(NASA-CR-132417) VIKING '79 ROVER STUDY. VOLUME 1: SUMMARY REPORT Final Report (Martin Marietta Aerospace, Denver, Colo.) 116 p HC $9.00 CSCL 13F

N74-19888

Unclas

G3/11 34381

NASA CR-132417

Contract NAS1-12425

Volume I

Summary Report

March 1974

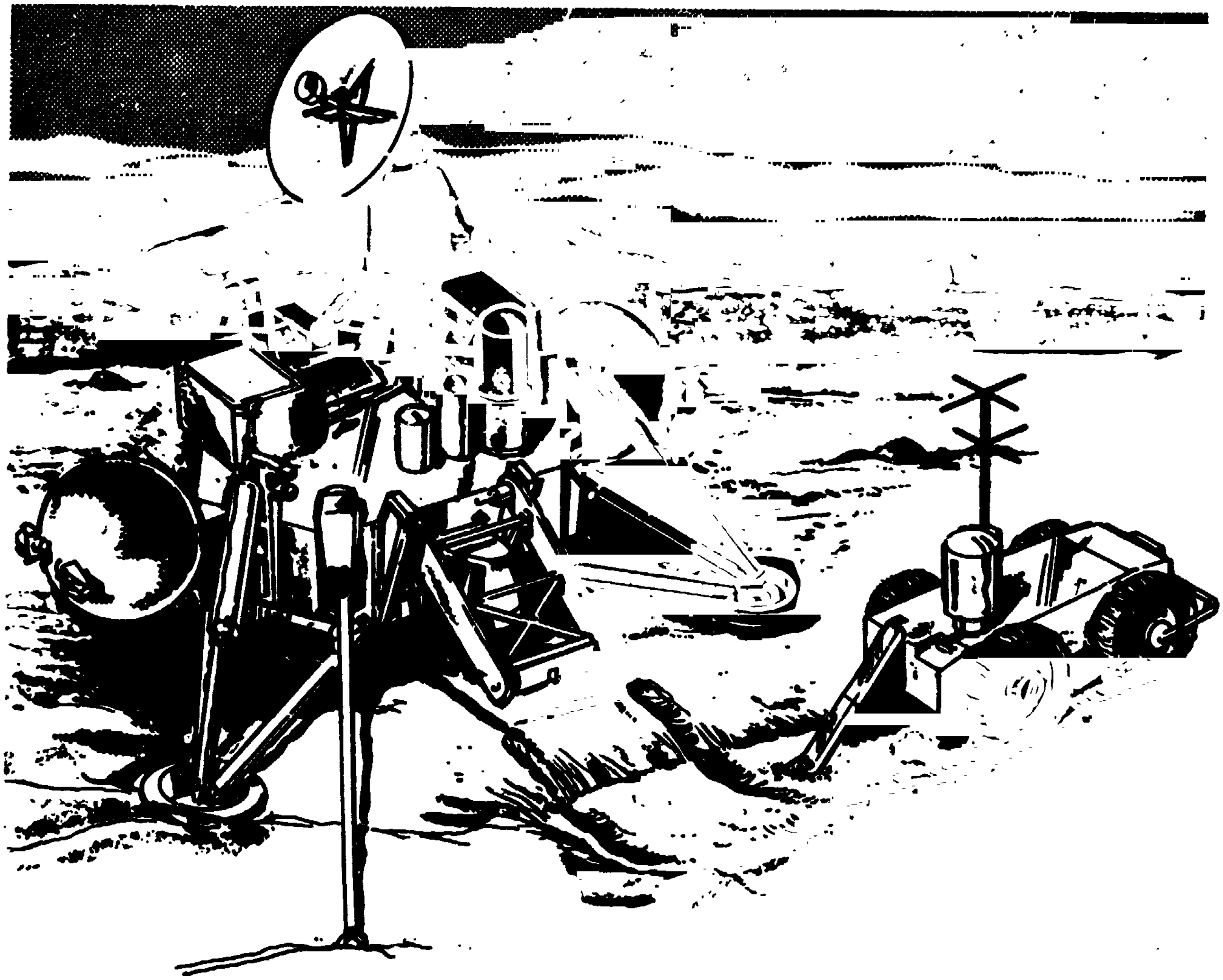
VIKING '79 ROVER STUDY

Final Report

Approved

Carlos A. de Moraes
Program Director

MARTIN MARIETTA CORPORATION
P.O. Box 179
Denver, Colorado 80201



FOREWORD

This is the final report on a Viking '79 Rover Study, performed by Martin Marietta Aerospace.

This study was performed for the Langley Research Center, NASA, under Contract NAS1-12425 between June 27, 1973 and March 27, 1974. Mr. Wayne L. Darnell of the Langley Research Center was the Technical Representative of the Contracting Officer.

This final report consists of two volumes:

Volume I - Summary

Volume II - Detailed Technical Volume

CONTRIBUTORS

L. R. Anderson
J. W. Berry
R. B. Blizard
L. D. Bohler
A. J. Butts
B. C. C'ark
C. A. de Moraes
W. E. Do-roh
R. F. Drobnik
K. H. Farley
J. Gliozzi
G. E. Heyliger
K. H. Hopper
D. A. Howard
R. K. McMordie
H. V. Perttula
W. J. Pragluski
A. M. Sandoval
W. L. Smeton
R. W. Stoffel
W. H. Tobey
P. J. Dick (Teledyne Isotopes Inc.)
F. A. Russo (Teledyne Isotopes Inc.)

CONTENTS OF VOLUME I

	Page
Frontispiece	ii
Foreword	iii
Contributors	iv
Contents	v
List of Figures	vii
List of Tables	viii
1. Summary	1 thru 8
2. Introduction	9 thru 10
3. Major Rover Design Considerations	11 thru 32
4. Candidate Rover Concepts	33 thru 36
5. Baseline Rover Selection and Description	37 thru 74
6. Baseline Rover Support	75 thru 82
7. Required Technology Developments	83 thru 90
8. Program Development Schedule and Plan	91 thru 96
9. Conclusions and Recommendations	97 thru 100

CONTENTS OF VOLUME I

	Page
Abbreviations	101 thru 103
Symbols	104 thru 105
Definitions	106
References	107

LIST OF FIGURES

Figure		Page
1	Baseline Rover System	3
2	Summary Plan - Rover Development and Integration	6
3	Mars Surface Thermal Environments (Viking '79)	17
4	Entry Capsule	19
5	Initial Viking '79 Performance Data	21
6	Initial Viking '79 Performance Data	22
7	Entry Corridor Sensitivity to Entry Mass	24
8	Min/Max PER_{Nom} Capabilities	25
9	Flight Performance Limits on Landing Site Latitude . . .	27
10	Lander Communication Link Constraints on Landing Site Latitude	29
11	Midterm-Preferred Configuration	36
12	Baseline Science Configuration, Electronics Block Diagram	39
13	Integrated Science Package	42
14	Integrated Electronics Concept	45
15	Baseline Rover Mobility Concept	47
16	Potential Wheel/Motor Design for Baseline Rover	48
17	Baseline Rover Thermal Design	51
18	Representative Viking '75 Orbiter Picture	63
19	Original Mission Plan	64
20	Representative Rover Panorama of Emi Koussi	65 thru 71
21	Orbiter-to-Rover/Lander Communications	77
22	Program Plan - Rover Option	92
23	Rover Structural/Mechanical Development Program	94
24	Typical Development Program for Rover Electronic Components	95
25	Typical Rover Science Instrument Development Program . .	96

LIST OF TABLES

Table		Page
1	Some Key Scientific Questions Regarding Mars	12
2	Rover Tasks	13
3	Mission Thermal Environments	16
4	Maximum Viking '79 VLC Performance Capability	26
5	Science Payload Characteristics	40
6	Baseline Rover Mobility Subsystem Parameters	49
7	Baseline Rover Masses (Wt)	56
8	Baseline Viking '79 Masses (Wt)	57
9	Viking 1975-1979 Mass Comparisons (Metric Units)	58
10	Viking 1975-1979 Mass Comparisons (English Units)	59
11	Rover Internal Component Mass and Volumes	60
12	Rover Features and Performance Summary	61
13	Software Modifications for the Rover Mission	79
14	New Programs Required for Rover Mission	80
15	Overview Timeline	81

1. SUMMARY

This report summarizes the results of a study performed by Martin Marietta Aerospace for the NASA Langley Research Center to define a roving vehicle suitable for inclusion in a 1979 Viking mission to Mars. The study focused exclusively on the 1979 mission incorporating a rover that would be stowed on and deployed from a modified Viking lander. The overall objective of the study was to define a baseline rover, the lander/rover interfaces, a mission operations concept, and a rover development program compatible with the 1979 launch opportunity. During the study, numerous options at the rover system and subsystem levels were examined and a baseline configuration was selected. Volume I of the Final Report presents this baseline configuration and Volume II presents all facets of the study including the analyses of those system and subsystem concepts that were examined enrou e to the selected baseline rover.

Launch vehicle, orbiter, and lander performance capabilities were examined to ensure that the baseline rover could be transported to Mars using minimum-modified Viking '75 hardware and designs. The results of these analyses are presented in both report volumes and the detailed technical derivations are given in Volume II.

The remainder of this section briefly discusses the highlights of the study and its conclusions. The remaining sections expand upon this material in greater detail. Volume I summarizes the analyses and results discussed in depth in Volume II.

Baseline Rover System Description

The baseline system evolved from many concepts considered during the study and was developed to support a science payload recommended by a NASA science planning group chaired by Dr. I. Rasool.

The Rasool committee's payload consists of a Viking '75 facsimile camera and window duster, an alpha backscatter spectrometer, an X-ray diffractometer and grinder, and a scoop sampler.

The baseline rover, which is based on Viking '75 technology to minimize development risk, is shown in the Frontispiece as it would appear shortly after separation from the lander. Having erected the camera to its operating position, the rover has moved a few meters away from the lander and is ready to begin its scientific mission.

The rover has been designed with the capability to support the lander mission while within communication range of the lander. Rover support includes returning soil and rock samples to the lander for analysis and transmitting camera pictures including long base stereo pictures to the lander for storage and retransmission to Earth. In addition, the rover can perform a science mission completely independent of the lander, having the capability to travel many kilometers from the lander and communicate to the Earth via the orbiter. Earth commands can be relayed to the rover through either the lander or the orbiter.

Power is provided by a new 20-watt selenide thermoelectric RTG. A battery composed of Viking '75 cells is used to handle the peak loads. Thermal control of the rover is achieved by taking heat from the RTG through a Viking '75 type thermal switch to an isothermal plate on which all electronic assemblies are mounted.

A directional gyro/gyrocompass is used as a navigation heading reference. Wheel odometers are used to calculate distance traveled. Hazard sensors are used to detect rocks, holes, and excessive slope conditions, thus allowing the rover to travel hundreds of meters per day on command from Earth without direct manual control from Earth.

A control sequencer and memory controls the rover operational sequences based on stored sequences, ground commands, and real-time inputs from onboard sensors. A data processor buffers and formats the science data for transmission to Earth. All electronics are packaged together into a single Integrated Electronics Assembly.

The rover is configured with a single, rigid body compartment, as shown in Figure 1. The rear axle is articulated with respect to the chassis using a roll gimbal. Simple scuff steering is incorporated.

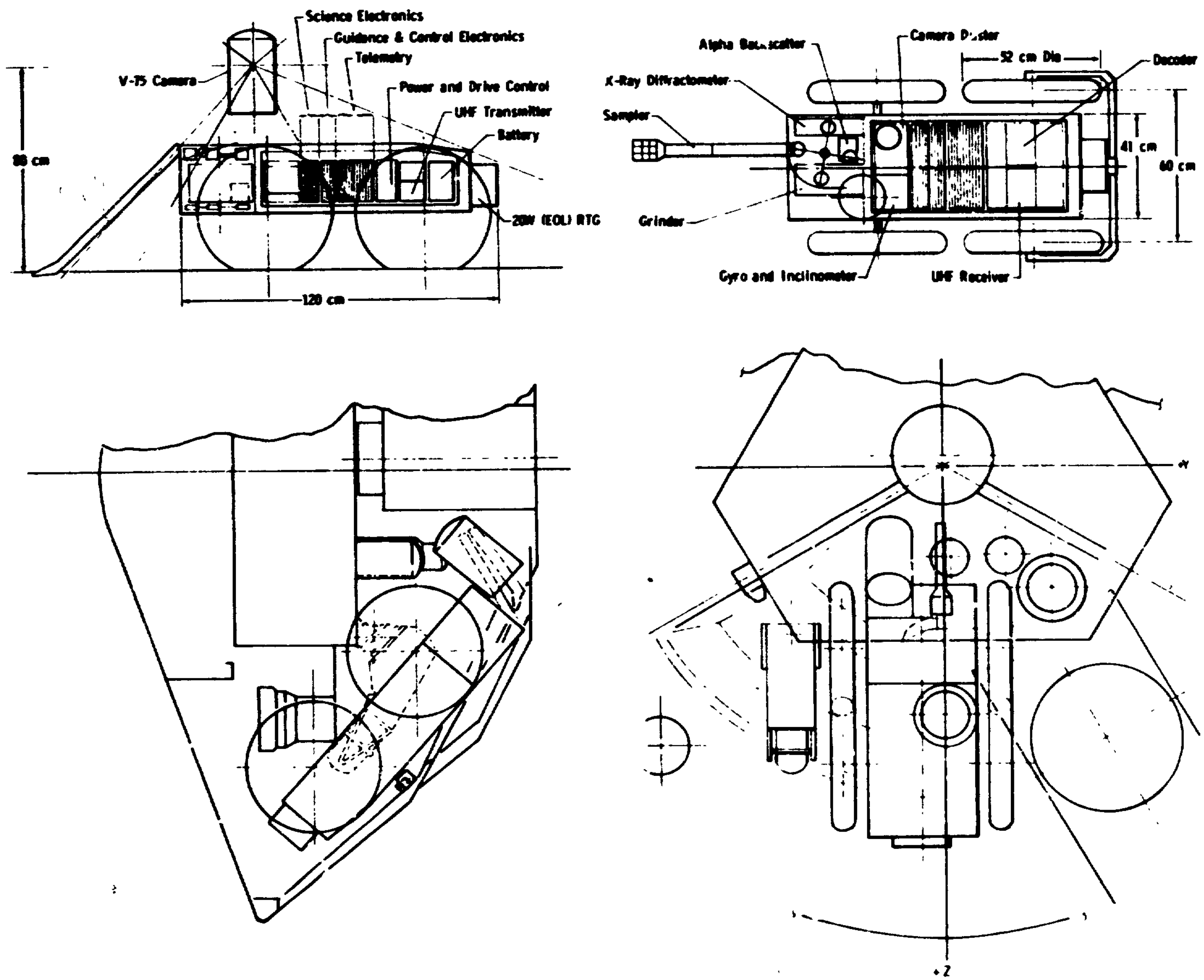


FIGURE 1 BASELINE ROVER SYSTEM

Lander modifications that are required to accommodate the rover are the removal of one camera, installation of new RTGs, relocation of the surface sampler, design of a new base cover, deletion of meteorology and XRFS, addition of a UHF two-way communications system, and addition of a pressure regulation system for the terminal descent propellant system. Because of the shift in the c.m. of the VLC due to the addition of the rover, components mounted to the aeroshell are also relocated. Other lander science changes include removal of the biology instrument and the addition of new biology and X-ray diffractometer instruments.

With the addition of the pressure regulation system and incorporation of new RTGs on the lander, the capability exists to land 745.7 kg of dry mass, well above the current estimate of 719.4 kg for the landed dry mass requirement.

Required Technology Developments

Two categories of technology developments were investigated. One category is the technology that was required and included in the baseline configuration to satisfy the basic design requirements and the second category is the technology that, if adopted, would further optimize the rover system.

Developments that are included in the baseline rover are as follows:

Radioisotope Thermoelectric Generators using selenide thermoelectric materials.

Minaturized directional gyro/gyrocompass.

Adaptive controls using requisite hazard sensors and control sequencer software subroutines.

Technology developments that are not included in the baseline design, but that would significantly improve rover performance if adopted are as follows:

Resonant circuit switching converter to minimize high frequency switching losses.

Hybridized circuits containing C/MOS chips.

Also identified in the preliminary design of the rover are technical areas that need additional study to fully understand the impact on the rover development. These include:

Rover-to-lander soil transfers

Polar ice-cap operation (if polar ice-cap operation is planned)

Rover Development Plan

The rover development plan (based on launches in 1979), which includes rover integration on the lander, is shown in Figure 2. This plan has been constructed to be compatible with the Viking '79 baseline plan, e.g., qualification of the rover is completed coincident with the start of the VLC flight article assembly and test, and first flight rover delivery is immediately before lander encapsulation, because flight acceptance tests and modifications to the lander for rover integration are coincident with refurbishment of baseline lander components. Also, in the interest of minimizing the required program funding before FY 1977, the rover development program has been scheduled as late as practical.

Conclusions

The objective of this study was to define a baseline Viking rover, rover/lander integration concepts, and mission operation concepts that would provide a significant increase in the scientific capability of a Viking '79 Mission. Implicit in this objective was the derivation of a total hardware concept that makes maximum use of the Spare and Proof Test Viking '75 lander hardware. This has been accomplished.

The study results clearly indicate that a significant improvement in the present lander scientific capability is achieved by including the baseline rover in the Viking '79 mission. The lander science instruments would have access to samples from a large surface area, the samples having been selected and screened for scientific interest and returned to the lander by the rover. The value of

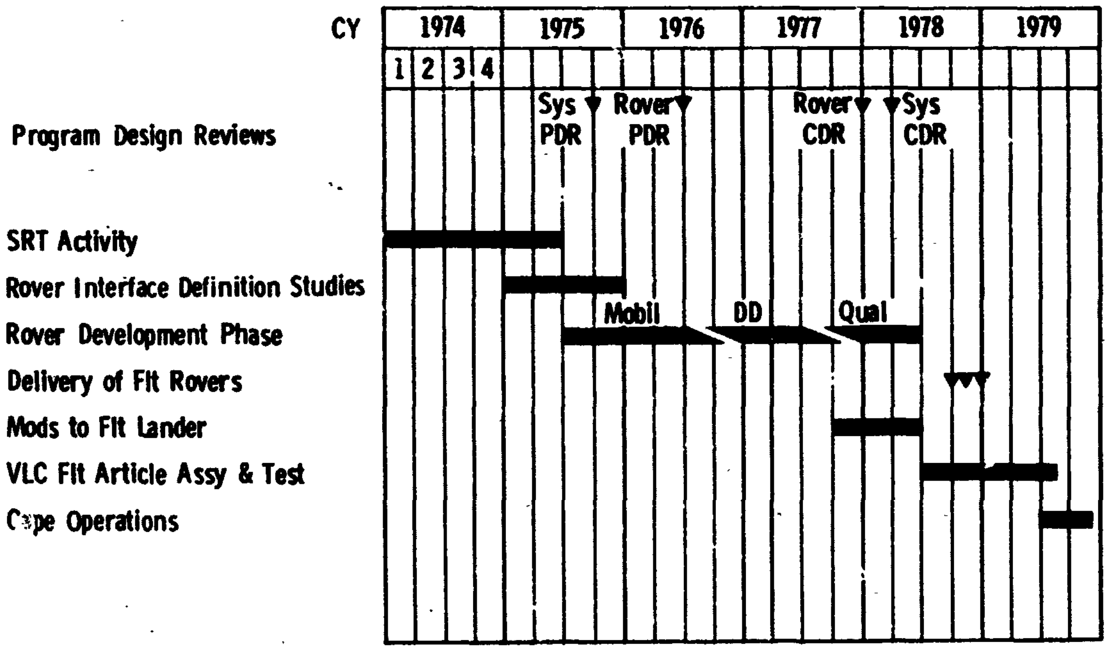


FIGURE 2 SUMMARY PLAN - ROVER DEVELOPMENT AND INTEGRATION

the imagery mission is tremendously improved by using the rover's camera for long baseline stereo and by taking pictures of geological interest over a large surface area.

The impact of integrating the rover on the Viking '75 Lander can be divided into (1) changes required to stow and deploy the rover, (2) changes in the entry and terminal descent system required to land the rover system, and (3) changes required to operate the rover with other mission elements. An evaluation of these changes indicates that maximum use of existing Viking '75 hardware and technology has been made and that only minimum changes are required to existing hardware.

In summary, this study has verified the rover's feasibility, which was first identified in previous studies, and has proved that a Viking '79 rover mission built around the hardware and experience of Viking '75 is feasible, practical, and scientifically rewarding.

PRECEDING PAGE BLANK NOT FILMED

2. INTRODUCTION

Although Mars rover missions have appeared regularly in proposed plans for the 1985-1990 time period, recent studies by the National Aeronautics and Space Administration's Langley Research Center and Martin Marietta Aerospace have indicated that spare and proof-test Viking '75 lander hardware could be used as early as 1979 for missions to Mars with roving vehicles added to the landers. This evidence of an early, feasible, and cost-effective opportunity to perform Mars rover missions led to the study described in this report.

This report presents the results of a study performed by Martin Marietta for the Langley Research Center to define a baseline Viking rover, lander/rover and orbiter/rover interfaces, and system operational characteristics for a 1979 mission to Mars. The mission can logically follow and respond to the results of successful Viking '75 landings in 1976; however, valuable lander/rover missions can be defined now using existing data that show Mars to be an extremely heterogeneous planet, shaped and modified by a variety of surface and atmospheric processes that make Mars the most Earth-like of our planetary neighbors.

To explore and understand the Martian surface through observation, sampling, and analysis, some form of roving vehicle is required. Earlier studies have shown that a number of different rover scientific payloads are feasible, practical, and capable of providing high scientific returns (ref. 1), that the Viking system is capable of carrying extra mass to the surface of Mars in 1979, and that this mass is sufficient to allow integration of a roving vehicle (ref. 2). Accordingly, the study was initiated to determine the characteristics of Viking '79 rover candidates, define the requirements for lander/rover and orbiter/rover integration and mission operations, define a selected baseline rover and rover/lander integration concept, and evolve a program plan for implementation of the selected concept.

The study was divided into two phases. In Phase 1, a number of candidate rover configurations were prepared. In Phase 2, a selected rover, its associated lander/rover and orbiter/rover integration provisions and mission operations concept, and an appropriate program plan were defined. The candidate rover configurations varied according to the size and characteristics of the rover's science payloads; the level of modifications required on the lander; the level of technology used in the rover subsystems, and the operational relationship between the rover and the lander and/or the orbiter during operations on the Martian surface. Evolution of these candidates and the selected baseline concept took place in concert with two closely related activities. These were (1) a NASA-sponsored Viking '79 Science Planning Group was formed and its lander and rover science payload recommendations were integrated in the candidate configurations during the second phase of the study, and (2) an AEC-sponsored analyses of potential radioisotope energy sources for the rover were conducted and their preliminary results were integrated in the study.

These activities served to sharpen the focus of the study. For example, small tethered rovers capable of returning samples to the lander from ranges up to 100 meters from the lander were discarded early in the study because of their limited science potential. Analyses of power requirements for the resultant separable landers and rovers indicated that a new RTG would be required to power the rover and that the technology could be applied to new lander RTGs at a significantly lower mass which in turn could be applied to a larger rover scientific payload. Accordingly, the AEC study of advanced RTGs was instrumental in shaping the selected concept. Given the mass, volume, and power limitations, the configuration shown in the frontispiece was derived. This vehicle incorporates significant science capabilities, is based on Viking '75 technology, and can be integrated into the Viking system with a practical set of lander and orbiter modifications. A mission operations concept was evolved for a mission that includes six vehicles; two orbiters, two landers, and two rovers, the rovers being able to communicate with Earth through both the orbiters and the landers.

3. MAJOR ROVER DESIGN CONSIDERATIONS

The primary function of the rover is to perform *in situ* observation and sampling of the Martian surface over an area many times larger than that accessible from a fixed lander and the total system must perform satisfactorily under all environmental conditions imposed by the mission. These basic considerations influenced and constrained the system design. The areas were examined to derive the major system design requirements for the baseline rover. The following paragraphs summarize major considerations in the scientific, environmental, mass and volume, and pecial subsystem design areas.

Scientific Goals

The primary goal of Viking '79 will be to capitalize on the scientific results of the Viking '75 and Soviet landers to extend our knowledge of Mars. The diversity of the Martian surface offers many opportunities for fruitful exploration, not only because of its geologic richness, but also because the strong interplay between geologic and atmospheric factors on Mars may well result in isolated ecological niches in which Martian organisms exist.

Many scientific questions are presently being asked about Mars but the major ones concern the history of Mars in a cosmogonic sense and particularly how it applies to the possible evolution of life forms. An important consideration is the present existence and past abundance of liquid water on the surface of the planet. Also there is the consideration of whether or not Mars may have been through a geologic evolution within its bulk and on its surface similar to Earth. Such dynamics does not exist on the Moon, but is the major factor in the shaping of Earth crustal geology and its dynamics. The foregoing ideas lead to the posing of the five scientific questions in Table 1.

TABLE 1 SOME KEY SCIENTIFIC QUESTIONS REGARDING MARS

Has Mars been through an aqueous climatic phase?
Does free or loosely-bound water exist on Mars today?
What processes have formed and shaped the Martian crust?
Does plate tectonics apply to Mars?
Do biological organisms or organic compounds exist on Mars?

A rover can assist in answering these questions by transporting science instruments to the Martian surface locations where direct *in situ* measurements can be made, for only such direct measurements can finally resolve the questions.

Rover science modes. - We have identified five modes in which the rover can be used to expand and enhance the scientific value of a landed mission. These are as follows:

Reach a predetermined target area;

Explore the surface terrain;

Collect samples and return them to the lander for analysis by lander-based instruments;

Conduct dual-station science between the rover and lander or rover and orbiter, and

Deploy sensitive instruments away from the lander.

Each of these methods of operation abet the science value of the mission in different ways.

In Table 2 we present some of the requirements derived by comparing the five basic operating modes given above with the five scientific questions posed in Table 1.

Note that in reaching a predetermined target such as a geologic unit observed from orbit, the range of the rover must be equal to the size of the semimajor axis of the footprint. Of course, it is then possible to trade off engineering

TABLE 2 ROVER TASKS

BASIC REQUIREMENT	DERIVED REQUIREMENTS
Reach Predetermined Target	Descent Pictures Range Footprint Min. Science: Imagery (Macro, Micro) Geochemistry Water Detector?
Exploration	Seek Outcrops, Boulders, Scarps, Other Specific Landforms Min. Science: Imagery, Articulated Geochemistry, Derived Altimetry, Physical Properties, Seismic Kamikaze?
Obtain Samples for Lander Instruments	Imagery for Sample Documentation and Selection, Soil for Biology, Organic, Soil Water (Temp. Excursion 10°C) Geochemistry: Rocks 6 Each, 2-5 cm Major Diameter Soil 3 Samples, 50 cc Each
Dual-Station Science	Ranging and Timing Accuracy

developments that reduce the footprint size against other developments that allow an increase in rover range, at the minimum cost. Alternatively, one could target the landing footprint to include several geologic units, and then proceed to the nearest unit.

Samples collected by the rover should be as numerous and varied as practical. In our derived requirements we present a rather minimum requirement of six rocks and three soil samples, the exact number being of course relatively arbitrary. If the rover includes an active geochemistry experiment that monitors the soil composition as the rover traverses the terrain, a simple computer algorithm could be employed to determine whether the chemical composition is constant or changing. Upon detecting a change, the rover might automatically stop and execute a sampling sequence. Any sampling system should also include the capability to dump samples upon command from Earth should it be decided that one or more samples already obtained are of less value than those that are now available.

Requirements for deploying instruments are not known and were not included in our baseline rover design, but estimates based on present studies are that they would be deployed 20 to 100 meters or more from the lander for the types of experiments that have so far been considered.

To obtain the greatest value from a science rover mission, it is desired to be able to react to the potential surprises that may greet the ground operating crew. It is thus desired that the scientists be able to redirect the path of the rover as well as control in some detail the frequency of sampling, type of samples obtained, and analysis performed.

A certain amount of built-in adaptative capability through onboard electronic circuit operating modes will be necessary to guarantee the survivability of the rover. This self-reliance includes the avoidance of terrain hazards and continued movement of the rover in a severe dust storm to avoid burial. Because such capabilities must be included in the rover, it is possible that moderate additions to these electronic functions can be used to enhance certain science objectives.

Environmental Factors

The Viking '79 Mission Environments are essentially the same as those used for the Viking '75 design except for nuclear radiation, landing shock, and thermal. The impact of the potential nuclear radiation and landing shock environmental changes are rather minor, whereas, the change in thermal environments has a much greater impact on the design of mission hardware.

New RTG designs use fuel elements that are as "clean" as the SNAP-19 fuel elements and therefore should not produce neutron flux densities in excess of those experienced on Viking '75. Confirmation of this preliminary evaluation must be made during the AEC development program for new RTGs.

The landing shock for Viking '79 has been evaluated and there appears to be three methods available for handling the change in landed mass. The first method is to leave the present Viking '75 landing legs unmodified, which will result in a decrease in lander clearance of approximately 4 cm. The second method is to change the landing leg shock absorbing characteristics (new honeycomb design) and thereby maintain the specified 22 cm clearance. The third method is to change the final descent rate from 2.4 m/s (8 ft/sec) to a lower value and compensate by adding approximately 0.9 kg (2 lb) of propellant. Further studies must be performed to select one of these solutions and hence the actual landing shock.

The anticipated Viking '79 mission thermal environments are summarized in Table 3. Figure 3 presents a summary of the expected Viking '79 Mars surface thermal extremes.

The Viking '79 trans-Mars cruise thermal environment is changed from the '75 mission by the addition of the rover. The rover carries its own RTG, thereby increasing the VLC internal heat load during cruise, and requires a thermal design that will reject most of the rover RTG heat to space.

Thermal analysis has shown that the lander internal temperature will increase approximately 6°K (10°F) above the Viking '75 level for the proposed rover RTG heat rejection design.

TABLE 3 MISSION THERMAL ENVIRONMENTS

Sterilization:

All Components must survive a Minimum of Three Sterilization Cycles

Cruise:

Solar Constant, 1350 to 710 W/m^2 (430 to 225 $Btu/Hr\text{-}Ft^2$) Deep Space Sink 3^oK (-453^oF)

Mars Surface:

	Hot Environment	Cold Environment
Landing Site Latitude, Degrees	-30^o	-90^o
Solar Irradiance	710 W/m^2 (225 $Btu/Hr\text{-}Ft^2$)	690 W/m^2 (219 $Btu/Hr\text{-}Ft^2$)
Surface Absorptivity, α_S	0.85	0.50
Surface Emissivity, ϵ_{IR}	0.89	0.90
Sky Temperature	152^oK (-185^oF)	85^oK (-370^oF)
Wind Velocity	0	45 m/s (130 ft/sec)
Mean Ground Temperature	248^oK (-12^oF)	--
Peak Ground Temperature	319^oK ($+115^oF$)	147^oK (-195^oF)

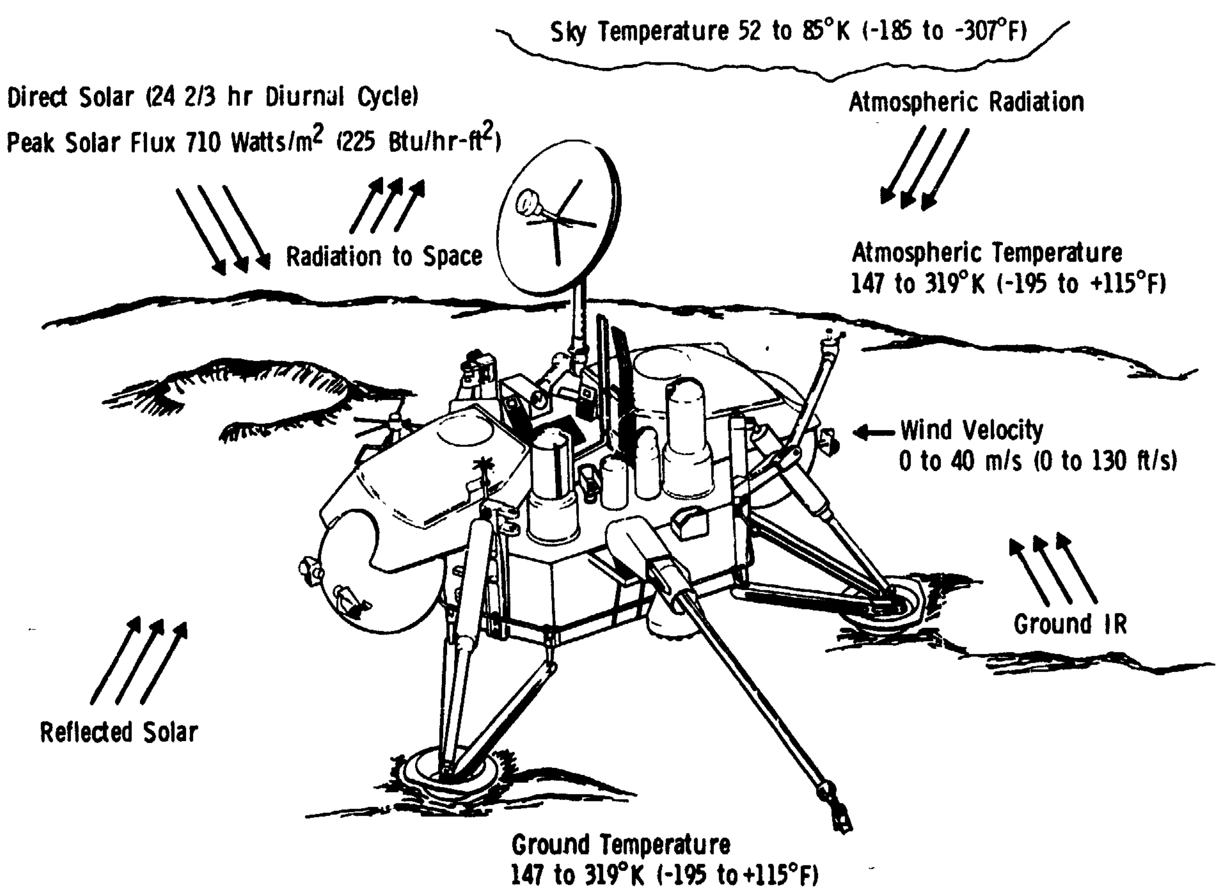


FIGURE 3 MARS SURFACE THERMAL ENVIRONMENTS (VIKING '79)

Stowage on Lander

Design considerations that affect stowage of the rover on the lander also determine the ultimate size of the rover. A study of the Viking '75 hardware configuration was performed and it established the constraints primarily associated with the allowable mass, volume, and center of mass. These characteristics were considered for the case of minimum entry capsule modification and also major modifications to consider those options wherein a rover might be used to replace the lander science. The Viking '75 entry capsule, shown in Figure 4, is the governing factor in determining the maximum rover envelope. The study, which was performed on the entry capsule, revealed that, with the exception of a small volume near the -Z axis, the only area available to locate the rover is at the +Z axis. An additional criterion established for stowing the rover was to impose a requirement that the c.m. for the entry capsule be on a radius of 4.19 cm. The requirement is imposed so that the L/D ratio is established at 0.16. Any deviation from this distance would require compensating ballast, which is undesirable. A study of the center of mass constraint showed that should the rover be located at the +Z axis, the center of mass offset could be maintained near the required 4.19 cm. However, this moves the c.m. from -Z axis as it exists on the Viking '75 across the centerline to the +Z axis. The final rover envelope, shown in Figure 4, was established by a lander modification requiring a slight movement of the surface sampler. This change did not affect the performance of the surface sampler. It is to be noted that this selected location for rover stowage was also the one which required the least amount of ballast to be added to achieve the required c.m.

The selected baseline rover configuration will be stowed as shown in Figure 4. The rover will be structurally mounted to the lander body and will have a minimum of 3.8 cm of dynamic clearance between any point on the rover and the inside structural line of the aeroshell. The rover will have a minimum of 2.5 cm of dynamic clearance between any point on the rover and the inside structural line of the base cover. The rover, although located on the +Z side of the entry capsule, will not extend into the terminal engine plume. This location provides the maximum available volume in the entry capsule for rover stowage.

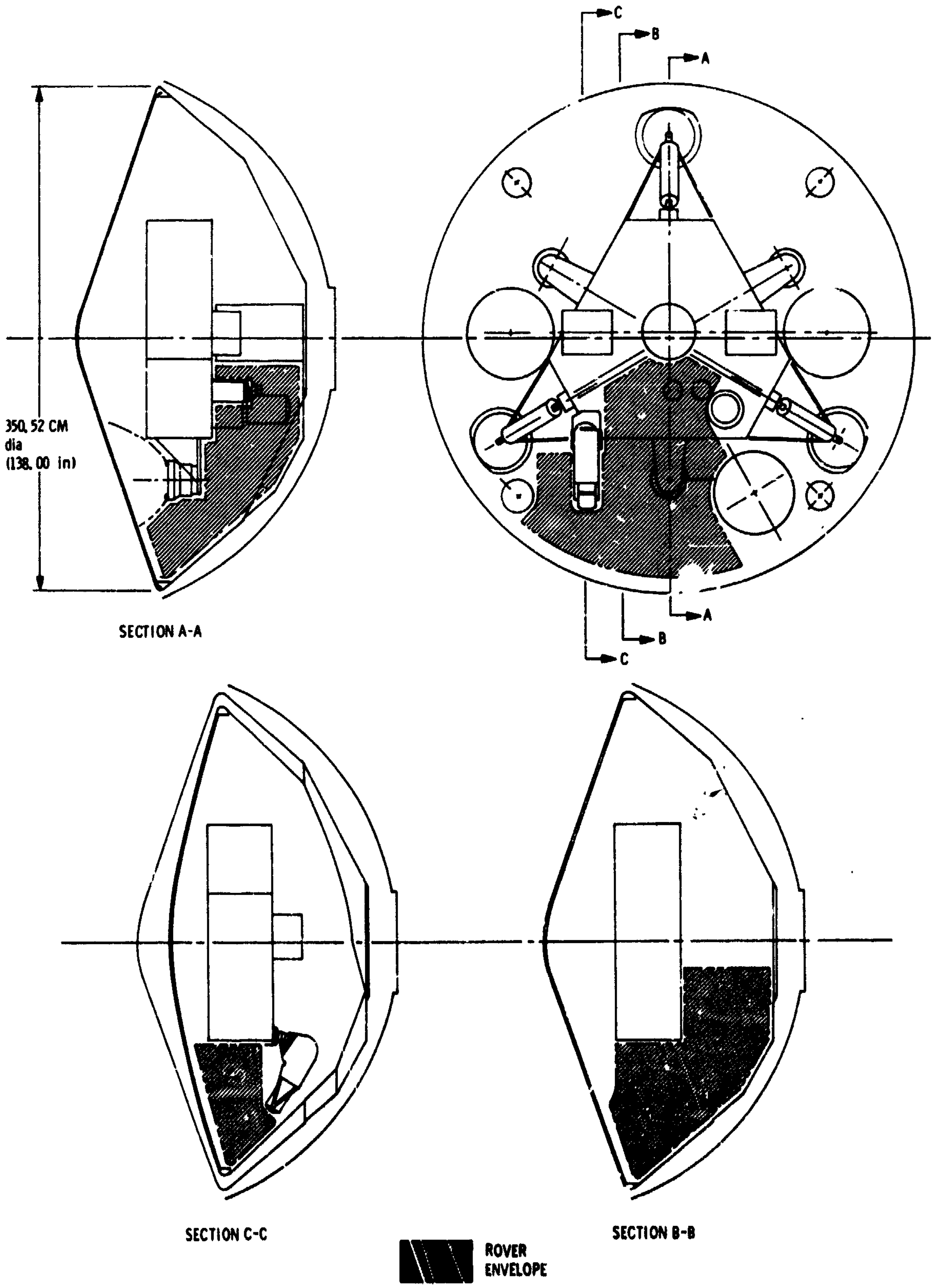


FIGURE 4 ENTRY CAPSULE

Launch Through End of Mission Performance Analysis

Trans-Mars performance capability. - The trans-Mars performance capability for the Viking '79 rover mission is based upon the Viking '75 launch vehicle and spacecraft performance characteristics without change. The key operational assumption impacting the 1979 mission opportunity performance is that both rover missions will be flown to sites preselected from the results of the Mariner 9 and Viking '75 missions (i.e., major retargeting flexibility not required). In addition, the ΔV budget has one component, ΔV_{STAT}, reduced from 175 m/s to 100 m/s because of the favorable approach geometry associated with the 1979 mission (similar to the Viking '75 Mission A).

These assumptions lead to the typical launch date/arrival date performance capability shown in Figures 5 and 6 for spacecraft mass-in-orbit increases of 181.4 kg (400 lb) and 272.2 kg (600 lb), respectively. These masses are referenced to those in the October 1973 Viking Mass Properties Report. The data in the figures show the excess ΔV still remaining in the spacecraft in orbit after performing all maneuvers identified in the ΔV budget. The maximum allowable mass-in-orbit increase for a 30-day launch period is 310.7 kg (685 lb).

Representative 1979 Mission A and B launch periods (10 days each, separated by 10 days) are also shown on Figure 5 together with the associated operations functional timelines from last midcourse correction to touchdown. The timelines are identical to the current Viking '75 Mission A timelines. As shown in the figure, encounter date separation between the two missions of 25 days minimizes functional overlap in the operations timelines for the dual mission.

Lander deorbit performance capability constraints. - The lander deorbit performance capability, coupled with the spacecraft and entry system capabilities, limits the allowable mass-in-orbit of the lander/rover system. The assumptions used in the analysis are that the orbit control capability (i.e., position and size relative to the desired landing site) is identical to that being used in Viking '75, and that the deorbit propulsion subsystem and aeroshell characteristics are identical to the current Viking '75 capabilities.

Launch Mass = 3861.0 kg (8512 lb)
Drop Mass = 210.9 kg (465 lb)
Prop Mass = 1404.8 kg (3097 lb)
ΔV Cap. = 1362.8 m/s
Del Mass in Orbit = 181.4 kg (400 lb)
ΔV Budget = 175 m/s
Prop I_{sp} = 2828 N-s/kg (286 s)
Orbit = 1500 km/24.623 hr

Arrival Date, 1980

ΔV Capability
-ΔV MOI (Finite Burn)
-ΔV Budget

ΔV Excess

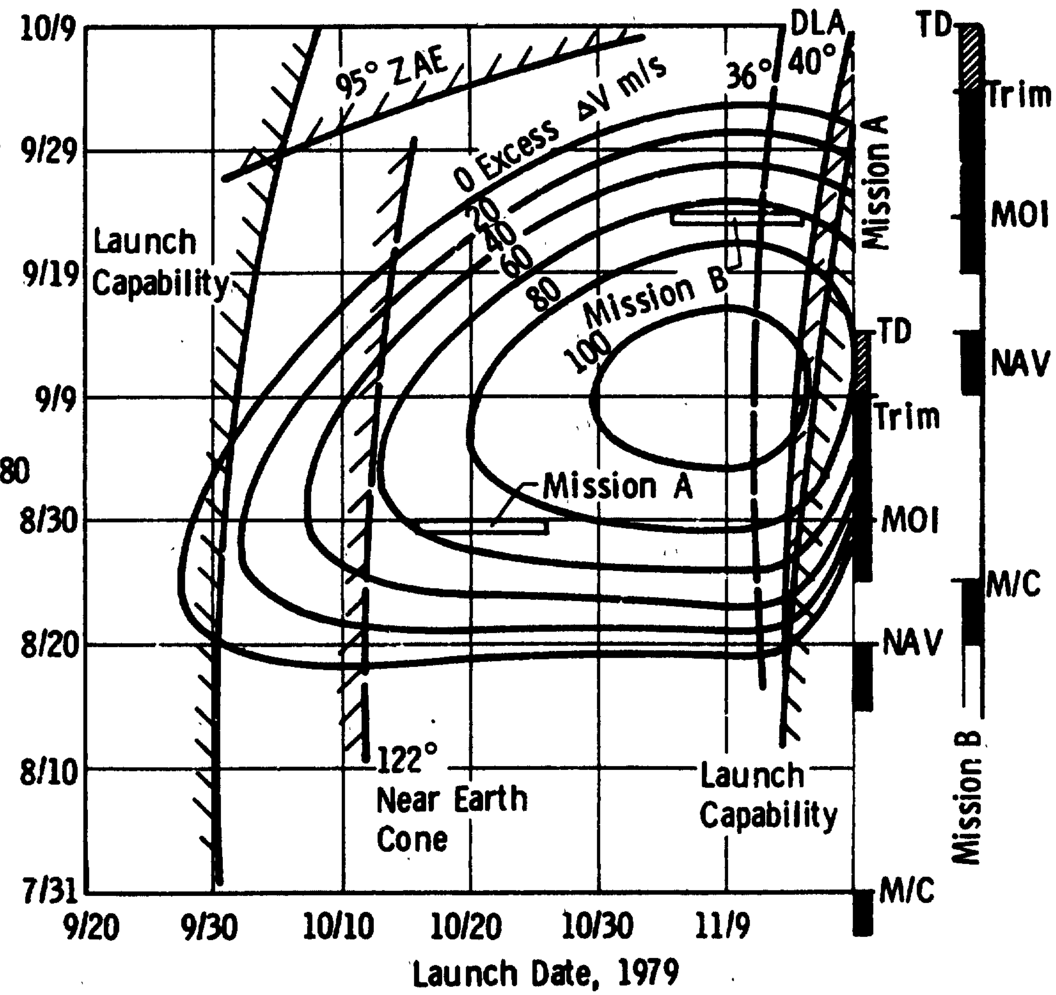


FIGURE 5 INITIAL VIKING '79 PERFORMANCE DATA

Launch Mass = 3951.7 kg (8712 lb)
Drop Mass = 210.9 kg (465 lb)
Prop Mass = 1404.8 kg (3097 lb)
ΔV Cap = 1320 m/s
Del Mass in Orbit = 272.2 kg (600 lb)
ΔV Budget = 175 m/s
Prop I_{sp} = 2828 N-s/kg (286 s)
Orbit = 1500 km/24.623 hr

ΔV Capability
$-\Delta V$ MOI (Finite Burn)
$-\Delta V$ Budget
ΔV Excess

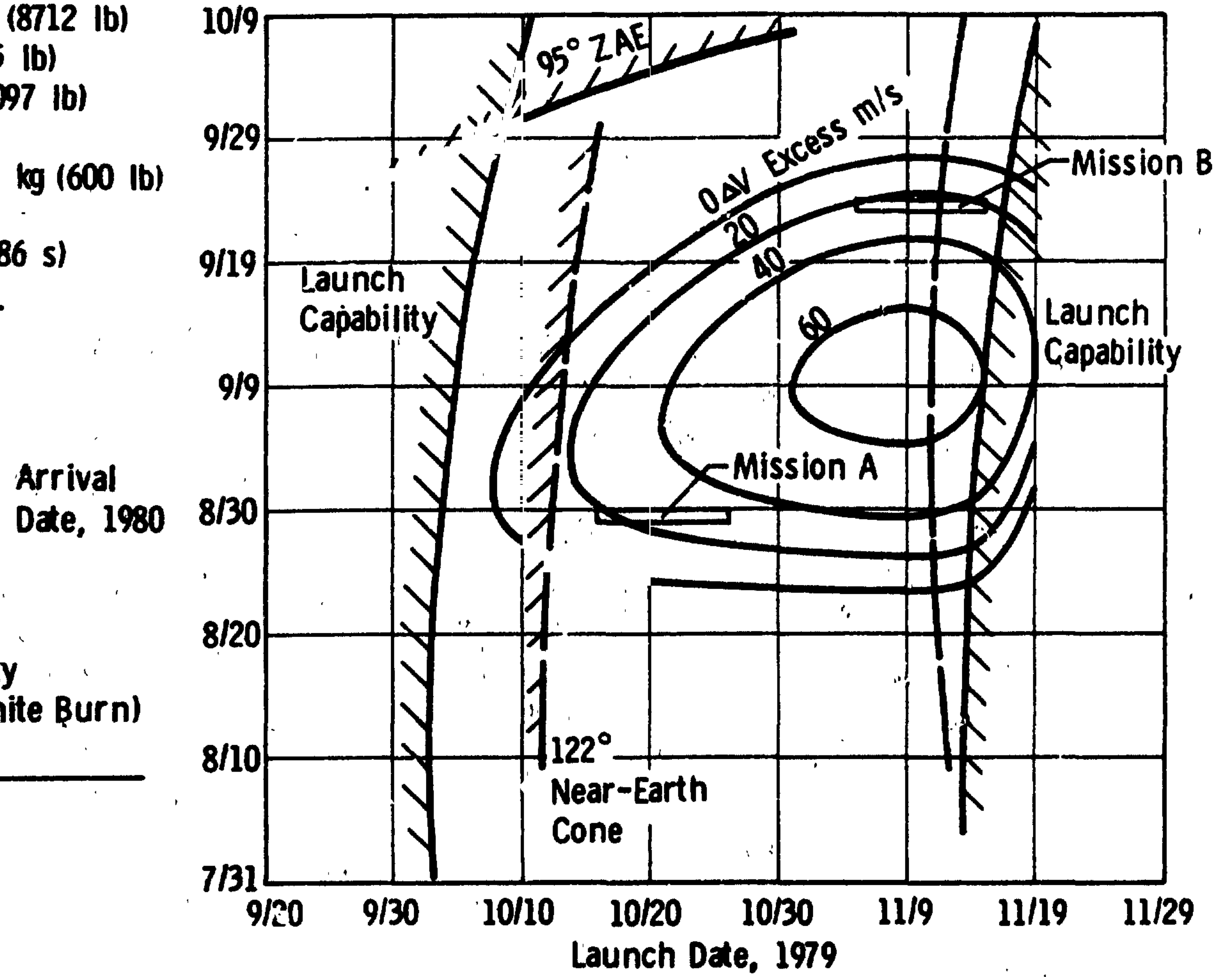


FIGURE 6 INITIAL VIKING '79 PERFORMANCE DATA

These assumptions lead to the representative entry corridor characteristics shown in Figure 7. Combining these data with the Viking '75 orbiter position and periapsis control capability and deorbit performance leads to the entry mass limits shown in Figure 8. The minimum allowable ΔV_D is 147 m/s. This corresponds to a maximum allowable entry mass of 1145.3 kg (2525 lb) or a maximum allowable delta mass-in-orbit of 233.6 kg (515 lb) charged to the lander/rover compared to the spacecraft capability of 310.7 kg (685 lb).

<u>Entry-to-touchdown performance capability</u>. - The entry-to-touchdown performance analysis is based on maintaining the Viking '75 aeroshell (entry) and parachute mortar fire maximum dynamic pressure constraints. In addition the assumption is made that the atmosphere (density) and terrain height uncertainties in 1979 will be one-half of those used in 1975, based on Viking '75 and Russian mission data. The most adverse half of the Viking '75 atmosphere uncertainty band has been assumed (i.e., MIN ρ_S/MEAN).

These constraints, coupled with the heavier entry masses, result in a new (near) optimum nominal L/D of 0.16 for the 1979 mission, including the effect of the Viking '75 balancing uncertainty of L/D = $\pm$0.02.

The only variation from Viking '75 performance capability used in this analysis is that a pressurant tank and regulator are combined with the existing terminal descent propulsion system to provide a pressure regulated system to achieve the additional average thrust necessary to land the additional mass. In addition, the demonstrated engine test performance has been used rather than the current specification thrust. All other Viking '75 vernier propulsion and guidance system characteristics have been used in determining the entry-to-touchdown performance capability.

The resultant entry-to-touchdown performance capability is summarized in Table 4 and compared with current mass estimates (which include 20 percent contingency for new hardware). A sizeable margin exists at each entry phase.

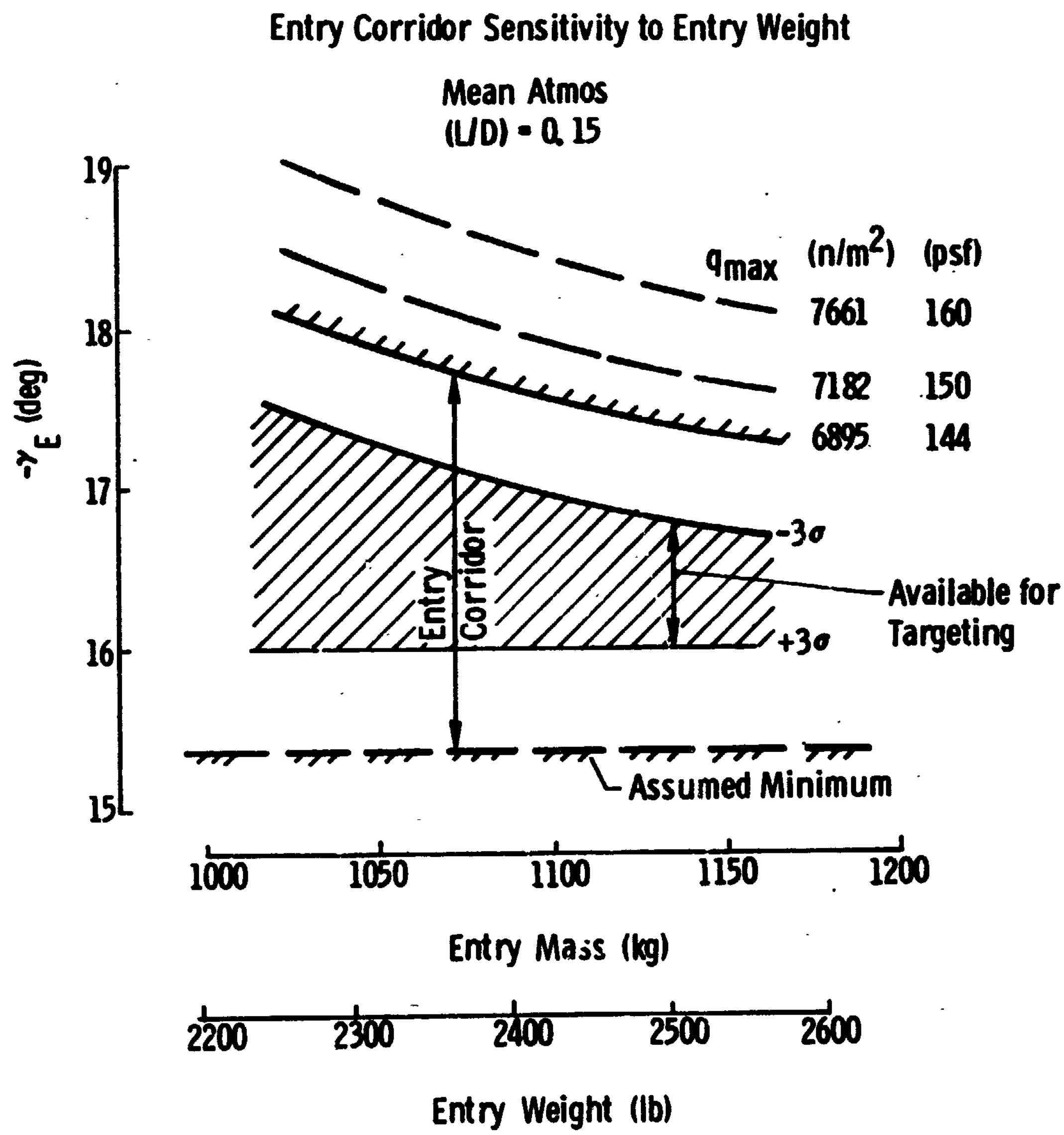
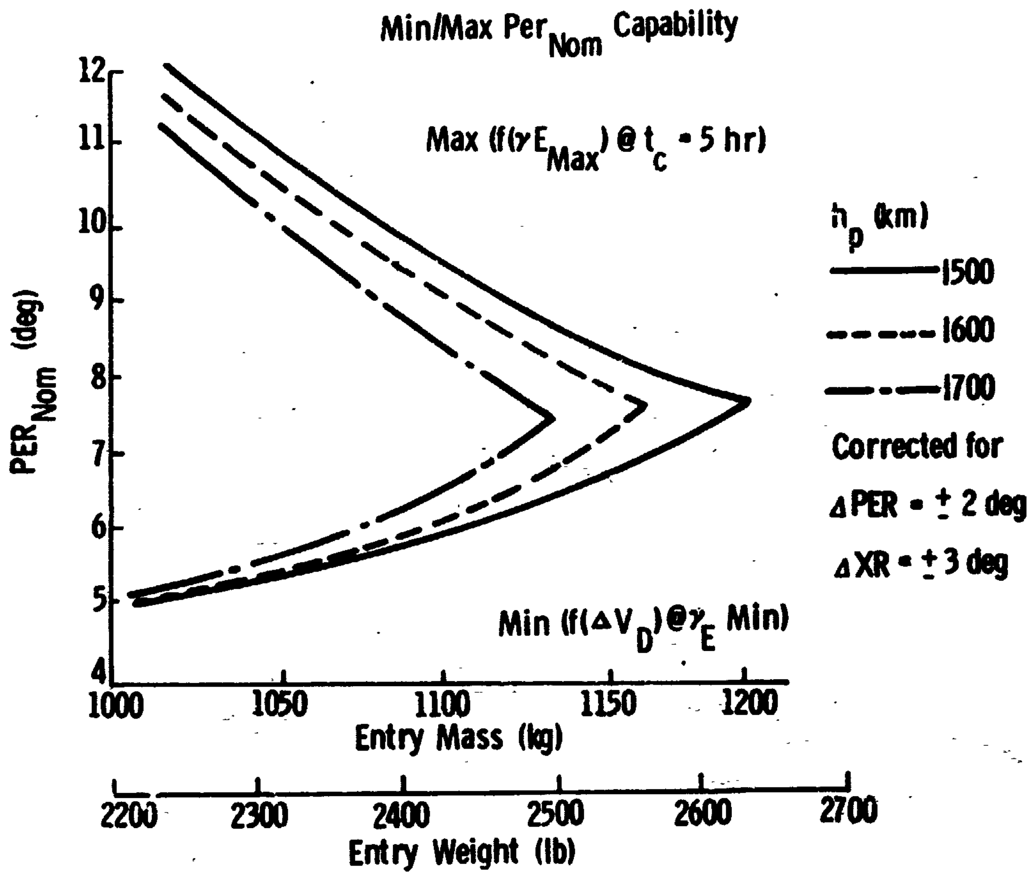


FIGURE 7 ENTRY CORRIDOR SENSITIVITY TO ENTRY MASS



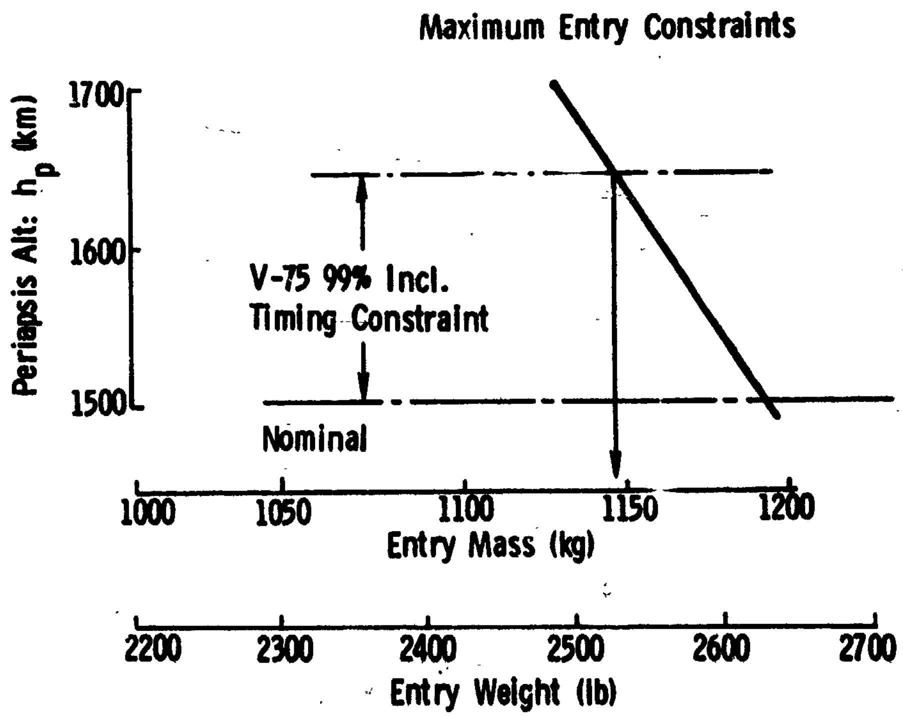


FIGURE 8 MIN/MAX PER$_{NOM}$ CAPABILITIES

TABLE 4 VIKING '79 VLC PERFORMANCE CAPABILITY

	CAPABILITY		CURRENT ESTIMATE	
	kg	(lb)	kg	(lb)
Landed Dry Mass	745.7	(1644)	719.4	(1586)
Total Landed Mass	758.4	(1672)	732.1	(1614)
Mass at Vernier Ignition	839.1	(1850)	812.8	(1792)
Mass on Parachute	950.7	(2096)	924.4	(2038)
Mass at Entry	1145.3	(2525)	1130.8	(2493)
Separated Mass	1224.2	(2699)	1209.7	(2667)
VLC Loaded Mass	1351.3	(2979)	1336.7	(2947)

Landing site accessibility. - Landing site accessibility is constrained only in latitude. Any longitude can be acquired by orbit timing maneuvers before lander deorbit. Latitude constraints are derived from the following:

- Mars orbit insertion (MOI) performance capability.
- Sun elevation-angles at touchdown (SEA_{TD}). Angles between 15 to 65 degrees are required for good predeorbit landing site pictures from orbit.
- Orbiter power constraint with lander attached. No orbiter sun occultation allowed for 50 days after MOI.
- Direct command and telemetry link geometry (Martian surface-to-Earth).
- Thermal limits on lander or rover.

Thermal constraints are discussed in the preceding paragraphs and in Volume II. Remaining constraints are discussed in the follow paragraphs.

The latitude constraints imposed by the forementioned first three factors are shown in Figure 9 as a function of mass to orbit. The maximum Northern and Southern latitudes are constrained by the low SEA_{TD} limit for both Mission

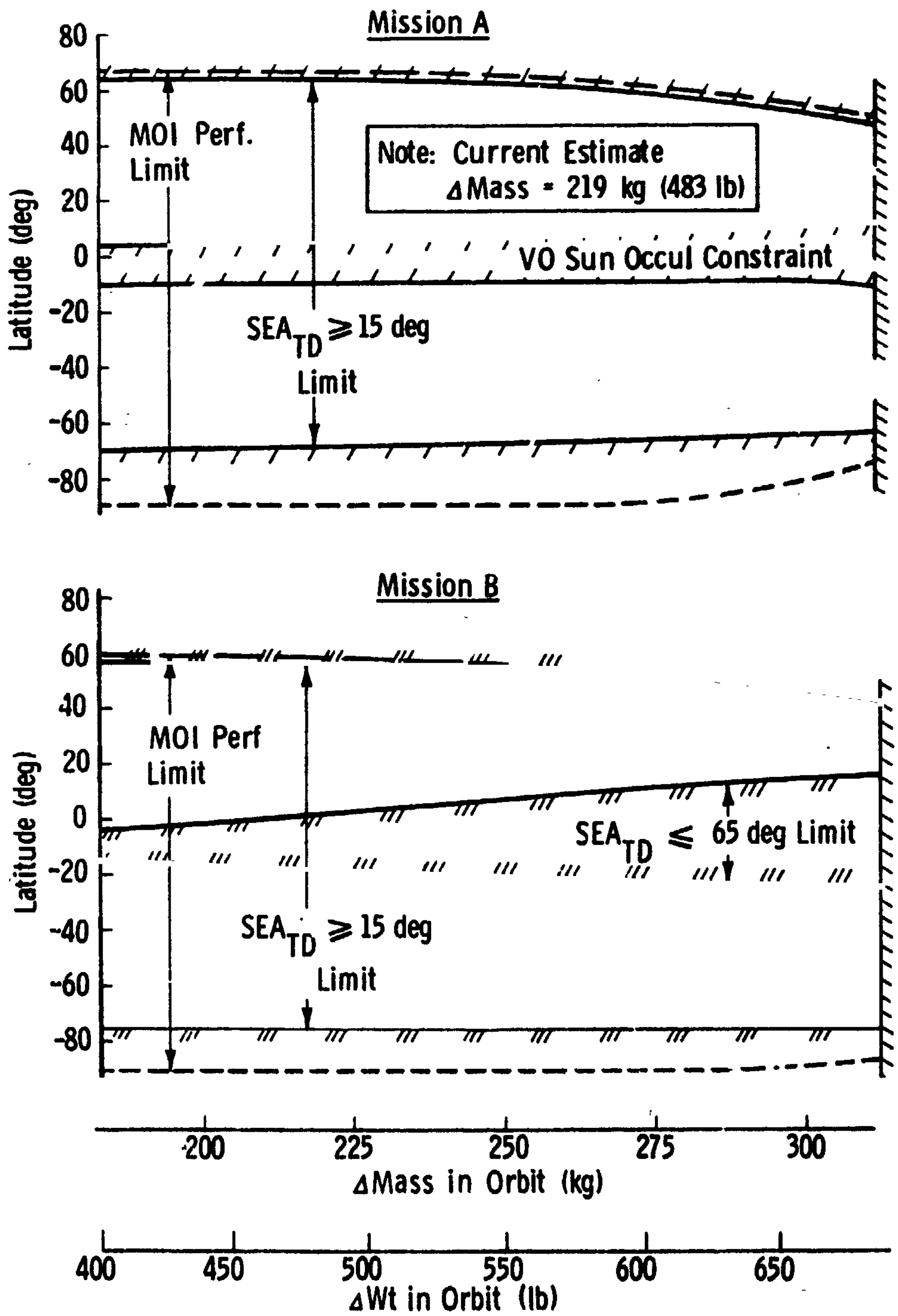


FIGURE 9 FLIGHT PERFORMANCE LIMITS ON LANDING SITE LATITUDE

A and B. The equatorial region is eliminated by the orbiter power constraint for Mission A, and by the SEA_{TD} 65 degrees constraint for Mission B. At the current Δmass = 219 kg (483 lb) estimate, latitudes between approximately 60°N to 70°S can be acquired with the equatorial region between 4°N to 20°S eliminated. Relaxation of the prelanding imagery and communications constraints allows landing at the South Pole.

The requirement for direct communications between the lander and Earth further constrains the maximum Northern and Southern latitudes. The characteristics used in defining these constraints are as follows:

- Minimum of 2.5 hours link time per day
- High gain antenna (HGA) operating over a 10-degree elevation mask
- Low gain (command) antenna (LGA) half power beam width of 170 degrees
- Lander located on an adverse slope of 15 degrees
- Viking '75 radio performance
- Links required for full 90-day mission over both HGA and LGA.

The resultant communication constraints on landing site latitude are presented in Figure 10. Mission A will be constrained between 60°N and 53°S. Mission B is constrained between 53°N and 57°S. All constraints are a result of the LGA limits. Northern latitudes are constrained by links at the end of mission, and Southern latitudes are constrained by conditions at touchdown. If the slope assumption is relaxed, the latitude bands can be increased approximately ±10 degree.

Special Rover System Considerations

A major factor that influenced the rover conceptual designs was the rover power source. Prior studies indicated that travel beyond 0.5 to 1.0 km from the lander would require the rover to have an independent electrical power source because batteries to power such traverses would be excessively large. Solar panels were ruled out as a power source due to uncertain wind and dust conditions.

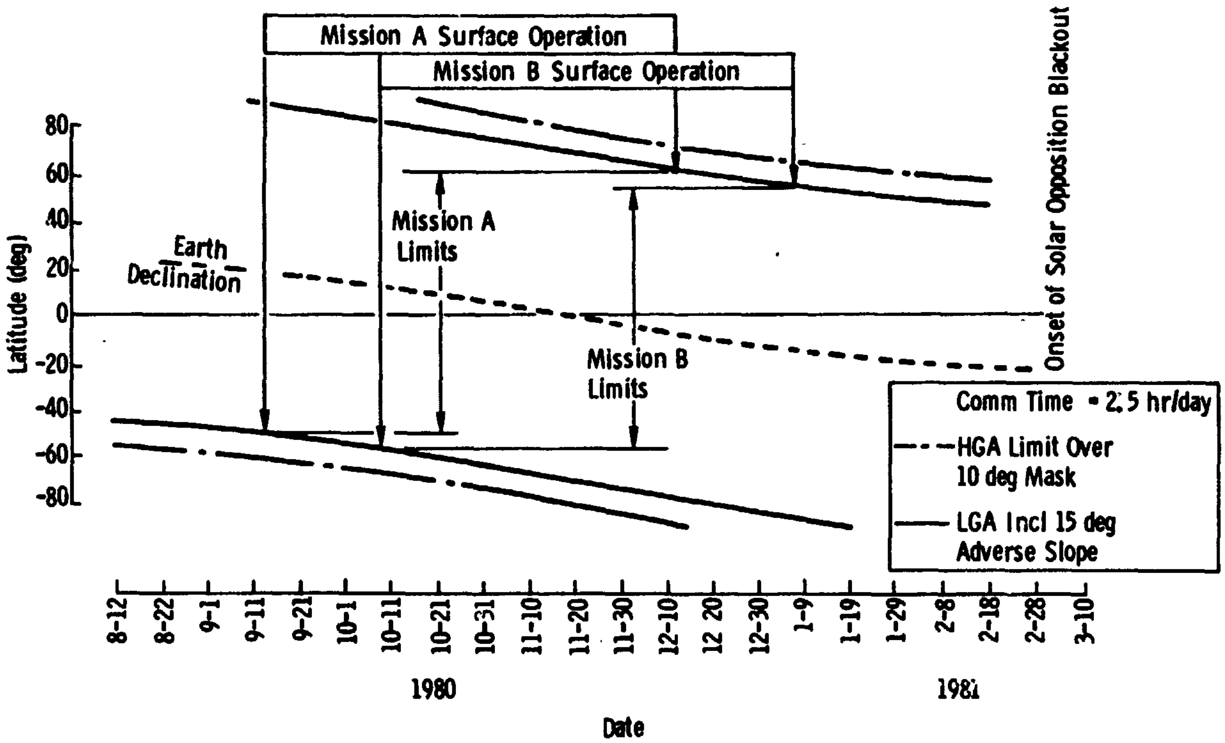


FIGURE 10 LANDER COMMUNICATION LINK CONSTRAINTS ON LANDING SITE LATITUDE

Radioisotope Thermoelectric Generators (RTGs) offered the only acceptable source for the thousands of watt-hours required to support traverses over tens of kilometers. Accordingly, data on potential rover RTGs for a 1979 launch were requested from the AEC. Preliminary data from the AEC indicated such RTGs could be fabricated and that they would probably produce on the order of 3.3 electrical watts per kg (1.5 watts per lb) and 16 thermal watts for each electrical watt. These figures were used in defining the rover concepts examined during the study. Detailed information relative to these studies has been included as Appendix B, Volume II.

Constraints imposed by the Viking Lander Capsule (VLC) cruise thermal control system influenced the design of the RTG-equipped rovers. During Earth-Mars cruise, the thermal output of the rover's RTG cannot be transmitted to the entire capsule without overheating some of the lander subsystems; therefore, a decision was made to design all rover candidates so the rover's RTG would be located toward the outer edge of the capsule. An insulating shield would then be used to keep the bulk of the rover RTG heat away from the rest of the capsule and to reflect the heat to a portion of the base cover especially blackened to radiate this excess heat to space.

A NASA Science Planning Group examined science objectives and payloads for advanced Mars missions. This activity influenced the study by providing rover and lander payload recommendations to NASA/LRC and MMC at the midpoint of the study. These payload recommendations were integrated in the guidelines for the study and the final selected rover and lander concepts reflect this group's recommendations.

Another major factor that influenced rover concepts was the Viking '75 Project from which Viking '79 will be derived. Throughout the study, technical results and program plans were reviewed by Viking '75 personnel at NASA/LRC and MMC. These reviews produced a number of decisions, the most significant of which was the decision at midterm to proceed with configurations incorporating Viking '75-class electronics with all electronic subsystems packaged in a single housing that also serves as the thermal control compartment. This concept was selected over concepts incorporating hybridizable microelectronics and concepts with Viking '75-class electronics packaged in individual boxes, with the boxes then installed in a thermally-controlled compartment as on Viking '75.

Viking '75 personnel also contributed to the study by assessing the various lander modifications available to increase the landed mass capability in 1979 to accommodate the rover system. Their assessment led to recommendations to alter atmospheric uncertainties in a conservative manner based on the assumption that Viking '75 data will decrease the atmospheric uncertainties. These personnel also reviewed and approved proposed modifications to the terminal descent propulsion system. These modifications were required to land the selected rover system mass.

These influences are reflected throughout the subsequent chapters that cover candidate definition, subsystem analyses, and the baseline concept selected.

PRECEDING PAGE BLANK NOT FILMED

4. CANDIDATE ROVER CONCEPTS

A wide range of rover concepts were considered during the course of this study, limited primarily by the mass and volume constraints of the Viking Lander Capsule. Small tethered rovers were eliminated early in the study as not providing a sufficient increase in scientific data returns over a Viking lander. Also eliminated as being too ambitious for a 1979 mission were the large, fully autonomous rovers with the capability to travel hundreds of kilometers over the Martian surface.

The constraints placed on the rover design at the onset of the study centered around using the Viking '75 spare and proof-test lander capsules as vehicles for carrying the rover to the Martian surface in 1979. The inclusion of a rover should require minimal modifications to the lander systems, and should be stowed in the capsule in such a way that entry performance is not degraded. The rover must be capable of operating in the environments and under the same surface conditions for which the lander is designed.

Preliminary concepts. - The rover concepts considered early in the study were designed to bound the parameters, and to provide alternates that could be traded off to arrive at a baseline concept. This set of concepts consisted of two classes of rovers, one of which was completely dependent on the lander for its command, control, and data handling, and the second class operated independently of the lander after off-loading, communicating to the Earth via the orbiter, and receiving commands directly from the Earth. Each of these classes was subdivided into three configurations. The first of these configurations carried a minimum payload and required no changes to the lander science. The third configuration carried a maximum science payload, with all of the lander science removed, and the second configuration fell between these extremes. As anticipated, each of the six configurations has drawbacks, but as a group, they provided the data for trade off to develop a baseline concept.

System level trades. - These trades can generally be classified as follows:

Operational requirements and constraints - such as operating out of the range of the lander, communicating through the lander, orbiter or both, and the effects of the long communications delay for Earth commands.

Level of technology - the use of available hardware, existing designs and Viking '75 piece parts, or some level of advanced technology.

Configuration Considerations - effects of lander interfaces, and the mobility and thermal designs on the configuration.

Additional landed mass - various methods investigated to increase this capability, e.g., propulsion thrust level, regulated tanks, and parachute size.

Subsystems level trades. - Many subsystem level trades were also conducted, both in support of the system trades, and others which were internal to the subsystem. These included:

Mobility - number of body compartments, types of traction elements, steering components, wheel designs, and drive motors.

Power - Centralized or decentralized system for power conversion and distribution, and power bus voltage level.

Thermal control - various design approaches, including thermal switch(es), radiators, and pumped fluid systems.

Communications - number and types of links between the rover, lander, orbiter, and Earth, and the carrier frequency of each link.

Data handling - centralized or decentralized data processing, and the amount of data storage required to include in the rover.

Navigation - type of heading reference to use, and number and type of hazard sensors.

Control sequencer - perform control function in the lander computer (GCSC) or provide a rover sequencer.

Off-loading mechanisms - four different concepts considered.

The results of these subsystem trades are described in the Baseline Description section of this volume.

Midterm perferred configurations. - The early configurations and the system and subsystem trades were used to develop a first baseline configuration, referred to as the Midterm preferred configuration, shown in Figure 11. This rover, with a total mass of 72 kg (159 lb), carries a 10 kg (23 lb) science payload, has a design range of 50 km, and operates either with the lander or through the orbiter (independent of the lander). All electronics are integrated into a single assembly and hybridized microelectronics are used to minimize the rover mass. Many of the characteristics of the concept were carried over to the final baseline configuration.

Minimum lander change concept. - Another concept was considered in an attempt to minimize the change to the lander. A rover was designed to fit "around" the existing lander components, requiring only that the stowage and off-loading equipment be added, but with no further change to the lander. Although this is a feasible design, its asymmetrical chassis requires more thermal control power, less efficient packaging, critical wheel deployments and a resulting 4.5 kg (10 lb) mass penalty; therefore, this concept was not pursued further.

Midterm preferred configuration with Viking '75 type electronics. - A brief study was undertaken to determine the effect of replacing the hybrid electronics with Viking '75 devices, and maintaining the integrated packaging concept. The result was a mass increase of approximately 13 kg (29 lb), but one that eliminates the development risks associated with the hybrid components.

Baseline configuration. - The final baseline configuration combined the midterm-preferred configuration, the use of Viking '75 type electronics, and the incorporation of the Rasool Committee science payload. It is described in the following section this report.

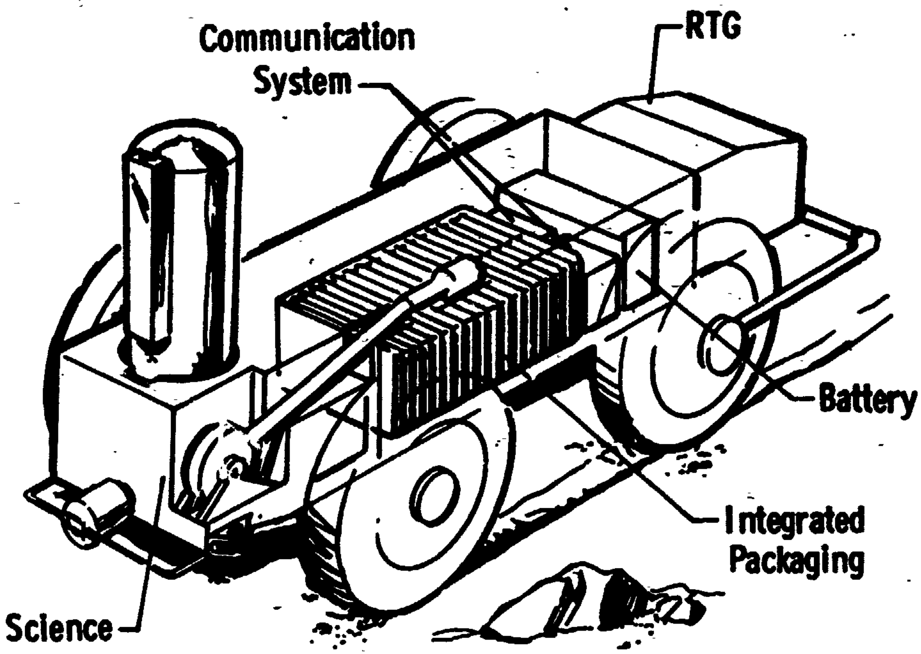


FIGURE 11 MIDTERM-PREFERRED CONFIGURATION

5. BASELINE ROVER SELECTION AND DESCRIPTION

Baseline Rover Selection

The baseline rover configuration was selected through a process of studying different configurations as discussed in Volume II. Each of these configurations was based on a different set of criteria. The study and evaluation of this wide variety of configurations was valuable in that we were able to assess the inherent advantages and disadvantages of each and select a baseline configuration that contains the largest number of desirable features.

The maximum rover mass [107.95 kg (238 lb)] and volume [116 000 cc (7080 cu in.)] are provided in the baseline configuration as determined from these studies. The baseline configuration also has the capability to operate through the lander or through the orbiter. From our lander-dependent rover studies it was determined that insufficient power was available to perform rover guidance and navigation computations on board the lander, therefore, the baseline rover is capable of performing these functions on board. Further, the rover was constrained to operate within a 6 to 7 km range of the lander. It was determined that the science mission would be greatly enhanced by the capability to leave the lander and examine areas outside the landing footprint. This eliminated all lander-dependent configurations and focused our attention on lander-independent or orbiter-dependent rovers that used an orbiter/rover UHF link for commands and data. Evaluation of this class of rovers pointed out the need for a large amount of data storage on board the rover to allow the collection of imagery data at various times during the day. (The large data storage capacity on board the lander was used for this purpose in the lander-dependent rovers.) Studies of the lander-independent rovers concluded that the mass and volume for a 5 to 10 M-bit data storage unit was not available on board the rover. Thus the selected baseline rover is configured so it can communicate with both the lander and orbiter providing the capability to take imaging data at various times during the day when near the lander and to leave the lander and explore distant areas of 40 to 50 km range, taking pictures in real time only when in communication with the orbiter.

The baseline rover contains the 21 kg (46 lb) science payload recommended by the Rasool Committee, which provides the capability to perform scientific analysis of the wide variety of surface samples available within range of the rover.

The candidate vehicles in Volume II feature either hybridized C-MOS microelectronics or Viking '75 electronics technology for use in the bulk of the rover's electronic subsystem. Viking '75 electronics technology was selected for the baseline vehicle to minimize developmental risks.

A summary description of the baseline rover and its performance characteristics are described in the following paragraphs. The baseline rover block diagram is shown in Figure 12.

Science payload description. - A typical payload has been selected by NASA for detailed study of its implementation into the selected rover design. This payload, the characteristics of which are listed in Table 5, consists basically of an X-ray diffractometer system with grinder, an Alpha Backscatter Geochemical instrument, a sample scoop that is capable of obtaining rock and soil samples, and a storage mechanism by which samples may be retained and transferred to the lander sampling assembly on return of the rover to the lander. The imagery system specified is a Viking '75 lander camera. No attempt has been made at this point to improve the resolution of this camera by the addition of external magnifier optics. It will provide adequate data for interpretation of the environment in which the rover finds itself but will not provide all geologic information desired on rock structure or soil particle shapes. The camera will have the capability to take panoramic pictures by taking a picture, moving from one to several meters, and taking another picture. In this manner, a stereo pair can be generated from which it will be possible to determine relative distances of observed land forms and features. The payload list shown in Table 5 includes the pertinent physical characteristics of the instruments as they are presently known. The total mass of this payload is 20.9 kg (46 lb). Power consumption varies enormously depending upon the mode of operation; however, in no case is it necessary to operate more than one instrument at a time. Therefore, the camera, diffractometer, and the grinder, which require high power levels, can be operated sequentially to prevent

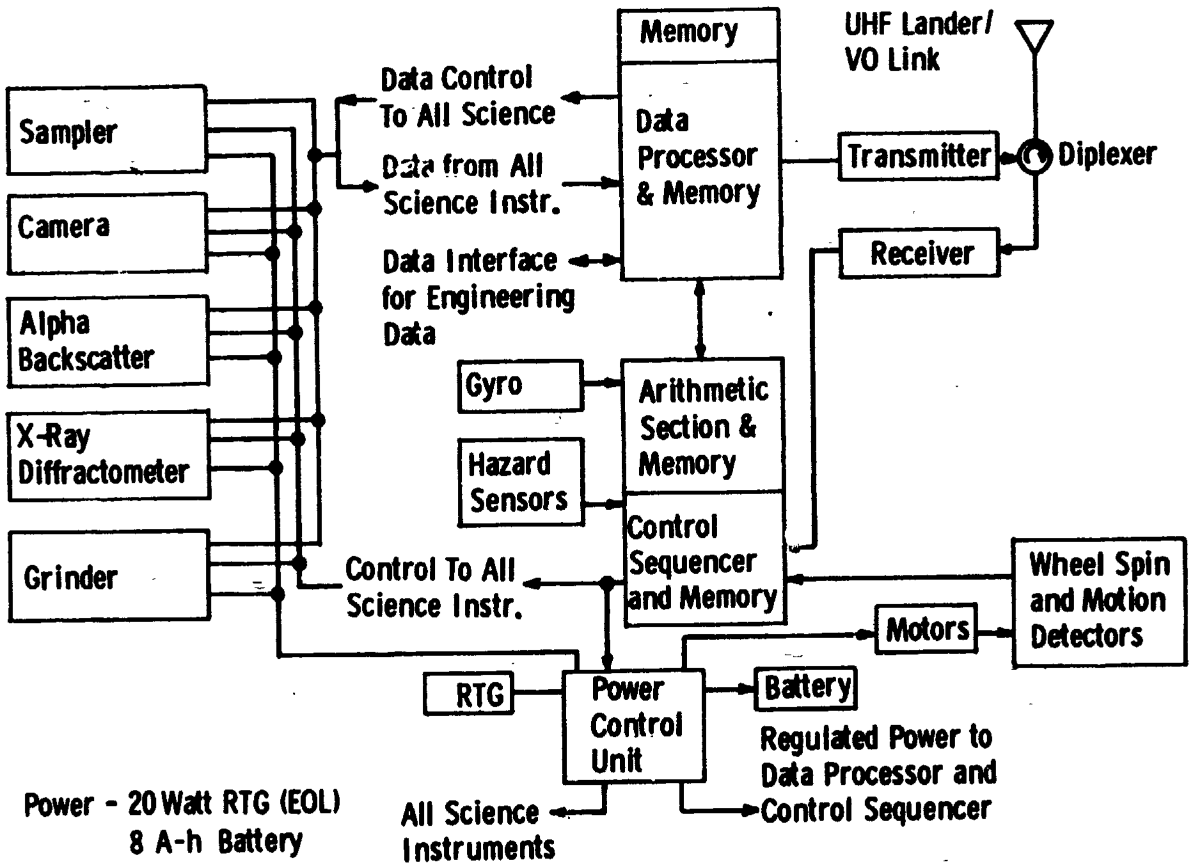


FIGURE 12 BASELINE SCIENCE CONFIGURATION, ELECTRONICS BLOCK DIAGRAM

TABLE 5 SCIENCE PAYLOAD CHARACTERISTICS

INSTRUMENT	MASS	VOLUME	POWER	DATA	REMARKS
Viking '75 Camera	6.4 kg				
Sensor (3.7 kg)		1300 cc	30.2W (Max Avg Survey Scan)	29.2×10^6 Bits - Hi Resol Mode (Panoramic)	Duration of Experiment Determined by Dividing Data Quantity by Data Rate (16 Kbps or 250 Bps)
Electronics (0.9 kg)			107W (Slew Mode 4 Sec Max)	9.5×10^6 Bits - Lo Resol Mode (Panoramic)	
Camera Duster (1.8 kg)		4300 cc	4.5W (Avg) 66W Peak for 10 Msec	--	Powered on When Camera is Operating
Alpha Backscatter Spectrometer	2.8 kg				
Sensor (1.4 kg)		700 cc			
Electronics (1.4 kg)			4 Watts	2×10^5 Bits/Analysis	5 Hours/Analysis
X-Ray Diffractometer	4.5 kg	2500 cc	30 Watts (Avg)	10^4 Bits/Anal	2 Hours/Analysis
Grinder	2.8 kg	4100 cc	40 Watts (Avg)	--	20 Minutes/Day. Used before Each X-ray Diffractometer experiment
Sampler	4.5 kg	-	2 Watts (Avg)	--	5 Minutes/Day. Power is for two Motors
X-ray Fluorescence (Add-on Option)	1.4 kg	100 cc	2.6 Watts (Avg)	8.192×10^3 Bits/Analysis 81.92×10^3 Bits/Day	If used as Science Instrument Operates 15 Minutes/Analysis; 10 Analysis/Day

overload of the power supply. Data requirements are relatively minimal except for the alpha backscatter spectrometer and the camera. The alpha backscatter data analysis will require about 80 percent of the rover data storage capacity per analysis. A single low resolution camera picture of dimensions 25^{o} in azimuth by 20^{o} in elevation also will require approximately 80 percent of the data storage capacity. Therefore, it will not be possible to operate and store data from both experiments without an intervening communication link to either the lander or orbiter. In fact, most picture taking must be made via one of these two direct communication links with real time transmission of data as it is taken by the cameras. This limits picture taking, except for the small pictures mentioned above, to times of the day when coverage by the lander or the orbiter is possible.

The alpha backscatter spectrometer employs alpha and proton spectroanalyses in its measurements. Another X-ray fluorescence option is included, however, and is based upon the XRFS technique presently employed on the Viking '75 lander. This system can analyze an unlimited number of samples, requires only 15 minutes to perform the analysis, and generates a relatively small number of bits per analysis.

Several X-ray diffractometer designs are available and the 4.5 kg (10 lb) allotment is in the range of most proposed approaches. The design considered in the present study, however, does not include the cryogenic detector approach recently proposed, but could be modified to do so. Analysis by the diffractometer is relatively slow unless this cryogenic approach is selected.

A grinder has been incorporated to prepare the surface material for geochemical analysis. Another potential use of this design approach is that it may be capable of transmitting sufficient energy through the rover body and wheels to the ground to be detected by the lander seismometer. This would provide some capability of probing the subsurface in the vicinity of the lander.

In Figure 13 we see the integrated rover science package. Prominent is the sample scoop, which acquires samples by being lowered to the surface and collects material as the rover drives forward. If grinding is desired, a cup

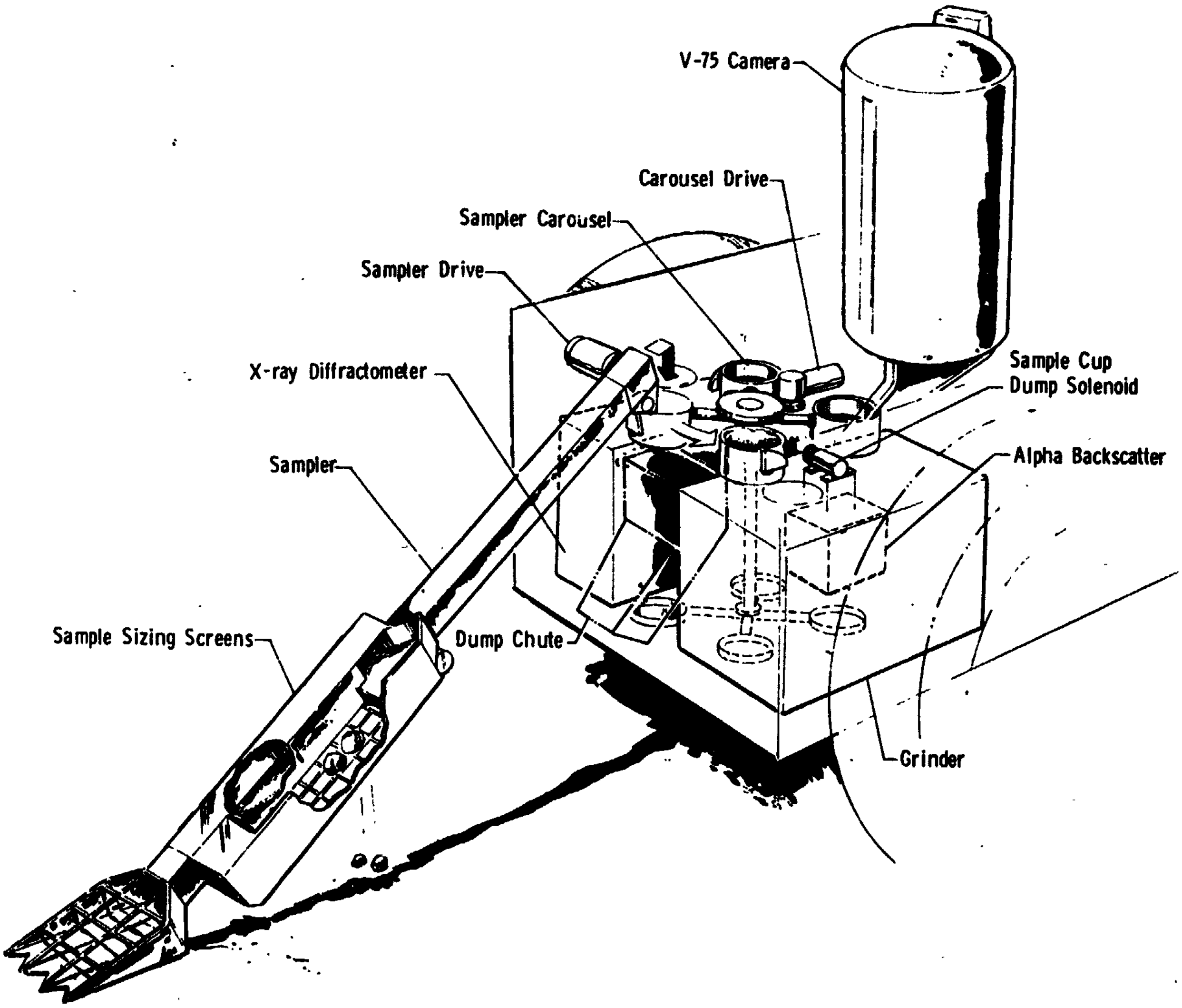


FIGURE 13 INTEGRATED SCIENCE PACKAGE

is then positioned over the grinder, and through actuation of a cam the material is dropped into the grinder. After grinding is completed, the material is passed into a lower sample cup that mates with the diffractometer system and also can be positioned below the alpha backscatter analysis system. The surface sampler from the Viking lander can place a receptacle beneath the chute and the sample can thereby be transferred to the lander sampler arm and thence to lander instruments for subsequent analysis.

This payload contributes to a variety of science objectives of interest. As it is capable of collecting samples and returning them to the lander, any number of potential analyses such as soil water, biological, and organic analyses can be performed on samples obtained great distances from the lander. A mission operations tradeoff will be to compare the value of having the rover return to the lander for sample transfer versus the desirability of exploring even more territory. As the rover contains an imagery system, an inorganic analysis system, and a mineralogic analysis system, it can obtain a wealth of pertinent information on the surface characteristics of Mars at any location. Thus, even when it is not practical to return to the lander because of distance or intervening hazards, the rover will remain as an excellent science platform in itself from which to conduct exploration of the planet. With the types of instrumentation included it will be possible to address a large number of the scientific questions that can now be posed as to the origin and evolution of the Martian surface.

Rover system layout. - The baseline rover is shown in the stowed position and operational configuration in Figure 1. The Viking entry capsule defines the maximum rover dimensions. The rover is stowed above the No. 2 terminal descent engine in the lander capsule with the wheels in the operational track width and wheel base position (i.e., wheel deployment is not required). The rover RTG is located at the aft end of the rover so when stowed the RTG is near the base cover and RTG heat generated during cruise can be radiated to space.

The rover is stowed with the forward wheels compressed 4 cm against the top of the lander. The baseline rover has 52 cm diameter wheels. This diameter was determined by the 22 cm rock clearance criteria and a 4 cm combination of wheel compression and sinkage into soft surfaces. The rover has a wheel base of 60 cm and a track width of 60 cm. The major rover assemblies are a science compartment, a thermally-controlled electronics compartment, a mobility subsystem, and an RTG. The baseline rover has the two front axles fixed to the chassis and the rear axle is articulated on a roll pivot aft of the RTG. The rover equipment arrangement is shown in Figure 1. The thermally-controlled compartment contains the electronic equipment, the communication equipment, the gyro, the camera duster, and the battery. The science compartment is also thermally-controlled but it has a wider temperature limit band. Due to volume and mass constraints, a concept of integrated electronics packaging was used in the baseline rover configuration.

The integrated packaging concept removes the cases from the electronic boxes and mounts the printed circuit and component boards directly to the chassis. All the subsystems requiring electronic components, with the exception of the communication equipment and the science sensors, are packaged in the integrated electronics module. All the boards within this module are interwired. All wires terminating at other components such as science sensors and communication will have harnesses terminating with plugs. The boards in the electronics module are 16 x 33 cm spaced at 1.25 cm. A typical cross section through the rover showing a concept of how the boards would be mounted is shown in Figure 14.

The rover's aluminum chassis is inside the insulation. The chassis consists of two side beams, an isothermal plate with heat pipes bonded to the plate, two end bulkheads, and a top plate. The science compartment is supported from the forward bulkhead, the forward axles are supported from the side beams, and the RTG, the thermal switch, and the rear axle pivot are supported from the aft bulkhead.

The function of the thermal switch is to couple or uncouple the chassis thermally from the RTG. The thermal switch has an actuator located on the isothermal plate and a contactor between the aft bulkhead and the RTG. The RTG will be mounted from the aft bulkhead with a thermal isolator. The insulation around the thermally-controlled compartment is 2.54 cm thick. A thin

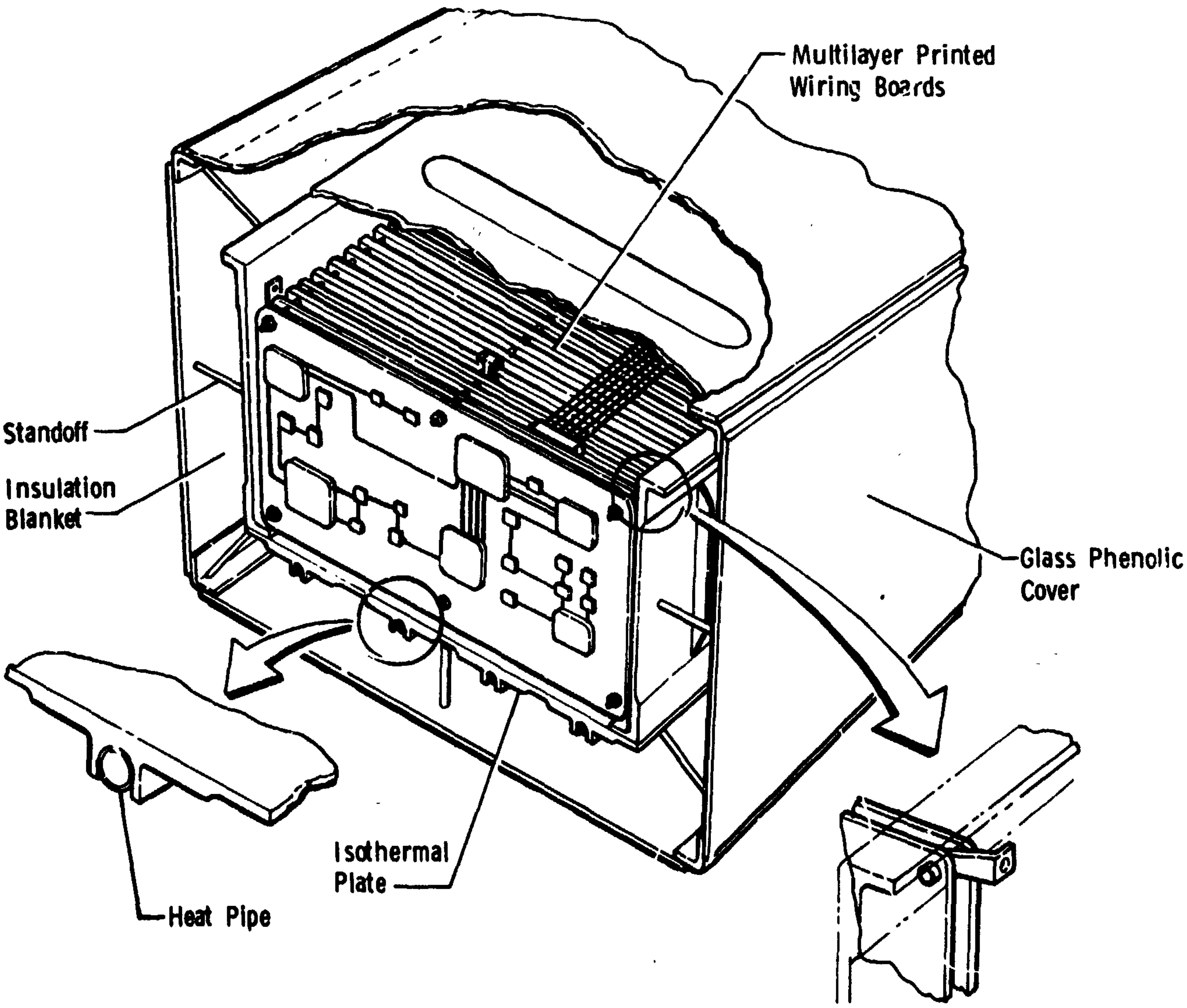


FIGURE 14 INTEGRATED ELECTRONICS CONCEPT

glass phenolic cover protects the insulation and maintains a controlled insulation thickness. The protective cover is supported by non-metal standoffs that are attached to the chassis. Brackets that penetrate the insulation to support the front axles, the rear axle pivot, and the antenna support will be constructed from titanium to minimize the heat leak through these penetrations.

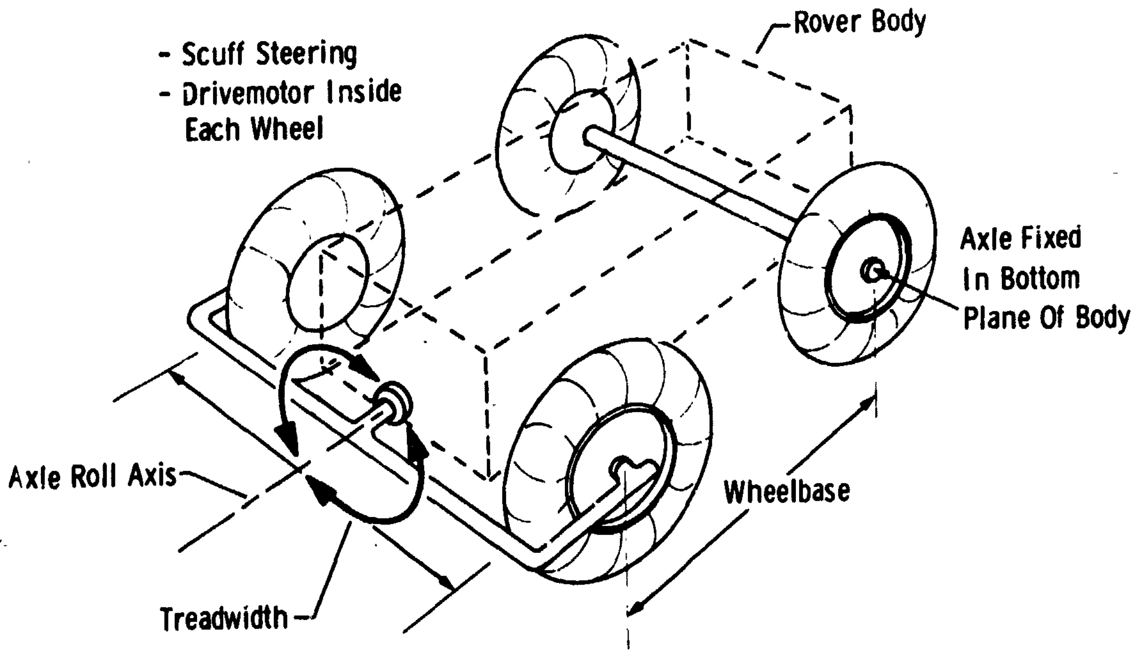
The UHF antenna will be deployed with a Stacer spirally-wound, self-extending tube. The rover camera will be deployed after landing and before off-loading the rover. The camera will be mounted to the camera deployment mechanism. The mechanisms will be a simple hinge joint driven by a motor system. The camera will be held in the stowed position by a hot wire pin puller. In the operational position the mechanism will be locked in place by a spring-loaded latch. Five radioisotope heating units will be mounted in the latch plate. With the heaters in this position, the heaters will only supply heat to the camera when the camera deployment mechanism is actuated.

Baseline Rover Subsystems

Mobility subsystem. - The mobility subsystem concept selected for the baseline rover is illustrated in Figure 15. Figure 16 illustrates a potential wheel/motor design incorporating a Viking '75 surface sampler elevation motor inside a wheel derived from the Apollo Lunar Rover Vehicle wheel. Table 6 summarizes the parameters of the concept that was selected for the 108 kg (238 lbm) baseline vehicle based on the mobility subsystem analyses and trade studies discussed in Volume II.

The wheel shown in Figure 16 will produce sinkage of less than 2 cm (0.8 in) in the worst-case surface material, loess. This occurs with an average contact pressure of 0.5 N/cm^2 (0.74 lb/in^2), which assumes (for each wheel on loess) a contact area 10 cm (3.9 in) wide by 20 cm (7.8 in) long and a vertical load of 100 N (23 lb).

Power subsystem. - The power subsystem consists of those components that provide electrical power to the rover and it consists of three major components, namely, an RTG, a battery, and a Power Control Unit (PCU). The RTG is a 20-watt end-of-life GFE unit. The battery that will be used for the rover uses



$$\frac{\text{Wheelbase}}{\text{Treadwidth}} \leq 1.25 \text{ (Required for Scuff Steering)}$$

FIGURE 15 BASELINE ROVER MOBILITY CONCEPT

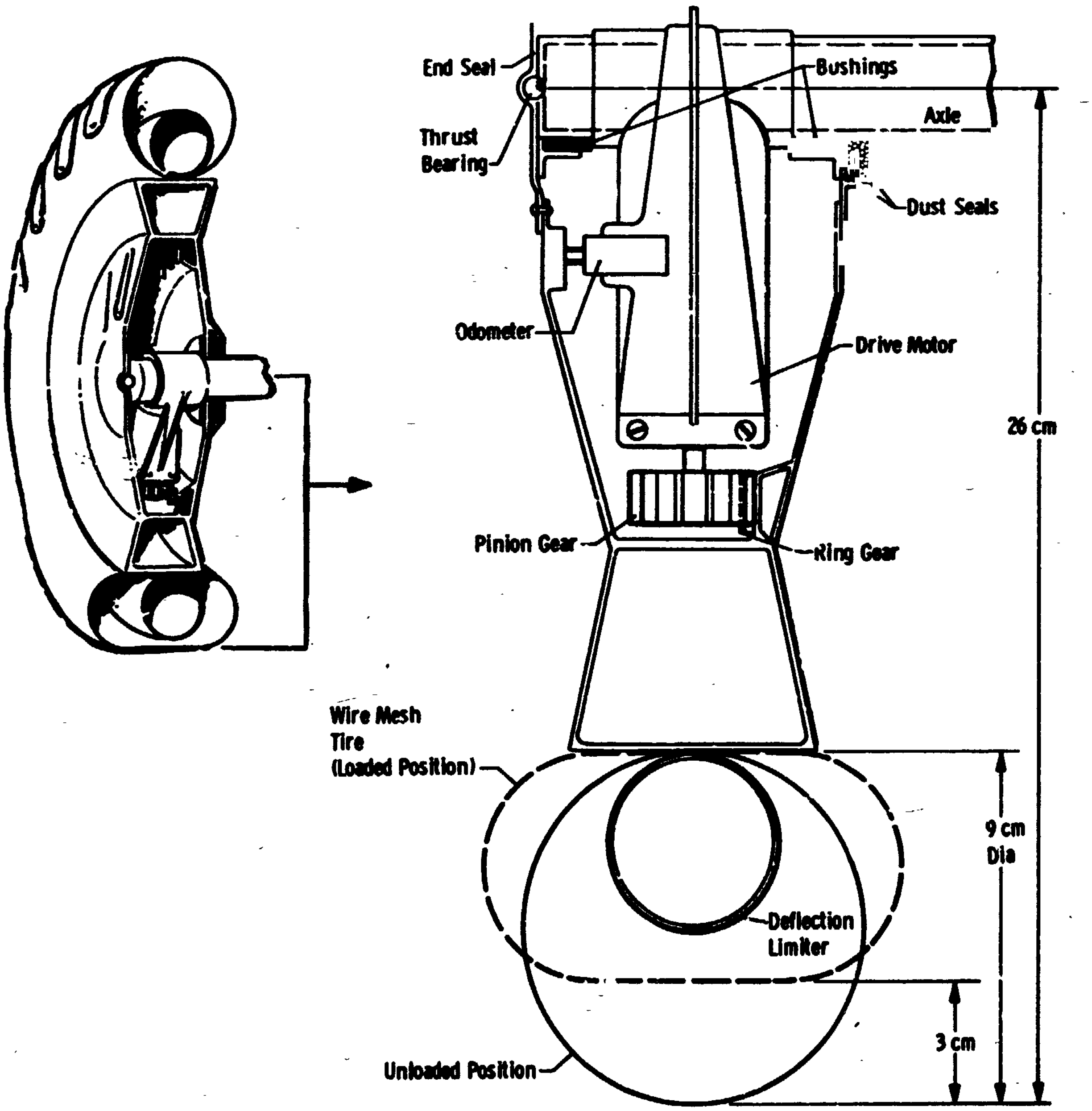


FIGURE 16 POTENTIAL WHEEL/MOTOR DESIGN FOR BASELINE ROVER

TABLE 6 BASELINE ROVER MOBILITY SUBSYSTEM PARAMETERS

	kg	(lbm)
Mass (1 Wheel Unit):		
Drivemotor	0.90	(2.00)
Wheel	1.36	(3.00)
8:1 Output Gearing	0.15	(0.33)
Axle	0.12	(0.26)
Motor Mount	0.05	(0.10)
Bushing/Seal	0.03	(0.06)
Total	2.61	(5.75)
Mass (4 Wheel Units)	10.4 kg	(23.0 lbm)
Wheel Diameter	52.0 cm	(20.5 in)
Wheelbase	60.0 cm	(20.3 in)
Treadwidth	60.0 cm	(23.6 in)
Ground Clearance:		
On Loess	21.0 cm	(8.3 in)
On Harder Surfaces	23.0 cm	(9.1 in)
Vertical Load/Wheel	100.0 N	(23.0 lb)
Nominal Power Consumption (Loess, 0° Slope)	6.5 Watts	
Nominal Operating Velocity	88.0 meters/hour	(292.0 ft/hr)
Maximum Slope Capability	5° less than natural angle of repose	
Roll Stability Limit	40°	
Pitch Stability Limit	60°	
Steering:		
Type	Scuff	
Nominal Turning Rate	1.6 deg/sec	

the existing Viking '75 NiCd battery cells, packaged into a 15-volt battery (12 cells). The PCU contains all the electronics for conditioning the RTG outputs, battery charging, providing regulated voltages, and providing the electronics for driving all motors, solenoids, and pyrotechnics.

The primary features of the power subsystem are:

- 480 watt hours (at 5 volts) of electrical energy is available each day from a GFE RTG;
- Battery energy storage is 120 watt-hours;
- Regulated voltages are provided to all rover electronics;
- 5 volts are taken directly from the RTG to power all 5-volt circuits;
- Rover bus voltage is set at 15 volts;
- Power loads are switched as required to minimize power consumption;
- Fault protection is provided to minimize impact of loss of science experiments due to circuit failures in other science instruments;
- Twenty percent power margin is provided in the system capability.

Physical characteristics of the power subsystem are:

- The battery is packaged in its own case and together with the load bank has a mass of 6.8 kg (15 lb);
- The RTG mass is 5.5 kg (12 lb).

The power control unit, which is packaged with the integrated electronics assembly, has a mass of 3.2 kg (7 lb) and is on five printed wiring boards.

Thermal control. - The final rover thermal design is as shown in Figure 17. Those components that cannot survive the Mars surface environment, and do not, by operational necessity, have to be mounted external to the rover, are located in a thermally-controlled compartment. The RTG carried by the rover for electrical power is also used for thermal energy. A thermal switch controls the flow of heat from the RTG to the rover thermally-controlled compartment. The thermal compartment is insulated with low density fiberglass

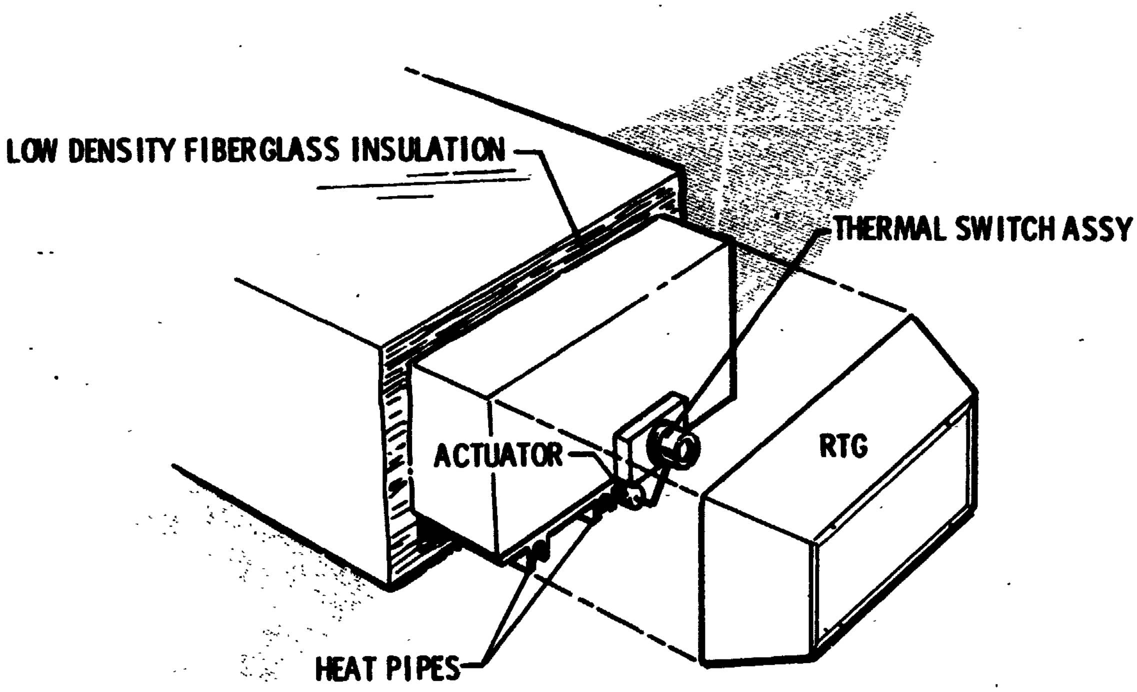


FIGURE 17 BASELINE ROVER THERMAL DESIGN

insulation to minimize the compartment heat loss. The RTG heat is distributed internally to the thermal compartment by a heat pipe equipment mounting plate (isothermal plate). The mass of the thermal components is 5 kg (11 lb).

Communications. - The communications subsystem consists of those components that allow the rover to communicate with either the orbiter or the lander. The system consists of an antenna, a diplexer, a transmitter, and a receiver. Transmission from the rover to either the orbiter or the lander occurs at a UHF frequency of 405 MHz and receives from the orbiter or lander at a frequency of 381 MHz. The modulation scheme is a non-coherent, wideband FSK system. Rover-to-lander communications will use a rover transmitter power fo 2 watts that will allow the rover to operate at a maximum radius from the lander of 2 km. When transmitting to the orbiter, the rover will use a 20-watt RF power mode and maintain link times of approximately 25 minutes. The rover/orbiter link duration will be improved over Viking '75 because a two-way transmission exists and the link does not depend on a specific time for turn on. The capability exists to transmit and receive simultaneously. Data rates will be 16 kbs.

The rover antenna has two pattern modes to allow it to communicate with both the lander and the orbiter. By controlling the phase of the signal applied to the turnstile elements, directivity in either the vertical plane or the horizontal plane is obtained. Rover-to-lander communication of up to 2 km range can be obtained by deploying the rover antenna 1.7 m above the surface.

The transmitter and receiver will be packaged in their own case and will be mounted inside the thermally-controlled compartment. The antenna will be stowed before launch and will be deployed when the rover is activated on the surface of Mars. The communication subsystem mass is 5.9 kg (13 lb).

Data handling and processing. - The data handling and processing subsystem consists of those components that collect and process data and consists of a data processor, a 250 kilobit memory, and temperature transducers. A centralized data processing system is used wherein circuits to multiplex, signal condition, analog-to-digital conversion, formatting, and data storage are common to all data sources. These data sources include engineering data and all science instrument data. A total of five formats are provided for collecting data. Format construction is compatible with Viking '75 formats and synchronization schemes. Outputs to the UHF transmitter are biphase coded with alternate bits complementing. Data rates are 16 kbs or 4 kbs with data rates being accurate and stable to ±0.01% with a time jitter less than 360 nanoseconds.

The Data Processor and Memory are packaged on 12 printed wiring boards as part of the integrated electronics assembly. Total mass of the data handling and processing subsystem is 5.5 kg (12 lb).

Navigation. - The navigation subsystem includes the sensors required for navigation and hazard avoidance. The navigation sensors include sensors for heading and distance. For hazard avoidance, sensors are included to detect rocks, holes, and adverse slopes, and to measure the angle between the articulated axle and the chassis.

The selected heading sensor is a directional gyro (DG) with a gyrocompassing capability, which provides an initial heading reference error of less than 35 mrad (2°) in the gyrocompassing mode, and a drift rate of less than 0.72 rad/sec (0.15°/hr) while traversing in the DG mode. The estimated package mass is 2.3 kg (5 lb) and consumes 3 watts while operating.

Four odometers, one per wheel, were selected as the simplest method of measuring distance. Each odometer is of the cam and microswitch type, providing 8 pulses per resolution of wheel motion. All four odometers are summed and averaged in calculating distance traveled.

Two-axis linear inclinometers provide rover attitude information required both in the navigational calculations and to avoid excessive slopes. Simple pendulous potentiometer devices will be used to minimize the mass and power required. Quantization of the A/D converter will be approximately 17.5 mrad (1°). While the functional requirement for slope stability is 0.78 rad (45°) the actual limit will be a variable, computed based on the traction coefficient of the soil.

Simple bumpers and microswitches will be used to detect nonnegotiable rocks.

The most difficult hazard to detect is a crevice. Unfortunately, crevices are also more dangerous to the vehicle than other obstacie types. The baseline system is of the non-contact type, namely reflected energy intensity ranging. This consists of a source of X-ray energy, detectors, and associated electronics. The electronics are packaged as two boards in the integrated electronics assembly.

Control. - The control sequencer and memory provides total control of the rover operations, including navigation, science instrument sequencing, power switching, and data processing instructions. More specifically the system provides the capability to:

- Navigate from point A to point B, using heading, distance, and rover attitude information. Included are such special features as hill climbing (steepest ascent) and contour following (constant altitude).
- Avoid havards such as non-negotiable rocks, holes wider than 0.6 of a wheel diameter and local slopes of greater than a calculated maximum.
- Compute the traction coefficient of the soil being traversed. This is then used to define the maximum slope that can be safely negotiated by the rover.
- Control the power sequencing-to-rover equipment, based ona predefined or self-formulated sequence of events, ground commands, and rover events.
- Issue commands to the rover data processor to control the formatting and sequencing of the data processing and transmission.
- Issue command sequences for all science instruments to control their movements, sample rates, and transmission of their data to the data processor.
- Modify the rover's predefined operational sequence, based on hazards or interesting science detected by the science instruments while traversing.

The baseline sequencer and memory (CSM) consists of approximately 14,000 words of C/MOS read-only memory, 2000 words of C/MOS random access memory, a microprocessor and the associated I/O. These C/MOS devices, operating at a 500 kHz clock frequency are used to minimize the power required. Word length is 8 bits and the sample interval is less than one second. The CSM is packaged as five boards in the integrated electronics assembly.

Rover masses and volumes. - Table 7 is a mass breakdown for the baseline rover. The rover subsystem totals 90.26 kg (199 lb) including 20.87 kg (46 lb) of science, with 20 percent of the total allocated for contingency. The total baseline rover mass is 107.95 kg (238 lb). Table 8 incorporates this rover plus the baseline lander science changes, the lightweight RTGs, and the regulated propulsion system to arrive at a landed dry mass of 719.25 kg (1586 lb). Tables 9 and 10 use this landed mass, builds the masses up to the total launch mass, and compares these masses to Viking '75 masses. Table 11 is a tabulation of the volume and masses of the rover components.

System Performance Summary

Rover subsystems described in preceding paragraphs provide the capability of performing a scientific mission, navigating and controlling the mobility of the rover, and establishing communications with either the orbiter or the lander. The extent to which any of these functions can be performed with the selected hardware are limited primarily by the amount of power available on a daily basis.

Design margins for the rover include 20 percent in the areas of mass, volume, and power.

Table 12 summarizes the primary features and performance characteristics for the rover.

Additional performance features are described in the following paragraphs.

Power performance. - The maximum power requirements occur during traverse (mobile mode) or during the science mode. A power analysis was performed to determine the energy requirements during the operating modes. This analysis

TABLE 7 BASELINE ROVER MASSES (WT)

SUBSYSTEM	kg	kg	(lb)
Science		20.87	(46)
Viking '75 Camera	4.54		
Camera Duster	1.81		
Alpha Backscatter	2.72		
X-Ray Diffractometer	7.26		
Sampler	4.54		
Structure		17.24	(38)
Mechanism Camera Deployment		0.91	(2)
Thermal		4.99	(11)
Thermal Switch	1.81		
Insulation	1.36		
Paint	0.45		
RTG Cooling	0.45		
Heat Pipes	0.91		
Drive System		10.43	(23)
Motors & Gears	4.08		
Wheels	5.44		
Axles, Bushing, Seals	0.91		
Power		15.42	(34)
Battery	6.80		
RTG	5.44		
Power & Drive Control	3.18		

SUBSYSTEM	kg	kg	(lb)
Telemetry		5.44	(12)
Data Processor	1.36		
Data Processor Memory	3.63		
Transducers	0.45		
Communication		5.90	(13)
UHF Receiver	1.36		
UHF Transmitter	2.72		
UHF Antenna	0.91		
Diplexer	0.91		
Guidance & Control		6.79	(15)
Gyro	1.36		
Inclinometer	0.45		
Bumpers	0.91		
Control Sequencer & Memory	2.26		
Wind Detector	0.45		
Odometer	0.45		
Hole Detector	0.91		
Cabling		2.27	(5)
		90.26	(199)
Contingency (20%)		17.69	(39)
TOTAL ROVER		107.95	(238)

TABLE 8 BASELINE VIKING '79 MASSES (WT)

	kg	(lb)
Lander Additions		
Stowage & Deployment	12.25	(27)
Communication	3.17	(7)
Relocate Equipment	0.45	(1)
Thermal	0.91	(2)
New Biology	16.33	(36)
X-Ray Diffractometer	7.26	(16)
New RTG	17.24	(38)
Reg. Propulsion System	9.98	(22)
	67.59	(149)
Contingency (20%)	13.15	(29)
	80.74	(178)
Lander Deletions		
1 Camera	-6.80	(-15)
Meteorology	-4.54	(-10)
XRFS	-2.27	(- 5)
Biology	-17.24	(-38)
V'75 RTG System	-37.19	(-82)
	-68.04	(-150)
Total Rover	107.95	(238)
Lander Additions	80.74	(178)
	188.69	(416)
Lander Deletions	-68.04	-(150)
	120.65	(266
V '75 Anticipated Larded Mass	598.74	(1320)
V '79 Landed Dry	719.39	(1586)

TABLE 9 VIKING 1975-1979 MASS CONPARISONS (METRIC UNITS)

	V-75 ALLOCATION (kg)	ANTICIPATED V-75	V-79 BASELINE	RCVER DELTAS
LANDER DRY MASS	564.15	598.62	719.25	120.63
LANDER PRESSURANT	6.35	6.35	6.35	0
RESIDUAL PROPELLANT	4.99	4.99	6.35	1.36
LANDED MASS	575.49	609.96	731.95	121.99
USABLE PROPELLANT	59.41	68.48	80.72	12.24
TERMINAL IGNITION MASS	634.90	678.44	812.67	134.23
AERODECELERATOR DRY MASS	116.10	109.29	111.56	2.27
MASS ON PARACHUTE	751.0	787.73	924.23	136.50
AEROSHELL DRY MASS	168.25	181.40	195.91	14.51
AEROSHELL PRESSURANT	3.17	3.17	3.17	-
RESIDUAL/ACS PROPELLANT	11.79	7.26	7.26	-
ENTRY MASS	934.21	979.56	1130.57	151.01
A/S USABLE DEORBIT PROPELLANT	72.56	78.91	78.91	-
SEPARATED LANDER MASS	1006.77	1058.47	1209.48	151.01
BIOSHIELD BASE DRY MASS	65.30	72.56	72.56	-
BIOSHIELD CAP DRY MASS	45.35	54.42	54.42	-
VLC LOADED MASS	1117.42	1185.45	1336.46	151.01

TABLE 10 VIKING 1975-1979 WEIGHT COMPARISONS (ENGLISH UNITS)

	V-75 ALLOCATION	ANTICIPATED V-75	V-79 BASELINE	ROVER DELTAS
LANDER DRY WEIGHT	1244	1320	1586	266
LANDER PRESSURANT	14	14	14	0
RESIDUAL PROPELLANT	11	11	14	3
LANDED WEIGHT	1269	1345	1614	269
USABLE PROPELLANT	131	151	178	27
TERMINAL IGNITION WEIGHT	1400	1496	1792	296
AERODECELERATOR DRY WEIGHT	256	241	246	5
WEIGHT ON PARACHUTE	1656	1737	2038	301
AEROSHELL DRY WEIGHT	371	400	432	32
AEROSHELL PRESSURANT	7	7	7	0
RESIDUAL/ACS PROPELLANT	26	16	16	0
ENTRY WEIGHT	2060	2160	2493	333
A/S USABLE DEORBIT PROPELLANT	160	174	174	0
SEPARATED LANDER WEIGHT	2220	2334	2667	333
BIOSHIELD BASE DRY WEIGHT	144	160	160	0
BIOSHIELD CAP DRY WEIGHT	100	120	120	0
VLC LOADED WEIGHT	2464	2614	2947	333

TABLE 11 ROVER INTERNAL COMPONENTS MASSES AND VOLUMES

COMPONENT	MASS kg	(lb)	VOLUME cm^3	(in^3)	BOARDS IN ELECTRONICS MODULE
Alpha Backscatter	2.73	(6)	525	(32)	-
X-Ray Diffractometer	4.55	(10)	2450	(155)	-
Grinder	2.73	(6)	4920	(300)	-
Science Electronics	*				6
Camera Duster	1.82	(4)	3280	(200)	-
Gyro	1.37	(3)	1800	(110)	-
Inclinometer	0.46	(1)	645	(40)	-
Control Sequencer & Memory	2.27	(5)	-		5
Data Processor	1.37	(3)	-		4
Data Processor Memory	3.64	(8)	-		8
Power and Drive Control	3.18	(7)	-		6
UHF Receiver	1.37	(3)	1230	(75)	-
UHF Transmitter	2.73	(6)	2460	(150)	-
UHF Diplexer	0.92	(2)	1230	(75)	-
Battery	6.82	(15)	4510	(275)	-

*Science electronics mass is included in the individual instruments.

TABLE 12 ROVER FEATURES AND PERFORMANCE SUMMARY

SURFACE OPERATION

22 cm Rock Clearance
Stable on 19° Slopes (Including 22 cm Rocks)
  Pitch Stability Limit $>60^{\circ}$
  Roll Stability Limit $>40^{\circ}$
Detects and Avoids Slopes
  $5^{\circ} <$ Natural Angle of Repose
Detects and Avoids Crevices/Holes $>$0.6 Wheel Diameter
Detects and Avoids Rocks $>$22 cm Under Body
Soil - Operates on all MEM Soils
Speed $>$80 M/Hr (Forward and Reverse)
Braking - Stops in $<$5 cm, Holds Position (Power off) on Slopes 30°
Turns - Scuff Steering (Pivots in Place)
Survives Thermal Environment at any Point on the Planet
Operates Independent of Lander
Mission Limited to Orbiter/Rover Life
Move $>$500 M/Day

PHYSICAL FEATURES

Payload - 20.87 kg Science
Rover System Weight - 107.96 kg
Rover Body: 40 cm Wide x 110 cm Long x 26 cm Deep
Wheelbase = 60 cm
Track = 60 cm
Three Point Attachment to Lander
One Point Attachment to Deployment Mechanism
Wheel Spin and Motion Detectors
Wind Detector
Deployment - on Slopes $< \pm 19^{\circ}$
Soil Collector
Deployable Camera

FUNCTIONAL

Integrated Science and Engineering Electronics (Data/Power)
Dual UHF Data Output Links $< 2 \times 10^{7}$ B/Day
Dual UHF Relay Command Input (VL or VO)
Cross Range Error $<$10% of Distance Travelled
All Navigation and Guidance Functions on Board
Evasive Maneuvers Around Hazards
Soil Collection and Return to Lander
Data Storage of 250 Kbits

shows that the power subsystem can support these requirements and maintain an adequate margin. The analysis includes a 20 percent power margin, which ensures system performance and allows for growth. The following paragraphs discuss the performance during these two operating modes.

Maximum Mobility Mode - This is the maximum traverse mode where eight hours of drive power is required. In addition, power is provided for imagery data transmission, and commands.

The system can support the power requirements with the battery fully charged at the end of the 24-hour period. System constraints are met assuming the operating sequence is such that the depth of discharge on the battery is limited by allowing charge time between the start or end of the 8-hour mobility period and data transmission. During this mode it is also assumed that the hole detector is in operation as part of the navigation system.

Science Mode - The science mode includes operation of the science experiments including imagery, data transmission, and commands.

The system can support the power requirements and the battery will be fully charged at the end of the 24-hour period. The science mode does not require as much power as the mobility mode since it is assumed that all science instruments operate in sequence, i.e., two or more instruments cannot operate simultaneously.

Typical Rover Surface Mission

A representative rover surface mission has been constructed to aid in the evaluation of mission suitability and development of mission operations philosophies and system requirements. The mission has been built around a representative Mariner 9 photograph for gross planning and a detailed mission through a known caldera in the Sahara Desert (Emi Koussi) for which detailed topological and imagery data are available. Examples are shown in Figure 18 through

FIGURE 18 REPRESENTATIVE VIKING '79 ORBITER PICTURE

FIGURE 19 ORIGINAL MISSION PLAN

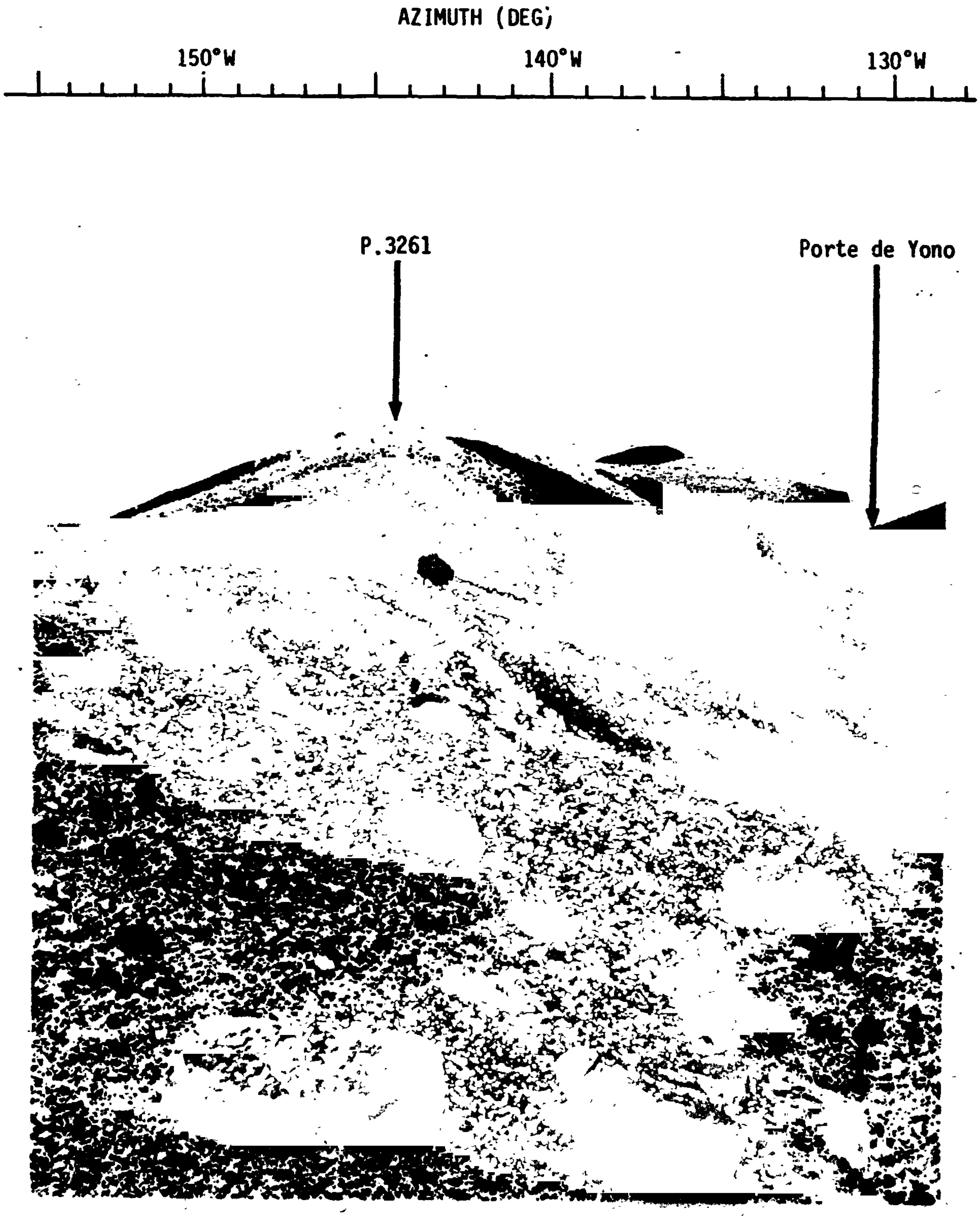


FIGURE 20 REPRESENTATIVE ROVER PANORAMA OF EMI KOUSSI (SHEET 1 OF 7)

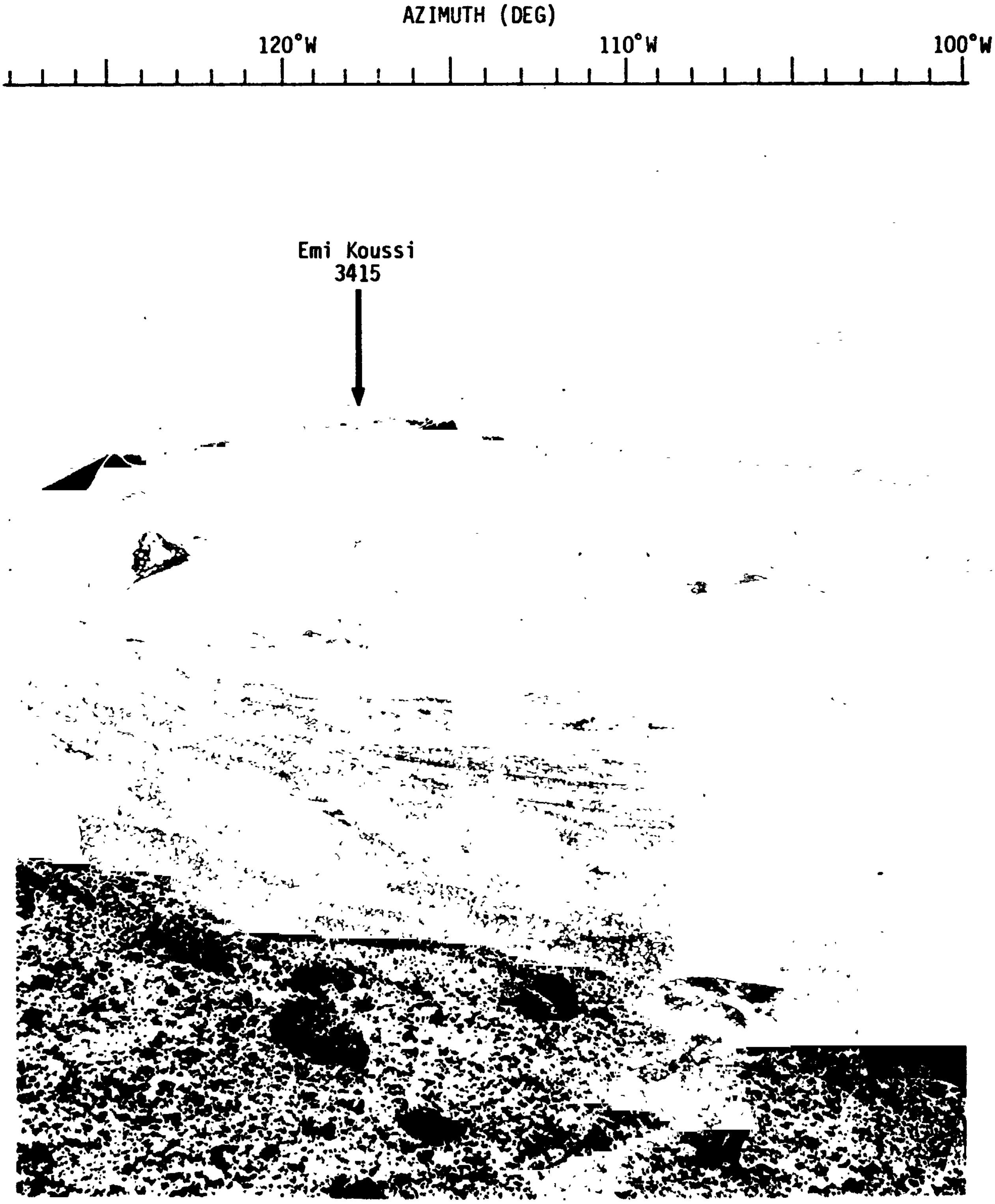


FIGURE 20 REPRESENTATIVE ROVER PANORAMA OF EMI KOUSSI (SHEET 2 OF 7)

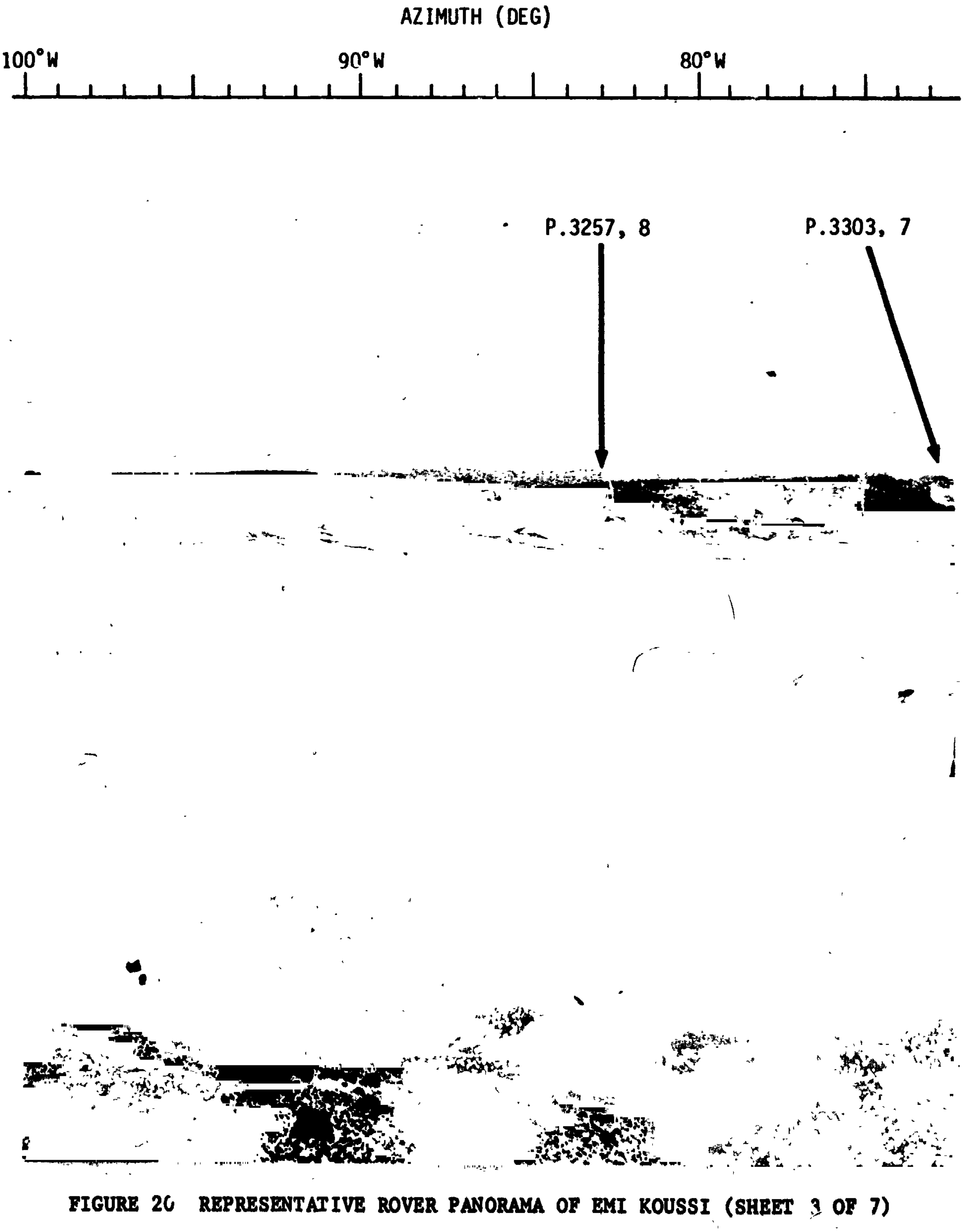


FIGURE 20 REPRESENTATIVE ROVER PANORAMA OF EMI KOUSSI (SHEET 3 OF 7)

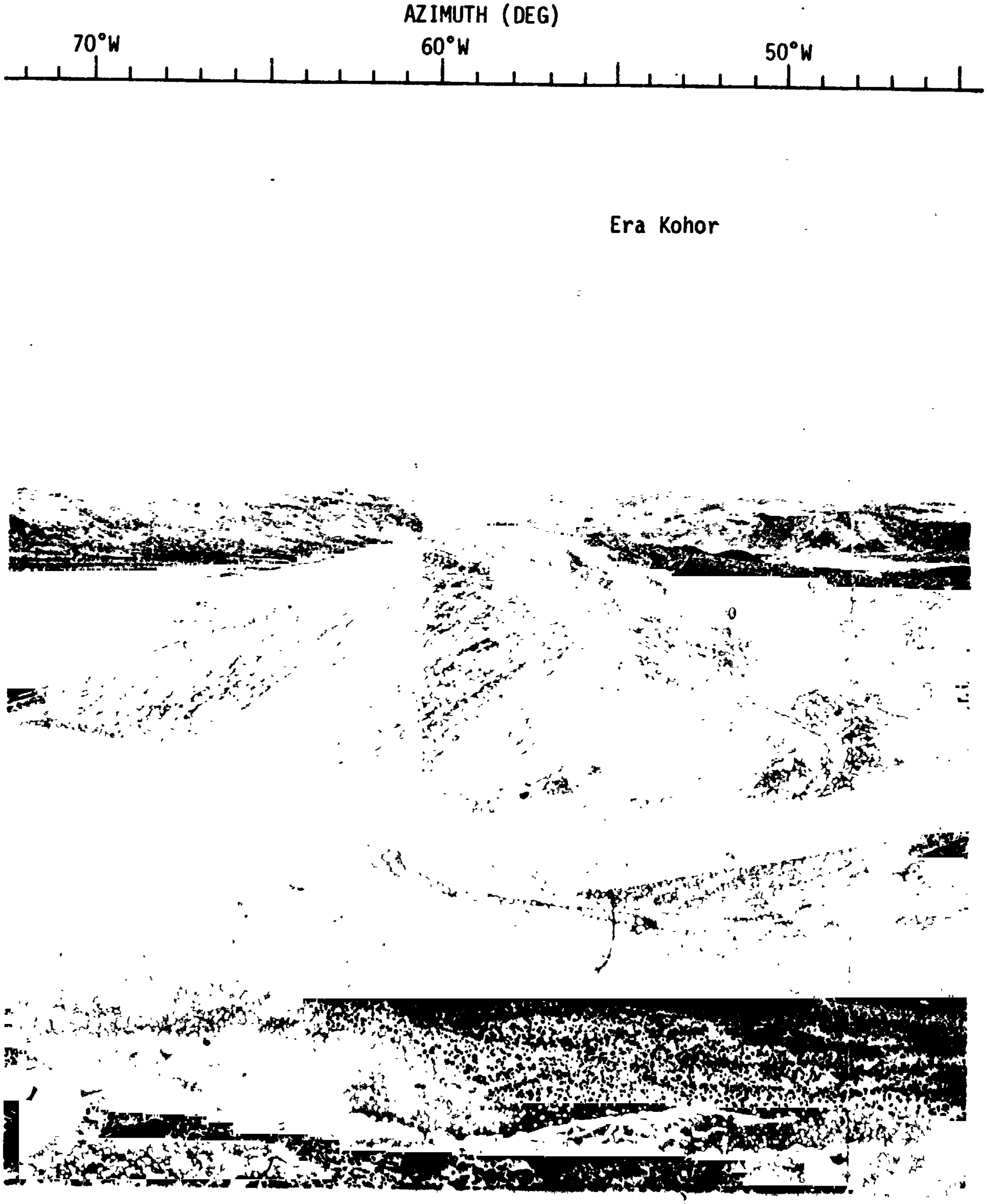


FIGURE 20 REPRESENTATIVE ROVER PANORAMA OF EMI KOUSSI (SHEET 4 OF 7)

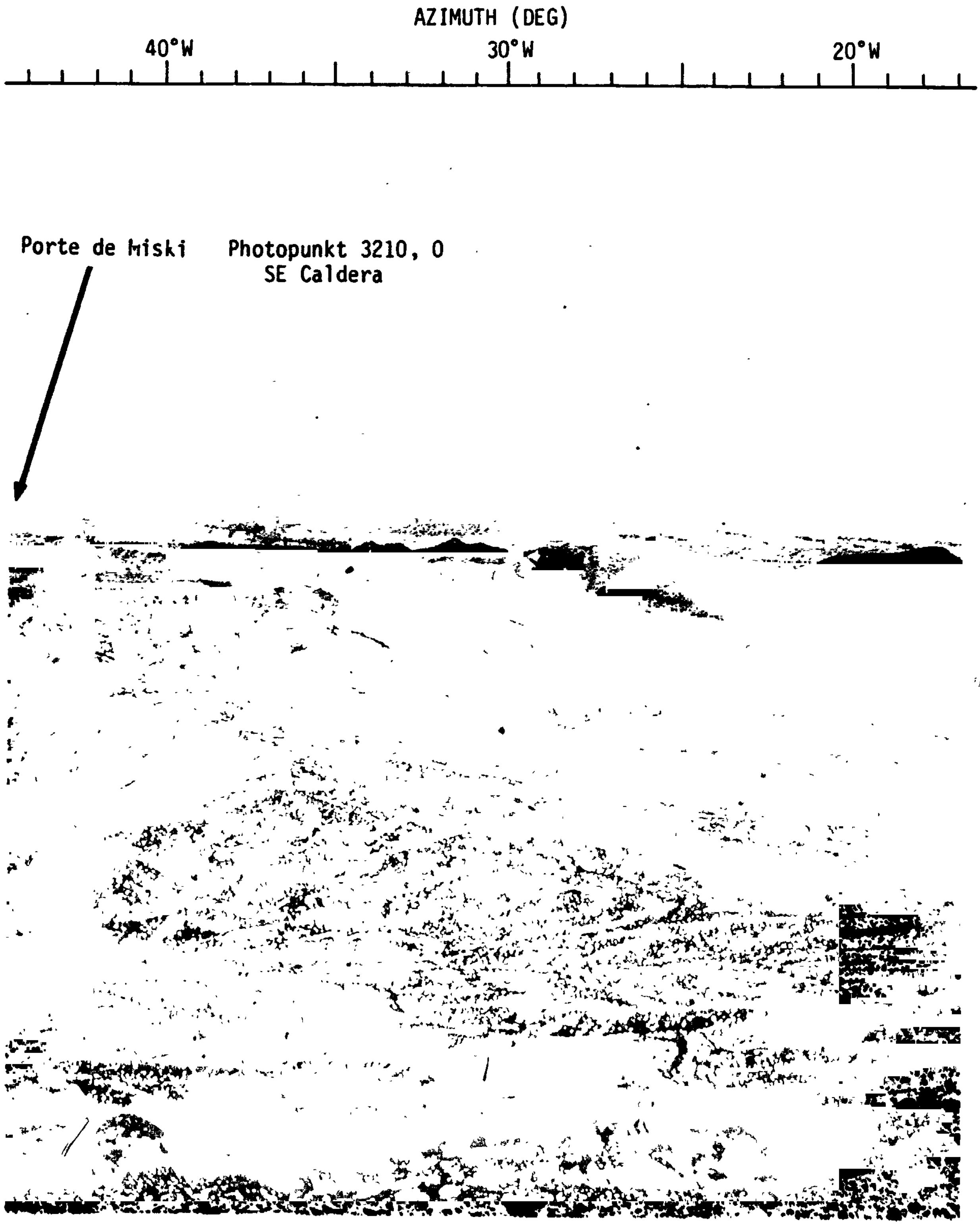


FIGURE 20 REPRESENTATIVE ROVER PANORAMA OF EMI KOUSSI (SHEET 5 OF 7)

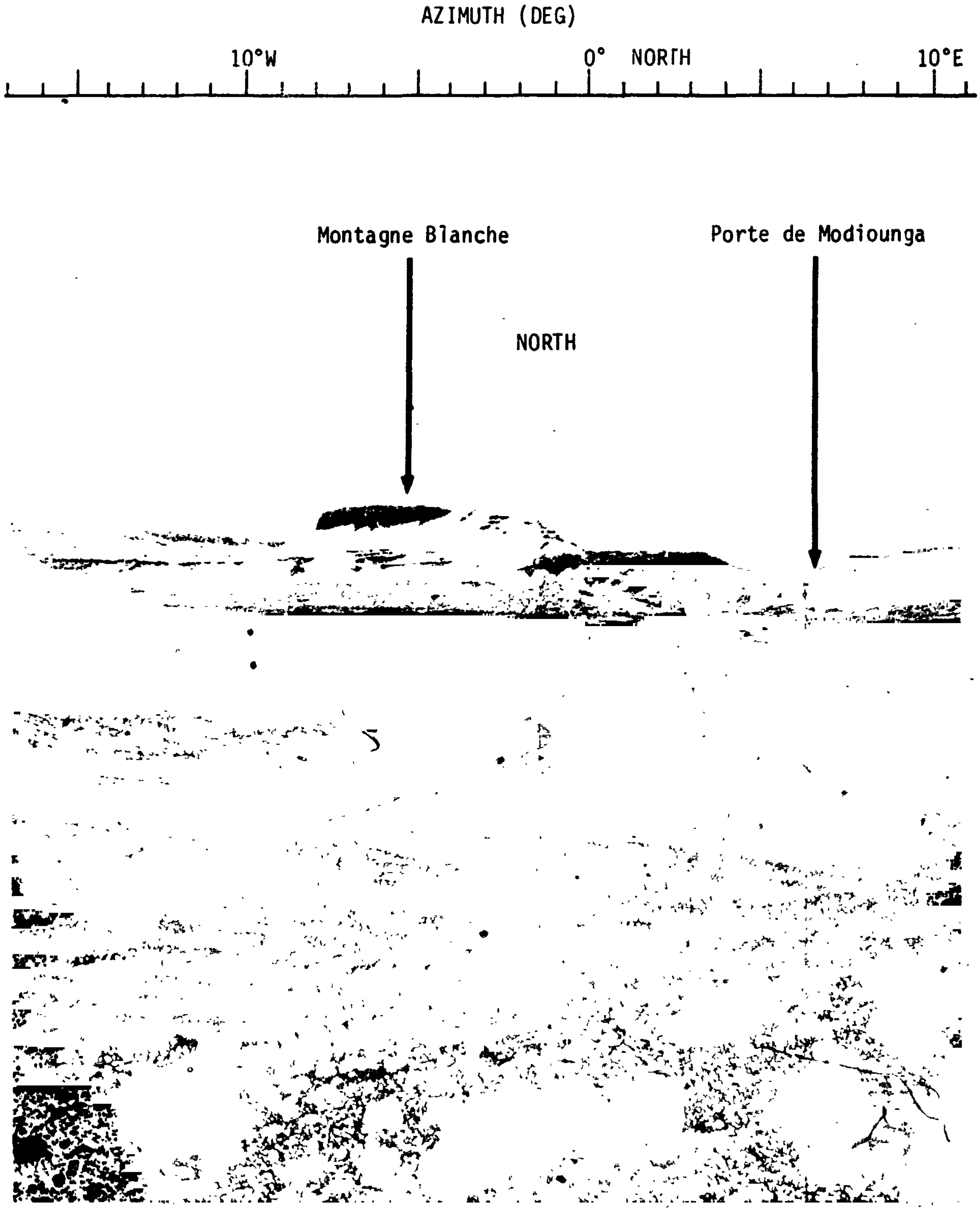


FIGURE 20 REPRESENTATIVE ROVER PANORAMA OF EMI KOUSSI (SHEET 6 OF 7)

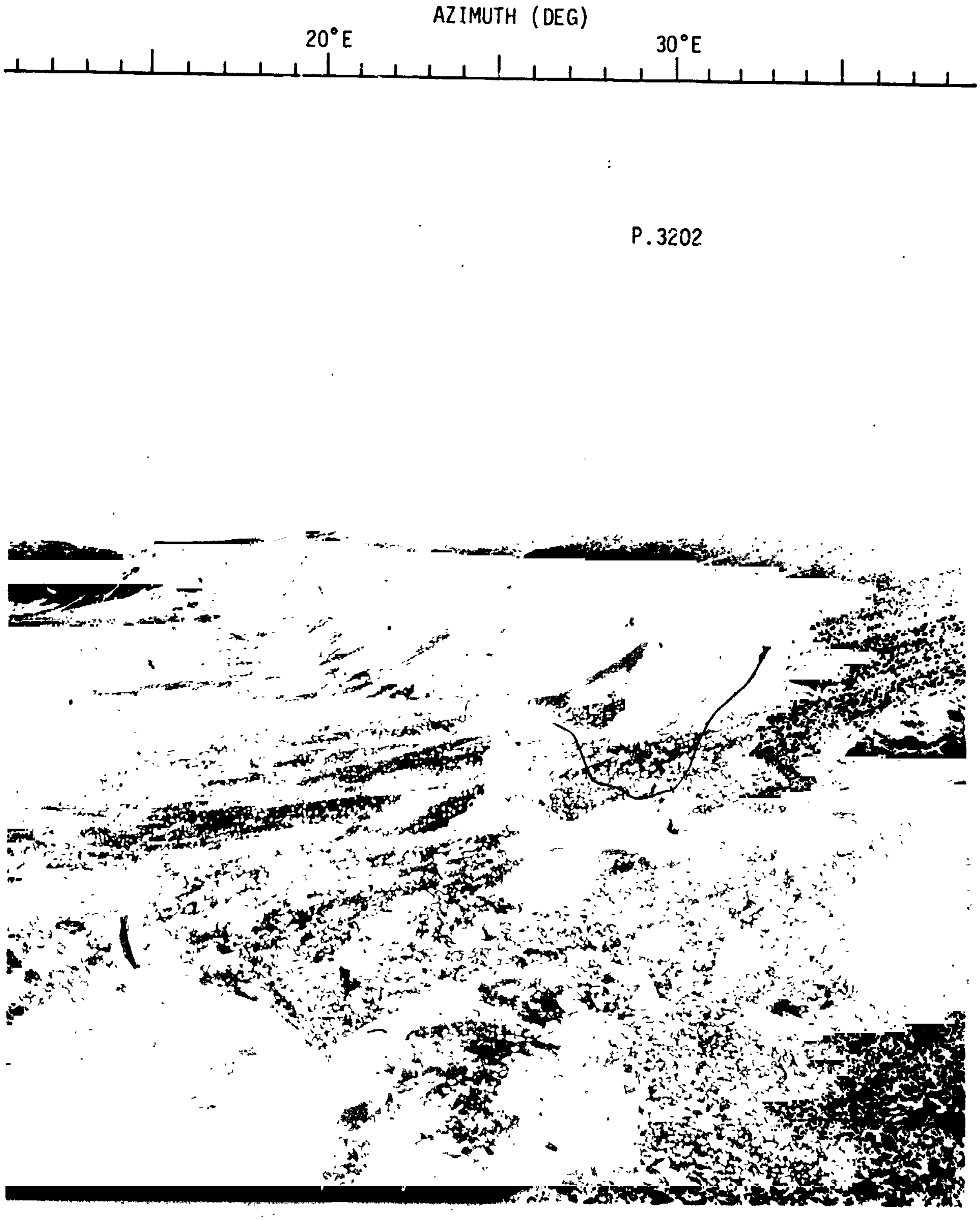


FIGURE 20 REPRESENTATIVE ROVER PANORAMA OF EMI KOUSSI (SHEET 7 OF 7)

20. The mission scenario has been developed assuming the available imagery data were taken during an actual mission. Supplementary detailed data were used to check the conclusions drawn from the pictures. This mission is detailed in Volume II with the key results summarized below.

The rover significantly enhances the value of a Martian surface mission. The scenario developed to demonstrate this conclusion has two primary mission phases; lander support and rover independent. During the former, the rover cooperates with the lander to obtain relatively long baseline stereo imagery of the area around the lander while the rover operating characteristics are evaluated. A period of time has been allocated for detailed science evaluation in the vicinity of the lander (several hundred meters) culminating in the delivery of at least one interesting sample to the lander. During this time interval (approximately 25 days) an area of scientific interest (crater, caldera, gorge, etc.) within a few tens of kilometers of the lander will be identified from orbiter pictures and a preliminary traverse to the area planned.

The rover mission design continues with a traverse to the area of scientific interest with only a few dwell periods along the way for detailed scientific exploration (based on objects visible in orbiter pictures). During the traverse, daily imagery and XRFS (hole detector) data will be returned and full science data will be returned during the dwell periods.

Once at the area of interest, a long (typically one kilometer) baseline stereo imagery pair will be returned for detailed planning of the final phase of the rover mission along a path such as the one shown in Figure 19. For the example used in the development of this scenario (caldera Emi Koussi) many different types of geological features are readily identifiable in the original picture (i.e., outcroppings, rocks, cliff face strata, drainage patterns, drifted sand, areas of different albedo, etc.). These pictures lead to an initial rover mission science plan in which the rover investigates each of these features. During the scenario development, new data were added as a function of mission time leading to "inflight" mission redesigns and demonstrating the adaptive capabilities associated with the rover. These were all accomplished within the context of mission operations system capabilities and relatively relaxed personnel timelines.

This rover mission design led to a preliminary definition of rover mission design philosophies to maximize the rover's scientific contribution to the landed science mission as well as mission operations system capabilities impact or rover system design criteria. The key mission design philosophies include:

- Support the lander for a limited period to enhance the value of the lander's science complement.
- Leave the lander and travel quickly to an area where the rover's mobility can be used to return a broad spectrum of science data.
- The rover-independent portion of the mission is most effective when planned around a sequence using a few days of traverse between areas of local interest followed by a few days dwell for detailed exploration.
- Take advantage of the rover's adaptability, but not at the expense of delaying science data return from many different types of geological features.
- The orbiter relay link operations will be shared between the lander and rover when the two are working together. After the rover leaves the area of the lander, the rover will have priority on relay link contacts and the lander will depend on its direct link (i.e., all science data with limited imagery).

Some key mission operations system impacts on flight systems design criteria are summarized below:

- Rover commands will be validated at the orbiter before relay to the rover. The rover will execute upon receipt. This defines both Earth-to-orbiter and orbiter-to-rover command coding requirements. It also imposes a rover design requirement to be "fail-safe" relative to receipt of bad commands (i.e., stop before damage and wait for new commands).
- The rover computer/sequencer shall be capable of accepting a multi-leg set of traverse commands covering a few days traverse.

- The above requires the rover to have both hazard sensors and capability to negotiate around simple hazards and continue.
- The rover software must have several special software modules that can be easily called in any sequence with simple commands. These include modes such as climb to the top (bottom) of a hill and stop, take a navigation picture pair in a given direction, etc.
- The orbiter must be capable of accepting an interrupted relay signal (e.g., the above real time navigation picture pair) or the rover telemetry system must fill the gap with useful engineering data or a signal to maintain lock.

General design criteria of these types are continuing to be developed as the scenario development goes on. At the same time, design requirements on the ground operations system are also evolving.

6. BASELINE ROVER SUPPORT

Lander Hardware Changes - Lander hardware changes and the reason for the changes are tabulated for the lander and the rover with the baseline science payloads in the following listing.

Change	Reason for Change
Lander Body Changes	
Remove XRFS experiment	Science definition
Remove meteorology	Science definition
Remove one lander camera	Science definition
Lightweight lander RTGs	Gain mass for the rover
Add regulated propulsion system	Gain landed mass capability
Relocate surface sampler acquisition unit	Provide volume for the rover
Revise RTG cooling loop system	Include rover RTG cooling in series with the lander cooling loop
Add UHF receiver, diplexer, and antenna	Rover communication with the lander
Add rover mounting and deployment provisions	Addition of a rover
New internal and external wiring harness	Addition of the rover and new or changes science
Revise the power control and distribution assembly	Component additions and deletions and interface with the rover and lightweight RTGs
Revise the lander pyro control assembly	New pyro functions for rover off-load and regulated propulsion system
Revise data acquisition and processing unit	Interface with the added receiver/decoder for rover communication
Aeroshell Changes	
Relocate the radar altimeter antenna	Viking '79 c.m. is on the +Z axis as opposed to Viking '75 that is on the -Z axis

Change	Reason for Change
Aeroshell Changes (continued)	
Relocate entry science instruments	Viking '79 c.m. is on the +Z axis
Add provisions for rover RTG thermal radiation	Thermally isolate rover RTG from lander in the cruise configuration
Base Cover Changes	
Provide a domed glass phenolic panel	Provide volume for the rover

Orbiter Hardware - Impact on orbiter hardware as a result of the rover is the addition of hardware to provide a two-way UHF link between the orbiter and the rover and keeping the existing receiving link for the lander. A block diagram of the orbiter system is as follows in Figure 21.

The antenna will change from the Viking '75 system as a result of having to transmit at 381 MHz and receive at 405 MHz. To provide simultaneous transmit/receive capability, a diplexer, a transmitter and an additional receiver are required. To provide the capability for communicating with either the rover or the lander, a lander/rover select switch is required. To obtain optimum link performance, the orbiter antenna will be a single boresite antenna but the orbiter will use maneuvers for improving link performance. The orbiter must provide the capability to receive 450 bits of command information for the rover from Earth and verify receipt of the message before storing the command in memory.

Mission Operations

Changes in the Mission Operations System include modification to procedures and ground data system software, and incorporation of new rover peculiar software system.

The major impact of the rover on the Viking operational procedures from liftoff to touchdown is the rover checkout operations and rover offloading. The relative simplicity of the rover minimizes the impact of these operations. Primary changes are modifications to the orbiter and lander flight computers to handle the new telemetry format. Post-landing procedures will have to be modified to include the orbiter command function and rover/lander interfaces as

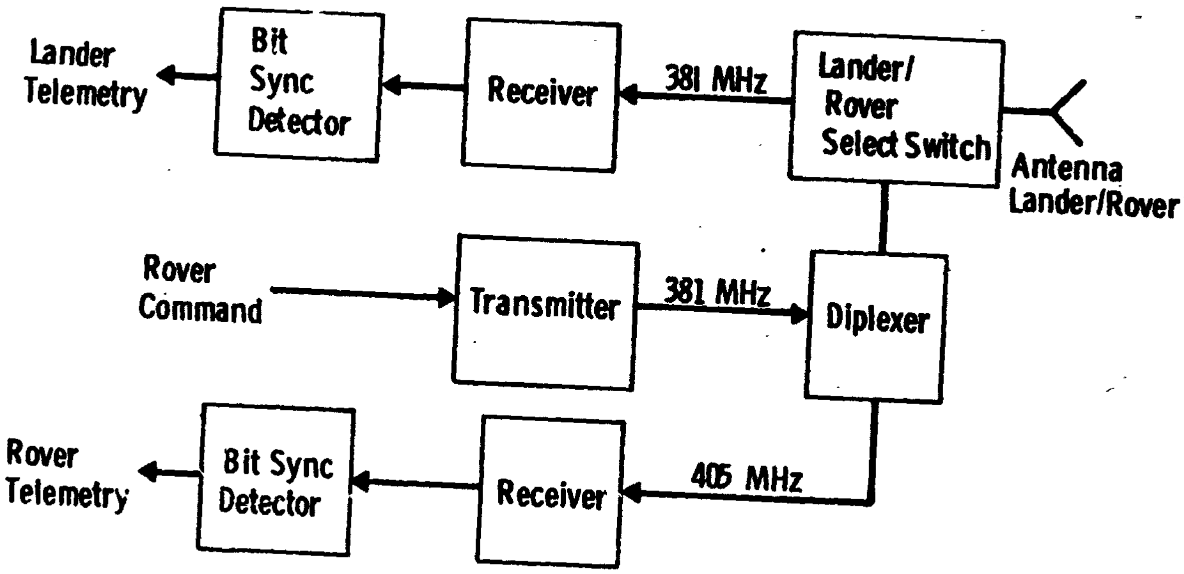


FIGURE 21 ORBITER-TO-ROVER/LANDER COMMUNICATIONS

described in Section 8, paragraph titles Typical Rover Surface Mission.

Rover ground operations, as currently conceived, will include provisions for transforming a suitable orbiter picture into a surface map. As surface pictures become available, this map will be expanded. The rover mission traverse will be hand-plotted on this chart from knowledge of commands sent to the rover and results from rover navigation imagery. Rover FPA, SPA, and SSCA functions will be new.

A preliminary evaluation of the Viking '75 ground data software system indicates some modification to 21 programs. These modifications are identified in Table 13. Modifications include addition of the rover in the mission planning software set, addition of the rover relay command in the orbiter telemetry set, addition of rover telemetry in the orbiter and lander telemetry set, and possible modifications to the imagery software to include rover azimuth and inclinometer data for stereo picture evaluation.

New software required for the rover is identified in Table 14. It includes software required for navigation, spacecraft performance, and science evaluation as well as software required to interface with existing mission planning, and command, and telemetry software. A total of 17 new programs is estimated.

Mission profile.- The Viking '79 rover mission from launch to touchdown is identical to the corresponding Viking '75 mission profile. The minimum launch period is 30 days with 10 days allowed for each of the two launches and a minimum of 10 days between launches. The interplanetary phase is similar in duration to the 1975 mission, taking between 308 to 323 days. The midcourse correction policy is identical to Viking '75.

The overview timeline for the 1979 mission is shown in Table 15. The timeline between MOI and touchdown for Mission A is identical to the current Viking '75 Mission A, taking 16 days. Mission B MOI to touchdown timeline has been extended an additional two days to allow completion of the Rover A support of Lander A phase of the Mission A before Mission B touchdown. Assuming a rover mission timeline similar to that presented in foregoing paragraphs, the rover missions will have the Rover A on its long traverse during Rover B-to-Lander support and Rover A detailed science mission during the Rover B long traverse.

TABLE 13 SOFTWARE MODIFICATIONS FOR THE ROVER MISSION

EXISTING SOFTWARE SYSTEM (VIKING '75)							
PROGRAM	ORIGINATOR MMC	ORIGINATOR JPL	MODIFICATION REQUIRED FOR ROVER	PROGRAM	ORIGINATOR MMC	ORIGINATOR JPL	MODIFICATION REQUIRED FOR ROVER
MOIOP		X		LPWR	X		X
MOTOP		X		LTOP	X		
MDPLAN	X		X	LATS	X		
POGASIS		X		LTRAN	X		X
ORCON		X	X	LTEMP	X		X
VLPLAN	X		X	DECSET	X		X
COALES	X		X	PREPR	X		
MFILE	X		X	LTARP	X		
DPTRAJ		X		MKIV		X	
MMOP		X		ICAN	X		
TRAP		X	X	ATMORG	X		
APOP		X		SANMET	X		
PSOP		X		SASEIS	X		
MAPS		X		SEDRGN	X		X
SEQGEN		X	X	IMAGERY S/W		X	(Possible Minor Mods)
SCANOPS		X		VOTLMP		X	X
OSTRAN		X	X	ETGE		X	
OCOMSM		X	X	MAWDAPT		X	
PSPA		X	X	MAWDRAD		X	
CINDA3G		X	X	MAWDMAP		X	
CRS				IRTMAN		X	
LOHARP		X		IRTMAV		X	
LDLINK	X			IRTMTP		X	
RLINK	X			OPSYS		X	
CASPER	X			OMSET		X	
BIOLGY	X			VISRAP		X	
LSEQ	X			VOTPP		X	X
LCOM	X			TDRP		X	
LCOMSM	X		X	AVTPAP		X	X
				TOTALS (excluding Imagery) MMC 11, JPL 10			

It is assumed that all MCC, DSN, and basic Flight Path Analysis software (i.e., DPODP, etc.) is unchanged.

TABLE 14 NEW PROGRAMS REQUIRED FOR ROVER MISSION

PROGRAM	ORIGINATOR		REQUIRED FOR
	MMC/INTEG	ROVER	ROVER
RPLAN	X		X
I/R with VO Cmd	(JPL)		X
RCLINK (R Cmd)	X		X
RRLINK (Relay)	X		X
CLSEQ (I/F)	X		X
LCINF (LCOM I/F)	X		X
RSEQ		X	X
RCOM		X	X
RCOMSM		X	X
RPWR		X	X
RTEMP		X	X
RNAV		X	X
RNAVSM		X	X
RPOS		X	X
SAALPHA		X	X
SAXR		X	X
RHAZ		X	X

TOTALS		
	MMC/INTEG	5
	Rover	11
	JPL	1

Note

The above assumes the Rover contractor will develop the rover peculiar software from requirements generation through coding and testing. A more effective approach to reduce the number of new interfaces is to have the rover contractor establish requirements and UATs and have MMC/Integration code and test.

TABLE 15 OVERVIEW TIMELINE

	MISSION A	MISSION B
LAUNCH DATE (FIRST)	10-16-79	11-5-79
C_3 $(km/s)^2$	12.0	10.5
MARS ORBIT INSERTION	8-29-80	9-23-80
V_{HE} (km/s)	2.72	2.70
TOUCHDOWN DATE	9-14-80	10-11-80
DISEMBARK ROVER	9-17-80	10-14-80
ROVER DEPART LANDER	10-9-80	11-5-80
NOMINAL END OF MISSION	12-13-80	1-9-81

Because the rover missions are adaptive, this would allow the Rover A detailed science data return to influence the last third of the Rover B mission design.

7. REQUIRED TECHNOLOGY DEVELOPMENTS

The conceptual design of the rover system has been constrained to designs that would fit within the volume and mass constraints imposed by the Viking '75 Lander System. The design process involved an investigation of a number of rover configurations that could fit within these constraints. In the process of looking at the various configurations and examining their associated subsystems, a number of approaches to hardware implementation were identified that would meet all the requirements. Some approaches required more technology developments than others; the selected configuration was based largely on a technology consistent with that being developed for Viking '75; however, a more advanced technology could be used to provide either a lighter and smaller rover, or provide more capability within the mass, volume, and power envelope.

Two categories of technology developments are discussed in this section. One category is the technology that was included in the basic design configurations and the second category is the technology to further optimize the rover performance. Also identified in this section are the technical areas that need additional study to determine the magnitude of development required and to determine if new technology is indeed required.

Microelectronics

Two areas in microelectronics technology have been considered for use in the rover electronic subsystems for reducing mass, volume, and power. These are large scale integrated circuits and hybrid circuits.

Large scale integrated circuits have been included in the baseline rover concept. Although LSI technology is not new, there are a number of new circuits that the LSI manufacturers are adding to their product lines. The basic process technology for LSI circuits is proven and test data exist on these processes; however, test data on the new LSI circuits do not exist. It should be noted that some LSI circuits were used on the Viking '75 lander system. The LSI circuits that are incorporated in the rover design include a microprocessor chip, read-only-memory chips, random-access-memory chips, and other arithmetic and logic chips. Complementary MOS field effect transistor technology for making these LSI circuits is incorporated in the design, primarily for reducing power consumption. The technology development that needs addressing in LSI circuits is in the development of methods for qualifying new circuits and MOS processes, particularly to the sterilization requirements.

Hybrid circuits were considered in the study for reducing mass and volume; however, these were not included in the selected baseline configuration as a result of VPO direction. Hybrid circuit technology, though not a new technology, has encountered developmental problems for some of the hybrids that were selected for use on Viking '75. The approach during the study was the packaging of ten complementary MOS chips in a 1-sq in. (2.54 sq cm) package. The C/MOS chips, being low power, reduce the total power for the system and potentially increase the reliability of the hybrid because the power per unit area on the hybrid substrate is extremely low. This concept of packaging C/MOS chips in hybrid form makes it feasible to have a solid state memory that can store the same amount of data in a significantly lower volume. Exploration of this concept can significantly improve the electronics packaging efficiency, especially in the area of the memories for both the Data Processor and Control Sequencer.

It should be noted that the rover baseline design uses hybrid relay driver circuits and diode matrix circuits that were developed for the Viking '75 program without any significant problems.

Power Conditioning

Boosting the low output voltage from RTGs requires regulators that use magnetics and capacitors whose mass is inversely proportional to operating frequency. However, use of higher frequencies in square wave converters creates inefficiencies because of power switching losses. New technology developments in the design of converters would increase the power conversion efficiencies and increase the performance capability of the rover. Martin Marietta Aerospace has, as a part of research projects, investigated this area of design and has provided conceptual ideas which at this time appear quite feasible for improving converter designs. These approaches need to be proved with breadboard tests.

Radioisotope Thermoelectric Generator (RTG)

The AEC has been exploring the use of selenide thermoelectric material in RTGs with a goal of providing more electrical power per unit of mass. Selenide designs not only increase the power efficiency of the RTGs, but they significantly increase the RTG operating temperature, thereby improving the RTG volumetric efficiency and providing the potential for a greater heat flow into the thermally controlled compartments of both the lander and the rover. A ramification of this increased volumetric efficiency is a much smaller wind screen and a substantially lower mass for the lander RTG/windscreen compared to the Viking '75. This lower mass has been applied to enhance rover capability. The AEC studies and development work needs to be continued and focused to the Viking '79 program.

Hazard Sensors

The rover must be equipped with sensors to avoid hazards. The two general types of sensors required are those that can detect holes and crevices before coming into contact with these hazards and those that can sense that the rover has encountered an obstruction that impedes its progress in either the forward or reverse directions. Because these sensors must be operational during the mobility mode, it is essential that they be either low power units or passive units. The proposed method for accomplishing the hole and crevice detection on the baseline is to use an X-ray sensor with the required electronics. This selection is based on the fact that X-ray sensors can be used to categorize soil composition. Lab tests using this concept have shown this to be a feasible approach.

This approach and other approaches should be examined in some detail and a breadboard of one or more approaches built and tested for evaluation of the technology development which will be required. The tactile sensors proposed for the baseline consist of passive switches mounted on bumpers. No specific technology studies are required for these sensors.

However, for the hazard avoidance to be effective the proposed hardware sensors must be combined with necessary software hazard avoidance subroutines. These software subroutines become part of the rover software used to perform adaptive control, which is another technology development concern.

Adaptive Control

The baseline rover includes the capability to adapt partially to its environment. The requisite sensors and software subroutines have been incorporated in the basic design to allow the rover to perform its commanded mobility functions semi-autonomously, i.e., with commanded operations from Earth but without commands to solve a certain class of rover problems. The adaptive control capability allows operational changes to be made on the basis of scientific discoveries and variations in performance of rover equipment. It also simplifies the interface between the mission controllers and the rover and permits an increase in autonomy of the rover as the mission progresses.

Many basic concepts and algorithms have been developed in the past for autonomous control of roving vehicles; this effort must be continued with particular emphasis on simple methods of analyzing data and determining from a practical standpoint those decisions that can properly be made autonomously by the rover, and those that must be made on Earth. Further development is required in the area of priority determination for actions to be taken by a rover, based on its analysis of science and engineering data within the priority conditions commanded from Earth.

Directional Gyro/Gyrocompass

Existing DGs are designed primarily for marine or aircraft use and hence are too heavy and too power-consuming for a rover application. Another concern of existing DGs is their ability to withstand Viking environments.

particularly the sterilization environment. The rover baseline incorporates a minaturized DG having the following general characteristics:

Gyrocompass accuracy: 35 miliradian (3σ) at 60° latitude

Mass: Less than 2 kg (3 lb)

Power: Less than three watts of regulated power

Volume: Less than 80 cubic inches

Environments: Sterilization

The current development status for directional gyros has progressed to a level where DG manufacturers feel that the technology presently used can be scaled down to achieve the mass, volume, and power constraints defined above.

The ability to use existing technology and to verify whether or not the DG can perform in the Viking environment must be performed through a predevelopment effort.

Wheels

The baseline rover incorporates 1.34 kg (3.0 lb) wheels of the design type used by the Apollo Lunar Rover Vehicle (LRV). This wheel mass estimate is based on the Apollo LRV design, taking into account the Viking '79 rover's much slower velocity and much lower dynamic loads. An appropriate approach would be to use LRV wheel design methods and fabricate and test a 50 cm (20.5 in.) diameter wheel to determine its mass and performance characteristics for the rover application to confirm the predicted Viking '79 rover wheel mass and traction performance. Also required in the development of wheels for the rover are the seals to protect mechanisms and lubricants. This development is required because of the fine particle and dust environment to which the wheels will be exposed, combined with the longer lifetime required of the mechanisms and lubricants than has previously been experienced.

Wheel Drivemotors

The Viking '75 Surface Sampler boom elevation motor was selected for the baseline rover. This motor has excellent output torque and backdrive resistance characteristics. However, the qualification tests for this motor in the Viking '74 program is for 80 operating hours. The Viking '79 rover wheel drive applications will require on the order of 1000 operating hours during qualification tests. Data on the '75 motor indicate that the particular motor brushes and commutator will probably not function for 1000 hours and the particular lubrication may not be adequate from a long term gear wear point of view. To insure successful resolution of these problems, the brushes, commutators and gear lubricants should be investigated. These investigations should include analysis, design, fabrication, and test of motors and gears to meet the 1000 hour qualification requirement.

Additional Study Areas

During the rover study, a number of technical problems arose that require further study to determine their impact on the rover development. These problems are discussed in the following paragraphs.

Thermal switch. - A significant developmental effort was required to obtain the Viking '75 thermal switch. The baseline rover incorporates a smaller, lighter mass switch. To achieve this, however, does not mean that the Viking '75 switch can be directly scaled down. This development should result in a prototype thermal switch that will provide predictable and repeatable switch conductance, open/close actions, stroke distances, and switch closing forces.

Soil transfer. - The rover baseline operations concept provides that the rover will collect soil samples and transfer them to the lander for analysis. The depth of the rover study did not permit an evaluation of the number of possible approaches conceived to provide this soil sample transfer. Follow-on effort must involve the evaluation of mechanisms for collecting soil and transferring the soil in addition to an evaluation of the navigation and control of the rover to position its soil dump for sample transfer to the lander.

Polar operation. - If the scientific mission requires landing in the polar region, an evaluation must be performed on the effect of ice buildup on hardware, especially mechanisms. Whether or not ice buildup occurs and what approaches could be used to eliminate any undesirable effects must be determined by studies and tests conducted under simulated Martian polar environmental conditions.

Gyrocompass errors also increase as the landing site approaches a pole. Evaluation must be performed, and possibly, alternate navigational systems developed.

C-2

PRECEDING PAGE BLANK NOT FILMED

8. PROGRAM DEVELOPMENT SCHEDULE AND PLAN

The rover development plan, which includes rover integration on the lander, has been constrained to be compatible with the Viking '79 baseline plan. This constraint has established the need for completing the rover qualification program by July 1, 1978 so assembly of the VLC flight articles can proceed without risk of configuration change. The plan has also established the required dates for rover flight article deliveries (two flight articles and one spare) in that they must be assembled on the flight landers for acceptance testing before encapsulation.

The early part of the rover development plan has been constrained by the desire to minimize the required funding before the start of FY'77. This funding constraint has resulted in the development program being delayed as long as practical, consistent with a 1979 launch. The complexity of the rover development dictates that hardware development commence at the beginning of FY'76 and requires that conceptual studies and program definition studies commence before FY'76. These early studies will enable interface definition between the rover, lander, and orbiter to be completed by January 1, 1976, thus enabling hardware development to proceed in an orderly manner.

Because integration of the rover on the lander and the hardware elements of the rover vary in nature and complexity, four separate plans are presented to encompass the total tasks, and are shown in Figures 22 through 25.

The first of these plans (Figure 22), entitled "Program Plan - Rover Option," identifies the required schedule for long lead conceptual and program definition studies, and identifies the significant milestones associated with rover development and integration activities on the Viking Lander Capsule.

The total time span allocated for rover development is thirty-six months. This span is based on similar developments for Viking '75, and is predicated on conducting development and qualification tests on the complete rover assembly rather than at the subassembly level. It is intended that the rover be treated as a component rather than an assembly of subsystems. This does not however,

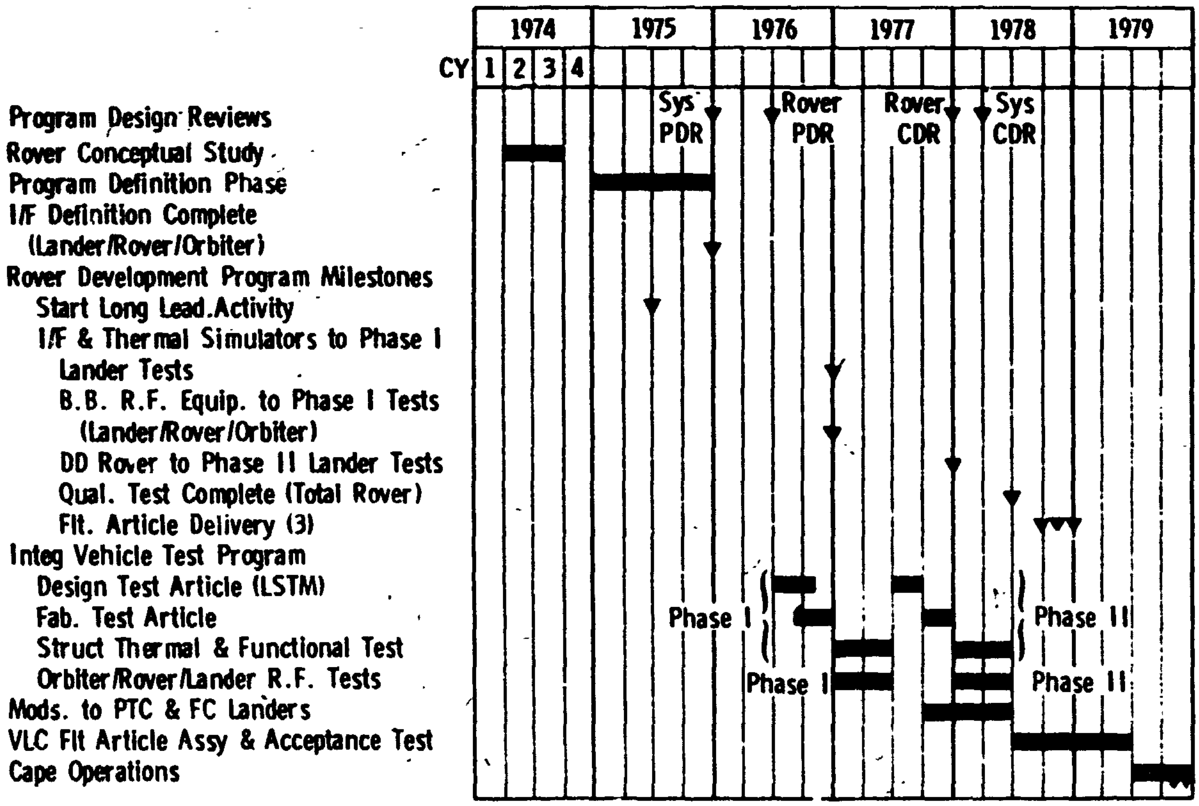


FIGURE 22 PROGRAM PLAN - ROVER OPTION

preclude the need for some environmental testing at the device/subassembly level during the development test phase.

Viking Lander Capsule system level compatibility tests are to be conducted in two series designated as Phase I and II. The existing LSTM lander body will be modified to include rover mounting and deployment capability as well as the necessary mass/thermal simulators to enable thermal, structural, and functional compatibility tests to be conducted. The Phase I tests will be used to obtain design data, and the Phase II tests, with operating hardware, will be used for design verification. In addition, RF link compatibility tests will be conducted during the same time spans. These RF tests will require rover, lander, and orbiter communications equipment.

The other three plans indicate the detailed development schedule for (1) Structural and Mechanical Hardware, Figure 23, (2) Typical Electronics Hardware, Figure 24, and (3) Typical Science Instruments, Figure 25. The allotted thirty-six months for science instrument development is considered to be a viable plan only if it is preceded by design feasibility work under SRT activities as shown.

Development of electronic assemblies for the rover will be accomplished in a thirty-month span. Although the total time span is less than for the rover as an entity, the development test span and the qual test span are coincident with those of the rover to facilitate combined testing.

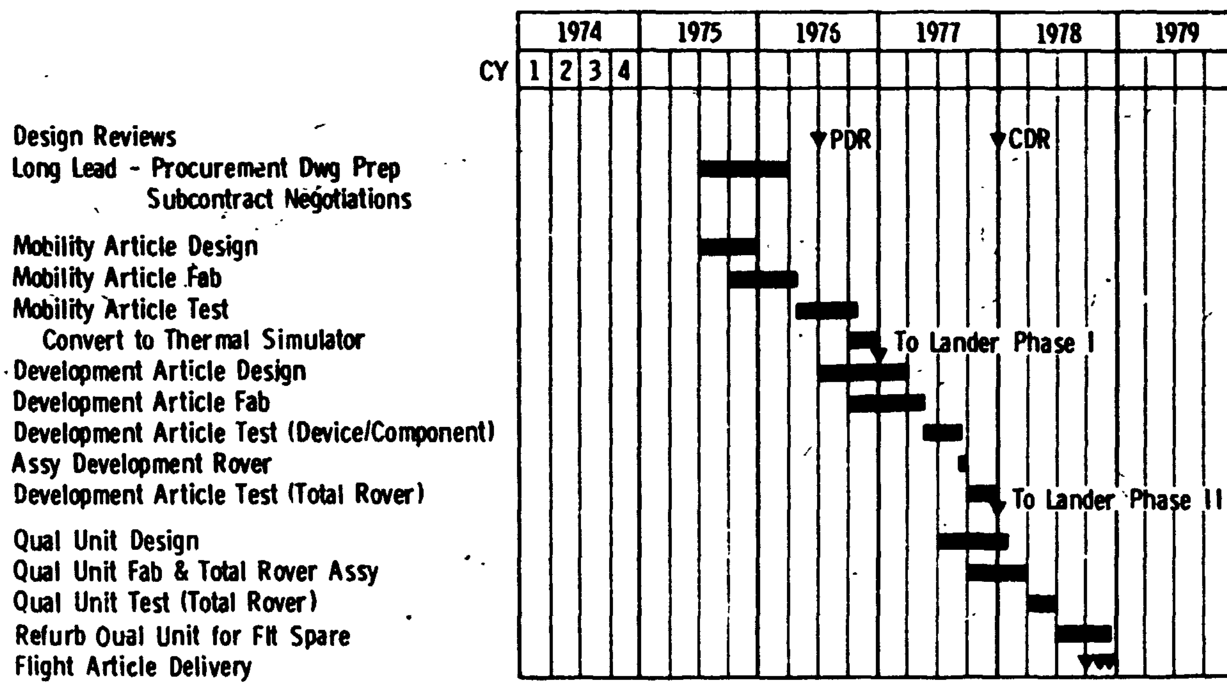
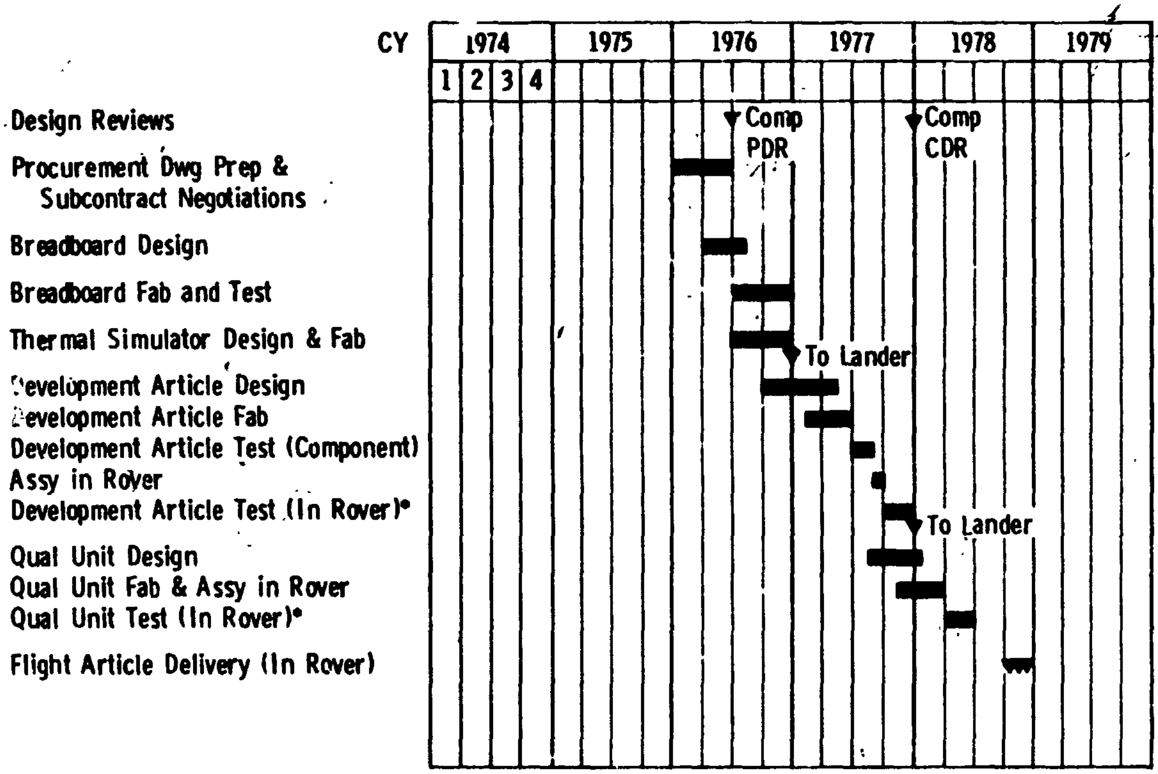
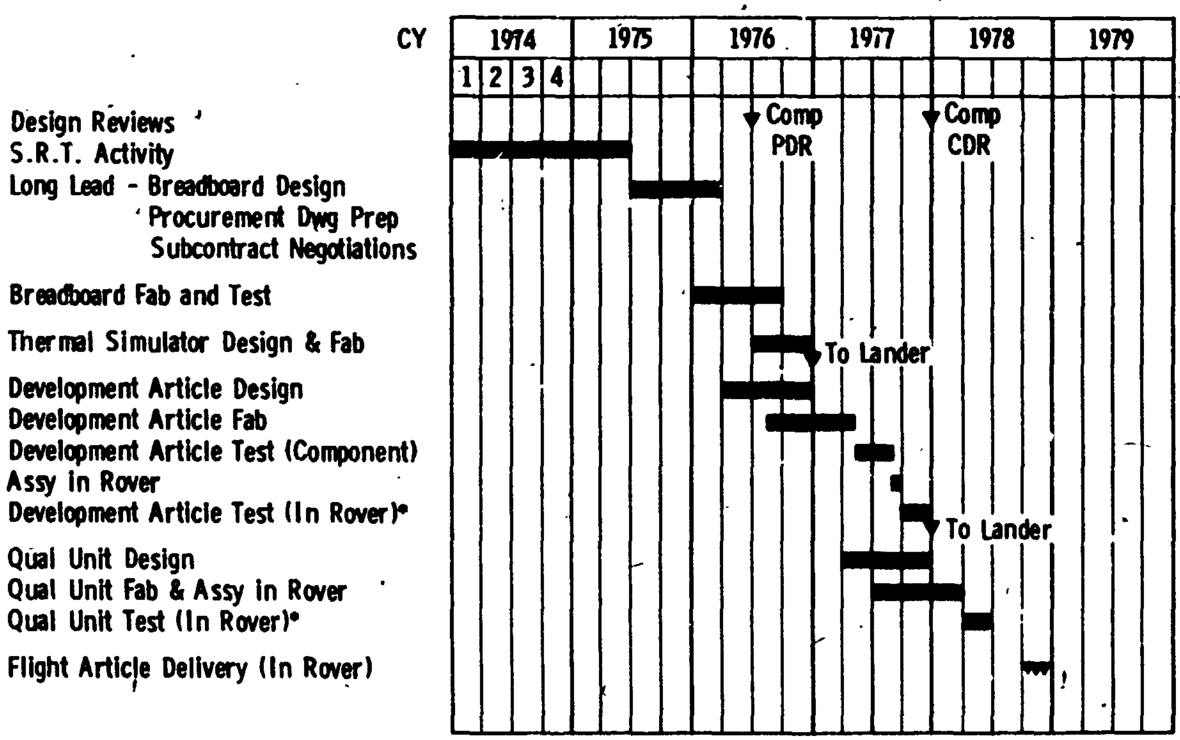


FIGURE 23 ROVER STRUCTURAL/MECHANICAL DEVELOPMENT PROGRAM



*Rover Components will be tested with the complete rover unit.

FIGURE 24 TYPICAL DEVELOPMENT PROGRAM FOR ROVER ELECTRONIC COMPONENTS



*Science Instruments will be tested with the complete rover.

FIGURE 25 TYPICAL ROVER SCIENCE INSTRUMENT DEVELOPMENT PROGRAM

9. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The objective of this study was to define a baseline Viking rover, rover/lander integration design concepts, and mission operation concepts that would provide a significant increase in the scientific capability of a Viking '79 Mission. Implicit in this objective was the derivation of a total hardware concept that makes maximum use of the Spare and Proof Test Viking '75 lander hardware. This has been accomplished.

The key features of the 107.95 kg (238 lb) baseline rover, selected as a result of the study, are summarized below:

Science - 21 kg (46 lb) geologically-oriented payload

- Surface Sampler - sample, store, and return to lander
- Alpha Backscatter elemental analyzer
- X-ray Diffractometer and rock grinder
- Viking '75 facsimile camera - long baseline stereo

Power - 20 watt (EOL) RTG

Data/Commands - Two-way link with both the orbiter and lander

Mobility - Travel up to 735 m per day and explore regions outside the landing footprint.

Navigation - Uses a directional gyro for heading reference and a control sequencer for semi-autonomous operation and a hazard detection system.

Range - Limited only by system reliability and mission operations duration

The study results clearly indicate that a significant improvement in the present lander scientific capability is achieved by including the baseline rover in the Viking '79 Mission. The lander science instruments would have access to samples from a large surface area that have been selected and screened for scientific interest by using the rover sample return capability. The value of the imagery mission is tremendously improved by using the rover for long baseline stereo capability and for its ability to explore and take pictures of geological interest over a large surface area.

In addition to improving the scientific value of the lander mission, inclusion of the rover in the Viking '79 Mission adds a unique science exploration dimension to the overall mission. The rover has the capability to operate through the orbiter, independent of the lander, and extend our geological knowledge of the present state and past history of Mars by sampling the many geologic units (e.g., lava flows, ejecta blankets, exposed sedimentary layers, outcrops, channel beds, escarpments, and lag gravel plains) that can be traversed by such a rover.

The impact of integrating the rover on the Viking '75 Lander can be divided into: (1) those changes required to stow and deploy the rover, (2) changes in the entry and terminal descent system required to land the rover system, and (3) those changes required to operate the rover with other mission elements. These changes are discussed in detail in Sections 5 and 6 and are summarized below:

Rover/Stowage Changes

- Remove one facsimile camera
- Move surface sampler
- Provide base cover bulge

Entry Performance and Landed Mass Increase Changes

- New lander RTGs
- Provide pressure regulation for the Terminal Descent Propulsion System
- 2.1° entry corridor
- Reduce atmospheric uncertainty
- Shift entry equipment because of c.m. change
- Remove meteorology

Rover Operation

- Add UHF receiver/antenna and diplexer to lander
- Add UHF transmitter and diplexer to orbiter

An evaluation of these changes indicates that maximum use of existing Viking '75 hardware and technology has been used and that only minimum changes are required to existing hardware.

Recommendations

The conclusions reached as a result of this study indicate the feasibility of the rover design and integration concepts, and for developing these concepts for a Viking '79 mission. To continue in the process leading to final definition of the rover system and the integration requirements, follow-on activities in the form of technology development and definition studies are identified in Section 6. These activities should be undertaken in a timely manner if the rover development is to proceed along the time span of the development plans for a Viking '79 mission.

Additional consideration should be given to the fact that the baseline rover design does not account for potential problems that can arise as a result of a polar landing. The primary concern is that of ice formation that could cause mechanisms to fail in addition to other unknown effects. Early investigation of this phenomena would preclude entering into a hardware development program without fully understanding the technology areas that must be studied.

PRECEDING PAGE BLANK NOT FILMED

ABBREVIATIONS

AEC	Atomic Energy Commission
A-h	Ampere-hour
Atmos	Atmosphere
A/D	Analog to digital
A	Amperes
Bldr	Blowdown Ratio
BPS	Bits per second
B/day	Bits per day
BER	Bit error rate
c.m.	center of mass
C/MOS	Complementary metal-oxide-semiconductor
C/30, C/20	Battery charge ract
C1, C2, C3, C4	Rover configurations
CLa	Clock angle
CA	Cone angle
Cmd	command
C_3	Earth departure energy $(km/s)^2$
D1, D2, D3	Rover configurations
DD	Design development
DSC/EGA	Differential scattering calorimetry/evolved-gas analysis
dB	decibel
dBm	decibels using one milliwatt as reference power
dc	direct current
D.G.	directional gyro
DLA	declination of the departure asymptote (related to azimuth). (degrees)
D_{PARA}	parachute diameter
DSN	deep space network
ELMS	elastic loop mobility system (Lockheed)
EOL	end of life
EMP	equipment mounting plate

EGA	evolved gas analysis
EM	electromagnetic
FSK	frequency shift keying
FOV	field-of-view
fps	feet per second
GCSC	Guidance Control and Sequencing Computer
GCMS	Gas Chromatograph Mass Spectrometer
GDC	General Dynamics Corporation
HGA	high gain antenna
Hz	hertz
in.	inch
I/O	input/output
JPL	Jet Propulsion Laboratories
kg	Kilogram
km	Kilometer
^{o}K	degrees Kelvin
kbs	kilobits per second
LGA	low gain antenna
LSI	large scale integrated circuits
MCCC	Mission Control and Computing Center
Min	minimum
MOI	Mars orbit insertion
MSI	medium scale integrated circuits
m/s	meters per second
msec	millisecond
MEA	Meteorology Electronics Assembly
Max	maximum
MHz	Megahertz
MUX	multiplexer
MEM	Mars Engineering Model
mrad/hr	milliradians per hour
N	Newton
N-s/kg	Newton-second/kilogram

N/m^2	Newton per $meter^2$
nsec	Nanosecond
PCDA	Power Conditioning and Distribution Assembly
psf	pounds per square foot
RTG	Radioisotope Thermoelectric Generator
RHU	Radioisotope Heater Unit
RCVR	receiver
Ref.	reference
RF	radio frequency
RDF	radio direction finding
ROM	read-only-memory
RAM	random-access-memory
s	second
SSCA	Surface Sampler Control Assembly
SYS	system
sym/s	symbols per second
TETM	Thermal Effects Test Model
TWTA	Traveling Wave Tube Amplifier
TR	tape recorder
Tlm/Cmd	telemetry/command
TTL	transistor-transistor logic
TD	touchdown
UHF	ultra high frequency
VO	Viking orbiter
VLC	Viking Lander Capsule
VMCCC	Viking Mission Control and Computing Center
W	watt
Wh	watt hour
XRFS	X-ray fluorescence spectrometer
XMTR	transmitter
XPNDR	transponder
ZAE	angle at Mars created by the Earth to Mars vector and spacecraft to Mars vector

SYMBOLS

Al	aluminum
Ca	calcium
C	carbon
Fe	iron
h_D	parachute mortar fire altitude above mean Mars surface (km)
h_p	periapsis altitude (km)
h_t	terrain height above mean Mars surface (km)
I_{sp}	rocket motor effective exhaust velocity divided by Earth G
L/D	Viking lander hypersonic lift to drag ratio
M_D	Mach number at parachute mortar fire
Mg	magnesium
NiCd	nickel-cadmium
Na	sodium
O	oxygen
P	orbital period (hours)
PER	touchdown location measured in orbit plane back from the subperiapsis point (degrees)
q	dynamic pressure (N/m^2)
q_D	dynamic pressure at parachute mortar fire (N/m^2)
SEA_{TD}	sun elevation angle at touchdown (degrees)
sol	time between Viking lander to Viking orbiter relay links - approximately one sidereal day
t_c	Viking lander coast time from deorbit to entry (hours)
TMI	trans-Mars injection
T	terminal descent engine thrust (per engine)
V_{WIND}	wind velocity from the MEM (m/s)
V_{HE}	hyperbolic excess velocity at Mars (km/sec)
ΔV	velocity change (m/s)

ΔV_{MV}	midcourse correction, ΔV budget (m/s)
ΔV_{STAT}	Δvelocity budget to compensat .or navigation uncertainties through MOI (m/s)
ΔV_{TRIM}	ΔV allocation for in-orbit trim maneuvers (based on spacecraft mass) (m/s)
ΔV_{IMP}	impulsive ΔV_{MOI} (m/s)
ΔV_{CAP}	total ΔV capability of the spacecraft (m/s)
ΔV_{D}	deorbit ΔV (m/s)
$W_{A/S}$	mass (kg) dropped at aeroshell separation
W_{PARA}	mass (kg) dropped at parachute separation
W_{PROP}	mass (kg) of terminal descent propellant (total)
W_{SEP}	mass (kg) of VL at separation from the VO
W_{E}	mass (kg) at VL entry
W_{PROP_D}	mass (kg) of the VL deorbit propellant (total)
XR	touchdown location measure perpendicular to the orbital plane (degrees)
γ_E	VL entry flight path angle (degrees)
λ	Orbiter lead angle; relative angular position or the VO and VL at entry measured at the center of Mars (degrees)
TD + nd	touchdown plus "n" days
A + mh	.ime reference defined in text plus "m" hours

DEFINITIONS

Component	An electronics black box.
Converter	Power supply which accepts a DC voltage and converts it to other DC voltages.
Deflation	The removal of material from a land surface by the wind.
Eolian	Of or related to action of the wind.
End-of-life	Characteristic of a piece of hardware and the term is used as being synonymous with end-of-mission.
Ecological Niche	A combination of environmental factors (soil composition climate) that favor the existence of only certain life forms.
Limonite	Hydrous iron oxide that is brown, yellow, or red in color.
Regolith	The layer of loose, incoherent rock material that rests upon the underlying solid or "bed" rock. Synonymous with soil.
System	Description of a group of subsystems that when combined perform a specific function, i.e., rover system.
Subsystem	Description of a group of related components and functions that perform a specific task, i.e., power subsystem.
Plate Tectonics	The widely accepted theory that the surface of the Earth is covered by several distinct units or plates, which move relative to one another.

REFERENCES

1. Choate, R.; and Jaffee, L. D.: *Science Aspects of a Remotely Controlled Mars Surface Roving Vehicle,* JPL Report No. 760-76, July 1, 1972.

2. Darnell, W. L.; and Wessel, V. W.: *Conceptual Design and Operational Characteristics of Mars Rovers for Advanced Viking Science Missions,* Langley Working Paper 1113, Langley Research Center, June 5, 1973.