N73-16219

NASA TECHNICAL MEMORANDUM

NASA TM X-64719

RECOMMENDATIONS RELATIVE TO THE SCIENTIFIC MISSIONS OF A MARS AUTOMATED ROVING VEHICLE (MARV)

Mission and Payload Planning Office
Program Development

January 1973

NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

MSFC - Form 3190 (Rev June 1971)

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
NASA TM X-64719		

4. TITLE AND SUBTITLE	5. REPORT DATE
Recommendations Relative to the Scientific Missions of a Mars Automated Roving Vehicle (MARV)	January 1973
	6. PERFORMING ORGANIZATION CODE PD-MP-P
7. AUTHOR(S) Compiled and Edited by Robert L. Spencer	8. PERFORMING ORGANIZATION REPORT #
9. PERFORMING ORGANIZATION NAME AND ADDRESS George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812	10. WORK UNIT NO.
	11. CONTRACT OR GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Planetary Programs Office (CODE SL) Planetology Group Washington, D.C. 20546	13. TYPE OF REPORT & PERIOD COVERED Technical Memorandum
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Prepared by the Planetology Group, Mission and Payload Planning Office, Program Development.

16. ABSTRACT

This document establishes logical scientific objectives, defines specific science systems requirements, and recommends scientific experiment payloads which will effectively accomplish the established objectives through the utilization of an automated roving vehicle systematically exploring the surface of Mars.

No concepts of the roving vehicle itself have been presented or recommended. It is intended that this document be used in the formulation of any such vehicle design concepts.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Mars Surface Exploration Automated Roving Vehicle Remote Controlled Science Systems	Unclassified-Unlimited Herman P. Gierow HERMAN P. GIEROW Director, Mission and Payload Planning Office

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	64	NTIS

MSFC - Form 3292 (May 1969)

For sale by National Technical Information Service, Springfield, Virginia 22151

PREFACE

Fundamental questions about the origins of the solar system and of life have been pondered for centuries and are still unanswered. Scientists and non-scientists are excited at the possibility of having answers within their lifetimes. Ever-increasing knowledge of the universe, with its closely related vast technological spinoff, is an inevitable product of planetary exploration and must be sustained or accelerated for our nation to retain her present global leadership. Exploration of the planet Mars offers the best opportunity in the near future to extend both our scientific knowledge and our level of technological achievement in space.

The environment of Mars makes it one of the most interesting planets for the search for molecules of possible biological or prebiotic origin and may reveal the potential consequences of mixing the biologies of planets as well as yielding information on the evolution of life. Understanding Mars in terms of its origin and evolution requires that an investigation be made of its entire environmental spectrum by conducting petrographic and geochemical studies to provide limits on bulk composition and planetary differentiation history, geophysical studies to provide structural context for compositional and historical interpretation, atmospheric studies to lend insight into surface processes, and geological studies to interpret the processes and the sequence of events that formed the planet.

Field observations and analyses adequate to characterize and to interpret the significance of major geologic and biotic elements of the Martian surface require the mobility offered only by roving vehicles as well as imaging and analytical capabilities. Most surface features within detailed viewing and sampling range of stationary landers are unresolvable at the scale of orbital imagery. Therefore it would ordinarily be impossible to determine the representativeness and precise geologic and biologic significance of analytical data obtained only in the immediate vicinity of a landing site. Similarly, individual landers are unlikely to sample a representative organic suite and could well fail to find organics solely because of unfortunate landing site selection. Roving vehicles on the other hand provide the means to cross and examine possible biotic zones as well as geologic units that are significant at the scales of orbiter imagery. They make possible knowledgeable selection of sites for sampling and for geophysical and geochemical measurement and bio-ecological studies (if life is present), and they provide the comprehensive observations necessary to relate analytical and geophysical data to features ranging in size from those visible only in the near field of view of landed cameras to those visible only in orbital imagery. Roving vehicles will replace the need for the many landers that would be required to obtain the same amount of significant information.

It is becoming increasingly important to justify future planetary flights on the basis of philosophical and scientific yield rather than on the physical accomplishments of man. Surface mobility is the key toward achieving this goal.

This document presents the consensus of members of the study panel. Its purpose is to establish logical scientific objectives, define specific science systems requirements, and recommend scientific experiment payloads that will effectively accomplish those objectives through the utilization of a Mars Automated Roving Vehicle.

This report includes the results of an in-house study to develop a representative science program for a hypothetical unmanned mission to Mars using an Automated Roving Vehicle. This work was accomplished in 1971 and 1972. It was an advanced planning effort and was not in support of an approved Agency program.

The members of the study panel are as follows:

Chairman

Robert Spencer	Marshall Space Flight Center

Members

Duwayne Anderson	Cold Regions Research and Engineering Laboratory Hanover, New Hampshire
Frank Cuttitta	U.S. Geological Survey Washington, D.C.
Palmer Dyal	Ames Research Center Moffett Field, California
Harold Masursky	U.S. Geological Survey Flagstaff, Arizona
Robert Regan	U.S. Geological Survey Flagstaff, Arizona

Donald Senich	NASA Headquarters Code: MAL
Edward Wolfe	U.S. Geological Survey Flagstaff, Arizona
Richard Young	NASA Headquarters Code: SB

TABLE OF CONTENTS

LIST OF TABLES

RECOMMENDATIONS RELATIVE TO THE SCIENTIFIC MISSIONS OF A MARS AUTOMATED ROVING VEHICLE (MARV)

SECTION I. INTRODUCTION

The purpose of a Mars Automated Roving Vehicle (MARV) is to provide mobility for the scientific exploration of the Martian surface. Driving and scientific operations will be remotely controlled from Earth with routine scientific operations conducted at approximately 0.5-kilometer intervals during the traverses between major sites. Brief stops for imaging will be made at more frequent intervals. A lifetime of one year can be expected.

Conclusions from engineering studies indicate that scientific experiments carried on the rover can be quite diversified, consisting of reconnaissance geology, geodesy/cartography, bioscience, geochemistry, geophysics, atmospherics, and meteorology.

Since geochemical and biological analyses of Mars material are high-priority mission goals, the capability to selectively collect and analyze samples is required. A long-range imaging system will be required to reveal relations among the visible land forms and to provide basic navigational and photogeologic information. A closeup imaging system will be required to supply views of the rocks and soil encountered and will guide the sampling. A sample collecting device will manipulate the surface materials to provide information on Martian physical properties and to present samples to the analytical devices that will supply chemical, biological, and mineralogical data. By proper integration of these functions, through a control loop including competent scientists on Earth, the machine will provide observations closely resembling those of a field scientist reconnoitering an unexplored area.

SECTION II. SCIENCE SYSTEMS

A. Bioscience

1. Objectives. Although it is probable that organic molecules are present on Mars, the sampling of discrete areas by the limited sampling system on the Viking missions will not assure detection and evaluation of life forms on Mars. It is likely, however, that a mobile laboratory on Mars will extend discrete area findings, whether positive or negative, into generalizations of the entire Martian surface.

Negative results from Viking would not conclusively indicate the lack of some form of life indicator but may reflect unfavorable sampling sites. The bioscience objective of a roving mission after negative Viking results would be to continue the search for life or some form of life indicator.

Positive results from Viking would indicate a high probability that some form of life exists in at least one locale on Mars and that organic matter of the kind associated with life on Earth has been found on Mars. The specific objectives of a roving mission after positive results would be to follow up on such observations in order to:

- Determine the nature and distribution of Martian life.
- Compare the molecular structure of Martian life to terrestrial forms.
- Establish metabolic processes of Martian life.
- Establish potential hazards to life on Earth.
- Determine implications for manned exploration on Mars.

2. Systems Requirements. Uncontaminated samples from various sites on Mars must be obtained for chemical analysis with the same general constraints as on Viking — that is, without prolonged or extreme heating during acquisition and without being contaminated biologically or chemically by the vehicle.

a. Site Selection. Sample sites will be selected on the basis of visual reconnaissance during traverse so that the analytical results can be interpreted in the light of environmental context.

b. Sample Selection. Samples will be selected on the basis of both reconnaissance and closeup viewing.

c. Documentation. Site documentation will consist of a traverse image record from which site location and geologic significance will be determined. Sample documentation will consist of pictorial records that show the mode of occurrence of the sampled material and provide data necessary to relate the sample to local and regional geologic settings. In general, the location of samples must be known to an accuracy approximating the size of the features they represent.

d. Sample Acquisition. In order to perform the organic and biological investigation, Viking lander must obtain an unaltered sample from the surface. This is done by extending a small scoop on a long boom, similar to a long-handled shovel, and returning the sample into a soil processor that distributes it to various analytical instruments. The long reach is to avoid the soil beneath the lander, which might have been heated or chemically (or biologically) altered by the retrorockets on landing.

For post-Viking missions, a different concept is being developed wherein, rather than bring a surface sample into the instrument thereby disturbing its natural configuration considerably, it is planned that the monitoring apparatus will be taken to the sample, thus preserving the natural ecology of the surface to be studied.

The concept requires a boom capable of extending beyond the vehicle and its sphere of contamination and reaching the surface. Weight and power will probably be similar to the Viking sampling arm. An encapsulating configuration, capable of enclosing (from above) about 6 to 12 cubic inches of surface material and airspace will be necessary. This space will be monitored for changes in gas composition (O_2, H_2O, NH_3, CH_4, CO_2, CO, SO_2, H_2S) as a function of time using a gas chromatographic monitoring system. This should weigh about 10 to 12 pounds. The gas chromatograph should be similar in requirements to the one in the Oyama portion of the Viking biology instrument or a probe (about 2 in. in diameter and 2 ft long, weighing 6 to 8 lb) containing a gas chromatographic monitoring system, as above. This will be inserted into the ground to monitor gas exchange.

e. Sample Analysis. The problem of detecting microbial forms of life with automated equipment is unique to planetary exploration. No similar pieces of equipment are in use on Earth, so each mission requires new instrument development. Life detection on Viking has required the development of an "active biology" instrument consisting of four experiments. The four biology experiments complement one another; no single test by itself, if negative, will rule out the possibility of life on Mars. If there is life, biologists anticipate specialized and adapted microbial forms rather than higher ones. So far, the data obtained from Mars have neither confirmed nor eliminated the possibility of life; but biologists are aware that Mars has an environment dissimilar to Earth and are therefore trying to design tests to detect some life process, such as growth, metabolism, or photosynthesis.

The complex chemical analyzer (vaporizer-pyrolyzer GC/MS) is the heaviest instrument on board the Viking. This device for detecting organic molecules combines several laboratory techniques into one. The soil sample is placed in an oven, where it is heated to drive off volatile gases. Later, the sample is heated in stages to higher temperatures to break down the larger molecules so that they can be analyzed in gaseous form. These gases are separated into certain groups using a gas chromatograph, and the groups are further analyzed by a mass spectrometer, which determines the molecular weights. From this information the identification of the gas is made. Identification of the original complex compounds is expected to be based on laboratory data of their known breakdown products. In addition to the organic determination, the GC/MS will be used to determine the trace constituents of the Martian atmosphere and monitor their changes during the day-to-night period.

The detection of organic matter on Mars by Viking and/or subsequent missions will impose a requirement for further and more detailed analyses. The detection of life forms will also require additional analytical capabilities. The basic Viking GC/MS will leave the following questions unanswered: the distribution of organics, the exact molecules detected; whether the organics detected are of biological origin; and the composition of life forms, if present. Modification of the Viking instrument will allow such tests. The GC/MS will be modified so that it can be used to monitor the gas exchange in acquired soil samples and also monitor the atmosphere.

In addition, the capability for "wet chemistry" will be added. This includes the following:

- An extraction system which now exists in breadboard form and provides the capability of extracting the soil with suitable solvents, thus separating the organics from the soil particles before further analysis. This concentrates the organics and reduces background noise. This will allow better separation of specific molecules, and thus better identification than possible in Viking. For example, it will not only be known that amino acids are present, but which amino acids and in what proportion.

- A derivatizer system is used in making optically active derivatives of the amino acids. In this way one will be able to determine the optical activity of the original amino acids and thus determine whether they were of biological or nonbiological origin, by use of the gas chromatograph or the GC/MS. The derivatizer hardware is in prototype phase, and specifications should be available soon.

The capability of determining the amount and nature (bound or free) of water in and near the Martian surface is the most important variable (with regard to life) on Mars. A very sensitive technique is needed because of the apparent low amount of water present. The Differential Scanning Calorimetry (DSC)-Effluent Gas Analysis (EGA) and Differential Thermal Analysis (DTA) techniques, together with five water sensor techniques (Al_2O_3, P_2O_5, quartz crystal, infrared, and microwave), offer a sound approach for the determination of water present in the Martian surface in the free (including precipitable), adsorbed, and chemically combined forms. Until another technique can be identified and shown to be more appropriate, the DSC-EGA instrument is the recommended choice to accomplish the following tasks:

- Measurement of water present in free, adsorbed, and chemically combined forms on Martian surface.
- Measurement of water content of the subsurface Martian soil at a depth where permafrost or at least a region of enhanced moisture content might exist.
- Search for possible abiotic or biotic activity.

All these experiments should be designed to be repeatable each time the rover stops for a new site. Sampling sites should be selected and monitored visually.

If life has been found by earlier missions, a series of experiments will be required which are aimed at a characterization of the life forms present. The above described experiments will be suitable for providing information on the distribution of organisms and some information of their metabolism. However, in anticipation of returning samples to Earth for additional study, an assessment of the more detailed characteristics of life forms must be made in order to determine to some degree the potential danger such organisms pose for life on Earth. Such experiments cannot be designed at this time since they will depend on earlier results but may well include the capability for:

- Automated microscopy — resolution comparable to oil immersion (1000 X magnification) on Earth.

- Culture capability on a variety of media with video monitoring.

- Immunological testing.

All three will require considerable weight and power, as well as sophisticated instrumentation. No realistic estimates can be made at this time.

B. Geochemistry, Mineralogy, and Petrology

1. Objectives. Geochemistry, mineralogy, and petrology objectives are as follows:

- Determine geochemical limits on the bulk composition of Mars.

- Determine the identity and abundance of elements present in Martian surface materials.

- Characterize Martian surface materials petrographically.

- Determine the amounts of water present in free, adsorbed, and chemically combined forms.

- Search for geologic evidences of an environment conducive to organic or biological activity.

- Evaluate the abiotic organic geochemical system existent on the Martian surface.

- Obtain age-dating of Mars.

2. Systems Requirements

a. Sampling of Martian Surface

(1) Site Selection. Sample sites will be selected on the basis of visual reconnaissance during traverse so that the analytical results can be interpreted in the light of geologic context.

(2) Sample Selection. Samples will be selected on the basis of both reconnaissance and closeup viewing to provide the best possible characterization of Martian surface materials.

(3) Documentation. Site documentation will consist of a traverse image record from which site location and geologic significance will be determined.

Sample documentation will consist of pictorial records that show the mode of occurrence of the sampled material and provide data necessary to relate the sample to local and regional geologic settings. Resolution of 0.5 millimeter is desirable in the sample site. In general, the location of samples must be known to an accuracy approximating the size of the features they represent.

(4) Sample Acquisition. A sampling instrument similar in function and design to the Viking sampler rather than a drill- or auger-type sampler appears to have the most utility for surfaces covered with particulate material. This type of sampler can be directed to any selected fragment or area on the surface that the television (TV) viewer desires. Thus, unique specimens that appear to be important to the geological mission can be acquired. This type of instrument also has great utility for scratching at the surface of outcrops, uncovering contacts, and even trenching to provide data about the vertical distribution of surface material and permitting a TV view of the subsurface.

For the long-traverse reconnaissance-type mission, a drill sample of coherent surface rock is preferable to a chipped or cored one. This is because the acquired samples must be presented to a variety of fixed analysis instruments and a drill tip can be made to provide the size fragments required for analysis without additional sample grinding or sorting. A drill-type sampler also provides a low-power, rapid technique for subsurface sampling, and it should be mechanized for use against vertical outcrops.

An auger-type sampler may be practical for digging up a pile of subsurface materials that can be subsequently picked over, sorted, and selected by the sampler. This type of operation needs to be viewed by the near-field imaging system.

b. Sample Handling and Preparation for Analysis

(1) Sample Manipulation. Sample handling will be carried out by remote-controlled manipulators. Long electronics transmission time will necessitate maximum preprogramming and automation of manipulation activities.

(2) Sample Viewing. Viewing of the sample in situ (0.5-mm resolution) and during manipulation (0.5- and 0.05-mm resolution) is necessary for the following reasons:

- To identify rock type and to examine megascopic features, such as vesicles and layering, that are indicative of the rock's origin and history.

- To compare with previous samples and determine geologic significance.

- To ascertain anomalies.

- To document pictorially.

- To provide a basis for selection of analytical operations.

Requirements for sample viewing are described later in this document as part of the geology requirements.

(3) Sample Preparation. The intent in sample preparation is to allow the instrument to generate the best data possible and not to constrain the accuracy or precision of the data by the condition of the sample. It is important to include sample preparation as a factor in the trade-off studies involving expected science return, power, weight, volume, etc. The preparation, in general, will involve one or more of the operations of comminuting, shaping, and containing the sample.

Sample conditioning requirements of several instruments may be able to make use of a common sample conditioning device. This is particularly true for the instruments requiring sample comminution and sizing. A similar argument is made for selecting experiments using common support instruments; e.g., spectrometry and diffractometry using a multichannel analyzer with similar specifications.

c. Analysis of Surface Materials

(1) General Statements. Materials analysis here refers to any analysis of surface materials providing information on rock chemistry and the arrangement and distribution of mineral phases.

The number of samples and the selection of analytical measurements on any single sample will vary with the geologic objectives of the sample site. Possibly several thousand samples will be analyzed during the automated mission.

Periodic calibration of MARV instruments is a continuing requirement throughout the automated mission.

(2) Priorities. Priorities must be assigned to the elements required for meaningful geochemical interpretations. The highest priority is assigned to those characterizing most rock types and/or substances of organic geochemical import, i.e., C, N, O, Na, Mg, Al, S, Si, P, K, Ca, Ti, Fe, and H_2O; the second priority to Cr, Mn, Ni, Th, and U; and the third priority to B, F, Cl, Cu, Zn, Rb, Sr, Zr, Ba, and Pb.

(3) Analytical Techniques. It is necessary to use a variety of analytical techniques to satisfactorily determine all the geochemically significant elements. Since a mineralogic analysis is essential to a better understanding of any elemental data, commonality of instrumental subsystems should be of prime importance. Extra-vehicular deployment and in situ analysis without the need for sample acquisition and processing are particularly desirable for regolith analysis. The following presents a selected list of analytical instruments suitable for geochemical exploration.

(a) Alpha Particles Techniques (Cm-242, Cf-254, Es-254, or Po-210) in the Backscatter, Proton, and X-Ray Fluorescence Modes. The alpha particle (backscatter and proton modes) technique is the only fully planetary mission-proven analytical instrument available at this time for geochemical exploration (Surveyor Program). Research and development (R&D) studies that are still in progress indicate that this technique can meet the rigorous constraints of Martian surface exploration. Combination of the backscatter, proton, and X-ray fluorescence modes into a single analytical system would offer not only good results for light elements (especially C, O, N, Na, Mg, Al, and Si) but a discrimination of the highly geochemically diagnostic elements K, Ca, Ti, Fe, and possibly some trace elements such as Rb, Sr, and Zr.

(b) X-Ray Spectrometry. Depending on excitation source (isotopic sources or generators) this versatile technique offers not only a capability for determining both light and heavy elements but a high degree of compatibility with various methods of phase analysis (X-ray diffractometry). The sample should be particulate, about 80 mesh in grain size with no more than a 20-percent range in particle size. The sample surface must be presented in a fixed form, either in a container or restrained in shape by an instrument-sample interface.

Geochemically significant elements determinable by X-ray fluorescence spectrometry are (C, O, N, and Na as a group), Mg, Al, Si, K, Ca, Ti, Cr, Mn, Fe, and some trace elements such as Cl, Cu, Zn, Rb, Sr, Y, Zr, Th, and U. Additional capabilities of the X-ray fluorescence technique are that it can provide not only geochemically significant elemental ratios (i.e., Mg/Si, Al/Si, K/Ca, and Rb/Sr) without resorting to a knowledge of their elemental abundances but can as well furnish spectral signatures useful in characterizing gross rock types.

(c) X-Ray Diffractometry. Mineralogic composition is important to geochemical exploration as an elemental analysis because of its relevance to identifying a rock unambiguously and thereby inferring past and present weathering processes as well as the primary rock forming processes. No other technique offers the same combination of generality, specificity, and quantitative data so useful for goechemical interpretative purposes. Diffractometric studies can also permit detection and characterization of mineral phases of bioscientific import (i.e., ammonium compounds, nitrates, phosphates, and carbonates) or both. The sample should be particulate and about 80 mesh in grain size. It must be presented to the instrument in a fixed form either on an adhesive backing or in a sample tray. The volume required is generally far less than 1 cubic centimeter.

(d) Determination of Water. The measurement of the water content of the surface and near subsurface materials of Mars is important in understanding processes by which rock and soil materials originate and are altered. Taking advantage of commonality of tasks and sample and instrumental requirements, the DSC-EGA and DTA technique as described in Section II.A (Bioscience) of this document is the recommended choice to accomplish the following additional tasks:

- Deriving mechanisms of planetary crustal changes.
- Searching for present or past marine environment.

(e) Organic Geochemistry. The molecular analysis investigation of the Mars Viking 75 Project consists of two measurements: one of the organic content of the surface and the other of the atmospheric constituents. The associated technique employs a pyrolysis oven and GC/MS capable of analysis from 5 to 5000 parts per million of total organic material in the Martian surface. Organic molecules that are of relatively low-molecular weight and are sufficiently volatile need not be pyrolyzed for analysis. Therefore low-molecular weight fatty acids or hydrocarbons could be analyzed best without pyrolysis and would provide basic fingerprint-type information. Nonvolatile substances or macromolecules that may be present will have to be pyrolyzed to make them amenable to GC/MS analysis. These latter molecules may be of interest in the bioscience program or may be critical in evaluating the abiotic organic geochemical system existent on the surface. Again, the organic geochemistry and organic bioscience analyses are mutually related through commonality of sample and instrumental requirements.

(f) Neutron-Gamma Techniques. Using radioisotopic sources or neutron generators, the procedures generally provide activation, inelastic scatter neutron-capture, and/or die-away reactions providing data concerning chemical composition and bulk density. Neutron activation, in particular, can be used for trace element analysis which is not possible by either backscatter or X-ray fluorescence. The sample volume subject to activation must be constant or known. Combined pulsed neutron instrumentation (CPN) has been developed weighing about 13 pounds, requiring 30 to 40 watts of power and a measurement time of about 100 minutes. While this approach does not require sample acquisition, deployment is the only feasible mode of analysis since a relatively large sampling area is required. Research and development activities aimed at miniaturizing the CPN instrument so that it weighs less than 13 pounds are underway. This instrument would provide six neutron-gamma modes of elemental analysis including elemental ratios) — quiescent gamma-ray and neutron backgrounds (K, Th, and U), inelastic neutron scattering (C, O, Mg, Al, Si, and Fe), thermal neutron capture (H, Na, Si, Ca, Ti, and Fe), fast activation (O and Si), epithermal die-away (H), and thermal die-away (density).

Concurrent with the CPN R&D activities, another system weighing 7.5 pounds has undergone studies. This neutron-gamma technique uses a radiative-inducing Cf-252 radioisotope neutron source (half-life = 2.6 years) with a Ge (Li) detector in the capture (includes inelastic scatter) and delayed modes. Results of feasibility tests indicate great promise for performing major, minor, and trace element analyses and simultaneous density measurements on the lunar surface and on planetary surfaces such as Mars and Venus. Theoretical calculations indicate that the abundances of the following elements may be determined on the surface — H, C, N, O, Na, Mg, Al, Si, S, Cl, K, Ca, Ti, V, Cr, Fe, Ni, Cu, As, Au, Hg, Pb, U; in the atmosphere — H, C, N, O, S, Cl, Fe, and Hg. Theoretical calculations also suggest that atmospheric density variations can be measured with great sensitivity from approximately 10 to 100 atm. The experimental direction is designed so that no a priori knowledge of chemical composition or concentration is required. Elemental ratios and spectral signatures which permit characterization of gross rock types are also provided.

(g) Natural (Passive) Gamma. Measurement of natural radioactivity from elements such as K-40, Th, and U provides some information concerning rock evolution and thereby the degree of differentiation which has occurred. Commonality of analyzer and telemetry components with other instrumental packages on board the MARV is an advantage of this light-weight experiment.

(h) Epithermal Neutrons (Energies Between about 0.2 to 100 eV). The thermalization of neutrons by passage through hydrogen-containing substances (water and organics) has become a means of measuring the hydrogen content of a substance. The chief drawbacks are the indistinguishability of hydrogen in substances such as water, hydroxyl groups, other hydrogeneous materials, and organic compounds and the confusion that might arise from other moderators such as certain rare earths and beryllium. However, an extremely lightweight (1- to 2-lb) instrument can be developed which would provide meaningful data.

(i) Microscopy. The microscopic viewing of the sample (either particulate or coherent) in polarized light must have portions less than 30 microns in thickness. The sample must be embedded in or held by a mount in such a way as to allow transmitted light viewing and positioning in the imaging system. Microscopic examination permits the determination of the association between minerals and organic matter, textural relationships and information as to whether organic matter was deposited in situ or whether it was fluid at some time and flowed into its present location, where it then condensed or polymerized.

(j) Age-Dating. The age-dating of extraterrestrial materials is a prime scientific parameter in determining the history of our solar system. Because of the extreme unlikeliness of returning samples to Earth of extraterrestrial planetary materials, i.e., from Mars or Venus, in the next few decades, the potential scientific value of unmanned age-dating of planets becomes even greater. Present laboratory techniques used in returned lunar sample age-dating involve: fission track ages, Rb/Sr internal isochrons, total rock Rb/Sr model ages, isotopic age-dating by U-Th-Pb systematics, chemical age-dating by U-Th-Pb systematics of U-rich mineral phases, and the A^{40}/A^{39} modifications to the K/A method. In these techniques, there is either a strong need for an evaluation of the planetary sample in terms of its geologic context and/or a knowledge of its radiation history.

The problem of unmanned age-dating of planets is a difficult one and will require modification of existing techniques (e.g., the modification of the argon ratio approach) or a fundamental breakthrough in new age-dating concepts. Moreover, known age-dating instrumentation and hardware do not meet space flight constraints and requirements. Cosmochromological investigative activities are presently underway which will permit the implementation of R&D efforts in space-oriented age-dating concepts and instrumentation. Hopefully, appropriate techniques and hardware can be developed for use on unmanned missions to the planets.

d. Communications. Telemetry capability will be defined primarily by the video and imaging equipment flown. Pulse code modulation at the standard Apollo rates and configurations can be expected. A TV bandwidth of 500 kilohertz will be required for textural analysis. Computer support should be assumed for real-time analysis. Off-line computer support requirements should be specified by the science investigators.

C. Geophysics

1. Objectives. The geophysical experiments are designed to yield information on the structure, composition, and thermodynamic state of the Martian interior. These measurements will supplement the geological observations in the understanding of surface features such as craters, mountains, maria, etc., and will aid in the determination of the origin, evolution, and constitution of Mars.

2. System Requirements

a. Seismic Experiment. This experiment will measure ground motion induced by internal and external processes. Sources would include Martian quakes, vulcanism, meteorite impacts, and rocket impacts. Artificial sources would be used in conjunction with the emplaced sensor array to determine the seismic velocity structure within the outer layers of Mars. The velocity structure can then be used to estimate the density, elastic constants, compaction, and other physical properties of the Martian subsurface.

(1) Measurement Requirements. The seismic experiment can be accomplished with a station seismometer deployed near the landing site.

The station seismometer deployed near the landing site should include a three-orthogonal axis, long period (0.005- to 2-Hz) device with a 0.3-nanometer sensitivity at 0.1 Hz and a single-axis vertical short period (0.05- to 20-Hz) device with a 0.3 nanometer sensitivity at 1-Hz frequency.

(2) Other Requirements. The station seismometer required 300 bits per second.

b. Magnetic Field Experiment. This experiment will measure the vector field and gradient over the dimensions of the automated rover traverse and will also measure the time dependence of the surface magnetic field in order to determine the internal electrical conductivity and temperature of Mars.

(1) Measurement Requirements. The equipment for the magnetometer experiment should consist of the station magnetometer deployed near the landing site and the one carried on the rover. Both magnetometers should have a three-axis vector field sensor with 0.1-gamma sensitivity, a dynamic range from 0 to ±400 gamma, and a frequency response from 0 to 1 hertz.

(2) Other Requirements. The relative location of the rover to the station instrument should be known to within 5 percent of the distance. The location of the station instrument on the Martian surface should be known to within 0.10 degree in longitude and latitude.

The telemetry requirement for the station as well as for the traverse magnetometer is 100 bits per second. The instrument should be mounted on the rover with the sensors on an extendable boom in order to minimize the influence of artificial magnetic fields associated with the rover.

c. Gravimeter Experiment. This experiment will measure the acceleration of gravity at several points along the rover traverse. The measurements will be used to determine the density and/or material variations over the dimensions of the traverse and will also relate the measurements to local geological structures and to the Earth.

(1) Measurement Requirements. The gravimeter should have a range of 370 through 980 ±20 centimeters per second squared with a resolution of 0.5×10^{-3} centimeters per second squared. This will be used to measure the local gravity acceleration at various points along the traverse and at several points around geological features of interest.

(2) Other Requirements. The gravimeter should be deployable or capable of being isolated from the rover. A bit rate of 100 bits per second is required, and a 5-minute warmup and stabilization time are required after deployment. The position of the gravimeter must be known to ±30 meters over a 10-kilometer traverse and ±10 meters in elevation relative to the first measurement at the landing location.

d. Electric Field Experiment. This experiment will measure the electrical properties of the near-subsurface utilizing radio interferometry. These measurements can be used to determine discontinuities in electrical permittivity and conductivity caused by the presence of water, material differentiation, etc.

(1) Measurement Requirements. This experiment should consist of a transmitter located near the lander and a receiver carried on the automated rover. A continuous wave transmitter operating at discrete frequencies between 0.5 and 30 megahertz with 1-watt power is required at the lander. A receiver on the rover is used to continuously record the

signal strength and phase. The data can be tape recorded and subsequently transmitted to Earth at a higher bit rate.

(2) Other Requirements. The dipole and loop antenna should be deployed near the lander in an orientation orthogonal to the traverse direction. The location of the receiver should be known to ±5 percent of the distance traversed. A telemetry bit rate of 1000 bits per second is intermittently required in order to play back the tape after the rover has moved beyond the range of the transmitter.

D. Geology

1. Objectives. The ultimate objective of MARV geology investigations, carried out in concert with geochemistry and geophysics investigations, is to gain understanding of the origin and history of Mars from knowledge of the planet's structure, composition, and surface-shaping processes.

Several lines of evidence indicate that the surface of Mars is compositionally and structually heterogeneous. Assuredly, the materials of the surface are products of fractionating and redistributing processes and do not represent the planet's bulk composition. These processes have undoubtedly differed from area to area so that any single rock or soil sample, or any geophysical measurement, is not representative of the entire planetary surface and may not be representative of even a small part thereof. Consequently, the immediate function of the geology investigation is to ascertain and document the representativeness and geologic significance of samples obtained for analysis and sites chosen for geophysical measurement. In support of this function, the immediate objectives of the geology investigation are:

- To characterize the surface materials in terms of composition, texture, form, and distribution.
- To classify the materials, at all scales, into genetically significant geologic units.
- To determine the structural and relative chronologic relations among the units.
- To determine the mode of origin of the units.
- To determine the processes, both endogenetic and exogenetic, that have modified the geologic units.

2. Systems Requirements.

a. Imaging. In addition to its navigation and guidance functions, the imaging system is vital as the prime means of visual observation for scientific purposes. Its geoscience functions center primarily on the following:

(1) Selection of sites for sampling and geophysical measurement.

(2) Provision of the geologic context necessary to interpret the geophysical and analytical data.

(3) Documentation of sample and geophysics sites.

(4) Direction of sampling operations and instrument deployment.

(5) Sample examination.

Functions (1) and (2) in combination with function (5) and with the returned analytical and geophysical data represent the very heart of the combined geoscience effort. In effect this effort consists of integrating analytical and geophysical measurements with the imagery to interpret the three-dimensional distribution, processes of emplacement, and history of formation of geologic units.

In order to support functions (1) and (2), the imaging system should have the capability to:

- Record a panorama in which the near and far fields are integrated into a full field with normal perspective.
- Resolve, in the near field of view, the textural detail of rock or soil particles as small as 0.5 millimeter.
- Produce overlapping high-resolution panoramas with geometric quality suitable for stereoscopic geologic interpretation, photogrammetric measurements, and planimetric mapping at both large and small scales.

These requirements can be fulfilled by the two facsimile cameras on the rover. The cameras should be rigidly mounted with respect to each other so as to provide steroscopic imagery with vertical base separation of approximately 1 meter. Angular resolution of the two cameras should be 0.05 degree for 360-degree panoramas and 0.01 degree for high-resolution views (partial panoramas) of selected areas. In order to permit color reconstruction, one camera should be equipped with at least three diodes, each sensitive to a different part of the visible spectrum.

Routine operations will consist of obtaining stereoscopic 360-degree panoramas made with both cameras in the low-resolution (0.05-deg) mode at intervals of about 50 meters along the traverse. These panoramas will provide overlapping stereoscopic imagery of the full area covered by the traverse. Thus, in combination with the available orbital imagery, they will provide the data needed for knowledgeable selection of sites for instrumentation and for geologic interpretation. The product would be maps and cross sections that portray the analytical and geophysical data in geologic context.

Functions (3) and (4), site documentation and direction of mechanical operations, require stereoscopic high-resolution (0.01-deg) near-field imagery from which instrument manipulations can be readily programmed. Dual-facsimile cameras with vertical separation of approximately 1 meter can fulfill this requirement.

Sample examination [function (5)] should include stereoscopic observation of samples with resolution of both 0.5 and 0.05 millimeter. A variety of perspectives with reproducible, hence artificial, illumination would be desirable. Thin section observation with 0.005-millimeter resolution under transmitted light, both plane and cross polarized, would also be desirable.

Because of the long transmission time, sample manipulations should be preprogrammed and carried out automatically. An imaging system, either TV or a facsimile system, that can provide magnification and stereoscopic views from several perspectives is required.

Such rapid but detailed examination provides a means of characterizing geologic materials and of judging which samples are appropriate for more thorough analysis. In addition, thin-section views provide valuable and unique textural data that are important in evaluating rock-forming processes.

b. <u>Sampling</u>. Sampling requirements were described in detail previously in this section (Geochemistry, Mineralogy, and Petrology). Hence, only a brief summary statement follows.

- Sampling of both particulate debris and coherent rock fragments is required.
- Desirable samplers include:
    - Surveyor-type sampler for particulate matter.
    - Coring device or hard rock drill that produces cuttings for sampling coherent materials. Rock cores, preferably oriented, would be desirable if samples can be returned to Earth.
- Sample storage, retrieval, and discard capabilities required regardless of whether sample return is possible.
- Because of long electronic transmission time, sampling procedures must be preprogrammed and automated insofar as possible.

E. Geodesy/Cartography

1. Objectives. If properly designed and calibrated, the stereoscopic imaging systems on a roving vehicle can be used to make detailed maps and measurements for support of orbital mapping and other experiments. These capabilities could be used to locate the spin axis of the planet, provide vertical control for orbital mapping, and make maps at scales suitable for grain counting, soil mechanics evaluation, and for documenting the geologic context of sampling and geophysics sites.

2. Techniques. The wide variety of picture types taken of planetary surfaces has unique applications to cartography and geodesy. These applications vary with picture scale and ground resolution. In a geometric sense, small-scale, low-resolution pictures taken far from the planet are primarily useful for the computation of a planet-wide coordinate system of consistent precision (i.e., geodesy). As ground resolution improves, increasingly detailed maps of smaller and smaller areas can be made. The geodetic control system also can be made more detailed by use of large-scale pictures, but planet-wide consistency becomes increasingly more difficult to maintain because of the large amount of data that must be evaluated. When an imaging system is landed on the surface, maximum ground resolution suddenly becomes orders of magnitude better than the best orbital resolution; but the area

appearing in the pictures is small, irregularly shaped, and imaged with highly variable resolution, depending on distances between the surface features and the spacecraft. With a mobile system, however, it becomes possible to select and photograph at high resolution features and areas important to the mapping (Fig. 1).

Although most geodetic computations are best done with small-scale pictures, it has been extremely difficult to compute accurately the spin axis of Mars by this means. A carefully planned series of pictures of stars as seen from the surface could be used for this computation, resulting in a major contribution to Martian geodesy.

Specifically, the following operations should be performed at intervals throughout the traverse.

Pictures should be taken of the pole star region of the sky at regular intervals no less than four times without changing the location of the imaging system. This operation should be repeated periodically during the traverse, preferably at night. The resulting series of star pictures should permit accurate computation of the spin axis of the planet.

Panoramas taken at each stop should be used to determine the exact location of the imaging system on pictures taken from orbit. This can be accomplished by the standard surveying method of resection. The angles between at least three distant features whose map locations are known are measured on the panoramas, providing sufficient information to determine uniquely the map location of the camera station. The more points that are measured from any station, the higher the probability that precise determination will be made.

The topographic elevations of each feature used in the resection should be computed as a function of its distance from the camera and its angular elevation above or below the camera. As many features as possible should be used in the above computations, not only to improve the accuracy of the resection but to increase the density of vertical control points for small-scale topographic mapping from orbit.

Large-scale topographic maps of the traverse should be made to show features not resolved on pictures taken from orbit. This can be done in part by utilizing stereoscopic pictures taken by the two camera systems on the roving vehicle. Stereoscopy is not useful for mapping at distances much greater than 20 times the baseline length, so only relatively small areas can be mapped

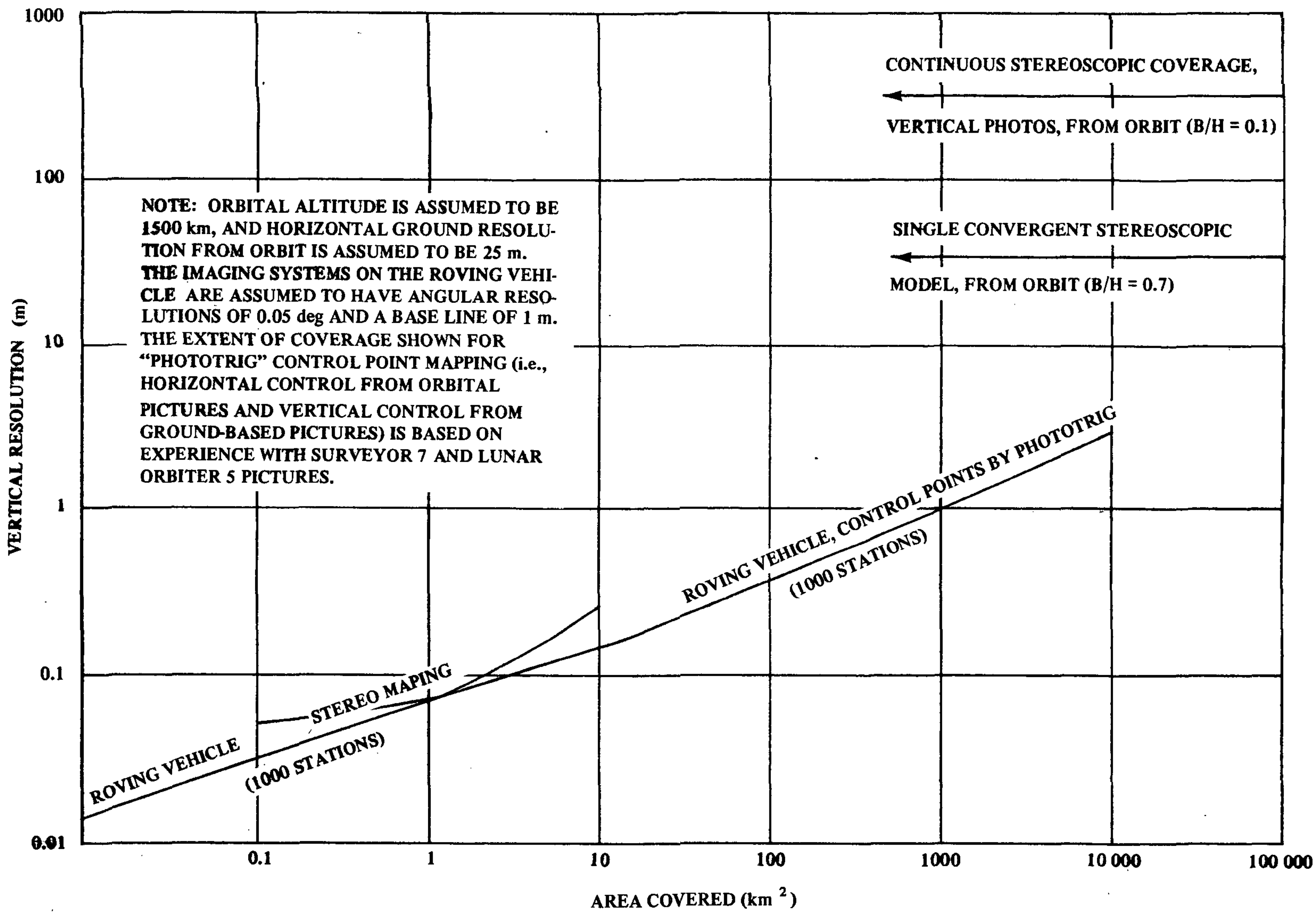

Figure 1. Vertical resolution with various kinds of mission designs.

in this way. Furthermore, very long baselines are not always useful stereoscopically because of the extreme foreshortening of features viewed from both camera stations. In areas of special interest, therefore, it may be necessary to take panoramas at closely-spaced intervals for optimum stereoscopic mapping.

Extra-large-scale maps of surface structures, tire tracks, blocks, and sample areas should be made as required for scientific purposes. The maps would be produced by standard photogrammetric methods utilizing stereoscopic pictures from the two imaging systems.

3. Systems Requirements. To accomplish the cartographic goals outlined above, both imaging systems should have the following characteristics:

- Angular resolution of at least 0.05 degree.
- Horizontal fields of view of 360 degrees and vertical fields of view from 60 degrees below horizontal to 40 degrees above.
- Horizontal and vertical angles must be measured accurately on the pictures for satisfactory mapping. Images must therefore be stable and measurable to less than 0.1 degree horizontally and vertically.
- Camera attitude sensor with readout accurate within 0.1 degree.
- Cameras spaced at least 1 meter but no more than 2.5 meters for optimum stereo.
- Sufficient dynamic range to record the full range of surface scene luminances as well as stars brighter than fourth magnitude.

F. Atmospheric Composition

1. Objectives. The primary objective of the atmospheric analysis is the identification of constituents of the Martian atmosphere and the determination of their abundances, including possible variations, that are not detectable using remote optical spectroscopy. Of special interest is the abundance of the noble gases, particularly argon and nitrogen and their isotopes. The abundance of other minor constituents, some of considerable significance to

the biological exploration of Mars, should also be investigated. An isotopic analysis of the major constituent, CO_2, should be carried out to complement existing spectroscopic determinations.

2. Measurement Requirements. Because of the unknown and tenuous nature of the atmosphere, mass spectroscopy appears to be the only method which has the necessary sensitivity and versatility for studying the composition. Instruments will require a large dynamic range in order to sample both normal atmosphere and localized outgassing.

Data from several widely spaced sites are necessary to locate large outgassing sources and to distinguish large-scale atmospheric variations from localized measurements. The ability to conduct the atmospheric investigations with or without removal of CO and CO_2 is required. The removal of CO is to allow the abundance of N_2 (same molecular weight as CO) to be determined. The removal of CO_2 is to eliminate its contribution to mass 28 and to concentrate the minor constituents in the sample. Measurement accuracy for all atmospheric constituents, regardless of percentage abundance, shall be ±2.5 percent.

G. Meteorology

1. Objectives. The meteorology objectives include measuring the meteorological environment near the surface and obtaining information about the atmospheric motion systems.

2. Systems Requirements. The elements to be determined are pressure, temperature, wind velocity, and water vapor content of the atmosphere. Temporal and spatial variations of the meteorological parameters are of particular importance. Information can be acquired by using devices that have found recent Earth application; i.e., transducers for atmospheric pressure, hot film anemometers for wind speed and direction, and thermocouples for ambient temperature.

Data are to be obtained using a flexible data system that has an averaging mode, a rapid sampling mode, and a trigger mode. The averaging time, the rapid sampling rate and duration, and the trigger level are to be selected by command. Normal operation will consist of using the averaging mode in combination with the trigger mode. The trigger is to be used to switch to the rapid sampling mode when an aperiodic event results in a preselected level being exceeded. It is required that the rapid sampling mode also be commanded from Earth.

The range and accuracy requirements for the meteorology instruments are presented in Table 1.

TABLE 1. METEOROLOGY ACCURACY REQUIREMENTS

Element	Range	Absolute Accuracy (3 Sigma)	Relative Accuracy (3 Sigma)
Pressure	1-30 mb	± (0.36 mb + 0.6% of reading)	---
Ambient Air Temperature	100-350° K	±6° K	±3° K
Wind Speed	2-150 mps	±6 mps or ±30% of reading (whichever is greater)	±1.5 mps or ±15% of difference (whichever is greater)
Wind Direction	0-360 deg	±30 deg (25-150 mps), ±60 deg (5-25 mps)	---
Water Vapor	180-225° K (frost point)	±15° K at 180° K to ±6° K at 210° K and higher (linear variation)	---

H. Surface Engineering Properties

1. Objectives. Engineering experiments designed to obtain information on the physical and mechanical properties of the Martian surface along selected traverses and at selected sites are desirable. This information will be needed to optimize near real-time traverse planning as well as to define engineering properties for subsequent missions. The approach to determine these properties will be to make maximum use of the vehicle itself and its basic onboard equipment as measuring devices with a minimum expenditure of additional power, equipment, and mission time.

2. Systems Requirements. Much, if not most, of the required information can be obtained from data available from the MARV imaging system, the surface sampling device(s), and the engineering sensors mounted in the wheels, in the drive mechanism on the surface sampler, and on the chassis in suitable locations and configurations.

a. Data Acquisition Techniques. In selecting the recommended techniques, the burden of the work has been shifted to ground data processing equipment, and priority has been given to those techniques that appear to be the simplest and the most reliable although not necessarily the most desirable in terms of the quantity and accuracy of the data. A summary of engineering properties, techniques and required sensors is shown in Table 2.

b. Martian Surface Model. The lunar surface model has been adopted as the nominal model for the Martian surface; but because Mars has an atmosphere of appreciable proportions, other models must be considered. Five model surfaces are being considered: (1) the lunar surface, (2) a lag gravel surface, (3) dune sand, (4) loess, and (5) hard rock. Details of each model are given in Table 3.* From this tabulation it is seen that determinations that ultimately must be derivable from imagery, the surface sampling device and special static and dynamic engineering sensors, either independently or in conjunction with one another, are the basic physical soil properties: grain size distribution, bulk density, cohesion, angle of internal friction, porosity and pore size distribution. Inasmuch as the MARV may be expected to encounter surface conditions embraced by all five models, the range of values that must be derived from the suite of sensors and imagery is that shown in Table 3 for each property. Large areas of Mars are almost certainly underlain by permafrost. This is explained in Table 3. Determining the depth to the permafrost layer is a task of prime importance, as is the determination of the thickness, ice content and other properties of the layer. Answers to questions pertaining to permafrost may be provided by remote sensing devices on orbiters and certain geochemical and geophysical experiments envisioned for the MARV and described in other sections of this document; but it is possible that accelerometers, strain gages, etc., on the MARV and on the soil sampling boom will yield important information relating to this subject.

c. Other Requirements. Other requirements are:

- Navigation and positioning same as the imagery requirements.
- Data transmission — data rate requirement will be moderate, but data storage and subsequent transmission capability may be required.
- Additional instrumentation may be proposed by interested scientists when the MARV configuration is finally established.

---

*Mars Engineering Model. NASA-Langley Research Center, Hampton, Virginia, Viking 75 Project Document No. M75-124-0, March 13, 1970.

TABLE 2. SUMMARY OF ENGINEERING PROPERTIES

Property	Measurement Technique	Sensor
Roughness	Photogrammetry of TV and facsimile	TV and facsimile
Bearing strength	Correlation with wheel sinkage from photo-grammetry of tracks	Sinkage markers and TV
Soil density	Weigh known volume of soil	Instrumented sampler arm
Shear strength	100% wheel slip, vehicle stationary	Torque sensor
Soil compressi-bility	Observation of soil failure	TV and facsimile
Aggregate strength (friability)	Compressive tests	Instrumented sampler arm
Rolling resistance	Measure wheel drag	Torque sensors Inclinometer
Effect of compac-tion on bearing strength	Analysis of sinkage and rolling resistance data	
Wheel thrust versus slip	Torque control of reference wheel	Torque sensors Tachometers
Soil dynamic response	Compare actual vehicle behavior on rough soil with predicted behavior on rough terrain minus soil	Center of gravity accelerometers Tachometers
Power consumption	Monitor wheel drag and speed	Torque sensors Tachometers
Soil adhesion	Direct observation and photometric analysis	TV and facsimile
Slope stability	Measure slope and effective ϕ	TV Torque sensors Inclinometer

TABLE 3. MARTIAN SOIL MODELS

	Lunar (Nominal)	Lag Gravel	Dune Sand	Loess	Rock
Grain Size 100% Distribution 75% 50% 25% 0%	1 μ 15 μ 40 μ 300 μ	1 000 μ 1 000 μ 20 000 μ 1 860 μ 150 000 μ 4 120 μ 530 000 μ 16 000 μ large large	50 μ 50 μ 150 μ 400 μ 190 μ 500 μ 230 μ 600 μ 1000 μ 1600 μ	3 μ 1 μ 20 μ 9 μ 37 μ 20 μ 60 μ 30 μ 1000 μ 149 μ	Rock Surface
Bulk Density (ρ) (g/cm^3)	1.35 to 1.8 1.5	1.4 to 1.7	1.4 to 1.7	1.0 to 1.6	2.7 to 3.2 3.0
Porosity (%)	48 ±8	49 ±5	49 ±5	56 ±10	Very low 3±
Cohesion ($dynes/cm^2$)	10^3 to 10^4 3.5×10^3 to 7×10^3	0	0 to 10^3	0 to 10^6	10^8 to 5×10^8
Angle of Internal Friction (deg)	30 to 40 35 to 37	35 ±5	35 ±5	33 ±8	45 ±5
Permeability (cm^2)	10^{-7} to 10^{-8}	10^{-3} to 10^{-1}	10^{-3} to 10^{-6}	10^{-6} to 10^{-8}	Very small
Thermal Inertia $(k\rho c)^{-1/2}$ cgs units	500 to 800	100	165	220	Large
Dielectric Constant cgs units	3.0 2.5 to 3.8	3.5 Mars Avg. 3 to 4	3.5 Mars Avg. 3 to 4	3.5 Mars Avg. 2.3 to 4	8 to 9
Pore Pressures	Probably important when $\rho = 1.0$, c is small, and near surface.	Unimportant	Unimportant	Probably important when $\rho = 1.0$, cohesion is small, and near surface.	Unimportant
Permafrost	Freeze-thaw makes materials weak and porous during thaw. Increases strength during freeze.	Unimportant during freeze-thaw. Increases strength during freeze.	Unimportant during freeze-thaw. Increases strength during freeze.	Freeze-thaw makes materials weak and porous during thaw. Increases strength during freeze.	Unimportant
Composition	Basaltic	Basaltic	Basaltic	Basaltic	Basaltic

SECTION III. PROPOSED SCIENCE PACKAGES

The proposed science experiments are listed here in the order of their priority (Tables 4 and 5). The proposed packages do not include all experiments considered in the text of this report.

TABLE 4. EXPERIMENT PACKAGE NO. 1

Experiment	Weight (lb)	Experiment Parameters Page Number
Imagery		
Two facsimile cameras with appropriate optical trains	1.5	49
Bioscience		
GC/MS (including sampler)	33	39,40
Integrated biology experiment (similar to Viking)	24	38
Geochemical		
X-ray diffractometer and spectrometer	15	47
Alpha-backscatter; proton, X-ray/ fluorescence spectrometer	11	41
DSC-EGA for soil water and volatile mineral determination	5	42
Microscopy	7	46
Geophysics		
Seismometer (passive)	20	55
Magnetometers	25	53, 54
Gravimeter	20	52
Atmospherics		
Mass spectrometer	8.5	37
Meteorology		
Multiple sensor assembly	18	56, 57, 58
Total Weight	187.0	

TABLE 5. EXPERIMENT PACKAGE NO. 2

Experiment	Weight (lb)	Experiment Parameters Page Number
Imagery		
Two facsimile cameras with appropriate optical trains	1.5	49
Bioscience		
GC/MS (including sampler)	33	39,40
Integrated biology experiment	24	38
Geochemical		
X-ray diffractometer and spectrometer	15	47
DSC-EGA for soil water and volatile mineral determination	5	42
Share GC/MS and sampler with bioscience		39,40
Geophysics		
Seismometer (passive)	20	55
Magnetometer (station)	15	53
Meteorology		
Multiple sensor assembly	18	56, 57, 58
Total Weight	131.5	

SECTION IV. CONSIDERATIONS RELATIVE TO THE ARRANGEMENT OF SCIENTIFIC EQUIPMENT ON MARV

A. Radiation

The effect of nuclear particle radiation from the Radio Isotope Thermoelectric Generator RTG on the diffractometer and the effect of the vehicle's magnetic field on the magnetometer, both in the stowed and deployed configurations were analyzed. The data obtained and conclusions drawn from these analyses are summarized in the following paragraphs.

Since the measurement of X-radiation is fundamental to the diffractometer experiment, there is potential interference from X-radiation emmitted by the RTG. Using data on the X-ray spectra from the SNAP-19s measured with a proportional counter and data on energy discrimination and background radiation level in the diffractometer, the X-radiation from a 100-watt RTG was compared with the normal background in the diffractometer. The data indicate that at distances of 3.5 feet, the X-radiation from the RTG is 20 to 30 times that of the normal background of the spectrometer portion of the instrument. The data also indicate that at this distance, 0.3 to 0.6 pound of lead shielding would be required to reduce the RTG radiation to 10 times the background level in the spectrometer. The conclusion from this analysis is that the diffractometer should be located as far as possible from the RTG. Even if the separation distance is as much as 3.5 feet, more than 1 pound of lead shielding will be required in the diffractometer to keep the background near the normal level in the spectrometer portion of the instrument. This conclusion is based on the assumption that shielding each proportional counter would be sufficient. Additional analysis and testing will be necessary to determine the validity of this assumption and what background level is tolerable in the instrument.

In the magnetometer analysis the major sources of magnetic field on the vehicle were identified as the transmitter power amplifier, the RTG, and both the traction and steering drive mechanisms. Using measured field data from simulated components and assumed fall-off rates, the variation of magnetic field with distance from the vehicle was determined. Although the data are limited, some gross conclusions can be drawn. In order to attain a background level of 0.1 gamma, the magnetometer sensors will have to be deployed about 40 feet from the vehicle. If the background requirement is relaxed to 1.0 gamma, this distance is only reduced by 50 percent. In view of this problem, several configuration options for deploying the magnetometer should be considered, i.e., vertical and horizontal booms, off-loading and trailer.

B. Thermal

1. Classes of Scientific Equipment. Scientific equipment is of three classes with regard to thermal control considerations:

- Purely mechanical equipment requiring only gross thermal control. Thermal control can be achieved by means of thermal coatings.

- Equipment that is stowed on and removed from the MARV for operation. This type of equipment obviously has to have self-contained thermal control.

- Equipment that is mechanically and electrically integrated with the MARV for its entire period of operation of the Martian surface. The facsimile camera, diffractometer, traverse magnetometer, gravimeter, mass spectrometer, water detector, and analytical instruments for bioscience, meteorology, and atmospherics measurements are in this class.

The following approaches to thermal control may be considered for this last class of equipment: thermally integrated science package, thermal integration of each individual package with the MARV, and thermal isolation of each equipment package.

a. Thermally Integrated Science Package. A thermally integrated MARV science package is not feasible considering the total volume of the science payload and the requirements for distribution of equipment.

b. Thermal Integration with the MARV. Thermal coupling of the experiments with the RTG using heat pipes is not recommended, since the temperature of the heat source (RTG cold junction) is too high (500 to 600° F) to be applicable. Radiative/conductive coupling is feasible but difficult. The very nature of the RTG compels complete (insofar as possible) thermal isolation from the vehicle chassis. Uncontrolled heat transfer through the chassis could upset the thermal balance of the thermal enclosures sharing the chassis with the RTG. Similarly, radiative decoupling is also required.

From the RTG standpoint the highest efficiency is realized when all the thermal energy is transferred through the thermoelectric modules. Therefore, any losses that occur through the insulation (bottom and sides) are undesirable.

c. Thermal Isolation of Science Equipment. If additional thermal power is required to maintain an experiment at its minimum survival temperature during the Martian night, first consideration should be given to electrical heaters. Isotope heaters can be used to conserve electrical power, but they can never be turned off.

2. Recommended Interface. In summary, it is recommended that each individual equipment package be thermally isolated from the MARV and provide its own thermal control. To minimize thermal interaction between equipment packages and between scientific and MARV subsystems, it is further recommended that, insofar as possible, the equipment not extend appreciably above the level of the remainder of the equipment on the MARV, and that heat rejection be primarily from the top of the envelope. Special consideration will have to be given to the thermal design of the magnetometer and meteorological sensors and booms since they are exposed, in their operation position, to thermal radiation from the MARV power subsystem, in particular the RTG and battery. Additional analysis will be necessary to determine the effect of dust degradation of surfaces exposed to solar radiation. Protective deflectors or dust removal equipment may be required.

C. Mechanical

The primary mechanical interface requirements of scientific equipment in the baseline complement are summarized on the individual experiment data sheets in Section V. The goal in configuring the MARV is to satisfy as many of these requirements as possible.

The requirements of the scientific equipment will significantly influence the MARV design. The requirement to locate the sampler at the front of the vehicle leads to the requirement that the diffractometer, which must interface with the sampler, be located in the forward portion of the chassis. This, in turn, leads to the location of the TV camera/antenna mast in the same part of the vehicle because the TV interfaces with the sampler.

It is apparent from the above that the location of the sampler on the vehicle is critical in the arrangement of the scientific payload because the chain of interface requirements between equipment leads to the grouping of a large portion of the science equipment around the sampler.

Standardizing techniques should be used where possible to allow substitution of one experiment for another without modifications to the vehicle chassis. Considering the range in volume of the various items in the science payload, almost two orders of magnitude, it is obvious that use of a standard package size is out of the question. Standardization can be achieved, however, by having the base dimensions of each package as multiples of standard dimensions. Standardization of package base size would be more important than package height.

If standardization were established from the initial development of the equipment and if package height were not strictly standardized, there should be no severe weight or volume penalty from standardization.

SECTION V. INTERFACE PARAMETERS FOR SCIENTIFIC EQUIPMENT

This section contains data sheets summarizing the scientific equipment interface parameters. They are collated in alphabetical order, by discipline in the order shown below.

EXPERIMENT TITLE:	Atmospheric Composition		
NAME OF COMPONENT	Viking Atmospheric Mass Spectrometer		
WEIGHT (lb)		8.5 lb	
DIMENSION (LWH) (in.)	7.5	7.5	13.25
	STANDBY	WARM-UP	OPERATION
TIME (min)		10 min	
POWER (W) (–V)	Peak 21.5 W	Average	16.5 W
DATA TYPE & NUMBER OF CHANNEL	1 digital	1 analog (ion pump current 0-40 MV)	
FREQUENCY OR SAMPLE RATE	16 bit bytes @ 50 bytes/sec		
ACCURACY OR NO. BITS			
COMMAND CHANNELS	7	ORIENTATION	N/A
NO. BITS	800/sec	FOV	

Cognizant Organization:
Viking Project Office
Langley Research Center
Hampton, Virginia 23365

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F) TBD MAGNETIC FIELD TBD

RADIATION (PARTICLE) TBD (RF) TBD

LIGHTING N/A

STABILIZATION/POINTING ACCURACY N/A

THERMAL OUTPUT (W) TBD OTHER OUTPUT N/A

SPECIAL INTERFACE OR SUPPORT:

PD-DO-9-72 (OT)

EXPERIMENT TITLE:

NAME OF COMPONENT	Active Biology (Viking)		
WEIGHT (lb)		24	
DIMENSION (LWH) (in.)	10	11	9.5
	STANDBY	WARM-UP	OPERATION
TIME (min)	N/A		
POWER (W) (–V)	Avg. 9.63 W	Peak 73.0 W	(does not include thermal control)
DATA TYPE & NUMBER OF CHANNEL	Digital No. of Channels TBD		
FREQUENCY OR SAMPLE RATE	16 kbps		
ACCURACY OR NO. BITS	TBD		
COMMAND CHANNELS	32	ORIENTATION	N/A
NO. BITS	TBD	FOV	N/A

Cognizant Organization:
Viking Project Office
Langley Research Center
Hampton, Virginia 23365

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F) 50 + 90° F MAGNETIC FIELD TBD

RADIATION (PARTICLE) TBD (RF) TBD

LIGHTING Internal lighting for pyrolytic release and light scattering.

STABILIZATION/POINTING ACCURACY N/A

THERMAL OUTPUT (W) TBD OTHER OUTPUT TBD

SPECIAL INTERFACE OR SUPPORT:

1. No more than 20% of surface sample shall have been heated in excess of 40° C.

2. Special contamination control and sterility are required.

3. Nutrient solutions must be maintained above freezing temperatures.

PD-DO-9-72 (OT)

EXPERIMENT TITLE: Gas Chromatograph/Mass Spectrometer

NAME OF COMPONENT	GC/MS-Viking		
WEIGHT (lb)	13		
DIMENSION (LWH) (in.)	14.25	9.5	10
	STANDBY	WARM-UP	OPERATION
TIME (min)	TBD		
POWER (W) (–V)	Organic Analysis: 60 W or -85-W Peak Atmospheric Analysis: 10 W or 16.5-W Peak Ion Pump 2 W or -10-W Peak		
DATA TYPE & NUMBER OF CHANNEL	Digital		
FREQUENCY OR SAMPLE RATE	TBD		
ACCURACY OR NO. BITS			

COMMAND CHANNELS 25 commands ORIENTATION N/A

NO. BITS Orig. Anal. 10^7/Analysis; Atmos. Anal. 210 K FOV N/A

Cognizant Organization:
Viking Project Office
Langley Research Center
Hampton, Virginia 23365

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F) TBD MAGNETIC FIELD TBD

RADIATION (PARTICLE) TBD (RF) TBD

LIGHTING N/A

STABILIZATION/POINTING ACCURACY N/A

THERMAL OUTPUT (W) TBD OTHER OUTPUT TBD

SPECIAL INTERFACE OR SUPPORT:

Organic contamination cannot exceed 10^{-8} -gm/gm sample.

PD-DO-9-72 (OT)

EXPERIMENT TITLE: Surface Sampler

NAME OF COMPONENT	Sampler	N/A	N/A
WEIGHT (lb)	20	N/A	N/A
DIMENSION (LWH) (in.)	12 × 10 × 20	N/A	N/A
	STANDBY	WARM-UP	OPERATION
TIME (min)	10	N/A	5+
POWER (W) (–V)	5	N/A	15
DATA TYPE & NUMBER OF CHANNEL	5 ch	N/A	10 ch
FREQUENCY OR SAMPLE RATE	8 bps	N/A	4000 bps
ACCURACY OR NO. BITS	----	N/A	---------

COMMAND CHANNELS 20 ORIENTATION N/A

NO. BITS 8 bit/ch FOV Access to Surface

Cognizant Organization:
Viking Project Office
Langley Research Center
Hampton, Virginia 23365

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F) -40/+257 F MAGNETIC FIELD N/A

RADIATION (PARTICLE) N/A (RF) N/A

LIGHTING As required for viewing operation of sampler

STABILIZATION/POINTING ACCURACY N/A

THERMAL OUTPUT (W) Unknown OTHER OUTPUT N/A

SPECIAL INTERFACE OR SUPPORT:

1. Requires easy, accurate access to objects on lunar surface.
2. Requires preprogrammed instructions.
3. Must place sample analysis device on the surface.
4. Requires operator control at Mission Control Center during operation.

PD-DO-9-72 (OT)

EXPERIMENT TITLE:	Inorganic Analysis Experiment		
NAME OF COMPONENT	Alpha Backscatter/X-ray Fluorescence Spectrometer		
WEIGHT (lb)	11 lb (includes deployment mechanism)		
DIMENSION (LWH) (in.)	0.2 ft^3 (volume)		
	STANDBY	WARM-UP	OPERATION
TIME (min)			
POWER (W) (–V)	0.5 W night survival		3 W continuous
DATA TYPE & NUMBER OF CHANNEL			
FREQUENCY OR SAMPLE RATE			
ACCURACY OR NO. BITS			
COMMAND CHANNELS		ORIENTATION	
NO. BITS		FOV	10^4 bits/day

Cognizant Organization:

Planetology Program Office, Code SL
NASA Headquarters
Washington, D.C. 20546

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F) -40 to +50° C opr.
-188 to +135° C nonoperating

MAGNETIC FIELD

RADIATION (PARTICLE) (RF)

LIGHTING

STABILIZATION/POINTING ACCURACY

THERMAL OUTPUT (W) OTHER OUTPUT

SPECIAL INTERFACE OR SUPPORT:

1. On lander or surface (surface preferred).

2. Requires radioisotopic sources (Cm-242, Cf-254, Es-254, or Po-210) at 50 millicurie strengths at time of analysis.

EXPERIMENT TITLE: Soil Water and Volatile Mineral Determination

NAME OF COMPONENT: Differential Scanning Calorimeter - Effluent Gas Analyzer (DSC-EGA)

WEIGHT (lb): 5 lb

DIMENSION (LWH) (in.):
Mechanical Package: 2.5 × 3.75 × 2.75
Electronic Package: 3.25 × 4.25 × 1.75

	STANDBY	WARM-UP	OPERATION
TIME (min)	10	N/A	75 min
POWER (W) (–V)	2	N/A	5 to 15 (peaks)
DATA TYPE & NUMBER OF CHANNEL	7 channel		
FREQUENCY OR SAMPLE RATE	Measurements at 5-sec intervals		
ACCURACY OR NO. BITS	-		

COMMAND CHANNELS: -   ORIENTATION:

NO. BITS: -   FOV:

Cognizant Organization:
Planetology Program Office, Code SL
NASA Headquarters
Washington, D.C. 20546

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F): 100 to +75 F   MAGNETIC FIELD: N/A

RADIATION (PARTICLE): N/A   (RF): N/A

LIGHTING: N/A

STABILIZATION/POINTING ACCURACY: N/A

THERMAL OUTPUT (W): unknown   OTHER OUTPUT: none

SPECIAL INTERFACE OR SUPPORT:

1. Requires soil sample delivered at Mars ambient temperature.
2. Ovens and sample must be kept at Mars ambient temperature until oven power is turned on.
3. Video viewing of sample desirable when taken and during oven loading.

PD-DO-9-72 (OT)

EXPERIMENT TITLE: Age-Dating of Planets or Cosmochronology

NAME OF COMPONENT	Ion Microprobe Mass Analyzer (IMMA)		
WEIGHT (lb)			
DIMENSION (LWH) (in.)			
	STANDBY	WARM-UP	OPERATION
TIME (min)			
POWER (W) (—V)			
DATA TYPE & NUMBER OF CHANNEL			
FREQUENCY OR SAMPLE RATE			
ACCURACY OR NO. BITS			
COMMAND CHANNELS		ORIENTATION	
NO. BITS		FOV	

Cognizant Organization:
Planetology Program Office, Code SL
NASA Headquarters
Washington, D.C. 20546

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F) ____ MAGNETIC FIELD ____

RADIATION (PARTICLE) ____ (RF) ____

LIGHTING ____

STABILIZATION/POINTING ACCURACY ____

THERMAL OUTPUT (W) ____ OTHER OUTPUT ____

SPECIAL INTERFACE OR SUPPORT:

PD-DO-9-72 (OT)

EXPERIMENT TITLE: Combined Pulsed Neutron Experiment (CPNE)

NAME OF COMPONENT: Pulsed Neutron Gen., He^3/Cd Detec. NaI Detec.,

WEIGHT (lb): 13 lb includes generator, power supply, detectors, & shielding

DIMENSION (LWH) (in.): 36 in. L by 4 in. D

	STANDBY	WARM-UP	OPERATION
TIME (min)			
POWER (W) (–V)			
DATA TYPE & NUMBER OF CHANNEL			
FREQUENCY OR SAMPLE RATE			
ACCURACY OR NO. BITS			

COMMAND CHANNELS ______ ORIENTATION ______

NO. BITS ______ FOV ______

Cognizant Organization:
Apollo Lunar Exploration, Code MAL
NASA Headquarters
Washington, D.C. 20546

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F) ______ MAGNETIC FIELD ______

RADIATION (PARTICLE) ______ (RF) ______

LIGHTING ______

STABILIZATION/POINTING ACCURACY ______

THERMAL OUTPUT (W) ______ OTHER OUTPUT ______

SPECIAL INTERFACE OR SUPPORT:

1. Deployment device may be required.

2. Modes of analysis (6): Activation
   Inelastic neutron scatter
   Passive (gamma and neutron)
   Thermal neutron capture
   Die-away (epithermal)
   Die-away (thermal).

3. Components.

PD-DO-9-72 (OT)

EXPERIMENT TITLE: Radiative Capture — Delay Experiment (RCDE)

NAME OF COMPONENT	Cf-254/Be or CF-252	neutron source,	Ge(Li) detector
WEIGHT (lb)			
DIMENSION (LWH) (in.)			
	STANDBY	WARM-UP	OPERATION
TIME (min)			
POWER (W) (–V)			
DATA TYPE & NUMBER OF CHANNEL			
FREQUENCY OR SAMPLE RATE			
ACCURACY OR NO. BITS			
COMMAND CHANNELS		ORIENTATION	
NO. BITS		FOV	

Cognizant Organization:

Apollo Lunar Exploration Program, Code MAL
NASA Headquarters
Washington, D.C. 20546

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F) ______ MAGNETIC FIELD ______

RADIATION (PARTICLE) ______ (RF) ______

LIGHTING ______

STABILIZATION/POINTING ACCURACY ______

THERMAL OUTPUT (W) ______ OTHER OUTPUT ______

SPECIAL INTERFACE OR SUPPORT:

1. Deployment may be required.

2. Modes of Analysis (3): Passive
Capture (includes inelastic scatter)
Decay.

3. Components.

EXPERIMENT TITLE: Microscopy

NAME OF COMPONENT			
WEIGHT (lb)	7		
DIMENSION (LWH) (in.)			
	STANDBY	WARM-UP	OPERATION
TIME (min)			
POWER (W) (–V)			
DATA TYPE & NUMBER OF CHANNEL			
FREQUENCY OR SAMPLE RATE			
ACCURACY OR NO. BITS			
COMMAND CHANNELS		ORIENTATION	
NO. BITS		FOV	

Cognizant Organization:
Planetology Group
Jet Propulsion Laboratory
Pasadena, California

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F) ______ MAGNETIC FIELD ______

RADIATION (PARTICLE) ______ (RF) ______

LIGHTING ______

STABILIZATION/POINTING ACCURACY ______

THERMAL OUTPUT (W) ______ OTHER OUTPUT ______

SPECIAL INTERFACE OR SUPPORT:

PD-DO-9-72 (OT)

EXPERIMENT TITLE: Mineralogic And Inorganic Analysis Experiment

NAME OF COMPONENT	X-Ray diffractometer/spectrometer		
WEIGHT (lb)	15		
DIMENSION (LWH) (in.)			
	STANDBY	WARM-UP	OPERATION
TIME (min)			
POWER (W) (–V)			
DATA TYPE & NUMBER OF CHANNEL			
FREQUENCY OR SAMPLE RATE			
ACCURACY OR NO. BITS			
COMMAND CHANNELS		ORIENTATION	
NO. BITS		FOV	

Cognizant Organization:

Planetology Program Office, Code SL
NASA Headquarters
Washington, D.C. 20546

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (^{o}F) ____ MAGNETIC FIELD ____

RADIATION (PARTICLE) ____ (RF) ____

LIGHTING ____

STABILIZATION/POINTING ACCURACY ____

THERMAL OUTPUT (W) ____ OTHER OUTPUT ____

SPECIAL INTERFACE OR SUPPORT:

1. Surface deployment preferred.

2. Can be coupled with bioscience sample retriever.

PD-DO-9-72 (OT)

EXPERIMENT TITLE: Inorganic Analysis Experiment

NAME OF COMPONENT: X-Ray Spectrometer utilizing four proportional counters

WEIGHT (lb): 3 lb (includes electronics and sample assembly and storage)

DIMENSION (LWH) (in.) ______ ______ ______

	STANDBY	WARM-UP	OPERATION
TIME (min)			
POWER (W) (–V)			
DATA TYPE & NUMBER OF CHANNEL			
FREQUENCY OR SAMPLE RATE			
ACCURACY OR NO. BITS			

COMMAND CHANNELS ______ ORIENTATION ______

NO. BITS ______ FOV ______

Cognizant Organization:
Planetology Program Office, Code SL
NASA Headquarters
Washington, D.C. 20546

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F) ______ MAGNETIC FIELD ______

RADIATION (PARTICLE) ______ (RF) ______

LIGHTING ______

STABILIZATION/POINTING ACCURACY ______

THERMAL OUTPUT (W) ______ OTHER OUTPUT ______

SPECIAL INTERFACE OR SUPPORT:

1. Can be integrated into the GC/MS sample train.
2. Heat sterilizable.
3. Sample size, 1-in. diameter or greater.
4. X-ray sources are radioisotopes Fe-55 and Cd-109.
5. Requires four detectors (two filtered and two unfiltered).

PD-DO-9-72 (OT)

EXPERIMENT TITLE: Imagery

NAME OF COMPONENT	360-deg Panoramic	Facsimile	Camera
WEIGHT (lb)	0.7 lb		
DIMENSION (LWH) (in.)	6-in. L by 1-in. D		
	STANDBY	WARM-UP	OPERATION
TIME (min)			30 sec
POWER (W) (—V)			1.5 W (14 Vdc)
DATA TYPE & NUMBER OF CHANNEL	Analogue		
FREQUENCY OR SAMPLE RATE	54 kHz (108 000 elements/sec)		
ACCURACY OR NO. BITS			
COMMAND CHANNELS	Digital -2 ch	ORIENTATION	
NO. BITS		FOV	

Cognizant Organization:

Planetology Group, Mission and Payload
Planning Office (PD-MP-P)
Marshall Space Flight Center
Huntsville, Alabama 35812

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F) -10 to +150 MAGNETIC FIELD

RADIATION (PARTICLE) (RF)

LIGHTING 25-10 000 ft Lamberts Dynamic Range

STABILIZATION/POINTING ACCURACY has to remain still for 30 sec.

THERMAL OUTPUT (W) OTHER OUTPUT

SPECIAL INTERFACE OR SUPPORT:

1. Required to view horizon for full 360 deg and include portion of front and rear of MARV. Use as backup for and in conjunction with MARV TV for driving, sampler operation, and other functions.
2. Require relative orientation data for camera tilt (provided by MARV).
3. Analog-to-digital converter is optional.
4. Control functions:
   Select on-off; monitor on-off
   Activate scan
   Pitch and yaw
   Video display (near real time), film recorder, and data storage at MCC
5. Require two vertical positions for 360-degree stereo pairs

PD-DO-9-72 (OT)

EXPERIMENT TITLE: Electric Field

NAME OF COMPONENT	Receiver		
WEIGHT (lb)	15		
DIMENSION (LWH) (in.)	10 × 10 × 10		
	STANDBY	WARM-UP	OPERATION
TIME (min)			1
POWER (W) (–V)			3
DATA TYPE & NUMBER OF CHANNEL			Analog, 10 ch
FREQUENCY OR SAMPLE RATE			0.5 to 30 MHz
ACCURACY OR NO. BITS			10 bits

COMMAND CHANNELS	5	ORIENTATION	
NO. BITS		FOV	

Cognizant Organization:

Pioneer Project Office
Ames Research Center
Moffett Field, California 94035

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F) -22 to +140 MAGNETIC FIELD

RADIATION (PARTICLE) (RF)

LIGHTING

STABILIZATION/POINTING ACCURACY

THERMAL OUTPUT (W) 3 OTHER OUTPUT

SPECIAL INTERFACE OR SUPPORT:

Minimize radio-frequency interference (RFI) with other equipment.

PD-DO-9-72 (OT)

EXPERIMENT TITLE:	Electric Field		
NAME OF COMPONENT	Transmitter		
WEIGHT (lb)	20		
DIMENSION (LWH) (in.)	10 × 20 × 20		
	STANDBY	WARM-UP	OPERATION
TIME (min)			5
POWER (W) (—V)			3
DATA TYPE & NUMBER OF CHANNEL			Digital, 10 ch
FREQUENCY OR SAMPLE RATE			0.5 to 30 MHz
ACCURACY OR NO. BITS			10 bits
COMMAND CHANNELS	5	ORIENTATION	
NO. BITS		FOV	

Cognizant Organization:
Pioneer Project Office
Ames Research Center
Moffett Field, California 94035

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F) -22 to +140 MAGNETIC FIELD

RADIATION (PARTICLE) (RF)

LIGHTING

STABILIZATION/POINTING ACCURACY

THERMAL OUTPUT (W) 3 OTHER OUTPUT

SPECIAL INTERFACE OR SUPPORT:
Minimize RFI with other equipment.

PD-DO-9-72 (OT)

EXPERIMENT TITLE: Gravimetry

NAME OF COMPONENT	Gravimeter		
WEIGHT (lb)	20		
DIMENSION (LWH) (in.)	24 × 8 × 8		
	STANDBY	WARM-UP	OPERATION
TIME (min)			5
POWER (W) (–V)			15
DATA TYPE & NUMBER OF CHANNEL			Digital, 2 ch
FREQUENCY OR SAMPLE RATE			
ACCURACY OR NO. BITS			10 bits
COMMAND CHANNELS	3	ORIENTATION	
NO. BITS		FOV	

Cognizant Organization
Apollo Project Office
Manned Space Center
Houston, Texas

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F) 14 to +122 MAGNETIC FIELD

RADIATION (PARTICLE) (RF)

LIGHTING

STABILIZATION/POINTING ACCURACY

THERMAL OUTPUT (W) 15 OTHER OUTPUT

SPECIAL INTERFACE OR SUPPORT:

Deploy to surface at selected locations.

PD-DO-9-72 (OT)

EXPERIMENT TITLE: Magnetic Field

NAME OF COMPONENT	Station Magnetometer		
WEIGHT (lb)	15		
DIMENSION (LWH) (in.)	20 × 10 × 10		

	STANDBY	WARM-UP	OPERATION
TIME (min)			1
POWER (W) (—V)			8 W avg., 12-W peak
DATA TYPE & NUMBER OF CHANNEL			Digital - 3 ch
FREQUENCY OR SAMPLE RATE			100 bps
ACCURACY OR NO. BITS			10 bits

COMMAND CHANNELS	8	ORIENTATION	±1 deg
NO. BITS		FOV	

Cognizant Organization:

Space Physics Branch, MS-240-4
Ames Research Center
Moffett Field, California 94035

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F) -22 to +140 MAGNETIC FIELD ≦ 0.2 gamma

RADIATION (PARTICLE) ______ (RF) ______

LIGHTING ______

STABILIZATION/POINTING ACCURACY ______

THERMAL OUTPUT (W) 8.0 OTHER OUTPUT ______

SPECIAL INTERFACE OR SUPPORT:

PD-DO-9-72 (OT)

EXPERIMENT TITLE:	Magnetic Field		
NAME OF COMPONENT	Traverse Magnetometer		
WEIGHT (lb)	10		
DIMENSION (LWH) (in.)	20 × 10 × 10		
	STANDBY	WARM-UP	OPERATION
TIME (min)			1
POWER (W) (–V)			8 W avg., -12-W peak
DATA TYPE & NUMBER OF CHANNEL			Digital - 3 ch
FREQUENCY OR SAMPLE RATE			100 bps
ACCURACY OR NO. BITS			10 bits
COMMAND CHANNELS	8	ORIENTATION	±1 deg
NO. BITS		FOV	

Cognizant Organization:
Space Physics Branch, MS-240-4
Ames Research Center
Moffett Field, California 94035

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F) -22 to +140 MAGNETIC FIELD ≦ 0.2 gamma

RADIATION (PARTICLE) ____ (RF) ____

LIGHTING ____

STABILIZATION/POINTING ACCURACY ____

THERMAL OUTPUT (W) 8.0 OTHER OUTPUT ____

SPECIAL INTERFACE OR SUPPORT:

PD-DO-9-72 (OT)

EXPERIMENT TITLE: Seismometry

NAME OF COMPONENT	Passive Seismometer		
WEIGHT (lb)	20		
DIMENSION (LWH) (in.)	10 × 10 × 12		
	STANDBY	WARM-UP	OPERATION
TIME (min)			
POWER (W) (–V)			8 W avg., 13-W peak
DATA TYPE & NUMBER OF CHANNEL			Digital, 6 ch
FREQUENCY OR SAMPLE RATE			300 bps
ACCURACY OR NO. BITS			10 bits
COMMAND CHANNELS		ORIENTATION	
NO. BITS		FOV	

Cognizant Organization:
Apollo Program Office
Manned Space Center
Houston, Texas

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F) -22 to +140 MAGNETIC FIELD

RADIATION (PARTICLE) (RF)

LIGHTING

STABILIZATION/POINTING ACCURACY

THERMAL OUTPUT (W) 8 OTHER OUTPUT

SPECIAL INTERFACE OR SUPPORT:

PD-DO-9-72 (OT)

EXPERIMENT TITLE: Wind Speed and Direction

NAME OF COMPONENT	Anemometer		
WEIGHT (lb)			
DIMENSION (LWH) (in.)			
	STANDBY	WARM-UP	OPERATION
TIME (min)			
POWER (W) (–V)			
DATA TYPE & NUMBER OF CHANNEL			
FREQUENCY OR SAMPLE RATE			
ACCURACY OR NO. BITS			
COMMAND CHANNELS		ORIENTATION	
NO. BITS		FOV	

Cognizant Organization:
Viking Project Office
Langley Research Center
Hampton, Virginia 23365

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F) ______ MAGNETIC FIELD ______

RADIATION (PARTICLE) ______ (RF) ______

LIGHTING ______

STABILIZATION/POINTING ACCURACY ______

THERMAL OUTPUT (W) ______ OTHER OUTPUT ______

SPECIAL INTERFACE OR SUPPORT:

PD-DO-9-72 (OT)

EXPERIMENT TITLE: Ambient Temperature

NAME OF COMPONENT	Thermocouple		
WEIGHT (lb)			
DIMENSION (LWH) (in.)			
	STANDBY	WARM-UP	OPERATION
TIME (min)			
POWER (W) (–V)			
DATA TYPE & NUMBER OF CHANNEL			
FREQUENCY OR SAMPLE RATE			
ACCURACY OR NO. BITS			
COMMAND CHANNELS		ORIENTATION	
NO. BITS		FOV	

Cognizant Organization:
Viking Project Office
Langley Research Center
Hampton, Virginia 23365

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F) ______ MAGNETIC FIELD ______

RADIATION (PARTICLE) ______ (RF) ______

LIGHTING ______

STABILIZATION/POINTING ACCURACY ______

THERMAL OUTPUT (W) ______ OTHER OUTPUT ______

SPECIAL INTERFACE OR SUPPORT:

PD-DO-9-72 (OT)

EXPERIMENT TITLE: Atmospheric Pressure

NAME OF COMPONENT	Transducer		
WEIGHT (lb)			
DIMENSION (LWH) (in.)			
	STANDBY	WARM-UP	OPERATION
TIME (min)			
POWER (W) (–V)			
DATA TYPE & NUMBER OF CHANNEL			
FREQUENCY OR SAMPLE RATE			
ACCURACY OR NO. BITS			
COMMAND CHANNELS		ORIENTATION	
NO. BITS		FOV	

Cognizant Organization:
Viking Project Office
Langley Research Center
Hampton, Virginia 23365

ENVIRONMENTAL CONSTRAINTS

TEMPERATURE LIMITS (°F) ______ MAGNETIC FIELD ______

RADIATION (PARTICLE) ______ (RF) ______

LIGHTING ______

STABILIZATION/POINTING ACCURACY ______

THERMAL OUTPUT (W) ______ OTHER OUTPUT ______

SPECIAL INTERFACE OR SUPPORT:

PD-DO-9-72 (OT)

APPROVAL

RECOMMENDATIONS RELATIVE TO THE SCIENTIFIC MISSIONS OF A MARS AUTOMATED ROVING VEHICLE (MARV)

Coordinated by Program Development

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

Hugh J. Dudley

HUGH J. DUDLEY
Chief, Planetology Group

Herman P. Gierow

HERMAN P. GIEROW
Director, Mission and Payload Planning Office

James T. Murphy

JAMES T. MURPHY
Director, Program Development

Page Intentionally Left Blank

DISTRIBUTION

INTERNAL

DIR
DR. REES

DEP-T
DR. LUCAS

AD-S
DR. STUHLINGER

PD-DIR
MR. MURPHY
MR. JEAN
DR. MRAZEK

PD-MP-DIR
MR. GIEROW

PD-MP-P
MR. DUDLEY
MR. SPENCER (24)

PD-DO-DIR
MRS. KOZUB

A&PS-MS-D
MR. GARRETT

A&PS-MS-I
MR. REMER

A&PS-MS-IP
MR. ZIAK (2)

A&PS-MS-IL
MISS ROBERTSON (8)

A&PS-MS-H
MR. AKENS

A&PS-PAT
MR. WOFFORD

A&PS-TU (6)

EXTERNAL

U.S. ARMY COLD REGIONS
RESEARCH AND ENGINEERING
LABORATORY
HANOVER, NEW HAMPSHIRE 03755
ATTN: DR. DUWAYNE M. ANDERSON (6)

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON D.C. 20242

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON D.C. 20242
ATTN: NYA/DR. FRANK CUTTITTA (6)

NASA AMES RESEARCH CENTER
SPACE SCIENCES DIVISION
MOFFETT FIELD, CALIFORNIA 94035
ATTN: DR. PALMER DYAL (6)

NASA HEADQUARTERS
WASHINGTON D.C. 20546
ATTN: DR. RICHARD YOUNG, CODE SL (6)
MR. STEVEN E. DWORNIK
COL. DON SENICH, CODE MAL (6)

CENTER OF ASTROGEOLOGY
601 EAST CEDAR AVENUE
FLAGSTAFF, ARIZONA 86001
ATTN: MR. HAROLD MASURSKY (6)
MR. ED WOLFE (6)
MR. ROBERT REGAN (6)

U.S. GEOLOGICAL SURVEY
601 EAST CEDAR AVENUE
FLAGSTAFF, ARIZONA 86001
ATTN: CHIEF, BRANCH OF ASTRO-GEOLOGIC STUDIES
CHIEF, BRANCH OF SURFACE PLANETARY EXPLORATION

SCIENTIFIC AND TECHNICAL INFORMATION FACILITY
COLLEGE PARK, MARYLAND 20740
ATTN: NASA REPRESENTATIVE
(S-AK/RKT) (25)