BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

SUBJECT: Minutes of the August 12-14 Meeting of an Ad Hoc Working Group on the Science Objectives of Apollo Missions 12-20.

DATE: August 18, 1969

FROM: F. El-Baz
D. B. James

TO DISTRIBUTION:

Attached are the minutes of the meeting of an ad hoc working group on the science objectives of Apollo missions 12-20. The meeting was held in Washington, D.C. on August 12-14 at the request of NASA Headquarters.

The minutes are divided into three sections: (1) an Introduction which covers the scope of the meeting, a list of the participants, the ground rules which were followed and the most important results (p. 1-5) ; (2) scientific objectives of missions 12-15 (p. 6-16) ; and scientific objectives of missions 16-20 (p. 17 -p.55).

This study is preliminary and should be continued when the constraints are better known following an iteration by MSC engineering groups.

Farouk El-Baz
F. El-Baz

D. B. James
D. B. James

2015-FEB-DBJ-sms

(NASA-CR-107922) MINUTES OF THE 12-14 AUGUST MEETING OF AN AD HOC WORKING GROUP ON THE SCIENCE OBJECTIVES OF APOLLO MISSIONS 12-20 (Bellcomm, Inc.) 56 p

N79-71833

Unclas
00/12 12740

[redacted] (NASA CR OR TMX OR AD NUMBER) (CATEGORY) [redacted]

FEB 1970
RECEIVED
NASA STI FACILITY
INPUT BRANCH

30

INTRODUCTION

An ad hoc working group on science objectives for the Apollo missions 12-20 (see p. 3 for list of participants) met at the request of NASA Headquarters on August 12-14, 1969. The purpose of the three day meeting was to establish science objectives, tentative designs and priorities for nine Apollo missions with emphasis on the last five.

The group considered the sites which were approved for planning purposes by the ASSB on July 10, 1969 (see p. 4).*

This first iteration on EVA planning was based on a number of constraints, some of which are only current estimate of future capabilities (p. 5). These included 5 Km maximum radius of surface operations, OPS, SLSS, PLSS lifetime, line-of-sight constraints on communications, BTU rates, and length and number of EVA's. Variations in those constraints will profoundly effect the traverse layouts and the science return from each mission.

Thus this report on science EVA planning should be used as a guide to the general scope of site-related science. Extreme caution is necessary in drawing any conclusions with respect to science return as a function of hardware capability. For example, the geophysical instruments and experiments were given cursory attention and not the serious considerations they deserve.

---

*These sites are by no means cast-in-concrete. Changes could be made when there are strong reasons through the proper channels (GLEP Site selection Subgroup and ASSB).

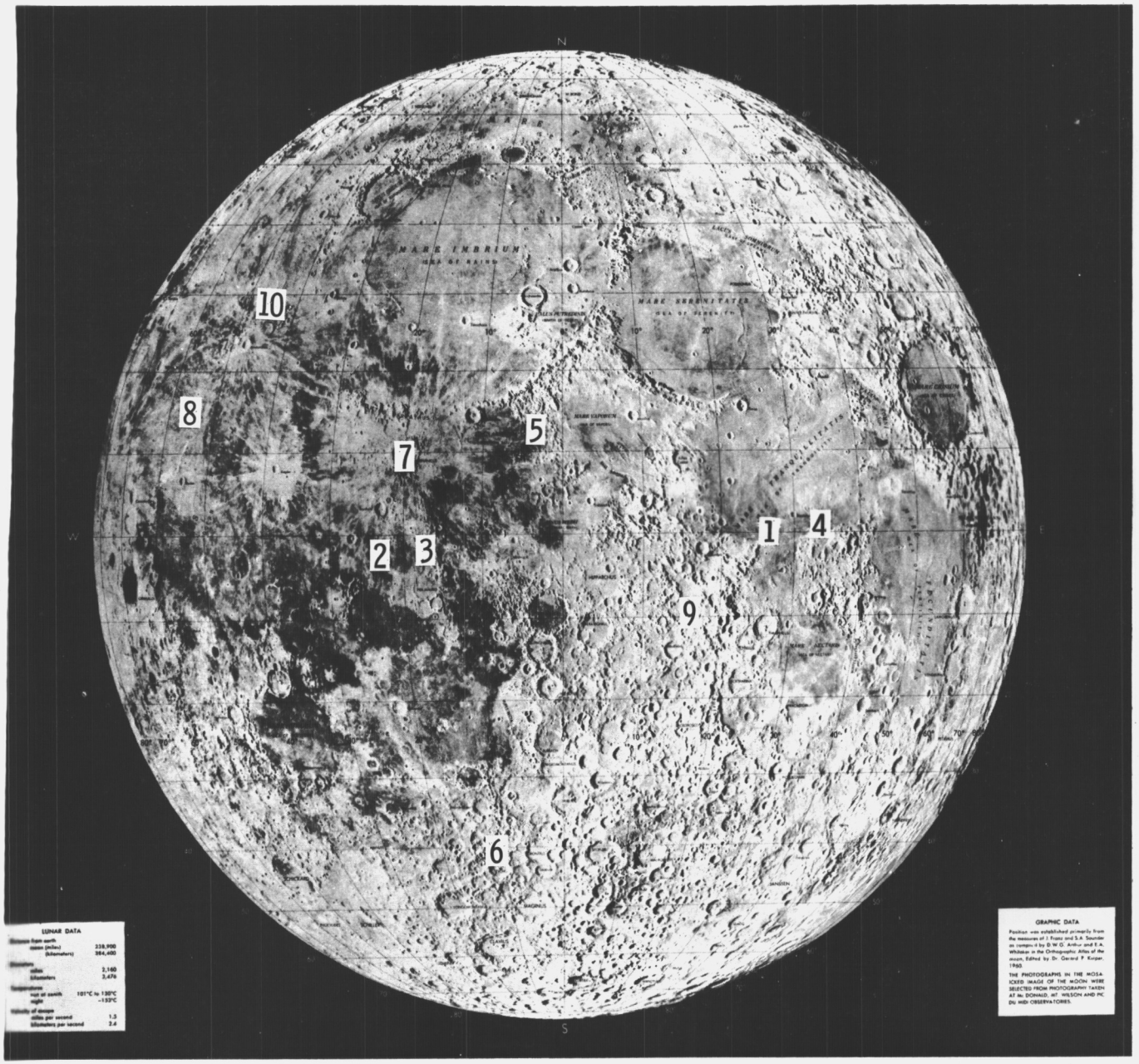
Attention has been focused on a small number of configuration options, and as the constraints for each option are clarified realistic EVA plans can be developed. The next iteration, then, could provide a more meaningful comparison of the science return possible for each option.

Photographic requirements for operational needs have not been considered, because there are no firm guidelines at this time. However, from the scientific point-of-view and for mission planning purposes photography is required for the site of Descartes and an augmentation of presently available photography of Fra Mauro Fm. and Censorinus is desirable.

The only conclusions that should be drawn from this preliminary study are the obvious needs for increased astronaut mobility, the SLSS, and a solution to the communication and navigation problems.

LIST OF PARTICIPANTS

PARTICIPANT	ORGANIZATION
Appleton, D. T.	TRW/MSC
Beattie, D. J.	NASA/HQ
Behun, M.	NASA/MAT
Boysen, A. P. , Jr.	MAS/Bellcomm
Brokaw, A. L.	USGS
Chidster, A. H.	USGS
Crum, E. M.	NASA/MSC
Dietrich, J. W.	NASA/MSC
El-Baz, F.	Bellcomm
Elston, D. P.	USGS
Gerke, P. D.	NASA/MSC
Goldberg, J. N.	NASA/HQ
Green, R. J.	NASA/MAL
Hanley, J. B.	NASA
Head, J. W., III	Bellcomm
James, D. B.	Bellcomm
Karlstrom, T. N. V.	USGS
Maloney, P. R.	NASA/MSC
Masursky, H	USGS
McKay, D.	NASA/MSC
Perrine, C. H.	USGS
Perry, W. R.	NASA/MFC/PM-SAT-LRV
Regan, R.	USGS
Sanders, A.	NASA/MSC/AMPO
Sennewald, P. F.	Bellcomm
Slaybaugh, J.	Bellcomm
Stoney, W.	MA
Swann, G. A.	USGS
Tom, T.	NASA/MA
Ulrich, G. E.	USGS
Wade, L. C.	NASA/MSC/TJ
Wertz, C.	NASA/JPL
Wilhelms, D. E.	USGS
Wise, D. N.	NASA/MAL
Yates, M. T.	Bellcomm



INDEX

1. APOLLO SITE 2
2. APOLLO SITE 7
3. FRA MAURO FM.
4. CENSORINUS
5. RIMA BODE II
6. TYCHO (RIM)
7. COPERNICUS (PEAK)
8. MARIUS HILLS
9. DESCARTES
10. RIMA PRINZ I

OPERATIONAL CONSTRAINT

1. Landing accuracy ($\sim$ 1 km radius)
   ΔV limitation and weight impact

2. Range of operations - 5 km maximum
   Return capability
   walk 1 km/OPS ; 5 km/SLSS
   ride 2.5km/OPS ; 5 km/SLSS

3. EVA number and duration
   2-4 EVA's as maximum (1250 BTU/hr)
   Short EVA: 2.5 hr/-6 PLSS
   Long EVA : 3.5 hr/-7 PLSS

4. Speed of mobility
   4 km/hr for walking
   10 km/hr for riding

5. Communications limit
   2.5 km

6. Payload trade-offs
   Rover vs. ALSEP vs. landing accuracy

7. Availability of hardware

SCIENTIFIC OBJECTIVES FOR THE "H" MISSIONS
- Apollo 12 Through Apollo 15 -

LANDING SITE 7 (APOLLO 12)

I. BACKGROUND

This site is located entirely within relatively old (Imbrian) mare material. There are many large subdued craters 200-600 m in diameter; the number of intermediate size craters 50-200 m in diameter is fewer than on younger mare material in other sites. This crater distribution is common on many apparently old surfaces including the Imbrian blanket (Fra Mauro Formation). It may reflect a thicker layer of surficial debris in these areas of relatively old terrain so that intermediate size craters have an initially soft appearance and are rapidly destroyed. An alternative explanation is that a mantle of pyroclastics is present. This site also includes the crater in which Surveyor III landed.

II. PRIMARY SCIENTIFIC OBJECTIVES

A. Deploy the first ALSEP, consistent with a seismic net.

B. Demonstrate redesignation capability in a mare landing as preparation for future, more difficult sites.

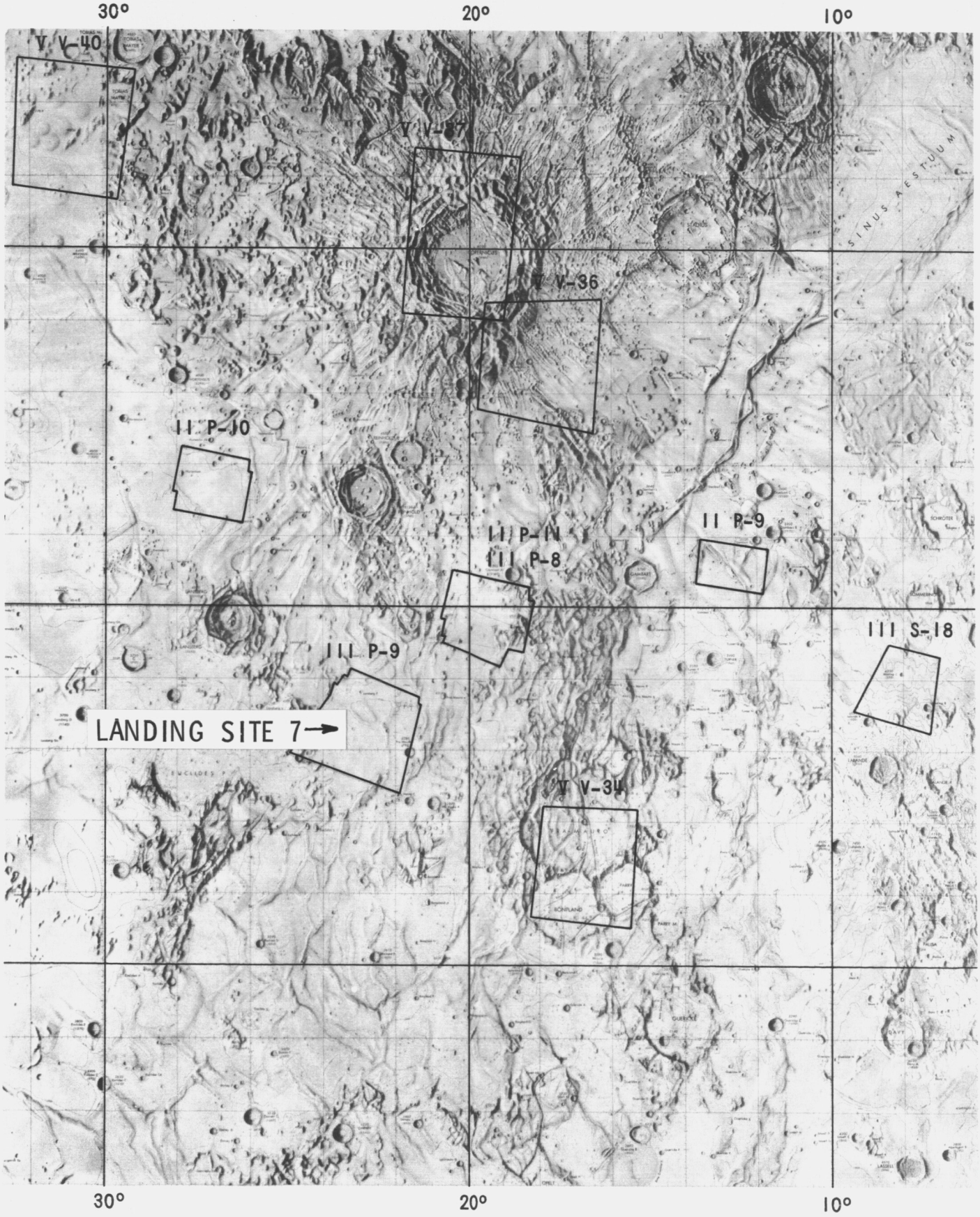
C. Effectively sample a second mare for comparison with Apollo 11 and Surveyor data. The purpose is to learn the variability in composition and age of the "Imbrian" mare unit.

D. Obtain high resolution photography (from orbit) of future candidate landing sites Fra Mauro and Descartes.

III. SECONDARY SCIENTIFIC OBJECTIVES

A. Examine Surveyor III site for indications of changes to the lunar surface or the spacecraft.

B. Attempt to discriminate between mare and Copernican ray material.


30°
20°
10°
V V-40
V V-37
V V-36
II P-10
II P-11
III P-8
II P-9
III S-18
III P-9
LANDING SITE 7
V V-34
SINUS AESTUUM
30°
20°
10°

LANDING SITE 5 (APOLLO 12 ALTERNATE)

I. BACKGROUND

This site is located within relatively young (Eratosthenian) mare material. In contrast to Tranquility Base and Landing Site 7, the area of this site displays a large number of intermediate size craters 50-200 m in diameter and a small number of larger subdued craters 200-600 m in diameter. The site is surrounded by well-developed ray clusters of the Kepler system. Small, weakly-developed crater clusters and lineaments radial to Kepler occur within the site. Thus some material derived from depth at Kepler may be present in the surficial material and fine-scale textural details related to the Kepler rays may also be present. There are more resolvable blocks (> 2 m) around craters than in the three sites to the east (Landing Sites 1, 2 and 3) suggesting that the surficial material is generally coarser grained.

II. PRIMARY SCIENTIFIC OBJECTIVES

A. Deploy the first ALSEP, consistent with a seismic net.

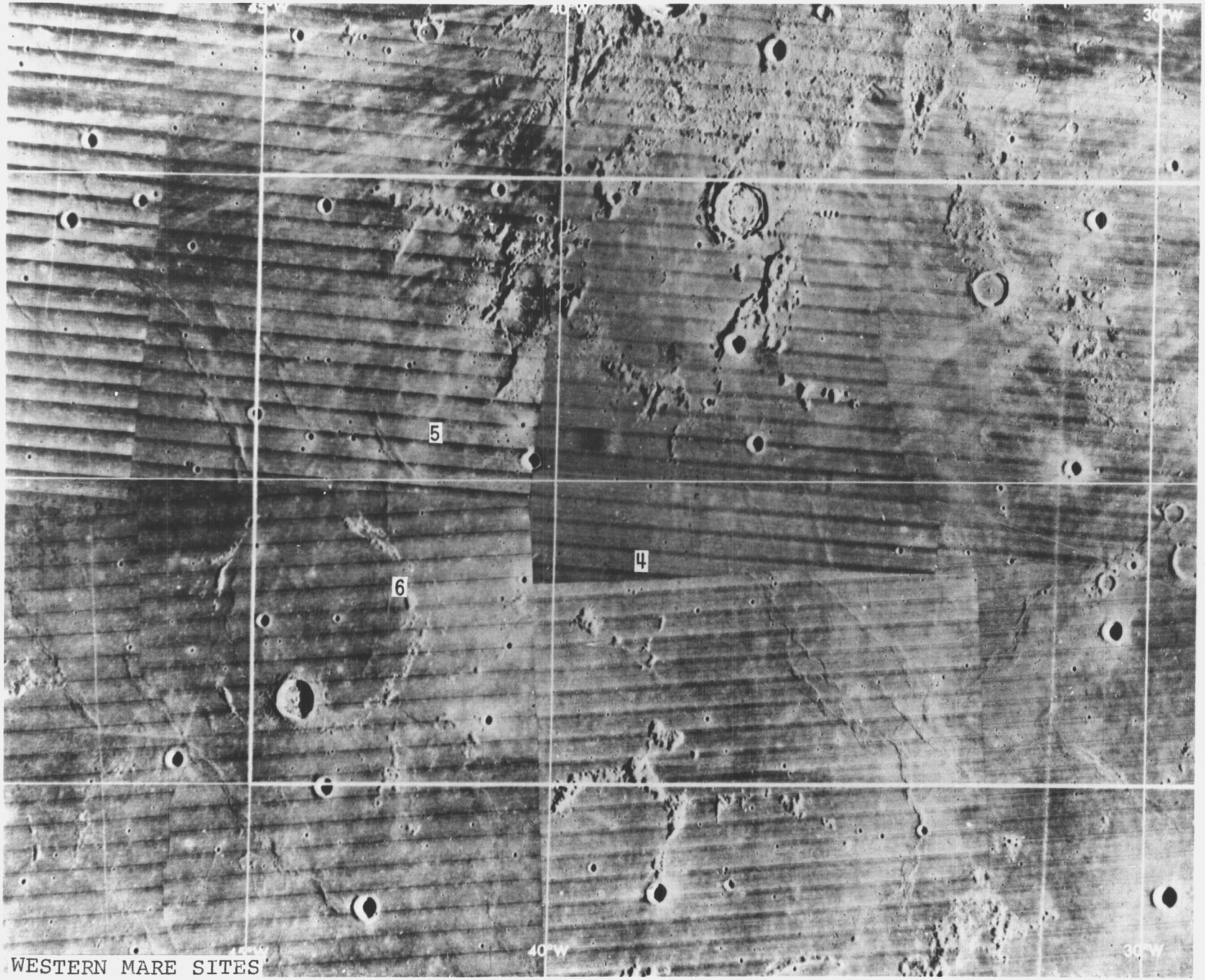
B. Demonstrate redesignation capability in a mare landing as preparation for future, more difficult sites.

C. Effectively sample Eratosthenian age mare material for comparison with the samples from Apollo 11.

D. Obtain high resolution photography (from orbit) of future candidate landing sites Fra Mauro and Descartes.

III. SECONDARY SCIENTIFIC OBJECTIVES

Attempt to discriminate between mare and Keplerian ray material.



WESTERN MARE SITES

FRA MAURO FORMATION*

I. BACKGROUND

The site of the Fra Mauro Formation is in an extensive geologic unit covering great portions of the lunar surface around Mare Imbrium. Therefore a mission to this site would result in an understanding of the nature, composition, and origin of this widespread formation, which is interpreted as ejecta from Imbrium.

II. PRIMARY SCIENTIFIC OBJECTIVES

A. Effectively sample the Fra Mauro formation. Blocks of (previously) deep-seated material and intensely shocked material should be sought.

B. Deploy ALSEP consistent with a seismic net.

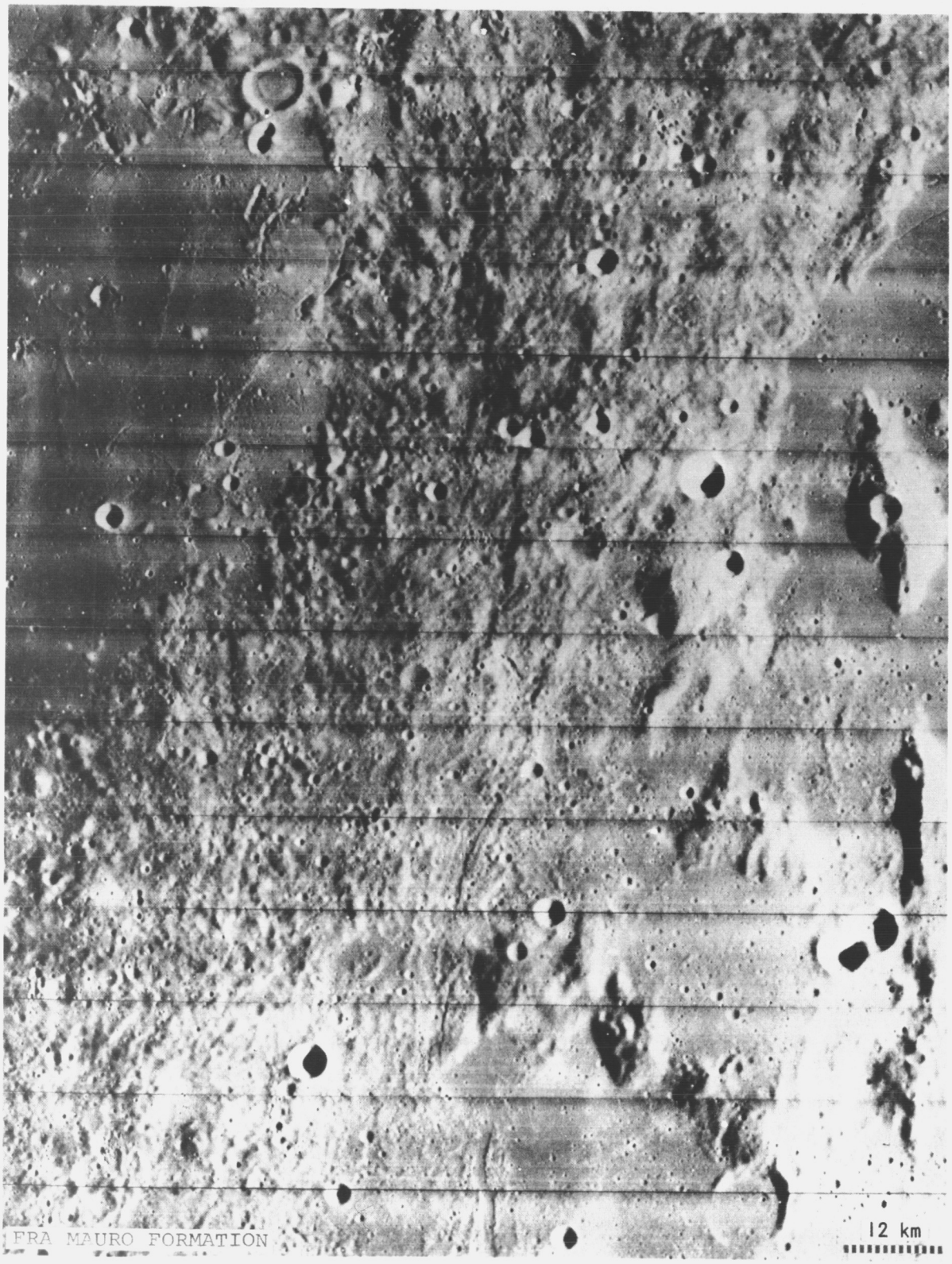
III. SECONDARY SCIENTIFIC OBJECTIVES

A. Impact the S-IVB stage to enhance the data return from the passive seismic experiment.

B. Obtain additional landing site photography of Censorinus.

---

*No Apollo mission designation is given for this site or subsequent since the sequence of the sites is as yet undetermined.


FRA MAURO FORMATION
12 km

CENSORINUS-NORTHWEST

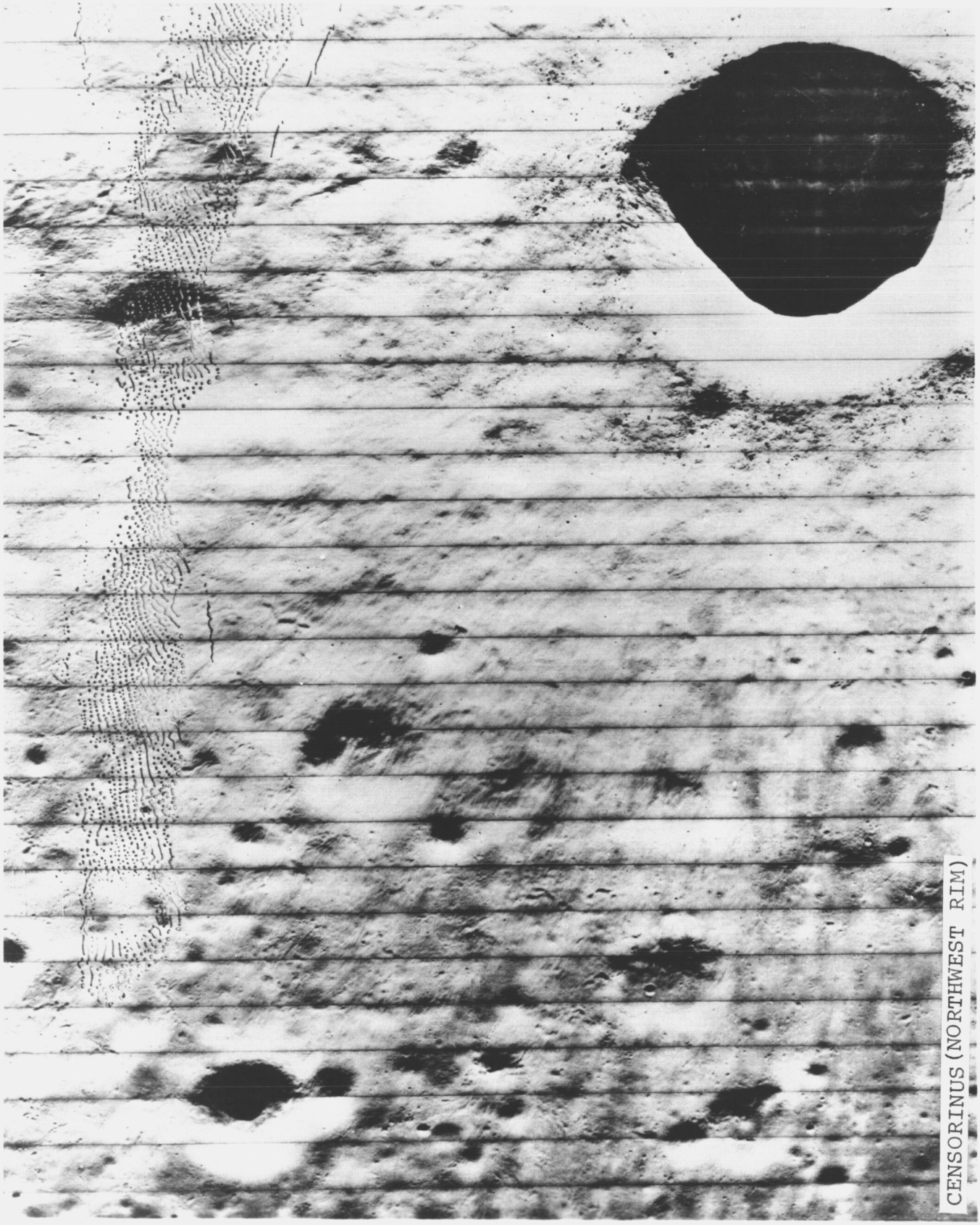
I. BACKGROUND

Censorinus is a 3.8 km diameter impact(?) crater located within, but near the edge, of a highland area south-southeast of Mare Tranquillitatis. The proposed landing site is to the northwest of the crater within the ejecta blanket. The site offers a unique opportunity to sample, early in the lunar explroation plan, both highland material and features associated with a fresh impact crater.

II. PRIMARY SCIENTIFIC OBJECTIVES

A. Sample a variety of highland material exposed as ejecta of a young, upland crater. This sampling may be done on the distal edge of the ejecta blanket originating from Censorinus.

B. Deploy ALSEP consistent with a seismic net.



CENSORINUS (NORTHWEST RIM)

RIMA BODE II

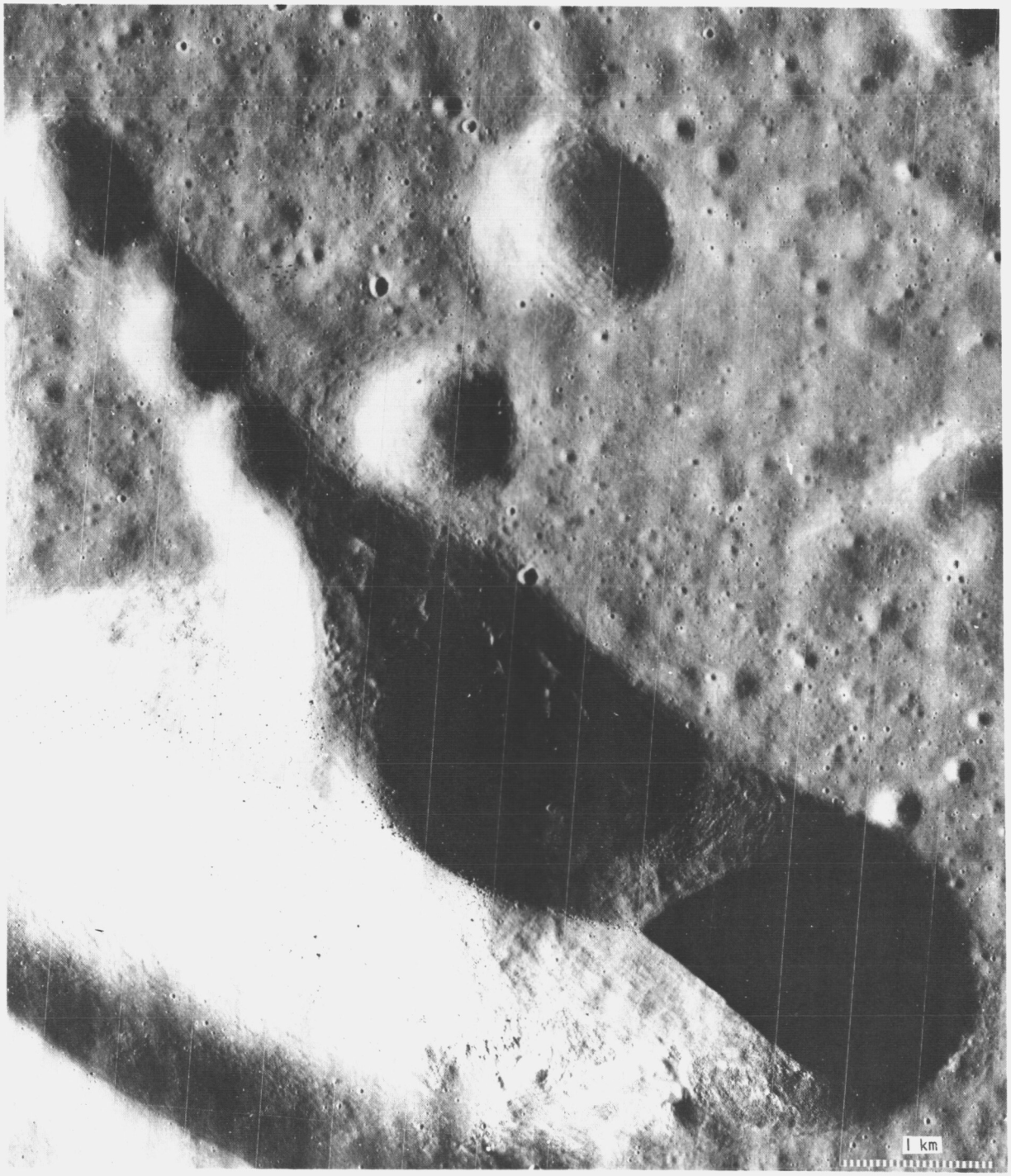
I. BACKGROUND

This site is adjacent to a single linear rille which runs close to a fresh, elongate crater and a crater chain. Both the rille and the crater are possible sources of a number of dark geologic units probably of volcanic origin. Earth analogs of some of these structures yield rocks brought up from great depths.

II. PRIMARY SCIENTIFIC OBJECTIVES

A. Sample ejecta associated with the crater chain, specifically looking for material of deep-seated origin.

B. Deploy ALSEP if consistent with a seismic net.


1 km

SCIENTIFIC OBJECTIVES FOR THE "J" MISSIONS
- Apollo 16 Through Apollo 20 -

TYCHO-NORTH RIM*

I. BACKGROUND

Tycho is a 90 km diameter bright crater in the southern highlands. Its prominent ray system extends over much of the front face of the Moon. The proposed landing site is located on the continuous ejecta blanket and consists of both bright and dark material. The landing site is located near the Surveyor VII spacecraft.

II. PRIMARY SCIENTIFIC OBJECTIVE

The primary scientific objective is to collect a wide variety of upland rock types excavated by the impact event from that part of the lunar "crust" representative of southern highland materials. TV pictures show that a highly varied assemblage of rocks lies on the lunar surface in a small area around the spacecraft. The variety of rock types should allow sampling of lunar rocks representing a vertical range of several kilometers. The materials should shed light on intrusive and extrusive processes in the lunar highlands which may be fundamentably different from those processes operating in the mare basins. Additionally, emplaced geophysical instruments will allow a comparison to be made with respect to mare areas as to the nature and thickness of the "crust" in the lunar uplands. Radiometric techniques should allow the dating of the original consolidation of the crustal rocks and the date of the young impact event.

---

*Prepared by H. Masursky, G. Swann, D. Elston, and J. Slaybaugh.

III. SECONDARY SCIENTIFIC OBJECTIVES

The secondary objectives are to investigate and sample the structured ground, the spectacular flows, and the "ponds" that are interpreted variously as ejecta, post-impact volcanics and post-impact debris flows. Examination of the distrubed lunar surface near the Surveyor sapcecraft will also provide information on the character and rate of lunar weathering and erosion. Pieces of the Surveyor spacecraft would be collected to determine the degradation of mechanical systems exposed to the lunar environment for comparatively long periods of time. Lastly, the various flow-like features and the dark halo part of the ejecta blanket conceivably may contain volatiles in minerals or as ice.

IV. MISSION REQUIREMENTS

General

Evaluation of the high resolution Orbiter V photograph of the Tycho rim material in the vicinity of Surveyor VII suggests that a substantial part of the area to be investigated would not be traverseable by a roving vehicle. Because of this, only foot traverse exploration has been outlined. For selected sites, foot traverse operations within approximately a 3 km radius could investigate most of the different geological units recognized. A spot landing would be required for foot transverse exploration. Landing should occur in a "transition" zone about midway between the inner bright rim material and the enclosing "dark halo" part of the ejects blanket.

The geologic complexity and the rough terrain in the Tycho ejecta blanket will probably pose some problems to the missions in terms of logistics. But the presence of many large blocks, and relatively thin "regolith" will aid in sampling and making unabiguous geologic observations.

A. Landing accuracy

To adequately sample and study several of the most important features in the area will require a point landing to within about 1/2 km accuracy in a north-south direction and about 1 1/2 km in an east-west direction.

B. Optimum radius of operations

The optimum radium of operation is 2.6 km.

C. Minimum radius of operation

Although the Surveyor VII site would be deleted for a minimum traverse, this would not decrease the required 2.6 km radius of operations that is the minimum acceptable for meeting the primary scientific objectives.

D. Shape of target

The areas to be studied lie dispersed along a narrow north-south zone.

E. Photo requirements

(1) scientific - the available Lunar Orbiter V photographs are adequate for scientific planning of this mission.

(2) operational - the available Lunar Orbiter V photography is not adequate for detailed study of communications problems that might be encountered due to occulation by topography.

F. Scientific equipment

1. Emplaced - the most important instruments are passive seismometer and laser ranging retroreflector in order to take advantage of the high latitude of this site. A mass spectrometer may detect volatiles associated with recent volcanism. Gravimeter and magnetometer would provide additional data to characterize the southern highlands, however these are not required at this site.

2. Astronaut - Geologic hand tools, the LSS, and a second camera, preferably sterometric, for the other astronaut, and sample containers for 100 - 200 lb of samples, are required.

3. Orbital - High resolution camera for photographing the Tycho site for detailed post-mission mapping and application of returned data and a gamma-ray spectrometer are desirable.

G. Number of EVA's

A minimum of three EVA's are required to accomplish the major geologic objectives, and an additional EVA for the deployment of the ALSEP.

H. Site-dependent science requirements

The passive seismometer, laser retroreflector, and mass spectrometer are site-dependent instruments. The seismometer and retroreflector require such a high latitude site to optimize net operation, while the mass spectrometer will be used to detect any gaseous volcanic residue associated with this site.

I. Communications problems

Topography will present a communications problem on traverses greater than a few tems of meters long. The landing site is on sufficiently high ground which will help alleviate the problem, but it is expected that the astronaut will be occulated from the LM for short periods due to topographic irregularities.

J. Sample return requirements

Due to the variability in surface features, and the depth from which Tycho ejecta was derived, it is expected that a wide variety of materials will be present. Therefore, the sample return capability must be at least 100 lbs and preferably 200 lbs.

K. Engineering considerations

The attached Table shows the on site times available with both the -6 and the -7 PLSS for the 3 geologic traverses. These times are marginally adequate with the -6 PLSS. Either the -7 PLSS or more liberal

assumptions concerning the -6 PLSS are required to insure sufficient time at this very complex site. The maximum emergency return distance (2.6 km) will require the capabilities of a SLSS. The degree to which the navigation and communication requirements are not met due to occultation by surface topography will require further analysis but will probably be severe.

The hardware items necessary to accomplish the outlined mission are the following:

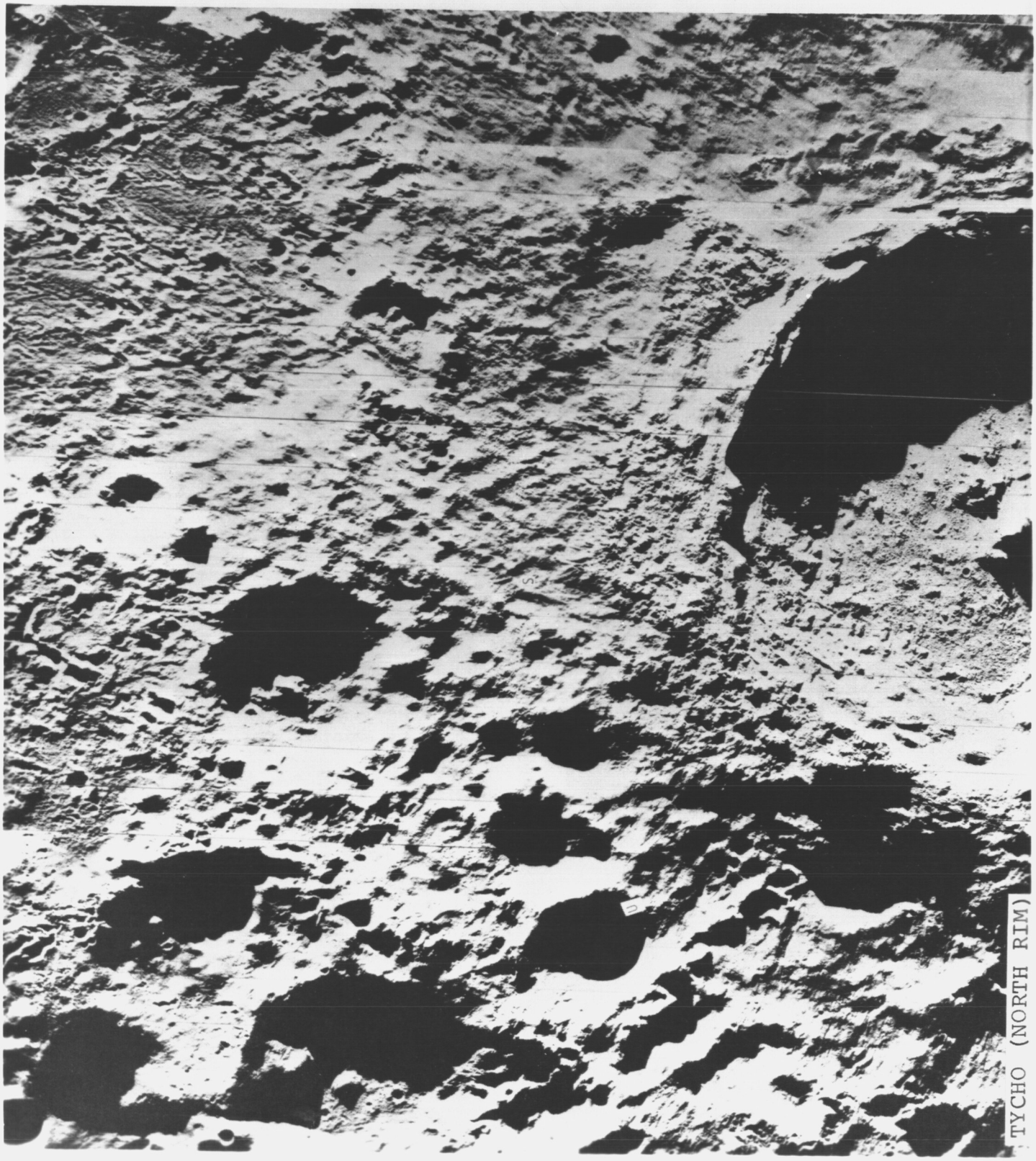
1. Point landing with 0.5 km redesignation capability.
2. ALSEP (including passive seismic station).
3. Constant volume suit.
4. -7 PLSS.
5. 54 hr stay time.

The engineering matrix on which these conclusions were based is attached.

FIGURE 4

TRAVERSE (1)	NO. (2) OR OPTION	Traverse DIST. (Km)	Traverse (Km/hr)	Traverse TIME (h:m)	On Site TIME (3) (h:m)	On Site NO. (4)	Emer. Return DIST. (km)	LSS (5) OPTION	SYSTEMS REQ'D (6)	CONSTRAINTS VIOLATED (7)
SHORT EVA (2 1/2 hr.)	I	3.5	4	:53	1:37	4	1.1	SLSS	-6 PLSS	None
					(:27)			(< OPS)		
LONG EVA (3 1/2 hr.)	I	3.5	4	:53	2:37	4	1.1	SLSS	-7 PLSS	NONE
					(:39)			(< OPS)		
SHORT EVA (2 1/2 hr.)	II	6.25	4	1:34	:56	6	2.6	SLSS	-6 PLSS	Comm. (?)
					(:09)					
LONG EVA (3 1/2 hr.)	II	6.25	4	1:34	1:56	6	2.6	SLSS	-7 PLSS	Comm. (?)
					(:19)					
SHORT EVA (2 1/2 hr.)	III	5.25	4	1:20	1:10	4	2.1	SLSS	-6 PLSS	None
					(:17)					
LONG EVA (3 1/2 hr.)	III	5.25	4	1:20	2:10	4	2.1	SLSS	-7 PLSS	None
					(:32)					

(1) ENTER "SHORT EVA," LONG EVA, ETC.
(2) DESIGNATES NO. FOR TRAVERSE (IF REQ'D) - COULD BE ORDER OF PRIORITY OR MOBILITY OPTION (e.g.,
  (1) Walk
  (2) Ride
(3) TOTAL EVA TIME LESS TRAVERSE TIME
(4) NUMBER OF SITES VISITED
(5) OPS, SLSS
(6) PLSS, ROVER
(7) COMMUNICATION, EMERG. RETURN, MISSION DURATION, TOTAL EVA's, ETC.



TYCHO (NORTH RIM)

COPERNICUS CENTRAL PEAKS*

I. BACKGROUND

The crater Copernicus is typical of large fresh craters believed to have been formed by impact. It has massive central peaks believed to expose deep-seated rocks uplifted from beneath the crater floor. Smaller dome-like hills near the central peaks may be related to the central peak or have a different origin.

The central peaks, domes, and the crater floor material can be sampled within 4 to 5 km of a landing site (site 2 on map) on a smooth floor material north of the most central large peak. An alternate site (site 1 on map) is nearer the central peak area but the approach is more hazardous and the landing area contains a higher concentration of small craters.

The central peak of Copernicus is currently considered as the target for Apollo 16 which is tentatively scheduled for launch in April 1971.

II. PRIMARY SCIENTIFIC OBJECTIVES

A. To sample representative materials in the central area of a large rayed crater. In order of importance the sampling areas are:

1. Central peak
2. Domes or hummocks
3. Crater floor materials (smooth and rough)

---

*Prepared by J. W. Dietrich, G. Ulrich, D. T. Appleton, and E. M. Crum.

B. To obtain extensive photographic documentation and careful descriptive data of the structural characteristics of bedrock, outcrops, soils, and block fields within the largest possible area including IIA, 1-3.

III. SECONDARY SCIENTIFIC OBJECTIVES

A. Perform reconnaissance exploration of the crater walls utilizing multispectral photography from a mounted, long focal-length camera.

B. Install a long-life, passive seismometer for obtaining sub-surface structural information from below the crater floor.

IV. MISSION REQUIREMENTS

A. Landing Accuracy

Pinpoint landing accuracy is required. (1/2 km radius) at either landing site.

B. Optimum Radius of Operation

2.5 km for landing site 1.

5.0 km for landing site 2.

C. Minimum Radius of Operation

The minimum radius of operation is 2.5 km for landing site 1 and 5 km for site 2.

D. Shape of Target

The landing targets for both landing sites are approximately 1-km diameter circles.

E. Photo Requirements

Metric photography of a 300 sq. km area with 0.5 to 2 meter resolution for topographic analysis would permit more effective mission planning. This photography could be obtained from Rima Bode mission (H-3).

F. Scientific Equipment

1. Emplaced
   a. Passive Seismic Experiment (not necessarily entire ALSEP)
   b. Heat Flow (3-m drill required)
2. Astronaut carried
   a. Hand tools
   b. LGEC
   c. LSS
   d. SRC (3)
   e. Long focal-length camera (Questar?)
3. Orbital
   a. Pan Camera
   b. S-Band Transponder
   c. Laser Altimeter

G. Number of EVA's and Traverses

Landing site 1 requires 3 EVA's with one long, one intermediate and one short traverse plus those necessary for emplaced experiments and housekeeping. Landing

site 2 requires 2 EVA's with long traverses and a part of the housekeeping EVA for a short traverse plus time necessary for emplaced experiments.

H. Site Dependent Science Requirements

A long-life passive seismic experiment (emplaced as part of a seismic net) should provide significant data about the sub-surface structure of Copernicus. Active seismic devices are not recommended because the complex structure expected in the sub-surface near the central peaks probably requires extensive surveys for significant results.

Copernicus Peaks provides the only opportunity in the first ten Apollo Missions to emplace a heat flow experiment on the floor of a large, rayed crater of probable impact origin. Heat-flow data in this region might be significant after the "normal" heat flow of the moon is established - on either earlier or later missions. However, heat-flow data have low priority in comparison with the requirements for astronaut equipment, a seismometer, and additional mobility if available. The value of a single determination is doubtful in light of the apparent cost in weight. If surveillance TV can be mounted at the LM primarily for EVA, it should be mounted high on the structure.

It would be desirable to carry a long focal-length camera (Questar?) for photographing the interior of

Copernicus (360° panoramic of wall and central peaks) from the LM area. The camera requires a stable mount. If mount is part of LM, multiple mounts should be provided to permit the 360° panorama. A tripod mount could be placed clear of the LM. From landing site 1, more than 180° of crater rim can be photographed. From landing site 2, more than 210° of crater rim is visible. From either site, the central peaks will occult only part of the remaining rim.

I. Communication Problems

Some short LOS periods are expected on all traverses. From site 2, possible undetectable gentle topographic features could cause extensive LOS on longer traverses.

J. Sample Return Requirements

1. Both rock and soils; those from bedrock must be carefully documented.
2. Three SRC's - 150 lbs of samples.

Each box will include samples from one or more of the following types of feature:

1. - Samples from foot of peaks that are characteristic of the variety of rocks there and description of the rocks that indicate relative abundance of each type.
2. - Samples from several small domes characteristic of the types found, with an indication of the relative abundance.

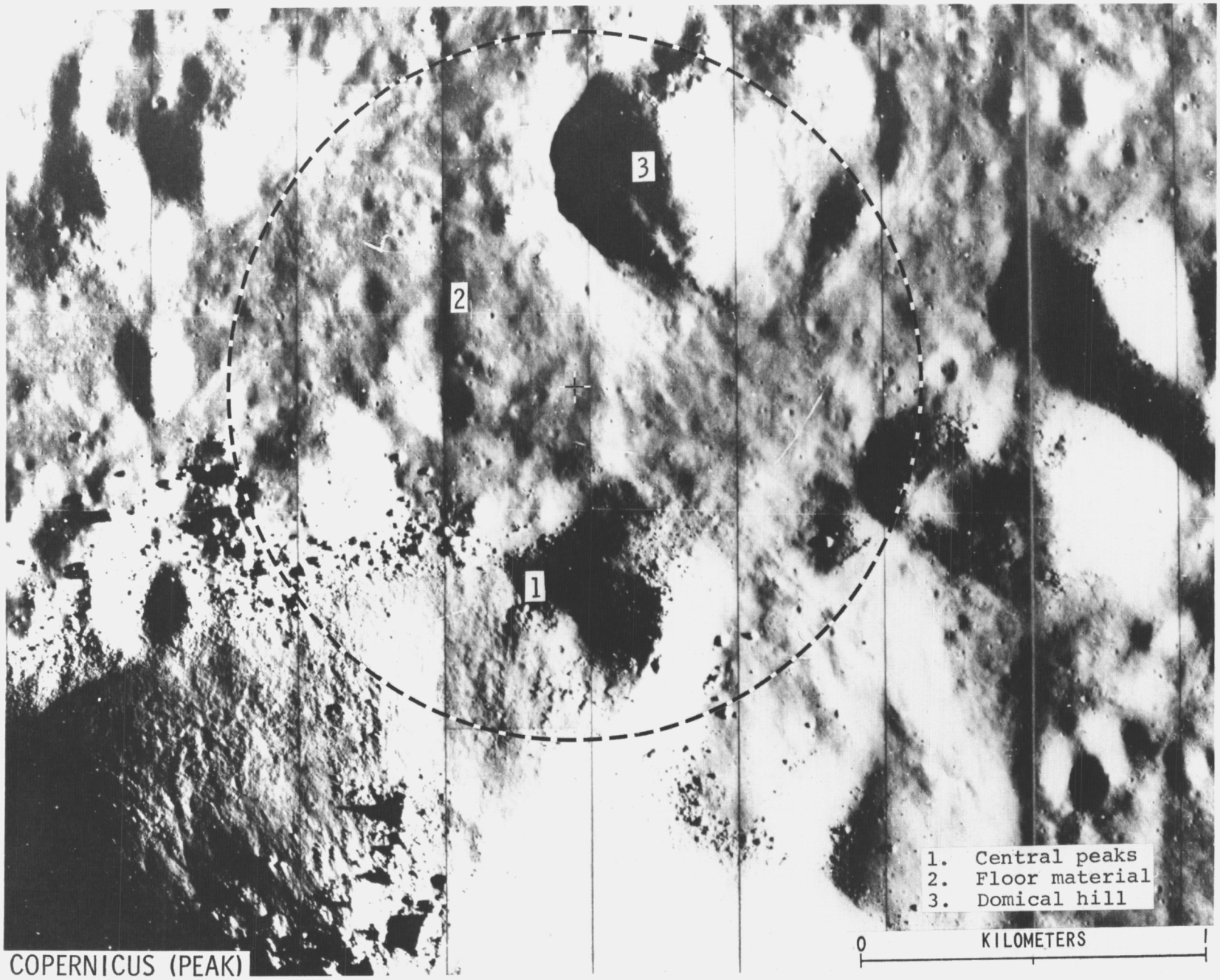
3. - Typical samples from the crater floor, preferably from both smooth and rough materials now mapped. Also samples from 300 m blocky crater to obtain subfloor materials.

K. Engineering Consideratons

A representative sampling of the central peaks requires a larger areal coverage than that shown in the traverses drawn from either site 1 or site 2. A landing at site 1 permits a walking traverse that samples one small area in 30 to 90 minutes which will be far from representative. The addition of mobility (LRV) will increase the length of useful EVA time for scientific tasks by as much as 200%. It would conserve the energies of the astronauts by requiring less than one fourth the BTU's en route. These factors combine to increase the length of traverse available for more comprehensive coverage of critical areas like the base of the peaks by proportional amounts. A delay of the Copernicus mission until the LRV is available is desirable. Other engineering considerations are summarized in the attached table.

		Traverse			On Site		Emer. Return		COPERNICUS PEAKS	
TRAVERSE (1)	NO. (2) OR OPTION	DIST. (Km)	(Km/hr)	TIME (h:m)	TIME (3) (h:m)	NO. (4)	DIST. (km)	LSS (5) OPTION	SYSTEMS REQ'D (6)	CONSTRAINTS VIOLATED (7)
CENTRAL PEAKS-LDG SITE I (PRI. I)	WALK	6 1/2	3.2	2:00	0:30-6 1:30-7	Face of Peaks	2 1/2	OPS	CANNOT DO WITH OPS	OPS Need 1/2 KM LDG
	RIDE		5	1:20	1:10-6 2:10-7		2 1/2	SLSS	MUST HAVE SLSS	Need 1/2 KM LDG
CENTRAL PEAKS-LDG SITE 2	WALK	10	3.2	3:00	0:30 -7	"	5	OPS	CANNOT DO WITH OPS or -6	-6/OPS/COMM
	RIDE		5	2:00	0:30-6 0:30-7		5	SLSS		
NORTH TRAVERSE LDG SITE 1 (PRI. 2)	WALK	5	3.2	1:30	1:00-6 2:00-7	5 Fea - tures	2 1/2	OPS	CANNOT DO WITH OPS	OPS/COMM
	RIDE		5	1:00	1:30-6 2:30-7		2 1/2	SLSS		COMM
WEST TRAVERSE LDG SITE 1 (THIRD PRIORITY)	WALK	2 KM	3.2	1:00	1:30-6 2:30-7	5 Features & Photo (Wall Pan)	1 KM	OPS		
	RIDE		5	0:40	1:50-6 2:50-7			SLSS		
WEST TRAVERSE LDG. SITE 2 (SECOND PRI.)	WALK	4 KM	3.2	1:15	1:15-6 2:15-7	12 Fea- tures	1.4 KM	OPS		Slight COMM/OPS
	RIDE		5	0:50	1:40-6 2:40-7			SLSS		
PHOTO RECON LDG SITE 2 (THIRD PRI.)	WALK	LDG AREA			2:30	360° Pan	N/A			None
					3:30					None

(1) ENTER "SHORT EVA," LONG EVA, ETC.
(2) DESIGNATES NO. FOR TRAVERSE (IF REQ'D) - COULD BE ORDER OF PRIORITY OR MOBILITY OPTION (e.g.,
  (1) Walk
  (2) Ride
(3) TOTAL EVA TIME LESS TRAVERSE TIME
(4) NUMBER OF SITES VISITED
(5) OPS, SLSS
(6) PLSS, ROVER
(7) COMMUNICATION, EMERG. RETURN, MISSION DURATION, TOTAL EVA's, ETC.



COPERNICUS (PEAK)

MARIUS HILLS*

I. BACKGROUND

The Marius Hills volcanic complex, near the center of Oceanus Procellarum, is one of the most concentrated and varied arrays of probable volcanic features on the Moon. It lies athwart one of the longest continuously developed ridge systems on the Moon and is near the center of, and parallel to, the major axis of Oceanus Procellarum, the largest continuous expanse of maria on the Moon. The Marius Hills region, the Aristarchus Plateau, and the Rumker Hills all lie along this "mid-oceanic" Procellarum ridge system and are similar in certain respects to terrestrial oceanic plateaus such as Iceland and the Azores. On Earth, plateaus of this type are located along major rift zones commonly attributed to rising convection currents within the Earth's mantle. Its unusual regional setting, therefore, raises the question as to whether the

---

*Prepared by T. Karlstrom, W. Perry, M. T. Yates, and R. D. Raymond. Further reference should be made to:

"Preliminary Lunar Exploration Plan of the Marius Hills Region of the Moon" by T. N. V. Karlstrom, J. F. McCauley, and G. A. Swann. U.S. Geological Survey Interagency Report: Astrogeology 5, February 1968.

from which much of the background material for this report is taken. See also

"Five Day Mission to Investigate the Geology of the Marius Hills Region of the Moon" by D. P. Elston and C. R. Willingham. U.S. Geological Survey Interagency Report: Astrogeology 14, April 1969.

Marius Hills volcanic complex is indeed the product of deep-seated lunar convection. The range in form of probable volcanic features raises the additional question of whether magmatic differentiation has occurred on the Moon. If so, how did it occur and what are the end products? Are this and other mid-Procellarum plateaus the final differentiation products of the more primitive basaltic magmas that initially filled the mare basins? Even if such questions are only partly answered, our understanding of lunar volcanism and its role in surface evolution will be greatly improved. The Marius Hills is ideal, from the standpoint of logistic ease and potential scientific return for a manned lunar landing designed to investigate lunar volcanic problems.

II. PRIMARY SCIENTIFIC OBJECTIVES

The scientific requirements of a surface mission in this area are to gather geologic and geophysical data that bear on the origin, history, and the age of the Marius Hills. If the steep domes, punctured cones, and narrow ridges are composed of different types of volcanic rock that are more acidic than the rocks of the maria, magmatic differentiation must have occurred on the Moon, attesting to a long and complicated volcanic history for even this small planetary body. Geophysical data in context with the geology, petrology, and geochemistry, may contribute to establishing the character of local upper-crustal

fracture control. An important byproduct may be the discovery of concentrations of now crystallized volatile materials that were initially released beneath the insulating regolith.

Therefore, the primary scientific objectives of the Marius Hills mission are:

A. To explore and sample a highly diverse probable volcanic complex.

B. To emplace an ALSEP, with the minimum required experiments including an Active Seismic Experiment, a Passive Seismic Experiment, a Mass Spectrometer, and a Heat Flow Experiment.

In order to achieve these primary objectives 1) several of each type of the major constructional features must be described and sampled in detail, 2) the origin of the punctured cones and associated features must be established by field description, photography, and sampling, 3) the exceptionally fresh narrow ridge in the southwest part of the exploration area should be investigated with the view of establishing whether or not it is eruptive, 4) a local stratigraphic sequence should be established by direct observation of local superposition and intersection relations, and 5) in order to establish subsurface structure, geophysical measurements should be made over the longest possible base lines.

III. SECONDARY SCIENTIFIC OBJECTIVES

None.

IV. MISSION REQUIREMENTS

A. Landing Accuracy

In order to maintain the advantage of preplanned traverses it is necessary to land at the designated point. The currently anticipated point landing guidance error of ± 1 km is marginally acceptable, it is highly desirable to be able to redesignate closer to the planned landing point. Landing close to the designated point may help alleviate the surface navigation problem, if navigation is based on area maps with appropriate landmarks.

B. Optimum Radius of Operations

Although a large radius of operations would allow a more comprehensive scientific exploration mission to be carried out, a 5 km optimum radius of operations should be sufficient to achieve the minimum scientific objectives.

C. Minimum Radius of Operations

Due to the extremely complex nature of this region, the scientific objectives of this mission cannot be achieved with less than a 4.5 to 5 km radius of operations, assuming a point landing.

D. Shape of Target

As presently configured, the planned traverses approximately define a 4 by 9 km ellipse with the major axis approximately east-west.

E. Photo Requirements

Lunar Orbiter photography is sufficient for scientific and operations planning.

F. Scientific Equipment

1. Emplaced -

ALSEP, with the minimum required experiments including an Active Seismic Experiment, a Passive Seismic Experiment, a Mass Spectrometer, and a Heat Flow Experiment.

2. Astronaut-carried

Apollo Lunar Field Geology Equipment. It is necessary to provide aids to direct the astronauts to each science location and to enable identification of the points at which they stop. Since some of the sites are out of line-out-of-site of the LM, an additional navigation capability beyond that available with the present staff is required. Similarly, a capability for non-LOS communication is required.

3. Orbital

Multi-spectral photography, Alpha-Particle Spectrometer, Gamma Ray Spectrometer.

G. Number of EVA's and Traverses

Four traverses are required and are outlined in the reference documents. These will require four EVA periods.

H. Site-Dependent Science Requirements

The ALSEP instrumentation outlined above is considered site dependent at Marius Hills, since their data is expected to pertain to the interpretation of this geologically complex region.

I. Communications Problems

The planned traverse will take the astronauts out of line-of-sight of the LM. Obstacles to communication include distance (over the horizon), hills, and surface undulations. A capability for non-LOS communication is required.

J. Sample Return Requirements

Because of the duration of the mission and the complexity of the terrain, at least 150 lbs of rocks should be collected, requiring at least three Sample Return Containers.

K. Engineering Considerations

The system configuration needed to accomplish the stated science objectives include:

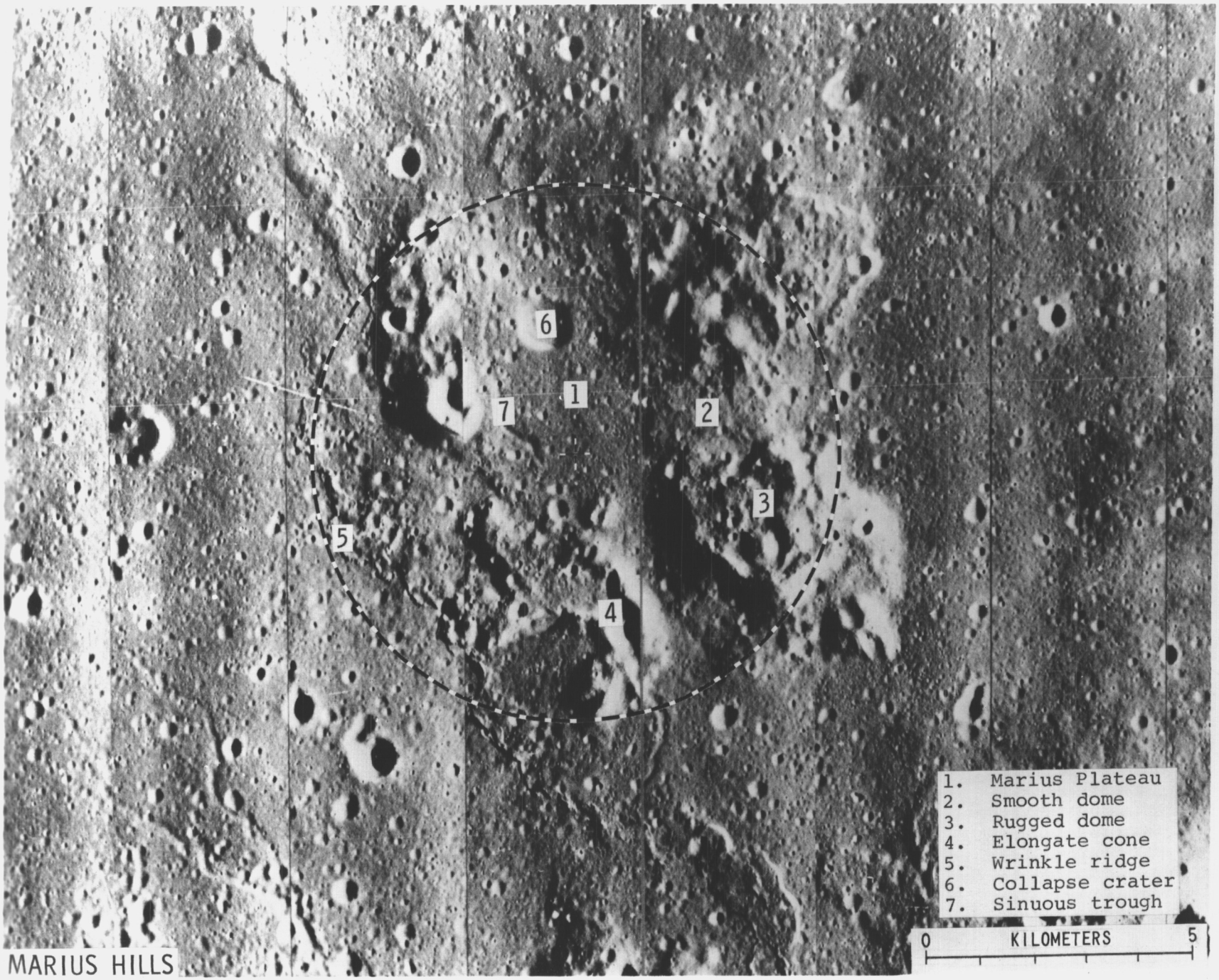
1. A three-day ELM to accommodate four EVA's;

2. A lunar roving vehicle to reach the sites and provide the required science time at the locations;
3. An EMU to provide the 3 1/2 hour EVA (-7 PLSS) and extended contingency return capability (SLSS);
4. An ALSEP including an active seismic experiment;
5. Navigation aids to locate the specified sites;
6. Communications aids to prevent interruption due to hills, horizon limits and undulations;
7. Point landing with redesignation propellant available to allow the traverses to start from the planned point.

MARIUS HILLS

TRAVERSE (1)		NO. (2) OR OPTION	Traverse DIST. (Km)	Traverse (Km/hr)	Traverse TIME (h:m)	On Site TIME (3) (h:m)	On Site NO. (4)	Emer. Return DIST. (km)	LSS (5) OPTION	SYSTEMS REQ'D (6)	CONSTRAINTS VIOLATED (7)
RI	LONG EVA	RIDE	3.7	10	:26	2:35	4	1.8	OPSS	-7 PLSS ROVER ALSEP	COMM. NAV.
		WALK		4	1:03	2:35			SLSS	-7 PLSS ALSEP	SAME
RII ↑ OR ↓	LONG EVA	RIDE	6.85	10	:50	2:00	4	3.7	SLSS	-7 PLSS ROVER	COMM. NAV.
		WALK		4	1:59*	2:00			SLSS	-7 PLSS	SAME + EVA LIMIT
RIIA	LONG EVA	RIDE	8.75	10	1:05	2:25	6	4.8	SLSS	-7 PLSS ROVER	COMM. NAV.
		WALK		4	2:32*	2:25			SLSS	-7 PLSS	SAME + EVA LIMIT
RIII	LONG EVA	RIDE	5.7	10	:40	2:15	6	3	SLSS	-7 PLSS ROVER	COMM. NAV.
		WALK		4	1:37*	2:15			SLSS	-7 PLSS	SAME + EVA LIMIT
RIV	LONG EVA	RIDE	9.4	10	1:07	2:23	4	5.3	SLSS	-7 PLSS ROVER	COMM. NAV.
		WALK		4	2:41*	2:23			SLSS+	-7 PLSS	SAME + EVA LIMIT & SLSS LIMIT
									*WALKING VIOLATES 3 SIGNIFICANTLY REDUCES		1/2 EVA OR SCIENCE RETURN

(1) ENTER "SHORT EVA," LONG EVA, ETC.
(2) DESIGNATES NO. FOR TRAVERSE (IF REQ'D) - COULD BE ORDER OF PRIORITY OR MOBILITY OPTION (e.g.,
  (1) Walk
  (2) Ride
(3) TOTAL EVA TIME LESS TRAVERSE TIME
(4) NUMBER OF SITES VISITED
(5) OPS, SLSS
(6) PLSS, ROVER
(7) COMMUNICATION, EMERG. RETURN, MISSION DURATION, TOTAL EVA's, ETC.



MARIUS HILLS

DESCARTES*

I. BACKGROUND

The origin and evolution of the lunar highlands are problems which are basic to understanding the moon. The primary evidence relating to these questions must come from actual highland samples and from a close examination of highland geologic features. The Descartes area bears on these questions in several important respects. First, it is the only highland area except the craters Censorinus and Tycho that is being considered for an Apollo landing, and consequently it affords the only chance to sample in situ any of the geological units associated with the highlands. Major units in the Descartes area are the light terra plains material and the Descartes hilly-and-furrowed type material. Both are common types of highland materials whose nature must be learned if lunar highland evolution is to be understood. The Descartes area appears to be volcanic and may in fact be a more mature version of a Marius Hills type area. The hills may be volcanic constructional forms and the wormy furrows may be volcanic vents. The light terra plains materials is immediately adjacent to the hilly-and-furrowed region and will provide a relatively smooth landing site within

*Prepared by D. E. Wilhelms, D. S. McKay, L. C. Wade, A. H. Chidester, and J. D. Richey.

easy walking distance of a furrowed ridge typical of the hilly-and-furrowed material. Samples of the light terra plains material will provide a comparison with typical mare material.

The emplacement of key instruments in the ALSEP package would be necessary as this is the only non-crater highlands type site visited in Apollo, and the only site in the southeast part of the Moon.

II. PRIMARY SCIENTIFIC OBJECTIVES

A. To learn the nature, primarily through sampling, of the hilly-and-furrowed Descartes material, a widespread and significant lunar highland unit.

B. To emplace ALSEP, specifically the passive seismic, the active seismic, and the heat flow experiment.

III. SECONDARY SCIENTIFIC OBJECTIVES

A. To sample the light terra plains material, another widespread unit.

B. To determine the genetic and age relations between the light terra plains material and the hilly-and-furrowed material.

IV. MISSION REQUIREMENTS

A. Landing Accuracy

Landing should occur on the light colored terra plains material that embays the Descartes hilly-and-furrowed material. The prime landing area should be within walking distance of the typical furrowed ridge.

A traverse length of between 3 and 4 kilometers, depending on the landing accuracy, should result.

B. Optimum Radius of Operation

With nominal landing, the optimum radius of operation is between 1 and 1.5 km.

C. Minimum Radius of Operation

The minimum radius of operation is about 1 km for a successful mission.

D. Shape of Target

The shape of the target is areal with less than pinpoint landing accuracy required. A landing target on the terra plains material in an elliptical area with a major east-west axis of 2 kilometers and a minor north-south axis of 1 kilometer will allow all the scientific objectives to be accomplished. The terra plains material spreads westward from the hilly-and-furrowed material. The target area is in the easternmost extreme of the terra plains material.

E. Photo Requirements

The scientific photo requirement for Descartes is to obtain high resolution photography for more detailed traverse planning and the preparation of surface data packages.

Operational photo requirements for Descartes are high resolution monoscopic and stereoscopic photography of the landing site for LM landing analysis, and moderate resolution stereoscopic photography for analysis of the approach and the preparation of training materials and onboard charts and photo maps. This moderate resolution photography will also contribute to the scientific analysis of this site.

Additional photography is required to put this site in an operational category. Present photography is barely adequate for minimum mission planning.

F. Scientific Equipment

1. Emplaced - The minimum emplaced equipment in order of priority is:
   a. Passive Seismic (ALSEP)
   b. Heat Flow (ALSEP)
   c. Active Seismic (ALSEP)
   d. Gravimeter
2. Astronaut carried - The minimum astronaut carried equipment in order of priority is:
   a. Hand Tools
   b. Portable Sample Container
   c. Stereo Camera
   d. Drill (3-meter) for heat flow hole.
   e. Possibly a long focal length lens (to photograph up the furrow).

3. Orbital - The minimum scientific experiments to be carried in the command module in order of priority are:

   a. Gamma-Ray Spectrometer

   b. X-Ray Fluorescence Spectrometer

   c. Alpha Particle Spectrometer

G. Number of EVA's and Traverses

Without high-resolution photography, determination of number, length, and location of traverses and number of EVA's is premature. Tentatively, the Orbiter IV photographs suggest that a single loop traverse north of the landing site would suffice for examination of the hilly-and-durrowed material. From a landing site 1 km south of the furrowed ridge, the traverse would entail first a 1 km walk to the ridge, then a 500 m walk westward along the base of the ridge and into the furrow then a 500 m walk towards a fresh, probably blocky 1 km crater whose ejecta probably includes material from the hilly-and-furrowed unit, and finally, a 1 km walk back to the LM. A second EVA would be necessary for deployment of the ALSEP. A third EVA for a traverse devoted to the plains material or to other objects revealed by the high-resolution photographs will doubtless also prove desirable. Additional high resolution photography may reveal features worthy of additional EVA time.

H. Site-Dependent Science Requirements

The four experiments listed in the IV F (1) and IV F (3) above are site dependent in the sense that they are included because this is a highland site. The composition of the site may be different from other sites, and may show more radioactivity. Other experiments may be added to the ALSEP and orbital package as desired but would not be site dependent. The astronaut-carried equipment is standard and while necessary for a successful mission, is not site dependent.

I. Communications Problems

As the radius of operations is always within 2 km and the principal objectives lie higher than the landing site, line-of-site communication can be maintained. In instances where topographic features cut off communication, the second astronaut can be used as a relay. Without detailed photos it is impossible to indicate exactly where this will occur on the traverses.

J. Sample Return Requirements

It appears now that two major types of materials will be sampled and that the two standard rock boxes will be adequate to return the samples. It is necessary to provide an adequate portable sample container (bag) to be carried by the astronauts on the foot traverse which can hold on the order of 50 pounds of rock.

K. Engineering Considerations

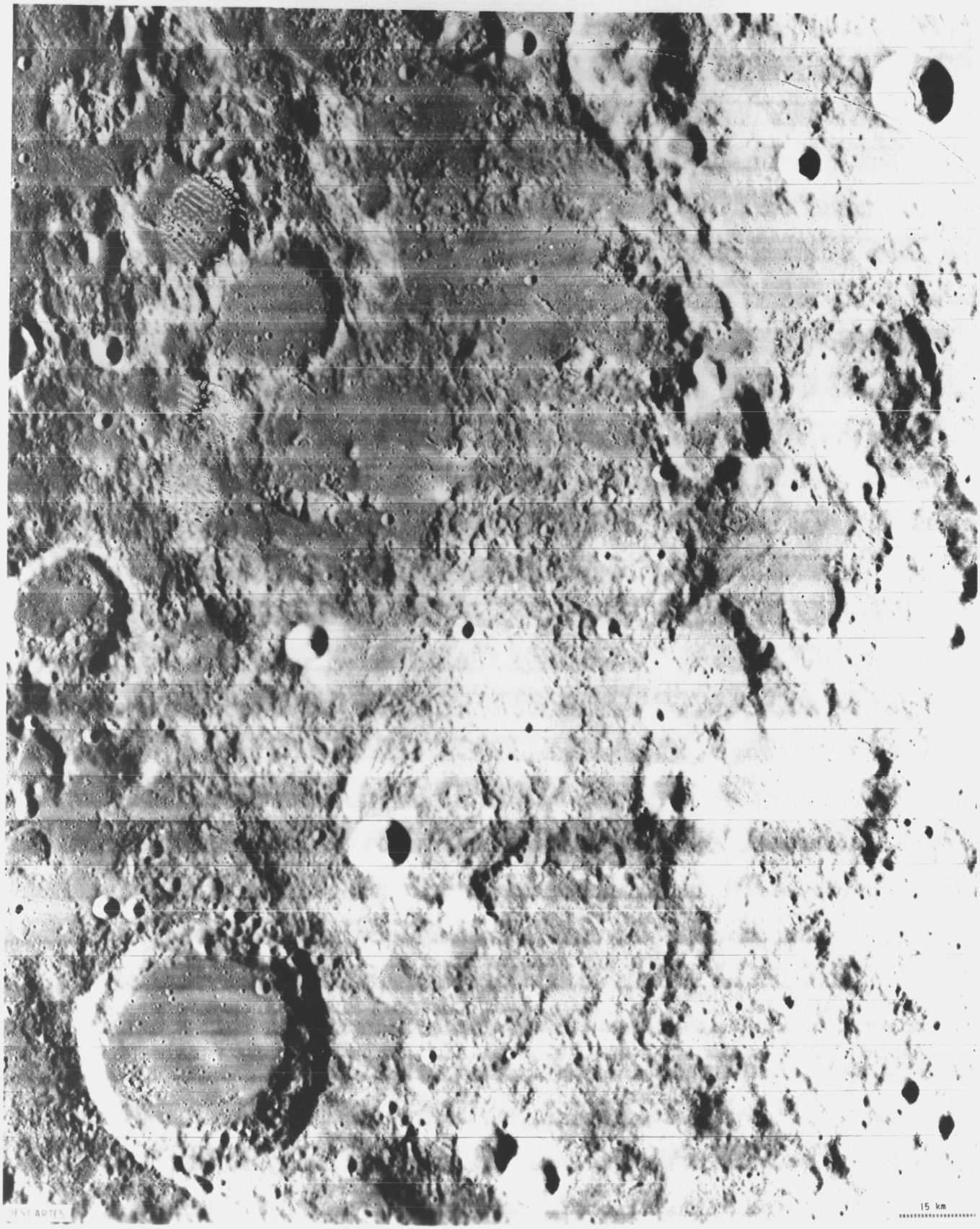
This study is preliminary and limited to a walking traverse. For this walking traverse, it appears the -6 or -7 PLSS will be satisfactory, depending on the time needed on site. The OPS will be adequate for an emergency return. The attached chart shows the estimated times and distances for the traverses.

DESCARTES MISSION

TRAVERSE (1)	NO. (2) OR OPTION	Traverse DIST. (Km)	Traverse (Km/hr)	Traverse TIME (h:m)	On Site TIME (3) (h:m)	On Site NO. (4)	Emer. Return DIST. (km)	LSS (5) OPTION	SYSTEMS REQ'D (6)	CONSTRAINTS VIOLATED (7)
SHORT EVA	WALK	3	4	0:45	1:45	3	1	OPS	-6 PLSS	
					2:45			OPS	-7 PLSS	
ALSEP (3 METER DRILL)		.1	4	0:15	∿2:30	1	.1	OPS	-6 PLSS	
					∿3:30			OPS	-7 PLSS	

(1) ENTER "SHORT EVA," LONG EVA, ETC.
(2) DESIGNATES NO. FOR TRAVERSE (IF REQ'D) - COULD BE ORDER OF PRIORITY OR MOBILITY OPTION (e.g.,
  (1) Walk
  (2) Ride
(3) TOTAL EVA TIME LESS TRAVERSE TIME
(4) NUMBER OF SITES VISITED
(5) OPS, SLSS
(6) PLSS, ROVER
(7) COMMUNICATION, EMERG. RETURN, MISSION DURATION, TOTAL EVA's, ETC.

J.D. Richey


DESCARTES
15 km

RIMA PRINZ I*

I. BACKGROUND

The Harbinger Mountains region of the moon includes numerous sinuous rilles and associated materials. The longest and, most probably, the youngest of the sinuous rilles in this area is Rima Prinz I. This is a double sinuous rille, i.e., a small meandering rille enclosed within a larger sinuous rille. Sinuous rilles have aroused considerable interest because of the implications of the mode of their formation to the origin of the moon and its history. To study a sinuous rille, one must get down to the valley floor to sample the material and examine the displayed structures. Rima Prinz I was selected because of the freshness of its details. A landing near the mouth or terminus of the rille would allow an examination of the lower part of the eroded valley.

II. PRIMARY SCIENTIFIC OBJECTIVES

Exploration of a sinuous rille and examination and sampling of rille deposits.

III. SECONDARY SCIENTIFIC OBJECTIVES

Aristarchus secondary crater field and ridge.

IV. MISSION REQUIREMENTS

A. Landing accuracy

Landing to within a 1 km circle is required.

B. Optimum radius of operations

The optimum radius of operations is 5 kilometers.

---

*Prepared by F. El-Baz, J. Head, and T. Bottomly.

C. Mimimum radius of operations

In order to achieve the minimum scientific objectives, a minimum radius of 4.5- km is required.

D. Shape of target

The shape of the target is roughly circular but because of the nature of the rilles, landings cannot be made in all parts of the target.

E. Available photography

Medium resolution stereo

High resolution 3. m

F. Scientific equipment

a. Seismometer - high latitude site

b. Mass spectrometer

c. Heat flow measurement

G. Number of EVA's

	Total Traverse Distance	Sampling Locations
1. Landing area and ALSEP deployment	0.6 km	1
2. Rima Prinz I wall and floor	10.2 km	12
3. Rima Aristarchus III and Aristarchus secondaries	11.2 km	8
4. Surface deposits and ridge	9.7 km	7
5. Rille "mouth" deposits	4.4 km	4

H. Site dependent science requirements

1. Mass spectrometer

2. Seismometer

I. Communications problems

- Undulating surface
- Loss of site within rilles (traverses 2 and 3)

J. Sample return requirements

32 sample locations, about 10 samples each, i.e., 320 samples or about 160 pounds. Therefore, three sample return containers are required.

K. Engineering Considerations

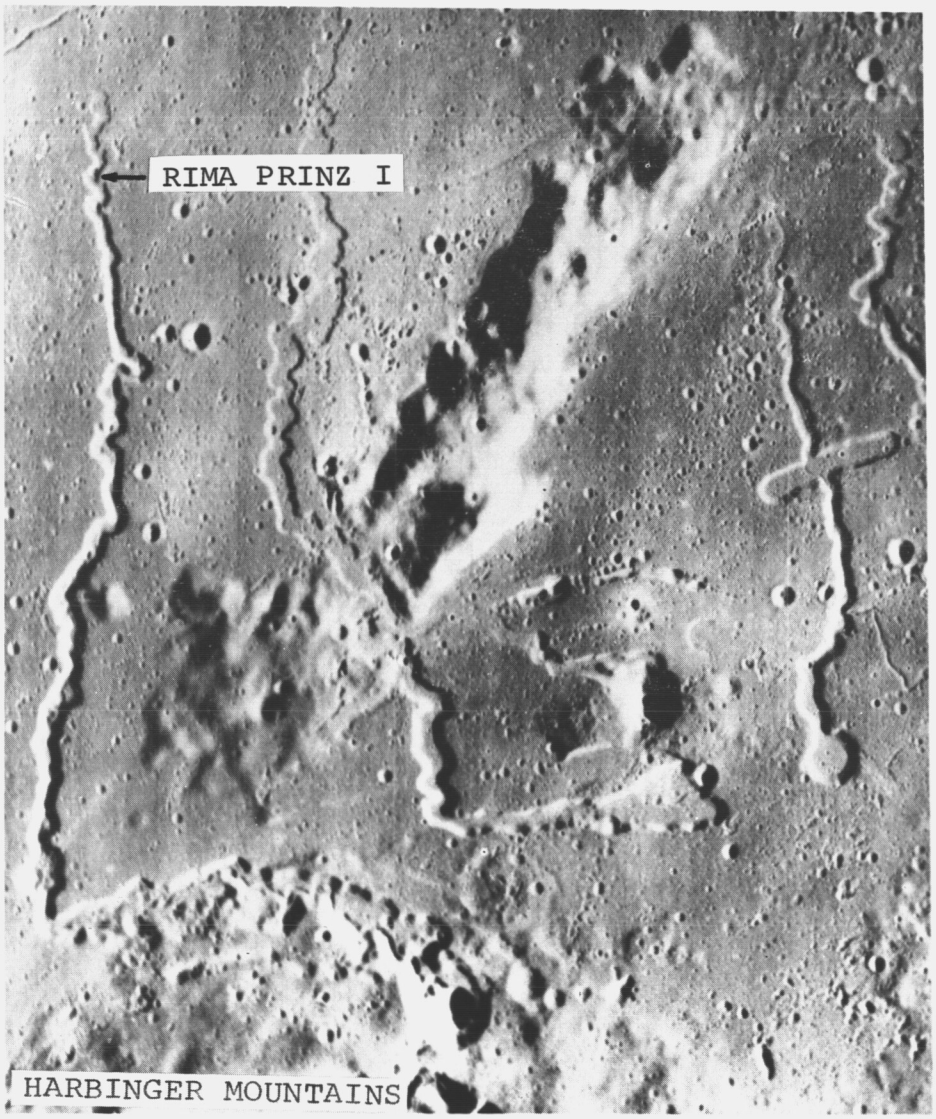
As indicated on the attached table, the hardware required for the successful completion of the primary science objectives at Rima Prinz I is as follows:

1) Lunar Roving Vehicle
2) A three day or more ELM to accomodate five EVA's, i.e., two EVA's on each of two days.
3) An EMU to provide for the 3.5 hr. EVA's would require the -7 PLSS and the SLSS.
4) An ALSEP, including Mass Spectrometer and Passive Seismometer.
5) Navigation aids; communication aids for LOS in rilles and hilly areas.
6) Point landing (within 1 km) to allow all traverses to reach the desired sampling locations.

RIMA PRINZ I		Traverse			On Site		Emer. Return			
TRAVERSE (1)	NO. (2) OR OPTION	DIST. (Km)	(Km/hr)	TIME (h:m)	TIME (3) (h:m)	NO. (4)	DIST. (km)	LSS (5) OPTION	SYSTEMS REQ'D (6)	CONSTRAINTS VIOLATED (7)
1. SHORT EVA (ALSEP DEPLOYM'T (LM INSP, FAM.)	WALK	0.6	4	0:09	2:21	1	0.3	OPS	-6, ALSEP	NONE
2. LONG EVA	RIDE (2.5)	10.2	10	1:01	1:29	(7 M)	5.1*	SLSS	-6, ROVER	COMM.
	RIDE (3.5)				2:29	12 (12 M)			-7, ROVER	COMM.
3. LONG EVA	RIDE (2.5)	11.2	10	1:07	1:23	(10M)	5.6*	SLSS	-6, ROVER	COMM.
	RIDE (3.5)				2:23	8 (18M)			-7, ROVER	COMM.
4. LONG EVA	RIDE (2.5)	9.7	10	0.58	1:32	(13M)	4.2	SLSS	-6, ROVER	COMM.**
	WALK (3.5)		4	2:25	1:05	7 (9M)			-7,	COMM.**
5. SHORT EVA	WALK (2.5)	4.4	4	1:06	1:24	(21M)	2.0	SLSS	-6	NO. OF EVA's
	WALK (3.5)				2:24	4 (36M)			-7	

*RETURN ALONG TRAVERSE ROUTE REQ'D
**NOT L/S LIMITED

(1) ENTER "SHORT EVA," LONG EVA, ETC.
(2) DESIGNATES NO. FOR TRAVERSE (IF REQ'D) - COULD BE ORDER OF PRIORITY OR MOBILITY OPTION (e.g.,
  (1) Walk
  (2) Ride
(3) TOTAL EVA TIME LESS TRAVERSE TIME
(4) NUMBER OF SITES VISITED
(5) OPS, SLSS
(6) PLSS, ROVER
(7) COMMUNICATION, EMERG. RETURN, MISSION DURATION, TOTAL EVA's, ETC.


RIMA PRINZ I
HARBINGER MOUNTAINS

DISTRIBUTION LIST

NASA Headquarters
R. J. Allenby/MAL
D. J. Beattie/MAL
M. Behun/MAT
G. F. Esenwein/MAL
R. J. Green/MAL
J. B. Hanley/MAL
L. J. Kosofsky/MAL
M. Malloy/MAL
L. Scherer/MAL
W. Stoney/MA
R. Toms/MAL
C. Wertz/MAL
D. U. Wise/MAL

NASA/MSC
A. Calio/TA
E. M. Crum/TE
J. Dietrich/TH2
J. W. Gerke/TD3
W. N. Hess/TA
J. Hodge/FC
J. Loftus/HA
G. Low/PA
J. McDivitt/PO
D. McKay/TH2
P. R. Maloney/TD
A. J. Meyer/ET
C. H. Perrine/PO
A. Sanders/ANPO
J. H. Sasser/TH3
H. H. Schmitt/CB
C. Vaughan/EP4
L. C. Wade/TH3

TRW Systems
D. T. Appleton
L. E. Wood

USGS/Flagstaff
A. L. Brokaw
A. H. Chidster
D. P. Elston
T. N. V. Karlstrom
H. Masursky
R. Regan
G. A. Swann
G. E. Ulrich

USGS/Menlo Park
J. F. McCauley
N. J. Trask
D. E. Wilhelms

NASA/MSFC
W. R. Perry/PM-SAT-LRV

Bellcomm, Inc.
C. Bidgood
T. Bottomley
A. P. Boysen, Jr.
J. O. Cappellari, Jr.
D. R. Hagner
W. G. Heffron
N. W. Hinners
B. T. Howard
V. S. Mummert
R. Raymond
J. Richey
I. M. Ross
P. F. Sennewald
J. Slaybaugh
R. J. Sperry
J. W. Timko
R. L. Wagner
All Members Department 2015
Center 10 File
Central Files