slope of the ring material in contact with the mare material is convex while terrestrial talus slopes are nearly always concave. This suggests that the slopes are the result of volcanic action and not mass wastage. G. Fielder [2] in his analysis of the Orbiter I and III photography of the Surveyor I site proposes that both Flamsteed θ (figure 11a) and Flamsteed β (figure 11b) are parts of an old volcanic ring structure. L. Rowen [3] and D. Milton [4] argue that the angle of repose of the slope materials is not a good indicator of the source of these slope materials and that the slopes are the result of mass wastage; however, they do not preclude the possibility that these formations are a ring or coulee covered by a layer of fragmental debris. During a geological mission, it would be interesting to investigate the origin of the formations to the north and to the east of Surveyor I.

A typical geological sortie, designated as "1" on figure 12, using the flyer to study the Flamsteed θ is as follows:

1. One astronaut would ready the vehicle and fly to the Flamsteed θ region north of the site, while the other astronaut remains in the shelter to perform scientific studies and for logistics and safety reasons.

2. While at the remote site, the first astronaut would (1) study the contact between the hills and the mare floor, (2) examine several different types of craters within the immediate area, (3) study, select, and package various samples of materials which can be brought back to the LM laboratory for study, (4) photograph the site at high resolution for survey locations data and record his observations, (5) drill, core and log a 3-meter hole and emplace a small active remote scientific station, (6) reactivate the flyer, check out for operation, and fly back to the shelter, and (7) study the samples during the remainder of the time.

At least two other sorties will be required to emplace scientific stations at Flamsteed β and at one other location between β and θ to establish the geology of these features and provide environmental information.

B. Engineering Analysis Mission

A single engineering mission can help to establish effects on equipment and materials of long time exposure to the lunar environment. A typical engineering mission sortie, designated as "2" on figure 12, is outlined as follows:

One astronaut will (1) ready the roving vehicle and drive to the Surveyor I site, (2) inspect the solar panels and the planetary array for any buildup of fine-grained materials on any part of the spacecraft, (3) examine and photograph the spacecraft and selected painted surfaces, obtain a sample of paint to determine the effects of prolonged exposure to lunar environment, (5) inspect accessible wiring and electrical connections for damage to insulation, etc., (6) inspect the Compartment A Vycor glass mirror which was shattered during the lunar night and observe any other damage, (7) inspect the Compartment A battery to determine cause of failure, and, if possible, remove the battery and bring it back to the LM for analysis, (8) remove the TV camera or other components, as directed by ground control, for analysis at the LM shelter, (9) sample the soil thrown out by the Surveyor foot pad and sample soil that was not disturbed by the landing of Surveyor I to determine the amount of radiation damage, and (10) return to the LM shelter, collecting rock samples along the route as time permits.

C. Geophysical Mission

The geophysical mission will be performed using the roving vehicle. Seismic and other geophysical measurements will be made. A typical geophysical sortie, designated as "3" on figure 12, is as follows:

One of the astronauts would perform the following duties, while the other astronaut remains at the shelter: (1) Ready the roving vehicle and proceed on a 20-km pre-planned closed-loop traverse making periodic gravity measurements and continuous magnetic measurements. (2) Photograph and survey the terrain while on the traverse and at each of the pre-planned stops, thus establishing a controlled terrain for use in the analysis of the gravity, magnetic and seismic measurements to be performed on later sorties. The seismic arrays assembled later will consist of explosive charges placed on the surface and buried, and a recording network to monitor the sound ray path after detonation. This technique allows the collection of information about the sub-surface structure. (3) Collect samples of soil, rocks, and other items of interest at pre-planned stops, recording his observations. (4) Return to the shelter, analyze the collected items, and perform other required tasks. At later times during the overall mission, five additional sorties will be performed to provide as much geophysical data as possible.

VI. TIME LINE ANALYSIS

In developing a lunar exploration mission, the most important factors are the time and logistics requirements. Table I shows the amount of time required to carry out a proposed total mission once the astronauts are on the surface and their equipment is operational. This budget includes the time required for landing and the return to the CM-SM.

VII. CONCLUDING REMARKS

Typical scientific missions and sorties which can be performed by a team of astronauts to yield a large amount of scientific data have been described. Since the explorers are faced with a unique environment, a great deal of time must be devoted to travel, rest, meals and personal care leaving comparatively little time for scientific study. However, with good mission planning and serious consideration of the problems which could conceivably arise and alternate procedures to alleviate these problems, man should be able to carry out successful scientific and engineering programs on the lunar surface.

The author wishes to express his appreciation for the information and encouragement provided for this study by his colleagues in NASA Headquarters, Manned Spacecraft Center, Marshall Space Flight Center, and the U. S. Geological Survey.

TABLE I

Time Budget for the Total 14-Day Mission

Function	Total Man Hours	Percent
Landing via LM-taxi, transfer to LM shelter, checkout of shelter and equipment, return to LM-taxi, and return to CM-SM in orbit via LM-taxi	31.6	4.7
Roving vehicle travel time	35.6	5.3
Flying vehicle travel time	3.2	0.4
Scientific surface activity	68.8	10.2
Scientific laboratory activity in or near the shelter	54.2	8.1
Communications and planning	40.0	5.9
Monitoring operations	74.6	11.2
Rest, meals, and personal care	364.0	54.2
TOTAL	672.0	100.0

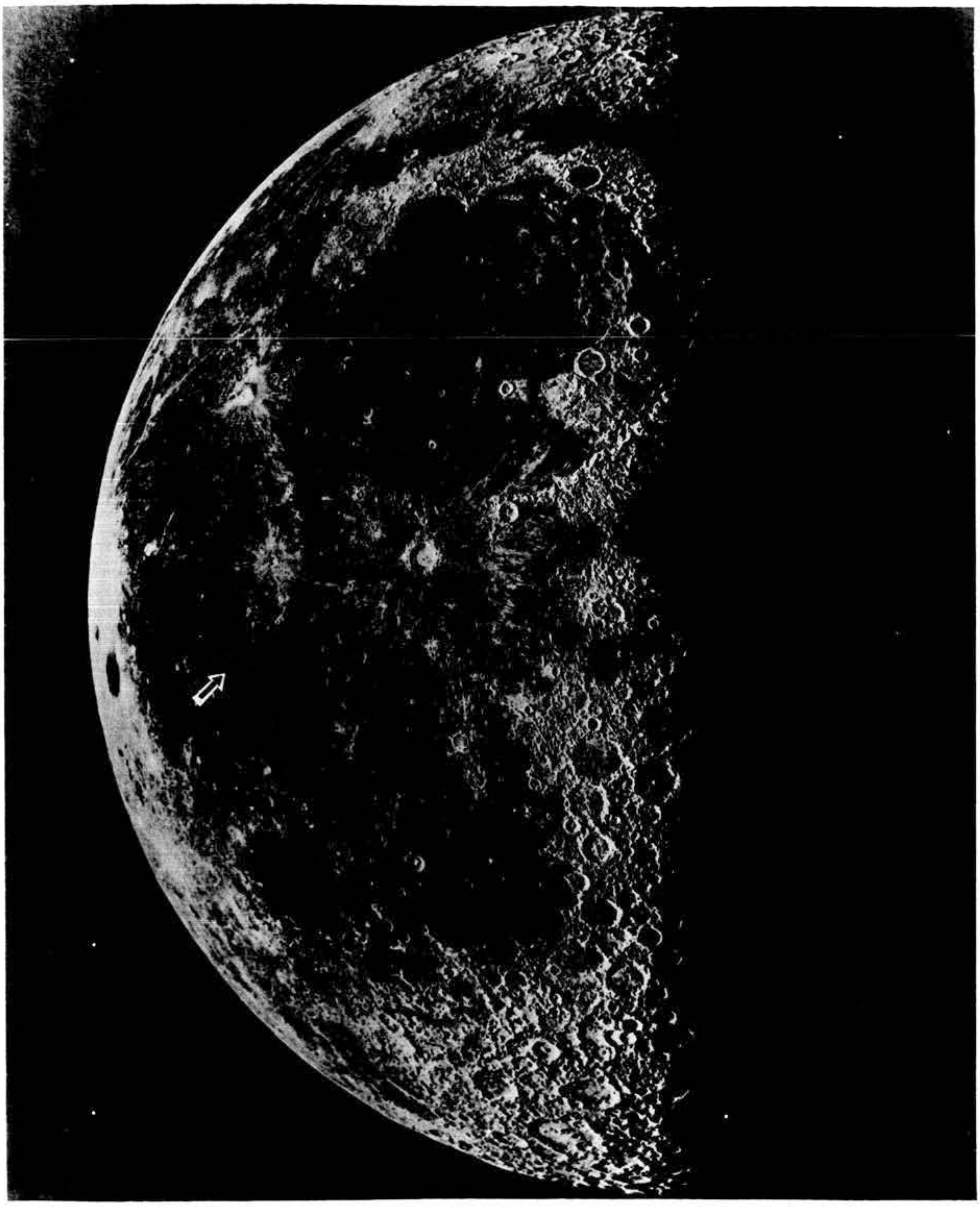

Figure 1. Mission Landing Region

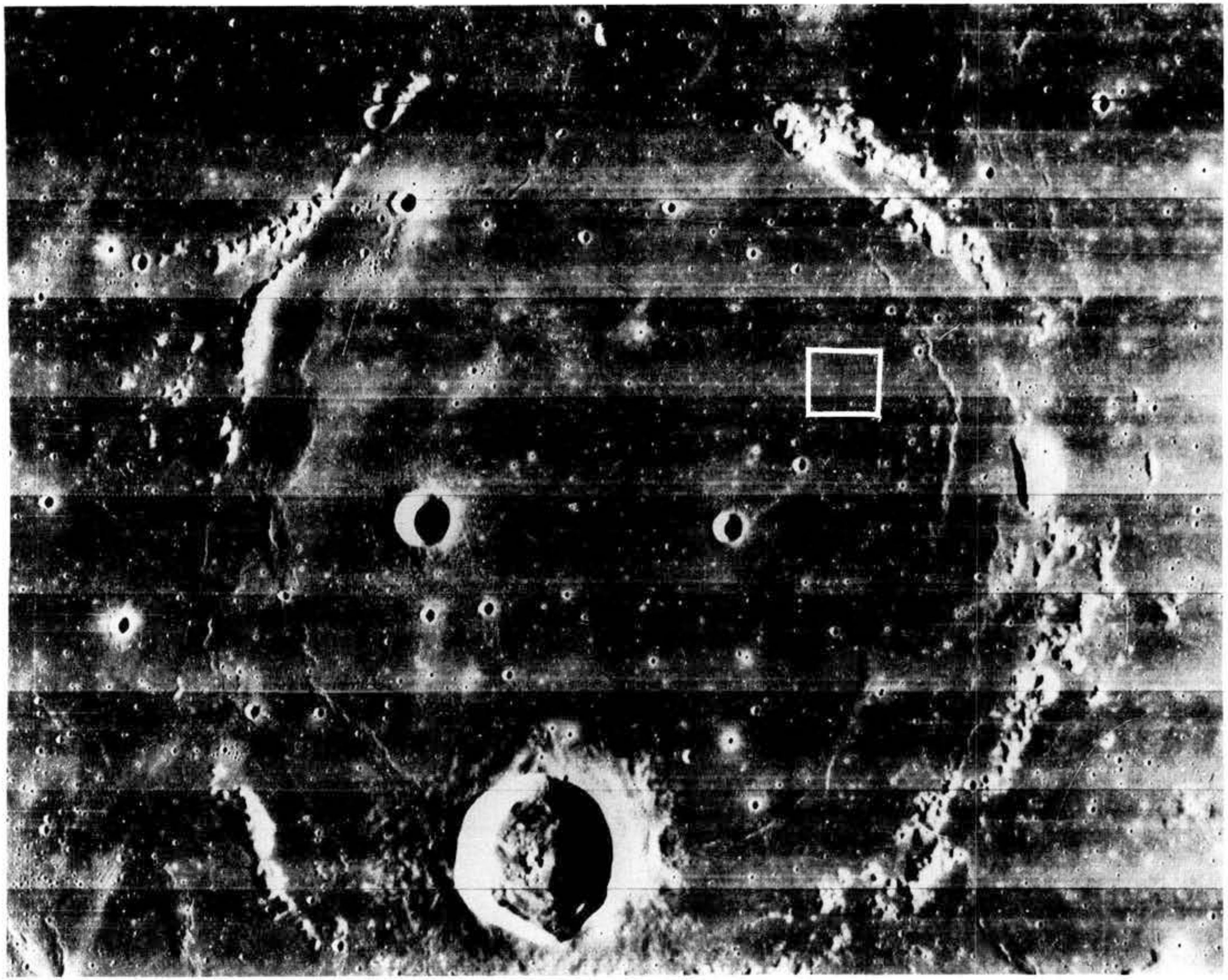

Figure 2. Mission Landing Site at 100 Meter Resolution

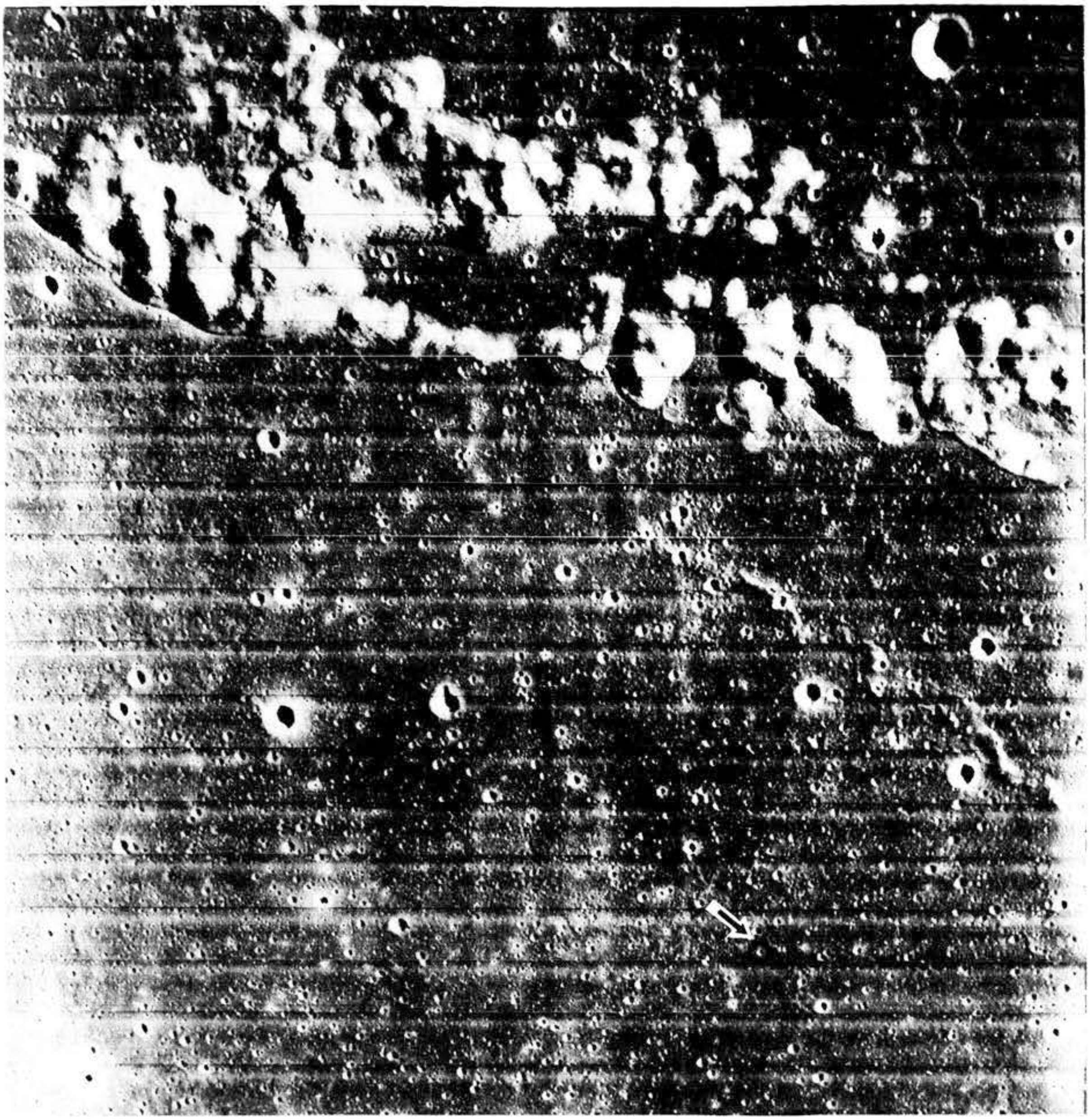

Figure 3a. Surveyor I Site at 8 Meter Resolution

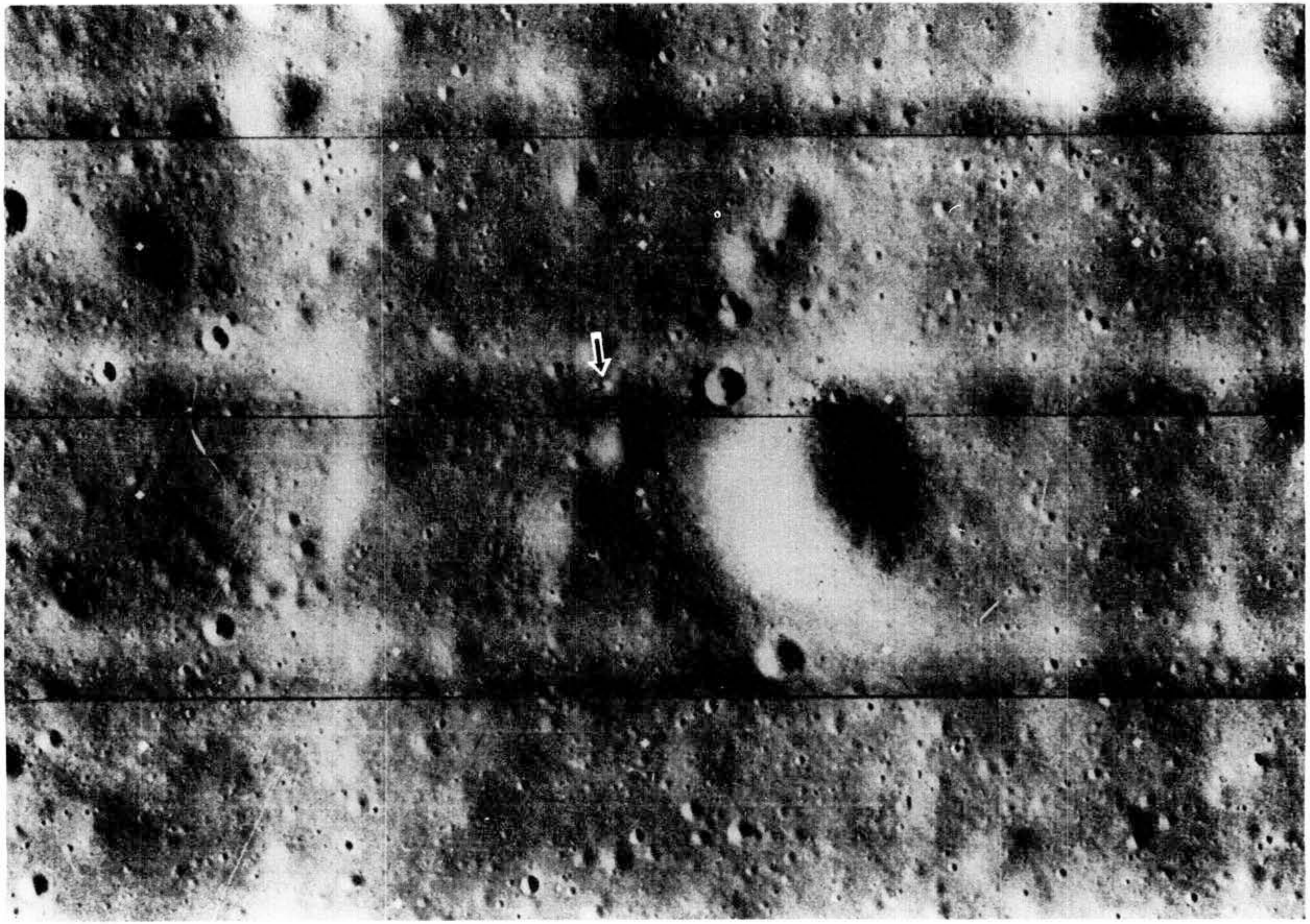

Figure 3b. Surveyor I Site at 1 Meter Resolution

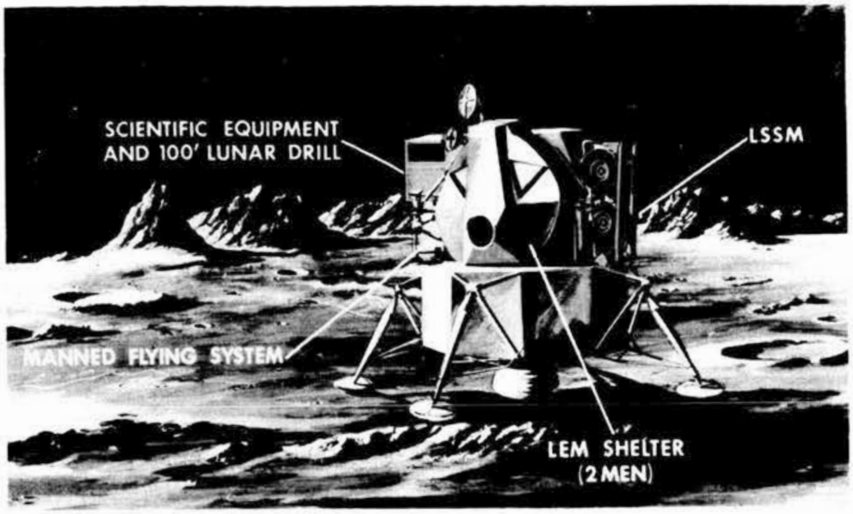

Figure 4. Lunar Shelter Concept

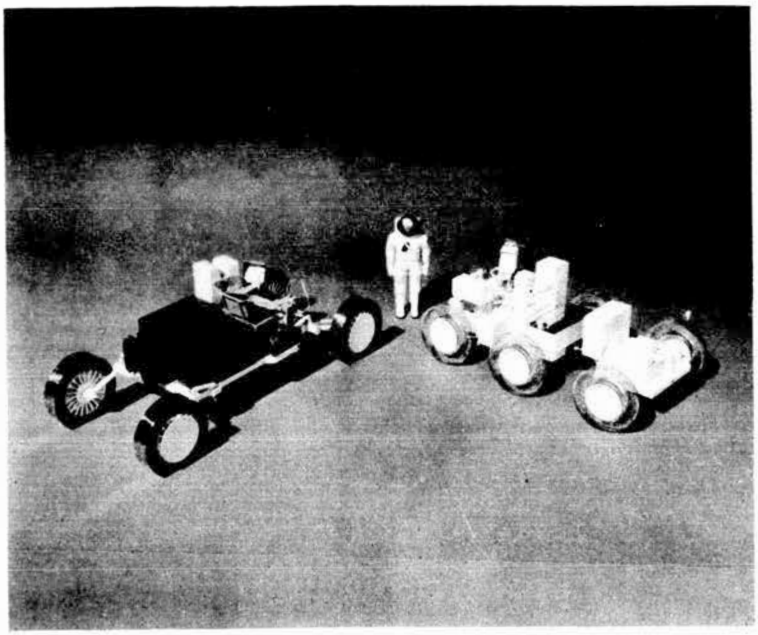

Figure 5. Roving Vehicle Concepts

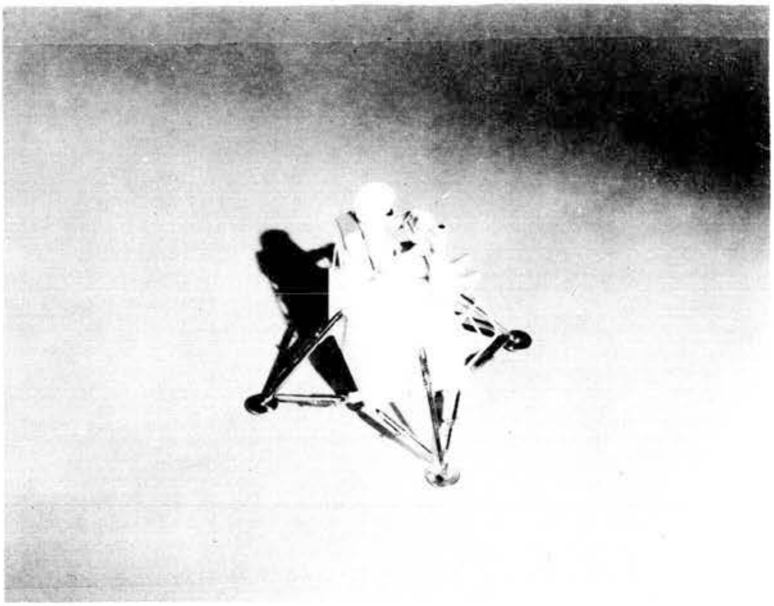

Figure 6. Flying Vehicle Concept

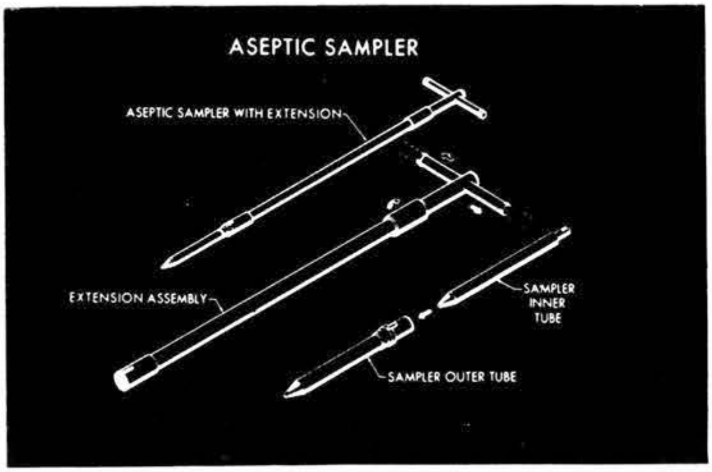

Figure 7. 3 Meter Hand Drill

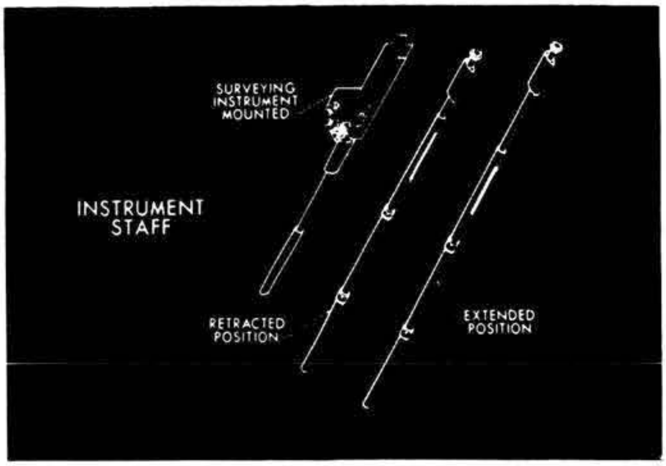

Figure 8. Surveying Staff

Figure 9. Emplaced Remote Scientific Station

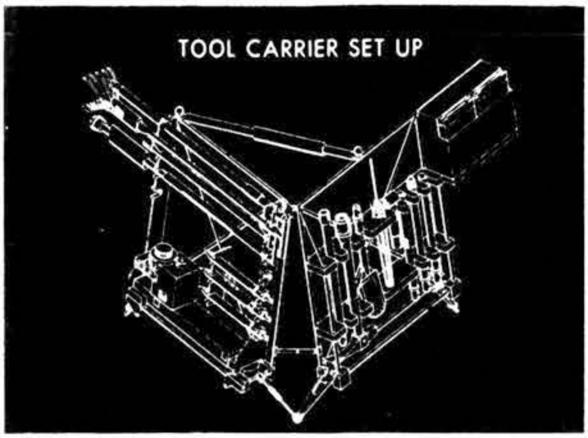

Figure 10. Tools and Carrier

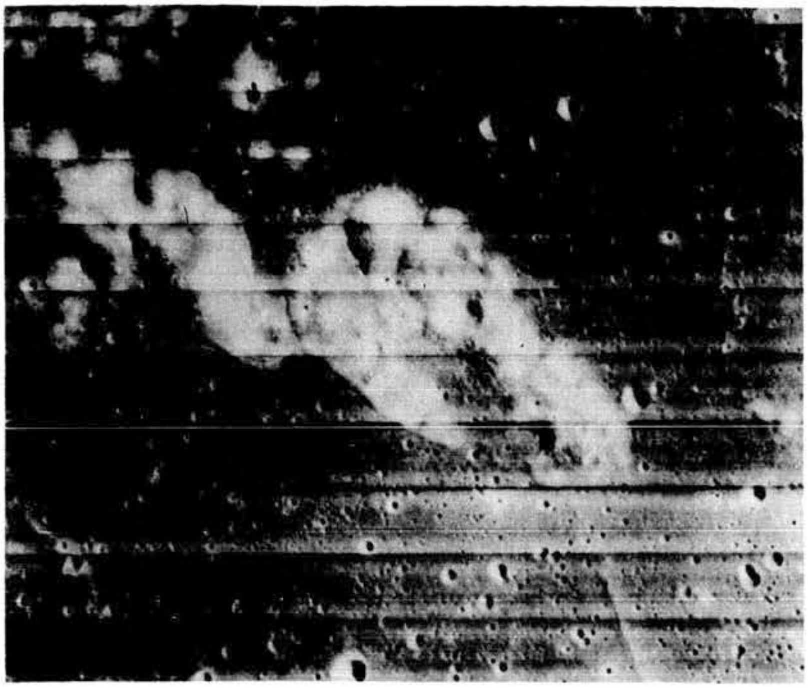

Figure 11a. Flamsteed Ø

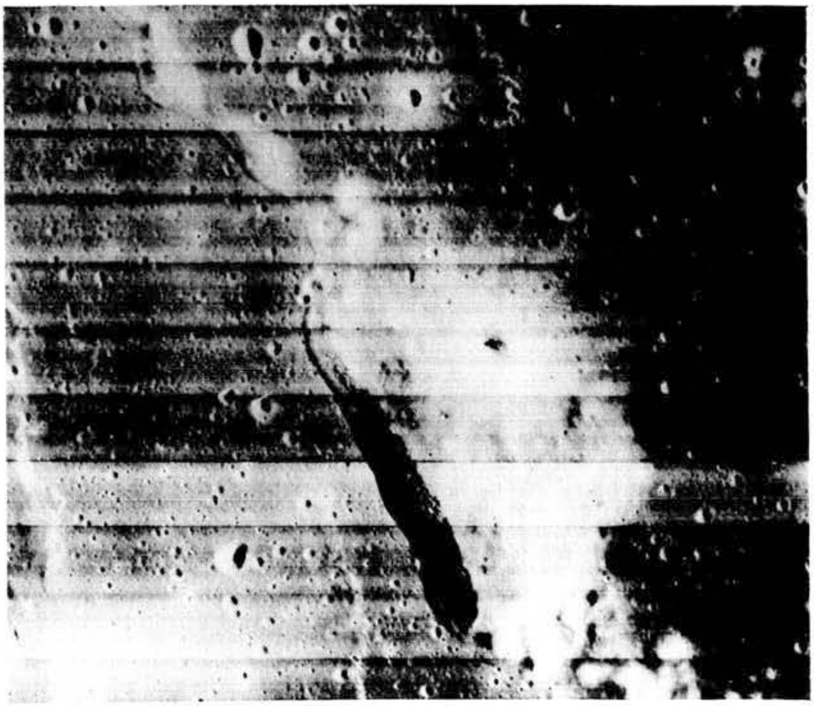

Figure 11b. Flamsteed β

Figure 12. Landing Site and Typical Sorties

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