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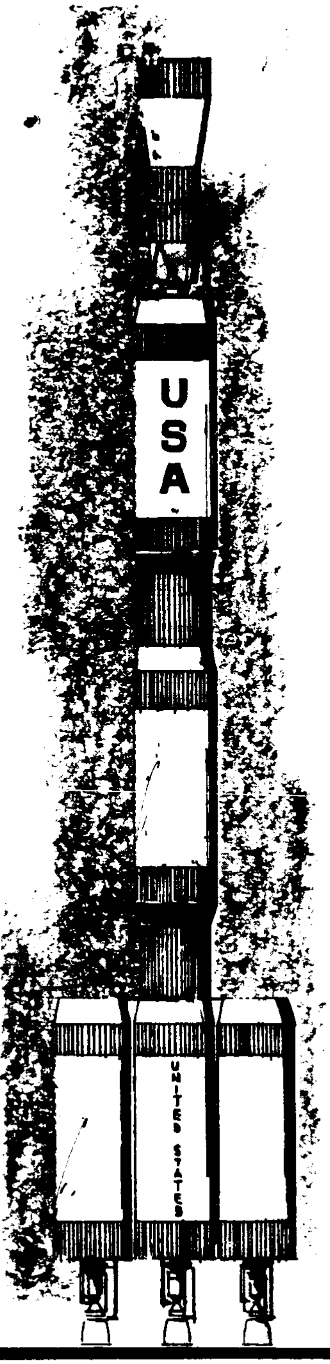

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INTEGRATED MANNED INTERPLANETARY SPACECRAFT CONCEPT DEFINITION

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Volume III
D2-113544-3-2

System Analysis
(part 2—Experiment Program)

The BOEING Company • Aerospace Group • Space Division • Seattle, Washington

NASA CR-66561

INTEGRATED MANNED INTERPLANETARY SPACECRAFT CONCEPT DEFINITION

FINAL REPORT

VOLUME III
SYSTEM ANALYSIS

PART 2
EXPERIMENT PROGRAM

D2-113544-3-2

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LANGLEY RESEARCH CENTER
Hampton, Virginia

NASA CONTRACT NAS1-6774

January 1968

AEROSPACE GROUP THE BOEING COMPANY SEATTLE, WASHINGTON

RECOMMENDED INTERPLANETARY MISSION SYSTEM

The recommended interplanetary mission system:

- Is flexible and versatile
- Can accomplish most of the available Mars and Venus missions
- Is highly tolerant to changes in environment, go-ahead dates, and funding.

It provides:

- Scientific and engineering data acquisition during all mission phases
- Analysis, evaluation, and transmission of data to Earth
- Return to Earth of Martian atmosphere and surface samples

The mission system is centered around the *space vehicle* which consists of the *space acceleration system* and the *spacecraft*.

The *space acceleration system* consists of five identical nuclear propulsion modules:

- Three in the Earth departure stage
- A single module in the planet deceleration stage
- A single module in the planet departure stage

Propellant is transferred between the stages, as necessary, to accommodate the variation in ΔV requirements for the different missions. This arrangement provides considerable discretionary payload capacity which may be used to increase the payload transported into the target planet orbit, the payload returning to the Earth, or both.

The *spacecraft* consists of:

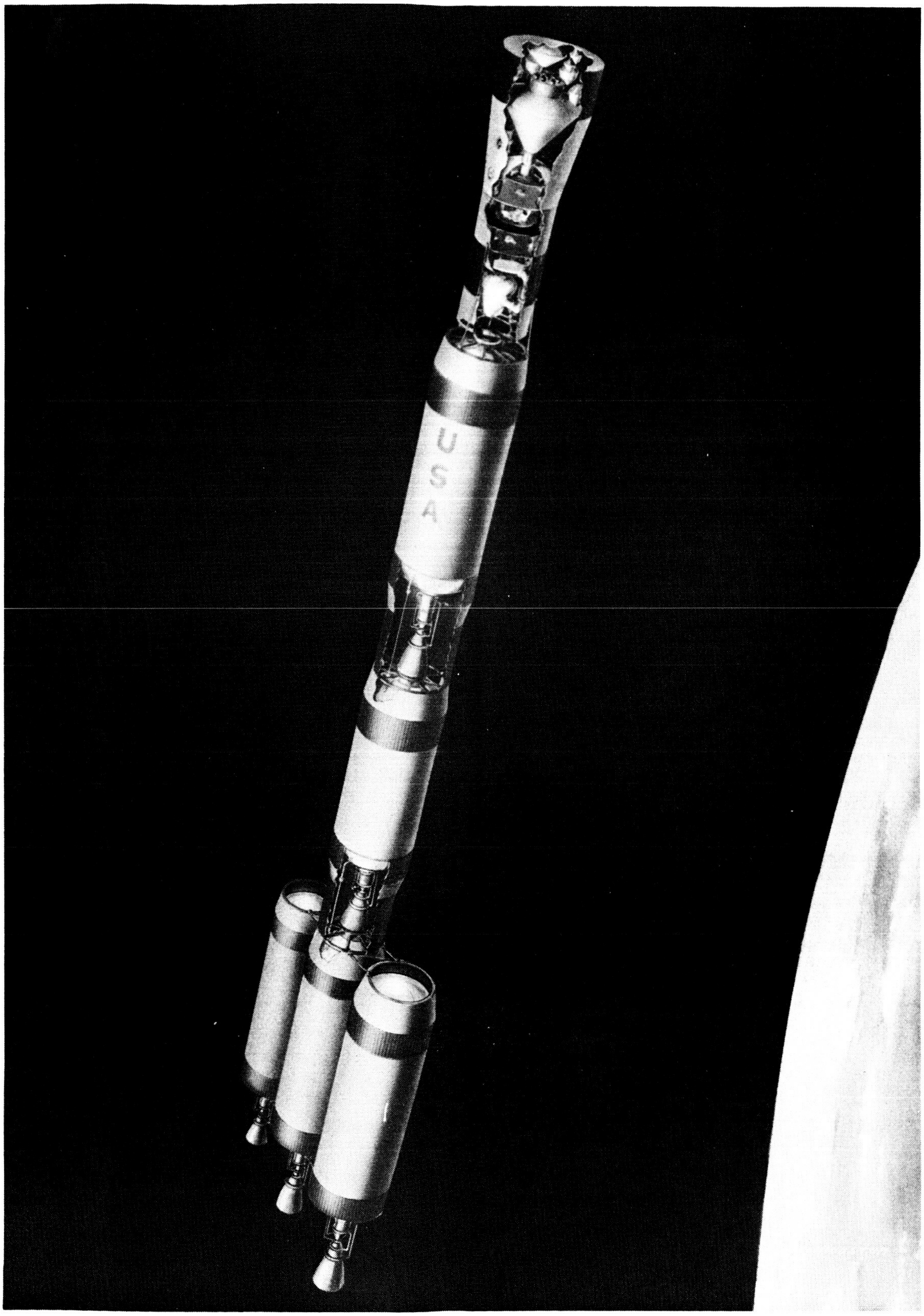
- A biconic Earth entry module capable of entry for the most severe missions
- An Apollo-shaped Mars excursion module capable of transporting three men to the Mars surface for a 30-day exploration and returning
- A mission module which provides the living accommodations, system control, and experiment laboratories for the six-man crew
- Experiment sensors and a planet probe module

The spacecraft and its systems have been designed to accomplish the most severe mission requirements. The meteoroid shielding, expendables, system spares, and mission-peculiar experiment hardware are off-loaded for missions with less stringent requirements.

The space vehicle is placed in Earth orbit by six launches of an uprated Saturn V launch vehicle which has four 156-inch solid rocket motors atttached to the first stage. Orbital assembly crew, supplies and mission crew transportation are accomplished with a six-man vehicle launched by a Saturn IB.

A new launch pad and associated facility modifications are necessary at Launch Complex 39 at Kennedy Space Center to accommodate:

- The weight and length of the uprated Saturn V
- The launch rate necessary for a reasonable Earth orbit assembly schedule
- The solid rocket motors used with the uprated Saturn V
- The requirement for hurricane protection at the launch pad.



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ABSTRACT

This document describes the rationale developed to select the scientific payloads for the manned planetary space program. The experiment program was based on a categorization of planetary observables into classes of information which could be analyzed in terms of their interrelationships and their predictability to permit a knowledge base projection into the 1975-1990 time period. The method of projection and the method of selecting the measurements and observations to be performed during the various phases of the mission are described.

The document also describes the scientific payloads incorporated into the spacecraft designed during the Integrated Manned Interplanetary Spacecraft Concept Definition (IMISCD) study. The description is in terms of their design impact on the spacecraft as well as the measurements that they make in satisfying the objectives of the manned missions to Mars and Venus.

The payloads have been categorized as (1) basic instruments common to the Mars and Venus orbit missions, (2) unmanned probes and orbiters required to supplement the manned instruments, (3) analytical and support hardware for the surface, and (4) concepts of manned laboratories aboard the spacecraft. The contributions that man makes to the program are developed in terms of decisions necessary in the acquisition of data.

FOREWORD

This study was performed by The Boeing Company for the National Aeronautics and Space Administration, Langley Research Center, under Contract NAS1-6774. The Integrated Manned Interplanetary Spacecraft Concept Definition Study was a 14-month effort to determine whether a variety of manned space missions to Mars and Venus could be accomplished with common flight hardware and to define that hardware and its mission requirements and capabilities. The investigation included analyses and trade studies associated with the entire mission system: the spacecraft; launch vehicle; ground, orbital, and flight systems; operations; utility; experiments; possible development schedules; and estimated costs.

The results discussed in this volume are based on extensive total system trades which can be found in the remaining volumes of this report. Attention is drawn to Volume II which has been especially prepared to serve as a handbook for planners of future manned planetary missions.

The final report is comprised of the following documents, in which the individual elements of the study are discussed as shown:

Volume	Title	Part	Report No.
I	Summary		D2-113544-1
II	System Assessment and Sensitivities		D2-113544-2
III	System Analysis	Part 1--Missions and Operations	D2-113544-3-1
		Part 2--Experiment Program	D2-113544-3-2
IV	System Definition		D2-113544-4
V	Program Plans and Costs		D2-113544-5
VI	Cost-Effective Subsystem Selection and Evolutionary Development		D2-113544-6

The accompanying matrix is a cross-reference of subjects in the various volumes.

● Primary Discussion

X Summary or Supplemental Discussion

	DOCUMENTATION						
STUDY AREAS	Volume I/D2-113544-1 Summary Report	Volume II/D2-113544-2 System Assessment and Sensitivities	Volume III/D2-113544-3 System Analysis Part 1 - Missions and Operations	Part 2 - Experiment Program	Volume IV/D2-113544-4 System Definition	Volume V/D2-113544-5 Program Plans and Cost	Volume VI/D2-113544-6 Cost Effective Subsystem Selection and Evolutionary Development
MISSION ANALYSIS	X		●				
Trajectories and Orbits	X	X	●		X		
Mission and Crew Operations	X	X	●	●	X		
Mission Success and Crew Safety Analysis	X	X	●		X		
Environment	X	X	●				
Scientific Objectives	X	X		●			
Manned Experiment Program	X	X		●			
Experiment Payloads and Requirements	X	X		●			
DESIGN ANALYSIS	X				●		
Space Vehicle	X				●		
Spacecraft Systems	X				●		
Configurations	X	X			●		
Subsystems	X	X			●		
Redundancy and Maintenance	X				●		
Radiation Protection	X				●		
Meteoroid Protection	X				●		
Trades	X				●		
Experiment Accommodations	X				●		
Space Acceleration Systems	X				●		
Primary Propulsion--Nuclear	X	X			●		
Secondary Propulsion--Chemical	X	X			●		
System and Element Weights	X	X			●		
IMIEO Computer Program					●		
Earth Orbit Operations and Assembly Equip.	X	X			●		
Earth Launch Vehicles	X	X			●		
Facilities	X	X			●		
System Trades	X				●		
Space Acceleration--Earth Launch Vehicle	X				●		
Space Acceleration Commonality	X				●		
Space Vehicle--Artificial Gravity	X				●		
SYSTEM AND PROGRAM ASSESSMENT	X	●					
System Capability	X	●		●		X	
Design Sensitivities	X	●			X		
Program Sensitivities	X	●					
Adaptability to Other Space Programs	X	●					
Impact on Other Space Programs	X	●					
Technology Implications	X	●					
Future Sensitivity Studies	X	●					
Program Schedules and Plans	X	X				●	
Test Program	X	X				●	
Facilities Plan	X	X				●	
Program Cost	X	X				●	
Cost Effective Subsystems							●

ABBREVIATIONS

A.U.	Astronomical unit
bps	Bits per second
C/O	Checkout
CM	Command module (Apollo program)
CMG	Control moment gyro
CONJ	Conjunction
CSM	Command service module (Apollo program)
ΔV	Incremental velocity
DSIF	Deep Space Instrumentation Facility
DSN	Deep Space Network
⊕	Earth
ECLS	Environmental control life support system
ECS	Environmental control system
EEM	Earth entry module
ELV	Earth launch vehicle
EMOS	Earth mean orbital speed
EVA	Extravehicular activity
FY	Fiscal year
fps	feet/sec
GSE	Ground support equipment
IBMC	Inbound midcourse correction
IMIEO	Initial mass in Earth orbit
IMISCD	Integrated Manned Interplanetary Spacecraft Concept Definition
I_{sp}	Specific impulse
IU	Instrument unit
KSC	Kennedy Space Center
λ'	Ratio of propellant weight to overall propulsion module weight
LC	Launch complex
LC-34 & -37	Launch complexes for Saturn IB
LC-39	Launch complex for Saturn V
LH_2	Liquid hydrogen
LO	Long
LO_2 or LOX	Liquid oxygen
LRC	Langley Research Center

ABBREVIATIONS (Continued)

LSS	Life support system
LUT	Launch umbilical tower
♂	Mars
MEM	Mars excursion module
MIMIEO	Minimum initial mass in Earth orbit
MM	Mission module
MODAP	Modified Apollo
MSC	Manned Spacecraft Center (Houston)
MSFC	Marshall Space Flight Center (Huntsville)
MTF	Mississippi Test Facility
NAC	Letters designate the type of acceleration systems First letter--Earth orbit depart Second--planetary deceleration Third--planet escape Example: NAC = Nuclear Earth depart/aerobraker deceleration at planet/chemical planet escape
OBMC	Outbound midcourse correction
OPP	Opposition
OT	Orbit trim
P/L	Payload
PM-1	Propulsion module, Earth orbit escape
PM-2	Propulsion module, planet braking
PM-3	Propulsion module, planet escape
RCS	Reaction control system
SA	Space acceleration
S/C	Spacecraft
S-IC	First stage of Saturn V
S-II	Second stage of Saturn V
SH	Short
SOA	State of art
SRM	Solid rocket motor
S/V	Space vehicle
SWBY	Swingby

ABBREVIATIONS (Continued)

T/M	Telemetry
TVC	Thrust vector control
VAB	Vehicle assembly building
♀	Venus
V_{HP}	Hyperbolic excess velocity

CONVERSION FACTORS

English to International Units

Physical Quantity	English Units	International Units	Multiply by
Acceleration	ft/sec^2	m/sec^2	$3.048x10^{-1}$
Area	ft^2	m^2	$9.29x10^{-2}$
	in^2	m^2	$6.45x10^{-4}$
Density	lb/ft^3	Kg/m^2	16.02
	lb/in^3	Kg/m^2	$2.77x10^4$
Energy	Btu	Joule	$1.055x10^3$
Force	lbf	Newton	4.448
Length	ft	m	$3.048x10^{-1}$
	n.mi.	m	$1.852x10^3$
Power	Btu/sec	watt	$1.054x10^3$
	Btu/min	watt	17.57
	Btu/hr	watt	$2.93x10^{-1}$
Pressure	Atmosphere	$Newton/m^2$	$1.01x10^3$
	lbf/in^2	$Newton/m^2$	$6.89x10^3$
	lbf/ft^2	$Newton/m^2$	47.88
Speed	ft/sec (fps)	m/sec	$3.048x10^{-1}$
Volume	in^3	m^3	$1.64x10^{-5}$
	ft^3	m^3	$2.83x10^{-2}$

CONTENTS

CONTENTS (Continued)

1.0 INTRODUCTION

The primary objective of any space mission to the planets is to obtain scientific data contributing to an understanding of the origin and evolution of the universe, of the galaxies which compose it, of our solar system, and of the life that may be present within it. Manned interplanetary space flight offers an unparalleled opportunity to conduct a wide range of measurements and observations on the surface and in orbit about other planets to contribute to these overall objectives. But it becomes necessary to develop an experiment program rationale to define in a practical way what experiments should be performed and what information is necessary to take effective advantage of manned interplanetary flight. That was the primary purpose of this part of the study--to develop a rational and objective process for experiment definition.

The additional objectives of this portion of the study were as follows:

1) Include consideration of present and proposed unmanned space program contributions and their possible application to the broad objectives associated with manned planetary missions;
2) Develop a logical planetary experimental program to meet the broad scientific objectives for manned exploration of Mars and Venus with emphasis on the roles of man;
3) Determine general sensor and instrument requirements in each measurement area and generate specific example payloads for use in the system design and performance studies;
4) Identify those areas which may be critical and recommend appropriate research and test programs, including those things that should be included in planning Earth-orbit programs.

The process that was developed for defining planetary exploration programs is outlined in Section 2.0. Each step of the process is then presented in Sections 3.0 through 6.0 using the results obtained during the present study to illustrate its application. The rationale for the process is relatively simple, but the detailed analysis necessary to the successful application of the process is complex and requires a great deal of effort by highly skilled people. Ultimately it will be successful only if inputs and judgments are provided by the scientific community. For this reason, the specific results should be viewed as an example, not an end product. The advantage of the process is that it provides a way of interpreting a very large spectrum of individual scientific goals or experiments in terms of overall accomplishment for alternative programs.

The selection of specific payloads and the definition of other system requirements is contained in Section 7.0.

Section 8.0 covers the technology implications and the Earth orbital test requirements.

2.0 THE PROCESS

The process that was developed in the study is diagrammed in Figure 2.0-1. The number in each block refers to a section in this report.

The first step expanded on the basic questions concerning the origin and evolution of the solar system and the search for life by defining five categories of scientific investigation and subdividing these into a total of 49 classes of observations and measurements essential to an understanding of the basic questions. Once these were defined they were analyzed in several ways to provide inputs to each remaining step in the overall process.

A summary of all measurement and observation requirements for each information category and class has been made in circular format (Exhibit A). An explanation of the information levels in the Experiment Program Definition Wheel is shown in Exhibit B, and the wheel for the Mars orbital mission is shown in Exhibit C at the back of this document.

Next, an estimate was made of the present knowledge level in each of the 49 classes of observations and measurements. This estimate demonstrates the gross inadequacies of present knowledge related to the broad objectives and provides a logical base for planning future unmanned and manned programs.

It is logical to next consider all of the modes of investigation and experimentation that can contribute knowledge. Although the methodology developed and used in the study is applicable to as broad a survey as might be desired, for the present study the modes considered were restricted to one postulated program of unmanned flights to Mars and Venus and to a manned program including two flights to orbit Venus and three flights to Mars with both an orbiter and a manned lander. Stay times for the manned missions were restricted to 40 days and extended surface mobility on Mars was not considered. These alternatives could well be a subject for future study.

For the postulated unmanned program an estimate was made of its contribution to the knowledge base. Using the same methodology it would be possible to iterate on this step to provide an insight into the tradeoffs available and to try to identify the limitations of the unmanned programs.

The next step defined the manned programs in detail and attempted in so doing to identify the specific role of man. Specific measurement and observation objectives were defined and these were ordered according to expected return.

Finally, the measurement techniques for the manned missions were identified and specific payload compliments were estimated. Related mission requirements were also identified. With these definitions of manned missions it was possible, using the methodology developed in the study to assess the potential contribution of the manned missions to the knowledge about the basic scientific questions. Again, it is possible to iterate around the selected definition of manned missions in order to evaluate tradeoffs with respect to planet stay time, crew size, surface mobility, etc.

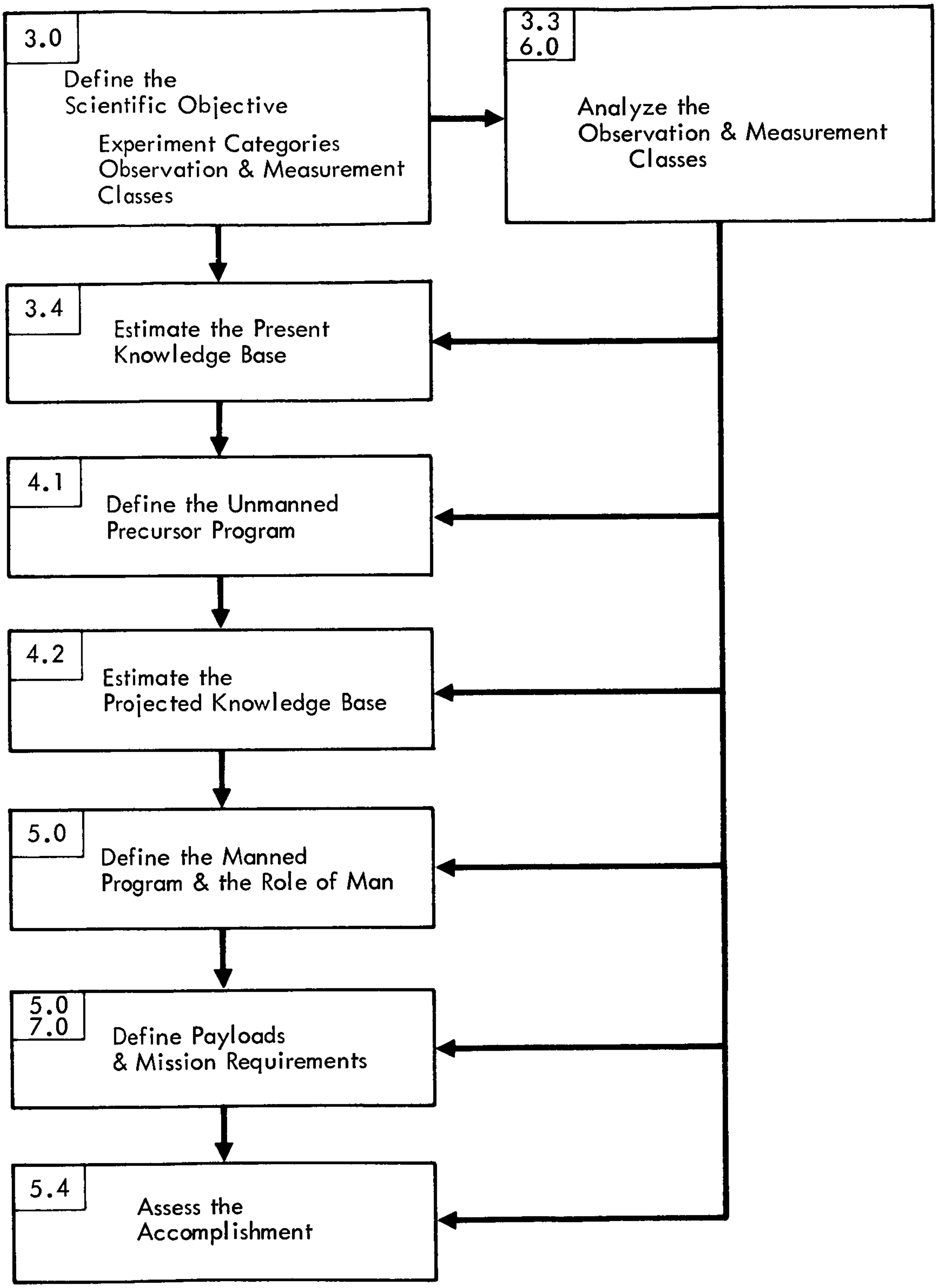
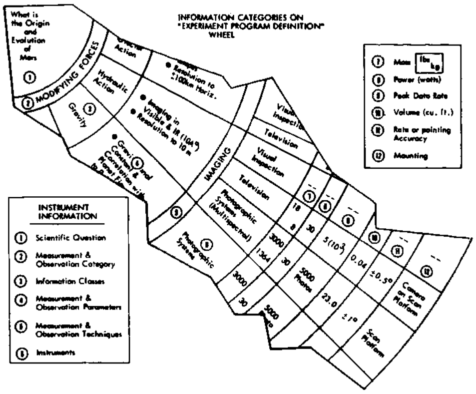


Figure 2.0-1: THE PROCESS



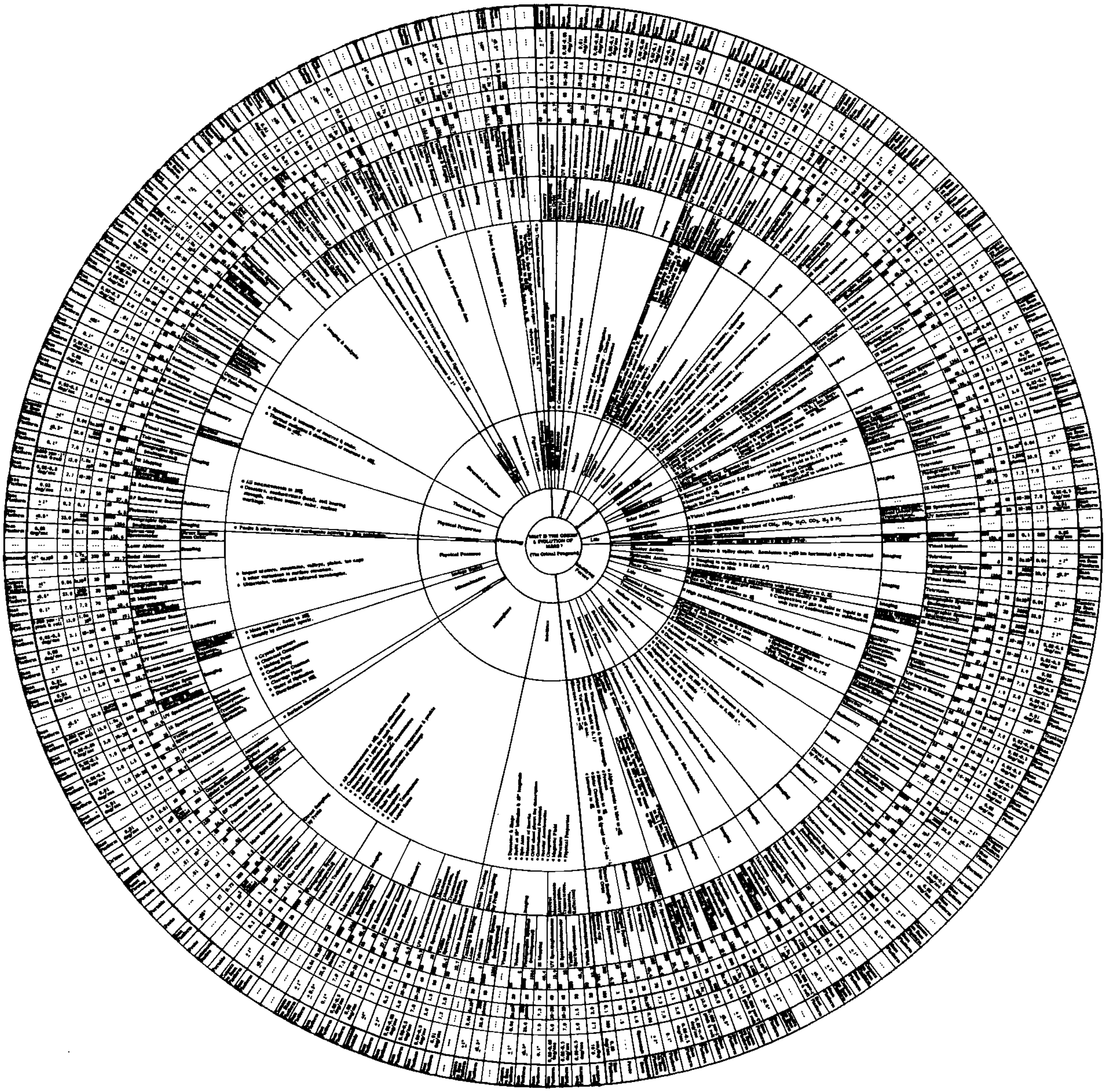


Exhibit A: EXPERIMENT PROGRAM DEFINITION MARS ORBITAL

3.0 EXPERIMENT PROGRAM CATEGORIES AND OBSERVATION AND MEASUREMENT CLASSES

The first step was to state specifically the basic objective of scientific space exploration and then to further define the specific experiment program categories relating to the planets Mars and Venus. This section further expands these categories into classes of observations and measurements necessary to the development of knowledge within each category. The results constitute a definition of the problem which is the basis of all further analysis.

3.1 EXPERIMENT PROGRAM CATEGORIES

A review was made of the scientific objectives and proposed experiments stated in the following reports:

1) NAS SP-88 NASA 1965 Summer Conference on Lunar Explorations and Science,

2) SSD NAS NRC 1964-1965 Study on Biology and the Exploration of Mars, and

3) SSB NAS NRC 1965 Study of Space Research--Direction for the Future.

It was found that the objectives fall into three logical knowledge areas: (1) solar system origin and evolution, (2) space resources, and (3) technology, as illustrated in Figure 3-1. This study emphasized the solar system's origin and evolution as the major planetary scientific objective. Aspects of the other objectives were introduced when the manned missions were planned, taking advantage of the fact that the in-transit phase offers the opportunity to include experiments in astronomy, astrophysics and solar system observation. Engineering objectives were also introduced in relation to mission operational requirements and future missions.

The next step was to establish measurement and observation categories relative to the planets that would be required to help determine solar system origin and evolution. The selected categories, also shown in Figure 3-1 are, in the order of their importance: 1) planetology, 2) environment, 3) composition, 4) modifying forces, and 5) life. This selection was based on the following rationale.

First, the definition of the problem is the study of a planet to determine its origin and evolution. The question of "What is a planet?" then establishes planetology as the most important class of information.

The second question which requires investigation is "What is the environment or surrounding media?" since this bears directly on three different levels of investigation:

1) It permits an evaluation of the techniques required to study the planet; i.e., engineering problems such as how to land on the surface and how to see through the atmosphere.

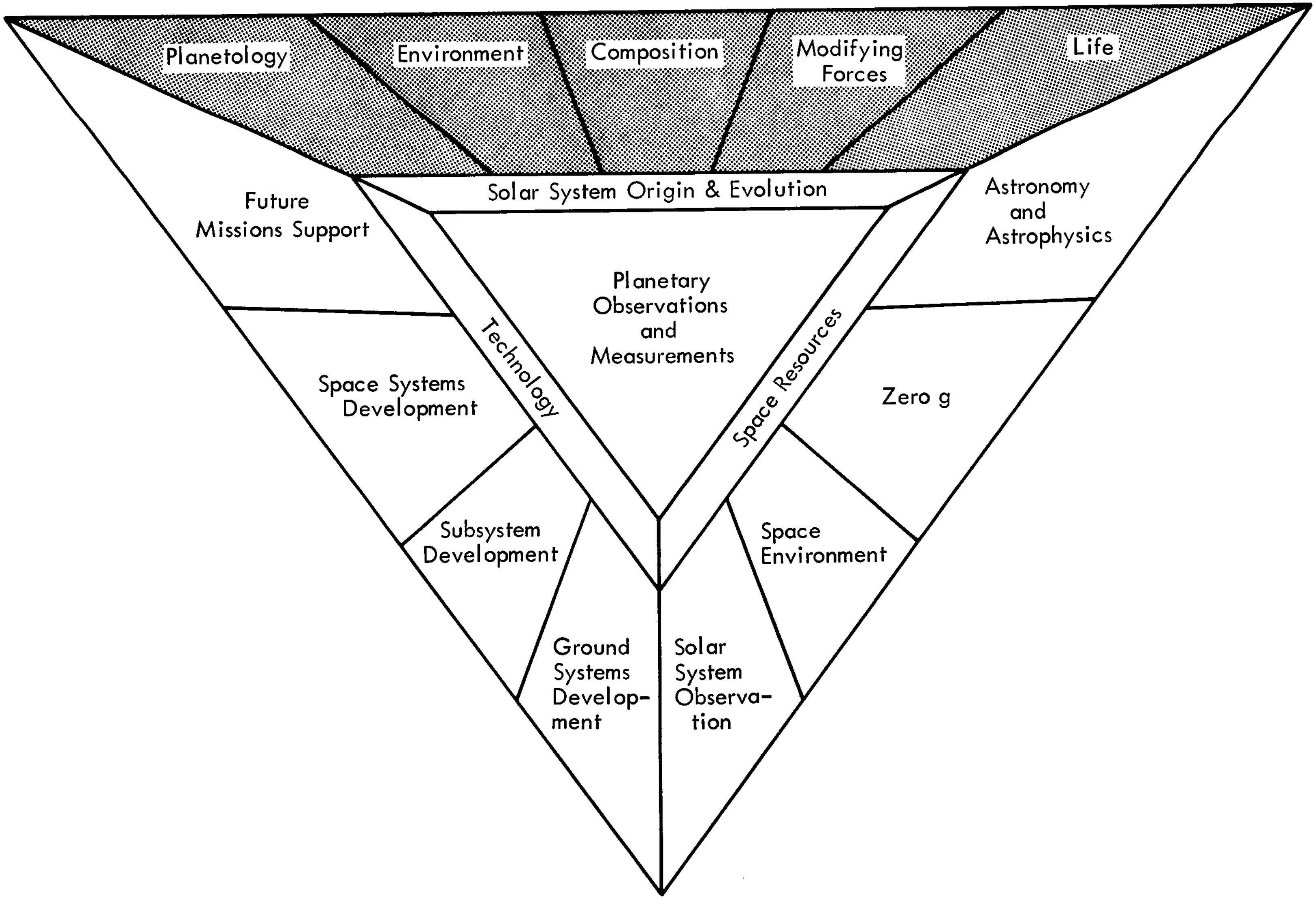


Figure 3-1: PLANETARY SCIENTIFIC OBJECTIVES

2) It gives a clue to the formation of the solar system as a whole.
3) It establishes the ranges of interacting forces.

Once past the barrier of the surrounding media and the interactions between the planet and its environment, the next question of importance "What is its composition?" becomes one of isolating the planet's constituents; not only to identify them but also to provide an insight to their interrelationships with the environment and similar parameters here on Earth.

The fourth subdivision--modifying forces--is engendered because of the interactions permitted or brought about by the environment and the constituents acting either singly, such as solar electromagnetic radiation; or together, such as seismic activities involving the formation of chemical compounds, phase changes and the presence of gravity.

Life, the anomaly in a physical world, can be investigated much more meaningfully after planetology, the environments, the composition, and the modifying forces are understood to some degree. In fact, the study of these four categories will significantly contribute to the study of life. This ordering places a different priority on these categories than man's basic curiosity about himself would assign, but the ordering appears logical from the point of view of obtaining an answer to the basic question, "What is the origin and evolution of the solar system?"

Finally, it should be noted that the investigation of planetology and the environments are essential to the design of the spacecraft and missions required to investigate the other categories.

3.2 OBSERVATION AND MEASUREMENT CLASSES

The definition of observation and measurement classes is a key step; all subsequent analysis depends on a clearly defined set. The following discussions summarize the derivation of the classes. A more detailed discussion of the classes is contained in Appendix B.

3.2.1 PLANETOLOGY

What is a Planet?

This question suggests at least the eight characteristics derived from the following rationale:

When looking at a planet the first obvious answer is that it is round with certain surface features. Hence the *figure* of a planet is suggested as a class. (Not all bodies of the solar system need necessarily be round.) The *physical features* may have a contribution to make to the story of its evolution and hence these become the second class. Perhaps next in order may be the appearance of a *satellite* or moon. This then can be considered another class of knowledge about the planet if not about the solar system. The features of the planet are often obscured by clouds or a haze and hence an *atmosphere* is suggested. The figure of the planet indicates a *structure* with *physical properties* such as density, conductivity and so on. The features of a planet also reveal the possible existence of shrinking and cracking and thus *seismicity* should be a characteristic. But seismicity suggests change and a clue to changing structures and changing features is the degree of *mineralization* apparent.

What are its bodily characteristics?

Other characteristics that planets appear to have are: 1) Its *gravitational field* which ties it to the sun and to all the other bodies of the solar system, 2) a *magnetic field*, at least for Earth, why not other planets?, 3) A *rotation* or spinning about an axis also seems characteristic. This spinning then implies the importance of 4) a *moment of inertia* which is dependent on a mass distribution or gravitational field.

Where is it?

The answer to this question suggests the *orbital parameters* as yet another class. Since these usually mean a distance and a velocity with respect to the sun, two other classes are suggested. These are 1) the planet's *thermal budget* and 2) its *moment of inertia*. This last has been included in the category previously established.

How old is it?

Age has been established as an additional class and, of course, is fundamental to answering the question of origin. If origins of planets occurred at different times under certain conditions then the *isotope ratios* are established as another possible characteristic of the planet.

The following table summarizes the classes of information established for the category *planetology*.

PLANETOLOGY

What:

- Figure
- Physical Features
- Satellites
- Atmosphere
- Structure
- Physical Properties
- Seismicity
- Mineralization

How Old:

- Age
- Isotope Ratios

Where:

- Orbital Parameters
- Thermal Budget

Other Characteristics:

- Gravitational Field
- Magnetic Field
- Rotation
- Moment of Inertia

3.2.2 ENVIRONMENT

The Orbit's Influence---Where a planet is with respect to the Sun implies an amount of *solar radiation* which is different for each planet. Since the orbit is elliptical *seasonal changes* are suggested. Two other classes influenced by the orbit are the *meteroid* micrometeoroid or interstellar dust and the *magnetic field* environments.

The Influence of The Shape and Its Rotation---Because a planet is a three dimensional body spinning in space the apparent environment is influenced by the rotation rate or *decimal* influences as well as by the tilt of its axis of rotation and its shape, and therefore the distance from the equator of the planet or its *latitude*.

The Microenvironment---The interaction of a number of factors as yet unknown in degree can produce a localized environment which may not be characteristic of the planet as a whole. The generic name, *micrometeorology*, has been applied to this statistical phenomenon and includes the local temperature, wind, atmosphere, cloud cover, pressure, precipitation and humidity, or its equivalent on the planet under investigation.

A further interaction is the radiation due to the *radioactive decay* and other nuclear phenomena present such as cosmic rays, which may be localized in their impact at any one time either due to distribution or to planet rotation.

The classes under environment are summarized in the following table.

ENVIRONMENT

Solar Radiation
Radioactive Decay
Meteoroid
Micrometeorology
Magnetic Field
Latitude
Seasonal
Diurnal

3.2.3 COMPOSITION

An obvious class under this category would be the chemical elements composing all material as we know it. But to differentiate the sources of these, several breakdowns within this class are suggested. The first, is the isotopic composition or *isotopes* of the chemical elements which would be present even if all planets were formed from the same chemical crucible. There may have been a difference originally and there is a different accumulation going on now simply because the number of protons (hydrogen nuclei) or alpha particles, i.e., *charged particles* reaching a specified volume in space is different. This can imply that there might be a major difference in the amount of H_2 or *molecular* gases present. The alpha particles, which are helium nuclei, suggest that there could be a difference in the *atomic elements* especially the noble gases among the planets.

Another category to be incorporated is that of the *mineral* composition of the planet. This appears to overlap that of mineralization in planetology but is considered to ask the question "What are the minerals?" that contribute to the degree of mineralization existing on the planet which may have resulted from the original formation of the planet as a molten mass. This category reveals a history of the planet's chemistry and is certainly significant in tracing the changes that have taken place in the arrangements of the chemical elements and their distribution since the formation of the planet. But not all chemical elements are combined as minerals or are free as gases; hence a final category of *chemicals* must be postulated.

In summary the classes are:

COMPOSITION

Charged Particles	Atomic Elements	Molecular Elements
Isotopes	Chemicals	Minerals

3.2.4 MODIFYING FORCES

Initial Modifications---Initially, planetary matter was modified by an increasing gravitational field simply because it all collected. Hence *gravity* must be the single most important force identifiable today. Gravity in turn produced *temperature changes* which resulted in a further differentiation of the planets constituents in the form of *chemical reactions*. As the planetary gravitational field grew, it produced a *phase change* in the minerals either directly as pressure or indirectly as temperature. Phase changes have been included because at specific temperature-pressure relationships the physical properties of most chemicals are drastically modified. These phase changes may be responsible for the *volcanic activity* of a planet which certainly modifies the outer surface of the planet along with *seismic activity*. Both, of course, may be outgrowths of the gravitational field and variations in structure or density of the planet. The outpouring of lava on the surface of the planet can cause the planet to readjust its shape and this leads to the *isostatic forces* which tend to keep the gravitational field uniform over the surface of the planet. A complex interaction of a cooling planet, with a variation in density and the isostatic forces can produce additional deformations in the planet's crust. To this force has been given the name *diastrophism*.

The External Forces---Forces which have their source external to the planet are designated as external forces. Gravity can be classified as an external force because of the proximity of other planetary bodies. It has been included in the above under initial modifications. Two other external forces are the *solar radiation* interacting with the planet and its constituents and the meteorites striking the surface. Composition and shape changes are produced by meteorites; hence *meteoroid impacts* are included.

The Inherent Forces---An inherent force is one that is produced as a result of the composition or the presence of another action. For example, *nuclear reactions* produce modifications due to heat and actual chemical composition change. These played a major role in changing the planet's composition as a whole and the structure of the planet since the formation of the solar system. As the planet evolved other forces came into play almost directly as a result of an evolving atmosphere. First *wind* and its ability to transport matter as well as heat from one area to another produces changes. Second liquid precipitation under the influence of gravity and the wind changes huge areas through the redeposition of surface material through *hydraulic action*. Another force which is the result of the atmosphere is that due to *glacier action* which has caused major surface changes on Earth. Whether both of the latter, exist on another planet is not known. But it can be assumed that during the evolution of a planet both of these are present to different degrees.

A final modifying force is *life* which on Earth has changed both the atmosphere and the crust.

In a sense, all of these forces interacting to varying degrees in present time produce the microenvironment of the planet. However, these must be evaluated and their periods of interaction determined to establish the origin and evolution of a planet.

A list of the modifying forces is presented below:

MODIFYING FORCES

Initial Modifiers:

- Gravity
- Chemical Reactions
- Temperature Changes
- Phase Changes
- Volcanic Activity
- Isostatic Forces
- Seismic Activity
- Diastrophism

External Forces:

- Solar Radiation
- Meteroid Impacts

Inherent Forces:

- Nuclear Reactions
- Surface Winds
- Hydraulic Action
- Glacier Action
- Life

3.2.5 LIFE

The last category, life, must be structured in terms of what can be detected now rather than on any classification devised to catalog its various forms here on Earth. If it is detected on any planet and the other life influencing characteristics are isolated then a more comprehensive breakdown must be made. At present, biologists have simple concepts of how certain organic compounds can be synthesized. They do not have sufficient information to project life concepts to another planet since only the diverse life forms on earth have been studied and they are not necessarily understood. The large forms of life whether as aggregates in the form of lichens on rocks or elephants in forests are designated as *macroscopic* life.

This class should be discernible from in orbit about the planet by the changing patterns which it produces as it goes through its cycles of growth and reproduction. The second class of life requires a microscope to detect and the culture of specimens to study hence it is designated as *microscopic* life. A third class is based on the detection of past life forms and this has been called *fossil* life. Evidence for this may be found in the sediments on the planet. A final category which can be defined is based on the assumption that life originated with certain gaseous compounds under the influence of an external energy source. This class has been designated as *protoorganic* life.

In summary then there are four classes of life defined by their detectability:

LIFE

Macroscopic	Microscopic
Fossil	Protoorganic

Table 3-1 summarizes the entire set of observation and measurement classes by experiment program categories.

TABLE 3-1

CLASSES WITHIN EACH OF THE EXPERIMENT PROGRAM CATEGORIES

Planetology	
Orbital Parameters	Rotational Parameters
Figure of Planet	Moments of Inertia
Gravitational Field	Magnetic Field
Structural Features	Thermal Budget
Physical Properties	Seismicity
Physical Features	Isotope Ratios
Mineralization	Age
Atmosphere	Satellites
Modifying Forces	
Solar Radiation	Meteroid Impacts
Isostatic Forces	Seismic Activity
Diastrophism	Volcanic Activity
Surface Winds	Temperature Changes
Chemical Reactions	Life
Phase Changes	Gravity
Hydraulic Action	Glacier Action
Nuclear Reactions	
Composition	
Charged Particles	Atomic Elements
Molecular Elements	Minerals
Chemicals	Isotopes
Environment	
Diurnal	Seasonal
Latitude	Magnetic
Micrometeorological	Meteoroid
Radioactive	Solar Radiation
Life	
Macroscopic	Microscopic
Protoorganic	Fossil

3.3 ANALYSIS OF THE OBSERVATION AND MEASUREMENT CLASSES

A review of the set of observation and measurement classes reveals that two kinds of interdependency exist; i.e., a measurement addressed to any one class may require that observations be made in another class in order to properly interpret the information. Inversely, any one class may need to be measured to support the measurements of many other classes.

Further analysis reveals that the observations and measurements can be classified according to whether they are stable with time, vary predictably with time, or randomly with time, and how these stability properties are affected by the location of the instrument; i.e., in orbit about the planet or on the surface.

The interdependencies and the stability properties were analyzed in several ways to provide inputs to succeeding steps in the process.

(1) An analysis can be made to help identify those observations and measurements that can provide the most total information relative to all categories of knowledge--or for that matter, relative to any one category that might for other reasons be given priority. For instance, if the search for life were assigned a top priority, those measurements and observations which would produce the most information relative to life could be identified. However, in the present study the five categories were given equal weight. This analysis can be interpreted as a selection of measurement priorities for a mission, assuming that resources (payload weight, power, volume, or crew size) are limited. A set of priorities was generated in the present study (Section 5.2).

(2) Given a particular mission definition, the analysis can be used to help estimate the contribution of that mission to the knowledge base. This was done in the present study for a specific precursor unmanned program and for an arbitrarily selected manned program consisting of two orbiter flights to Venus and three orbiter-lander flights to Mars (Sections 4.0 and 5.4).

(3) The analysis can be used to help assess the contribution of Man. An example of this use was developed in the present study (Section 5.3).

The derivation and details of these analyses are given in Section 6.0

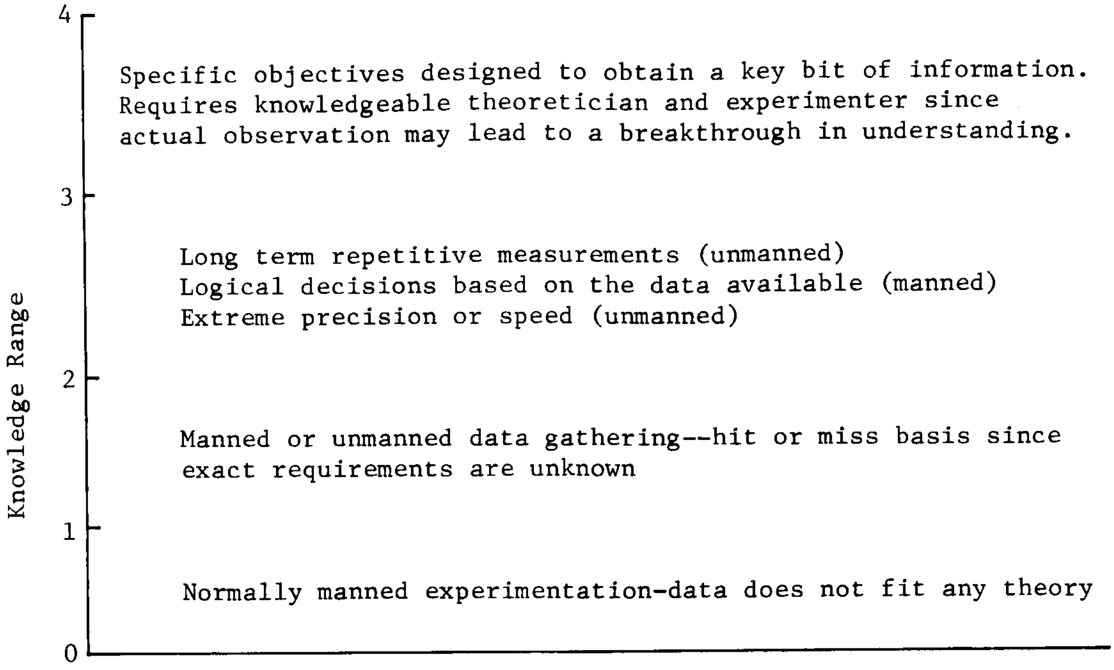
3.4 PRESENT KNOWLEDGE BASE

A knowledge range scale was developed and is briefly summarized in Figure 3-2. Elaboration on the meaning of the scale is contained in Section 6.8. Using data and theories from the literature, the 49 observation and measurement classes were assigned a maximum and minimum value on the knowledge scale.

Table 3-2 is indicative of available data for Venus. It shows the classes describing the planet for the present time frame. They are divided between those identified as broad exploration and important questions. This format suggests how the basic data can be tabulated for each planet and for each class of factors. It is easily seen that the knowledge base illustrates a series of apparently unrelated facts which could not lead to verification of theory about the origin and evolution of the planet.

The data from Table 3-2 has been used in the preparation of the maximum and minimum knowledge levels shown in Table 3-3 for Venus. Similar data for Mars resulted in the predictions given for that planet. The average of the maximum values is summarized for Mars and Venus in Figures 3-3 and 3-4.

The present average knowledge on Mars, 1.5, indicates that most data permits a "yes" or "no" answer with some value ranges, with the possible exception of life. The average for Venus, 1.1, indicates that few meaningful relations are available.



Specific objectives designed to obtain a key bit of information. Requires knowledgeable theoretician and experimenter since actual observation may lead to a breakthrough in understanding.

Long term repetitive measurements (unmanned)
Logical decisions based on the data available (manned)
Extreme precision or speed (unmanned)

Manned or unmanned data gathering--hit or miss basis since exact requirements are unknown

Normally manned experimentation-data does not fit any theory

Data Required

0-1 Data permits ambiguous interpretations, conjectures, is generally open ended.

Example: Atmosphere of Venus is all CO_2
Temperature of planet is 600°K

1-2 Data permits "yes or no" answers with a value range

Example: Temperature range on October 18 was -140°C at an altitude of 60 miles which increased linearly to 270°C on the surface.

2-3 Data permits correlation or conclusions of degree

Example: The atmosphere of Venus is composed of 90% CO_2, 0.5% H_2O, 0.6% O_2 with the remainder either A or N_2.

3-4 Data verifies theory or permits the development of a new theory.

Figure 3-2: KNOWLEDGE RANGE SCALE

Table 3-2: PRESENT KNOWLEDGE BASE FORMAT FOR VENUS

Parameter	Value
Orbital Parameters	
Synodic Period (S.D.)	583.93
Perihelion (A.U.)	0.718418
Aphelion (A.U.)	0.728264
Eccentricity	0.006791
Sidereal Period (S.D.)	224.701
Orbital Velocity (mi/sec)	21.7
Orbit Inclination	3°23'
Mean Orbit Radius (A.U.)	.72
Solar Constant (E=1)	2.0
Albedo	0.76
Diameter (MI)	7,700
Period of Rotation (hours)	720-5520
Pole - Inclination	?
Oblateness	?
Mass (E=1)	0.817
Gravity (E=1)	.86
Density (H_2O = 1)	4.86-5.15
Atmospheric Pressure (atmos.)	3-200
Temperature (°F)	8.8-800
Magnetic Field	?
Atmospheric Constituents	?
Structure - Atmosphere	?
Radiation Belts	?
Structure - Planet	?
Composition	?
AGE	?

Table 3-3:A PRESENT KNOWLEDGE BASE

Knowledge Base	IMISCD Categories																																																					
	Planetology																	Modifying Forces																Composition							Environment									Life				
	Orbital Parameters	Rotational Parameters	Figure of Planet	Moments of Inertia	Gravitational Field	Magnetic Field	Structural Features	Thermal Budget	Physical Properties	Seismicity	Physical Features	Isotope Ratios	Mineralization	Age	Atmosphere	Satellites	Summary	Solar Radiation	Meteoroid Impacts	Isostatic Forces	Seismic Activity	Diastrophism	Volcanic Activity	Surface Winds	Temperature Changes	Chemical Reactions	Life	Phase Changes	Gravity	Hydraulic Action	Glacier Action	Nuclear Reactions	Summary	Charged Particles	Atomic Elements	Molecular Elements	Minerals	Chemicals	Isotopes	Summary	Diurnal	Seasonal	Latitude	Magnetic Field	Micrometeorology	Meteoroid	Radioactive Decay	Solar Radiation	Summary	Macroscopic	Microscopic	Protoorganic	Fossil	Summary
Mars																																																						
Present—Maximum	3	3	2	2	3	1	2	2	2	1	2	1	1	1	2	2		2	1	1	1	1	1	1	2	1	1	2	2	1	1	1		2	2	2	1	1	1		2	2	2	1	1	2	1	2		1	1	1	1	
Minimum	2	2	1	1	2	0	1	1	1	0	1	0	0	0	1	1		1	0	0	0	0	0	0	1	0	0	1	1	0	0	0		1	1	1	0	0	0		1	1	1	0	0	1	0	1		0	0	0	0	
Venus																																																						
Present—Maximum	3	2	1	1	3	1	1	2	1	1	1	1	1	1	1	1		2	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1		1	1	1	1	1	1	1	2		1	1	1	1	
Minimum	2	1	0	0	2	0	0	1	0	0	0	0	0	0	0	0		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0	0	1		0	0	0	0	

Code

0-1 Data ambiguous or nonexistent.

1-2 Approximate ranges are established; degree of change apparent.

2-3 Complete present ranges established; permits theory formulation.

3-4 Permits theory verification or rejection; origin not necessarily established.

21 Table 3-3:A

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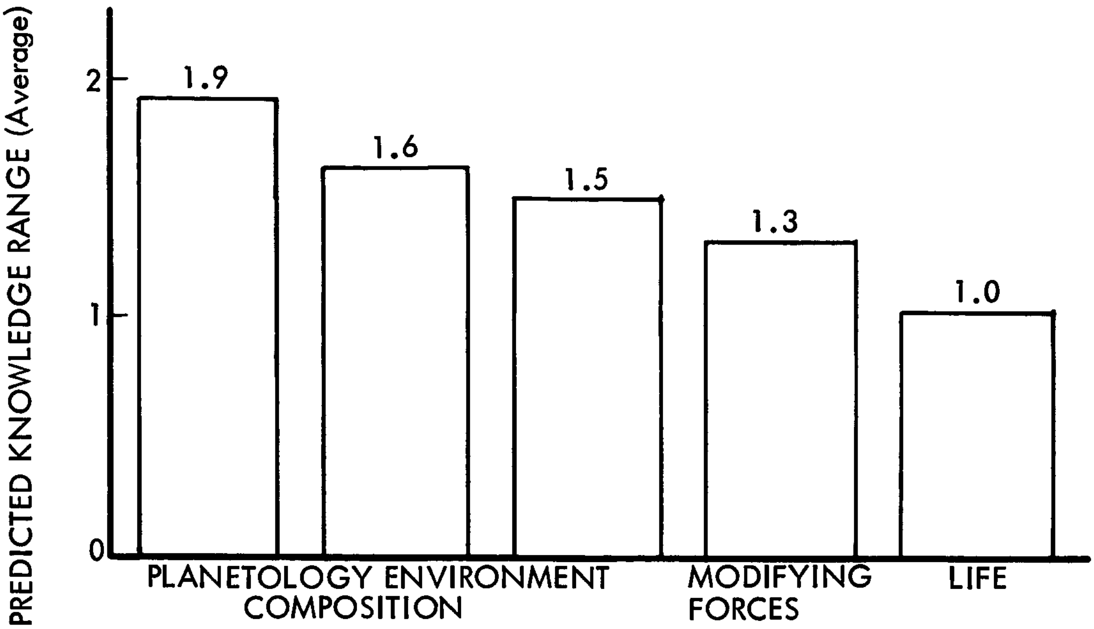

Figure 4.2-9: PRESENT IMISCD KNOWLEDGE BASE — MARS

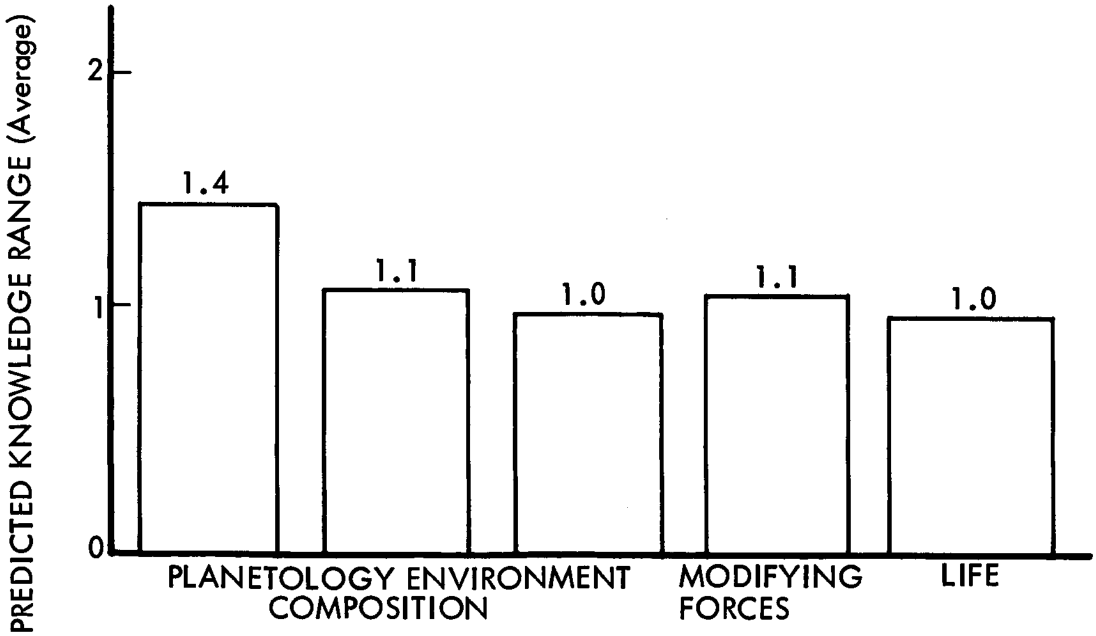

Figure 3-4: PRESENT IMISCD KNOWLEDGE BASE — VENUS

4.0 UNMANNED PRECURSOR PROGRAMS AND THE PROJECTED KNOWLEDGE BASE

The current space programs were reviewed along with others which have been studied or are in initial planning stages. An approximate schedule for these space programs is given in Table 4-1. Some of these programs may be combined with others or deleted altogether. However, it is important to indicate the areas in which the knowledge base may be expanded. Table 4-2 summarizes the more important programs contributing to the origin and evolution of the solar system. Table 4-3 details the primary and secondary objectives of the programs presently making measurements and observations. Some of the possible programs of the future and the contributions which they can make are discussed in more detail in Appendix A. From the programs summarized here and with the help of the instrumentation data contained in Appendix A, an unmanned precursor program was defined, as follows:

MARS	VENUS
1) One unmanned flyby	1) Two unmanned flybys
2) One orbiter	2) Two probes or hard landers
3) One soft lander	
4) Two probes or hard landers	

Assuming successful completion of these programs, projections were made for the knowledge base, using the methodology discussed in Section 6.0. The projections are shown in Figure 4-1 for Mars and in Figure 4-2 for Venus. The present knowledge base has been included for comparison. Table 4-4 gives the projections for each of the 49 observation and measurement categories.

Table 4-1: CURRENT SOLAR SYSTEM EXPLORATION

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Comets											
Interstellar Environment	OA →	→	→	→	→	→ RA →	→	→	→	→	→ T →
Solar System Environment	E → OA → OS →	→ → →	→ A → → →	→ → → →	→ → →	→ → →					T →
Sun	OS →	→	→	→ $\boxed{S}$	→	→					
Other Planets								G-J			V →
Venus	M-II		M-V					M B →	→	→	→ V →
Mars	OA → M	→	→	→					M		V →
Lunar Probes	L_o →	S → →	→ →	→	Ⓐ →	→	→	→	→	→	→

E = Explorer
A = Atlantic
M = Mariner
B = Balloon Probe
T = Orbiting Telescope
OA = (Orbiting Astronomy Observatory
Ⓐ = Apollo

G-J = Galactic Jupiter
S = Surveyor (S$_T$ Surveyor Test)
V = Planetary Explorer
OS = (Orbiting Solar Observatory)
RA = Radio Astronomy
L_o = Lunar Orbiter
$\boxed{S}$ = Sunblazer

Table 4-2: PRESENT PROGRAMS

	SUN	INTRANSIT SPACE & STARS	SOLAR SYSTEM BODIES
Size, Shape, Volume	OSO-II, -III		Vanguard I Mariner I, V Mariner 1969, 1971 Lunar Orbiter
Composition	OSO-I, -II, -III	Explorer I-VIII, IX, XII, XVII, XIX, XXIII, XXVI Pioneer IV-V Vanguard IV Ariel OAO Ranger VI	Pioneer IV Ranger VI, VII, VIII, IX Lunar Orbiter Pegasus, OGO Surveyor
Velocity Distance			Explorer VII Mariner II, IV, V Ranger V, VII, VIII, IX
Energy Production Mechanism	OSO-I, -II, -III Sunblazer	OAO	
Radiated Energy (Erg/Sec)	Explorer XI Sunblazer OSO-I, -II, -III	Explorer VII, XI, XVIII	Mariner II
Magnetic Field ($\Upsilon = 10^{-5}$ gauss)	Explorer X, XXVIII	Pioneer V Explorer X, XVII, XV, XVI, XXI Ariel Ranger	Explorer VI Vanguard III Mariner II, IV, V
Mass Density (Earth ~ 1)		Explorer X, XIV	Mariner IV, V Lunar Orbiter Surveyor
Electric Field			Surveyor
Gravitation			Mariner IV, V Explorer XXVII
Temperature			Mariner II, IV
Evolutionary Model	OSO-I, -II, -III Sunblazer	OAO	
AGE	OSO-I, -II, -III Sunblazer	OAO	

Table 4-3: CURRENT PAYLOADS

PROGRAM	PRIMARY OBJECTIVES	MEASUREMENTS AND INVESTIGATIONS
Lunar Orbiter	1. Provide photographic Map of Apollo Landing Sites 2. Scientific Data	Medium and High Resolution Pictures, Micrometeorite Flux, Lunar Gravitational Field
Surveyor	1. Support Apollo 2. Develop Control Guildance, Communications, and Landing Techniques	TV, Soil Mechanics, Micrometeorite Detector, Surface Sampler X-Ray Diffractometer, Seismograph, Alpha Particle Device
Mariner (Mars)	1. Photograph Surface 2. Search for Life 3. Atmospheric Composition	TV Camera, Ion Chamber, Helium Vapor Magnetometer, Trapped Radiation Detector, Cosmic Ray Telescope, Ultraviolet Photometer
Planetary Explorer	1. Orbit Mars for Extended Periods 2. Soft Land on Mars	Bioscience, Planetology, Planetary Atmosphere, Particles and Fields, Solar Physics, Ionospheres and Radiophysics
Orbiting Solar Observatory	1. Measure Solar Radiation and Related Phenomena	Make Observations, In X-Ray, Gamma-Ray, Ultraviolet, Infrared, and Visible Region of Electromagnetic Spectrum
Orbiting Astronomical Observatory	1. Survey the Sky and Catalog Stars	Catalog Over 100,000 Stars. Survey Sky in Three Spectral Bands, Obtain Data on Small Nebula, Observe Interstellar Gas
Advanced Pioneer	1. Advance Out of Ecliptic Solar Orbits to Within 0.1 AU of Sun	Magnetic Field, Radio Propagation, Plasma Spectrometry, Ionization Levels, Solar High- and Medium-Energy Particles

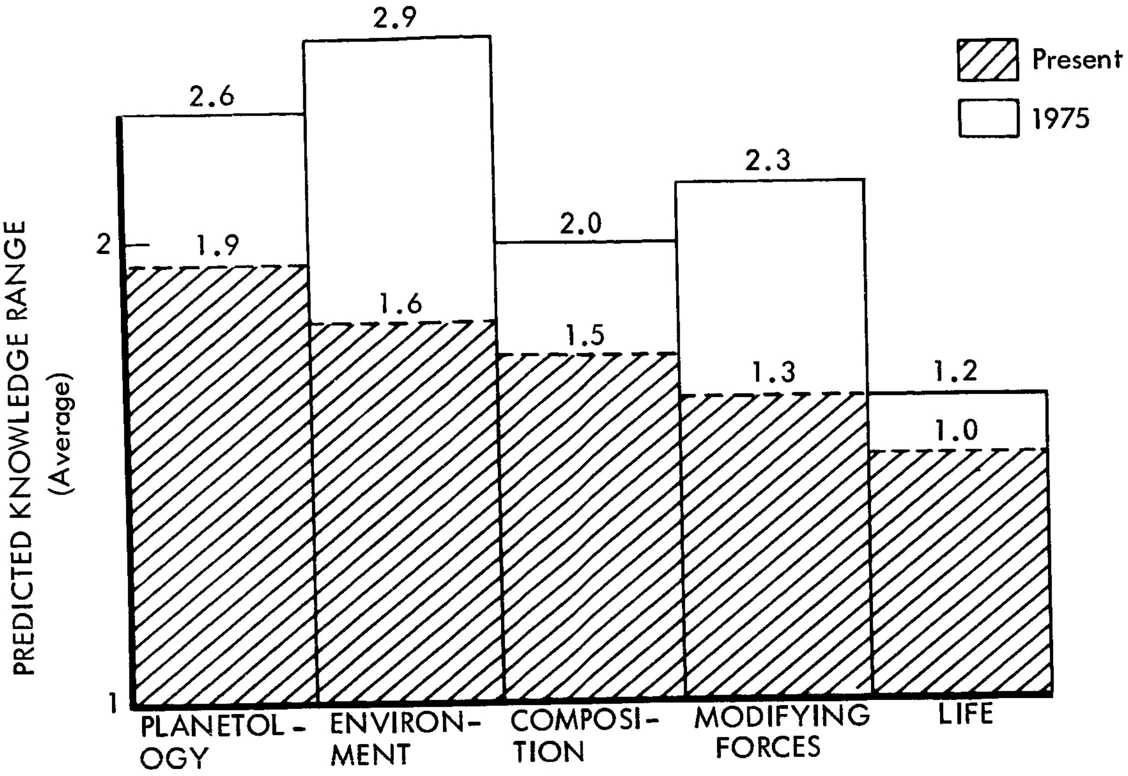

Figure 4-1: IMISCD KNOWLEDGE BASE COMPARISONS— MARS

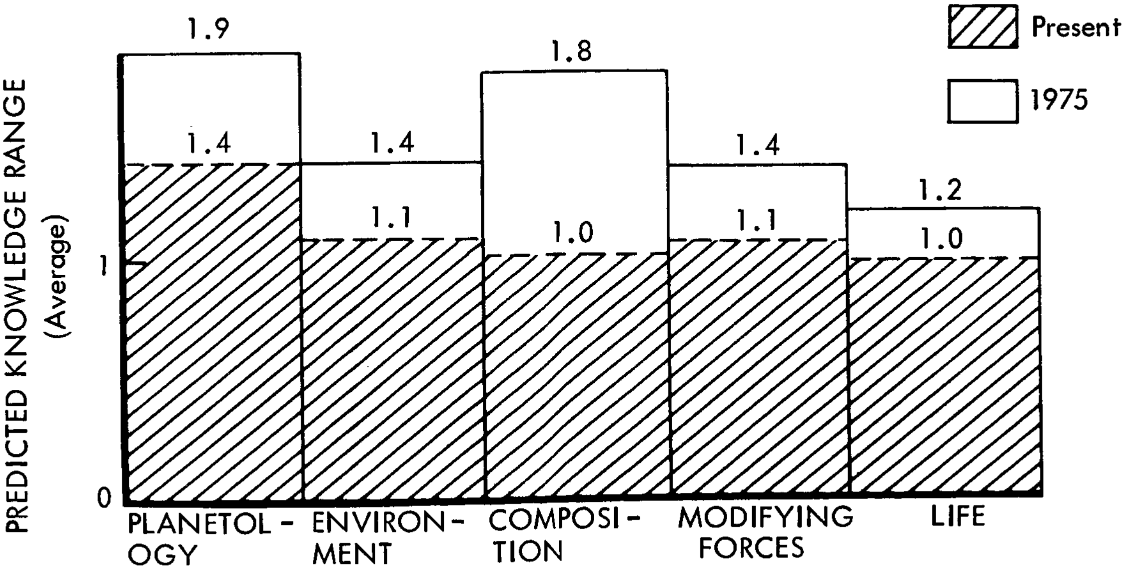

Figure 4-2: IMISCD KNOWLEDGE BASE COMPARISONS — VENUS

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Table 4-4: KNOWLEDGE BASE PROJECTIONS — MARS-VENUS

Knowledge Base	Planetology																
	Orbital Parameters	Rotational Parameters	Figure of Planet	Moments of Inertia	Gravitational Field	Magnetic Field	Structural Features	Thermal Budget	Physical Properties	Seismicity	Physical Features	Isotope Ratios	Mineralization	Age	Atmosphere	Satellites	Summary
Mars																	
Present - Maximum	3	3	2	2	3	1	2	2	2	1	2	1	1	1	2	2	
- Minimum	2	2	1	1	2	0	1	1	1	0	1	0	0	0	1	1	
Projected - Maximum	4	4	3	3	4	3	2	3	2	1	4	1	1	1	3	2	
- Minimum	3	3	2	2	2	2	1	2	1	0	3	0	0	0	2	1	
Venus																	
Present - Maximum	3	2	1	1	3	1	1	2	1	1	1	1	1	1	1	1	
- Minimum	2	1	0	0	2	0	0	1	0	0	0	0	0	0	0	0	
Projected - Maximum	4	3	1	1	4	2	2	3	2	1	2	1	1	1	2	1	
- Minimum	3	2	0	0	2	0	1	2	0	0	0	0	0	0	1	0	

Knowledge Base	Modifying Forces															
	Solar Radiation	Meteoroid Impacts	Isostatic Forces	Seismic Activity	Diastrophism	Volcanic Activity	Surface Winds	Temperature Changes	Chemical Reactions	Life	Phase Changes	Gravity	Hydraulic Action	Glacier Action	Nuclear Reactions	Summary
Mars																
Present - Maximum	2	1	1	1	1	1	1	2	1	1	2	2	1	1	1	
- Minimum	1	0	0	0	0	0	0	1	0	0	1	1	0	0	0	
Projected - Maximum	3	2	3	2	2	2	2	2	2	2	2	3	2	3	2	
- Minimum	2	1	1	1	0	1	1	1	1	1	1	2	1	1	1	
Venus																
Present - Maximum	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
- Minimum	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Projected - Maximum	3	1	1	1	1	2	2	2	1	1	1	1	1	1	2	
- Minimum	2	0	0	0	0	1	0	0	0	0	0	0	0	0	1	

Knowledge Base	Composition							Environment									Life				
	Charged Particles	Atomic Elements	Molecular Elements	Minerals	Chemicals	Isotopes	Summary	Diurnal	Seasonal	Latitude	Magnetic Field	Micrometeorology	Meteoroid	Radioactive Decay	Solar Radiation	Summary	Macroscopic	Microscopic	Protoorganic	Fossil	Summary
Mars																					
Present - Maximum	2	2	2	1	1	1		2	2	2	1	1	2	1	2		1	1	1	1	
- Minimum	1	1	1	0	0	0		1	1	1	0	0	1	0	1		0	0	0	0	
Projected - Maximum	3	2	2	2	2	1		4	4	4	2	2	3	2	2		2	1	1	1	
- Minimum	1	1	1	0	1	0		3	3	3	1	1	2	1	1		1	0	0	0	
Venus																					
Present - Maximum	1	1	1	1	1	1		1	1	1	1	1	1	1	2		1	1	1	1	
- Minimum	0	0	0	0	0	0		0	0	0	0	0	0	0	1		0	0	0	0	
Projected - Maximum	3	2	2	1	2	1		1	1	1	2	1	1	2	2		1	1	2	1	
- Minimum	1	1	1	0	1	0		0	0	0	1	0	0	1	1		0	0	1	0	

Code
0-1 Data ambiguous or nonexistent.
1-2 Approximate ranges are established; degree of change apparent.
2-3 Complete present ranges established; permits theory formulation.
3-4 Permits theory verification or rejection; origin not necessarily established.

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TABLE 4-4:A

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5.0 MANNED PROGRAMS

Measurement requirements were developed for each phase of the manned planetary flights to Mars and Venus, considering the knowledge base provided by the unmanned precursor programs. These requirements are stated in Section 5.1 without regard for constraints that may be imposed by a particular spacecraft, its crew capabilities, or the duration of the visit to the planet for a particular mission. They are the requirements at the beginning of the manned planetary program and would be expected to change from mission to mission as information is accumulated. When constraints are imposed by the space vehicle, crew capability or stay time, requirements would be selected from those given here, based on the priorities established for the time of the particular mission. The priorities are given in Section 5.2 for the initial missions, based on the assumed precursor unmanned programs of Section 4.0.

Instrument classes were identified for all of the required measurements and these were collected on the basis of commonality into an instrument complement for the mission module (the orbiter) which included the in-transit requirements, an instrument complement for the Mars lander, and a complement of unmanned supporting spacecraft. It was found that the mission module complement could be essentially common for both Mars and Venus and, therefore, the major differences between the Mars and Venus payloads is in the supporting unmanned spacecraft complement and the manned lander at Mars.

The payloads needed to cover the entire range of observation and measurement requirements were found to be reasonable so that it should not be necessary to limit the basic instrument complement on a priority basis. However, the payoffs that could be obtained with additional unmanned probes and landers were not assessed.

The contribution that man can make is an important factor in the assessment of mission accomplishment. Section 5.3 discusses the role of man. Section 5.4 presents an estimate of the contribution of the manned programs.

5.1 MEASUREMENT REQUIREMENTS AND INSTRUMENT CLASSES

The observation and measurement requirements were developed for the in-transit phase and the orbital phase for trips to Mars and Venus, and for the manned landing at Mars. Instrument classes were identified, drawing upon the literature and on other planetary studies. Because of the orbital constraints at the planets and the limited surface mobility at Mars and because of the requirements for operational or engineering data, the basic instrument complements were augmented with supporting unmanned probes, orbiters and landers.

The following sections summarize the requirements, the instruments, and the probes. Additional detailed requirements for the Mars and Venus orbiters and the Mars lander, including estimated accuracy requirements, are given in Appendix C.

Total payloads and other system requirements are given in Section 7.0.

5.1.1 IN-TRANSIT PROGRAM AND ITS REQUIREMENTS

The in-transit measurements are divided into the three major areas of solar system, extra-solar system and space resources depicted in Figure 5-1. The most important phases of the in-transit program are observations of the destination planet, either Mars or Venus, not only because of the scientific contributions but also for planning the mission itself. The second area of the program takes advantage of the unique synergistic space environment for the performance of measurements in a zero g, low-magnetic field environment. The third segment is concerned with the possible astronomical or extra-solar system observations.

5.1.1.1 Mission Oriented Observations

The in-transit measurements and observations were selected on the following basis. First, those that contributed to the success of the mission such as the orbital parameters, the rotation, the figure of the planet and the gravitational field. Second, all measurements in planetology with the exception of the moments of inertia, the isotope ratios, the mineral composition and planet age figure prominently in mission operations. Third, only those modifying forces were considered that exhibited gross characteristics and were detectable from an examination of the planet's features with the resolution obtainable from in-transit distances. Fourth, the composition of the gaseous and charged envelope which may affect the orbit selected. Fifth, those that affected the landing site. The site should, in general, be in the daylight during the landing phases with a predictable environment.

The observational program is influenced by the nature of the cloud cover; e.g., whether it is merely the blue haze which covers Mars most of the time or the presumed yellow dust clouds. If the cloud cover at Venus is continuous most of the observations will emphasize atmosphere circulation, cloud patterns and radar observations. If the cloud cover is broken and transitory and viewing of the surface is feasible, then the program will focus on the optical system observations. If only a top layer of clouds is broken and observations of lower layers is permitted, their circulation and composition determination will be attempted. Continued observation during the in-transit phases will aid in planning and establishing the observational program. This flexibility may be unique to the manned program but Earth orbital stations should provide initial planning data.

The orbits of the two moons of Mars affect the observational program as well as the mission. Hence their orbits must be established prior to planetary orbit injection. There is no evidence of satellites in orbit about Venus. However, the observing opportunities while in transit are far superior to those either from the Earth's surface or from Earth orbit. Observations may establish both their existence and their orbits.

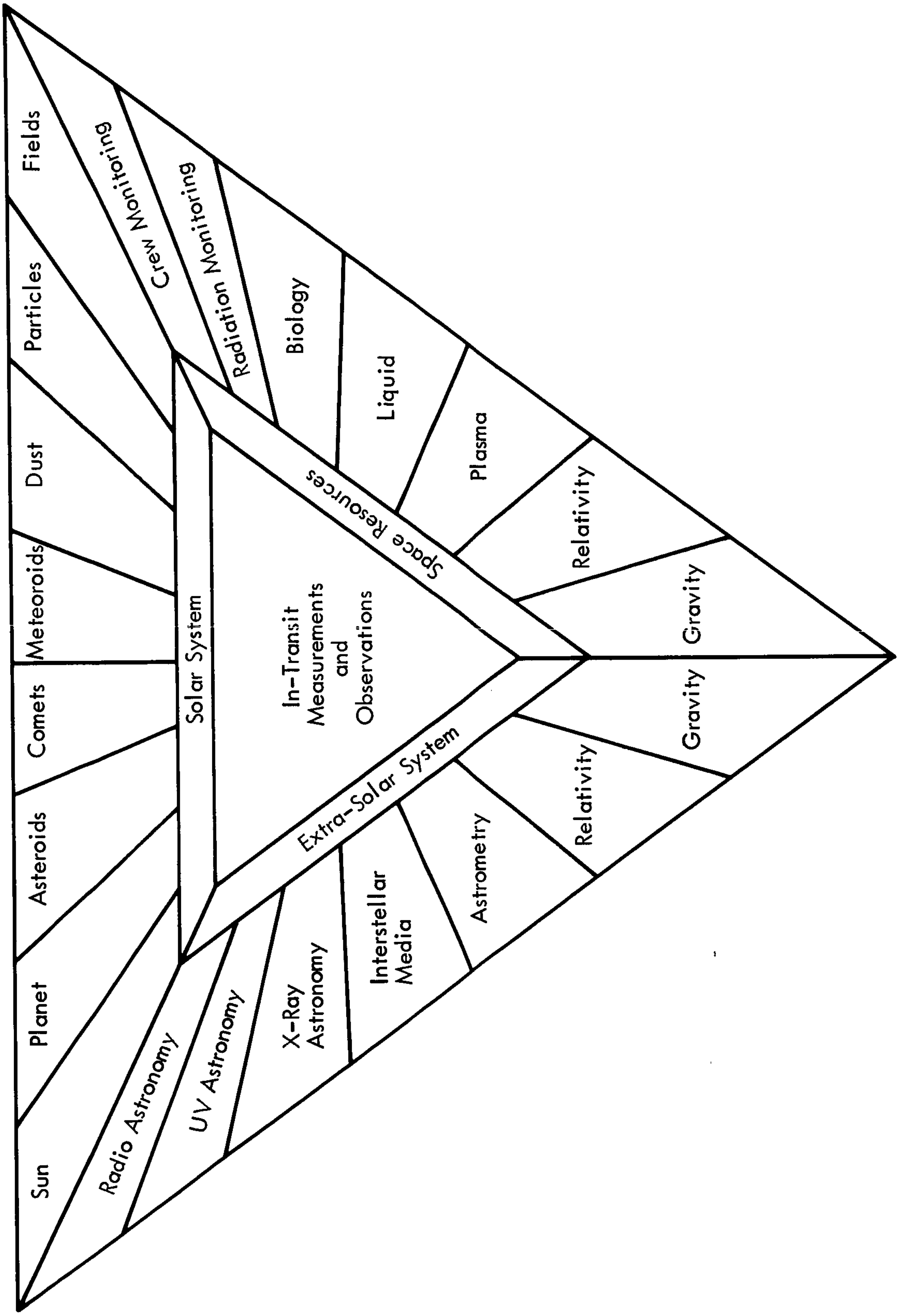

Figure 5-1: IN-TRANSIT SCIENTIFIC OBJECTIVES

The scientific observations and measurements requiring observations of the planet as a whole to be performed during the in-transit phases are:

1) Albedo measurements in the UV and the visible spectrums. These will permit the correlation of many Earth-observed phenomena which may not appear while the mission is in progress.
2) Figure of the planet determination. The planet presents a different aspect as it revolves and its perimeter or outline varies with the spectrum with which it is observed.
3) Areas of interest visible on the planet's surface. These observations affect the choice of the landing site, the sequence in which they are observed in orbit and the relative priorities of the type of observation.

5.1.1.2 Solar System Observations

Table 5-1 establishes the measurements to be made on the other bodies of the solar system including the Sun. It also correlates the major parameters with the general requirements.

Radioactivity of Jupiter---This observation is of interest for the following reasons:

1) Jupiter is more sun-like in its density and composition than any of the four terrestrial planets. This implies that its major constituents are frozen hydrogen, methane, ammonia, and other gases. The presence of radio-activity determines the presence of terrestrial matter. Most of this is assumed concentrated in its satellites which appear to have tenuous atmospheres if any at all. Hence the experiment is feasible and will provide data concerning the composition of the planet itself and its satellites. This in turn may aid in establishing their origin.
2) Jupiter is also warmer than is explainable under present theories. Radio-activity is a possible source of this heat.
3) Jupiter emits radio frequencies, influenced by its moons. Present explanations require a magnetic field interacting with charged particles. Since the charged particles from the Sun are supposed to recombine within the orbit of Jupiter, radioactivity may be the source of the charges in the Van Allen-type belts producing the radio frequencies.

Age of the Sun---The Sun is aging in at least two respects. First, it is "burning" tons of hydrogen every second. As a part of the process some of the heavier elements are being formed. Experienced observers may be able to distinguish their spectral lines in-transit. Zodiacal light and other Earth shine phenomena may mask them in Earth orbit observation.

Table 5-1: IN TRANSIT MEASUREMENT REQUIREMENTS
(In Order of Priority)

Measurements	Parameters	Requirements
Radioactivity--Jupiter	Frequency and intensity of electromagnetic radiation. Structure of trapped belts. Correlation with satellites. Composition of Jupiter.	Measurement of the spectrum from the lowest RF to the highest microwaves within 1 cps. Intensity and distribution to within 1%.
Age--Sun	Spectrum and intensity. Solar wind clouds and distribution of heat.	Identification of vacuum UV lines to within 0.1A. Intensity whether of absorption or emission to within 1%.
Temperature Changes	Emission from the planet surface. Variation over the surface of the Sun. Correlation with activity.	Temperature with altitude to 1°K to 1 km. Rate of change of temperature for both hemispheres.
Chemical Elements	Atmospheric absorption. Use absorption of starlight as planet occults stars.	Measure spectral lines to within 0.1%.
Meteoroid Impacts	Possible "noise" (RF) created when meteor enters planet atmosphere.	For planets with dense atmosphere RF noise will occur at very low frequency. To be measured during possible showers.
Gravitational Fields	Track satellites of planets. Orbit of Icarus.	To be tracked to 0.1 m/sec.
Thermal Budgets	Reflected and emitted radiation spectrum and intensity.	Measure frequencies to within 0.01%. Intensities to within 0.1 db.
Orbital Parameters	Satellite and Pluto orbits.	To be established to the nearest min.
Chemical Reactions	Atmospheric constituents, temperatures, thermal budgets and UV impinging on the surface.	Extrapolations of data and utilization of energy requirements for the initiation of chemical reactions and their equilibrium.

Table 5-1: IN TRANSIT MEASUREMENT REQUIREMENTS (Continued)
(In Order of Priority)

Measurements	Parameters	Requirements
Rotational Parameters	Period, axis, mutation and precession. Icarus and satellites of planets.	To be established to 1 sec. for rotation and axis to within 0.01°.
Surface Winds	Dust clouds and cloud patterns.	To be measured within 1 km/hr.
Physical Properties	Densities, color, patterns, reflectivities, emissivities.	To be measured within 10%.
Isotopes--Sun	Spectra and intensities.	UV spectra 50 to 3500 Å to within 0.001 Å. Vis. (3500-9000) to within 0.01 Å.
Figures--Sun, Satellites and Planets	Ecliptic and non-ecliptic radii.	To be measured to within 0.001%.
Physical Features	Surface markings and their variation with time, rotation of satellites.	Imaging. Timing to be a function of the feature rate of change.
Moments of Inertia	Gravitational waves, planet figure, sun figure rotation rates and orbital parameters.	Variations to within 5%.
Activity--Planets --Sun	Hot spots, cool spots, cloud cover. Rates of change of the above.	IR imaging. Resolution on order of km.
Magnetic Fields	Field strength, polarization, rate of change. Affect of Sun spot activity. Tracking of frozen magnetic field.	Magnitude to ± 1 gamma. Rate of change with respect to time and distance from Sun within 10%. Pole to 1°.
Meteorology	Cloud cover and patterns. Precipitation, spherics, velocities.	To be measured within 10%.

Second, the Sun is "burning" in a turbulent fashion--boiling off its hydrogen and helium as well as the daughter products formed. It is essential to know how much matter in space really originates in the Sun and how it is distributed in space.

Gravitational Fields---Icarus, a relatively small body in a highly elliptical orbit about the Sun, is only a 13th-order magnitude star when it is 4 million miles from the Earth. Earth viewing conditions do not permit observations of this body sufficiently accurate to verify that the general relativity concepts of Einstein apply. In transit the observational conditions are near perfect.

5.1.1.3 The Space Environment In-Transit

The space environment in-transit program has three significant areas: 1) psychological impact on the crew, 2) the zero-g physical changes and 3) the solar flare prediction program.

Psychological Impact---This impact on the crew comes with the realization that after certain phases of the mission there is no return or hope of rescue. This thought coupled with the duration of even the short missions implies that the crew must be highly motivated and must remain motivated. This is an extreme condition that provides essential behavior information not obtainable in any simulation.

The Zero-G Program---The measurements of the physical changes that will take place during the mission in the crew and in the test plants and animals have been included. The crew, the animals and the plants will be a part of the back contamination program discussed in Appendix C. Table 5-2 summarizes those measurements to be performed in transit. These measurements will assure the development of a base from which deviations resulting from exposure to the samples from the surface of Mars or from a mutation induced by the unique environment of the mission can be observed. Included in these measurements is a recording of the accumulated radiation dose to which the life of the spacecraft has been exposed.

Solar Flare Predictions---The phenomena observed on the Sun's surface will be correlated with sunspot activity and solar flare prediction. The in-transit phases of the mission will reveal a portion of the Sun not immediately observable from the Earth because of the different angular position of the spacecraft. These observations will be correlated with those from Earth to add to the solar scientific program. Solar flare observations are also mission oriented in that the safety of the crew may be jeopardized unless flare conditions are recognized in their early formative phases.

5.1.1.4 "Extra" Solar System Observations

These measurements have been restricted to those that can be made with the equipment provided for the solar system observations. Since this equipment consists of a good optical telescope with interferometers of high quality, many measurements similar to those made by astronomers

Table 5-2: MISSION BIOSCIENTIFIC MEASUREMENTS

Experiment	Earth[(1)] Orbit	Mars			Venus				
		Transit[(1)]	Orbit	Lander[(2)]	Transit	Orbit	Size (ft^3)	Weight (lb)	Power (watts)
Medical Monitoring		x	x	x	x	x	0.9	4	15
Cardiac Hemotology Effects	x	x	x		x	x	2.9	142	60
Cardiac Conditioning	x	x	x		x	x	1.2	7	2
Muscle Mass & Strength	x						---	1	---
Mineral Metabolism	x	x			x		1.6	31	500
Otolith Mech.	x						2.1	7	35
Pulmonary Functions	x	x			x		1.5	29	56
Nutritional Status	x						0.6	6	---
Thermal Regulation	x						1.5	53	1
Microbiological Evaluation	x	x			x		5.5	19	50
Sensory & Perception	x						2.5	60	100
Psychomotor Function	x						incl.	incl.	incl.
Higher Mental Processes	x	x			x		incl.	incl.	incl.
Habitability	x						---	---	---
Morphological Changes	x	x					0.4	4	10
Plant Morphological Seeds	x	x					2.0	11	50
Genetic-Microorganisms	x						1.0	24	25
Limb, Wounds	x						3.6	82	5
Capture, Enumerate Microorganisms	x	x	x		x	x	6.9	106	45
Immune Defenses	x						36.0	398	250
Drugs-Mammalian Behavior	x						11.2	497	50
Vigilance — Man	x						3.3	58	13
Mission or Mission Portion Size (ft^3)	84.7[(1)]	25.6	12.1	0.9	23.2	12.1			
Weight (lb)	1539[(1)]	431	277	4.0	416	277			
Total Power (watts)	1267 (1)	913	147	15.0	853	147			

(1) It should not be construed that all the experiments proposed will be flown at once.

(2) Only data, microbiological plates, and "soil" samples are returned to Earth.

today will be repeated; emphasizing those measurements in the UV and the IR portions of the spectrum. A partial listing of these observations follows:

Stellar evolution within and off the main sequence

Thermonuclear reaction rates

Statistics of the double stars

Masses of eclipsing double stars

Masses of visual binary stars

Observations of the galactic magnetic field

$\mathrm{O\overline{H}}$ molecules in the interstellar medium

Quasi-stellar objects

The dynamics of galaxies

Stellar compositions

5.1.1.5 Summary

A brief summary of the measurements and observations to be performed in-transit along with their general requirements is presented in Table 5-3.

Table 5-3: IN-TRANSIT MEASUREMENTS AND OBSERVATIONS

Measurements and Observations	General Requirements
1. Determination of the structure of interplanetary magnetic fields with its associated dynamic nature and turbulence and its effect on charged particles. These three objectives of the program are:	Helium vapor magnetometer with triaxial response. Measurement should be in association with charged particle measurements. A change in flux of 0.1 gamma should be measurable.
a. Determination of the structure of the field	In addition to the triaxial magnetometer, the release of a source of ions and the tracking of these ions should be considered.
b. Determination of the sources of the field	
c. Determination of its interaction with the planetary and solar magnetic fields.	
2. Measurements of interplanetary particulate matter to establish:	Micrometeoroid detector must permit the analysis of captured matter without self-destruction, i.e., replaceable panels or units.
a. Composition	It may be possible to "capture" this dust through the use of electronic precipitators which can take advantage of the charge on the dust.
b. Origin	
c. Structure	

Table 5-3: IN-TRANSIT MEASUREMENTS AND OBSERVATIONS (Continued)

Measurements and Observations	General Requirements
d. Velocity	
e. Charge	
f. Flux	
3. Measurement of the emitted particle and photon flux from the Sun to establish solar system exchange mechanisms.	Selected energy bands throughout the photon and energetic particle ranges. Lines to be observed will be specified later.
4. Observations of the planet of interest and its moons, if any, to establish:	
a. Albedo in UV, IR and visible	The entire face of the planet should be scanned in five broad bands ranging from 50 Å to 50,000 Å. The specific bands to be determined with the analysis of Voyager atmospheric data.
b. The figure of the planet and of the moons.	The equatorial and the polar (2) radii are to be determined to ±1 km.
c. The periods of rotation and their axes.	Period to be established to within 0.01 sec and the tilt of the axis to within 1 sec.
d. The orbits of the moons.	Maximum and minimum distances to 1 km. Periods to within 1 sec. Plane to within 1 sec.
e. Cloud cover.	General occurrence and frequency of cloud formation. Applies to Venus during swingby.
f. Areas of interest.	These may have been established by previous programs but anomalies in general are to be photographed multispectrally.
5. Other astronomical observations.	To be defined.

Table 5-3: IN-TRANSIT MEASUREMENTS AND OBSERVATIONS (Continued)

Measurements and Observations	General Requirements
6. Biological monitoring of crew, test animals and test plants.	The microscopic life associated with the crew, test animals and test plants will change during the flight. The magnitude of this change must be recorded and compared to that existing on Earth. (The impact of these changes in the ability of man, plants and animals to adapt to new and induced diseases must have been determined previously.)
7. Radiation monitoring.	The integrated radiation dose to which plants and animals should be recorded in milliroentgens at regular and solar flare intervals.

5.1.1.6 In-Transit Instruments

The in-transit instruments can be classified into four technique areas: spectrography or the photography of spectra; radiometry; imaging and direct sampling with probes. The instrument classes listed under these headings are presented in Table 5-4. The application of these instruments to the in-transit measurements and observations of the other bodies of the solar system is summarized in Table 5-5.

During the in-transit phases of the mission, the magnetic field will be studied for structure. At least three measurement phases are considered. First, to determine the distortion of the field due to the presence of the spacecraft. Second, to determine the structure of the interplanetary field and third to observe the structure of the field when a solar flare perturbs it. The UV spectrophotometer of the spacecraft is used to scan the ions released into the magnetic field and to record the changes which occur as the solar wind clouds recede. The other instruments are external to the spacecraft and also measure the solar wind, its constituents and the interplanetary fields and particles.

All of the instruments for the in-transit phase were integrated with those for the orbital phase in the mission module.

Table 5-4: MANNED AND UNMANNED MEASUREMENT TECHNIQUES--IN-TRANSIT

Technique	Instrument Class
1. SPECTROGRAPHY The recording and observation of electromagnetic radiation extending from radiofrequency wavelengths thru gamma-ray wavelength. Frequency, Intensity and Polarization are the parameters to be measured.	a. RF Counter-Timer + Polarimeter b. mm Wavemeters, Bolometers + Polarimeter c. IR Spectrophotometers + Polarimeter d. Visible Spectrophotometers + Polarimeter e. UV Spectrophotometers + Polarimeter f. Gamma-ray Spectrometer g. UV Interferometer h. Visible Interferometer i. IR Interferometer j. RF Astronomy
2. RADIOMETRY The broadband measurement of Radiofrequencies.	a. RF Noise Detectors b. RF Radiometer Scanner c. IR Radiometer Scanner d. IR Photometer e. RF Bolometers f. RF Astronomy
3. IMAGING Essentially Intensity Recording in two dimensions	a. Visual Inspection b. Television-Tape Recording c. Photographic Systems d. IR Mapping e. Radar Mapping f. Spectroheliograph
4. DIRECT SAMPLING--PROBES Includes Magnetic Fields, Solar Wind and other interplanetary particle counting.	a. Magnetometers b. Charged Particle Detectors c. Cosmic Dust Detectors d. Mass Spectrometers e. Gamma-ray Spectrometers f. Ion Releasing Devices

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Table 5-5:8 IMISCD FACTORS VERSUS INSTRUMENT TECHNIQUE SUMMARY
Measurements and Observations — In-Transit

	Planetology															
	Orbital Parameters	Rotational Parameters	Figure of Planet	Moments of Inertia	Gravitational Field	Magnetic Field	Structural Features	Thermal Budget	Physical Properties	Seismicity	Physical Features	Isotope Ratios	Mineralization	Age–Sun	Atmosphere	Satellites	Summary
Priority (1)	8	10	14	16	6	18	20	7	12	17	15	13	21	2	20	6	
1 (2)		J						C,I		C		G,H	C,D	D,E F,G	A,J		
												I	E	H			
2						A,B		C,D	C	C					A,E		
						E											
3	C,J	C	C	C	C		C	D,F	C,D		C			D,F	C	C	
4																	

	Modifying Forces															
	Solar Radiation	Meteoroid Impacts	Isostatic Forces	Seismic Activity	Diastrophism	Volcanic Activity	Surface Winds	Temperature Changes	Chemical Reactions	Life	Phase Changes	Gravity	Hydraulic Action	Glacier Action	Nuclear Reactions (Jupiter)	Summary
Priority (1)	7	5	–	–	–	17	11	3	7	–	22	6	–	–	1	
1 (2)	A,F							B	B,C						A	
2		A				C,D			C		A					
3		C					C					C				
4																

	Composition						
	Charged Particles	Atomic Elements	Molecular Elements	Minerals	Chemicals	Isotopes	Summary
Priority (1)	1	4	4	–	9	13	
1 (2)		C,D	C,D		C,D	G,H	
		E,G	E		E	I	
2							
3							
4	B,D						

	Environment								
	Diurnal	Seasonal	Latitude	Magnetic Field	Micrometeorology	Meteoroid	Radioactive Decay	Solar Radiation	Summary
Priority (1)	19	19	19	18	19	5	1	7	
1 (2)									
2									
3	C	C	C		C				
4				A,E		C	E	B,D	
								E	

	Life				
	Macroscopic	Microscopic	Protoorganic	Fossil	Summary
Priority (1)	–	–	4	–	
1 (2)			C		
2					
3					
4					

(1) Crosshatching indicates that information from additional measurements and observations in these classes is not justified from orbit.

(2) The numbers in this column refer to the instrument techniques in Table . The letters of the alphabet in these rows refer to the specific instrument of the same table.

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5.1.2 ORBITER PROGRAMS AND REQUIREMENTS

Requirements were defined in 45 of the 49 observation and measurement classes for the Mars orbiter and in 43 of the 49 for the Venus orbiter. Many of these need verification with surface data to establish their validity. At Mars, this correlation is provided by the manned lander and by supporting unmanned probes and landers; at Venus the correlation depends entirely on the unmanned probes and landers.

5.1.2.1 Orbiter Instrument Classes

Tables 5-6 and 5-7 present the matrices of instrument classes and observation and measurement classes for the orbital phase at Mars and at Venus. The instrument classes are summarized in Table 5-8 and are briefly described below. Additional details of the orbiter requirements are given in Appendix C.

5.1.2.2 Orbital Spacecraft Instruments

In general, the orbiting spacecraft instruments can be designed to accommodate the range of variables from any planet but not necessarily from planet to planet. Examples of this are in the atmospheric pressure differences between Mars and Venus or in their surface temperature differences. Sun observations also represent measurements of different orders of magnitude. In general, some modification will be necessary but the same instrument types or classes can be used. The spectroheliograph, the coronagraph, and the magnetographs to be used for solar flare prediction may be specialized instruments that will be developed as the Sun is better understood. The instrument types common to the Mars and Venus missions are presented in Table 5-9. These include the requirements for the in-transit phases of the missions.

Table 5-6:B IMISCD FACTORS VERSUS INSTRUMENT TECHNIQUE SUMMARY

	Planetology																
	Orbital Parameters	Rotational Parameters	Figure of Planet	Moments of Inertia	Gravitational Field	Magnetic Field	Structural Features	Thermal Budget	Physical Properties	Seismicity	Physical Features	Isotope Ratios	Mineralization	Age	Atmosphere	Satellites	Summary
Mission Priority (1)	X	13	39	38	25	43	22	35	20	49	47	15	5	X	10	9	
1 (2)							A	B				D	A		A,B	A,B	
							C					E	E		C,E	C,E	
2							A,B	A,B	A,B		A,B				A		
							D	D	D		D				D		
3		C	C	C			B	D	A,B	C	A		A,C		A	A	
							E		E		E		E		D	D	
4							A	B							A	H	
							E	D							I	I	
5		D	B	B		A	A				B				A		
			C	D							C						
6			A	A	A											B	
			B	B	B												
7						A	B				E				D		
8							A								A		
							B								B		
9																	
10																	

	Modifying Forces															
	Solar Radiation	Meteoroid Impacts	Isostatic Forces	Seismic Activity	Diastrophism	Volcanic Activity	Surface Winds	Temperature Changes	Chemical Reactions	Life	Phase Changes	Gravity	Hydraulic Action	Glacier Action	Nuclear Reactions	Summary
Mission Priority (1)	4	26	33	48	28	21	37	46	42	30	24	13	29	34	6	
1 (2)	A							B	A	B	B					
	C								B	D						
2	D					A		A	A		A					
	B					B		B			B					
3		B,C	B,C	B,C	A	A	A,B						A	A		
		E	E	E	C	D	C						C	C		
4							A									
							B									
5																
6										A						
7	B,D														E	
	E															
8																
9																
10																

	Composition						
	Charged Particles	Atomic Elements	Molecular Elements	Minerals	Chemicals	Isotopes	Summary
Mission Priority (1)	36	14	40	8	12	19	
1 (2)		A	A	A	A	D	
		D	C	E	B		
2	C				A		
3				A			
				C			
4							
5							
6							
7	A					E	
8							
9							
10							

	Environment								
	Diurnal	Seasonal	Latitude	Magnetic Field	Micrometeorology	Meteoroid	Radioactive Decay	Solar Radiation	Summary
Mission Priority (1)	45	41	23	44	31	32	11	7	
1 (2)								A	
								C	
2									
3	A	A	A		A	A	D		
	D	D	D		D	C			
4									
5									
6									
7				A			E	A	
								B	
8									
9									
10									

	Life				
	Macroscopic	Microscopic	Protoorganic	Fossil	Summary
Mission Priority (1)	16	X	18	X	
1 (2)			B		
			D		
2					
3	A				
	D				
4					
5					
6					
7					
8					
9					
10					

(1) Crosshatching indicates that information from additional measurements and observations in these classes is not justified from orbit.

(2) The numbers in this column refer to the instrument techniques in Table The letters of the alphabet in these rows refer to the specific instrument of the same table.

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Table 5-7B IMISCD FACTORS VERSUS INSTRUMENT TECHNIQUE SUMMARY

Measurements And Observations - Venus Orbit

Measurement or Observation Techniques	Planetology																
	Orbital Parameters	Rotational Parameters	Figure of Planet	Moments of Inertia	Gravitational Field	Magnetic Field	Structural Features	Thermal Budget	Physical Properties	Seismicity	Physical Features	Isotope Ratios	Mineralization	Age	Atmosphere	Satellites	Summary
Orbit Priority	-	1	21	19	22	29	18	24	15	-	25	11	-	-	5	2	
1												D E			AB C,D E	A B C	
2									A B C						C		
3		E	E				D E	D		E	D E		D E		B	A B C	
4															A- I		
5		C	C D												A		
6			A	A B	A B												
7						A											
8															A B		
9																	

Measurement or Observation Techniques	Modifying Forces															
	Solar Radiation	Meteoroid Impacts	Isostatic Forces	Seismic Activity	Diastrophism	Volcanic Activity	Surface Winds	Temperature Changes	Chemical Reactions	Life	Phase Changes	Gravity	Hydraulic Action	Glacier Action	Nuclear Reactions	Summary
Orbit Priority	4	26	-	-	-	17	-	-	-	16	12	3	-	-	-	
1	A- C, F					B			B						F	
2	D	C									C					
3		E	E	E	E	D E		B D			E		E	E		
4	C															
5																
6												A B				
7	A B D E															
8																
9										A- G						

Measurement or Observation Techniques	Composition						
	Charged Particles	Atomic Elements	Molecular Elements	Minerals	Chemicals	Isotopes	Summary
Orbit Priority	27	9	10	-	8	14	
1		A D	A B C		A B C	A- F	
2	C		A		A		
3							
4							
5	A						
6							
7	B						
8							
9							

Measurement or Observation Techniques	Environment								
	Diurnal	Seasonal	Latitude	Magnetic Field	Micrometeorology	Meteoroid	Radioactive Decay	Solar Radiation	Summary
Orbit Priority	23	20	6	30	-	13	-	-	
1	B C	A B C	A B C				B F	A- C, F	
2	A							D	
3	E	E	E		E	E			
4									
5	A								
6									
7				A					
8									
9									

Measurement or Observation Techniques	Life				
	Macroscopic	Microscopic	Protoorganic	Fossil	Summary
Orbit Priority	-	7	28	-	
1					
2					
3					
4					
5					
6					
7					
8					
9		A, G	B C		

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Table 5-8: MANNED AND UNMANNED ORBITER MEASUREMENT TECHNIQUES

Technique	Instrument Class
1. SPECTRAL MEASUREMENTS (Absorption, Transmission, Emission, Reflection)	a. UV Spectrophotometer
	b. IR Spectrophotometer
	c. Visible Spectrophotometer
	d. UV Interferometer
	e. Visible Interferometer
	f. Gamma-ray Spectrometer
2. RADIOMETRY	a. IR Radiometer Scanner
	b. RF Radiometer Scanner
	c. RF Noise Detector
	d. Photometers
3. IMAGING	a. Visual Inspection
	b. Television
	c. Photographic Systems (multi-spectral)
	d. IR Mapping
	e. Radar Mapping
	Monostatic imaging
	Bistatic holography
4. DIRECT SAMPLING BY PROBE	a. Pressure Sensor
	b. Temperature Probe
	c. Mass Spectrometer
	d. Radiometer
	e. Accelerometer
	f. Meteorological Sensors
	g. Gas Chromatograph
	h. TV
	i. Photosystems
5. SOUNDING	a. RF Topside Sounder
	b. Laser Altimeter
	c. Radar Altimeter
	d. Radar/Laser Tracking
6. ORBITAL TRACKING	a. Tracking and Ranging Radar
	b. Tracking and Ranging Laser
7. DIRECT SAMPLING FROM ORBIT	a. Magnetometer
	b. Charged Particle Detectors
	c. Cosmic Dust Detector
	d. Mass Spectrometer
	e. Gamma-ray Spectrometer
8. ATMOSPHERIC OPTICS MEASUREMENTS	a. Polarimeter
	b. Occultation (Solar and Generated RF)

Table 5-8: MANNED AND UNMANNED ORBITER MEASUREMENT TECHNIQUES (Continued)

Technique	Instrument Class
9. BIOLOGICAL SAMPLING (Drifter Lander)	a. Visual Inspection b. IR Interferometer c. Culturing d. Microscope e. Television f. Mass Spectrometer g. Gas Chromatograph

Charged Particle Detector---The charged particle detector determines the density of charged particles in orbit and in-transit during solar wind studies. This is a group of nuclear radiation and particle detectors.

Gamma-Ray Spectrometer---The gamma-ray spectrometer determines the presence of radioactive materials on the surface and identifies them. It includes a pulse height analyzer.

IR Interferometer---The IR interferometer determines the compounds present as well as the rate at which interactions are taking place. It is used during organic compound analyses, including the in-transit test plant and animal analyses.

IR Mapper---This mapper maps areas which are of interest because of their temperature differences. This includes cloud patterns, surface hot spots and polar ice caps. It records changes of temperature due to sunset or sunrise for surface conductivity studies.

IR Radiometer Scanner---This scanner determines presence of the CO_2 and water vapor. It identifies their concentration within specific localized areas.

IR Spectrophotometer---The IR spectrophotometer aids in the observation of planets and stars in-transit. It detects the IR radiation from the planet's surface whether emitted or reflected (chemical reactions produce IR during the reaction itself and may heat contiguous materials). The device will isolate surface areas within which chemical reactions are occurring.

Magnetometer---The magnetometer locates the magnetic poles on the surface of the planet. The magnitude of the fields and its variation will also be recorded with the position of the spacecraft.

Micrometeoroid Detector---This detector determines the density of cosmic dust with distance from the Earth. It also provides information on the momentum distribution of the impinging dust. Analysis may provide composition information.

Table 8 (Cont.)

Photographic System---This system is used during the mapping and imaging experiments associated with structure and feature categorization. It will provide high resolution images of selected areas. The telescope portion of this system will or can be used with the interferometers and the spectrometers to achieve resolution or isolation of small areas. Several camera systems are included to provide coverage and resolution.

Photometers---Photometers are used to determine the intensity of electromagnetic radiation in relatively broad bands. They are used during the photography of the planet surface or cloud tops and aid the study of the energy or heat balance of the planet.

Polarimeters---Three polarimeters--one each for UV, Vis, and IR bands, are included. Reflected and emitted light are distinguished by the polarization of the radiation reaching the detector.

Radar Altimeter---The altimeter determines the altitude of the spacecraft and develops altitude profiles. It permits determination of the height of the clouds above the terrain as well as their stratification.

Radar Mapping---The mapping radar is used to map the surface of the planet obscured by clouds as well as to determine the thickness of the ice cap and the surface material.

Radiometer---The radiometer is used to investigate specific parts of the spectrum detected by the scanner. It is also used in conjunction with the scanner and the RF noise detector.

RF Noise Detector---The RF noise detector determines the RF noise generated within the atmosphere (sferics) or within the cloud cover of a planet. Aids in determining the energy balance of the planet and its environment. Van Allen radiation will also be detectable.

RF Radiometer Scanner---The RF scanner maps areas through temperature differences. It will isolate areas of higher or lower temperatures than the surrounding areas and permit their intensive study. Continued recording can provide rates of change.

Television---The TV display presents surface and cloud features. If finer detail is required for analysis then photographs will be taken. Television displays are more flexible than those of a camera and may be used in lieu of the pointing telescope.

Topside Sounder---The sounder determines the density of the charge constituents of the ionosphere. Ionospheric density varies with exposure to the Sun's radiation and varies with the season and the diurnal period.

Tracking and Ranging Radar---This radar tracks orbiters and probes as well as determines their range and range rate. It determines the distance between two objects on the surface of the planet.

Table 8 (Cont.)

UV Interferometer---The interferometer makes more precise measurements of the UV wavelengths of many gases and ionized elements and aids in the determination of the isotopic composition of the materials or compounds under study. The composition of the ionosphere will also be determined.

UV Spectrophotometer---The UV spectrophotometer is used to observe the ions released in the study of the interplanetary magnetic field as well as the study of the reflected and emitted UV light from the planets and the stars. In orbit it determines the chemical reactions taking place as well as identifying the constituents, either charged or in excited levels.

Visible Interferometer---This interferometer determines the gaseous elements and other chemical compounds. The isotopes present require high spectral resolution provided by the interferometers.

Visible Spectrophotometer---This spectrophotometer measures the reflected, scattered and emitted visible light from the surface of the planet or cloud tops. The reflected spectrum provides information about the size of the scattering particles suspended in the atmosphere in the form of clouds or aerosols as well as their composition.

Table 9.2.1: SPACECRAFT INSTRUMENT REQUIREMENTS — MARS AND VENUS

Instrument Class	Mass		Power (watts)	Volume (cu ft)	Mounting	Rate or Pointing Accuracy	Peak Data Rate (kbs/sec)
	(lb)	(kg)					
UV Spectrophotometer	35	15.9	40	3.0	Scan Platform	0.02-0.05 deg/sec	10-20
IR Spectrophotometer	55	25	48	7.0	Scan Platform	0.02-0.5 deg/sec	10-20
Vis Spectrophotometer	100	45.4	50	2.0	Scan Platform	0.02-0.5 deg/sec	1.5
UV Interferometer	55	25	50	1.0	Scan Platform	0.01 deg/sec	10-20
Vis Interferometer	50	22.7	50	1.2	Scan Platform	0.01- deg/sec	2.0
IR Interferometer	50	22.7	25	2.0	Scan Platform	0.01 deg/sec	2.0
Gamma-Ray Spectrometer	300	136.4	150	360	Scan Platform	0.05 deg/sec	0.1
IR Radiometer Scanner	55	25	48	2.1	Scan Platform	0.02-0.5 deg/sec	10-20
RF Radiometer Scanner	60	27.3	55	3.9	Scan Platform	0.02 deg/sec	19
RF Noise Detector	40	18.2	40	2	Spacecraft Outside	± 1 deg	3
Photometers (UV, Vis, and IR)	10	4.5	2	0.2	Scan Platform	± 1 deg	0.1
Television System	18	8	30	0.04	Camera on Scan Platform	± 1 deg	5×10^3
Photographic System (Including Telescope)	3000	1364	30	23.0	Scan Platform	± 0.5 deg	80,000 Photos
IR Mapper	100	45.4	70	7.0	Scan Platform	0.1 deg	7.2
Radar Mapper	420	191	550	13.0	Scan Platform	0.05 yaw - 1 deg Pitch & Roll	1.8×10^5
Radiometer	100	45.4	200	27	Scan Platform	± 25 deg	0.72
Radar Altimeter	50	22.7	220	2.0	Spacecraft	± 1 deg	1.7×10^3
Tracking and Ranging Radar	290	131.8	435	8	Tracking Platform	± 10 deg	1.2×10^4
Magnetometer	6	2.7	7	0.2	Spacecraft Boom	Spacecraft	0.02
Charged Particle Detector	50	22.7	15	1.0	Spacecraft Boom	Spacecraft	0.10
Micrometeoroid Detector	20	9.1	10	1.0	Spacecraft Body	Spacecraft	0.01
Polarimeters (UV, Vis, and IR)	20	9.1	10	2.0	Scan Platform	0.01 deg/sec	0.01
Topside Sounder	120		6	1.3	Spacecraft Planet Viewing	± 10	10

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Table 5-10 B MEASUREMENTS AND OBSERVATIONS — MARS SURFACE

	Planetology																	Modifying Forces																Composition							Environment									Life				
	Orbital Parameters	Rotational Parameters	Figure of Planet	Moments of Inertia	Gravitational Field	Magnetic Field	Structural Features	Thermal Budget	Physical Properties	Seismicity	Physical Features	Isotope Ratios	Mineralization	Age	Atmosphere	Satellites	Summary	Solar Radiation	Meteoroid Impacts	Isostatic Forces	Seismic Activity	Diastrophism	Volcanic Activity	Surface Winds	Temperature Changes	Chemical Reactions	Life	Phase Changes	Gravity	Hydraulic Action	Glacier Action	Nuclear Reactions	Summary	Charged Particles	Atomic Elements	Molecular Elements	Minerals	Chemicals	Isotopes	Summary	Diurnal	Seasonal	Latitude	Magnetic Field	Micrometeorology	Meteoroid	Radioactive Decay	Solar Radiation	Summary	Macroscopic	Microscopic	Protoorganic	Fossil	Summary
Surface Priority	X	X	X	X	10	35	19	29	17	41	39	12	3	1	7	X		2	23	X	40	X	18	31	38	34	26	21	22	25	28	4		30	11	32	6	9	16		37	33	20	36	27	X	8	5		13	14	15	24	
1																																																		A	A	B	A	
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2					D	C		B	A	O	A	R		I	A			A						C	D			E									A				A	A	A		A			J						
								L	D	P				G	H			H						Q	L			H	D							H			R		H	H	H		H			L						
									V																			P								Q			Q		N	N	N					M						
3					Q	B	A	D											A	A	O	A	D		D		A	A	Q	A	A	C		I		E	A	I						C			K			A				
							D	E															N		L	L		P		D	D	S			R	R	D-I	R																
							E	L					A													R				E	E						KM ,N	T																
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							P																																															
							V																																															

Measurement or Observation Techniques

TABLE 5-10A

FOLDOUT FRAME

FOLDOUT FRAME

5.1.3 MARS SURFACE PROGRAM AND ITS REQUIREMENTS

Table 5-10 presents the matrix of observation and measurement classes against the instrument classes for the Mars surface exploration. The instrument classes are defined in Tables 5-11 and 5-12.

Because it is impossible to predict what will be found at the selected landing site, or if all of the surface investigations proposed can be undertaken, no further attempt can be made to clarify this most important phase of the mission. The philosophy pursued was one which would permit both intensive biological and geological sampling programs under the complete control of the astronaut. Automated data acquisition is proposed for those measurements of the surface environment which are repetitive in nature. Soil constituent analysis and water determination will require the intervention of man in meeting the sampling requirements.

Additional detailed requirements for the Mars landing phase are given in Appendix C.

Table 5-11: MANNED AND UNMANNED MEASUREMENT TECHNIQUES--MARS SURFACE

Technique	Instrument Class
1. BIOLOGICAL	a. Microscope + Camera b. Centrifuge c. Polarimeter d. Spectrophotometers IR and Visible e. PH Meter and Reagents f. Mass Spectrometer g. Gas Chromatograph h. Osmometer i. Refractometer j. Thermometers k. Scales l. Microtome + Stains and Slides m. Refrigerators n. Incubators o. Ovens p. Sterilizers q. Work Bench + Containers; Tubing and Reagents r. Micromanipulators s. Cleaner and Solvents t. Agitators and Blenders u. Emulsifier v. Sample Containers--Hand Tools w. Recorders x. Culture Media
2. ENVIRONMENT	a. Pressure Sensor b. Temperature Sensors c. Wind Velocity Transducers d. Cloud Cover Estimates e. Precipitation Gauge f. Photometers g. Atmosphere--Major Constituents h. Humidity--Gas Chromatography i. Charged Particles Detectors j. UV Photometer k. Gamma-ray Dosimeter l. Thermal Radiation (IR Spectrometer) m. Visible Radiation (Spectrometer) n. Magnetometer o. Gravimeter p. Hydrograph q. Mass Spectrometer r. Recorders

Table 5-11: MANNED AND UNMANNED MEASUREMENT TECHNIQUES--MARS SURFACE (Continued)

Technique	Instrument Class
3. GEOLOGICAL	a. Camera + Tripod b. Magnetometer c. Charged Particle Det. d. Drills--Heat Flow e. Coring Tools f. Rock Cutters g. Polishing and Etching h. Hand Tools--Hammer i. Sample Containers j. Recorders k. X-ray Diffractometer l. Thermometers m. Scales n. IR Spectroscope o. Seismograph--Passive p. Active Seismometry q. Gravimeters r. Mass Spectrometer s. Chemicals--Reagents, Acids t. Blow Pipe--Alcohol u. Hardness Scale v. Surface Transport

Table 5-12: MANNED AND UNMANNED MEASUREMENT TECHNIQUE--SAMPLE RETURN

Technique	Instrument Class
1. SAMPLING	a. Soil Samples b. Sedimentary Rock Samples c. Metamorphic Rock Samples d. Igneous or Magmatic Rocks e. Stratigraphic Core f. Water Samples g. Ice Samples (Solid CO_2) h. Life Samples (Lichens, Algae, Micro)
2. DATA RECORDING	a. Magnetic Tapes b. Photographs--Color c. Environment Records d. Notebooks (?)

5.1.3.1 The Surface Instruments

Three categories of surface instruments have been investigated: Analytical Instruments, Support Instruments, and Sample Return. These categories were established in order to avoid duplication between those which could be used to determine composition, environment, and life studies.

Suggested Analytical Hardware---Table 5-13 presents the suggested hardware which has specific analytical application, i.e., it is the equipment which is used to translate, enlarge, or sort and then make information available to the surface team. This equipment can be used to obtain biological information as well as geological information depending upon its use. The weather station will be automated.

Table 5-13: ANALYTICAL HARDWARE

Equipment	Requirements		
	Weight (lb)	Power (watts)	Volume (cubic ft)
Microscope and Cameras	15	20	1.2
Centrifuge	40	25	0.5
Polarimeters	14	5	0.2
Spectrophotometers (Vis., UV, X-Ray)	135	60	0.5
Nuclear Instrumentation	150	30	0.2
PH Meter Plus Reagents	41	3	0.2
Mass Spectrometer	10	3	0.5
Chromatographs	14	10	0.2
Osmoter	12	--	0.2
Refractometer	8	2	0.2
X-Ray Diffractometer	36	20	1.1
Thermometers	1	1	0.1
Scales	15	1	1.0
IR Spectroscopes	100	40	1.0
Weather Station(1)	100	5	2.5
Magnetometer	6	7	0.5
Seismographs (Active and Passive)	52	25	3.5
Gravimeter	30	5	1.0
Heat Flow (With Small Drill)	15	2	1.0
Total Analytical Hardware	794	264	15.9

(1)Automated with recorder and data transmission (10^4 bps peak)

The Support Hardware---Table 5-14 presents the suggested support hardware, i.e., that equipment which will aid in the preparation of the sample or its handling equipment and then aid in the analysis of the data.

Sample and Data Return---Table 5-15 presents estimates of the sample weights which should be returned to the spacecraft for analysis on the return mission. It includes specimens of microscopic life as well as photographs which have not been transmitted to the spacecraft whether because of the resolution required for analysis or because the information was obtained late in the surface operations and time limitations imposed on data transmitted. It should be noted that an 'icebox' has been included in order to assure the preservation of 'ice' or 'snow' samples which may have spores or other evidence of life and past geological changes.

Table 5-14: SUPPORT HARDWARE

Suggested Equipment	Requirements Weight (lb)	Power (watts)	Volume (cubic ft)
Microtome and Slides and Stains	25	15	0.3
Refrigerators	10	40	1.0
Incubators	20	100	2.0
Oven-Sterilizer	40	500	1.0
Work Bench and Glassware (Teflon)	55	-	30.0
Micromanipulators (In Above Bench)	22	5	-
Ultrasonic Cleaner Including Solvent	140	200	2.0
Agitators, Blenders	9	10	0.5
Emulsifier	10	8	0.5
Drilling and Coring	110	500	1.0
Rock Cutters	20	150	1.0
Polishing and Etching	20	50	0.5
Biosampler	11	-	0.2
"Pristine State" Mars Material Box	6	-	2.0
Geological Hand Tools and Containers	25	-	1.0
Data System(1)	50	25	0.5
Total Support Hardware	573	1603	43.5

(1) Include recorders and telemetry system with capability of transmitting video bandwidth information. Separate from command link between MEM and spacecraft.

Table 5-15: SAMPLE AND DATA RETURN

(1)Samples and Data	Weight (lb)	Power (watts)	Volume (cubic ft)
Sedimentary Samples	180	-	1.2
Stratigraphic Records	12	-	0.2
"Long" Core Samples	450	-	4.2
Photographic Records(2),(3)	6	-	0.1
Surface Soil Samples	150	-	1.0
Water Samples	8	-	0.1
Environment Data	6	-	0.1
Tape Recordings(3)	12	-	0.2
Ice Samples (Includes Refrigerator)	28	150	1.1
Specimens (Lichens, Algae)	60	-	1.0
Total Samples and Data Return	912	150	9.2

(1)Includes packaging where applicable.

(2)Transmission data bandwidth limitations may increase this.

(3)Data collected just prior to launch from Mars surface.

5.1.4 UNMANNED SUPPORT SPACECRAFT

An examination of the diverse data required in the 49 observation and measurement classes, the duration of planet stay time, the orbital constraints and limited surface mobility reveals the necessity for the use of supporting unmanned probes, orbiters and landers. In addition, there are requirements for operational and engineering data to assure the safety of the landing crew at Mars and to select the landing site.

The unmanned probes and orbiters permit three distinct classes of observations:

1) Those that make orbital scientific measurements or observations;
2) Those used to sample the Venus cloud properties, including life; and
3) Those used to obtain engineering atmospheric and surface data prior to deorbiting. These modes and the associated instrument classes are shown in Table 5-16.

5.1.4.1 Scientific Orbiters--Mars

The Occultation Detector---The occultation detector determines the variation of atmospheric density as observed from phase variations due to the atmospheric pressure effects on the transmitted frequency.

The Topside Sounder---The topside sounder determines the ionospheric constituents and their distribution in an orbit below that of the spacecraft.

The Magnetometer---The magnetometer will aid in mapping the magnetic field. This will augment the instrument in the spacecraft.

The Moon Probes---The Mars' moon probes include a television transmission to the spacecraft of the surface of the moon as it is approached. Permits an examination of their surface features in conjunction with spectrometric observations.

Mapping Radar---The mapping radar will determine the thickness of the solid overlay on the planet. If cloud cover prohibits optical observations of the surface, the radar will map the planet features.

5.1.4.2 Engineering Probes--Mars

Prior to landing at a site at least three types of information are required that may not be available from orbit. First, the site must have sufficient bearing strength to support the MEM during touchdown. Second, both the radiation background and the surface temperature should be known and third, surface wind with dust content should be determined. To obtain this information, a soft lander will follow a a small atmospheric probe that will determine the engineering characteristics of the atmospheric profile essential to landing in the area selected. The soft lander will verify the data obtained by the smaller atmospheric probes.

It is assumed that no commitment to land will be made if the surface area is obscured by clouds.

5.1.4.3 Scientific Orbiters and Probes--Venus

Because Venus rotates at an extremely low rate compared to the duration of the mission it is essential that the potential data acquisition of the spacecraft with its crew is augmented by unmanned orbiters to a greater degree than is the case with Mars. Two additional specific types of probes or orbiters are required for Venus that are not required for Mars. These are an RF window probe and an atmospheric bioprobe discussed in the following sections.

Cloud Data Probe---The cloud data probe determines the difference in cloud composition that may occur as a result of precipitation, of latitude, of longitude since the planet doesn't rotate and of altitude.

Atmospheric Drifter---The atmospheric drifter will collect data on the type of life that may have evolved in the atmosphere. The instrument will filter the atmosphere, culture it and then determine the presence of enzymes or of radioactive CO_2 due to life processes.

Radar Mapper---The radar will map the planet and determine surface material thickness. These are essential aids because of the planet's slow rotation. Cloud structure and stratified circulation patterns will also be obtained.

Radio Frequency Probes---The RF window probe will determine the frequency at which radiation cannot escape the atmosphere and determine other windows through which RF can be transmitted.

The Venus Soft Lander---The soft lander will be equipped with a complete weather station as well as a television camera which will scan from horizon through the zenith to determine the variation of the light reaching the surface as well as to photograph the surface itself. A sampling device will determine the mineral and the chemical composition.

The Swingby Mission---Both the bioprobe drifter and the RF window probe would be released at Venus from a Mars mission with Venus swingby. These two have been selected because the composition of a chemically active planet will change and hence the transmissivity of the atmosphere. The initial mission may not disclose life because the instrumentation methods were not applicable. A change in instrumentation is then warranted. If life is discovered, additional techniques may be justified to determine other life forms.

5.1.4.4 Required Engineering Data--Venus

Although there are no present plans for a manned lander to the surface of the planet, the acquisition of data for a lander should not be ruled out, especially if either polar areas or high altitude peaks provide suitable environments permitting manned operations on the surface. It may be that the planet's slow rotation will permit a 'night' side of the planet to cool sufficiently for a landing. This eventuality is being considered here because man must eventually land on the surface to verify planet age and other unique phenomena. An RF window probe is included to obtain information which may be required to assure the transmission of information through the Venusian atmosphere. This probe will measure such other atmospheric characteristics as temperature, wind velocity, spherics, precipitation, density and the various other information to guide the release of the soft lander.

In addition to the atmospheric composition there are at least three factors contributing to an environment which should be verified prior to an unmanned surface landing. The first is the high temperature generally thought to exist on the surface of the planet. The temperature measured may be the result of the atmosphere or existing volcanic activity, or of pools of molten material. At any rate the temperature maximum, heat conductivity and specific heat of the surface must be determined if a soft lander is to survive. A second factor and equally dangerous, which must be known prior to committing a soft lander to the surface is the maximum wind velocities and their duration with their sand or dust content. A third factor about which little is known is the type of precipitation or condensation in the Venusian clouds. The liquids may be exceedingly corrosive either to the lander or to contents designed to sample surface constituents.

Table 5-16 summarizes the instrumentation for the various probes and Tables 5-17 and 5-18 give additional requirements.

Table 5-16: UNMANNED MEASUREMENT AND OBSERVATION SPACECRAFT

Spacecraft Mode	Instrument Class
1. MARS HARD LANDERS (Atmospheric Entry Data)	a. Pressure Sensor
	b. Temperature Sensor
	c. Accelerometer
2. MARS SOFT LANDER (Surface Environment)	a. Radioactivity
	b. Bearing Strength
	c. TV Imaging
	d. Mass Spectrometer
	e. Pressure Sensor
	f. Temperature Transducer
	g. Accelerometer
3. OCCULTATION ORBITER	a. Atomic Clock
	b. RF Transponder
4. TOPSIDE SOUNDER ORBITER	a. Sweep Frequency-Pulsed Oscillator
5. MAGNETOMETER ORBITER	a. Magnetic Field
6. MARS MOON PROBES	a. TV Imaging
	b. Radioactivity
7. MAPPING RADAR--MARS AND VENUS ORBITER	a. Radar, Imaging
8. VENUS ATMOSPHERE BIOPROBE	a. Gas Chromatograph
	b. IR Spectrometer
	c. Temperature Transducer
	d. Pressure Sensor
	e. Biosampler
9. VENUS CLOUD DATA ORBITER	a. Gas Chromatograph
	b. Mass Spectrometer
	c. TV Imaging
	d. Radiometer
	e. RF Noise
	f. Temperature Sensor
	g. Pressure Sensor
10. VENUS RF WINDOW PROBE	a. Sweep Frequency (RF)
11. VENUS SOFT LANDER	a. TV Imaging
	b. Radioactivity
	c. Bearing Strength
	d. Mass Spectrometer
	e. Pressure Sensor
	f. Temperature Sensor
	g. Wind Velocity

Table 5-17: MARS ORBIT LAUNCH PROBES

Data Required	Qty	Weight ① (each)	Plane Change Capability	Mode
ENGINEERING PROBES:				
MEM Trajectory Data	5	20	20°	Hard Lander
Surface Bearing Strength & Radiation Background	2	100	20°	Soft Lander
SCIENCE PROBES:				
Occultation	2	6	5°	Orbiter
Ionosphere	2	22	5°	Orbiter
Magnetic Field	2	6	5°	Orbiter
Martian Moon Imaging	4	25	--	To Mars' Moons Hard Lander
Radiometric Maps (Polar)	2	420	20°	Orbiter

① Does not include propulsion or guidance

Table 5-18: VENUS ORBIT LAUNCH PROBES

Data Required	Qty	Weight ① (each)	Plane Change Capability	Mode
Atmospheric Life	2	50	--	Atmos. drifter to surface. Drift down rate of 20 miles per 20 days which may be inversely prop to atmospheric density from 1 atmos to 20 atmos hor vel. Not critical.
Cloud Data	2	150	20°	Orbiter
Surface Temperature Mapping Data	2	420	60°	Orbiter
Atmospheric RF Transmission	2	80	--	Atmos. drifter similar to above with a constant drop rate rather than a proportional rate.
Surface Spectral Data	2	320	--	Same as above but with soft lander capability.

① Does not include propulsion or guidance

5.2 MEASUREMENT PRIORITIES

Priorities were established using the methods presented in Section 6.0 for each phase of the Mars and Venus missions. These priorities can be used to select a specific payload complement if constraints limit the payload. Actually, in the present study it was found that the payload requirements (Section 7.0) for the entire list of measurements were acceptable as design requirements for the recommended vehicle. On the other hand, the crew time available is found to be critical except for the conjunction class or Venus long missions and therefore the priorities will establish the activities of the crew and will set automation requirements on equipment design so that the crew can devote its time to those tasks which will produce the greatest return.

Two priorities are given in Tables 5-19 through 5-24. These are "Mission Priority" and "Scientific Priority." Both priorities are designed to optimize the knowledge return, but the scientific priority gives more emphasis to those classes of observations and measurements about which the least is known. The derivation of these is given in detail in Section 6.0.

Table 5-19: IN ORBIT MARS MEASUREMENTS--IN ORDER OF MISSION PRIORITY

	Mission Priority		Scientific Priority
1.	Rotational Parameters	1.	Chemical Reactions
2.	Solar Radiation (surface)	2.	Temperature Changes
3.	Mineralization	3.	Mineralization
4.	Nuclear Reactions	4.	Seismicity
5.	Solar Radiation (environment)	5.	Volcanic Activity
6.	Mineral Composition	6.	Nuclear Reactions
7.	Satellites	7.	Mineral Composition
8.	Atmosphere	8.	Micrometeorology
9.	Radioactivity	9.	Radioactivity
10.	Chemical Composition	10.	Chemical Composition
11.	Gravitational Constant	11.	Solar Radiation
12.	Atomic Elements	12.	Surface Winds
13.	Isotope Ratios	13.	Meteoroid Impacts
14.	Macroscopic Life Indications	14.	Seismic Activity
15.	Protoorganic Gases	15.	Hydraulic Action
16.	Isotope Composition	16.	Seasonal Changes
17.	Physical Properties	17.	Glacier Action
18.	Volcanic Activity	18.	Life
19.	Structural Features	19.	Phase Changes
20.	Latitude Effects	20.	Thermal Budget
21.	Phase Changes	21.	Diurnal Effects
22.	Gravitational Field	22.	Meteoroid Environment
23.	Meteoroid Impacts	23.	Solar Radiation (surface)
24.	Diastrophism	24.	Diastrophism
25.	Hydraulic Action	25.	Atomic Elements
26.	Life as a Modifying Force	26.	Molecular Elements
27.	Micrometeorology	27.	Charged Particles
28.	Meteoroid Environment	28.	Physical Properties
29.	Isostatic Forces	29.	Isotopes Composition
30.	Glacier Action	30.	Latitude Effects
31.	Thermal Budget	31.	Isostatic Forces
32.	Charged Particles	32.	Structural Features
33.	Surface Winds	33.	Physical Features
34.	Moments of Inertia	34.	Macroscopic Life Indications
35.	Figure of Planet	35.	Atmosphere
36.	Molecular Elements	36.	Gravitational Field
37.	Chemical Reactions	37.	Gravitational Constants
38.	Magnetic Field (planet)	38.	Isotope Ratios
39.	Magnetic Field (environment)	39.	Magnetic Field (environment)
40.	Seasonal Effects	40.	Magnetic Field (planet)
41.	Diurnal Effects	41.	Figure of Planet
42.	Temperature Changes	42.	Moments of Inertia
43.	Physical Features	43.	Rotational Parameters
44.	Seismic Activity	44.	Satellites
45.	Seismicity	45.	Protoorganic Life

Table 5-20: MARS SURFACE MEASUREMENTS--IN ORDER OF PRIORITY

	Mission Priority		Scientific Priority
1.	Age	1.	Chemical Reactions
2.	Solar Radiation as a Force	2.	Temperature Changes
3.	Mineralization	3.	Age
4.	Nuclear Reactions	4.	Mineralization
5.	Solar Radiation Environment	5.	Seismicity
6.	Mineral Composition	6.	Volcanic Activity
7.	Atmosphere	7.	Nuclear Reactions
8.	Radioactivity	8.	Mineral Composition
9.	Chemical Composition	9.	Micrometeorology
10.	Gravitational Constant	10.	Radioactivity
11.	Atomic Elements	11.	Chemical Composition
12.	Isotope Ratios	12.	Solar Radiation Environment
13.	Macroscopic Life	13.	Surface Winds
14.	Microscopic Life	14.	Meteoroid Impacts
15.	Protoorganic Gases	15.	Seismic Activity
16.	Isotopes	16.	Hydraulic Action
17.	Physical Properties	17.	Seasonal Variations
18.	Volcanic Activity	18.	Glacier Action
19.	Structural Features	19.	Life as a Modifying Force
20.	Latitude Variations	20.	Phase Changes
21.	Phase Changes	21.	Thermal Budget
22.	Gravitational Field	22.	Diurnal Changes
23.	Meteoroid Impacts	23.	Microscopic Life
24.	Fossils	24.	Solar Radiation Force
25.	Hydraulic Action	25.	Atomic Elements
26.	Life as a Force	26.	Molecular Elements
27.	Micrometeorology	27.	Charged Particles
28.	Glacier Action	28.	Physical Properties
29.	Thermal Budget	29.	Isotope Composition
30.	Charged Particles	30.	Latitude Effects
31.	Surface Winds	31.	Structural Features
32.	Molecular Elements	32.	Physical Features
33.	Seasonal Variations	33.	Macroscopic Life
34.	Chemical Reactions	34.	Atmosphere
35.	Magnetic Field	35.	Gravitational Field
36.	Magnetic Environment	36.	Gravitational Constant
37.	Diurnal Variations	37.	Isotope Ratios
38.	Temperature Changes	38.	Fossils
39.	Physical Features	39.	Magnetic Environment
40.	Seismic Activity	40.	Magnetic Field
41.	Seismicity	41.	Protoorganic Gases

Table 5-21: THE MARS IN-TRANSIT MEASUREMENTS AND OBSERVATIONS

	Mission Priority		Scientific Priority
1.	Orbital Parameters	1.	Temperature Changes
2.	Rotational Parameters	2.	Seismicity
3.	Solar Radiation Force	3.	Volcanic Activity
4.	Solar Radiation Environment	4.	Micrometeorology
5.	Satellites	5.	Solar Radiation Environment
6.	Atmosphere	6.	Surface Winds
7.	Atomic Elements	7.	Meteoroid Impacts
8.	Protoorganic Gases	8.	Seasonal Effects
9.	Volcanic Activity	9.	Thermal Budget
10.	Structural Features	10.	Diurnal Variations
11.	Latitude Variations	11.	Meteoroid Environment
12.	Gravitational Field	12.	Solar Radiation Forces
13.	Meteoroid Impacts	13.	Diastrophism
14.	Diastrophism	14.	Atomic Elements
15.	Micrometeorology	15.	Molecular Elements
16.	Meteoroid Environment	16.	Charged Particles
17.	Isostatic Forces	17.	Latitude Variations
18.	Thermal Budget	18.	Isostatic Forces
19.	Charged Particles	19.	Structural Features
20.	Surface Winds	20.	Physical Features
21.	Figure of Planet	21.	Atmosphere
22.	Molecular Elements	22.	Gravitational Field
23.	Seasonal Variations	23.	Figure of Planet
24.	Diurnal Variations	24.	Rotational Parameters
25.	Temperature Changes	25.	Orbital Parameters
26.	Physical Features	26.	Satellites
27.	Seismicity	27.	Protoorganic Gases

Table 5-22. IN ORBIT VENUS MEASUREMENTS--IN ORDER OF PRIORITY

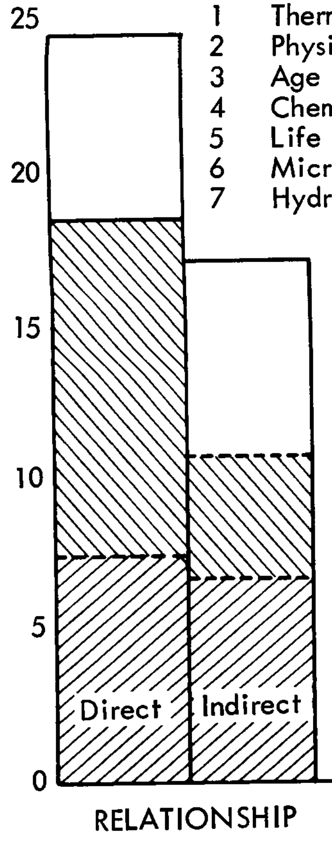
	Mission Priority		Scientific Priority
1.	Rotational Parameters	1.	Seasonal Effects
2.	Satellites	2.	Volcanic Activity
3.	Gravitational Constant	3.	Diurnal Effects
4.	Solar Radiation	4.	Meteoroid Environment
5.	Atmosphere	5.	Chemical Composition
6.	Latitude Effects	6.	Life as a Modifying Force
7.	Microscopic Life	7.	Phase Changes
8.	Chemical Composition	8.	Latitude Effects
9.	Atomic Elements	9.	Charged Particles
10.	Molecular Elements	10.	Satellites
11.	Isotope Ratios	11.	Thermal Budget
12.	Phase Changes	12.	Gravitational Constant
13.	Meteoroid Environment	13.	Meteoroid Impacts
14.	Isotope Composition	14.	Physical Reatures
15.	Physical Properties	15.	Microscopic Life
16.	Life as a Modifying Force	16.	Solar Radiation as a Modifying Force
17.	Volcanic Activity	17.	Atomic Elements
18.	Structural Features	18.	Molecular Elements
19.	Moments of Inertia	19.	Physical Properties
20.	Seasonal Effects	20.	Isotope Composition
21.	Figure of Planet	21.	Atmosphere
22.	Gravitational Field	22.	Structural Features
23.	Diurnal Effects	23.	Figure of Planet
24.	Thermal Budget	24.	Moments of Inertia
25.	Physical Features	25.	Gravitational Field
26.	Meteoroid Impacts	26.	Isotope Ratios
27.	Charged Particles	27.	Magnetic Field of the Planet
28.	Protoorganic Gases	28.	Magnetic Environment
29.	Magnetic Field of the Planet	29.	Rotational Parameters
30.	Magnetic Environment	30.	Protoorganic Gases

Table 5-23. VENUS SURFACE MEASUREMENTS--UNMANNED--IN ORDER OF PRIORITY

	Mission Priority		Scientific Priority
1.	Age	1.	Chemical Reactions
2.	Gravity	2.	Temperature Changes
3.	Mineral Composition	3.	Age
4.	Solar Radiation Forces	4.	Mineralization
5.	Atmosphere	5.	Mineral Composition
6.	Mineralization	6.	Micrometeorology
7.	Latitude Effects	7.	Seasonal Effects
8.	Nuclear Reactions	8.	Seismicity
9.	Solar Radiation Environment	9.	Surface Winds
10.	Macroscopic Life	10.	Volcanic Activity
11.	Microscopic Life	11.	Diurnal Variations
12.	Radioactive Decay	12.	Nuclear Reactions
13.	Chemical Composition	13.	Glacier Action
14.	Atomic Elements	14.	Seismic Activity
15.	Molecular Elements	15.	Hydraulic Action
16.	Isotope Ratios	16.	Radioactive Decay
17.	Phase Changes	17.	Chemical Composition
18.	Glacier Action	18.	Solar Radiation Environment
19.	Isotope Composition	19.	Life as a Modifying Force
20.	Physical Properties	20.	Phase Changes
21.	Hydraulic Action	21.	Latitude Variations
22.	Life as a Modifying Force	22.	Charged Particles
23.	Volcanic Activity	23.	Thermal Budget
24.	Structural Features	24.	Gravitational Constant
25.	Micrometeorology	25.	Meteoroid Impacts
26.	Fossils	26.	Physical Features
27.	Seasonal Variations	27.	Macroscopic Life
28.	Surface Winds	28.	Microscopic Life
29.	Gravitational Field	29.	Solar Radiation Forces
30.	Diurnal	30.	Atomic Elements
31.	Thermal Budget	31.	Molecular Elements
32.	Physical Features	32.	Physical Properties
33.	Meteoroid Impacts	33.	Isotope Composition
34.	Charged Particles	34.	Atmosphere
35.	Chemical Reactions	35.	Structural Features
36.	Protoorganic Gases	36.	Gravitational Field
37.	Magnetic Field	37.	Isotope Ratios
38.	Magnetic Environment	38.	Magnetic Field
39.	Temperature Changes	39.	Fossils
40.	Seismic Activity	40.	Magnetic Environment
41.	Seismicity	41.	Protoorganic Gases

Table 5-24: THE VENUS IN-TRANSIT MEASUREMENTS AND OBSERVATIONS

Mission Priority	Scientific Priority
1. Orbital Parameters	1. Seasonal Variations
2. Satellites	2. Volcanic Activity
3. Solar Radiation Forces	3. Diurnal Variations
4. Atmosphere	4. Solar Radiation Environment
5. Latitude Variations	5. Phase Changes
6. Solar Radiation Environment	6. Latitude Variations
7. Atomic Elements	7. Charged Particles
8. Molecular Elements	8. Satellites
9. Isotope Ratios	9. Thermal Budget
10. Phase Changes	10. Solar Radiation Forces
11. Volcanic Activity	11. Atomic Elements
12. Seasonal Variations	12. Molecular Elements
13. Diurnal Variations	13. Atmosphere
14. Thermal Budget	14. Isotope Ratios
15. Charged Particles	15. Orbital Parameters
16. Protoorganic Gases	16. Protoorganic Gases



		Priority		Relationship		Direct Overlap	Indirect Overlap
		Mission	Life	Direct	Indirect		
1	Thermal Budget	35	11	24	14	3 (2,3,4)	2 (8, 13)
2	Physical Properties	47	13	13	16	2 (1,3)	1 (13)
3	Age	1	1	6	23	0	3 (8,9,13)
4	Chemical Reactions	42	12	26	5	5 (1,3,5,6,7)	2 (11,13)
5	Life (Modifying Force)	30	9	26	8	5 (1,2,3,4,6)	1 (13)
6	Microscopic Life	17	4	25	16	5 (1,2,3,4,5)	0
7	Hydraulic Action	29	8	20	8	4(1,2,3,4)	2 (8,11)
8	Isotopes	19	5	13	1		
9	Isotope Ratios	15	3	12	1		
10	Structural Features	22	6	16	23		
11	Glacier Action	34	10	20	8		
12	Fossils	27	7				
13	Nuclear Reactions	6	2	9	5		

☐ Decisions Required

▧ Unmanned — Sufficient

▨ Sufficient Data Exists

Table 5-2: CLASSES OF MICROSCOPIC LIFE

5.3 THE ROLE OF MAN

In general, man is considered essential as an evaluator, integrator, selector, and planner, as well as a subject for study. Specific areas in which man is considered important are:

1) Search for patterns associated with life and activity on the plantes;
2) Selection of samples for age dating;
3) Selection of representative samples to determine the composition of the planet;
4) Search for possible fossil-bearing strata;
5) Identification of the presence and interaction of forces modifying the composition and structure of the planet.

The techniques developed for more specifically determining the role of man are illustrated in the following outline which considers the search for, and the study of the macroscopic life on the planet Mars.

5.3.1 EXPERIMENT PLANNING

It is noted that macroscopic life depends on a total of 25 directly related classes of knowledge and 17 indirectly related (see Section 6). An evaluation of the directly related classes reveals that preliminary information exists in eight of these classes: 1) orbit; 2) rotation; 3) atmosphere; 4) satellite; 5) solar radiation, as a modifying force; 6) solar radiation as contributing to the environment; 7) atomic elements, and 8) latitude variations.

Sufficient planning information will be added to these and to the following through the assumed unmanned programs: 1) the degree of mineralization; 2) the minerals present; 3) temperature changes; 4) charged particles; 5) molecular elements; 6) chemical composition; 7) diurnal variations; 8) seasonal changes; 9) phase changes; and 10) micrometeorology.

But information or data will be lacking in the following categories in which a man is considered essential because of the complexity of the decisions involved not only in gathering the information necessary but also in selecting the physical area within which to gather the data: 1) the thermal budget; 2) physical properties; 3) age; 4) chemical reaction; 5) life as a modifying force; 6) life as a symbiote and 7) hydraulic action.

The mission priority of these classes with their priority in the search for and study of life is given in Figure 5-2. The figure includes the priorities assigned to the indirectly related factors as well and the number of factors to which they in turn are related. The overlap of the directly and indirectly related factors requiring man are also indicated.

The Measurement Class---To further the illustration, the class "Thermal Budget" is used. It's 24 directly related classes of information are divided into the general areas of source, sink and perturbing classes. These have been summarized in Table 5-25.

The next step was the correlation of the parameters required for the complete definition of each class as it is related to life. These are summarized for the three general areas in Tables 5-26, -27, and -28. All measurements that could be made with an unmanned system were identified using the rationale developed in Section 7.2. The remaining factors were then evaluated in terms of the decisions required such as the identification of a measurement range, presence of a perturbation, the percent modification, possible equilibrium, etc. Those that were not associated with the known classes were automatically classified as requiring a man at the time of measurement or transducer emplacement.

The Directly Related Decisions---Within a total of 73 parameters required to determine the thermal budget of a planet, 43 decision areas were identified. Eighteen of these did not meet the criteria established for the automatic data acquisition system and hence were assumed to require man. The 18 different parameters directly related to the thermal budget of a planet which require selection, evaluation, and integration, either separately or in combination, are summarized in Table 5-29. It should be noted that 21 are identified but three overlap source or sink. Many of the effects discussed may contribute insignificantly to the final determination of the change with time of the thermal budget of a planet or even to the heat measured at a location. The purpose of this discussion is to illustrate possible factors which must be considered in the fixing the impact of a thermal budget on the development of life in a locale or on a planet. At any one location, or for any one determination anywhere from one to all of these, must be considered with sufficient information to determine the net effect through the evolution of the local area during the time period related to the life in question.

Perturbing Variables---Thirteen perturbing variables have been identified (Table 5-30) of which eight operations are to be made at the time of measurement to ensure that the perturbations introduced can be compensated accurately. Transients or anomalies must be detected and equilibrium conditions determined and achieved.

Thirty-four major design considerations have been identified as associated with the instrument techniques required for these measurements. See Table 5-31. Seven of these are usually fixed by the designer in the laboratory, while an additional 13 are incorporated in a fully automatic data acquisition system. If man is assumed as a potential operator, 14 new concepts are introduced. These are directly dependent on operation by man and on the philosophies adopted for the mission in the capabilities existing in man. Only three of these, transducer emplacement or insertion, sample selection and station emplacement are considered too complex for automation in an unknown environment. A summary of the above is presented in bar chart form in Figure 5-3.

Table 5-25: THERMAL BUDGET--DIRECTLY RELATED CLASSES

Sources	Sinks	Perturbing Classes
Solar Radiation (env)	Atmosphere	Orbital Parameters
Mineralization (exo)	Physical Properties	Physical Features
Nuclear Reaction	Chemicals	Isotope Ratios
Chemical Reactions (exo)	Mineralization (endo)	Age
Gravity	Atomic Elements	Solar Radiation (modifying force)
Radioactive Decay	Molecular Elements	Phase Changes
	Minerals	Diurnal
	Chemical Reactions (endo)	Seasonal
		Latitude
		Micrometeorology
		Charged Particles
		Volcanic Activity
		Atmosphere-Transmissivity

Table 5-26. SOURCE PARAMETERS

Classes (6)	Parameters (27)
Solar Radiation	Spectrum
	Radiant Energy
Mineralization (endothermic)	Temperature-Heat of Formation
	Thermal Capacity-Heat of Solution
	Mass Reacting-Distribution
	Total Mass Transformed
Nuclear Reactions (modifying force)	Energy-Flux
	Spectrum
	Reaction Rate-Half Life
Chemical Reactions (endothermic)	Temperature-Heat of Formation
	Reaction Rate-Heat of Solubility
	Thermal Capacity
	Mass Reacting-Distribution
Gravity	Gravitational Const., Planet
	Size
Radioactive Decay (environment of Planet-Cosmic Rays)	Decay Rate of Nuclei Produced Energy-Flux
	Incident Particle Rate

Table 5-27: SINK PARAMETERS

Classes (8)	Parameters (46)
Atmosphere	Thermal Capacity
	Transmissivity
	Circulation Rate
	Cloud Cover and Composition
	Conductivity
	Absorptivity
	Dust-Aerosols
	Backscatter
	Reflectance
Physical Properties (surface and subsurface)	Reflectance
	Emissivity
	Distribution
	Conductivity
	Thermal Capacity
	Absorptivity
Chemicals	Conductivity-Circulation-Heat of Solution
	Thermal Capacity-Emissivity-Rates
	Heat of Sublimation, Adsorption, Formation
Mineralization	Mineral Distribution-Degree
Atomic Elements	Thermal Capacity, Absorptivity, Dissociation Rate-Recombination Rate
Molecular Elements	Recombination Rate, Dissociation Rate
	Thermal Capacity-Absorptivity
Minerals	Conductivity, Solubility, Heat of Formation, Solution, Sublimation, Reflectivity
Chemical Reactions	Heat of Formation, Reaction Rate Distribution, Mass Reacting, Temperature

Table 5-28: PERTURBING CLASSES PARAMETERS

Classes (13)	Parameters (41)
Orbital	Distance from Sun
Physical Features	Altitude, Type, Proximity Reflectivity, Geometry, Shadows
Isotope Ratios	Ratios
Age	Isotope Ratios
Solar Radiation	Gram Calories/CM^2/min (angle of incidence) spectrum reaching surface
Phase Changes	Heat of Sublimiation, Vaporization, Fusion, Pressure, Quantity, Temperature
Diurnal	Night-Day Variations
Seasonal	Hemispherical and Seasonal Variation
Latitude	Variations from Equator to Poles
Micrometeorology	Local Temperature, Cloud Cover, Humidity, Wind Velocity, Precipitation Pressure, Haze Perturbation of Evaporation or Cooling Rates Due to Wind Velocity
Charged Particles	Formation Energy, Rate of Formation Recombination Rates (sources are Photoionization, Sferics and Ionizing Nuclear Particles)
Volcanic Activity	Temperature of Flow, Quantity, State, Distribution, Thermal Capacity
Atmosphere	Transmissivity, Absorptivity, Temperature Profile

Table 5-29: DECISIONS IN THE DETERMINATION OF THERMAL BUDGET

Parameters	Decisions
Source	
Temperature	Transducer selection and insertion.
Reacting Mass	Estimates of total mass, process identification, duration and rates of change. Thermal contribution.
Distribution	Surface and depth. Local effects process contributing to distribution. Time variations.
Heat of Formation	Sample selection compared to insitu measurements and estimates.
Heat of Solution	Solvent and solute identification. Transport mechanisms.
Thermal Capacity	Sample selection, original constituents, reacting mass, resultant mass.
Radioactivity	Sample selection, contribution, distribution, possible leaching.
Rate of Change	Selection of end points and impact of changing environment.
Heat of Condensation	Net heat contribution.
Sink	
Cloud Cover	Percent of area and time covered from evidence on site; also age dating.
Cloud Composition	Solid or liquid, particle or droplet size range and variation. Shape of solid particle and orientation insitu. Percent scattered from area of interest in terms of heat lost.
Emissivity	Sampling, variation with composition.
Heat Conductivity	Surface and sub-surface sampline. Sample preparation. Net loss estimates.
Electrical Conductivity	Same as above; source or sink?
Thermal Capacity	Same as source parameter.

Table 5-29. DECISIONS IN THE DETERMINATION OF THERMAL BUDGET (Continued)

Parameters	Decisions
Distribution	Same as source parameter with estimate of net loss of heat.
Heat of Sublimation	Heat loss, present and past.
Heat of Evaporation	Heat loss, present and past.
Heat of Liquification	Heat loss, present and past.
Gas Absorptivity-Adsorptivity	Variation of heat loss with mechanism.
Liquid, Absorption or Loss	Loss or absorption mechanism and loss contribution.
Dissociation-Recombination	Net heat loss, variation with time, composition, pressure, conductivity and dissociation mechanism.

Table 5-30: PERTURBING VARIABLES

ROLE OF MAN--THERMAL BUDGET MEASUREMENTS

Perturbing Variables	Parameters Measured	Decisions Required	Possible Preprog.
Reflectivity	Surface Structure and Text.,	Representative Selection	Yes
	Polarization and < of Reflec. and Incidence	Sampling for Comp.	No
	Surface Composition	Selection of Spect.	Yes
Emissivity	Spectrum and Flux	Area Identical to Above	Yes
	Composition and Temperature	Is Temperature Measuring Device Properly Placed	No
	Atmos. Temperature		
	Surface Text. and Struct.	Haze, Dust or Cloud Contributions	No
	Atmos. Abs. and Scat.		
Conductivity	Heating Rates	Emplacement of Trans.	No
	Specific Heat	Adequacy of Sample	No
	Cooling Rate	Anomalies Present	Yes
	Phase Change		
Cloud Cover	Duration and Composition	Night-Day Variations	Yes
	Reflect. and Trans.	Sampling Techniques	No
	Emiss. and Temperature	Adequacy of Data	No

Table 5-31: INSTRUMENTATION DESIGN

VARIABLE ORIENTED
(Usually Predetermined)

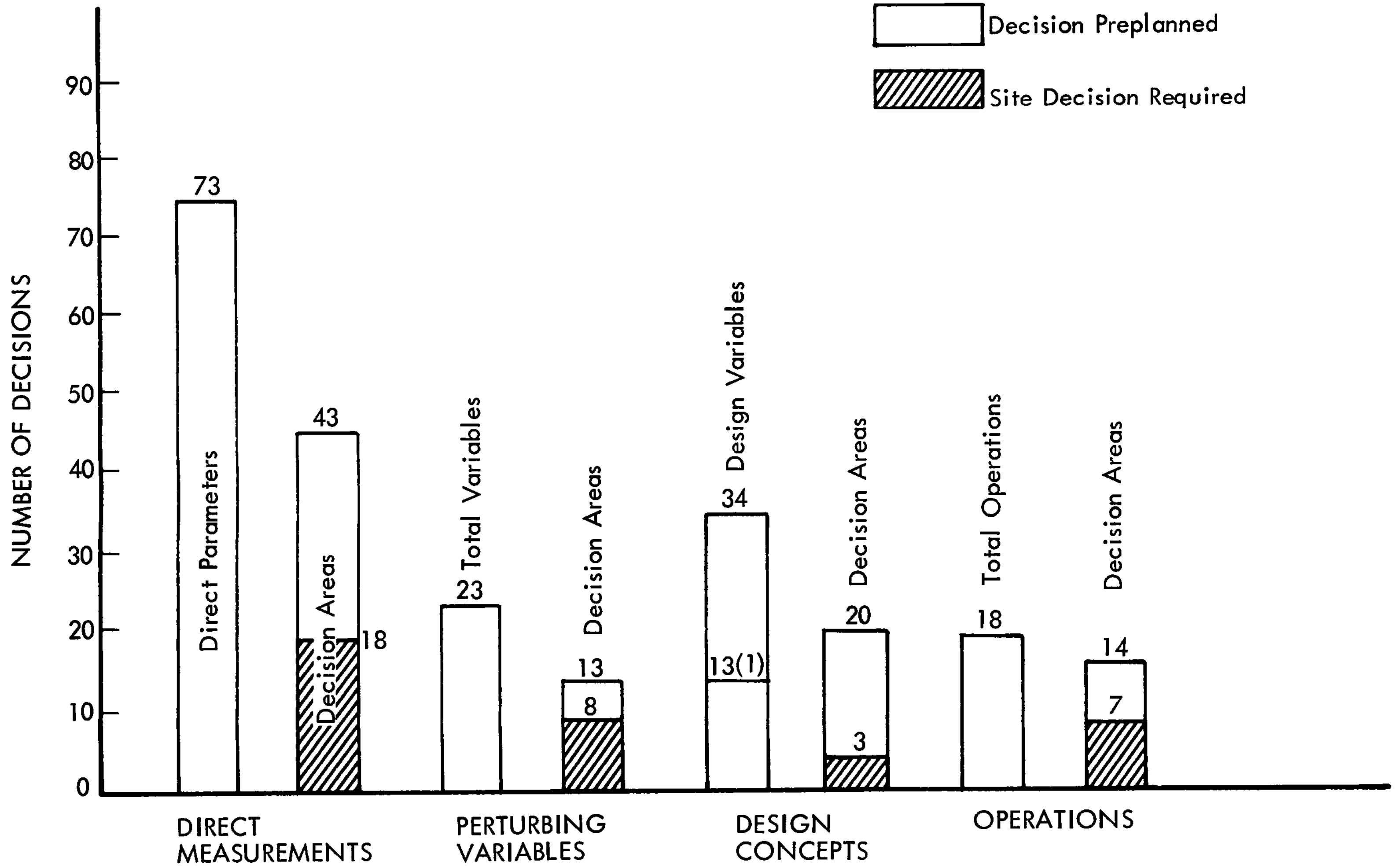
1. Accuracy-Error
2. Bandwidth
3. Resolution
4. Repetition Rate
5. Duration
6. Range and Range Switching
7. Transfer Function

OPERATIONS ORIENTED

1. Sensor Location
2. Data Formating
3. Self-Calibration
4. Self-Check Capabilities
5. Interrogation or Instructions
6. Support
7. Channels
8. Reliability
9. Packaging
10. Sampling Mech.
11. Self-Erection or Orientation
12. Self-Propulsion (mobility)
13. Mechanical Alignment

MANNED CONCEPTS

1. Degree of Automation
2. Softward and Reprogramming
3. Computation and Analysis
4. Consumables Required
5. Variable Selection
6. Recorder Replay or Load
7. Sample Selection
8. Displays
9. Controls
10. Transportability
11. Maintainability
12. Stowage
13. Emplacement
14. Assembly



(1) Introduced because of the role of man.

Figure 5-3: THERMAL BUDGET OF MARS — MEASUREMENT DECISIONS

5.3.2 EXPERIMENT OPERATIONS

Man's role in the operation of the instruments selected was investigated in general only. The specific devices to be used may change the titles of some of the blocks; however, the operations will be the same. Since the instrumentation will not be selected until after the objectives has been identified in this study, the details were not investigated; however, the general rule followed was that wherever selection was necessary for data or for a sample, man was essential. Using the 18 general operations associated with the conduct of experiments in general such as identified by the arrow heads in Figure 5-4, 14 were considered sufficiently complex to require decisions. Only 7 actually need man if the sequence of experimentation should proceed within a restricted time period (the oval boxes indicate those areas in which instrumentation designs are inflexible for a specific application). These areas are: 1) data sampling; 2) data reduction may require the collection or selection of additional data; 3) data reduction may also lead to the storage of some data for future reference; 4) from the display of data the decision may be made to transmit it directly or to analyze for possible experiment reprogramming; 5) experiment reprogramming may lead to the selection of additional or different data as well as the measurement devices to acquire the data; 6) data analysis may require the recall of information from storage and the selection of which data is required for analysis to complete the experiment; and 7) finally, man will decide when it is either useless to pursue the collection of similar data or when sufficient data has been collected to terminate the experiment. This is also depicted in Figure 5-3.

5.3.3 HARDWARE OPERATIONS

The specific operations for a piece of equipment performing measurement or observation are design dependent which in turn is state-of-the-art dependent. Detailed examination cannot be justified. Guidelines do exist, however, for determining the general role of an experienced observer when confronted with the unique opportunities permitted during an interplanetary space mission.

The Decisions---Man will determine which objectives can be met after he has observed the viewing conditions existing. He will select the parameters that will meet the objectives either totally or partially. These parameters in turn suggest a host of applicable techniques which, of course, will be limited to the tools available. Man can then set into motion an observation and measurement program which of itself may be completely automated. Figure 5-4 illustrates all decision points with a selector contact. Most decisions are based on degree rather than a 'yes'-'no'.

Selecting the Instrument---The method of measurement selected often depends on the background of the observer but in general the chosen instrument will measure or record a variable within some range to a pre-established accuracy. The instrument may actually sweep over a range of sensitivities or may within a predetermined range indicate and record a variable which may be either semiconstant or fluctuating widely

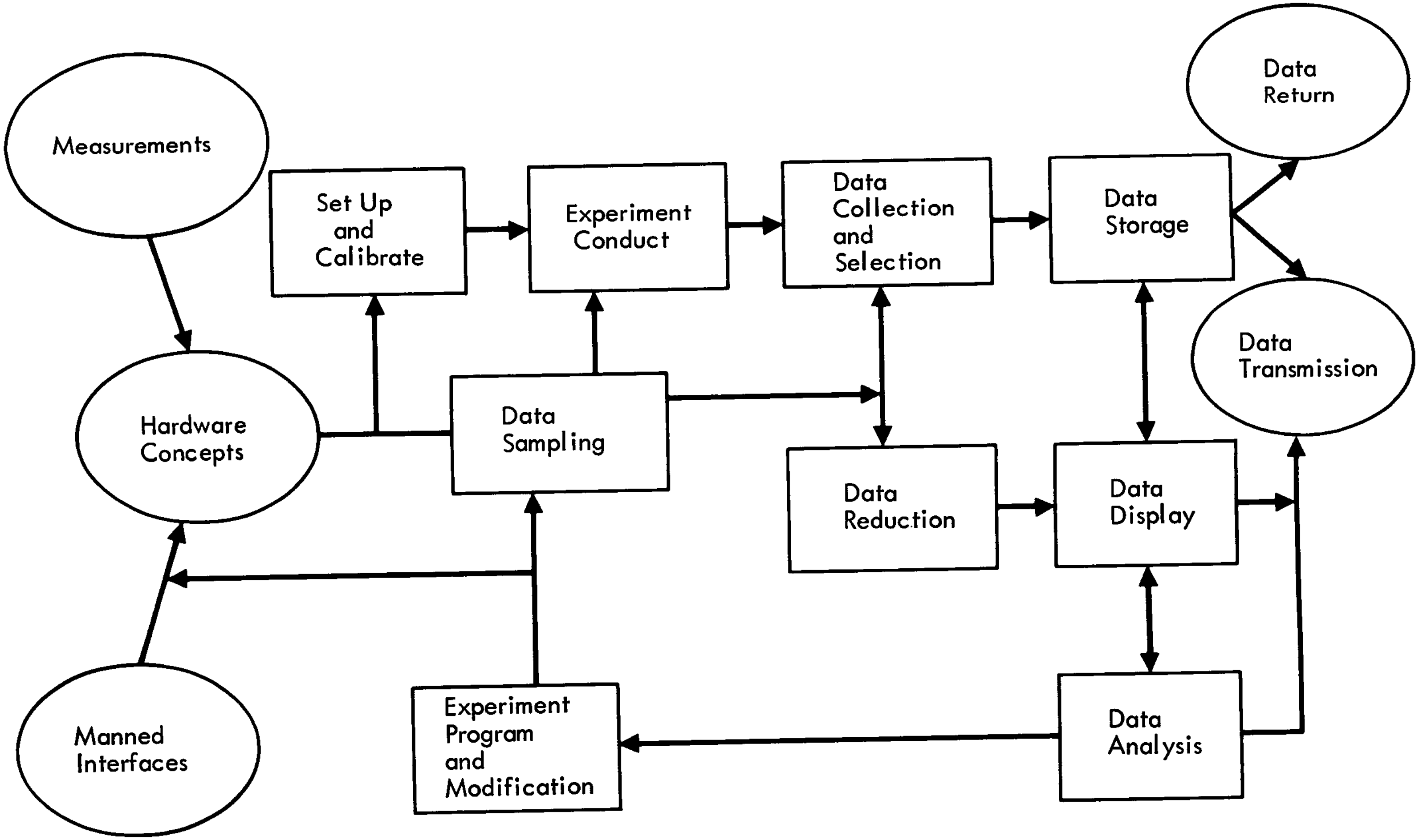


Figure 5-4: ROLE OF MAN — GENERAL OPERATIONS

in some fashion. The speed of response of the instrument must exceed the fluctuation rate of the variable if representative data are to be obtained. Experience of the competent observer has already assured him that instruments can determine rates which are higher and lower and far more accurate than he could do manually. In addition, the man as an evaluator will check the functional interfaces such as the displays and the recording equipment. The oval boxes of Figure 5-4 represent areas where previous design has imposed limitations on the experiment selection and are those areas which require the greatest preliminary planning. They will govern the flexibility of the total experiment program.

5.4 CONTRIBUTION OF THE MANNED PROGRAMS

An estimate of the contribution of the manned programs was made on the basis of three missions to Mars and two to Venus. In making the necessary value judgments, consideration was given to the role of man by accounting for the factors discussed in Section 5.3 for each observation and measurement class.

Figures 5-5 and 5-6 display the results for each experiment category. Also shown are the present knowledge base and the contribution made by the assumed unmanned precursor program. Further iteration on the unmanned and manned programs would no doubt alter the relative ratings and studies of that sort should probably be undertaken.

Obviously, no account can be taken in these estimates for unexpected discoveries.

Table 5-32 presents the estimates for the 49 measurement classes.

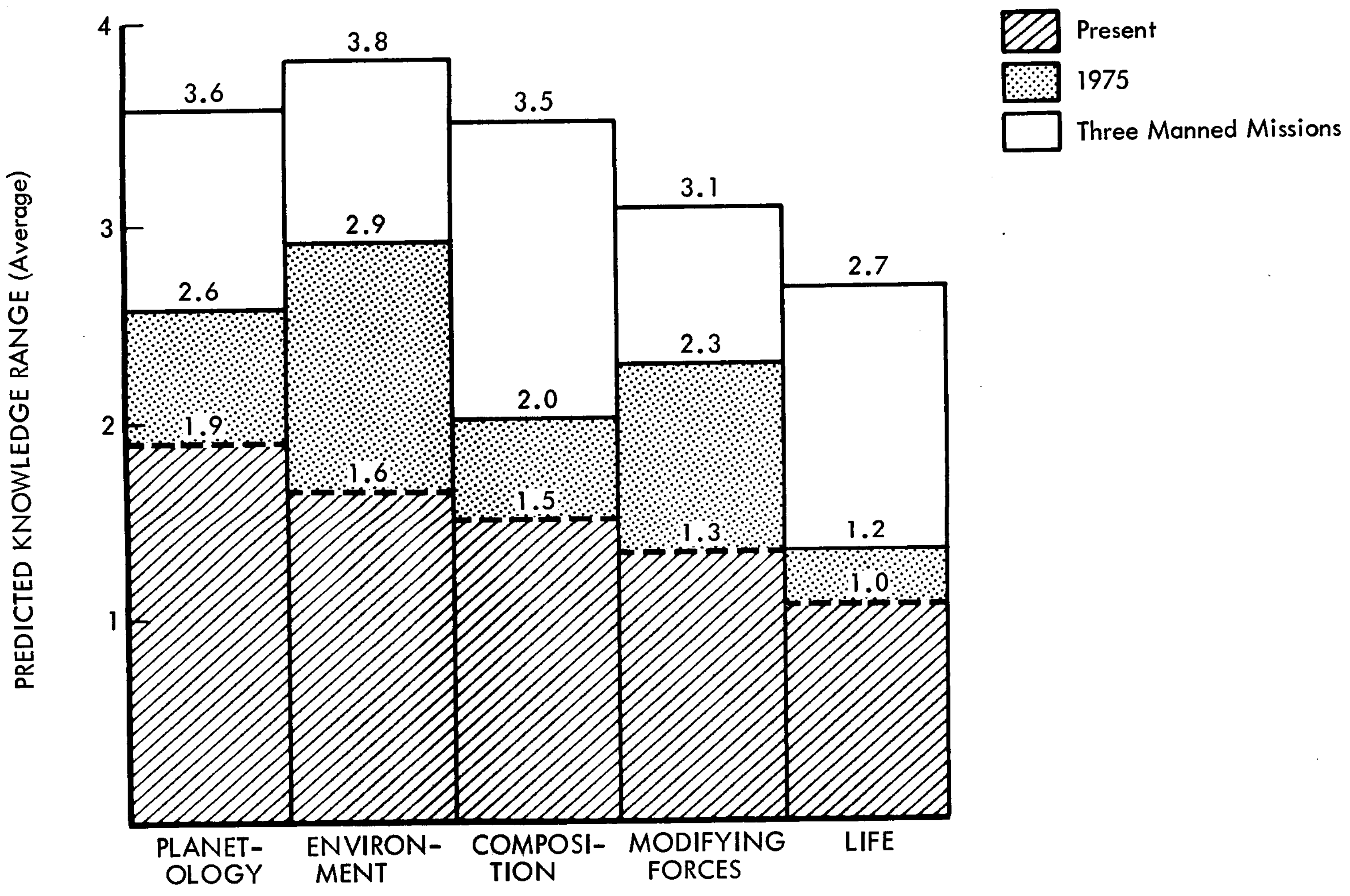


Figure 5-5: IMISCD KNOWLEDGE BASE COMPARISONS — MARS

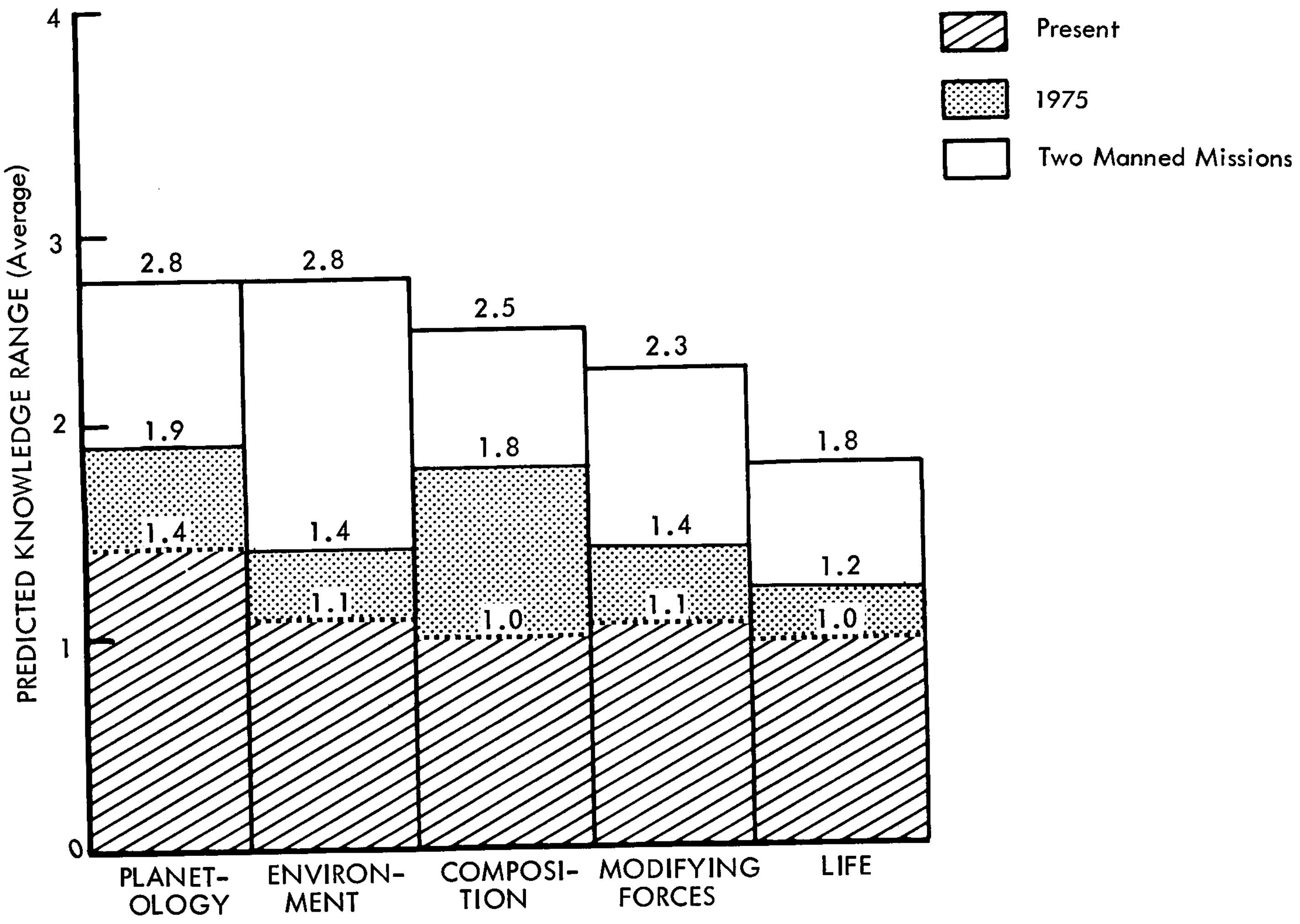


Figure 5-6: IMISCD KNOWLEDGE BASE COMPARISONS — VENUS

Table 5-32:B IMISCD KNOWLEDGE BASE — MARS - VENUS

Knowledge Base	Planetology																	Modifying Forces																Composition							Environment									Life				
	Orbital Parameters	Rotational Parameters	Figure of Planet	Moments of Inertia	Gravitational Field	Magnetic Field	Structural Features	Thermal Budget	Physical Properties	Seismicity	Physical Features	Isotope Ratios	Mineralization	Age	Atmosphere	Satellites	Summary	Solar Radiation	Meteoroid Impacts	Isostatic Forces	Seismic Activity	Diastrophism	Volcanic Activity	Surface Winds	Temperature Changes	Chemical Reactions	Life	Phase Changes	Gravity	Hydraulic Action	Glacier Action	Nuclear Reactions	Summary	Charged Particles	Atomic Elements	Molecular Elements	Minerals	Chemicals	Isotopes	Summary	Diurnal	Seasonal	Latitude	Magnetic Field	Micrometeorology	Meteoroid	Radioactive Decay	Solar Radiation	Summary	Macroscopic	Microscopic	Protoorganic	Fossil	Summary
Mars																																																							
Present — Maximum	3	3	2	2	3	1	2	2	2	1	2	1	1	1	2	2		2	1	1	1	1	1	1	2	1	1	2	2	1	1	1		2	2	2	1	1	1		2	2	2	1	1	2	1	2		1	1	1	1	
Minimum	2	2	1	1	2	0	1	1	1	0	1	0	0	0	1	1		1	0	0	0	0	0	0	1	0	0	1	1	0	0	0		1	1	1	0	0	0		1	1	1	0	0	1	0	1		0	0	0	0	
Projected — Maximum	4	4	3	3	4	3	2	3	2	1	4	1	1	1	3	2		3	2	3	2	2	2	2	2	2	2	2	3	2	3	2		3	2	2	2	2	1		4	4	4	2	2	3	2	2		2	1	1	1	
Minimum	3	3	2	2	2	2	1	2	1	0	3	0	0	0	2	1		2	1	1	1	0	1	1	1	1	1	1	2	1	1	1		1	1	1	0	1	0		3	3	3	1	1	2	1	1		1	0	0	0	
3 Mission Proj. — Max.	4	4	4	4	4	4	3	3	4	3	4	3	3	3	4	3		3	3	3	3	3	3	3	3	3	3	3	4	3	3	3		4	4	4	3	3	3		4	4	4	3	3	4	4	4		4	2	3	2	
Min.	3	3	3	3	3	3	2	2	3	2	3	2	2	2	3	2		2	2	2	2	2	1	1	1	2	1	1	3	1	1	2		3	3	3	2	2	2		3	3	3	2	2	3	3	3		3	1	2	1	
Venus																																																							
Present — Maximum	3	2	1	1	3	1	1	2	1	1	1	1	1	1	1	1		2	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1		1	1	1	1	1	1	1	2		1	1	1	1	
Minimum	2	1	0	0	2	0	0	1	0	0	0	0	0	0	0	0		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0	0	1		0	0	0	0	
Projected — Maximum	4	3	1	1	4	2	2	3	2	1	2	1	1	1	2	1		3	1	1	1	1	2	2	2	1	1	1	1	1	1	2		3	2	2	1	2	1		1	1	1	2	1	1	2	2		1	1	2	1	
Minumum	3	2	0	0	2	0	1	2	0	0	0	0	0	0	1	0		2	0	0	0	0	1	0	0	0	0	0	0	0	0	1		1	1	1	0	1	0		0	0	0	1	0	0	1	1		0	0	1	1	
2 Mission Proj. — Max.	4	4	3	3	3	3	2	3	2	2	2	2	2	1	4	4		3	3	2	2	2	2	2	3	2	2	2	2	2	3	3		4	3	2	2	2	2		2	2	4	4	2	2	3	3		2	1	3	1	
Min.	3	3	2	2	2	2	1	2	1	1	1	1	1	0	3	3		2	2	1	1	1	1	1	2	1	1	1	1	1	2	2		3	2	1	1	1	1		1	1	3	3	1	1	2	2		1	0	2	0	

Code

0–1	Data ambiguous or nonexistent.
1–2	Approximate ranges are established; degree of change apparent.
2–3	Complete present ranges established; permits theory formulation.
3–4	Permits theory verification or rejection; origin not necessarily established.

99 TABLE 5-32:A

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6.0 ANALYTICAL TECHNIQUES AND THE ANALYSIS OF OBSERVATION AND MEASUREMENT CLASSES

The 49 classes of observations and measurements were analyzed to provide inputs to the knowledge base projections, the selection of priorities and the consideration of the role of man. These analyses and the techniques used are given in this section. They depended on the definition of two properties of the observations and measurements; viz., interdependence and predictability (or stability).

6.1 CLASS INTERDEPENDENCE

Class interdependence recognizes a relationship in factor behavior over time; factors behave with various degrees of dependence or independence from other factors. A single three-component interdependence rating system has been established by which factors are:

- Independent
- Directly dependent on others
- Indirectly dependent on others

For example, planet rotation and its orbit may be considered independent factors. Examples of directly dependent factors are the moments of inertia and their dependence on both the orbital and rotational parameters. To illustrate indirect dependence, atmospheric density is indirectly dependent on a planet's micrometeorology and surface temperature is indirectly dependent on the isotopes present. The interrelationships established for the IMISCD classes have been summarized in Tables 6-2 through 6-6. They are summarized in Table 6-1.

In these tables, a factor versus factor matrix is shown which has a key of values corresponding to this simple three-component scale. Using a technique of this kind, professional judgments made with respect to the interrelationships among all the factors can be made explicitly and subjected to scrutiny.

The interdependence classification allows an important process to come into play. It allows projections to be made in a sequence dictated by their degree of firmness or reliability. That is, independent factors can be projected first because of the associated high reliability attached to such factors. Then the process can proceed to address each succeeding factor according to its degree of interdependence until finally the most difficult factors (dependent on the most other factors) can be projected. In this way, the ordering process allows factor interdependence and the associated relative reliability of each succeeding projection to enhance the validity of the projections made as well as their associated relative reliabilities.

The class interdependence has been summarized in Table 6-1. It can be seen that the most basic measurement to be made is the determination of the age from the mineral composition of the planet. It is from the

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Table 6-1A CLASS INTERDEPENDENCE — SUMMARY

Independent Factors — Planetology

Dependent Factors		Orbital Parameters	Rotational Parameters	Figure of Planet	Moments of Inetria	Gravitational Field	Magnetic Field	Structural Features	Thermal Budget	Physical Properties	Seismicity	Physical Features	Isotope Ratios	Mineralization	Age	Atmosphere	Satellites	Summary
Planetology	Dependent	3	6	5	5	5	1	6	7	9	3	3	2	10	11	4	6	
	Indirect	4	3	1	4	3	4	2	3	1	4	2	1	3	3	3	3	
	Independent	8	6	9	6	7	10	7	5	5	8	10	12	2	1	8	6	
Modifying Force	Dependent	8	6	3	2	9	1	8	9	8	3	6	1	6	11	7	1	
	Indirect	3	7	2	2	2	2	1	2	0	2	0	6	6	1	0	5	
	Independent	4	2	10	11	4	12	6	4	7	10	9	8	3	3	8	9	
Composition	Dependent	2	1	0	0	2	1	0	3	0	0	0	4	6	6	5	0	
	Indirect	4	2	0	0	2	0	0	0	0	0	0	0	0	0	1	0	
	Independent	0	3	6	6	2	5	6	3	6	6	6	2	0	0	0	6	
Environment	Dependent	6	4	0	0	0	1	0	1	2	0	4	1	3	4	6	0	
	Indirect	0	1	1	0	1	0	1	0	0	0	0	0	0	3	0	0	
	Independent	2	3	7	8	7	7	7	7	6	8	4	7	5	1	2	8	
Life	Dependent	2	2	0	0	0	0	1	2	2	0	0	0	4	4	4	2	
	Indirect	0	0	0	0	2	2	2	0	0	0	2	2	0	0	0	0	
	Independent	2	2	4	4	2	2	1	2	2	4	2	2	0	0	0	2	
Total	Dependent	21	19	8	7	16	4	15	22	21	6	13	8	29	36	26	9	
	Indirect	11	13	4	6	10	8	6	5	1	6	4	9	9	7	4	8	
	Independent	16	16	36	35	22	36	27	21	26	36	31	31	10	5	18	31	

Independent Factors — Modifying Forces

Dependent Factors		Solar Radiation	Meteoroid Impacts	Isostatic Forces	Seismic Activity	Diastrophism	Volcanic Activity	Surface Winds	Temperature Changes	Chemical Reactions	Life	Phase Changes	Gravity	Hydraulic Action	Glacier Action	Nuclear Reactions	Summary
Planetology	Dependent	6	7	5	3	3	5	1	5	5	2	11	10	4	4	9	
	Indirect	4	6	5	7	6	7	8	6	4	7	0	4	6	6	4	
	Independent	6	3	6	6	7	5	7	5	7	7	5	2	6	6	3	
Modifying Force	Dependent	8	3	4	2	6	7	2	6	4	1	8	7	2	3	4	
	Indirect	3	5	3	4	3	5	7	3	7	5	3	2	8	8	8	
	Independent	3	6	7	8	5	2	5	5	3	8	3	5	4	3	2	
Composition	Dependent	6	6	0	0	0	3	1	3	4	2	0	0	1	1	6	
	Indirect	0	0	0	0	0	0	1	1	0	2	0	3	2	1	0	
	Independent	0	0	6	6	6	3	4	2	2	2	6	3	3	4	0	
Environment	Dependent	6	0	1	0	2	1	3	1	0	1	0	2	0	1	2	
	Indirect	0	2	3	0	3	6	2	3	6	4	2	0	4	3	4	
	Independent	2	6	4	8	3	1	3	4	2	3	6	6	4	4	2	
Life	Dependent	4	1	1	1	0	1	1	3	3	3	2	0	2	1	0	
	Indirect	0	0	1	0	1	1	1	0	1	0	0	2	1	2	3	
	Independent	0	3	2	3	3	2	2	1	0	1	2	2	1	1	1	
Total	Dependent	30	17	11	6	11	17	8	18	16	9	21	19	9	10	21	
	Indirect	7	13	12	11	13	19	19	13	18	18	5	11	21	20	19	
	Independent	11	18	25	31	24	12	21	17	14	21	22	18	18	18	8	

Independent Factors — Composition, Environment, Life

Dependent Factors		Composition: Charged Particles	Atomic Elements	Monecular Elements	Minerals	Chemicals	Isotopes	Summary	Environment: Diurnal	Seasonal	Latitude	Magnetic Field	Micrometeorology	Meteoroid	Radioactive Decay	Solar Radiation	Summary	Life: Macroscopic	Microscopic	Protoorganic	Fossil	Summary	Summation D	Summation I	Summation Ind.
Planetology	Dependent	4	4	3	12	5	2		4	5	8	1	4	6	11	8		4	4	0	3		254		
	Indirect	4	8	8	1	7	6		3	3	3	2	4	7	0	2		6	6	4	2			200	
	Independent	8	4	5	3	4	8		9	8	5	13	8	3	5	6		6	6	12	11				314
Modifying Force	Dependent	2	3	3	9	6	1		6	7	9	0	7	2	8	9		3	2	1	0		234		
	Indirect	1	2	2	3	6	4		1	0	0	1	0	5	5	2		1	2	0	0			150	
	Independent	12	10	10	3	3	10		8	8	6	14	8	8	2	4		11	11	14	15				336
Composition	Dependent	3	4	5	4	4	0		4	4	2	1	5	1	6	6		0	0	0	0		112		
	Indirect	0	1	0	0	0	0		0	0	0	1	0	2	0	0		4	4	0	2			33	
	Independent	2	0	0	1	1	5		2	2	4	4	1	3	0	0		2	2	6	4				143
Environment	Dependent	4	2	2	4	4	2		0	3	5	1	3	0	0	5		1	0	0	0		88		
	Indirect	2	3	3	1	1	0		2	0	0	0	2	4	4	1		4	5	0	2			83	
	Independent	2	3	3	3	3	6		5	4	2	6	2	3	3	1		3	3	8	6				213
Life	Dependent	2	3	3	4	4	0		3	3	1	0	3	0	1	4		2	2	0	0		81		
	Indirect	0	0	0	0	0	4		0	0	1	2	1	2	2	0		0	0	2	2			39	
	Independent	2	1	1	0	0	0		1	1	2	2	0	2	1	0		1	1	1	1				72
Total	Dependent	15	16	16	33	23	5		17	22	25	3	22	9	26	32		10	8	1	3		769		
	Indirect	7	14	13	5	14	14		6	3	4	6	7	20	11	5		15	17	6	8			505	
	Independent	26	18	19	10	11	29		25	23	19	39	19	19	11	11		23	23	41	37				1078

Code

☐ Independent

D Dependent

I Indirect Depencence

Summation

D I Ind.

103 TABLE 6-1:A

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Table 6-2:B CLASS INTERDEPENDENCE — PLANETOLOGY

Code

☐ Independent

D Dependent

I Indirect Dependence

Dependent Factors	Independent Factors																																																						Summation		
	Planetology																	Modifying Forces																Composition							Environment									Life							
	Orbital Parameters	Rotational Parameters	Figure of Planet	Moments of Inertia	Gravitational Field	Magnetic Field	Structural Features	Thermal Budget	Physical Properties	Seismicity	Physical Features	Isotope Ratios	Mineralization	Age	Atmosphere	Satellites	Summary	Solar Radiation	Meteoroid Impacts	Isostatic Forces	Seismic Activity	Diastrophism	Volcanic Activity	Surface Winds	Temperature Changes	Chemical Reactions	Life	Phase Changes	Gravity	Hydraulic Action	Glacier Action	Nuclear Reactions	Summary	Charged Particles	Atomic Elements	Molecular Elements	Minerals	Chemicals	Isotopes	Summary	Diurnal	Seasonal	Latitude	Magnetic Field	Micrometeorology	Meteoroid	Radioactive Decay	Solar Radiation	Summary	Macroscopic	Microscopic	Protoorganic	Fossil	Summary	D	I	☐
Orbital Parameters				D	D	I		D				I	D	D		D													D																										7	2	39
Rotational Parameters				D	I	I	D		I	D	D		I	D	I	D												D	I																										7	6	35
Figure of Planet	I	D		I	I		D	I	D	D			I	D	I	D				D	I	I	I		D			D	D	D	D	D			I	I	D	I					D			I	D	D		I	I				17	15	16
Moments of Inertia	D	D	D				D	I	D		I		D			D			I	D	I	D	I	I	I		I	D	I	I	I	I			I	I	D	I					D			I				I	I				12	18	18
Gravitational Field			D	I			I		D	I	I		D	I		D			I	I	I	I	I	I	I	I	I	D	D	I	I	D			I	I	D	I			D	I	D			I	D			I	I				11	23	14
Magnetic Field		I		I			D	I	D				D	I				D	I	I	I	I	I	I	D	D		D		I	I	I		D	I	I	D	I				D	D		I	I									11	18	19
Structural Features		D	D	D	D			D		I			D	D		D		I	I	D	I	I	I	I	I	I	I	D	D	I	I	I			I	I	D	D	I		I	I	I		I	I	D	I		D	D	I			16	23	9
Thermal Budget	D								D		D	D	D	D	D			D	I	I	I	I	D	I	I	D	I	D	D	I	I	D		D	D	D	D	D	I		D	D	D		D	I	D	D		I	I	I			24	14	10
Physical Properties					I	I	I	D					D	D	I			D	D								I	D	D			D		I	I	I	D	D	I				I	I	I	D	D	D		I	I	I	I		13	16	19
Seismicity	I	I	D	D	D		D	D	D		D		I	I		I		I	D	D	D	D	D	I	I	I		D	D	D	D	D					D	I	I							I	D	D							20	12	16
Physical Features		D	I	I			D	D	D	D			D	D	D	I		I	D	D	D	D	D	D	D	D	D	D	D	D	D	I		I	I	I	D	I	I		D	D	D		D	D	D	D		D	D		D		32	10	6
Isotope Ratios	I												D	D	D			D	D													D		D	D				D							D	D	D							12	1	35
Mineralization	D	I				D		D						D	D			D	D				D	I	D	D	I		I	D	D	D		I	I	D	D	D	I		D	D	D	D	D	D	D	D		D	D		D		27	7	14
Age												D						I	I				I	I	I	I	I		I	I	I	D		I	D	I	I	I	D		I	I	I	I	I	D	D	I		I	I		I		6	23	19
Atmosphere		D			D			D	D	I			D	D		I		D	D	I	D		D		D	D	D	D	D			D		D	D	D	D	D			I	D	D		D	D	D	D		D	D	I	D		30	5	13
Satellite	I	D	D	D	D	I			D	I				D					D	I	I	I	I						D								D																		9	7	32
Dependent	3	6	5	5	5	1	6	7	9	3	3	2	10	11	4	6	86	6	7	5	3	3	5	1	5	5	2	11	10	4	4	9	80	4	4	3	12	5	2	30	4	5	8	1	4	6	11	8	47	4	4	0	3	11	254		
Indirect	4	3	1	4	3	4	2	3	1	4	2	1	3	3	3	3	41	4	6	5	7	6	7	8	6	4	7	0	4	6	6	4	80	4	8	8	1	7	6	34	3	3	3	2	4	7	0	2	24	6	6	4	2	18		200	
Independent	8	6	9	6	7	10	7	5	5	8	10	12	2	1	8	6	110	6	3	6	6	7	4	7	5	7	7	5	2	6	6	3	80	8	4	5	3	4	8	32	9	8	5	13	8	3	5	6	57	6	6	12	11	35			314

105 TABLE 6-2:A

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Table 6-3:A CLASS INTERDEPENDENCE — COMPOSITION

Code

- ☐ Independent
- D Dependent
- I Indirect Dependence

Independent Factors — Planetology

Dependent Factors	Orbital Parameters	Rotational Parameters	Figure of Planet	Moments of Inertia	Gravitational Field	Magnetic Field	Structural Features	Thermal Budget	Physical Properties	Seismicity	Physical Features	Isotope Ratios	Mineralization	Age	Atmosphere	Satellites	Summary
Charged Particles	D	D				D						D	D	D	D		
Atomic Elements	I				D			D				D	D	D	D		
Molecular Elements	I				D			D				D	D	D	D		
Minerals	I	I			I								D	D	D		
Chemicals	I	I			I			D					D	D	D		
Isotopes	D											D	D	D	I		
Dependent	2	1	0	0	2	1	0	3	0	0	0	4	6	6	5	0	30
Indirect	4	2	0	0	2	0	0	0	0	0	0	0	0	0	1	0	9
Independent	0	3	6	6	2	5	6	3	6	6	6	2	0	0	0	6	57

Independent Factors — Modifying Forces

Dependent Factors	Solar Radiation	Meteoroid Impacts	Isostatic Forces	Seismic Activity	Diastrophism	Volcanic Activity	Surface Winds	Temperature Changes	Chemical Reactions	Life	Phase Changes	Gravity	Hydraulic Action	Glacier Action	Nuclear Reactions	Summary
Charged Particles	D	D				D	I	I	D	I		I			D	
Atomic Elements	D	D						D				I			D	
Molecular Elements	D	D						D	D	I		I	I	I	D	
Minerals	D	D				D	D	D	D	D			D	D	D	
Chemicals	D	D				D			D	D			I		D	
Isotopes	D	D													D	
Dependent	6	6	0	0	0	3	1	3	4	2	0	0	1	1	6	33
Indirect	0	0	0	0	0	0	1	1	0	2	0	3	2	1	0	10
Independent	0	0	6	6	6	3	4	2	2	2	6	3	3	4	0	47

Independent Factors — Composition

Dependent Factors	Charged Particles	Atomic Elements	Molecular Elements	Minerals	Chemicals	Isotopes	Summary
Charged Particles		D	D	D	D		
Atomic Elements	D		D	D	D		
Molecular Elements	D	I		D	D		
Minerals		D	D		D		
Chemicals		D	D	D			
Isotopes	D	D	D				
Dependent	3	4	5	4	4	0	20
Indirect	0	1	0	0	0	0	1
Independent	2	0	0	1	1	5	9

Independent Factors — Environment

Dependent Factors	Diurnal	Seasonal	Latitude	Magnetic Field	~~Micrometeorology~~	Meteoroid	Radioactive Decay	Solar Radiation	Summary
Charged Particles	D	D	D	D	D		D	D	
Atomic Elements	D	D	D		D		D	D	
Molecular Elements	D	D			D		D	D	
Minerals				I	D	I	D	D	
Chemicals	D	D			D	I	D	D	
Isotopes						D	D	D	
Dependent	4	4	2	1	5	1	6	6	29
Indirect	0	0	0	1	0	2	0	0	3
Independent	2	2	4	4	1	3	0	0	16

Independent Factors — Life; Summation

Dependent Factors	Macroscopic	Microscopic	Protoorganic	Fossil	Summary	Summation D	Summation I	Summation ☐
Charged Particles						23	4	21
Atomic Elements	I	I				20	4	24
Molecular Elements	I	I				19	8	21
Minerals	I	I		I		19	8	21
Chemicals	I	I		I		18	8	22
Isotopes						13	1	34
Dependent	0	0	0	0	0	112		
Indirect	4	4	0	2	10		33	
Independent	2	2	6	4	14			143

107 Table 6-3:A

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Table 6-4:B CLASS INTERDEPENDENCE — MODIFYING FORCES

Code
☐ Independent
D Dependent
I Indirect Dependence

Dependent Factors	Independent Factors																																																					Summation		
	Planetology																	Modifying Forces																Composition							Environment									Life							
	Orbital Parameters	Rotational Parameters	Figure of Planet	Moments of Inertia	Gravitational Field	Magnetic Field	Structural Features	Thermal Budget	Physical Properties	Seismicity	Physical Features	Isotope Ratios	Mineralization	Age	Atmosphere	Satellites	Summary	Solar Radiation	Meteoroid Impacts	Isostatic Forces	Seismic Activity	Diastrophism	Volcanic Activity	Surface Winds	Temperature Changes	Chemical Reactions	Life	Phase Changes	Gravity	Hydraulic Action	Glacier Action	Nuclear Reactions	Summary	Charged Particles	Atomic Elements	Molecular Elements	Minerals	Chemicals	Isotopes	Summary	Diurnal	Seasonal	Latitude	Magnetic Field	Micrometeorology	Meteoroid	Radioactive Decay	Solar Radiation	Summary	Macroscopic	Microscopic	Protoorganic	Fossil	Summary	D	I	☐
Solar Radiation	D	I				D									D								I	I		I		I		I	I																	D							4	7	37
Meteoroid Impacts	D	D			D											I													D																	D									5	1	42
Isostatic Forces		D	I	D	D		D	D	D	D	D	I	I	D		D		I	I			D	D	I	I	I	I	I	D	I	I	D					I	I	I				D				I								15	16	17
Seismic Activity	I	I	D	I	D		D	I	D	D	D	I	I	D		I			D			D	D		I	I		I	D	I	I	I					D	I	I							D	D								14	15	19
Diastrophism	I	I	D	I	D		D	D	D	D	D	I	I	D		I		I	D	D	D		D	I	I	I	I	D	D	I	I	I					I	I	I							I	D								15	18	15
Volcanic Activity					D		D	I		I		I	I	D		I		I	I	D	D	D				I		D	I			I					I	I									D	I							8	13	27
Surface Winds	D	D						D				I		D	D			D				I	I		D	I	I	D		I	I	I			D	D					D	D	D		D		I	D		I	I				15	11	22
Temperature Changes	D	D				I	D	D				I	I	I	D			D	I	I	I	I	D	D		D	I	D		I	I	I					D	D			D	D	D		D	I	D	D		D	I				19	14	15
Chemical Reactions	D	D			I			D					D	D	D			D	I				D	I	D		D	D		D	D	D		I	D	D	D	D			D	D	D		D	I	D	D		D	D				26	5	17
Life	D	D			I		I	D	D				D	D	D			D					I	I	D	D		D	I	I	I	D		D	D	D	D	D			D	D	D	I	D		D	D		D	D	D			26	8	14
Phase Changes	I	I	I		D	I		D	D				D	D				D		D		D	D	I	D	D			D	I	I	I			I	I	D	D	I		D	D	D		D		I	D							19	12	17
Gravity		I	D	D	D		D		D	I	D		D			I			I	D	I	D	D	I				D		D	D	D					D	I					D			I	D	I							17	9	22
Hydraulic Action	D	I			D		D	D	D		D		D	D	D			D		I	I	I	I		D	D	I	D	D		D	I					D	D			D	D	D		D		I	D							22	8	18
Glacier Action	D	I			D		D	D	D		D		D	D	D			D		I	I	D	I	D	D	I			D			I					D	D			I	D	D		D		I	D							20	8	20
Nuclear Reactions												D	I	D				D	D															D	I	I	D	I	D							I	D	D							9	5	34
Dependent	8	6	3	2	9	1	8	9	8	3	6	1	6	11	7	1	89	8	3	4	2	6	7	2	6	4	1	8	7	2	3	4	67	2	3	3	9	6	1	24	6	7	9	0	7	2	8	9	48	3	2	1	0	6	234		
Indirect	3	7	2	2	2	2	1	2	0	2	0	6	6	1	0	5	41	3	5	3	4	3	5	7	3	7	5	3	2	8	8	8	74	1	2	2	3	6	4	18	1	0	0	1	0	5	5	2	14	1	2	0	0	3		150	
Independent	4	2	10	11	4	12	6	4	7	10	9	8	3	3	8	9	110	3	6	7	8	5	2	5	5	3	8	3	5	4	3	2	69	12	10	10	3	3	10	48	8	8	6	14	8	8	2	4	58	11	11	14	15	51			336

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Table 6-5:A CLASS INTERDEPENDENCE — ENVIRONMENT

Code

☐ Independent
D Dependent
I Indirect Dependence

Dependent Factors	Independent Factors																																																								
	Planetology																	Modifying Forces																Composition							Environment									Life					Summation		
	Orbital Parameters	Rotational Parameters	Figure of Planet	Moments of Inertia	Gravitational Field	Magnetic Field	Structural Features	Thermal Budget	Physical Properties	Seismicity	Physical Features	Isotope Ratios	Mineralization	Age	Atmosphere	Satellites	Summary	Solar Radiation	Meteoroid Impacts	Isostatic Forces	Seismic Activity	Diastrophism	Volcanic Activity	Surface Winds	Temperature Changes	Chemical Reactions	Life	Phase Changes	Gravity	Hydraulic Action	Glacier Action	Nuclear Reactions	Summary	Charged Particles	Atomic Elements	Molecular Elements	Minerals	Chemicals	Isotopes	Summary	Diurnal	Seasonal	Latitude	Magnetic Field	Micrometeorology	Meteoroid	Radioactive Decay	Solar Radiation	Summary	Macroscopic	Microscopic	Protoorganic	Fossil	Summary	D	I	☐
Diurnal	D	D									D			D	D			D		I		I	I	D	D	I	I	I			D	I		I	I	I						D	D		I		I	D		I	I				12	14	22
Seasonal	D	I									D			I	D			D		I		I	I	D	I	I	D			I		I		I	I	I					I		D		I		I	D		I	I				9	17	22
Latitude	D	D									D				D			D				D	I	D	I	I			D	I	I	I		D			I	I			I	D			D	I	I	D		I	I				13	13	22
Magnetic Field			I		I	D	I		D				D	I				D	I	I		I	I		I	I	I	I		I	I	I		D			D	D					D		D	I	I	I		I	I		I		9	21	18
Micrometeorology	D	D						D	D		D		D	I	D			D	I				I	I		I	I			I	I	D		D	I	I	D	D	D							I		D					I		13	12	23
Meteoroid	D													D	D														D														D												5	0	43
Radioactive Decay												D	D	D									I									D		D	D	D	D	D	D							I		D							10	2	36
Solar Radiation	D	D												D	D			D		D		D	D	I		I	I								D	D	D	D				D	D	D	D					D	I				17	4	27
Dependent	6	4	0	0	0	1	0	1	2	0	4	1	3	4	6	0	32	6	0	1	0	2	1	3	1	0	1	0	2	0	1	2	20	4	2	2	4	4	2	18	0	3	5	1	3	0	0	5	17	1	0	0	0	1	88		
Indirect	0	1	1	0	1	0	1	0	0	0	0	0	0	3	0	0	7	0	2	3	0	3	6	2	3	6	4	2	0	4	3	4	42	2	3	3	1	1	0	10	2	0	0	0	2	4	4	1	13	4	5	0	2	11		83	
Independent	2	3	7	8	7	7	7	7	6	8	4	7	5	1	2	8	89	2	6	4	8	3	1	3	4	2	3	6	6	4	4	2	58	2	3	3	3	3	6	20	5	4	2	6	2	3	3	1	26	3	3	8	6	20			213

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FOLDOUT FRAME

Table 6-6:B CLASS INTERDEPENDENCE — LIFE

Code
☐ Independent
D Dependent
I Indirect Dependence

Independent Factors — Planetology

Independent Factors	Orbital Parameters	Rotational Parameters	Figure of Planet	Moments of Inertia	Gravitational Field	Magnetic Field	Structural Features	Thermal Budget	Physical Properties	Seismicity	Physical Features	Isotope Ratios	Mineralization	Age	Atmosphere	Satellites	Summary
Macroscopic	D	D			I	I	I	D	D		I	I	D	D	D	D	
Microscopic	D	D			I	I	I	D	D		I	I	D	D	D	D	
Protoorganic													D	D	D		
Fossil							D						D	D	D		
Dependent	2	2	0	0	0	0	1	2	2	0	0	0	4	4	4	2	23
Indirect	0	0	0	0	2	2	2	0	0	0	2	2	0	0	0	0	10
Independent	2	2	4	4	2	2	1	2	2	4	2	2	0	0	0	2	31
Class Interdependences																	
Total																	
Dependent	21	19	8	7	16	4	15	22	21	6	13	8	29	36	26	9	
Indirect	11	13	4	6	10	8	6	5	1	6	4	9	9	7	4	8	
Independent	16	16	36	35	22	36	27	21	26	36	31	31	10	5	18	31	

Independent Factors — Modifying Forces

Independent Factors	Solar Radiation	Meteoroid Impacts	Isostatic Forces	Seismic Activity	Diastrophism	Volcanic Activity	Surface Winds	Temperature Changes	Chemical Reactions	Life	Phase Changes	Gravity	Hydraulic Action	Glacier Action	Nuclear Reactions	Summary
Macroscopic	D		I		I	I	I	D	D	D	D	I	D	I	I	
Microscopic	D					D	D	D	D	D	D	I	I	I	I	
Protoorganic	D	D							I						I	
Fossil	D		D	D				D	D	D			D	D		
Dependent	4	1	1	1	0	1	1	3	3	3	2	0	2	1	0	23
Indirect	0	0	1	0	1	1	1	0	1	0	0	2	1	2	3	13
Independent	0	3	2	3	3	2	2	1	0	1	2	2	1	1	1	24
Class Interdependences																
Total																
Dependent	30	17	11	6	11	17	8	18	16	9	21	19	9	10	21	
Indirect	7	13	12	11	13	19	19	13	18	18	5	11	21	20	19	
Independent	11	18	25	31	24	12	21	17	14	21	22	18	18	18	8	

Independent Factors — Composition and Environment

Independent Factors	Charged Particles	Atomic Elements	Molecular Elements	Minerals	Chemicals	Isotopes	Summary	Diurnal	Seasonal	Latitude	Magnetic Field	Micrometeorology	Meteoroid	Radioactive Decay	Solar Radiation	Summary
Macroscopic	D	D	D	D	D	I		D	D	D	I	D		I	D	
Microscopic	D	D	D	D	D	I		D	D	I	I	D	I	I	D	
Protoorganic		D	D	D	D	I						I	I	D	D	
Fossil				D	D	I		D	D			D			D	
Dependent	2	3	3	4	4	0	16	3	3	1	0	3	0	1	4	15
Indirect	0	0	0	0	0	4	4	0	0	1	2	1	2	2	0	8
Independent	2	1	1	0	0	0	4	1	1	2	2	0	2	1	0	9
Class Interdependences																
Total																
Dependent	15	16	16	33	23	5		17	22	25	3	22	9	26	32	
Indirect	7	14	13	5	14	14		6	3	4	6	7	20	11	5	
Independent	26	18	19	10	11	29		25	23	19	39	19	19	11	11	

Independent Factors — Life; Summation

Independent Factors	Macroscopic	Microscopic	Protoorganic	Fossil	Summary	Summation D	Summation I	Summation ☐
Macroscopic		D	I	I		25	17	6
Microscopic	D		I	I		25	16	7
Protoorganic						11	5	32
Fossil	D	D				20	1	27
Dependent	2	2	0	0	4	81		
Indirect	0	0	2	2	4		39	
Independent	1	1	1	1	4			72
Class Interdependences								
Total								
Dependent	10	8	1	3		769		
Indirect	15	17	6	8			505	
Independent	23	23	41	37				1078

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minerals that the chemical composition and hence the isotopic ratios can be determined. The isotopes present then permit age measurements not only of the minerals but also of the various rocks and crust features and structures. It will be through these that the ultimate age of the planet can be measured and compared to that of Earth, the moon and the other planets. Age, of course, helps the determination of origins and evolution.

From a planetary evolution sense the least important category is life while its least important factor is protoorganic life.

The average number of interdependent factors for each category is summarized in Table 6-7. The significance of this table is that a qualitative ranking of the categories emerges. Based on the highest average number of dependent factors, those factors included in the category of Composition are the most significant to measure. Next in order are Environment, Planetology, Modifying Forces and Life.

Table 6-7: CATEGORY INTERDEPENDENCE SUMMARY

Category	Dependent Factors		Indirect Dependence		Independent Factors	
	Total	AVE	Total	AVE	Total	AVE
Planetology (16 Classes)	260	16.3	111	6.9	397	24.8
Modifying Forces (15)	223	14.9	219	14.6	278	18.5
Composition (6)	121	20.2	76	12.7	151	25.2
Environment (8)	156	19.5	62	7.8	166	20.8
Life (4)	32	8.0	46	11.5	114	28.5

6.2 CLASS PREDICTABILITY

The second concept used in the analysis of the observation and measurement classes is termed class predictability, that is, inherent stability relative to the projection time span. For this concept, a tentative three-part coding system is also used:

- Stable (S)
- Uniform (U)
- Not stable (N)

Stable factors are those which, for time intervals equivalent to the projection time span, have historically exhibited a highly predictable pattern of performance regardless of the number of other factors on which they are dependent. Examples of stable factors include the planet's radius or its chemical composition. Factors which have a uniform inherent stability relative to the projection time span are those which historically exhibit a rate of change which is uniform and therefore predictable, regardless of the number of other factors upon which they depend. Examples of factors which exhibit uniform inherent stability might be those relating to the gravitational field or the change of the wave of darkening with the season. Factors which are not stable with respect to the projection time span are those which historically are volatile or subject to sudden change. Some examples of unstable factors are temperatures, wind velocities, clouds and so forth. Table 6-8 summarizes the predictability associated with each of the IMISCD classes.

6.3 DATA ACQUISITION CERTAINTY (DAC)

The codes are derived by assigning a relative importance of 1/2 to those factors only indirectly dependent. It is recognized that this relative weighting factor is subjective but the certainty of acquiring data, as derived, would be changed relatively little. The derivation of certainty was based on the following:

1) Certainty is a direct function of the predictability of the factor, i.e., f(PC). Using the predictabilities previously developed and assigning a numerical weighting factor of 3 for inherent stability (S), 2 for uniformity (U) and 1 for nonstability (N), then the relative certainty can be thought of as $\frac{f(PC)}{27}$ where 27 is S•S•S for the sensitivities assigned. The minimum value occurs when f(PC) = N•N•N = 1.

   The number 27, appearing in the denominator of DAC, is a nomalizing factor which reduces to one the certainty of obtaining a set of data if it depends on only one factor, has a predictability criteria of 27, and is not indirectly related to any other factor.

2) Certainty must be some function of the number of factors which must be measured to determine the factor under evaluation. Since the degree of certainty is less, the greater the number of factors upon which it depends (D) the simplest relationship is the inverse, $\frac{1}{D}$.

Table 6-8:A STABILITY FACTOR

Stability/Sensitivity	Factors: Planetology																
	Orbital Parameters	Rotational Parameters	Figure of Planet	Moments of Inertia	Gravitational Field	Magnetic Field	Structural Features	Thermal Budget	Physical Properties	Seismicity	Physical Features	Isotope Ratios	Mineralization	Age	Atmosphere	Satellites	Summary
Inherent Stability	S	S	S	S	S	S	S	U	S	N	S	S	S	S	S	S	
Orbit Sensitivity	S	S	N	N	N	N	U	S	S	N	U	S	U	U	S	S	
Site Sensitivity	S	S	S	S	S	U	U	N	N	N	N	N	N	N	S	S	

Stability/Sensitivity	Factors: Modifying Forces															
	Solar Radiation	Meteoroid Impacts	Isostatic Forces	Seismic Activity	Diastrophism	Volcanic Activity	Surface Winds	Temperature Changes	Chemical Reactions	Life	Phase Changes	Gravity	Hydraulic Action	Glacier Action	Nuclear Reactions	Summary
Inherent Stability	U	N	S	N	S	N	N	N	N	S	S	U	U	U	S	
Orbit Sensitivity	S	N	U	N	U	U	U	N	N	U	U	S	U	U	N	
Site Sensitivity	N	N	N	N	N	N	N	N	N	N	N	S	N	N	N	

Stability/Sensitivity	Factors: Composition						
	Charged Particles	Atomic Elements	Molecular Elements	Minerals	Chemicals	Isotopes	Summary
Inherent Stability	U	S	S	S	S	S	
Orbit Sensitivity	N	U	U	U	U	U	
Site Sensitivity	S	U	U	N	N	N	

Stability/Sensitivity	Factors: Environment								
	Diurnal	Seasonal	Latitude	Magnetic Field	Micrometeorology	Meteoroid	Radioactive Decay	Solar Radiation	Summary
Inherent Stability	N	N	U	U	N	N	S	U	
Orbit Sensitivity	U	U	U	N	U	N	N	S	
Site Sensitivity	N	N	U	S	N	N	N	N	

Stability/Sensitivity	Factors: Life				
	Macroscopic	Microscopic	Protoorganic	Fossil	Summary
Inherent Stability	S	S	S	S	
Orbit Sensitivity	U	U	S	N	
Site Sensitivity	S	S	S	N	

S Stable
U Uniform
N Nonstable

A stable factor is mission independent.

A uniform factor is mission or time dependent but predictable.

A nonstable factor is one that will be initially different for each mission, orbit, or site.

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1

3) Certainty is further complicated by the indirect inter-relationships (I) which exist. To weigh these as contributing the same degree of uncertainty as the direct factors is also fallacious. The simplest approach was to assign these 1/2 values and add directly to the D relationships. Hence,

$$\text{DATA ACQUISITION CERTAINTY (DAC)} = \frac{f(PC)}{27} \cdot \frac{1}{D + 1/2\ I} = \frac{2\ f(PC)}{2\ D + I}$$

6.4 DATA ACQUISITION PRIORITY (DAP)

The derivation of Data Acquisition Priority code based on interdependence is as follows:

1) The importance of a factor is directly proportional to the number of other factors depending on it. $f(DAP)\ \alpha \Sigma DO$.

2) Indirect dependence must also add to the relative priority but certainly not to the same degree. Hence,

$$f(DAP)\alpha\Sigma\frac{IO}{2}.$$

3) Priority may also be considered an inverse function of the number of factors completely independent of the factor to be measured, i.e.,

$$f(DAP)\alpha\Sigma\frac{I}{INDEP}.$$

The complete priority function can then be assumed to be:

$$DAP = \frac{\Sigma DO + \frac{\Sigma IO}{2}}{\Sigma\ INDEP} = \frac{\Sigma 2(DO) + IO}{2\Sigma(INDEP)}$$

6.5 MISSION PRIORITY

Mission priority can be ascertained by increasing the value of those measurements and objectives which first have the highest priority as previously derived from the interdependencies. In addition, it is possible to increase the value of any mission by measuring those objectives which can be ascertained with the highest degree of confidence, i.e., directly proportional to DAC. The most direct approach then is to multiply the DAC by the DAP.

This approach derives a general formula which can be applied to any planet by assuming that the urgency of the acquisition of data is inversely proportional to the knowledge base (KB). The philosophical basis for this is that all 49 categories must be equally well established to take meaningful steps backward in time to determine the origin and evolution of the planet. Hence,

$$\cdot MP = \frac{(DAC)(DAP)}{KB}$$

6.6 SCIENTIFIC PRIORITY

Based on the concept that origin and evolution can only be determined with assurance if all 49 categories are equally well determined, another formula--the scientific priority--can be derived. Again those factors having the highest priority are assumed as directly influencing the measurements and objectives selected for a particular planet. The difference between mission priority and scientific priority lies in assuming that the most urgent measurements are those about which the least is known, i.e., inversely proportional to the DAC. In addition, an inverse relationship is implied by the knowledge base (KB) predicted for a particular category. On this basis

$$SP = \frac{DAP}{KB(DAC)}$$

The equations are summarized in Table 6-9, Measurement and Observation Priority Formulas.

Other functions may also be derived but further analysis is required prior to further clarification. Each factor should be further divided into subfactors and the relative impact of the indirect factors assessed. Some weight factor other than two may be essential.

Table 6-9: MEASUREMENT AND OBSERVATION PRIORITY FORMULAS

$$DAC = \frac{PC}{27\ (D + 1/2)}$$

PC	Predictability Criteria
D	Direct Dependence Number
I	Indirect Dependence Number

$$DAP = \frac{(DO) + \frac{(IO)}{2}}{(INDEP)}$$

DO	Number of Classes Depending On
IO	Number of Classes Indirectly Depending On
INDEP	Total Classes Minus (DO + IO)

$$MP = \frac{100\ (DAC)\ (DAP)}{(KB)}$$

KB	1975 Knowledge Base

$$SP = \frac{DAP}{KB\ (DAC)}$$

6.7 PRESENT PRIORITY

The application of these analyses to the factors derived for planetary exploration sets present priorities for the planets (see Table 6-10). The difference between the planets Venus and Mars is in the use of the projected knowledge bases for them. By dividing by the knowledge base of the appropriate planet, the mission priorities for that planet are established.

Table 6-10:B FACTOR INTERDEPENDENCE SUMMARY — THE PRESENT PRIORITY

	Planetology																	Modifying Forces																Composition							Environment									Life				
	Orbital Parameters	Rotational Parameters	Figure of Planet	Moments of Inertia	Gravitational Field	Magnetic Field	Structural Features	Thermal Budget	Physical Properties	Seismicity	Physical Features	Isotope Ratios	Mineralization	Age	Atmosphere	Satellites	Summary	Solar Radiation	Meteoroid Impacts	Isostatic Forces	Seismic Activity	Diastrophism	Volcanic Activity	Surface Winds	Temperature Changes	Chemical Reactions	Life	Phase Changes	Gravity	Hydraulic Action	Glacier Action	Nuclear Reactions	Summary	Charged Particles	Atomic Elements	Molecular Elements	Minerals	Chemicals	Isotopes	Summary	Diurnal	Seasonal	Latitude	Magnetic Field	Micrometeorology	Meteoroid	Radioactive Decay	Solar Radiation	Summary	Macroscopic	Microscopic	Protoorganic	Fossil	Summary
(PC) Predictability Criteria	27	27	9	9	9	6	12	6	9	1	6	9	6	6	27	27		6	1	6	1	6	2	2	1	1	6	6	18	4	4	3		6	12	12	6	6	6		2	2	8	6	2	1	3	6		18	18	27	12	
(D) Depends Directly on	7	7	17	12	11	11	16	24	13	20	32	12	27	6	30	9		4	5	15	14	15	8	15	19	26	26	19	17	22	20	9		23	20	19	19	18	13		12	9	13	9	13	5	10	17		25	25	11	20	
(I) Depends Indirectly on	2	6	15	18	23	18	23	14	16	12	10	1	7	23	5	7		7	1	16	15	18	13	11	14	5	8	12	9	8	8	5		4	4	8	8	8	1		14	17	13	21	12	0	2	4		17	16	5	1	
DAC = $\frac{2\,(PC)}{27\,(2D+I)} = \frac{0.0742\,(PC)}{2D+I}$	.125	.100	.014	.016	.015	.011	.016	.007	.016	.001	.006	.027	.007	.013	.031	.08		.030	.007	.010	.002	.011	.005	.004	.001	.001	.007	.009	.030	.006	.006	.010		.009	.020	.019	.010	.010	.016		.004	.004	.015	.011	.004	.007	.010	.012		.02	.02	.074	.022	
(DO) Factors Dependent on	21	19	8	7	16	4	15	22	21	6	13	8	29	36	26	9		30	17	11	6	11	17	8	18	16	9	21	19	9	10	21		15	16	16	33	23	5		17	22	25	3	22	9	26	32		10	8	1	3	
(IO) Factors Indirectly Dependent on	11	13	4	6	10	8	6	5	1	6	4	9	9	7	4	8		7	13	12	11	13	19	19	13	18	18	5	11	21	20	19		7	14	13	5	14	14		6	3	4	6	7	20	11	5		15	17	6	8	
(IN) Factors Independent of	16	16	36	35	22	36	27	21	26	36	31	31	10	5	18	31		11	18	25	31	24	12	21	17	14	21	22	18	18	18	8		26	18	19	10	11	29		25	23	19	39	19	19	11	11		23	23	41	37	
DAP = $\frac{DO+0.5\,(IO)}{IN}$	1.66	1.59	0.28	0.29	0.95	0.22	0.67	1.17	0.83	0.25	0.48	0.40	3.35	7.91	.55	0.42		3.05	1.31	0.68	0.37	0.73	2.21	0.83	1.44	1.78	0.86	1.07	1.36	1.08	1.11	3.82		0.71	1.28	1.18	3.55	2.73	0.41		0.80	1.04	1.42	0.15	1.24	1.0	2.87	3.14		0.76	0.72	0.09	0.19	
Present Priority	⑪	⑫	㊹	㊸	㉗	㊻	㊲	㉑	㉙	㊺	㊳	㊶	④	①	⑬	㊴		⑥	⑰	㊱	㊷	㉝	⑨	㉚	⑭	⑩	㉘	㉔	⑯	㉓	㉒	②		㉟	⑱	⑳	③	⑧	㊵		㉛	㉕	⑮	㊽	⑲	㉖	⑦	⑤		㉜	㉞	㊾	㊼	

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6.8 KNOWLEDGE RANGE SCALE

Definitions of the knowledge range scale are presented in Figure 6-1. To illustrate these Figure 6-2 shows initial knowledge in the 0-1 range as a number of discrete observations, some of which are unrelated and some of which may appear irrelevant to the desire to understand. Some data may be useful. Most experiments duplicate previous information. Some new data may actually impede the flow of knowledge because it is collected too crudely to convey the full information and its limitations are not fully comprehended.

The second knowledge range between 1 and 2 may permit assigning a "yes" or a "no" answer to the relevance of additional data because a relationship or pattern has been established. This knowledge range is exemplified by the acquisition of knowledge for knowledge's sake. Skilled observers see gaps in knowledge and the need for new approaches to fill in the missing pieces. It may be at this point that the third range of knowledge is reached. A trained observer realizes that the knowledge is potentially useful. Once this potential is discovered, comparatively unskilled help may be employed under the direction of experienced scientists to produce the broad smooth spectrum leading to theory verification or selection.

4

Specific objectives designed to obtain a key bit of information. Requires knowledgeable theoretician and experimenter since actual observation may lead to a breakthrough in understanding.

3

Long term repetitive measurements (unmanned)
Logical decisions based on the data available (manned)
Extreme precision or speed (unmanned)

2

Manned or unmanned data gathering--hit or miss basis since exact requirements are unknown.

1

Normally manned experimentation-data does not fit any theory. Data acquired in intuitive fields based on man's observational techniques.

0

Data Required

0-1 Data permits ambiguous interpretations, conjectures, is generally open ended. Very little interrelation between areas of investigation.

Data Example: Atmosphere of Venus is all CO_2
Temperature of planet is 600°K

No relation established between temperature of planet and atmosphere composition.

1-2 Data permits "yes" or "no" answers with a value range:

Example: Temperature range on October 18 was -140°C at an altitude of 60 miles which increased linearly to 270°C on the surface, but the composition and pressure-temperature relations are still vague.

2-3 Data permits correlation or conclusions of degree:

Example: The atmosphere of Venus is composed of 90% CO_2, 0.5% H_2O, 0.6% O_2 with the remainder either A or N_2. "Greenhouse" theory still not accepted but relation to electromagnetic spectra established.

3-4 Data verifies theory or permits the development of a new theory.

Figure 6-1: KNOWLEDGE RANGE SCALE

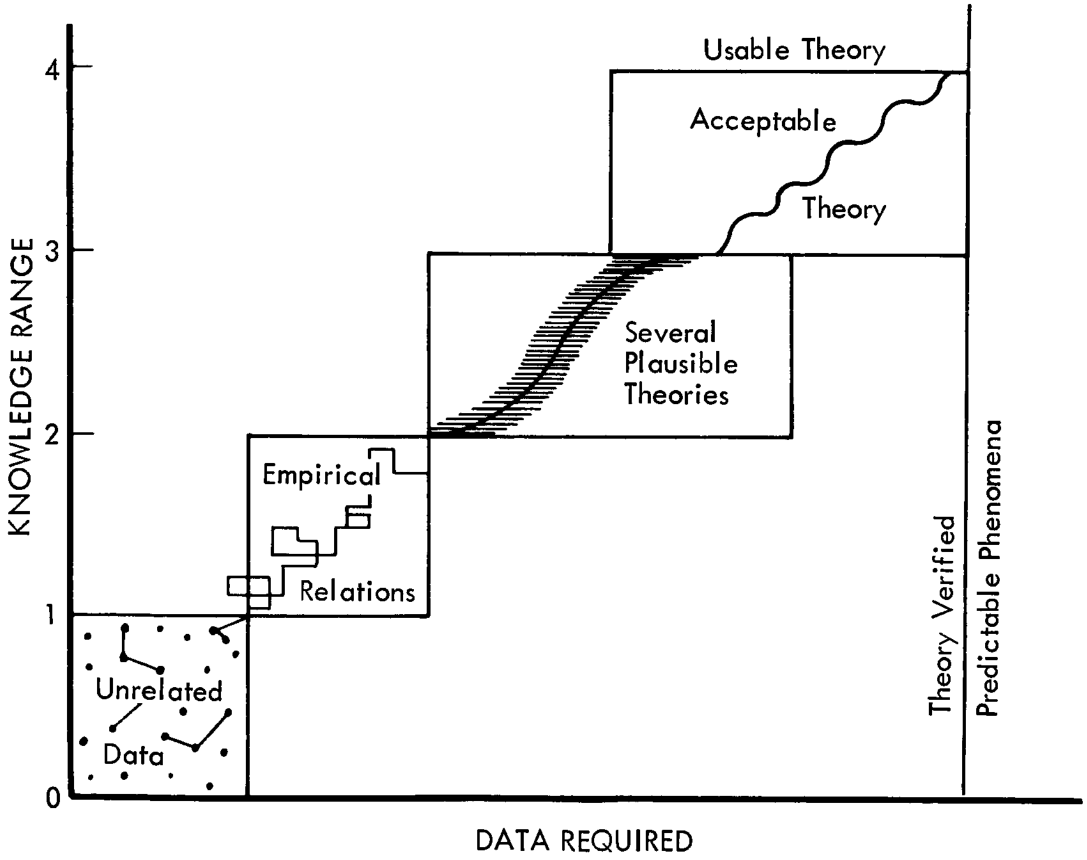

Figure 6-2: KNOWLEDGE RANGE VERSUS DATA REQUIRED

6.9 MISSION MODE EVALUATION AND KNOWLEDGE BASE PROJECTION

Certain classes of information can best be obtained during specific phases of a mission such as the in-transit phases, orbital phase or the surface. Some classes must be measured in orbit about the planet either because of their uniformity in distribution, at least statistically, or because the range of data required to identify the class can be obtained from orbital measurements; those classes actually requiring samples must be determined on the surface of the planet. Some of these classes can be measured in all three modes and some of these must be measured in all three to make effective use of the data gathering capabilities. Table 6-11 summarizes the measurement modes required or possible. The use of this table in conjunction with the present or planned program and the two concepts of predictability and interrelatedness permit the projection of the knowledge base into the future.

Table 6-11A MISSION MODE EVALUATION

	Factors																
	Planetology																
	Orbital Parameters	Rotational Parameters	Figure of Planet	Moments of Inertia	Gravitational Field	Magnetic Field	Structural Features	Thermal Budget	Physical Properties	Seismicity	Physical Features	Isotope Ratios	Mineralization	Age	Atmosphere	Satellites	Summary
Inherent Stability	S	S	S	S	S	S	S	U	S	N	S	S	S	S	S	S	
In-Transit Measurement (X)	⊗	⊗	⊗	X̲	X̲	-	X	X	-	X	X	-	-	-	X	⊗	
Orbit Sensitivity	S	S	N	N	N	N	U	S	S	N	U	S	U	U	S	S	
Orbital Measurement (X)	-	X̲	⊗	X̲	X̲	X̲	X̲	X̲	X̲	X̲	X̲	X	X̲	-	X̲	X̲	
Site Sensitivity	S	S	S	S	S	U	U	N	N	N	N	N	N	N	S	S	
Surface Measurement (X)	-	-	-	-	X	X̲	X̲	⊗	⊗	⊗	X	⊗	X	⊗	X̲	-	
Present & Planned Program Contributions																	
Hard Lander - Mars									X		X				X		
Soft Lander - Mars		X				X		X	X	X	X				X		
Hard Lander - Venus									X		X				X		
Flyby	X				X										X	X	
In-Transit (any mission)	X														X		
In-Orbit - Mars	X	X	X	X	X	X	X	X	X		X		X		X		
In-Orbit - Venus	X		X	X	X	X		X	X						X		

	Factors															
	Modifying Forces															
	Solar Radiation	Meteoroid Impacts	Isostatic Forces	Seismic Activity	Diastrophism	Volcanic Activity	Surface Winds	Temperature Changes	Chemical Reactions	Life	Phase Changes	Gravity	Hydraulic Action	Glacier Action	Nuclear Reactions	Summary
Inherent Stability	U	N	S	N	S	N	N	N	N	S	S	U	U	U	S	
In-Transit Measurement (X)	X	X	X	-	X	X	X	X	-	-	-	-	-	-	-	
Orbit Sensitivity	S	N	U	N	U	U	U	N	N	U	U	S	U	U	N	
Orbital Measurement (X)	X̲	⊗	⊗	X̲	⊗	⊗	X̲	X̲	X̲	X̲	X̲	⊗	⊗	⊗	X	
Site Sensitivity	N	N	N	N	N	N	N	N	N	N	N	S	N	N	N	
Surface Measurement (X)	⊗	X̲	X̲	⊗	X̲	X̲	⊗	X̲	⊗	⊗	⊗	X̲	X̲	X̲	⊗	
Present & Planned Program Contributions																
Hard Lander - Mars																
Soft Lander - Mars	X			X			X	X	X		X				X	
Hard Lander - Venus																
Flyby																
In-Transit (any mission)																
In-Orbit - Mars	X	X	X	X	X	X	X	X	X		X					
In-Orbit - Venus								X								

	Factors						
	Composition						
	Charged Particles	Atomic Elements	Molecular Elements	Minerals	Chemicals	Isotopes	Summary
Inherent Stability	U	S	S	S	S	S	
In-Transit Measurement (X)	X	X	X	-	-	-	
Orbit Sensitivity	N	U	U	U	U	U	
Orbital Measurement (X)	⊗	X̲	X̲	X̲	X̲	X̲	
Site Sensitivity	S	U	U	N	N	N	
Surface Measurement (X)	⊗	⊗	⊗	⊗	⊗	⊗	
Present & Planned Program Contributions							
Hard Lander - Mars							
Soft Lander - Mars	X	X	X		X		
Hard Lander - Venus							
Flyby							
In-Transit (any mission)							
In-Orbit - Mars	X	X	X				
In-Orbit - Venus	X						

	Factors								
	Environment								
	Diurnal	Seasonal	Latitude	Magnetic Field	Micrometeorology	Meteoroid	Radioactive Decay	Solar Radiation	Summary
Inherent Stability	N	N	U	U	N	N	S	U	
In-Transit Measurement (X)	X	X	X	-	X	X̲	-	X	
Orbit Sensitivity	U	U	U	N	U	N	N	S	
Orbital Measurement (X)	⊗	⊗	⊗	⊗	X̲	⊗	X	⊗	
Site Sensitivity	N	N	U	S	N	N	N	N	
Surface Measurement (X)	X̲	X̲	X̲	X̲	⊗	-	⊗	X̲	
Present & Planned Program Contributions									
Hard Lander - Mars									
Soft Lander - Mars	X	X	X	X	X		X	X	
Hard Lander - Venus									
Flyby						X		X	
In-Transit (any mission)						X		X	
In-Orbit - Mars	X	X	X	X	X	X	X	X	
In-Orbit - Venus	X	X	X	X		X	X	X	

	Factors				
	Life				
	Macroscopic	Microscopic	Protoorganic	Fossil	Summary
Inherent Stability	S	S	S	S	
In-Transit Measurement (X)	-	-	X	-	
Orbit Sensitivity	U	U	S	N	
Orbital Measurement (X)	X	-	X	-	
Site Sensitivity	S	S	S	N	
Surface Measurement (X)	X	⊗	X	⊗	
Present & Planned Program Contributions					
Hard Lander - Mars					
Soft Lander - Mars	X	X	X		
Hard Lander - Venus					
Flyby					
In-Transit (any mission)					
In-Orbit - Mars	X	X	X		
In-Orbit - Venus			X		

Code:

S	Stable	A stable factor is mission independent.
U	Uniform	A uniform Factor is mission or time dependent but predictable.
N	Nonstable	A nonstable factor is one that will be initially different for each mission, orbit or site.
X		Measurement can be made in mode identified.
⊗		Measurement must be made in mode identified.
X̲		Complementary and planning measurements in all designated modes should be made.

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FOLDOUT FRAME

FOLDOUT FRAME

6.10 PRIORITIES

Tables 6-12 and 6-13 summarize the knowledge base projections following the unmanned precursor programs and give the computations for Mission Priority and Scientific Priority.

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Table 6-12:A PRIORITIES — MARS MISSIONS

	Planetology																
	Orbital Parameters	Rotational Parameters	Figure of Planet	Moments of Inertia	Gravitational Field	Magnetic Field	Structural Features	Thermal Budget	Physical Properties	Seismicity	Physical Features	Isotope Ratios	Mineralization	Age	Atmosphere	Satellites	Summary
DAC	.125	.100	.014	.016	.015	.011	.016	.007	.016	.001	.006	.027	.007	.013	.031	.080	
DAP	1.66	1.59	0.28	0.29	0.95	0.22	0.67	1.17	0.83	0.25	0.48	0.40	3.35	7.9	1.55	0.42	
Mars KB (Maximum)	4	4	3	3	4	3	2	3	2	1	4	1	1	1	3	2	
In Transit M&O	X	X	X	-	X	-	X	X	-	X	X	-	-	-	X	X	
Orbit	-	X	X	X	X	X	X	X	X	X	X	X	X	-	X	X	
Surface	-	-	-	-	X	X	X	X	X	X	X	X	X	X	X	-	
MP = $\frac{(DAC)(DAP)}{KB}$ =	0519	0398	0014	0015	0047	0008	0054	0027	0064	0003	0007	0108	0235	1027	0160	0168	
Priority	2	3	39	38	25	43	22	35	20	49	47	15	5	1	10	9	
In Transity P	1	2	21	-	12	-	10	18	-	27	26	-	-	-	6	5	
Orbit P	-	1	35	34	22	38	19	31	17	45	43	13	3	-	8	7	
Surface P	-	-	-	-	22	35	19	29	17	41	39	12	3	1	7	-	
SP = $\frac{DAP}{DAC\ KB}$ =	3.32	3.976	6.67	6.05	15.83	6.67	20.9	55.7	25.9	250	20	14.82	47.86	608	16.68	2.63	
Priority	47	46	44	45	38	43	34	21	30	5	35	40	4	3	37	48	
In Transit P	25	24	23	-	22	-	19	9	-	2	20	-	-	-	21	26	
Orbit P	-	43	41	42	36	40	32	20	28	4	32	38	3	-	35	49	
Surface P	-	-	-	-	35	41	31	21	28	6	32	37	4	3	34	-	

	Modifying Forces															
	Solar Radiation	Meteoroid Impacts	Isostatic Forces	Seismic Activity	Diastrophism	Volcanic Activity	Surface Winds	Temperature Changes	Chemical Reactions	Life	Phase Changes	Gravity	Hydraulic Action	Glacier Action	Nuclear Reactions	Summary
DAC	030	007	010	002	011	005	004	001	001	007	009	030	006	006	010	
DAP	3.05	1.31	0.68	0.37	0.73	2.21	0.83	1.44	1.79	0.86	1.07	1.36	1.08	1.11	3.82	
Mars KB (Maximum)	3	2	3	2	2	2	2	2	2	2	2	3	2	3	2	
In Transit M&O	X	X	X	-	X	X	X	X	-	-	-	-	-	-	-	
Orbit	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Surface	X	X	-	X	-	X	X	X	X	X	X	X	X	X	X	
MP = $\frac{(DAC)(DAP)}{KB}$ =	0305	0046	0023	0004	0040	0055	0017	0007	0009	0031	0048	0136	0032	0022	0191	
Priority	4	26	33	48	28	21	37	46	42	30	24	13	29	34	6	
In Transity P	3	13	17	-	14	9	20	25	-	-	-	-	-	-	-	
Orbit P	2	23	29	44	24	18	33	42	37	26	21	11	25	30	4	
Surface P	2	23	-	40	-	18	31	38	34	26	21	10	25	28	4	
SP = $\frac{DAP}{DAC\ KB}$ =	33.9	93.6	22.67	92.5	33.2	22.1	103.8	720	890	61.3	59.4	15.11	90.0	61.7	191	
Priority	25	14	33	15	26	5	13	2	1	19	20	39	16	17	7	
In Transit P	12	7	18	-	13	3	6	1	-	-	-	-	-	-	-	
Orbit P	23	13	31	14	24	5	12	2	1	18	19	37	15	17	6	
Surface P	24	14	-	15	-	6	13	2	1	19	20	36	16	18	7	

	Composition							Environment									Life				
	Charged Particles	Atomic Elements	Molecular Elements	Minerals	Chemicals	Isotopes	Summary	Diurnal	Seasonal	Latitude	Magnetic Field	Micrometeorology	Meteoroid	Radioactive Decay	Solar Radiation	Summary	Macroscopic	Microscopic	Protoorganic	Fossil	Summary
DAC	009	026	019	010	010	016		.004	.004	.015	.011	.004	.007	.010	.012		.020	.020	.074	.022	
DAP	0.71	1.28	1.18	3.55	1.73	0.41		.80	1.04	1.42	0.15	1.24	1.00	2.87	3.14		0.76	0.72	0.09	0.19	
Mars KB (Maximum)	3	2	2	2	2	1		4	4	4	2	2	3	2	2		2	1	1	1	
In Transit M&O	X	X	X	-	-	-		X	X	X	-	X	X	-	X		-	-	X	-	
Orbit	X	X	X	X	X	X		X	X	X	X	X	X	X	X		X	-	X	-	
Surface	X	X	X	X	X	X		X	X	X	X	X	-	X	X		X	X	X	X	
MP = $\frac{(DAC)(DAP)}{KB}$ =	0021	0128	0011	0178	0137	0066		0008	0010	0053	0008	0025	0025	0144	0188		0096	0072	0067	0042	
Priority	36	14	40	8	12	19		45	41	23	44	31	32	11	7		16	17	18	27	
In Transity P	19	7	22	-	-	-		24	23	11	-	15	16	-	4		-	-	8	-	
Orbit P	32	12	36	6	10	16		41	40	20	39	27	28	9	5		14	-	15	-	
Surface P	30	11	32	6	9	16		37	33	20	36	27	-	8	5		13	14	15	24	
SP = $\frac{DAP}{DAC\ KB}$ =	26.3	32.0	31.1	177.5	136.5	25.6		50.0	65.0	23.7	6.82	.155	.426	143.5	130.8		19.0	36.0	1.216	8.63	
Priority	29	27	28	8	11	31		22	17	32	42	9	23	10	12		36	24	49	41	
In Transit P	16	14	15	-	-	-		10	8	7	-	4	11	-	5		-	-	27	-	
Orbit P	27	25	26	7	10	29		21	16	30	39	8	22	9	11		34	-	45	-	
Surface P	27	25	26	8	11	29		22	17	30	39	9	-	10	12		33	23	41	38	

Code
☐ Independent
D Dependent
I Indirect Dependence

Summation
☐ ☐ ☐

TABLE 6-12-A

Table 6-13: PRIORITIES — VENUS MISSIONS

	Planetology																
	Orbital Parameters	Rotational Parameters	Figure of Planet	Moments of Inertia	Gravitational Field	Magnetic Field	Structural Features	Thermal Budget	Physical Properties	Seismicity	Physical Features	Isotope Ratios	Mineralization	Age	Atmosphere	Satellites	Summary
DAC	125	100	014	016	015	011	016	007	016	001	006	027	007	013	031	080	
DAP	1.66	1.59	0.28	0.29	0.95	0.22	0.67	1.17	0.83	0.25	0.48	0.40	3.35	7.9	1.55	5.42	
VENUS KB (Maximum)	4	3	1	1	4	2	2	3	2	1	2	1	1	1	2	1	
In-Transity	X	-	-	-	-	-	-	X	-	-	-	X	-	-	X	X	
Orbit	-	X	X	X	X	X	X	X	X	-	X	X	-	-	X	X	
Surface (Unmanned)	-	-	-	-	X	X	X	X	X	X	X	X	X	X	X	-	
MP = $\frac{(DAC)\ (DAP)}{KB}$ =	0519	0530	0039	0046	0036	0012	0053	0027	0066	0003	0023	0108	0235	1027	0257	0435	
Priority	3	2	35	32	37	45	30	39	26	49	40	19	9	1	8	4	
In-Transit	1	-	-	-	-	-	-	14	-	-	-	9	-	-	4	2	
Orbit	-	1	21	19	22	29	18	24	15	-	25	11	-	-	5	2	
Surface	-	-	-	-	29	37	24	31	20	41	32	16	6	1	5	-	
SP = $\frac{DAP}{DAC\ (KB)}$ =	3.32	5.30	20.0	18.14	15.83	10.0	20.9	55.7	25.9	250	30	1483	478	608	25.0	67.7	
Priority	48	47	40	41	42	44	39	27	36	8	30	43	4	3	37	25	
In-Transit	15	-	-	-	-	-	-	9	-	-	-	14	-	-	13	8	
Orbit	-	29	23	24	25	27	22	11	19	-	14	26	-	-	21	10	
Surface	-	-	-	-	36	38	35	23	32	8	26	37	4	3	34	-	

	Modifying Forces															
	Solar Radiation	Meteoroid Impacts	Isostatic Forces	Seismic Activity	Diastrophism	Volcanic Activity	Surface Winds	Temperature Changes	Chemical Reactions	Life	Phase Changes	Gravity	Hydraulic Action	Glacier Action	Nuclear Reactions	Summary
DAC	030	007	010	002	011	005	004	001	001	007	009	030	006	006	010	
DAP	3.05	1.31	0.68	0.37	0.73	2.21	1.83	1.44	1.78	0.86	1.07	1.36	1.08	1.11	3.82	
VENUS KB (Maximum)	3	1	1	1	1	2	2	2	1	1	1	1	1	1	2	
In-Transity	X	-	-	-	-	X	-	-	-	-	X	-	-	-	-	
Orbit	X	X	-	-	-	X	-	-	-	X	X	X	-	-	-	
Surface (Unmanned)	X	X	-	X	-	X	X	X	X	X	X	X	X	X	X	
MP = $\frac{(DAC)\ (DAP)}{KB}$ =	0305	0022	0068	0007	0080	0055	0037	0007	0018	0060	0096	0408	0065	0067	0191	
Priority	7	41	23	48	21	29	36	47	13	28	20	5	27	24	11	
In-Transit	3	-	-	-	-	11	-	-	-	-	10	-	-	-	-	
Orbit	4	26	-	-	-	17	-	-	-	16	12	3	-	-	-	
Surface	4	33	-	40	-	23	28	39	35	22	17	2	21	18	8	
SP = $\frac{DAP}{DAC\ (KB)}$ =	33.9	44.3	68	185	66.3	221	229	720	1780	122.9	118.9	45.3	180	185	191	
Priority	33	29	24	14	26	10	9	2	1	20	21	28	15	13	12	
In-Transit	10	-	-	-	-	2	-	-	-	-	5	-	-	-	-	
Orbit	16	13	-	-	-	2	-	-	-	6	7	12	-	-	-	
Surface	29	25	-	14	-	10	9	2	1	19	20	24	15	13	12	

	Composition							Environment									Life				
	Charged Particles	Atomic Elements	Molecular Elements	Minerals	Chemicals	Isotopes	Summary	Diurnal	Seasonal	Latitude	Magnetic Field	Micrometeorology	Meteoroid	Radioactive Decay	Solar Radiation	Summary	Macroscopic	Microscopic	Protoorganic	Fossil	Summary
DAC	009	020	019	010	010	016		004	004	015	011	004	007	010	012		020	020	014	022	
DAP	0.71	1.28	1.18	3.55	2.73	0.41		0.80	1.04	1.42	0.15	1.24	1.00	2.87	3.14		0.76	0.72	0.09	0.19	
VENUS KB (Maximum)	3	2	2	1	2	1		1	1	1	2	1	1	2	2		1	1	2	1	
In-Transity	X	X	X	-	-	-		X	X	X	-	-	-	-	X		-	-	X	-	
Orbit	X	X	X	-	X	X		X	X	X	X	-	X	-	-		-	X	X	-	
Surface (Unmanned)	X	X	X	X	X	X		X	X	X	X	X	-	X	X		X	X	X	X	
MP = $\frac{(DAC)\ (DAP)}{KB}$ =	0021	0128	0112	0355	0136	0066		0032	0042	0213	0008	0050	0070	0143	0188		0152	0144	0013	0042	
Priority	42	17	18	6	16	25		38	34	10	46	31	22	15	12		13	14	44	33	
In-Transit	15	7	8	-	-	-		13	12	5	-	-	-	-	6		-	-	16	-	
Orbit	27	9	10	-	8	14		23	20	6	30	-	13	-	-		-	7	28	-	
Surface	34	14	15	3	13	19		30	27	7	38	25	-	12	9		10	11	36	26	
SP = $\frac{DAP}{DAC\ (KB)}$ =	78.9	32	31.1	355	136.5	25.9		200	260	94.7	6.82	310	142.9	143.5	130.7		38	36	3.21	8.64	
Priority	23	34	35	5	18	37		11	7	22	46	6	17	16	19		31	32	49	45	
In-Transit	7	11	12	-	-	-		3	1	6	-	-	-	-	4		-	-	15	-	
Orbit	9	17	18	-	5	20		3	1	8	28	-	4	-	-		-	15	30	-	
Surface	22	30	31	5	17	33		11	7	21	40	6	-	16	18		27	28	41	39	

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7.0 PAYLOAD SUMMARY AND OTHER MISSION CONSIDERATIONS

The payload requirements used in the recommended configuration described in Volume IV are summarized below. The other system considerations presented are planet orbits, crew time associated with the scientific mission, and crew skill requirements.

7.1 PAYLOAD SUMMARY

A review of the instrument ranges and techniques indicated that the orbiting spacecraft scientific payload is similar for both the Mars and the Venus missions. Table 7-1 summarizes these instruments with the requirements that they generate in terms of power, weight, volume, etc. These payloads differ somewhat from those given in Section 5.1.2, which represent a later iteration in the course of the study. The difference is not significant for the spacecraft design or performance capability.

The major payload differences are related to surface measurements on Mars and the unmanned probes. Tables 7-2, 7-3 and 7-4 summarize the instruments to be incorporated into the Mars Excursion Module and its return payload. Tables 7-5 and 7-6 indicate the unmanned orbiters and landers for the Mars and the Venus mission. No allowance has been made in these weights for their integration into the spacecraft, which is included, however in the spacecraft design of Volume IV.

There is a requirement for 5 separate laboratory facilities to be located in the spacecraft. Their requirements are summarized in Table 7-7.

The geological and bioscience laboratories for the Mars mission emphasize experiments on surface samples while analytical studies are emphasized for the Venus missions.

Table 7-1: MARS-VENUS EXPERIMENT INSTRUMENTS

INSTRUMENT Instrument	Weight (lb)	Power (watts)	Volume (ft^3)	Rate or Pointing Accuracy	Data Management (kbs/sec)	Mounting(1)
UV Spectrometer	135	60	3.0	0.02-0.05 deg/sec	10-20	
IR Spectrometer	100	40	7.0	0.02-0.5 deg/sec	10-20	
IR Interferometer	50	25	0.2	0.01 deg/sec	2.0	
Photographic System	2000	30	230.0	0.03 deg/sec ±0.50 deg	(2)	
UV Scanner	55	25	7.0	0.02-0.05 deg/sec		
IR Scanner	185	25	1.8	0.02-0.05 deg/sec	10-20	
Polarimeter	50	20	0.5	0.01 deg/sec	0.01	
Photometer	10	20	0.25	± 1 deg	0.1	
RF Radiometer	100	20	8.0	0.02 deg/sec	19	
Bistatic Radar	36	6	0.5			Boom
Magnetometer	6	7	0.2		0.2	Boom
Charged Particle Detector	50	15	1.0		0.1	Boom
Micrometeoroid Detector	115	1.5	1.4		0.01	Body Mounted
Mapping Radar	420	550	2.5	±0.05 yaw ±1.0 P&R	180	
Ion Probes (3)	300	10	10			
Tracking Radar	230	450	8	±10 deg	12	Track Platform
Altimeter	50	220	2	±1 deg	1.7	Body Mounted
Totals	3890	1265 (avg)	458			

---

(3) This probe category has been included as it is common to both Mars and Venus missions.

(2) 80,000 photos (one photo is equivalent to 6 x 10^9 bits.)

(1) Scan platform unless otherwise noted.

Table 7-2: ANALYTICAL HARDWARE — MEM

Equipment	Requirements		
	Weight (lb)	Power (watts)	Volume (cubic ft)
Microscope and Cameras	15	20	1.2
Centrifuge	40	25	0.5
Polarimeters	14	5	0.2
Spectrophotometers (Vis., UV, X-Ray)	135	60	0.5
Nuclear Instrumentation	150	30	0.2
PH Meter Plus Reagents	41	3	0.2
Mass Spectrometer	10	3	0.5
Chromatographs	14	10	0.2
Osmoter	12	--	0.2
Refractometer	8	2	0.2
X-Ray Diffractometer	36	20	1.1
Thermometers	1	1	0.1
Scales	15	1	1.0
IR Spectroscopes	100	40	1.0
Weather Station(1)	100	5	2.5
Magnetometer	6	7	0.5
Seismographs (Active and Passive)	52	25	3.5
Gravimeter	30	5	1.0
Heat Flow (With Small Drill)	15	2	1.0
Total Analytical Hardware	794	264	15.9

(1)Automated with recorder and data transmission (10^4 bps peak)

Table 7-3: SUPPORT HARDWARE

Suggested Equipment	Requirements Weight (lb)	Power (watts)	Volume (cubic ft)
Microtome and Slides and Stains	25	15	0.3
Refrigerators	10	40	1.0
Incubators	20	100	2.0
Oven-Sterilizer	40	500	1.0
Work Bench and Glassware (Teflon)	55	-	30.0
Micromanipulators (In Above Bench)	22	5	-
Ultrasonic Cleaner Including Solvent	140	200	2.0
Agitators, Blenders	9	10	0.5
Emulsifier	10	8	0.5
Drilling and Coring	110	500	1.0
Rock Cutters	20	150	1.0
Polishing and Etching	20	50	0.5
Biosampler	11	-	0.2
"Pristine State" Mars Material Box	6	-	2.0
Geological Hand Tools and Containers	25	-	1.0
Data System(1)	50	25	0.5
Total Support Hardware	573	1603	43.5

(1) Include recorders and telemetry system with capability of transmitting video bandwidth information. Separate from command link between MEM and spacecraft.

Table 7-4: SAMPLE AND DATA RETURN

(1)Samples and Data	Weight (lb)	Power (watts)	Volume (cubic ft)
Sedimentary Samples	180	-	1.2
Stratigraphic Records	12	-	0.2
"Long" Core Samples	450	-	4.2
Photographic Records(2),(3)	6	-	0.1
Surface Soil Samples	150	-	1.0
Water Samples	8	-	0.1
Environment Data	6	-	0.1
Tape Recordings(3)	12	-	0.2
Ice Samples (Includes Refrigerator)	28	150	1.1
Specimens (Lichens, Algae)	60	-	1.0
Total Samples and Data Return	912	150	9.2

(1)Includes packaging where applicable.

(2)Transmission data bandwidth limitations may increase this.

(3)Data collected just prior to launch from Mars surface.

Table 7-5: MARS ORBIT LAUNCH PROBES

Probe	Quantity	Science Payload (Weight lb)	Probe(1) Weight (lb)	Size (2) (ft)	Data to be Acquired
Engineering					
Hard Lander	5	20	330	7 (D) x 7 (L) (Apollo Shape)	MEM Trajectory Data
Soft Lander	2	100	3335	14 (D) x 7 (L) (Apollo Shape)	Surface Bearing Strength and Radiation Background
Science					
Orbiter	2	6	100	3 (D) x 3 (L) (Cylindrical)	Occulation
Orbiter	2	22	155	3 (D) x 4 (L) (Cylindrical)	Ionosphere
Orbiter	2	6	100	3 (D) x 3 (L) (Cylindrical)	Magnetic Field
To Mars' Moons Hard Lander	4	25	2600 3305	5 (D) x 10 (L) (Cylindrical) 5 (D) x 11 (L) (Cylindrical)	Martian Moon Imaging
Orbiter	2	420	1415	Cylindrical	Radiometeric Maps (Polar)

(1) Total probe weight = 22,255 pounds (for Venus swingby = 23,135 pounds)

(2) Total volume = 6350 cubic feet (For Venus swingby = 6610 cubic feet)

Table 7-6: VENUS UNMANNED PROBES

Probe Mode	Qty	Science Payload Weight (lb)	Probe(2) Weight (lb)	Size(3) (ft)	Data to be Acquired
(1)Atmospheric drifter to surface. Drift down rate of 20 miles per 20 days, which may be inversely proportionate to atmospheric density from 1 to 20 atmospheres horizontal velocity. Not critical.	2	50	775	5 (D) x 7 (L) (cyl)	Atmospheric Life
Orbiter	2	150	1,550	5 (D) x 8 (L) (cyl)	Cloud Data
Orbiter	2	420	11,575	5 (D) x 14 (L) (cyl)	Surface Temperature Mapping Data
(1)Atmospheric drifter similar to above with a constant drop rate rather than a proportional rate.	2	80	825	5 (D) x 7 (L) (cyl)	Atmospheric RF Transmission
Same as above, but with soft lander capability.	2	320	2,370	10 (D) x 7 (L) Apollo Shape	Surface Spectral Data

(1)Swingby Mission Complement
(2)Total Probe Weight = 34,190 pounds
(3)Total Volume = 9770 cubic feet

Table 7-7: EXPERIMENT LABS

Lab	Floor Area* (sq ft) (minimum)	Weight (lbs)	Power (watts) (maximum)
Bioscience	55	2670	500
Optics	55	1600	300
Geophysics	25	450	250
Electronics	55	250	250
Science Information	70	2000	1000

*7-foot height

Table 7-8: OUTBOUND IN-TRANSIT EXPERIMENTS

Measurements	Elapsed Time Required in Orbit (min/day)				Number of Persons Required in Orbit			
	1-5	5-25	25-180	180-200	1-5	5-25	25-200	200-220
Interplanetary magnetic fields	-	60	60	60	-	2	2	1
Interplanetary particulate matter	-	60	60	20	-	2	2	1
Solar radiation	10	10	10	10	1	1	1	1
Planet observations	-	-	130	150	-	-	2	2
Other astronomical observations	-	60	100	-	-	1	2	-
Biological monitoring	180	90	60	30	6	6	6	6
Radiation monitoring	10	10	10	10	6	6	6	6

7.1.1 MARS MISSIONS - TOTAL PAYLOAD

The science payloads for the Mars Mission are summarized below. The science laboratories and their equipment are included.

	Weight (lbs)	Vol. (ft^3)	Power (watt-ave)
Spacecraft Instruments ①	3,890	458	1,265
Surface Instruments	2,279	68.6	2,017
Experiment Laboratories	6,970	1,820	780 ④
Probes (Incl. Propulsion)	22,255 ②	6,350 ③	Self Contained
Totals	35,394	8,696.6	4,062.0

① Includes both orbiting and intransit instruments

② 23,135 lb for Venus Swingby

③ 6,610 cu ft for Venus Swingby

④ In orbit (1,660 watts, inbound trajectory).

7.1.2 VENUS MISSIONS - TOTAL PAYLOAD

The science payloads required to satisfy the Venus mission objectives are summarized below. The average laboratory power for the Venus orbital mission is higher than those for the Mars mission because in the orbit phase the total crew complement (6) is available for laboratory operation.

	Weight (lbs)	Vol. (ft^3)	Power (watts-ave)
Spacecraft Instruments ①	3,890	458	1,265
Experiment Laboratories	6,970	1,820	1,280 ②
Probes (Including Propulsion)	34,190	9,770	Self-Contained
Totals	45,050	12,048	2,545

① Includes both orbiting and in-transit instruments.

② In-orbit and in-transit inbound.

7.1.3 EXPERIMENT LABORATORIES

Separate work centers or laboratories are considered essential to the scientific program developed during the IMISCD study. Practical considerations limited the number of areas to centers devoted to bioscience, optics, geology, electronics, and a science information center.

The Bioscience Laboratory---The bioscience work center may serve three distinct functions. First, observations that are to be made on the crew, such as the radiation dose accumulated as the mission proceeds, muscle size and bone density will be required along with records of visual acuity. The second function supports the monitoring of the test plants and animals. These plants and animals also serve a dual function in providing additional data on the effects of zero-g on life which has evolved in a 1-g environment, as well as providing the test subjects and controls necessary for evaluating the back contamination problems associated with Martian life or viruses. The third function of the bioscience lab is to provide the facilities required for the study and culturing of the samples obtained during the surface program on Mars.

The Geophysical Laboratory---The geophysical center permits two diverse functions simultaneously. The first of these is the evaluation of displayed information either in the form of photographs or as electronic displays reproduced from electromagnetic recordings. This information may be gathered during the in-transit phases as well as the orbital phases. The second function is the analysis of rock samples collected while on the surface and collated with surface features which have been photographed in color and in IR.

The Optical Laboratory---The optical work center permits the operation, repair and calibration of all optical equipment used during the mission. As such it must be light-tight and constructed to reduce the light scatter from wall materials. It contains dark-room facilities, thin-film coating devices for the preparation of interference filters, densitometers and other equipment required for the interpretation of spectral data. This lab will support both the bioscience and the geophysical lab.

The Electronic Laboratory---The electronics work center will provide all the test equipment and facilities for the operation, repair and checkout of hardware essentially electronic in function and nature. These include the radiometric and RF experiments as well as the pulse height analyzers associated with the nuclear detection sensors. Most of the test equipment will be special to the space program but will perform standard test functions such as signal simulation, display, component testing, etc. Component testing will be at the lowest replaceable module level. Contemplated operations emphasize the in-transit program although orbital operation will be required.

The Experiment and Science Information Center---The science information center is an information storage and retrieval center which has the instruction and repair manuals as well as the scientific information required during the various mission phases. In addition it will display the essential mission program information as preplanned and then provide the necessary recording and control information to indicate the possible deviations from this plan. The purpose of these displays is to take advantage of man's decision-making capabilities and to provide both the long- and short-term memories essential to any computer. If it becomes necessary to reprogram any portion of the experiment timing or phasing or to make other deviations, these will be recorded in this center as well as in the captain's log. All comments and observations on data and the experiment program will be recorded here. Computation to support the experiments will be performed in this center.

7.2 PLANET ORBIT CONSIDERATIONS

The orbit parameters selected for the spacecraft determine the quality and quantity of the data acquired. General considerations are presented for Mars and Venus.

7.2.1 MARS

Circular Versus Elliptical---The scientific objectives associated with manned missions to Mars require observation of surface patterns and discrete spectral emissions or reflections. Since many of the observations depend on the correlation of data from one pass to another, it is desirable to gather data under conditions which are as uniform as possible both in illumination and in observable swath width. In contrast to this, there is little scientific benefit in conducting experiments from an orbit that varies in distance from the planet. It has been assumed that all magnetic field interactions, equivalent Van Allen belts, and so on, will have been explored sufficiently by the unmanned precursors and hence there is no requirement to traverse a wide range of altitudes. Therefore, it is recommended that an orbit as nearly circular as possible be established about the planet.

Orbit Inclination---Since one of the significant objectives associated with the exploration of Mars, the search for extraterrestrial life, may be achieved by observation of the wave of darkening which follows the recession of the polar caps, a primary consideration is an orbit which would permit extensive observation of this phenomenon. At its maximum, the South cap extends to 83 degrees in latitude while the North cap can extend as far south as 57 degrees. It is imperative that the orbit permit observation of the near-polar regions. In addition, should Mars be almost featureless the least valuable orbit would be an equatorial orbit which simply traverses the same territory again and again. The greatest diversity in phenomena is observable from near-polar orbits. For these reasons, an orbit ranging from 60 to 80 degrees in inclination is desired.

Altitude---The altitude of an orbit is obviously a compromise between the resolution and swath width desired and the primary optical system used. The maximum distance to the surface of the planet should be on the order of 1000 km.

7.2.2 VENUS

Circular Versus Elliptical---The scientific objectives associated with manned missions to Venus require the observation of cloud patterns with optics and the surface with radar. Again, standard illumination should be a goal to reduce the processing necessary to make good comparisons. A constant distance is extremely desirable since radar illumination depends on the fourth power of the distance. It is again assumed that the planet's environment will have been established prior to committing a manned mission to the planet so that a wide range of altitudes need not be covered. A circular orbit is highly desirable.

Orbit Inclination---At the present there is no visual indication that the polar regions differ markedly from those near the equator; however, spectral interpretations suggest that polar areas are cooler than equatorial regions. In order to determine the effects of this temperature gradient it is desirable to view the greatest climatic extremes possible. Polar observations may be of primary interest in the search for life because of the high temperatures presently assumed to exist on the equatorial surfaces of the planet. Sixty to 80-degree orbital inclinations are desired.

Altitude---If breaks are present in the Venus cloud cover, one-meter optical resolution is desirable for surface observations. The maximum distance to the surface of the planet should be less than 1600 km and on the order of 1000 km.

7.2.3 SUMMARY

Recommended spacecraft orbits for both Mars and Venus are near-circular with inclinations ranging from 60 to 80°. Altitudes should be near 1000 km based on the surface resolution desired, but this in general varies with the feature to be measured or observed.

For Mars an unmanned orbiter can be used to obtain added measurements in the polar regions.

For Venus, an additional unmanned orbiter is required to cover a significant portion of the planet (more than half) because of its slow rotation.

7.3 TIME REQUIREMENTS

The time required to perform certain functions associated with the measurements and observations for the in-transit phases of the Mars mission and the orbital phases of the Mars and Venus missions have been estimated. In addition, a comparison has been made for the total experiments to be performed for the three types of missions possible for Mars during 1986. This information is presented in Figures 7-1 through 7-3. The three phases of the Mars 1986 Opposition mission have been examined to determine the impact of experiment time requirements on them. A brief discussion of this data follows:

7.3.1 IN-TRANSIT OBSERVATIONS AND MEASUREMENTS

Estimates have been made for the time required to perform the operations required by the outbound in-transit measurements and observations. These estimates are presented in Table 7-8. It should be pointed out that the magnetic field measurements and the associated solar wind observations are essentially statistical in nature. Hence the estimates have been based on data gathered during the quiet Sun year of 1953, a year similar in activity to that predicted for 1986. The table is arranged to indicate that 2 men are required for an average of 60 min/day to make the magnetic field measurements during the 5-20 day period, between the 1st and 2nd midcourse maneuvers, as well as the 20-170 day period. During the 170-200 day period, i.e., after the 3rd midcourse maneuver, only one person is required on the average.

It should be noted that both biological and radiation monitoring is performed for each member of the crew, 6 in this case, throughout the mission and will require about the same amount of time whether in transit, in orbit or on the surface.

The same estimates have been presented in Figures 7-4 and 7-5 to call attention to the difference between the outbound and inbound transit phases of the Mars mission due to the collection of surface samples. If a surface mission has not been accomplished the two legs of the mission are approximately the same as the outbound phase. An inbound table similar to that of Table 7-8 for the outbound leg has not been prepared because of the general unpredictability of the surface findings.

7.3.2 IN-ORBIT OBSERVATIONS AND MEASUREMENT TIMES

The in-orbit observations and measurements times are those estimated to support a fully automated data acquisition system. The times are those considered necessary to perform such functions as reviewing data from the measurements and comparing them with that required to meet the objectives of the program. Anomalies will be noted where they can be identified and duties will include changing film drums, correlating spectra with features on the surface and determining the adequacy of the data.

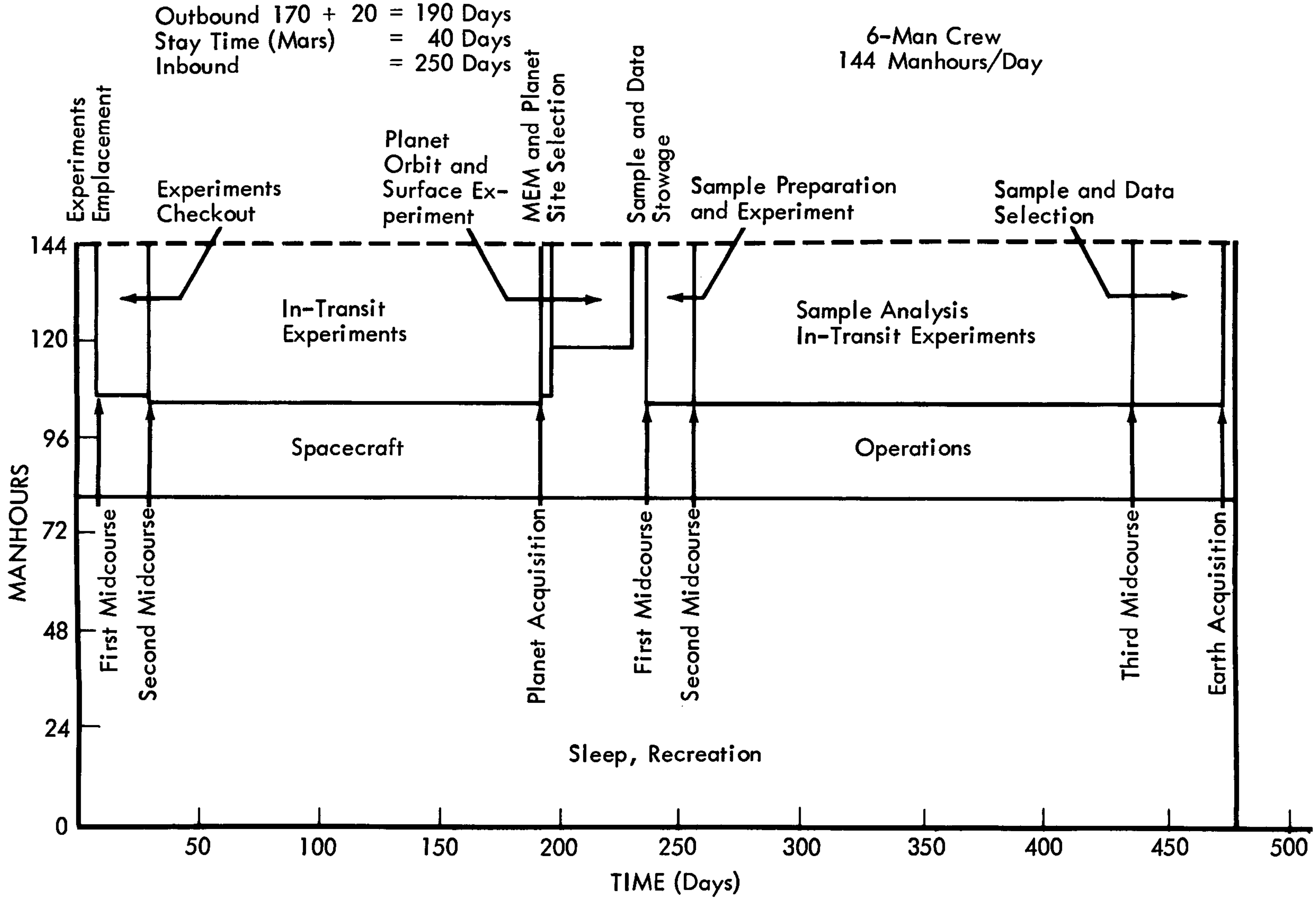

Figure 7-1: OPPOSITION 1986 CREW TIMELINE

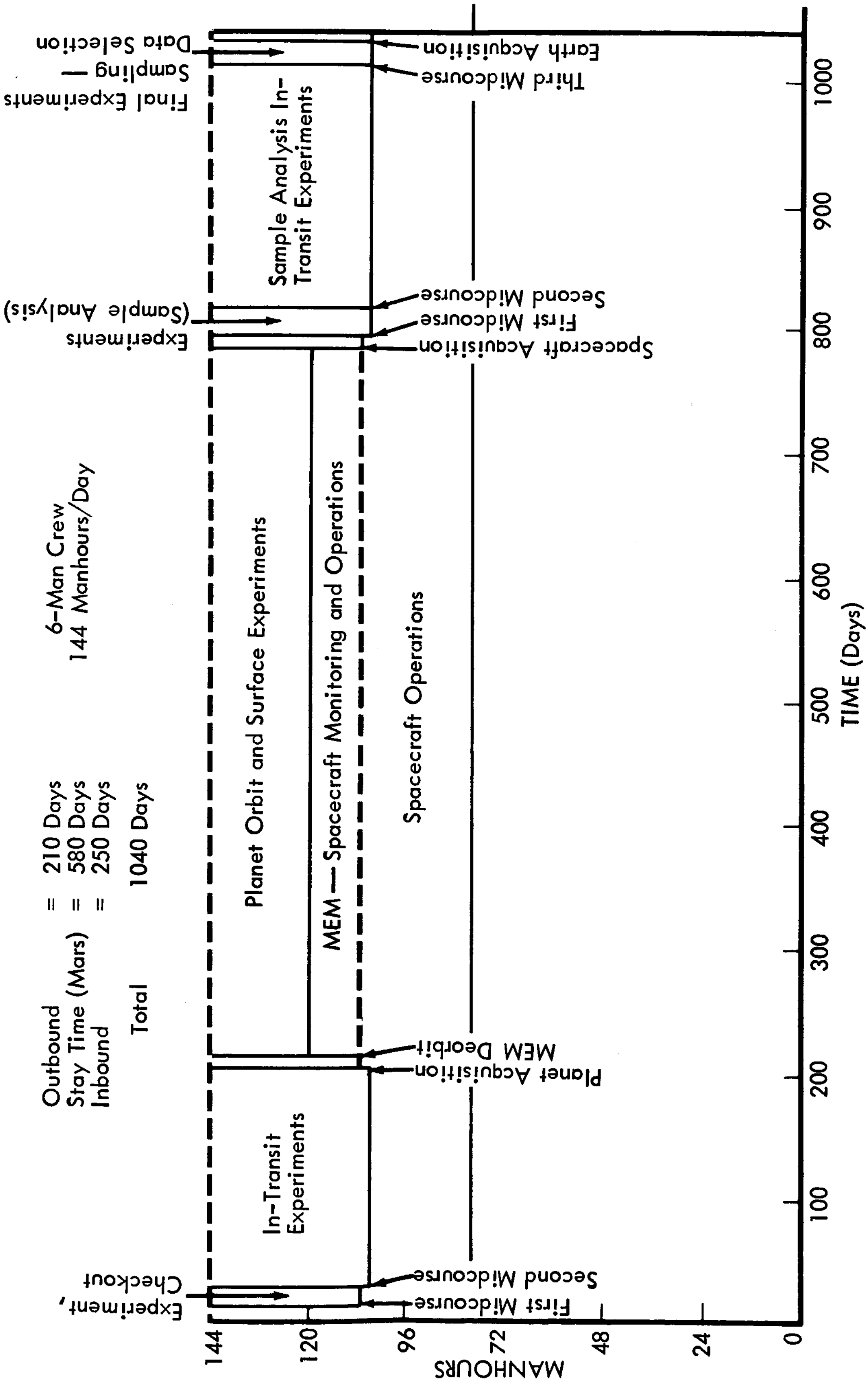

Figure 7-2: CONJUNCTION 1986 CREW TIMELINE

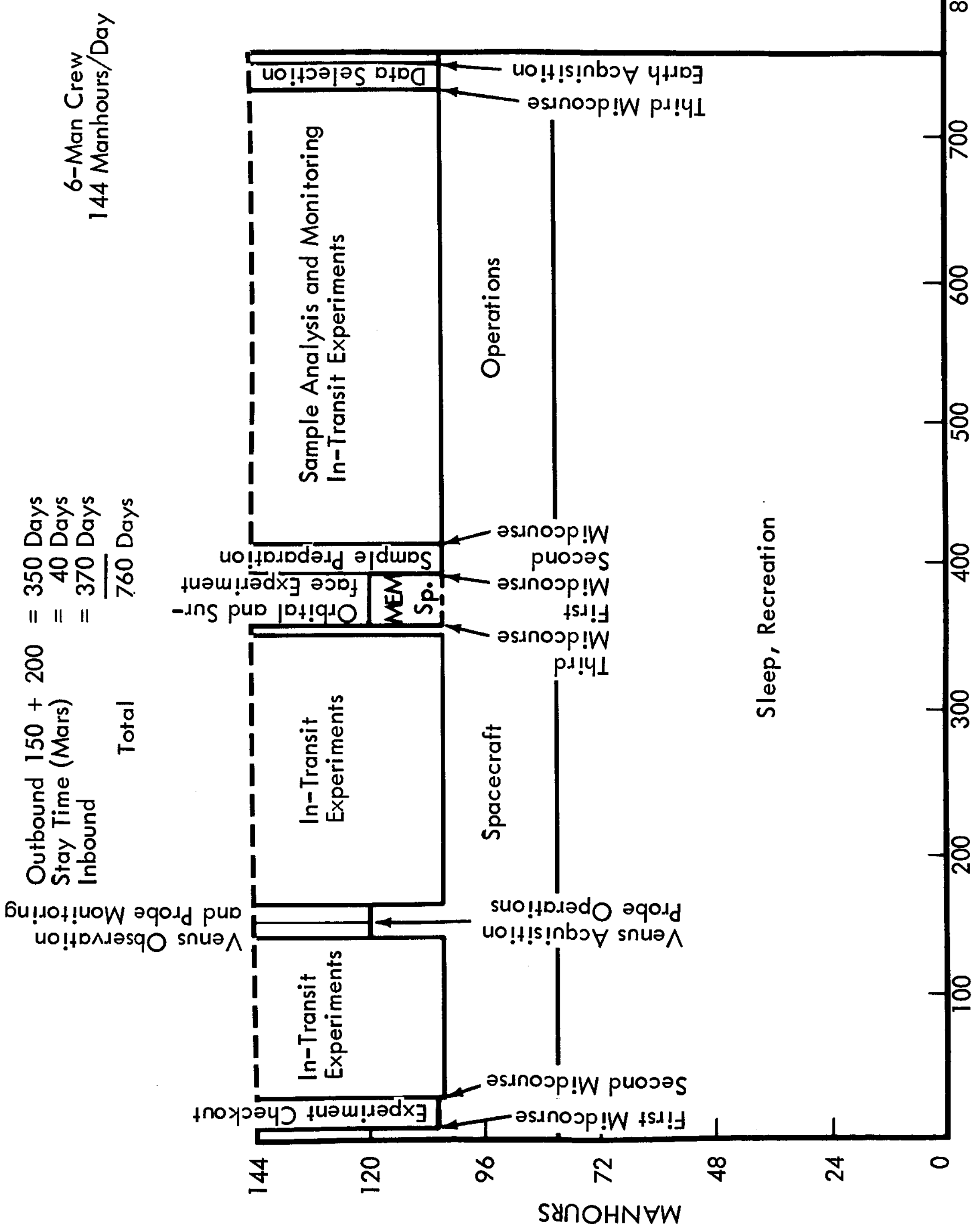

Figure 7-3: SWINGBY 1986 CREW TIMELINE

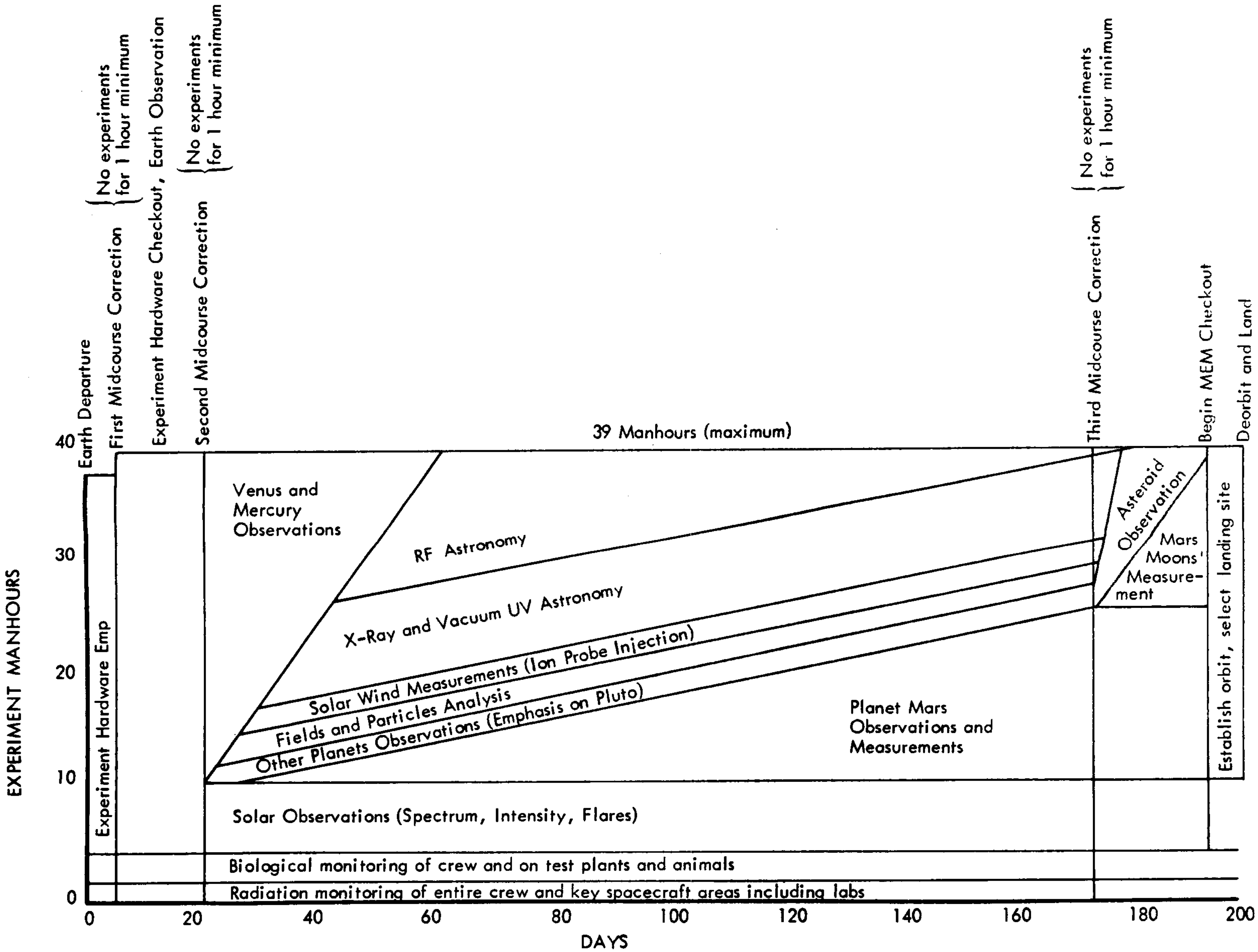

Figure 7-4: OUTBOUND IN-TRANSIT EXPERIMENTS — OPPOSITION MARS 1986

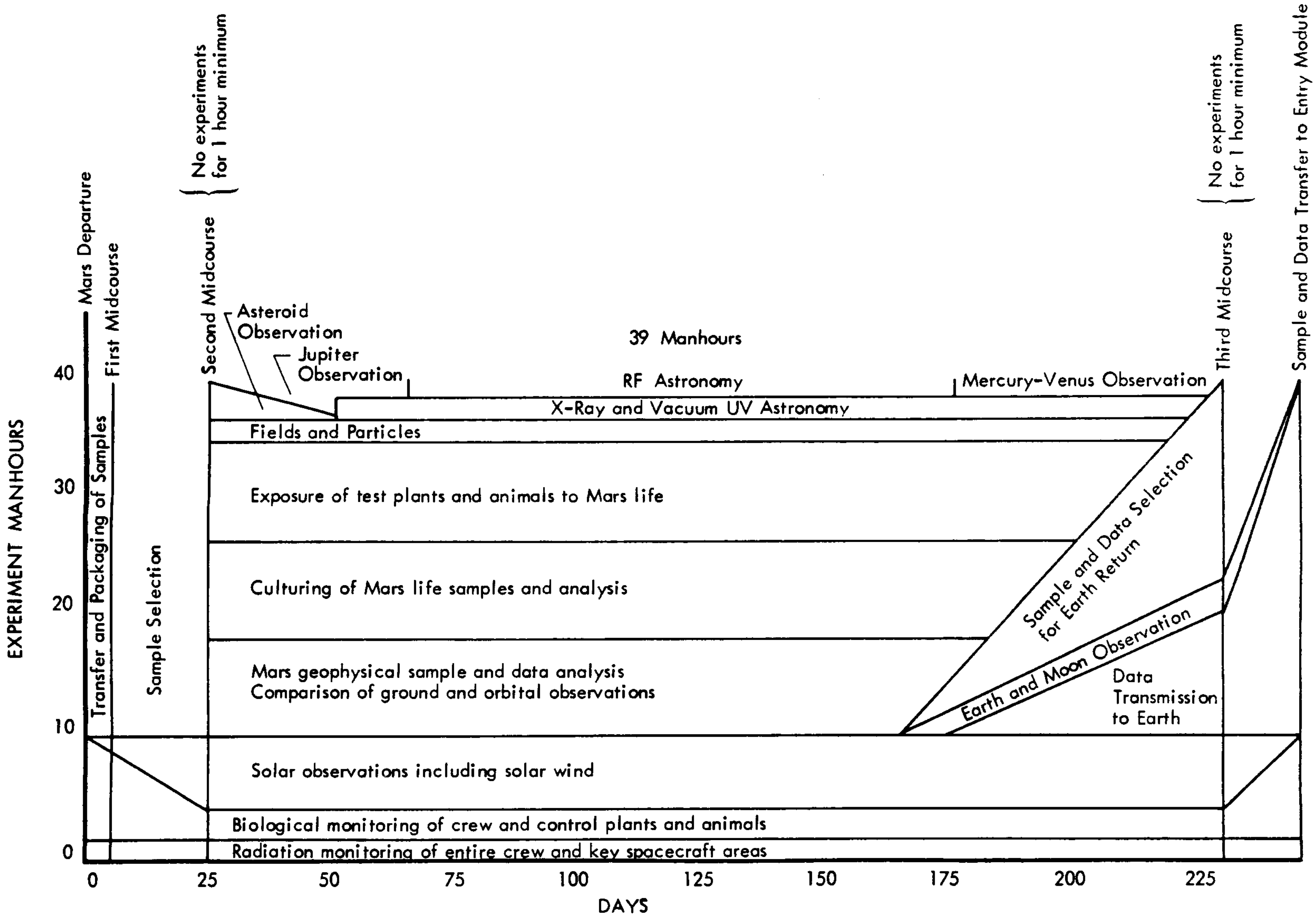

Figure 7-5: INBOUND IN-TRANSIT EXPERIMENTS — OPPOSITION MARS 1986

Most of the Mars orbital data can be acquired with one person only as indicated in Table 7-9, and is depicted on a per-day basis in Figure 7-6. The incident, reflected and radiated energy associated with a planet will require two members of the crew when recording media is to be exchanged. Some time included in this experiment should be allocated to multispectral imaging. To keep fractional manpower from appearing in the table full support during film changing has been put into the one experiment.

The table is organized in a similar fashion to that of the in-transit measurements, i.e., the elapsed time required is in minutes per day and the number of persons are those needed with a particular skill for the time estimates given.

The Venus orbit experiment times are presented in Table 7-10. These require increased manpower over those of the Mars orbiter because of the possible target of opportunity nature of most of these measurements. In addition, a greater number of probes and orbiters exist because of the dense cloud structure. These are also treated as targets of opportunity because of the possible diffraction of the electromagnetic spectra associated with the measurements and with the data transmission. It should be pointed out that the manpower requirements for the nuclear studies includes the nuclear radiation monitoring time for each member of the crew.

7.3.3 SURFACE PROGRAMS

7.3.3.1 Life

The program to be conducted on the surface can be condensed into 10 basic laboratory investigations. These with their time requirements are summarized in Table 7-11 and also presented in Figure 7-6.

7.3.3.2 Geological (Planetology, Environment, Composition and Modifying Forces)

The experiments summarized in Table 7-12 and again in Figure 7-6 are considered representative of the activity on the surface with experienced observers. Those experiments requiring mobility, such as the collection of rock or soil samples, are also dependent on suit design. In addition, core drilling depends on drill design and type of surface. The data corresponds to the average value used in the petroleum industry for coring operations. A suit mobility similar to that proposed for the Apollo program has been used. Analysis of three surface mobility ranges 1 km, 10 km and a 1000 km indicated that a surface vehicle which has an operational radius of about 10 km would permit full utilization of the 30-day stay time in the collection of samples from representative features and structures. It also permits the layout of a seismic station of at least 4 km on a leg which greatly enhances the information content of the data.

Table 7-9: MARS ORBIT EXPERIMENTS

Measurements	Elapsed Time Required in Orbit (min/day)				Number of Persons Required in Orbit			
	1-5	5-20	20-35	35-40	1-5	5-20	20-35	35-40
Incident, reflected and radiated energy	240	100	100	240	2	2	2	2
Moon orbits	-	10	10	-	-	1	1	-
Moon size and figures	-	2	2	-	-	1	1	-
Past or present activity	-	20	20	-	-	1	1	-
Daytime and nighttime temperatures	60	5	5	-	1	-	-	-
Cloud studies	-	10	10	-	-	1	1	-
Cloud temperatures associated with above	-	10	10	-	-	1	1	-
Surface wind velocities	-	60	60	-	-	1	1	-
Multispectral imaging of the surface of Mars	60	180	180	90	1	1	1	1
Distribution of water	-	20	20	-	-	1	1	-
CO_2, A, SG_2, CH_4 sources	-	120	120	-	-	1	1	-
Identify elements	-	60	60	-	-	1	1	-
Surface material depth measurements	15	10	10	-	1	1	1	-

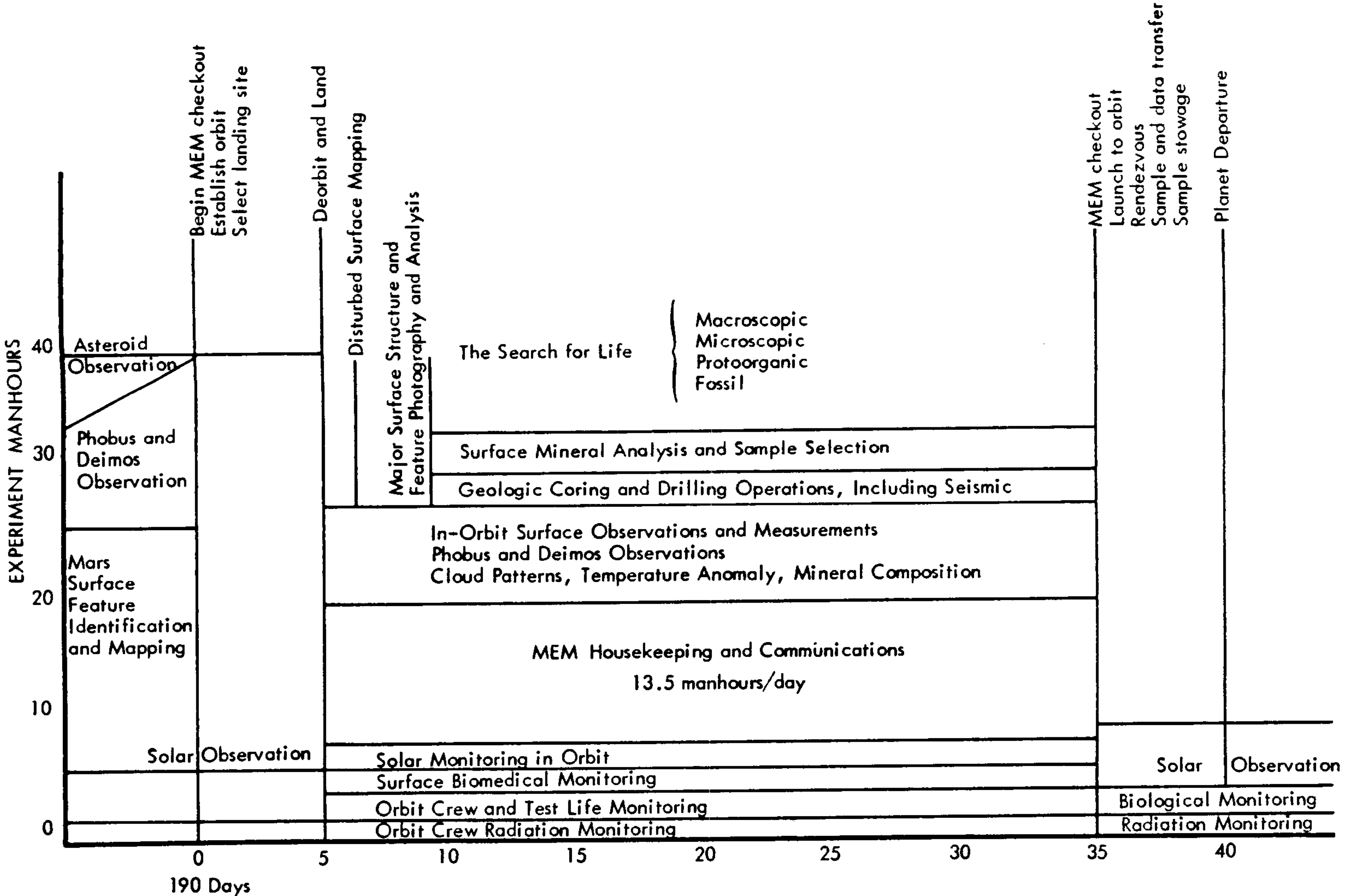

Figure 7-6: 40-DAY STAY TIME — MARS SURFACE AND ORBIT

Table 7-10: VENUS ORBITER EXPERIMENTS

Measurements	Elapsed Time Required in Orbit (min/day)				Number of Persons Required in Orbit			
	1-5	5-20	20-35	35-40	1-5	5-20	20-35	35-40
Incident, reflected and radiated energy	240	10	10	40	2	2	2	2
Rotational parameters	20	60	-	-	1	1	-	-
Figure of the planet	-	-	180	-	-	-	1	-
RF transmission	20	10	10	10	1	1	1	1
Solar radiation	60	60	60	180	2	2	2	2
Nuclear studies	40	10	10	10	6	6	6	6
Zodiacal light	-	30	30	30	-	1	1	1
Atmospheric parameters	240	120	120	-	2	3	3	-
Cloud parameters	180	180	180	200	2	2	2	2
Surface observation	60	60	60	90	1	1	1	2
Radar imaging	240	60	60	60	2	2	2	2
Surface material	60	60	60	60	2	2	2	2
Wind velocities and dust content	-	60	60	-	-	1	1	-
Temperature	-	10	10	10	-	1	1	1
Protoorganic molecules	-	120	120	-	-	1	1	-
Life characteristics	20	10	10	20	2	2	2	2
Earthlike environments	-	30	60	60	-	3	3	3
Magnetic fields	15	10	10	-	1	1	1	-

Table 7-11: MARS SURFACE PROGRAM--LIFE

Experiments--Life	Repetitions or Area to be Covered
1. Analysis for CH_4, NH_3, H_2O, H_2, etc. (Protoorganic Molecules)	The atmosphere should be sampled four times, approximately five rock and soil samples of four analysis each. Total of 44 analyses. Approximately 4-6 hours required per analysis.
2. C^{14} Rate Determination	Soil samples and atmosphere of above. At least four atmosphere samples and 20 samples of soil or other C containing compounds. Two to four hours required per sample.
3. Chemical Composition (a) Rocks and sails (b) Carbon compounds (c) Minerals (d) In water	Forty rocks or soil samples. In any one area. Only 2-3 mineral in (8-12 analyses), solubles in liquid (4). 52-56 determinations. Depending on number of compounds; one to three hours per analysis.
4. Microscopic Soil Analysis and Fossil Search	If sediments are found about 20 samples. Sample preparation and analysis will take 4-6 hours.
5. Cultures of Soil Samples	Total of 20 samples in six cultures each. Determinations total 120. Cultures examined about 10 minutes during first hours decay to about 10 minutes per six hours. Culture preparation about one hour.
6. Exposure of Test Animals	Four test animals exposed to liquid steeped in soil samples using various extracts. Feed animals nutrient cultures. Gas compressed to normal tolerances of animals. Same as cultures.
7. Exposure of Test Plants	Earth plants grown in diverse soil samples. Water with extracts, gas compressed. Same as cultures.
8. Study of Mars Life Forms	To be determined.
9. Age Dating	Assume five ages available four datings each. Depends on sample but eight hours per sample should be adequate. Astronaut time is about 20 minutes per dating.
10. Radiation Dose Monitoring	Background count about 1/2 hour determination unless background is extremely low. Use pulse height analysis techniques. Spectrum of background. Rock samples. If background low. Monitoring not required unless solar flare predicted and observed. About 10 minutes per day.

Table 7-12: MARS SURFACE PROGRAM--GEOLOGY

Experiments--Geological	Repetitions or Area to be Covered
1. Chemical Analysis	Five rock and soil samples, four analysis each. Total of 40 analysis. Isotopic ratios. Depending on complexity of sample, about 1-3 hours per analysis.
2. Age Dating	Same number of samples as above. About 20 minutes per dating.
3. Heat Flow and Down Hole Temperature	Five holes--four about 2 km from spacecraft--holes to be three meters deep. One at spacecraft about 30 meters. Approximate.
4. Seismic Measurements and Gravitational Anomalies	Use same five holes as above after all other measurements are complete for active seismic studies. Time from first preparation of charges to final data about 1/2 hour per reading.
5. Background Radioactivity	Same as 10 of Life, Table 7-11.
6. Core Drilling and Logging	About 300 meter core to be taken. Samples of core to be used for 1, 2, 7, 8 and 10 if applicable. Hole to be used for 3 and 4 as well after density conductivity, porosity, etc. are completed. About 0.5 meter/hour.
7. Surface Material Transport Studies	Study of sediments. Wind and water velocity and flux. Final analysis on earth. Assume 10 min. examination per sample.
8. Magnetic Studies	About 20 rock samples from core to be studied. A minimum of 30 min. for sample preparation and analysis.
9. Micrometeorology	Emplace weather station. Two hour minimum for checkout.
10. Minerals Determination	Five rock samples of each type mineral. Any of the three sites should yield a minimum of two different minerals. Dependent on site area, a maximum of six different minerals. Use of X-ray diffractometer for one hour/sample (average of four minerals and five samples, i.e., 20 hours exclusive of surface search time).
11. Sample Selection	Based on one hour analysis per sample, i.e., 80 hours total sample selection time.

7.4 CREW SKILLS

7.4.1 SKILL RANGE DEFINITIONS

The analysis of crew skills has been based on the knowledge range previously defined. The projected knowledge for 1975 which is given in Section 4.0 may be used as indicative of the skills required.

A skill level of one is considered to be similar to that of an automated device or a competent technician under the direction of a scientist. In some fields, even the highly trained astronaut can be considered as in this category, in which data is acquired based on available instruments and programs.

A skill level of two can be considered equivalent to that of a well-trained person gathering significant data with highly specialized equipment. The astronauts of the Gemini program took photographs of selected geological areas. If the desired types of areas were described in general only, together with the camera capabilities and lighting conditions desired, a level of 2 is indicated. If preselected areas and times were specified then the skill level is considered to be 1.

A skill level of three is indicated when an experiment program is modified to obtain specific data in one area for the purpose of verifying or negating a theory. In other words, a phenomenon was recognized and correlated with a basic knowledge of the underlying principles involved.

A skill level of four is indicated if a higher quality of data in several fields are required and the means of implementing the acquisition are recognized whether the instrument is available or not. This level requires a scientist well versed in theory, in experimentation and in analysis. Usually a team of experts is required to meet this level of effort and skill.

Table 7-13 presents the crew skill levels assigned for each of the 49 classes of observations and measurements.

7.4.2 SKILL AREAS

The following skill areas are based on the instrument techniques and data analysis required in each of the 49 data classes. It should be emphasized that the detection of life in the four classes requires a skill level of one only. For the initial missions, this level must be higher, however, because of the back contamination dangers. In addition the health of the crew will also require a higher skill level. This has been assigned a skill level of three and is equivalent to that of a well-trained general medical practitioner.

The skill areas are summarized in Table 7-14:

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Table 7-13:A SKILL LEVELS

	Planetology																Modifying Forces																Composition							Environment									Life				
	Orbital Parameters	Rotational Parameters	Figure of Planet	Moments of Inertia	Gravitational Field	Magnetic Field	Structural Features	Thermal Budget	Physical Properties	Seismicity	Physical Features	Isotope Ratios	Mineralization	Age	Atmosphere	Satellites	Summary	Solar Radiation	Meteoroid Impacts	Isostatic Forces	Seismic Activity	Diastrophism	Volcanic Activity	Surface Winds	Temperature Changes	Chemical Reactions	Life	Phase Changes	Gravity	Hydraulic Action	Glacier Action	Nuclear Reactions	Summary	Charged Particles	Atomic Elements	Molecular Elements	Minerals	Chemicals	Isotopes	Summary	Diurnal	Seasonal	Latitude	Magnetic Field	Micrometeorology	Meteoroid	Radioactive Decay	Solar Radiation	Summary	Macroscopic	Microscopic	Protoorganic	Fossil	Summary
Skill Level Required (Mars)	4	4	3	3	4	3	2	3	2	1	4	1	1	1	3	2		3	2	3	2	2	2	2	2	2	2	2	3	2	3	2		3	2	2	2	2	1		4	4	4	2	2	3	2	2		2	1	1	1	
Skill Level Required(Venus)	4	3	1	1	4	2	2	3	2	1	2	1	1	1	2	1		3	1	1	1	1	2	2	2	1	1	1	1	1	1	2		3	2	2	1	2	1		1	1	1	2	1	1	2	2		1	1	2	1	

TABLE 7-13: A
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FOLDOUT FRAME

FOLDOUT FRAME

Table 7-14: SKILL AREAS

Skill Area	Skill Level Mars	Venus
Animal Physiology	4	1
Astrophysics	4	4
Biological Monitoring	3	3
Computer Programming	2	2
Electromagnetic Radiation	2	2
Geomorphology	3	1
Geophysics	3	1
Infrared Imaging	2	2
Interferometry	1	1
Mapping (Cartography)	3	3
Medical Applications (Crew)	3	3
Meteoroid Analysis	3	1
Meteorology	2	2
Microbiology	3	1
Nuclear Physics	3	3
Orbital Mechanics	4	4
Photo Interpretation	4	2
Physical Chemistry	3	1
Physical Optics	3	3
Planet Physiology	4	1
Radar Imaging	2	2
Radar Operation and Maintenance	1	1
Radiometry	1	1
Solar Physics	3	3
Spectroscopy	3	3
Statistical Applications	2	2
Thermal Measurements	3	3

8.0 TECHNOLOGY IMPLICATIONS

This section summarizes important technology requirements that were identified in the course of the study of the scientific mission.

8.1 BACK CONTAMINATION

The complete safety of all plant and animal life on Earth as well as that on another planet must be assured. This requires that the baseline system for testing all forms of life be selected not only for its mutability in zero "g," but also for its benign effect on the life of a planet--once the test system is again established in a gravitational field. The mouse has been selected as a representative mammal. But if the mouse is going to be used as a biologic system for testing for contaminating effects of extraterrestrial samples, then its normal physiological and immunological responses to disease must be established for the space environment.

1) Does the new environment select for any genetic change?
2) Is the reproductive capacity altered--is the gestation period changed?
3) Is the normal life expectancy of the mouse altered?
4) Is the mouse able to elicit the same immune responses as on Earth?
5) Will a change in environment render the mouse "immune" to normally infectious organisms?
6) Or will the change in environment encourage infection in the mouse after exposure to normally benign microorganisms?

These questions could be answered by maintaining a mouse colony in Earth orbit and observing their biological patterns of reproduction, etc. Test groups also would be challenged with microorganisms that are: (a) normally nonpathogenic, (b) pathogenic or (c) pathogenic for animals other than mice. It may also be feasible to attempt to change the immunity of the mouse by administering drugs or chemicals and then challenging it with microorganisms.

If the space environment, alone or coupled with chemical suppressors, can be shown to encourage infection in the mouse from normally benign microorganisms, then this will establish more confidence in the use of the mouse as a test system for back contamination.

A research program such as the one outlined above would enable better interpretation of data resulting from exposure of animal life to extraterrestrial environments.

A similar program should be initiated to establish similar relationships for the plant kingdom. Cereals and yeasts are recommended as the test systems.

8.2 EXPERIMENT DEVELOPMENT

Since equipment developed in a 1-"g" environment for operation in zero "g" may require modification, or at least recalibration, final development testing must be performed in Earth orbit. In addition, field testing usually reveals weaknesses in design that are not apparent in the development period. In particular the following must be performed in Earth orbit:

1) Preliminary observations in the UV and millimeter portions of the electromagnetic spectrum, using spectrophotometers, photometers, polarizers and radiometers designed for the mission.
2) Assessment of the performance of both the hardware and man in making the decisions and the measurements and observations implied by the objectives of the mission.
3) Training of the astronaut in the operation of equipment using the established procedures but permitting modification of the training regime or procedure where necessary.
4) Using the spacecraft computer and the data obtained from probes or occultation devices to check out the concept of selecting a landing site within the footprint of the Mars Excursion Module and the soft landers to be developed for this mission.
5) Establishing the figure of the Earth from in-orbit data.
6) Verifying the validity of the measurements and observations established as achievable from in-orbit such as the operation of radar to obtain surface depth data, and operation of other equipment mounted on scan platforms (from an automated program established in orbit).
7) Establishing the maintenance and checkout philosophy for the various equipments.
8) Verifying the reliability predictions for the various designs.
9) Determining the crew skills required.

8.3 PROCEDURE DEVELOPMENT

Operation of both man and equipment in the space environment and in the Earth surface environment are sufficiently different to require that all procedures involving the measurements and observations of an interplanetary mission be established in Earth orbit. These procedures can only be confirmed with the final design of the hardware, and with men operating the equipment in space to gain experience in its operation. Such an approach is needed to establish the use of the equipment and the step-by-step procedure to be followed during:

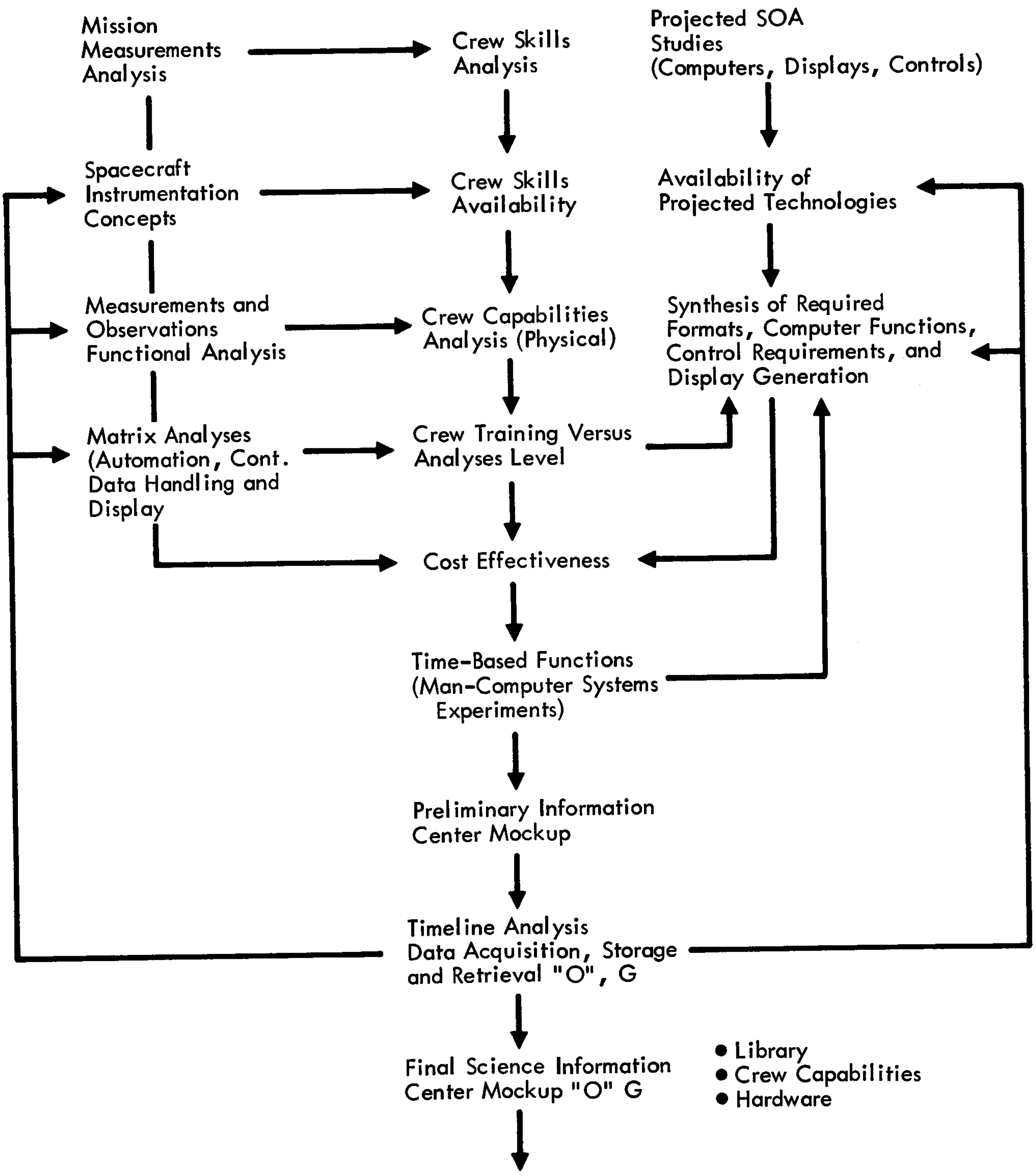
1) Equipment assembly after leaving Earth orbit;
2) Checkout and calibration prior to use in orbit or transfer between the spacecraft;
3) Datum point selection from display formats established during mockup of the science center;

4) Verification of spacecraft attitude and control prior to the use of the photosystem;
5) Scan platform operation for all equipment so mounted;
6) Data selection for science center storage or for transmission to Earth;
7) Equipment stowage or disposal, if not tagged for Earth re-entry;
8) Computer programming or reprogramming, should the experiment sequence warrant it;
9) Display interpretation and control for data acquisition such as atmosphere circulation;
10) Crew monitoring to establish techniques and monitoring consistency;
11) Test life colony monitoring and experimentation for back-contamination control;
12) Data and sample transfer from Mars Excursion Module to stowage in the spacecraft.

8.4 SCIENCE INFORMATION CENTER HARDWARE DEVELOPMENT

During the course of the study a requirement for specific tools to support the acquisition of scientific data became apparent. The mass of data required for the complete understanding of a planet and its life imposed three distinctly separate yet related requirements on the data handling system whether for data acquisition or for its disposal. These three needs are concerned with the display of information connected with selection of data, whether the initial desire was to collect additional data such as that associated with the measurements and the observations, or to store the data for future analysis or to transmit the data back to Earth. The technology implications are summarized below:

- A library of information on the planets and in the pertinent fields should be collected and formats determined which will permit easy assimilation, storage or display.
- To integrate equipment capabilities and the procedures for their operation, the astronaut must have available methodologies which permit him to organize the collection and storage of data, either for future analysis or for transmission to Earth.
- A data transmission system should be developed which will permit the transmission of high-resolution, high-color-contrast-range images. To dispose of information in an expedient manner and to reduce the amount of data recording media required to support a mission to the planets, data must be transmitted to Earth almost as rapidly as it is acquired.
- A mockup should be initiated which will permit storage or retrieval of information after high-resolution display. Figure 8-1 indicates the complexity of this step. To select targets or other data or samples, the astronaut must have readily available rapidly assimilated data which will permit him to make decisions for the acquisition of



Permits the rapid evaluation, selection and integration and disposal of scientific information at critical points during the mission.

Table 8-1: SCIENCE INFORMATION MOCKUP

all available information from a target or observable. To evaluate data he must not only recognize the implication of unique information, but he must be able to program a computer to make the pattern associations required for the evaluation and subsequent disposal.

8.5 PLANET SURFACE HARDWARE DEVELOPMENT

Time restrictions on surface operations have imposed requirements which if met could materially improve the acquisition of meaningful representative samples from the site selected. A transportation system should be developed which will permit the rapid transportation of two astronauts over distances on the order of hundreds of miles over the surface of the planet. This requirement is a result of the diversity of surface information required as well as the magnitude of the geological structures to be surveyed. Another need is for data from below the surface to depths of thousands of feet if not tens of miles. Superficial information from the surface will not permit a determination of the origin and evolution of a planet. A third need is for a spacesuit which will permit surface operations in excess of 4 hours on the surface. This may be met in part by the surface transportation system.

- A subsurface sampling concept should be explored, based on requirements to determine the structure of a planet and the composition of the subsurface material in terms of its mineral content, chemical composition and isotope ratios. The device can be based on the use of a laser beam to cut a cylindrical core to depths far exceeding any similar holes presently drilled into the Earth's surface. A laser beam is promising because it may permit the drilling of holes as well as their casing to prevent the escape of liquids or gases from the interior of the planet. Such a device should be considered for the exploration of the Earth's crust as well. A second concept may be the application of ultrasonics to pulverize planet materials and permit their removal and collection in an ordered fashion. This device may be useful as long as the drilled material remains dry. The two concepts should be evaluated on the lunar surface since it approximates that of Mars more closely than that of Earth.
- Adaptability of the MOLAB or other lunar surface transportation system should be evaluated in relation to the needs of the planetary exploration program.
- Requirements should be developed for surface transportation on the planet Mars. The system should permit the transport of equipment and easy access to the surface for sample collection, terrain observation and automated data station emplacement.
- A spacesuit should be developed which would permit the operation of hardware in a hostile environment for periods up to 10 hours or longer. The adaptability of prosthetic limb advances to the spacesuit or the development of different experiment hardware control mechanisms to the sensors are suggested as alternates.

8.6 EXPERIMENT HARDWARE PROCEDURES DEVELOPMENT

The efficient collection of scientific data requires that the equipment operator understand the limitations of his hardware and the time required for its operation. This information is also required to establish a timeline for assessing the impact of the synergistic space environment in the astronaut. It is recommended that procedures be developed for a zero-g environment in the following areas to ensure the full utilization of the equipment and manpower of both the spacecraft and the MEM:

- Operation of the orbiting experiment equipment in conjunction with the science information center (Section 2.4.4.1).
- The launch of hard landers, soft landers and orbiters into predetermined trajectories to verify that their objectives can be met.
- The performance of biological experiments to establish essential techniques and limitations to ensure the fulfillment of the back contamination objectives as well as the analysis of such biological data as may be necessary to establish a standard test colony.
- The selection of data from in-orbit with the broad guidelines leading to its disposal, storage or transmission.
- The training of astronauts in spacesuits in the acquisition of samples which are representative of the age and geological information of the landing site as well as of its biota with the surface hardware.

APPENDIX A

PROPOSED SPACE PROGRAMS

The following programs have been discussed in the past as possible during the time period of interest to the IMISCD study. The information which they might obtain has proven useful in the projections of the state of knowledge.

1.0 LARGE (OUT-OF-ECLIPTIC) SOLAR PROBE

Mission Objectives:

1) Sun spot studies at 0.2 AU and up to 35° latitude--temperature, magnetic fields--zeeman effect, Sun spot polarity, three-dimensional pictures.
2) Photosphere studies including granule studies (rice grain structures), temperature, electric, and magnetic fields.
3) Reversing layer studies--spectroscopy (infrared and ultraviolet).
4) Chromosphere studies (thickness at various latitudes).
5) Corona studies: ionization and excitation of coronal atoms; support and heating; electron density, proton and electron evaporation kinetic temperature.
6) Dust cloud measurements (zodiacal lights).
7) Solar prominence measurements (flares, tornados, quiescent, eruptive).
8) Gravitational constant evaluation.
9) Cosmic rays, X-rays, and γ-rays.
10) Cosmic particle measurements (iron nuclei).
11) Interplanetary space gas detection.
12) Meteor and micrometeor particle measurements.
13) Solar and galactic cosmic radiation and solar plasma measurements.

Payload Description:

1) Sensors: particle and field counters, spectrometers, α and X-ray detectors, magnetometers, spectroheliographs, cosmic ray sensors, ion chambers, cameras.
2) Weight requirements:

Scientific Instruments and Data Handling Gear	5,000 lb
Power Supply	500 lb
Propulsion Systems	1,000 lb
Total	6,500 lb

2.0 MULTI-PLANET SOLAR PROBE

Mission Objectives:

1) Venus Swingby
   a) Photograph surface
   b) Determine atmosphere and surface temperatures, pressure and composition
2) Soft Land Probe on Mercury
   a) Photograph surface
   b) Measure physical properties of surface and atmosphere-temperature, density, pressure, composition
   c) Radiation, magnetic, and electric field measurements
3) Flyby Sun to within 0.2 A.U.
   a) Measure cosmic rays, X-rays, γ-ray enroute
   b) Infrared and ultraviolet spectroscopy
   c) Zeeman effect in sun spots
   d) Temperature measurements of sun spots, granules, chromosphere, and corona
   e) Particle and field measurements (corona studies)
   f) Measurement of dust cloud (zodiacal lights)
   g) Solar prominence measurements (flares, tornados, quiescent, eruptive)
   h) Sun spot polarity study
   i) Gravitational constant measurements
   j) Measurements of meteor and micrometeor particles
   k) Reversing layer studies (Franhaufer lines)--optical spectroscopy
   l) Solar and galactic cosmic radiation and solar plasma measurements

Payload Description:

1) Sensors: TV cameras, magnetometers, spectrometers, counters ion chambers, electostatic sensors.
2) Weight Requirements:

Scientific Instruments and Data Handling	12,000 lb
Power Supply	1,000 lb
Propulsion System	4,000 lb
Total	17,000 lb

3.0 VENUS SOFT LANDER

Mission Objectives:

1) Photograph in infrared and visible light for topography studies during approach.
2) Measure physical properties of surface and atmosphere--pressure, temperature, density (mass), and chemical composition.
3) Life detection.
4) Measure period of rotation on axis.
5) Radioactivity measurements.
6) Infrared and ultraviolet spectroscopy.
7) Radiation belts and magnetic fields (on planet and surrounding space).
8) Corona (sun) gas detection.
9) Analyze for radio lead, radio carbon and helium (solar system age).
10) Gravity measurements.
11) Meteors and micrometeor particle measurements.

Payload Description:

1) Sensors: TV camera (vidicon) infrared and visible light, soil analysis instruments, counters, magnetometers, gravimeters, spectrometers, life detection instruments.
2) Weight Requirements:

Scientific Instruments and Data Handling Gear	6,000 lb
Power Supply	1,000 lb
Propulsion Systems	80,000 lb
Total	87,000 lb

4.0 MARS SOFT LANDER

Mission Objectives:

1) Photograph surface, moons (deimos and phobos) enroute.
2) Soft land on Mars.
3) Measure physical properties of surface and atmosphere: temperature pressure, density (mass), and chemical composition.
4) Life detection.
5) Radioactivity measurements.
6) Radiation belts and magnetic fields measurements (on planet and surrounding space).
7) Infrared and ultraviolet spectroscopy.
8) Extreme outer corona (sun) gas detection (interplanetary gases).
9) Analyze for radio lead radio carbon and helium (solar system age).
10) Gravity measurements.
11) Meteors and micrometeor particle measurements.

Payload Description:

1) Sensors: TV cameras (vidicon), soil analysis instruments, counters, magnetometers, gravimeters, spectrometers.
2) Weight Required:

Scientific Instruments and Data Handling Gear	6,000 lb
Power Supply	1,000 lb
Propulsion System	72,000 lb
Total	79,000 lb

5.0 CERES SOFT LANDER

Mission Objectives:

1) Photograph Ceres and if possible other asteroids in route.
2) Soft land on Ceres.
3) Measure physical properties of surface temperature, mass, chemical composition - determine origin of asteroids.
4) Analyze for radio carbon radio lead and helium (age of solar system).
5) Radioactivity measurements.
6) Test for magnetic fields on surface (iron detection).
7) Radiation measurements and magnetic field measurement in asteroid belt.
8) Meteor and micrometeor particle measurements.
9) Gravity measurements.

Payload Description:

1) Sensors: TV camera, soil analysis instruments, counters, magnetometers, gravimeters, spectrometers.
2) Weight Required:

Scientific Instruments and Data Handling Gear	6,000 lb
Power Supply	300 lb
Propulsion System	26,000 lb
Total	32,300 lb

6.0 JUPITER FLYBY PROBE

Mission Objectives:

1) Photograph Jupiter, satellites of Jupiter (Ganymede), and important asteroids enroute.
2) Measure physical properties of Jupiter's atmosphere--pressure, temperature, density, altitude, (also chemical composition).
3) Measure radiation (belts) and magnetic fields.
4) Measure natural radiowaves (red spot).
5) Infrared and ultraviolet spectroscopy.
6) Measure meteor and micrometeor particles in asteroid belt and at Jupiter.
7) Interplanetary space gas detection and analysis.
8) Mass evaluation (gravitational constant).

Payload Description:

1) Sensors: TV cameras, radiation detectors, magnetometers, counters, spectrometers.
2) Weight Required:

Scientific Instruments and Data Handling Gear	6,000 lb
Power Supply	1,000 lb
Propulsion System	1,000 lb
Total	8,000 lb

7.0 JUPITER MOON NO. 7 SOFT LANDER

Mission Objectives:

1) Photograph moon no. 7 surface, Jupiter, and asteroids enroute.
2) Measure physical properties of surface and atmosphere: temperature, density, pressure, (chemical composition).
3) Measure radiation belts and magnetic fields (Jupiter and moon).
4) Measure natural radio waves on Jupiter (red spot).
5) Infrared and ultraviolet spectroscopy (Jupiter and Ganymede).
6) Measure meteor and micrometeor particles in asteroid belt and at Jupiter moon.
7) Interplanetary space gas detection.
8) Test for radioactivity.
9) Analyze for radiocarbon, radiolead, and helium (age of solar system).
10) Gravity measurements.

Payload Description:

1) Sensors: TV cameras, soil analysis instruments, counters magnetometers gravimeters, spectrometers.
2) Weight Requirements:

Scientific Instruments and Data Handling Gear	5,000 lb
Power Supply	1,000 lb
Propulsion System	35,000 lb
Total	41,000 lb

8.0 SATURN FLYBY PROBE

Mission Objectives:

1) Photograph Saturn, rings of Saturn, Titan (satellite) enroute, asteroids enroute, (Jupiter on route if Jupiter swingby is used).
2) Measure physical properties of Saturn's rings and atmosphere pressure, density, temperature, chemical composition.
3) Measure radiation belts and magnetic fields.
4) Infrared and ultraviolet spectroscopy.
5) Test for natural radiowaves.
6) Measure meteor and micrometeor particles in asteroid belt and at Saturn (especially at Saturn's rings).
7) Interplanetary space gas detection.
8) Mass evaluation (gravitational constant).

Payload Description:

1) Sensors: TV cameras, radiation detectors, magnetometers, counters, spectrometers.
2) Weight Required:

Scientific Instruments and Data Handling Gear	6,000 lb
Power Supply	1,000 lb
Propulsion System	1,000 lb
Total	8,000 lb

9.0 TITAN SOFT LANDER

Mission Objectives:

1) Photograph Titan surface, Saturn, Saturn's ring, asteroids enroute, (Jupiter enroute if Jupiter swingby is used).
2) Measure physical properties of surface and atmosphere: temperature, density, pressure, and chemical composition.
3) Measure radiation belts and magnetic fields (Titan and Saturn).
4) Test for natural radiowaves on Saturn.
5) Infrared and ultraviolet spectroscopy (Saturn and Titan).
6) Interplanetary space gas detections.
7) Measure meteor and micrometeor particles in asteroid belt and at Titan.
8) Test for radioactivity.
9) Analyze for radiocarbon, radiolead, and helium (age of solar system).
10) Gravity measurements.

Payload Description:

1) Sensors: TV cameras, soil analysis instruments, counters, magnetometers, gravimeters, spectrometers.
2) Weight Requirement:

Scientific Instruments and Data Handling Gear	5,000 lb
Power Supply	1,000 lb
Propulsion System	34,000 lb
Total	40,000 lb

10.0 COMET RENDEZVOUS (MULTI-PROBE)

Mission Objectives:

1) Comet rendezvous ("parallel orbit" for long duration).
2) Spectroscopy in infrared, visible, and ultraviolet light, for studies of the nucleus, halo, coma, and tail.
3) Measure speed of receding expelled particles.
4) Measure mass of nucleus.
5) Measure temperatures of nucleus, halo, coma, and tail.
6) Measure fields (electric, magnetic, radiation) associated with plasmas produced.
7) Measure solar winds.
8) Measure radiation pressure of Sun.
9) Count particles produced.
10) Measure size of particles produced.

Payload Description:

1) Sensors: spectroscopes, counters, magnetometers.
2) Weight Requirements:

Scientific Instruments and Data Handling Gear	9,000 lb
Power Supply	3,000 lb
Propulsion System	3,000 lb
Total	15,000 lb

11.0 PLANETARY EXPLORER PROGRAM

The following instruments are being considered for the Explorer orbiter: 1) infrared scanner, 2) camera, 3) infrared spectrometer, 4) ultraviolet spectrometer, 5) subsatellite magnetometer, 6) ionosphere sounder, 7) dual frequency beacon, 8) plasma probe, 9) trapped radiation detector, 10) cosmis ray detector, 11) gamma ray detector, 12) micrometeoroid detector, 13) ion chamber instrument, 14) radio frequency noise detector, and 15) massive meteor detector.

These will obtain the following information about Mars:

1) The presence of both water vapor and carbon dioxide will be confirmed and their relative vapor pressures determined.
2) A thermal heat map with a resolution of 1 to 2 kilometers will be available covering about 75 percent of the planet.
3) Maps covering the same 75 percent of the planet will be available with a resolution of 50 meters. Additional maps of ten prospective landing sites will be available with a resolution of 1 meter.
4) The magnitude of the weak magnetic field will have been established and the interaction of the planet with the cosmic and solar magnetic field will have verified theories proposed for the Earth and the moon.
5) The meteoritic environment has been established as associated with the meteor belts of Jupiter. These meteors interact with the Martian atmosphere to produce persistent ion trails which have been disclosed by the ionospheric sounder and the other charged particle detectors.
6) The presence of radio frequencies, as yet unexplained but believed associated with the meteor swarms, will have been established.
7) The gamma ray background of the planet falls in the noise level of the cosmic ray background.
8) The major constituents of the planet's atmosphere have been established with the total pressure. The mechanism of the atmospheric circulation still requires explanation and further data.
9) The temperature of the atmosphere will be established and the conditions of cloud formation at least partially understood.

The above instruments will obtain the following information about Venus:

1) The upper air density will be established and the traces of atomic oxygen, carbon monoxide, atomic nitrogen as well as the halogen and flourocarbons will be established.
2) Extensive cloud coverage will be established with large quantities of dust.
3) Heat maps will show the presence of hot spots.
4) The ionosphere will be detected.

5) The meteoroid environment will be established.

6) Extensive radio noise will be discovered.

7) The interaction of the interplanetary magnetic fields with the planet will be established.

8) An anomalous radioactive background will be discovered.

Information is still lacking about the instruments assigned to the Mars lander but the primary emphasis will be on the detection of life. It is assumed that a weather station will be a part of the lander. This station will also obtain surface soil temperatures as well as soil bearing strength data. It is doubtful if life will have been proven as present or not present but at least traces of molecular activity will have been discovered on Mars.

At the present time balloon probes are being discussed in the exploration of Venus.

APPENDIX B
THE MANNED EXPERIMENT PROGRAM

The following descriptions of the various phases of the experiment program fall into two major categories. The first describes the program as it progresses in time while the second discusses the program in terms of the decisions necessary in planetology, environment, life, etc. The descriptions are meant to be operationally oriented to illustrate the role of man and not necessarily time sequenced or procedurally oriented. In addition, the discussion is limited to the Mars Opposition 1986 program.

1.0 OUTBOUND IN-TRANSIT OBSERVATIONS AND MEASUREMENTS

1.1 THE FIRST FIVE DAYS

This is the period just prior to the first midcourse maneuver and hence is reserved for emplacing and assembling experiment hardware that cannot be harmed during the midcourse maneuver itself. Neither the danger to the crew from loose equipment nor the possible damage to equipment has been assessed if the necessary precautions have not been taken. In any event it will be assumed that this period of time is devoted to the mechanical and electrical assembly of hardware that does not endanger the mission.

The Earth's reflected and scattered light as well as the radiofrequencies generated on Earth contribute to a high noise background, hence there is no advantage to the conduct of experiments other than the trend monitoring imposed by medical considerations of the crew and the test life.

1.2 PRIOR TO THE SECOND MIDCOURSE MANEUVER

During this period the spacecraft will be on the order of a million miles and more distant from the Earth, providing excellant opportunities to view Earth and to check the operation of practically all of the basic experiment equipment aboard the spacecraft. The use of the science information center to aid in the determination of features on the moon's surface and that of Earth can be checked. Communication with Earth or with a moon colony, if any, should permit a verification of the basic experiment approach. The recognition of lunar features provide excellent training for the recognition of Martian features as well as a determination of the environment and composition. These measurements and observations also serve as the required operational checkout of the experiment procedures, hardware and crew training levels.

1.3 BETWEEN THE SECOND AND THIRD MIDCOURSE MANEUVERS (CRUISE MODE)

The initial portions of cruise are primarily devoted to the solar system observations. Because of their proximity, Venus and Mercury will receive primary emphasis. High resolution observations of the Venus cloud cover should reveal the nature of the cloud cover. Interferometric observations should permit a determination of the gross isotope distributions of the cloud materials. These lines are observable because the chemicals of the atmosphere are ionized by solar radiation. Similarly the density of the Mercurian atmosphere and its constituents can be observed in addition to its shape and temperature variations.

The crew will devote about 6-man/hours per day to the observations of the Sun not only to supplement the solar flare monitors but also to obtain radiofrequency surveys which cannot be made in Earth orbit. Other single line solar measurements become possible because of the greater stability possible with the cruising spacecraft. A study of these faint lines is essential to a determination of the secondary processes occurring within the Sun.

Allied to the solar observations are those essential to a determination of the interplanetary magnetic field. This field is predominantly that associated with the Sun but galactic fields may also be detectable. The crew member responsible for determining the structure of the "frozen" magnetic field of the solar wind will also be responsible for the acquisition and reduction of the data to be obtained while tracking and plotting the distribution of the ions generated by the ion probes. The distortion of the interplanetary magnetic field produced by the spacecraft must be determined prior to the launch of the ion producing device. Solar wind measurements complement the magnetic field measurements. The operator will verify the design of the detectors and the limit to which the faint lines of the artificially produced ions are discernible. He will verify the complete energy and mass ranges of the particle clouds. At the present, solar wind constituents are assumed to combine with the free electrons of outer space outside the orbit of Mars; but some recombination may be itiitiated if not completed prior to reaching that distance from the Sun.

As Mars is approached and the features of the planet become distinguishable the possible landing sites should be brought under observation for an evaluation of meeting as many of the scientific objectives of the mission as feasible. The planning map produced by the unmanned explorer should be oriented and the distortions if any introduced by that system recognized and their effects counteracted. This aspect of the mission is essential since the lighting conditions existed during the manned flight will undoubtedly be different from those under which the planning map was produced. In this instance the crew will evaluate each site in turn and communicate their findings to Earth. Evaluation will be in terms of the gross biological and geophysical characteristics of the site with respect to the planet estimated time of arrival and the feasible deorbit mechanics. The initial 10 sites will be reduced to a maximum of four during this period and the orbit inclination will be selected. It should permit the close observation of the site during the first 5 days after orbit insertion and permit the deorbit maneuver to be determined by the best choice. These observations will be conducted by the crew members with geophysical and biological training as well as the crew captain.

It is anticipated that extrasolar system observation opportunities will be enhanced in many spectral regions because of the subsequent reduction in background "noise" as well as the increased stability of the spacecraft possible during this portion of the mission. The astrophysicist will observe predesignated areas or objects to determine fineline emission characteristics not observable from Earth orbit.

1.4 AFTER THE THIRD MIDCOURSE MANEUVER

After the third midcourse maneuver the major portion of the available experiment time will be devoted to planning the orbital program. The impact of atmospheric conditions will be determined and the orbits of the two moons, Phobus and Deimos, will be established. The decision may be made at this time to release the probes designed to impact on their surfaces to obtain both photographs and other data.

Asteroids will be photographed as targets of opportunity. The largest of these have characteristics and properties resolvable with the spacecraft instrumentation. The classification of these observables into improvised categories is anticipated. Their shapes, albedos, spectral properties and their rotations are to be observed.

2.0 THE ORBITAL PROGRAM

The orbital program is divided into an orbit establishment and a surface program planning phase, an orbital observation and measurement phase, a surface program support phase and a rendezvous phase.

2.1 ORBIT ESTABLISHMENT AND SURFACE PROGRAM PLANNING

During this period the orbit altitude is established. A near-circular orbit is preferred as previously mentioned, and require close coordination among the senior crew leader and the geo-bio groups. Orbit inclination had been determined prior to the third midcourse maneuver. Selection of the final MEM landing site is a major consideration during this period. In the final analysis crew safety is the prime consideration but every effort should be made to land in an area which will be accessible to varied geological formations and biological potentials. Sites near craters, crevices, streams, etc., are preferred.

The crew will consider such factors as the type of cloud cover in the vicinity of the landing site and its "growth" or circulation; the time of deorbit for the MEM, the possible impact on the rendezvous and surface stay time duration.

At this time the surface support requirements should be planned. Planning should include the type of supporting spectral observations, weather information, magnetic field variations, solar flare data, science information center data and analytical supporting techniques that may become essential as the program progresses.

2.2 ORBITAL OBSERVATION AND MEASUREMENT PHASE

This phase of the orbital program is restricted to the three crew members remaining with the spacecraft in orbit only one of which may be available at any one time for the orbital program. The other members of the crew are concerned with supporting the surface operations and the spacecraft housekeeping chores.

The orbital program is essentially a remote sensing program. Hence the basic skill required is one of multispectral analysis extending throughout the electromagnet spectrum of the data acquired by the basic spacecraft instrumentation. In addition, roughly 80,000 pictures will be taken of areas significantly different from the site selected. Any decisions that must be made will be made from the displays of the surface presented. These displays will require augmentation with information from the science center and hence will be in areas of surface features, surface material depth, cloud patterns, temperature and pressure relations on the surface and associated with the various features of the clouds. The diversity of the program planned requires that only that data which contributes to furthering an understanding of the phenomena which can be studied in detail should be analyzed in any depth during this part of the mission. This will require a depth of understanding of the intent of the total program and may restrict recording the various observable nuances.

The program outlined does not require that the entire surface should be investigated but only areas which will verify the salient features of planet origin and evolution. In particular older geological areas should be examined in detail for the location of the oldest geological formations. A specific age cannot be determined but the features and the structural details available can indicate relative aging and the processes involved if they are similar to those on Earth. Observations should be restricted to those bearing on the cosmic abundance of the elements and their isotopic ratios and the possibility of wide scale differentiation of the planet. Weathing processes should be identified if possible and the extent or distribution of the process should also be recorded through the selection of the images or spectra. Particular emphasis should be given to those structures which indicate layering or strata whether due to vulcanism or other surface transport of matter such as hydraulic or glacier action.

The two moons of Mars will be observed on a target of opportunity basis.

2.3 SURFACE SUPPORT PROGRAM

The surface program will require access to the information that has been stored in the Science Information Center because the three crew members of the surface group cannot be expected to retain all of the reference information that might be essential to the conduct of the surface experiments. Possible information required is the type of surrounding terrain to aid in the sampling process as well as the emplacement of the weather station. It is not the intent of the surface program to identify all of the elements present with the isotopes and their ratios. Present thought is that the crew should select samples on the basis of their statistical representation of the area features and structure with the detailed analysis to be made either in transit or by Earth scientists.

Other information that will be required is of a meterological nature and, of course, the major emphasis will be on wind velocities, possible precipitation, solar flare activity and cloud cover duration.

Since this crew member may be stationed in the science information center he may launch the probes to the moons and record significant information about these missions.

Only one large telescope has been included. Its use and that of the small pointing system as well must be determined as the program progresses. Other parts of the imaging system also have dual functions.

2.4 THE RENDEZVOUS PROGRAM

This portion of the program is essentially operational in nature. The discussion here is limited to the packaging and storage aspects of the mission.

About 900 pounds of samples are anticipated. They will have been divided into samples which bear on planet composition and structure as well as evidence on the existence of life. These latter samples should be stored in an area with an environment that duplicates that from which they were taken. Every precaution must be taken to keep them isolated from the environment of the spacecraft and potential contamination of it. Although life on Earth takes some time to adapt to a new environment it may well be that the adaptive mechanisms of extraterrestrial organisms can proceed at a faster pace. In addition, it is essential that only the life forms of the planet are studied. If life is as widely distributed on Mars as it is on Earth it may well be that even the geological samples will require isolation.

One function of the surface program has been to tag and allocate the various samples to the scientific disciplines. Those samples which do not indicate the presence of life can be divided into at least two groups, one for study during the interplanetary phases of the mission and one for return with the Earth module. This precaution forwards as much information as possible to prevent its loss should some mishap occur during the return leg of the mission.

Because the primary emphasis of the orbital mission was to study the planet remotely some of the MEM equipment such as microscopes may well have been duplicated and left on the surface. It may be that the crew will have returned some of this equipment for use either in the bioscience lab or in the geology lab because of its adaptability and anticipated usage during the in-transit phase. This equipment must be secured during this rendezvous phase. About 5 days have been allocated to complete stowage and sample transfer and packaging for Earth return or in-transit study.

3.0 THE SURFACE PROGRAM

This portion of the program cannot be detailed because it is site and environment dependent. However no matter what the site is, at least three different operations will be undertaken.

The first of these will consist of a close survey of the area for large life forms and other features. Most of the detailed planning for this program will be reviewed during this survey. It is suggested that no attempt be made to leave the MEM for at least a day because any mobile life form may have been frightened and second the exhaust gases of the descent stage should be permitted to disperse prior to sample collection and subsequent incorporation into the samples.

The second step of the program will require that a survey be made of the area affected by the MEM. The deep coring operation is to be initiated just as soon as practical.

The third step consists of sample selection and gross analysis for representativeness whether for life or for geological purposes. The seismic array should be laid out during this period. The time required to make the holes required will be dependent on the surface material characteristics and the decisions on depth and placement can only be made on the site. Depths ranging from 3 to 10 meters have been suggested. Samples should be divided and labeled as they are collected.

There are two reactions to the surface stay time anticipated. If the crew is restricted to movement by foot in a spacesuit and surface characteristics do not lend themselves to extensive core drilling operations then 30 days is too long. Spacesuit operations will restrict the study of life to that not destroyed and available in the vicinity. If sufficient mobility, say on the order of tens of kilometers, is permitted then 30 days may be adequate. The drilling and coring operations are automated in either case but in this instance a larger area can be sampled and photographed. Life forms can be studied for their life cycles and other characteristics and habitats recorded and measured.

If mobility on the order of hundreds of thousands of kilometers is available then 30 days will not be adequate. Hence mobility is a factor in stay time.

4.0 THE RETURN IN-TRANSIT MEASUREMENTS AND OBSERVATIONS

During this portion of the mission three widely separated areas constitute the scientific portion of the mission. The first will emphasize the observations required to reduce the dangers of back contamination, if this is necessary. As previously mentioned the range of adaptive mechanisms of most life varies as well as the rapidity with which the adaptation can take place. This imposes a unique requirement on the observation program. The biologist must study the life specimens to determine their adaptive characteristic ranges as well as their ability to adapt to the spacecraft environment. The test life system has been included to aid in this portion of the program. Information is to be transmitted as soon as it is available. A regular schedule is suggested on a daily basis.

The second emphasizes the analysis of samples whether for life composition or mineral structure. Again as much of this information should be transmitted to Earth as possible. All associated imaging and spectral information will be summarized with the specimen data and prepared for Earth return either in the EEM or with the communication system.

The third phase of the program is a repetition of that proposed for the outbound leg emphasizing observations of the outer planets and bodies in the early part of the in-transit program and the inner bodies on the later portions. The planets and bodies observed will be determined by the relative orbital distances and opportunities and will not be detailed here.

5.0 THE EXPERIMENT PROGRAM

The following sections present the general considerations that must be evaluated to study or detect the life of a planet and the planets origin and evolution. The general program emphasizes the categories devised for this study and the part a well-trained observer could play. The order of discussion is not to be construed as the order in which the general measurements are made since these will overlap to a considerable degree and will vary with opportunity. Each section stresses a definition initially, proceeds with a consideration of the mission phases in sequence and then is briefly summarized.

5.1 PLANETOLOGY

For the purposes of this study, planetology is defined as the study of the gross properties exhibited by a body of the solar system, including the Sun. The following planetary characteristics contributed to the development of the observations and measurements classes within this category. Each planet of the solar system has a unique position, shape, spin, moment of inertia, gravitational field, and thermal budget. It has gross physical properties such as mass, density, conductivity, etc., with a specific arrangement or structure and surface features. The chemical elements forming it may have unique isotopic ratios which may have been differentiated because of forces interacting for indeterminate periods of time commensurate with the age of the planet. Hence, mineralization, an atmosphere, its satellites, its gravitational and magnetic fields may be properties derived from the chemical composition, the mass, the thermal budget or the planets' passage near another body. If mineralization as a process is present or a rearrangement of the planet's structure is underway, seismism may also be a characteristic which should be fundamental to a planet.

5.1.1 IMPLICATIONS OF PLANETOLOGY

In summary form planetology deals with:

1) The formative processes of the solar system,

2) The period of formation,

3) The composition and structure of the forming constituents,

4) The physical laws responsible for the present outward characteristics,

5) The interrelation of the bodies of the solar system with each other, and

6) The relation of the physical and chemical composition of a planet to those on Earth.

5.1.2 THE PROGRAM

The program for a particular planet is based on measurements from three distinct observational vantage points. The first of these consists of those observations which must be made while approaching the planet in order to determine its environment, its shape, and its rotation. The second can be considered the surveying of the planet close at hand, as well as observing the interaction of the planet with its environment, i.e., in orbit about the planet. The third includes measurements required for age dating, sampling and ground truth data acquisition. The second phase will produce the planning map essential to the establishment of the shape of the planet and to the fixing of prominent features with respect to one another. In general, surface parameters will be measured or observed from orbit which may change from day to day, from season to season and from the equator to the poles.

The third part of the program will consist of landing on the surface to determine the localized interaction of the forces modifying the planet and in acquiring sufficient ground truth data to facilitate the orbital determination of composition, feature formation, structure and activity.

The key factors involving decisions by specialists are discussed in the following sections:

5.1.3 FEATURES AND PATTERNS

As the planet is approached, certain features will dominate the surface of the planet. In the case of Venus this undoubtedly will be the patterns of the clouds which will provide clues essential to understanding the circulation of the atmosphere and detecting the activity that may be taking place on the surface. The persistent fixed cloud structures may also be related to the surface features of the planet, such as high mountains or plain to plateau discontinuities. The type of cloud structure may well dictate the observational program. If there are no distinct features observable, orbiting radar mapping and the radio frequency probes will be released prior to the initiation of any other experiment program.

In the case of Mars the presence of the blue haze, white polar clouds, or equatorial yellow clouds will change the measurement order. If these are absent, undoubtedly the most significant features will be those of large craters. A program aimed at determining the presence of volcanic activity can then be initiated. If the craters are of meteoritic origin then the wall debris structure and appearance will be analyzed for clues of erosion or gradation mechanisms as well as internal structure of the planet. Should the clouds be present the program will be similar to that for Venus.

5.1.4 THE ENVIRONMENT

Because some of the modifying forces acting on a planet are undoubtedly due to the environment and the interaction of the environment with the planet, it is essential that measurements of the interplanetary magnetic field, cosmic dust, cosmic rays and total solar radiation be made during the terminal interplanetary phases of the planetary voyage. These will have been measured by almost every interplanetary probe preceding the manned mission. It is assumed that they are like the surface temperature of the planet which will vary within a range still to be determined.

5.1.5 THE PLANNING MAP

Initial unmanned mapping efforts were of necessity confined to black and white two-dimensional photography with some hint of color from a color wheel. It is doubtful, however, that an instrument will be devised to match the eye of the first human observer. For this reason it will be essential for a man to observe the possible landing sites prior to committing the MEM to a specific landing site even though selected sites had been thoroughly tested from a safety point of view. The planning map will be compared to the features and color patterns seen by the man. Probably several orbits will be required to review all of the data available. If the mission is to Mars and cloud cover persists, it may be that the entire landing mission will be canceled. Should the cloud cover persist radar mapping of the planet should be planned. Radar maps could then be correlated with the planning map and the cloud patterns observed.

5.1.6 SATELLITES

The orbital parameters of the satellites of a planet afford an opportunity to measure the moments of inertia of a planet. These moments of inertia provide additional insight into the planet's internal structure which in turn give evidence of internal composition and the variation of density with distance toward the center from the surface. The orbital parameters of the Martian moons - Phobos and Deimos - must be more firmly established. This too is an objective of the manned program because of the "target of opportunity" nature of these two moons.

One of the major mysteries of the solar system is the formation of the acquisition of the satellites. It is doubtful if the origin of the Earth's moon will have been determined by 1975 even though lunar samples will probably have been analyzed. Clues to the origin of these bodies may be obtained by the close investigation of the moons of Mars. It is conceivable that at least one of them could have been captured since present theories require the presence of a third body for a planet to capture a satellite. This does not explain the presence of the first. Differences in shape or structure between the two may be indicative of their origin. One of the major contributions made by man will be a decision to continue observation of one or both of these two satellites of Mars.

5.1.7 THE FIELDS

Both the gravitational field and the magnetic field may provide data about the composition and the internal structure of the planets. It may be established that neither Mars nor Venus will have magnetic fields of their own but the two planets certainly will have different permitivities and most certainly affect the interplanetary field differently. Once this difference is established, man can hasten the correlation of the difference to structural features or observational parameters. Once the correlation has been established it will be analysis by man that eventually establishes the sufficiency or the deficiency of the data acquired. In effect it will not necessarily be the absolute magnitude of the field that will be important but the variation, the manner of the variation and the correlation of the variation with other parameters of the planet that will provide the data essential to the establishment of the internal structure and composition of the planet.

5.1.8 THE ORBIT, THE PERIOD OF ROTATION, THE MOMENTS OF INERTIA AND THE FIGURE

It has been previously established that there is a disparity in the distribution of the orbital momentum and the rotational momentum within the solar system. One of the disparities is the lack of rotational inertia within the Sun. It is conceivable that this disparity will have been dispelled by the time of manned space flight since the rotation of the actual body of the Sun may be considerably faster than its atmosphere. The figure of a planet is a clue to its internal structure as well as an indication of tidal and centrifugal forces which may have existed. Coupling these data may clarify the evolutionary buildup of a planet. Man's contribution will be to check the data available and then to make observations that will correct the discrepancies. Discrepancies arise because of the differences observed in the radii of the planets as seen through the atmospheres of Earth and the planet. Computer aids may be essential.

5.1.9 SEISMICITY

The structural changes which a planet undergoes as it ages are only partially understood. Seismicity may be initiated by collisions with meteoroids or by phase changes induced by the interaction of the planets own gravitational field and its thermal budget. The patterns of the fractures and their association with either crater like structures or mountain-valley features will indicate possible causes. Of special interest will be the terminations or deviations of the fractures. Man's contribution will be to assure the photography of the complete pattern as well as the terminations of the fractures to aid in identifying the underlying structure of the planet.

5.1.10 ISOTOPE RATIOS

The isotopes of the gaseous constituents may be determinable in part from orbit. With existence of a hydrogen halo, the ratio of deuterium to tritium will indicate the degree of similarity to Earth processes. In addition the charged constituents of the other gases will provide answers to the isotope in ratios of these elements should they exist. These ratios may indicate in that the isotopic composition of the primordial mass may have changed with age and if the planets were formed over an extended period the isotopic ratios will provide the answer at least relative ages if not in absolute. Man will be able to determine the presence of isotopes and then will concentrate on those requiring specific attention if a sufficient disparity exists between that predicted by theory and that observed. An unmanned instrument could look at only those lines or bands for which it had been preprogrammed.

5.1.11 SUMMARY

Man, the selector, can choose the instrument appropriate to both the viewing conditions and the observational opportunities existing during his stay. He can select the features on the satellites and on the surface of the planet. The choice may be in terms of radiometric mapping, visual or spectrometric observations or photography and radar mapping. The choice may lie between the type of feature observed or a refinement of the spectrometric observations to be conducted. In any event, the integration process will be exemplified in the correlation of the data and equipment available with the data desired and viewing opportunities available. Decisions for more data or other observables will be made by man on the spot.

Decisions must be based on prior datum point knowledge, on equipment ranges, on intensity, polarization and emitted spectra and on an assessment of other perturbations. As an example, the impact of the presence of "haze", clouds, dust storms and shadows on the general target must be evaluated. An unmanned or automatic device would not be able to make such a decision. The surface reflection and its emissivity from an unknown is in general unpredictable.

5.2 MODIFYING FORCES

5.2.1 A DEFINITION

For the purpose of this study, all actions that have resulted in changes to the planet's composition, structure or figure are defined as modifying forces. These are summarized in Table B-1 with the modifications produced.

5.2.2 IMPLICATION OF MODIFYING FORCES

The physical and chemical compositions of all planets have been modified by the interaction of forces operating throughout the period of time since the planet's formation. Some of these forces appear to change only the physical appearance of the features present, such as life, meteoroid impacts, surface wind, gravity, diastrophism, glacier action, hydraulic action and isostatic forces when viewed casually but actually produce major redistributions of surface material internal structure as well as a readjustment of the planet shape itself. It is essential that the forces presently interacting on the planet are identified as to how long they have been present as well as when the present interplay was established. Most of the planet wide interactions are best established from orbit although reconstruction of the original shape and composition of the planet will only be established after the surface has been analyzed and dated at selected sites. In general, a man can detect these forces, analyze their impact and associate internal and external structural features with them even though the original state has been modified.

Table B-1: MODIFYING FORCES

Force	Interaction Period (yr)	Interaction Results on Surface Features
Phase Changes	$10^3 - 10^2$	Short term — usually a minor redistribution of material: earthquakes, lava flow, formation of blow holes, cloud formation changes.
	10	Medium term — usually a major change: buildup of ice at poles or in glaciers, change in shorelines, valley depths, mountain features, or course of rivers on plains.
	$10^3 - 10^5$	Long term — dramatic changes in relation of valleys to mountains and mouths of rivers or the appearance and disappearance of glaciers.
Temperature	10^3	Microstructural deformation or spallation. Cloud formation changes.
	10	Buildup at bases of cliffs tending to modify steepness.
	$10^3 - 10^5$	Major changes in precipitation and its collection. Cliff and protuberance structures completely modified.
Meteoroid Impacts	10^7	Crater formation size and composition dependent. Atmosphere composition changes. Ion changes.
	$10^6 - 10^8$	Major surface composition and structural changes dependent on rate and type.
Chemical Reactions	1	Major surface mineralization changes.
	$10^6 - 10^8$	Major mineral deposits, atmospheric redistribution and composition changes.
Nuclear Reactions	$10^6 - 10^8$	Changes in atmospheric composition, minerals, and isotope ratios. In large fluxes patterns of life are also affected.
Life	$10 - 10^3$	Intelligent life changes planet features.
	$10^3 - 10^6$	Plant life changes atmosphere, composition, and surface features. Adds to sediment buildup and soil formation.
Surface Wind	10^3	Minor redistribution of surface material. Major cloud redistribution. Cloud composition.
	1	Redistribution of surface material.
	$10^2 - 10^3$	Major redistribution of surface material.
	$10^5 - 10^6$	Major structural changes.

Table B-1: MODIFYING FORCES (Continued)

Force	Interaction Period (yr)	Interaction Results on Surface Features
Solar Radiation	10^2	Surface temperature changes. Ion formation changes.
	1	Surface chemical changes.
	$10^7 - 10^9$	Isotope ratio changes from the accumulation of hydrogen and helium and possible nuclear interaction.
Volcanic	$10^1 - 10^2$	Local feature buildup. Surface temperature changes.
	$1 - 10^2$	Major physiographic changes.
	$10^2 - 10^3$	Surface chemical changes. Atmospheric composition changes. Major physiographic changes.
Isostatic	$10^5 - 10^8$	Major continental uplifts or subsidence.
Diastrophism	$10^4 - 10^5$	Faulting and folding.
Seismic	10^4	Earthquakes are indicators of volcanic, isostatic, and tectonic forces. Changes noted above.
Gravitational	$10 - 10^3$	Major shoreline changes.
Tidal-H_2O	$10 - 10^3$	Major shoreline changes.
Atmos.	10^3	Changes in cloud structure and precipitation.
Planetary	$10^5 - 10^7$	Oblateness or eventual breakup.
Gravity — Planet Surface	10^5	Structural changes initiated by other forces such as winds, temperature, chemical, and hydraulic.
Glacier	$10^2 - 10^4$	Major factor in valley formation and surface deposit changes.
Hydraulic	$10^2 - 10^2$	Major factor in valley formation and river mouth delta changes. May cause collapse of surface due to undermining.

5.3 ENVIRONMENT

5.3.1 A DEFINITION

The environment of a planet is defined as the aggregate of all the external conditions and influences affecting a body in the solar system. This includes the gravitational fields of the system, the magnetic fields, cosmic ray intensities, the solar radiation and the interplanetary dust or meteoroid flux. Then because these are nonisotropic in nature and the interaction is not the same in all directions but is redistributed on the surface the environment must include seasonal effects, diurnal effects, latitude variations and micrometeorology.

5.3.2 THE IMPLICATIONS OF THE ENVIRONMENT

The environment is the interactions of all existing external modifying forces and their variable interfaces when acting on the planet as a whole. This implies that both the atmosphere and the surface of the planet are continuously modified by the environment. With modification of the surface such self-generating forces as depicted in Section 5.2 change the planet in toto.

5.3.3 THE PROGRAM

The environment of a planet is firmly established while in orbit. Initial measurements are undertaken during the in-transit phases of the mission. Final measurements are taken during the early phases of the return leg.

The key factors involving decisions by man are discussed in the following sections.

5.3.4 THE MAGNETOSPHERE

The magnetosphere is the interaction of the interplanetary magnetic field and that of the planet. A simplified interpretation of this interaction is illustrated in Figure B-1 which has been patterned after the graphic representation of the Earth's own interactions. The magnetospheres importance lies in its effectiveness as a shield against the solar wind. It is obvious that this pattern will vary with the strength of the solar wind and the strength of the Mars or Venus magnetic field. The weaker a planet's field the greater is the impact of the solar radiation with its possible deleterious effects on life. Venus and Mars may provide good intermediates between the extremes of the moon and of the Earth since their fields may lie somewhere between. Man's role will lie in a determination of the effectiveness of their magnetic fields at the present, possibly its existence in the past and in realizing when more data of the same kind only confuses the picture. At the present there is no effective technique for tracing its interactions throughout planetary history.

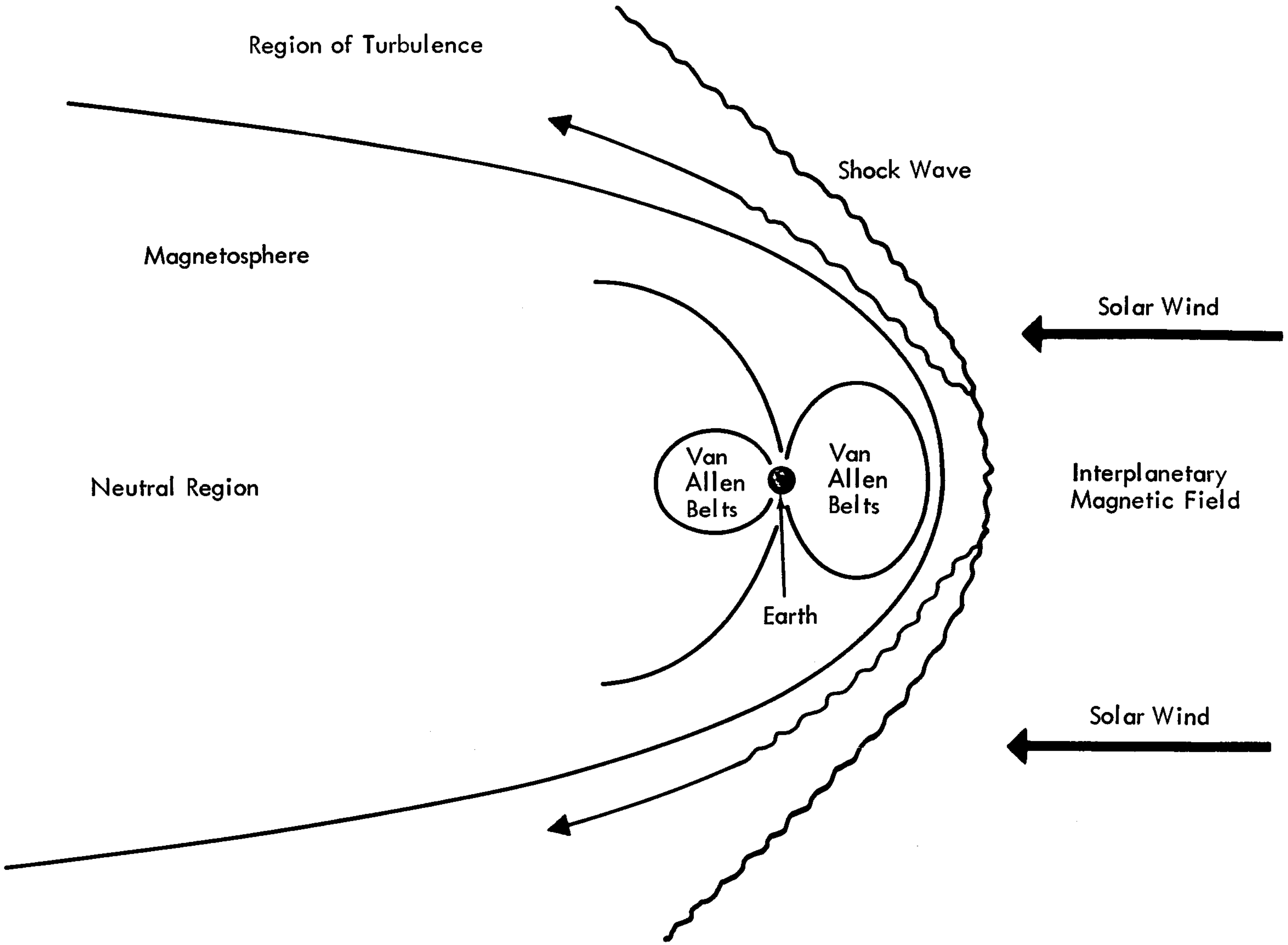


Figure B-1: THE MAGNETOSPHERE

5.3.5 METEOROIDS

If meteoroids originate in comets then their distribution between the Earth and the planet Mars should be approximately equal. In other words, Mars and the moon should show about the same distribution of meteor craters. A possible exception is the more rapid disappearance of the smaller craters from the surface of Mars because of its atmosphere. If meteors originate in the belts about Jupiter then the density of new larger craters on the Martian surface should be higher than on the moon. Man's role will be to select representative crater-pocked areas, if not individual craters, to permit an evaluation of the two theories. An unmanned spacecraft would, of necessity, photograph the surface indiscriminately. This would permit arriving at the same conclusion, but some other factor such as hue or magnetic field correlation would require the examination of a far greater number of surface photographs, if indeed this could be perceived in the data recorded. Even after several missions to a planet it may not have been possible to establish erosion rates on the various terrains because photography of an area may take place while modification is underway in an unrelated area.

5.3.6 DIURNAL, SEASONAL AND LATITUDE EFFECTS

In general these effects will be obtained through an analysis of the data recorded during the mission. Besides the analysis, man will select the data and establish the parameters which will indicate the degree, the rate and the magnitude.

5.3.7 MICROMETEOROLOGY

Because of the short duration of the mission, man can select the areas depicting the micrometeorological conditions existing without an undue quantity of data or the need for an extremely long mission. In effect, man will act as a programmed sensor which will respond to the observed conditions on the surface with the intent of gathering data to verify the effects of the environment on the planet. It is anticipated that with a man present all surface meteorological phenomena observable during the mission will be recorded. This could not be the case with an unmanned satellite not under the direct control of man because at this time, pattern recognition programming will not be advanced sufficiently for the device to recognize these cloud structural variations or to compensate for them with time, position, surface features, and seasons.

5.4 COMPOSITION

5.4.1 A DEFINITION

The composition of a planet has been defined as the constituents of the observable matter regardless of its stage. This leads to a breakdown which includes: 1) charged particles whether their sources are a lightning discharge or disintegration of nuclear particles; 2) the atomic elements whether the noble gases or the solids which can be found in the free stage such as gold or silver; 3) the molecular elements such as oxygen gas; 4) the chemicals such as methane or ammonia; 5) the minerals which are discrete arrangements of the chemical elements and in a sense are a history of combinations and the recombinations of the elements and finally; 6) the isotopes of the various chemical elements.

This breakdown avoids the physical composition categories of the planet such as the liquids, gases and solids. These are the same constituents in a different state and are covered under the name of phase changes included under modifying forces.

5.4.2 THE IMPLICATIONS OF THE COMPOSITION

The net effect of the composition is to determine the limits and transitions of characteristics of the exchange mechanisms of the planet with its environment and to establish the effective limitations of the modifying forces in their interactions on the planet's constituents and within themselves.

5.4.3 THE PROGRAM

To determine the composition of the planet in the time allocated per mission, a statistical sampling process must be initiated while in the terminal phases of the in-transit portion of the mission. The total planet must be surveyed and the discrete boundaries of the major subdivisions observed through imaging and spectral techniques. These must be evaluated to define the number of similar areas on the planet. For Earth, this would mean a preliminary division of the surface into land and water with a further subdivision of the land into continents and islands. During the orbiting phases, the features of planets could be classified on the basis of similarities to Earth structures or moon structures. The forces interacting to produce these forces could then be hypothesized and a program initiated to collect the data to prove or disprove the hypothesis. Part of the total program is the selection of samples not only from the surface but from the depths of a planet in areas which are considered representative. The second or third planetary missions could be concerned with the investigation of anomalies. The first mission, however, may remain an exploratory mission to isolate the areas to be investigated to as few as possible in order to reduce the data to that necessary for a determination of the composition of a planet.

The key factors involved in these decisions are discussed in the following sections.

5.4.4 THE INITIAL SURVEY

As previously mentioned, the initial survey from in-transit can determine the presence of oceans or continents or islands as well as icecaps. Icecaps of themselves may well be the largest structure observed, but may not necessarily be significant in the investigation of the planet. It is in the melting or sublimation of these that the real interest lies. Is the wave of darkening due to a wetting process or to the flourishing life which develops with the liquid released?

The major decision to be made in this phase is to locate the possible landing sites with correlation of the number of objectives to the observable parameters that can be met using the priorities previously established. Secondary decisions are guided by the presence of clouds, of the ionosphere, and of craters which appear to be volcanic in nature. These can change the entire sequence of observation and composition determination.

5.4.5 THE ORBITAL SURVEY

The major characteristics of the planetary orbital observation program will be determined during the in-transit phases. The composition of the atmosphere and the ionosphere will be determined. During the first five days in orbit, more information will be collected on the landing site and the representativeness of the surface features and with possible evidence for subsurface structural formations. The composition and the characteristics of these will be classified and recorded. The purpose of this is to guide the orbiting observations which will continue after MEM deorbit. The site preferred to determine planet composition will be at the intersection of a number of surface features, preferably on a plateau next to a deep gorge or crater to permit sampling of the various vertical structures, (see Figure B-2). Three possible sites have been indicated with site 3 preferred. This information can then be used to verify the distribution of similar materials over the remainder of the planet's surface. These decisions will be based on the reflected and emitted spectra as well as the images of the surface features.

5.4.6 THE SURFACE DECISIONS

The nature of surface material composition can actually be examined only on the surface. Representative samples of the loose surface material representing the planet will be collected. Its variation with depth will indicate its weathering or leaching. It may be necessary to make gross chemical composition surveys of a number of samples prior to the actual collection of specimens for return. During the coring process, which is considered as essential part of this program, the cores themselves will be examined for changes in composition. In addition, if the crater or gorge indicates stratification, the composition of the various strata and their interface will be determined and again representative samples selected. If the landing should be near an impact crater then at least

Igneous and Plutonic Intrusions
- Quartz
- Feldspar
- Mica
- Dark Minerals

Pegmatite Dikes and Miarolitic Cavities
- Granite Minerals
- Topaz
- Beryl
- Tourmaline
- Garnet
- Apatite

Contact-Metamorphic Ores
- Sulphides
- Scheelite
- Garnet
- Vesuvianite
- Epidote

Weathered Veins
- Malachite
- Azurite
- Copper
- Anglesite
- Cerussite
- Wulfenite
- Smithsonite

Fumaroles
- Sal Ammoniac
- Sulphur
- Sulphates, Hematite

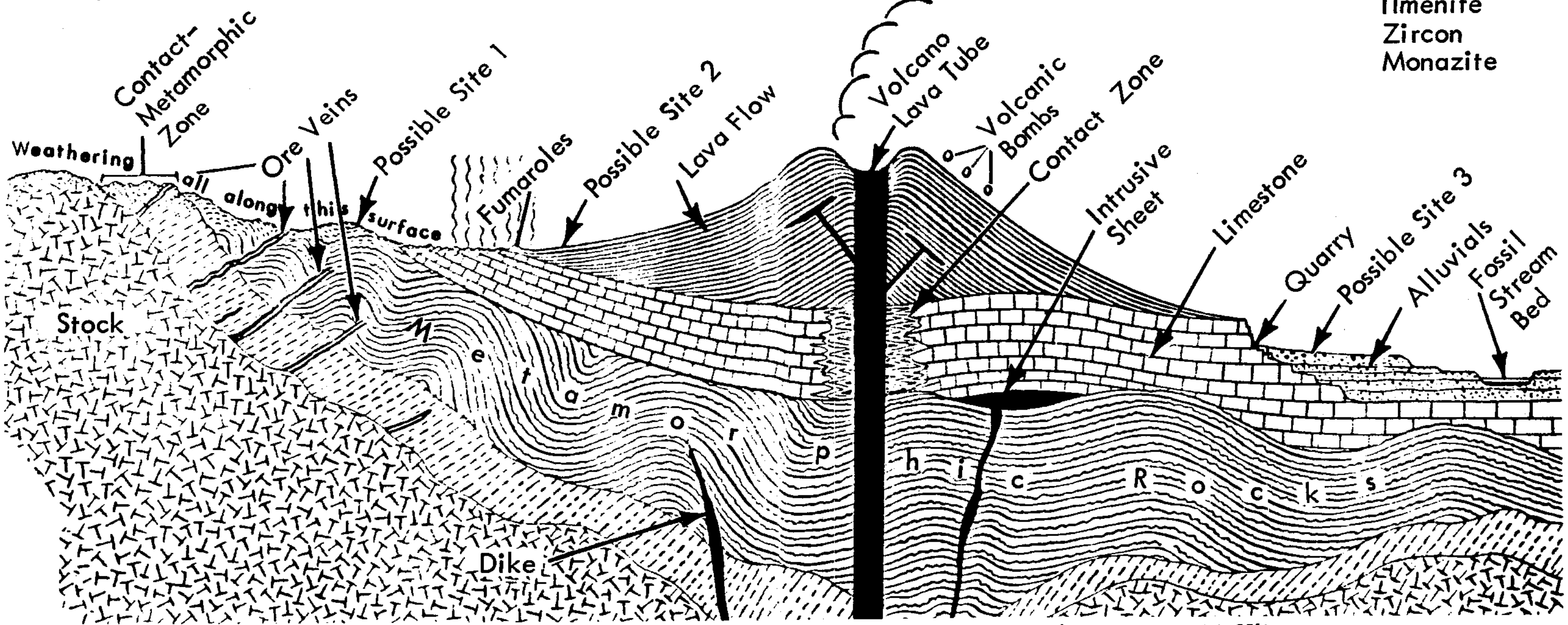
Ore Veins
- Sulphides
- Gold, Tellurides

Bombs-Volcanoes
- Contact-Metamorphic Minerals —
  - Olivine
  - Augite

Metamorphic Rocks
- Garnet
- Mica
- Andalusite
- Staurolite
- Sillimanite
- Kyanite
- Iolite

Limestone Quarry
- Calcite
- Dolomite
- Gypsum
- Fluorite
- Galena
- Sphalerite
- Celestite

Alluvials
- Gold
- Diamonds
- Cassiterite
- Columbite
- Magnetite
- Ilmenite
- Zircon
- Monazite



After "A Field Guide to Rocks and Minerals" Frederick H. Pough, Houton-Mifflin

Figure B-2: SITE SAMPLING

three types of samples are indicated. The first of these will be remnants of the meteorite. The second will be samples of the original surface while the third will be the glassy formations resulting from the melting that occurred with the impact. These will be examined both for distribution and composition of chemicals and minerals present. Figure B-2 illustrates the complexity of sample selection if the site is near an extinct volcano. Similar complexities exist for any landing site which can disclose internal structural information, and the composition which limited the characteristics of that structure. Site 3 was selected in this case because information is available about the geological structure of the surface as well as information which could be available about past stream history with any life that could have been present.

5.5 LIFE

5.5.1 A DEFINITION

Decisions involving the origin and evolution of life must be based on a definition of what constitutes life. The following definition forms the foundation for the program developed in the course of this study:

Life forms reproduce, grow, maintain a specific form with a boundary, utilize external energy, absorb material for food, store energy, excrete, sense the environment, react to the environment, age and die.

The complexity of the above definition suggests immediately that only the most elementary forms of life could be detected if at all by a preprogrammed mechanism. The definition excludes both the proposed proto-organic beginning of life and the records of fossil life left in sediments. It almost certainly restricts unmanned life detection schemes to those forms of life which are asexual in nature or if heterosexual to those which live in heterosexual colonies since if either the male or female alone are captured, reproduction may not take place. The mere detection of chemical changes does not assure the presence of life. Such a detection only indicates that a process basically similar to an Earth life process had taken place.

5.5.2 THE AIMS OF THE BIOLOGISTS

Biologists approach planetary exploration as evolutionary scientists. They assume that the origin of organisms is a chapter in the natural history of the Earth's surface. The hypothesis to be tested is a generalization from this single case: the origin of living organization is a probable event in the evolution of all planetary crusts resembling that of the Earth. The overall program is thus conceived as a systematic study of the evolution of the planet's surface and atmosphere. Hence the aims of the biologists in summary form are:

1) The determination of the physical and chemical conditions of the planet's surface as a potential environment for life,
2) The determination whether life is or has been present on the planet,
3) The determination of the characteristics of that life if any,
4) The investigation of the pattern of chemical evolution without life and the subsequent role of life in the formation of the crust and atmosphere of the Earth.

5.5.3 THE PROGRAM

The program will consist of four interrelated steps. The first of these must be a survey for planning purposes and for detecting possible life environments as they exist. This survey must collect sufficient data to permit a categorization of environmental factors and their variations whether or not they are similar to environments found on Earth. This, of course, can best be done from an orbiter equipped to make measurements such as temperatures, pressures, topographical features, seasonal changes, and their synergistic effects on that complex known as the environment.

The second phase is an analysis of photographs and environments for potential macroscopic life forms such as lichen-covered rocks, grassy plains or forested mountains . This phase may be undertaken while the first is still in progress. Suspect areas can be confirmed with Earth-based scientists by the transmission of high-quality temperature data and portions of high-resolution photographs.

The third step will require the landing in one of the promising areas discovered. If life forms do exist, then a specific study of the environment will be made as well as of the life form itself.

The final step is divided into two concurrent efforts: the search for fossils and the study of clues to a possible chemical evolution from primitive elementary molecules. This phase will be necessary whether or not life is discovered in phase two but may follow step three if life is found. It is essential to study the existing life, if any, to guide the search for fossil-bearing strata and the study of chemical evolution.

Observations and Measurements---Direct Relations--Life origin and evolution depends directly on the following factors or classes of observations and measurements: 1) orbit of the planet, 2) rotation of the planet, 3) thermal characteristics, 4) physical properties, 5) mineralization, 6) age, 7) atmosphere, 8) satellite, 9) solar radiation, 10) temperature change, 11) chemical reactions, 12) other life, 13) phase changes, 14) hydraulic action, 15) charged particles 16) atomic elements, 17) molecular elements, 18) chemicals, 19) diurnal changes, 20) seasonal, 21) latitude, and 22) micrometeorology.

The Indirect Relationships--It also depends indirectly on: 1) gravity, 2) magnetic field, 3) structural features, 4) physical features, 5) isotope ratios, 6) isostatic forces, 7) diastrophism, 8) volcanic activity, 9) surface winds, 10) glacier action, 11) nuclear reactions, 12) protoorganic gases, and 13) fossils.

5.5.4 THE ENVIRONMENT

Biologists have long realized the controlling importance of climatic and other environmental conditions on the development and on the very nature of life on Earth. Despite the variability and the changeability of life on any planet, it nevertheless has evolved within environmental conditions whose limits are set by the size and age of the planet, its axial tilt and rotation speed, its orbital parameters, its physical makeup, and its atmosphere composition and density. In addition the nature and distance of the Sun around which it circles, the strength of the magnetic field, the intensity of radiations and the energy of particle fluxes and last, but far from least, time, have all influenced the development of life. The element of chance must also be added; just how heavily it should be weighed has not been ascertained.

The key factors involving decisions by specialists, which have been shown to play an overriding influence on life, are discussed briefly in the following sections.

Atmospheric Composition and Its Density--Most geophysicists and geochemists feel that at one time a reducing rather than an oxidizing atmosphere existed here on Earth. In fact, it is thought that it was quite similar to the atmospheres of the outer planets as they are today, i.e., principally ammonia, methane, water vapor, carbon dioxide and free hydrogen. Photodecomposition action, the outgassing of oxygen, nitrogen and other elements from the surface became ever more prevalent until, after millions of years, the atmosphere came to its present state. Just when, on this atmospheric evolutionary scale, life appeared, is not known but a step in determining its contributions to the origin and evolution of life is a study of another atmosphere and its relation to life. The existing atmosphere must be examined for its trace constituents and these must be related to the crust of the planet to determine its initial constituents as well as its evolution.

Temperature, Pressure and Water--Temperature and pressure play two roles in the development of life. First, they determine the role that water can play in the continued existence of life in a specific locale. Second, they, with water determine the rate of certain chemical reactions which are fundamental to life and its evolution. Biochemists believe that as temperatures rise toward the boiling point of water, life, if it survives at all, cannot progress because chemical reactions and molecular buildups become destructive. Further, as the freezing point of water is reached, life can function only with difficulty. Biochemists find it hard to imagine carbon-containing organic compounds that do not require the presence of water either as a solvent or as a catalyst.

Because of this role of temperature and its effect on water in life here on Earth it is assumed that a life sustaining environment is one in which water must go through some portion of the liquid phase. This range of temperatures will be sought on the planet under investigation. The liquid phase is also determined in part by the atmospheric pressure existing, hence, atmospheric pressure is also an essential part of the environment that must be measured.

Solar Radiation--Biological processes were created under, evolved under and today, function under conditions that depend on the amount and kind of solar radiation reaching the life form. It is estimated that the biologically acceptable zone in terms of solar radiance is between 0.5 and 4.0 cal/cm^2-min. This may be misleading as a criterion to be applied to another planet. On Earth, life depends on the spectral distribution of the solar radiation reaching the surface after passage through a selective energy absorbing atmosphere as well as the rate of change and the intensity of that radiation.

In general, the amount and perhaps kinds of solar radiance reaching a planet depends on its distance from the Sun but the spectral absorption of the planet's atmosphere cannot be neglected. An experiment program, including the determination of calorie rate reaching the surface of the planet, must include a measurement of the spectral distribution of the energy as well.

Other Environmental Parameters--The effect of the above factors on life have been relatively easy to determine; but other conditions cannot be so easily measured. There is no general agreement on what influence the Earth's magnetic field had on the development of life processes, or how different life would be if the gravitational field were changed by as little as 10%. It is not known what would happen if radiation intensities and energetic particle fluxes increased or decreased slightly over a long period of time. Nor is it known what the result would be or would have been if the planet's rotation rate, the speed in its orbit or the relative rotation of the Moon about the Earth were different. It is known that tides affect present sea life along the shore and that tidal effects are dependent on the relation of the Moon to the Sun. Hence, the biologist requires a knowledge of these planetary influences and their perturbations through evolutionary time, not only to determine their possible influence on the life of the planet under study but to clarify their role on the development of life here on Earth.

5.5.5 THE SEARCH FOR MACROSCOPIC LIFE

Prior to the commitment of man to land on any planet, a thorough search should be made for macroscopic forms of life or evidence for life which may extend over large areas of the planet. This evidence can exist in the form of color, differential absorption, patterns or differential radiation over discernable areas of the planet. Changes in these with the passage of time changes in temperature or in the presence of water may be the clues sought.

Color - Spectral Reflection--On Earth, color is the response of the human eye to the narrow spectrum of radiant energy called visible light. This response to spectral energy is most assuredly different in the life of another planet. Yet life must absorb energy and the spectrum absorbed is usually in narrow ranges. In addition, the energy conversion process results in the radiation of energy at some lower portion of the spectrum. Hence, large areas of similar life must be associated with a discrete reflected and radiated spectrum which will differ from the surrounding terrain. It will be essential to differentiate between the spectrum and energy reaching the surface and that which has its origin on the surface. The range of solar radiance to be investigated may extend from the far IR to the far UV; but it may also be limited to several relatively narrow windows in this range. This reaffirms the necessity for measurements made on the transmittance of the atmosphere of the planet under study, a transmittance which may vary from day to night, from cloud cover to cloud cover, and from one season to another. This is essential because it is well known that many forms of Earth life change color during growth and reproductive phases. It is assumed that life on other planets will exhibit the same phenomenon.

Temperature--Another clue to the existence of macroscopic life is in the variation of temperature changes in areas where life exists compared to that in which life does not exist. Expanses of forests, grasses, lichens, etc., will absorb more energy in certain spectral regions than bare rock and soil and hence may appear cooler. In addition, in periods of relative darkness, plants will emit radiation which may indicate a higher temperature than the surrounding terrain. For this reason, the surface and atmospheric temperature ranges in environmental areas which overlap those thought to be conducive to the existence of life must be measured. The association of temperature with water, either in the form of the liquid or the gas should be established. It is well known that water can influence the color and texture of a surface as well as the temperature changes which can occur.

Patterns--Patterns are exhibited by a variety of life which ranges from that of intelligent beings to microscopic forms. Patterns may be rectilinear, circular or merely irregular lines which appear to ring or bypass obstacles such as crevices, mountains or major environmental areas. Intelligent life such as man constructs its roads, agricultural environs, fences, etc., in straight lines where permitted or dictated by terrain and natural obstacles. Animal life which travels in droves or bands tends to follow paths previously established or leading directly to a source of food or water. Relatively large environmental areas may be criss-crossed by paths which are not necessarily rectilinear but represent some habit pattern of life established in the evolutionary process. These lines must be examined critically to differentiate them from fault lines or other patterns produced by changing land form.

Many microscopic forms of life tend to grow in circles as long as an environment permits or until it reaches the end of a life cycle. These patterns may persist after life is extinct for comparatively extended periods of time and do not necessarily imply that some form of life activity is in process. Hence, a careful analysis must be made to distinguish active from inactive patterns.

Macroscopic Life Survey Summary--Because of the diverse forms of life and the varied environments to which life can adapt, it is essential that a preliminary survey of a planet include:

1) Photographic reconnaissance using spectral techniques applicable to the planet under investigation.
2) A temperature survey in the range over which water can be in a liquid phase at least for a part of the seasonal cycle and for a complete day.
3) A spectral survey of the energy and its spectrum reaching the surface or other area suspected as supporting life.
4) A spectral survey of the reflected energy from the region in which life may be extant.
5) A survey of the water distribution of the planet.
6) A survey of the climatic extremes anticipated in a specific locale. This survey to be based on an analysis of the altitude, the latitude and longitude, as well as the modifying influences which bodies of water and mountain ranges may have.
7) An analysis of the above with a correlation of the pertinent factors to categorize possible life forms and their environment. The topography associated with each site must then be evaluated in terms of a possible landing site.

If man were present he could probably see patterns which are associated with life such as (1) the color changes of plant life as it sprouts, flowers, matures and decays, (2) the traffic patterns associated with animal life in its search for food during the seasons to meet its survival needs, (3) the patterns established by life such as forests or grasses in their adaptation to a specific environment and (4) the patterns established by many life forms as generations of life cycles follow changing environments such as lakes drying up or plains changing into desert or swampy areas.

5.5.6 THE DISCOVERY OF LIFE

The third phase is initiated only after evidence of life is available. The existence of life on another planet will be established after the scientist on Earth will have studied motion pictures taken of that life or studied it through a microscope. Prior to this, all data will be accepted as possible evidence that some life form may have produced the particular effect measured. For this reason, this section will emphasize the return of both photographic evidence and life bearing samples. This step follows the discovery of macroscopic evidence of life as discussed in the preceding section, or the return of data from an ABL which was indicative of life-like processes. The landing of man on the planet is essential to this step.

Theories of Life--Perhaps more than any other science biologists have been confronted with facts so diverse that little progress could be made in the development of theories presenting a comprehensive picture of the varied forms of life on Earth. It has only been in the last few years that scientists established specific studies devoted to theoretical biology. Evolution is a hypothesis supported by overwhelming data on the striking step-like development of life but few theories can be tested in the laboratory. Considerable controversy exists how genera, families, orders, classes, and even phyla developed. Some emphasize the evolution discontinuities by incorporating some kind of large saltations, the exact nature of which is not clear. The opposite view is that the gaps represent the simple disappearance of the intermediate steps. Another problem is that certain lines of evolution seem to have a directiveness to them; they go in a straight line while others seem to radiate in all directions. Have similar irregularities occurred in the life on other planets? The answer may be provided by studies of one specie, by observing the shole of life on another planet or by the evaluation of the protoorganic molecules on the planet and perhaps not at all.

Microscopic Life--Microscopic life forms represent the life which can most easily be brought back to earth and hence can easily pose the greatest danger to man. This imposes the requirement that samples be cultured and studied in areas which are isolated and remote from the central activity of the spacecraft whether on the ruturn journey or on the surface of the planet. There is no method of predicting how rapidly both evolution and adaptation can occur with life evolved on another planet. It becomes a requirement to include remote sampling techniques that will permit an undetermined incubation period with exposure to test animals prior to man's first exposure to the life on another planet. An incubation period of about two weeks should follow ingestion before the animals are sacrificed and examined for exobiological life effects. It is assumed that the space suit will provide sufficient isolation between the scientist collecting the samples and the sample collected. Taxonomy can proceed on an orderly basis during the incubation period. The test animals should of necessity be rhesus monkeys. Provisions should be made for a minimum of four animals, two of each sex. A parametric study should be made to determine the feasibility of culturing the many forms from a planet using Earth animals because even the most primitive animal is parasitic in nature. Animal life per se preys on other animal life, on the products of the plant kingdom and on the plants themselves. Animals can provide the most varied host conditions and at the same time provide a means of testing the possible danger of exposing man to the microscopic life of another planet.

Similar back contamination dangers to plant life exist. Test plants such as yeasts, grasses, berries, evergreens, etc., should be included. For a complete discussion of a possible back contamination program, see Appendix D.

Botanists assure us that on Earth there are over 250,000 species or distinct types of living plants that have been discovered and described. Plants, in contrast to animals, are for the most part characterized by their independence. If life exists at all on another planet, some form of plant life will be included.

Plant life must be cultured in a media which supplies all the necessary ingredients including food, energy, temperature and temperature changes, an atmosphere, a liquid, and a support medium. Thus its very independence may make the culture of plant life adapted to another planet's environment exceedingly difficult in the environment of an Earth-designed laboratory. This fact makes it essential that the environment of the planet on which plant life is sought be thoroughly studied and readily duplicable in the environs of the lander. A small volume should be provided which can duplicate the environment of the planet if plant life is to be studied in the spacecraft laboratory. The plant's seed or spore can survive a variety of conditions which the animal cannot. Hence, some form of seed or spore collection will be undertaken and the 'fall' of the year will be preferred.

Macroscopic Life--Macroscopic life consists of both plants and animals. For the most part, both will be studied in their natural environment since large life will require large volumes with controlled environments that may be provided in subsequent specialized landers. The only tools required for the initial lander will be recording and observational hardware. Seeds may survive the possible toxic Earth atmosphere but should be collected and then preserved in an environment closely approximating the 'winter' climate of the plant. (Oxygen and H_2O concentrations may literally burn or drown the plant in the Earthly environment.)

5.5.7 CHEMICAL EVOLUTION AND THE SEARCH FOR FOSSILS

These two phases in the chemical evolution of a planet can proceed almost simultaneously because both will be involved with the analysis of the rocks and soils existing on the planet. A necessary adjunct to this, of course, is a detailed knowledge of the atmosphere. Since the atmosphere and its trace gases will have been determined for other reasons, it will not be treated here.

Fossils--The search for fossil evidence of life must of necessity include a skilled scientist, and probably one highly skilled in field work. Fossil remains of earliest life will probably be nonexistent, due partially to the destructive effects of time and the changing environment. (The changing environment will be recorded in the materials composing the crust, which man will be able to evaluate in terms of its impact if any.) Two conflicting requirements exist. The first is that in order to discover fossils it will be necessary to examine the exposed surfaces of rocks over relatively large areas. Rocks in which the remains of life are found will be rare, they are on Earth and if life itself is rare on a planet, then the chances for discovering the records in terms of fossils will be even more fortuitous. The second is that rocks which are exposed are also exposed to the environment. The environment will have the effect of erasing the very record exposed for discovery. In addition, the rocks which are exposed will have been altered by orogenic processes, processes responsible for the building of mountains, of plateaus and of large sedimentary deposits. In the end, it may be necessary to examine likely looking rocks from an Earthly point of view in an unearthly manner to determine unearthly life remains. The analysis of such rocks must follow the decisions made on the spot, perhaps after consultation with other crew members, perhaps after consultation with scientists on Earth. In either case, the collection of representative samples will be necessary and sampling techniques must be developed subject to modification by what is found. Hence, it is essential that one crew member be well versed in looking for promising fossil bearing formations. A landing near a cliff or exposed stratified layers is essential if the search for fossil evidence of life and its evolution is to proceed in an unfamiliar locale.

<u>Chemical Evolution</u>--Chemical evolution from primitive elementary molecules is an inevitable result of the application to them of various forms of energy. Virtually any kind of energy, such as heat, ultraviolet light, electricity, or cosmic rays can be the initial spark. It has been shown that energy when applied to a mixture of primitive molecules, whether in an atmosphere or in a liquid, will produce a mixture of amino acids which are the building blocks of proteins, the main constituent of living organisms. Some of these primitive molecules are methane, ammonia, water, hydrogen, and carbon dioxide. For an elementary flow diagram illustrating the possible building mechanisms, see Figure B-3.

The presence of these molecules will probably be established prior to any manned landing but the stage at which these gases appeared or disappeared from a particular environment can only be determined after an analysis of selected rocks and sediments whose ages can be established. If life does not exist, then the remaining step will be to establish why it did not evolve in the particular environment existing at the time. This again will require the proper collection of adequate samples by an expert in the field of analysis which in turn makes age-dating equipment and techniques essential. The samples must span the largest possible spread in age to establish the conditions associated with the primitive molecules under study. The complexities involved in programming a device to select the necessary samples of unknown characteristics in an unknown environment hardly need emphasis. A sample selected at random from the surface could only serve to bring into focus many more questions than it could answer.

5.5.8 SUMMARY

Figure B-4 presents a summary of the role of man in the search for life on a strange planet. In the final analysis man, the selector, will only be permitted the luxury of selecting instruments from those included in the spacecraft. His objectives will have been determined as will the

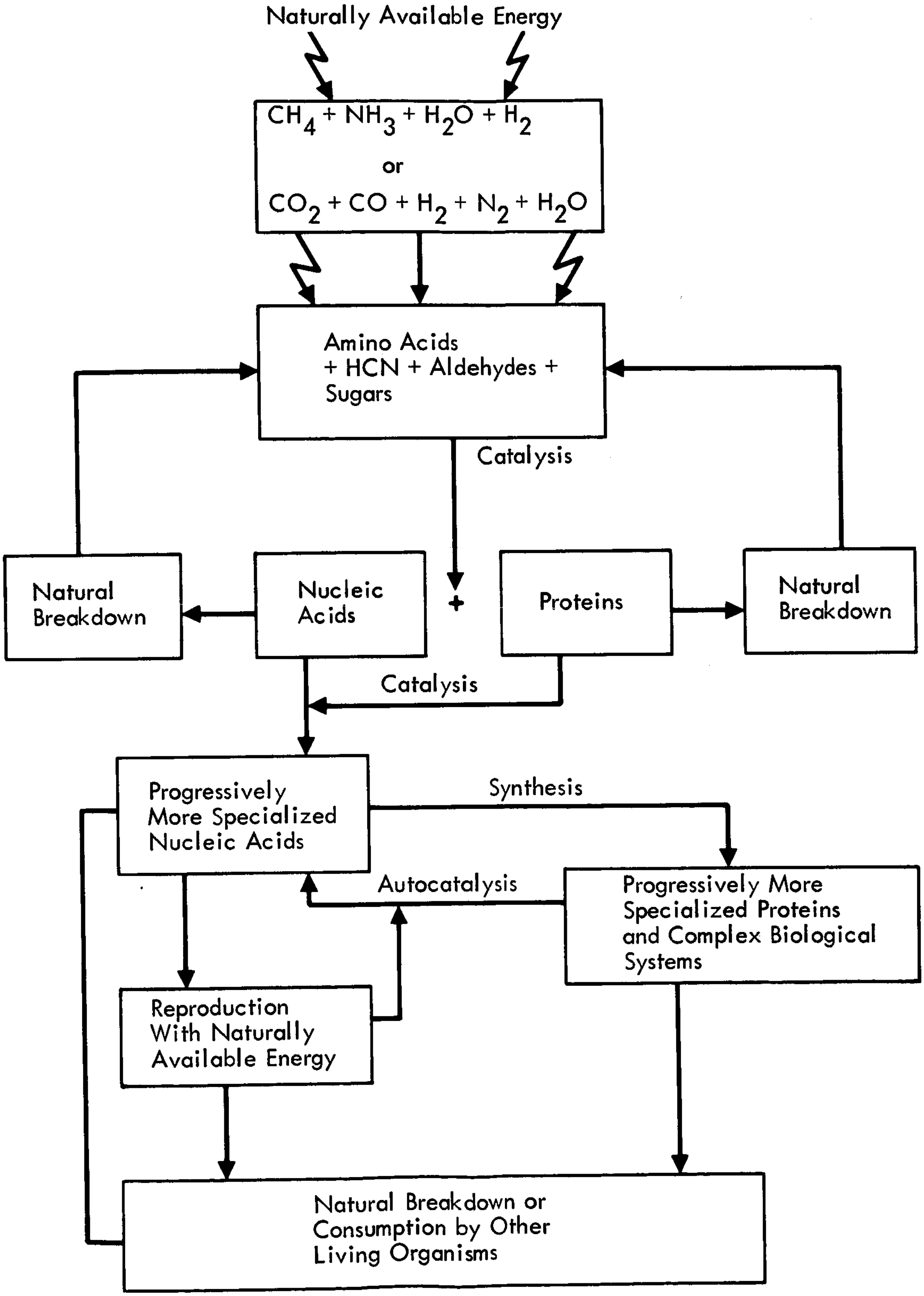


Figure B-3: MOLECULAR EVOLUTION

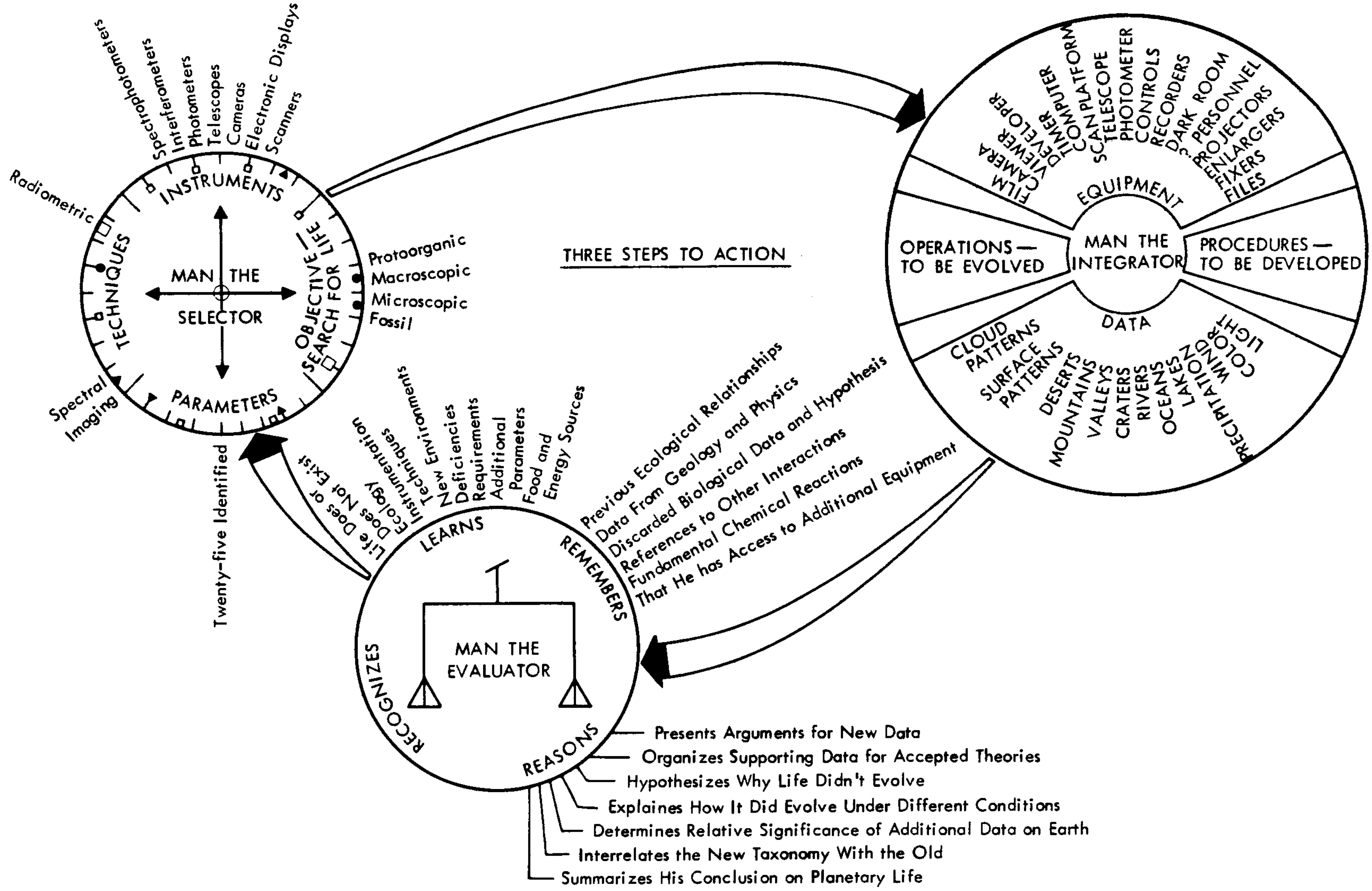


Figure B-4: THE ROLE OF MAN IN THE SEARCH FOR LIFE techniques available to him. He will be left with the decisions of which instrument to use to observe which parameter. If his experience warrants, he may have side latitude in the integration permitted. The degree to which he can evaluate the data with which he is presented, either visually or through the use of his instruments will depend on his initiative, on his time and on the depth of the planning that prepared him and his spacecraft system.

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APPENDIX C
MEASUREMENT REQUIREMENTS

C-1 MARS ORBIT
C-2 MARS SURFACE
C-3 VENUS ORBIT

C-1. IN ORBIT MARS MEASUREMENT REQUIREMENTS

Measurements	Parameters	Requirements
Atmosphere Composition	Constituents, partial pressures, scale heights or distribution.	Identify minor constituents to within 1 part in 10^6 and the major constituents, i.e., those composing more than 1% of the total atm., to within 10% in fractional composition. Determine partial pressures of measure constituents to within 0.1% and the distribution of the species to within 1 km from the surface to where the number density is twice that of free space.
Gross Features	Number density, mass density, potential density scale height, potential pressure scale height, geometric density scale height, geometric pressure scale height, lapse rate, columnar mass above a given altitude, circulation patterns, ionosphere, escape temperature, mean molecular weight, pressure profile, temperature profile.	Measure scale heights to within 1 km, and all other parameters to within 0.1%.
Clouds	Structure, patterns, altitudes, sferics, temperature distributions, precipitation pressure-temperature relation, composition, droplet size ranges.	Structure of the cloud should be determined to within 0.1 km. Determine reflected spectra to within 1.0A. Internal circulation velocities to 10%. All other parameters to within 1%.
Windows	RF transmission, light transmission, IR transmission and absorption, UV transmission and absorption. Scatter and refraction of all wavelengths.	Determine spectral resolution over predetermined portions of total spectrum from RV to UV. Refraction should be related to bands selected and the bending determined to within 1 arc sec.
Sources	Changes of state, chemical reactions, recombination, dust, meteorites, solar radiation, surface venting, nuclear activity and sferics.	Determine contribution of each of these sources to within 1%.

Measurements	Parameters	Requirements
Charged Constituents	Electrons, charged gases and evidence for surface charges.	Charged constituents can result from at least three sources. First, the effects of the Sun's radiation. Second, the effects of natural radioactivity; and, third, the result of lightning discharges. Charged constituents may last longer in the charged state than on earth because of the relatively poor conductivity of many materials at lower temperatures.
Chemical Composition	Chemical elements involved, their disbution and relative abundances. Absorption techniques for atmosphere. Reflection spectral analysis for selected surface areas.	Percentages on the order of 0.1% to be established. On Mars the distribution may be an indication of formation by accretion as well as formation from the Sun during a period of time other than that of Earth formation. Areal distribution on the order of average crater size desired. Approximate 0.1 km square resolution desired.
Chemical Reactions	Compounds involved and their rates. Evidence of chemoluminescence. Thermal emission and extent of area. Reactions involving oxidation and reduction. Hydration following wave of darkening.	Soil temperatures to 0.1°K. Rates to be established to within periods of Martian years. Delay of luminescence should be established within 0.1 min. Light wavelength probably in UV and visible. Accuracy to 1 A desired. Indicates differentiation.
Diastrophism	Mountain and valley formations.	To be obtained from maps and photographs or image.
Diurnal	The changes which occur as a result of the daily variation in heating, lighting, and exposure to the Sun's radiation.	On earth many plants and animals exhibit cycles which are the result of night and day cycles. Do these exist on Mars? Other phenomena may be tied to this variation. Shadows and color contrasts are one example. Wind velocities and surface temperatures are other examples.

Measurements	Parameters	Requirements
Figure	Polar and equatorial radii. Other radii as required to determine shape of the planet to five kilometers.	The general shape of the planet is required because of the evidence of internal structure. The valleys and the mountain peaks should be averaged out to a surface with a maximum deviation of five kilometers, i.e., ± 2-1/2 km.
Glacier Action	Patterns and valley shapes.	May be obtained from images. Evidence may suggest a previous denser atmosphere.
Gravity	Gravitational constant and the correlation with the figure of the planet.	The interaction of the two moons is desired. Gravity is one of the forces acting over large distance which has played an important role in the present shape of the solar system. Accuracy to 0.01% is desired.
Hydraulic Action	Imaging in visible and IR (10K Å.	Resolution to 10 meters adequate. Should be detectable with the onset of the wave of darkening. Images should be taken both prior and post passage of the wave.
Isostatic Forces	Relatively huge areas which are similar in construction sjch as the existence of continents on Earth.	Isostatic forces are the result of mass and gravitational imbalances brought about by the transport of matter or the change of density is extensive areas over over the planet. These forces are to be distinguished from diastrophism which is defined as the general forces which deform the crust of the planet.
Isotope Composition and Ratios	Possible chemical composition would give a clue to probable isotopes present.	Information to be obtained by the relative composition of the elements. If the ratio of the elements composing the surface are different, then it would only be logical to assume that the isotope ratios, at least those resulting from radioactive decay would be present to different degrees.

Measurements	Parameters	Requirements
Latitude	Average wind velocity, temperature, precipitation, surface texture, surface coloration, etc., with latitude from the equator to both poles is desired. Cross equatorial transport of both dust and gas is significant.	Latitude perturbations are essential to a final determination of origin and evolution. The impact of different environment superimposed on the total planet environment has not been sorted out completely here on earth. The less dense atmosphere of Mars may aid.
Life	Patterns.	Imaging Techniques. The first step would be to obtain the entire pattern and its relation to the geography of the planet. A second step would be several higher resolution photographs of an identifiable feature or interface.
Magnetic Field	Polarity with respect to the axis as well as field strength.	Determine magnetic moment to 5% and alignment of field to poles within 1°.
Meteoroid Impacts	Number and size distribution. Latitude distribution. Wall steepness. Crater depth and ray formation. Image and spectral response. Images up to 100's of KM in extent. Use lunar impact crater data.	Distribution to be obtained from imaging and mapping. Vertical resolution of 0.1 km. Horizontal resolution to 10 meters. Crater walls to be examined for flow.
Micrometeorology	Wind velocities, local surface temperatures, cloud structures, cloud patterns, precipitation, pressure differences, storm movement, cloud top temperatures and cloud base temperatures. Velocities to 200 km/hr. Cloud tops to 50 km. Cloud bases 1 km. Temperature near 100 to 200°K. Precipitation by surface reflectivity changes near 6000 A.	Wind velocities may be obtained by measuring the movement of dust clouds, resolution of 0.5 km horizontal adequate. Vertical resolution of 0.1 km. Velocities to 1.0 km/hr. Pressure differences may be obtained either through use of soft landers. Day and night variations as well as seasonal changes are to be measured. Temperatures to 1.0°K.

Measurements	Parameters	Requirements
Mineralization and Composition	Surface structure, reflectivity, contrast, emissivity. Reflectivity bands are determined by the spectral reaching the surface. Emissivity is restricted to the infrared. Reflectivity is differentiated from emissivity by the polarization and frequency of the measured waves. Magnetic field.	Reflectivity and emissivity should be measured to 1% in intensity and 10 Å in the infrared. Spectral bands in the UV and the visible should be measured to 1 Å. Magnetic Field to ±10. Correlation to surface images.
Moments of Inertia	To be calculated from rotation rates and planet figure data.	
Nuclear Reactions and Radioactivity	Gamma ray spectrum and intensity - 2 MEV and intensity of 10 MREM/hr.	Requirements for these measurements can only be met if the density of the Martian atmosphere is less than 10 MB at the surface with a scale height of 10 km. Resolution of ±10 km.
Phase Changes	Determine the change from molecular to charged atmospheric atoms and identify the specie. Use of absorption lines in ionosphere adequate. The number of electrons can be detected by sounding equipment. Changes from the gas to the liquid or the solid to be determined using either reflection changes (scattering of UV) or absorption changes of the reflected light from the surface. Intensity changes may be necessary if condensation such as clouds or fog do not appear. Phase changes within the interior of the planet may be detected by measuring the moments of inertia and the figure of the planet in association with the gross gravitational field of the planet. Composition can be infrared only.	Ionosphere composition should be determined to 1%, electron density to 10%. Composition of gas to solid or liquid to 1% with rate of condensation or sublimation established to 1 k^2 cm/hr in the case of large bodies of liquid or extensive fields of solid precipitation. Composition of evaporating or subliming body to be determined to 1%. Phase changes are significant because they represent both sources and sinks of energy which can change apparent rates planet modification depending on the latent heats involved and the extent to which they cover the planet. The phase change which occurs near the center of the earth is not verified. Evidence of a similar nature even on a planet the size of Mars is required.

Measurements	Parameters	Requirements
Physical Features	Impact craters, mountains, valleys, plains, ice caps, and any other variations in surface structure whether vertical or horizontal.	These are to be obtained through an examination of the surface images made in the ultraviolet, visible and infrared wavelengths.
Physical Properties	Densities, conductivity (heat), soil bearing strength, surface texture, rocky, sand or fine particles, color, surface markings and the variation of these over the planet's surface planet mass.	Measure all physical properties to 10%.
Protoorganic Compounds	Analyze spectra for presence of CH_4 NH_3, H_2O, CO_2, H_2 and N_2.	Possible sources of these gases are surface vents, meteorites, and primordial constituents.
Rotational Parameters	Period of the planet and its moons. Axis to be determined for all three.	Period to be determined to 1 minute and axis to 0.01°. Nutation and precession can be determined sufficiently accurate by periodic measurements of period and axis extending over months.
Seasonal	Average wind velocity, temperature, precipitation, texture, coloration and other observable surface feature changes.	These measurements should be made in both himispheres and covering at least four complete seasonal cycles.
Satellites	Orbital rotations, shapes, masses, surface characteristics and features. Dust belts if any. Semimajor axis in kilometers. Eccentricity in degrees. Inclination of the orbit to the ecliptic in degrees. Longitude of the ascending node on the ecliptic, measured from the vernal equinox in degrees. Longitude of the perihelion measured along the ecliptic from equinox to ascending node, then along the orbit from node to perihelion (degrees).	Determine orbits to within 1 sec. Identify features characteristics. Correlate to planet.

Measurements	Parameters	Requirements
Satellites (Continued)	Mean longitude at epoch of the planet. Secular terms, periodic terms. Sedereal period, mean synodic period. Perihelion distance, aphelion distance. Minimum distance from planet, maximum distance from planet. Mean orbital velocity. Oscillating elements; perturbations.	
Seismic Activity and Seismicity	Faults and other evidence of earthquake activity.	To be obtained from surface images. 10 meter resolution adequate since fault lines will be many kilometers long and vulcanic act. should also be discernible.
Solar Radiation Surface and Planet Environment	Spectrum and intensity. Particle flux and energy. Magnetic field polarization and intensity. Spectrum from FR to 20 MEV gamma. Solar wind electrons, protons and alphas. Magnetic field from 1 to 100 gamma.	Measure all frequencies to 0.1% and intensities to 1%. Measure radiation rigidities to 0.1%. Magnetic field accuracies to ±1 gamma. Time variations of field to 1 minute. This information essential in determining the present interactions with the planet and its atmosphere (ionosphere).
Structural Features	May be determined by imaging and analysis.	Structure is defined as the changes in the structure of the atmosphere as well as of the solid configuration of the planet.
Surface Winds	Average peak velocities and the duration and distribution of these are required. Night and day variations are desired with seasons.	Winds are a major factor in redistribution both surface material and surface gases which are sources of both energy and chemical changes. Planet crust may be so redistributed as to erase needed information.
Temperature Changes	Emission from planet surface, planet clouds and planet upper atmosphere. Thermal maps to be established for surface areas. Temperatures near 140°K to 290°K.	Rate of change of temperature to be established for both heating and cooling and for both hemispheres. Changes of 0.1K/min. desired. These measurements can establish composition change rates

Measurements	Parameters	Requirements
Temperature Changes (Continued)		as well as the presence of interactions initiated during wave of darkening or during the planet's summer and winter. Heat conductivity to be established. If planets were molten, then conductivity is essential. If planets heated by their internal pressure due to gravity or radioactivity, these measurements are essential.
Thermal Budget	Both the spectrum and the intensity of all energy sources and sinks are required. The Sun, volcanic activity, radioactivity and the specific heat of the planet contribute to the thermal budget of the planet.	The thermal radiation and the distribution of sources should be verified to within 10%. The extent of the sources should be determined within 2%. The thermal budget of a planet gives an indication of the rate of cooling and may be an indication of the possibility of life.
Volcanic Activity	Number of active and past volcanoes, lave flows, fissures and hot areas. Thermal map near 15,000 A images at 6000 A.	Number and distribution of volcanically active areas. Mapping in both IR and visible desired. Resolution in visual of 10 meters adequate. 10 meter resolution in IR necessary.

Measurements	Parameters	Requirements
Diastrophism	The epeirogeny and orogeny and isostasy.	The measurements and estimates of the broad uplifting forces acting on the planet are to be photographed; enlarged low resolution photographs which can depict continental outlines, evidence for mountain chains with folding faults, uplifting and sinking localized areas. Sinks surveying should indicate the apparent rise or sink rates, the age at which a rise or sinking occurred, and the general composition of the rise or sink measured. The differences and altitude to be measured to within 1 meter per km.
Diurnal Changes	The parameters established under micrometeorology should be measured for as many consecutive night/day cycles as are permitted by the mission. These should be transmitted to the orbiting spacecraft for correlation of other surface measurements.	Ten-percent accuracy will establish the necessary ranges involved. Wind velocity direction, however, should be established to within 1 degree.
Glacier Action	Moraines, rocks, polished boulders and u-shaped valleys are all evidence of glacier action.	Valley shapes will be obtained from images. Presence of moraines, rocks, etc., may require close-up photography and a recording or photo of the total environment. Age dating as well as the rate of glacier movement should be performed to within 1%.
Gravity	Gravitational attraction to standard or standardized Earth weights and utilization of a gravimeter.	Local gravity should be measured to within 0.01 of 1% and correlated with the local features such as mountains or valleys.

Measurements	Parameters	Requirements
Hydraulic Action	Rocks, sand and soil will bear evidence of deposition by water. Rounded rocks should be photographed, soil depth measured and variations in single deposition should be recorded and photographed.	The degree of soil deposition by hydraulic action should be estimated. The amount deposited should be measured thru boring holes and measurements layers to within 1 millimeter. Dating techniques should arrive at deposition rates of millimeters per year or should estimate the transport of smooth rocks or sand at geology units significant to the surface.
Isotopes and Ratios	Chemical analysis of the soil, rock, sand or other surface material, including the atmosphere.	Representative samples must be taken both of the immediate surface, as well as of the surface roughly 1 meter in depth. Isotopes should be determined to within 1%.
Latitude Effects	Surface temperatures, diastrophism, wind velocities and precipitation.	Accuracies to within 10% are sufficient to determine the variation of these from the equator to the pole. The surface site latitude should be determined to within 1 minute of arc.
Life		
A) Macroscopic	The large forms of life should have shapes, activities, weights, number of inhabitants per family unit, and number within the family or herd community. The interrelationship of the larger animals or plants should be established. It is assumed that a growth cycle for the macroscopic life form will not be established nor will samples be taken.	The kilogram meter second system shall be used to establish the parameters of the larger animals or plants. All nutrients should be measured in this system and consumption rates established.

Measurements	Parameters	Requirements
Life (Continued)		
B) Microscopic	The soil or other inhabitable ecological system supporting microscopic life will be photographed and analyzed for nutrients. Attempts should be made to establish the culture media while on the Martian surface. Life samples will be refrigerated with sufficiently large portions of the possible culture media and habitats to support the life for the duration of the space flight.	The number of types of microorganisms as well as the rate of multiplication and material growth conditions will be established.
C) Protoorganic Compounds	The protoorganic compounds to be sought are NH_3, H_2O, CO_2, N_2 and CH_4.	The spectral lines of these compounds are in the IR region for the most part. These lines should be measured to 10 A. The mass spectrometers should also be used to ascertain their relative abundance to 1%. Rock analysis will reveal presence to microliters ±1 microliters.
D) Fossils	Parameters are sedimentary, rock, fossilized animal and plant remains. Fossilized microbiology remains.	The presence of fossil remains should be estimated in terms of distribution per area as well as distribution within the certain strata of soil or rock. Care should be taken that the fossil remains are in their original environment and have not been transported prior to their deposition.
Magnetic Fields and Constant	The surface magnetic fields and paleo magnetic fields. Time variations or secular variations should be established.	Magnetic fields should be determined to within 1%. In paleo magnetic fields the direction or polarization of the fields of the individual strata should also be measured to within 1%. Daily measurements are adequate to 5 gamma.

Measurements	Parameters	Requirements
Meteoroid Impacts	The number of meteoroid impacts within the MEM area can be best ascertained from orbit. However, the presence of the fracture evidence for meteoroid impact should be photographed as well as measured. A sample of the surrounding material should be taken as well as the meteoroid itself. Particular evidence selected should indicate the degree of zonal melting which may have occurred, as well as of the strata revealed by the impact.	The height of the crater wall above the crater floor should be measured to within one meter and the general profile of the crater should be established. The depth of the floor of the crater below the surrounding "sea level" should be established. The meteoroid itself should be analyzed for the chemical constituents and the isotopes present.
Micrometeorology	Wind, soil, transport, precipitation, air temperature and percent cloud cover should all be noted. These measurements should cover the duration of the MEM stay time and if possible extending through radio contact time with the orbiting spacecraft.	All measurements should be made to approximately 10% accuracy for as long a period as possible. Precipitation gages should be positioned such that the collecting sensor is not disturbed by the MEM or some other geographical feature. These measurements should be made for the particular seasons as well as for any other season if communication with either Earth or the departing spacecraft permits.
Mineralization and Composition	The crystal structure of the mineral should be determined and the distribution of the crystals within the sample should be established. Generally, chemical reactions and ages of the minerals should also be measured.	The degree of mineralization within the MEM area should be estimated. The percentage of the total minerals with respect to the total composition of the surrounding area should be noted. Color, texture and general surface appearance of each mineral should be measured as well as the reactions required to determine the chemicals which compose the minerals.

C-2. MEASUREMENTS AND OBSERVATIONS--MARS SURFACE
(Apply to Mars and Its Satellites Where Applicable)

Measurements	Parameters	Requirements
Age	The samples selected above should be counted for the radioactivity decay in an area where the background is significantly less than the background due to the natural radioactivity in the soil.	Age of the rocks should be determined to three significant figures and the element selected should give the most significant information with respect to the differentiation present. Top surface soil selected for the carbon-carbon dioxide atmosphere interchange must be selected from samples taken at some distance from MEM discharge.
Atmosphere	(See Mars Orbit Experiments)	
Chemical Composition Including Atomic and Molecular Elements	The elements of the surface should be selected from samples which are representative of the surface as well as to each strata to the depth of the drill available.	The elements should be measured to 0.1 of 1% and the extent or distribution of these elements should be ascertained as a percentage of the geographical features observable.
Chemical Reactions and Composition	Chemicals available for reactions should be ascertained. Evidence for past reactions occurring in the region of the lander should be sought. The rate of the reaction as well as the temperature of the reactants should be established.	The rate of the reaction should be established at kilograms per hour if the reaction is rapid or to tons per year if the reaction is relatively slow. The area over which the reaction is taking place should be estimated and the depth to which its taking place should also be measured. Should it be possible to establish the sources of the reactants with the combination of orbiting spacecraft observations and ground observations, this should be attempted.

Measurements	Parameters	Requirements
Phase Changes	Phase changes occurring will either be gas, condensation to a solid or liquid, or the sublimation or evaporation of the solid or liquid to the gaseous state.	Rates should be established in terms of millimeters per occurrence. The duration should be measured in hours accurate to within 5 minutes. The rate of evaporation of the liquid body to gas should be estimated to units of square kilometer inches for large bodies or liters per hour.
Physical Features	Mountains, craters, rivers, buttes, oceans, lakes, etc.	The general description of the physical features at the site or near the site should be given. Directions of rivers, depth of lakes or craters should be measured, if possible. The approximate quantity of liquid flow to 10% should be determined. Boring should be performed on either fossil lake beds or ocean beds at 3 meters and examined for stratification or sedimentation.
Physical Properties	Heat conductivity, electrical conductivity, bearing strength, densities, hardness, color, texture and whether gas, liquid or solid.	The MKS system of units will be used and all accuracies measured to 0.1%.
Radioactivity, Nuclear Reactions and Charged Particles	Analysis of surface rocks or soil for the presence of U, Th, Lu, Sm, Rb, K and C.	The samples selected should be representative of the area in which the MEM is located. Particular attention should be given to evidence or differentiation of any type, whether leaching differentiation or gas loss due to fracture. Carbon 14 may have been intermixed with the top layer of soil, if any. The ratio of carbon 14 to carbon 12 and 13 in the atmosphere should be determined prior to sample analysis.

Measurements	Parameters	Requirements
Seasons	See Mars Orbit Parameters	
Seismicity		
A) Active Seismic Response	The depth of detonations and the time should be measured to within 0.1 sec. (See Paragraph 6.5.2.)	Approximately a 3-meter hole can be drilled and charge detonated after a set of stages (probably 4) separated by at least 1 km.
B) Passive Seismics	The onset of both waves should be measured as well as the duration.	In general, the seismometer must be mounted by experienced personnel. It may be necessary to cast platforms for the supporting structures.
Solar Radiation	The intensity and spectrum of the complete solar spectrum reaching the surface of the planet should be measured. This will include all charged particles, the magnetic fields and electromagnetic radiation extending from radio waves through X-rays.	Intensity should be measured at 0.01 cal per minute. The radio frequencies thru millimeter wavelengths should be established at one cycle per second. Thermal radiation should be measured at 10 A thru 10,000 A. The visible region should be measured at 1 A and the UV extending to the end of the atmospheric transmission to within 0.1 A.
Structure	Strata--whether sediments or volcanic; evidence for errosion; the core, mantel or crust; and the atmosphere with its clouds and dust.	Photographic evidence will be sufficient. Structure information to be correlated with the orbiting vehicle. Any evidence for change in structure should be age dated to within 1%.
Temperature Changes	Temperature changes are to be measured in °K and the rates should be established to °K per hour. The temperature changes apply to the particular time of day, season and locale in which the MEM is situated.	The requirements for temperature measurements should be met by at least 4 measurements with a probe which will not materially disturb the area in which the measurement is made. Preferably several inches of soil or rock if the heat conductivity of the soil and rock is adequate to support temperature measuring sensors.

Measurements	Parameters	Requirements
Thermal Budget	Heat measurements, temperature and temperature rate.	Heat measurements should be made to within calories per centimeter, and temperatures should be measured in °K accurate to 0.1°K. The temperature differences in the surface should be measured at the bottom of four 10-ft holes and one 40-ft hole, with the difference in temperature measured to 1 meter distance or above the bottom of the hole.
Volcanic Activity		
A) Active Volcano	The temperature of the lava should be measured and the affluence, both gas and liquid, should be analyzed for major and trace constituents. The molten rock should be analyzed for occulted gases and liquids. The solid material should be checked for presence of radioactive minerals as well as the normal constituents.	Evidence for changing temperature affluent should be sought as well as changing chemical composition from the present activity to past activity with a determination of the number of eruptions and the ages associated with these eruptions.
B) Volcanic Debris	The lava, cinders or other evidence for vulcanism should be analyzed for the chemical composition as well as for the mechanisms of weathering or erosion. The activity which may have preceded or occurred concurrently with the emission of lava should be ascertained.	Sampling techniques must be established by an experienced geologist and instructions given permitting the crew member selecting samples sufficient leeway to judge the adequacy of both the size and extent of sample areas.

C-3. IN ORBIT VENUS MEASUREMENTS AND OBJECTIVES VERSUS REQUIREMENTS

Measurements	Parameters	Requirements
Atmosphere		
a) Properties	Composition	Major constituents (1%) to accuracy of 10% in fractional composition. Identify minor (1 part on 10^6) constituents.
	Temperature profile	Temperature as function of altitude (±5°K at ± 1/2 scale height altitude accuracy).
	Pressure profile	Accuracies of 10% at altitude 0-200 km (determined to 10%).
	Density profile	10% at altitudes 0-200 km (determined to 10%).
	Temporal variations (especially diurnal)	Slow variations (changes over periods 1000 hrs).
	Latitudinal differences	In bands of 10° Lat, 0±90°.
	Ionosphere characteristics	Topside sounding for electron densities to 10% in layers located to ±10 km in alt.
	Circulation pattern	Atmospheric flow: mode (laminair or wave), magnitude (±50 km/hr), direction (±5°).
	Winds	Velocities 10 km/hr to 10% accuracy.
	Upper atmosphere processes (airglow, aurora)	Emission bands to ±10% A ; Visible glow: 1000 Rayleigh (imaging), 10R (photometric), altitudes of phenomenon to 1/2 scale height.
	Electrical characteristics (sferics, whistlers)	Visible flashes providing luminous energy 0.01 watts sec at vidicon; LF radio pulses 1 μv/m in 4 channels over frequencies

Measurements	Parameters	Requirements
b) Clouds	Composition (dust, aerosols, droplets, vapor)	Mass fraction of major constituents to 10%, particulate sizes 0.1μ ± 20%.
	Height and thickness	to 10%.
	Cloud and cloud-system patterns	Spatial configuration: resolution of 10 km in small areas, 10 Ω 200 km resolution disc coverage.
	Temperature	±2°K.
	Precipitation	Compcsition (major constituents) and measure of rate to 50%.
	Dynamics (motions within clouds, diurnal changes, etc.)	Velocities to 10%
	Windows (spectral transmission bands, all wave lengths)	Determined over predetermined portions of total spectrum from RF to UV. Measure quantity of charge to within 10%. Altitude distribution to 1 km. Probable source to be established and contribution ascertained to total.
Charged Particles	Chemical Specie and charge. Structure if any to charge particle distribution. Source such as meteors, sferics, radioactivity or solar radiation to be established.	
Chemical Elements	The elements within the atmosphere, the clouds and dust. The gases involved in the formation of the ionosphere. Both absorption and mass spectrometer techniques are to be used. If breaks in the cloud cover permit, then some surface reflection spectra are to be obtained.	The quantities of these elements are to be measured to within 100 ppm.
Chemical Reactions	Changes in atmospheric color and cloud color and structure. Changes in temperature and gaseous composition of both atmosphere and surface if possible.	Both the reflectivity and the emissivity of the clouds are to be measured to within 1%. The chemical reactions may occur only in the presence of lightning strokes or during the changes in temperature which will occur during night and day variations.
Diastrophism	Mountain and valley formations. General outlines of continently uplifts if any. Seismism.	To be obtained from maps and images.

Measurements	Parameters	Requirements
Diurnal	The changes in heating, wind velocity, cloud cover, cloud patterns and growth, precipitation, and lighting which can occur with the rotation of the planet. The changes in the ionosphere and the altitude variation of the atmosphere in general are also important.	All changes which occur with night and day are to be correlated to an accuracy of 10%.
Figure	Equatorial and polar radii. Other radii with their relation established to the plane of the ecliptic.	Measure all radii to ±5 km.
Glacier Action	Valley configurations or the solid surface material on the mountain slopes; appearance of liquids emerging from large solid surface material.	The extent of mountain slopes covered, the reflectivity of the material and the depth should be measured to within 10%. The estimates of the amount of liquid emerging, i.e., with the depth of "rivers." The mountain slopes should be measured to within 1°.
Gravity	Gravitational field, and content	To within 1 milligal.
Hydraulics	The variation in valley forms using radar techniques.	The length of these valleys which are evidence of hydraulic action should be traced from source to sink. The sink should be established whether a solid or liquid. The size of the transported material should be determined to the limits of the radar resolution.
Isotopes	Atmosphere, formation of C14. Composition ratios.	The ratios of the isotopic constituents are to be measured to within 1%.
Latitude	Determination of the equator and the poles cloud structure and wind velocities, atmospheric circulation.	The general circulation patterns of the clouds are to be measured to within 5 km, wind velocities to within 1 km per hour, temperature and pressure variations to within 1%, the atmospheric densities to 1%, changes in the ionosphere to within 10%, the magnetic field at present to within 10%.

Measurements	Parameters	Requirements
Life		
a) Macroscopic	Large forms may exist in the atmosphere; any transients in the radar reflection should be noted. Environment carbon chemistry.	Apparent size of the transient to within 1%. The velocity with which the image moved to within 1%. The radar mapping of the surface should not be stopped to track images.
b) Microscopic	The filtering of the atmosphere to detect Earth size unicellular organisms. Possible food sources: excretion material and atmosphere breathed. Microenvironment. Carbon chemistry.	Measure all life material for composition to within 0.1%. The rate of growth and reproduction should be in terms of mircroorganism weight per hour. Spectral resolution to 1 Å
c) Proto-Organic Gases	The atmosphere should be sampled for the percent ammonia, carbon dioxide, methane, water vapor and nitrogen compounds.	Measurement of the gases to within 0.1 of 1%. Composition of the compound to be determined accurately.
Magnetic Field	Both field strength and polarization.	Field strength to be established to within 1% and direction of the poles to within 1°.
Meteoroids.	Appearance of craters and radar images and the transmission of longwave radio waves on the meteor trails similar to whistlers in the Earth atmosphere.	The intensity of the ionization trails and the estimated length should be determined to within 1%. The number of impacts and the variation of these with latitude should be determined to within 10%.
Micrometeorology	Surface winds, clouds, atmospheric pressure and surface temperature or cloud temperatures with the difference in height between the lowest cloud layer and the surface (wander).	Wind velocities are to be measured to within 1 km per hour, cloud height to within 0.1 km, and the pressure variation to within 1 mb. Cloud structure, if discernible, should be photographed or radar images taken.
Mineralization	Radar reflectivity, wave contrast, (wander analysis).	Crystallization and detection using radar will be accurate to yes or no indication only. The microwave reflection should be measured to 1% intensity. Variations should also be measured to within 1%.

Measurements	Parameters	Requirements
Moments of Inertia	To be calculated from figure and rotational parameters.	
Phase Changes	Cloud structure and cloud structural changes, presence of solids or liquid on the surface; evidence for precipitation using radar, whether from cloud to cloud layer or reaching the surface.	To determine the gas to liquid temperatures to within 1% with the associated pressure. The radar images to within 0.1 km. The liquids on a surface, if any, should be identified by means of conductivity changes. Reflection intensity to within 1%.
Physical Features	Mountains, cloud structure, valleys, lakes, oceans, etc.	Their size and contiguous areas to be established within 0.1 km^2.
Physical Properties	Densities, conductivity, color, patterns, reflectivities, etc.	Physical properties to be measured to within 10%.
Rotation and Moments	Period of rotation and the axis. Nutation and precession. Variations in gravity.	Period to be measured to within 1 min. Axis to be determined to within 0.01°. Gravity to be measured to within 1 mgal.
Satellites	Orbits, shapes, distribution, masses, rotation if any, surface characteristics, dust belts if any.	Existence of satellites of diameter 10M. Determine orbit elements to 1%.
Seasons	Cloud structure variations, atmosphere circulation change.	Seasonal changes may be detected by observing the planet as it's approached with an optical telescope. One photograph every 4 hours of the planet face, from 30 days approaching the planet and 30 days receding from the planet. Mean cloud temperatures should be taken simultaneously with the photographs.
Solar Radiation	A general survey of the solar radiation reaching the planet and its atmosphere should be performed in all wavelengths. The spectrum and the intensity are to be measured, the particle flux and energy, the magnetic field polarization and intensity, the solar wind electrons, protons and alphas.	To measure the RF frequencies to within 0.1% and their intensities to 1%, radiation rigidities are also to be measured to within 0.1%, magnetic field accuracies to ±1 gamma, the direction of polarization to within 1°, the time variations of the magnetic field to 1 minute, the Rf spectrum to be measured through 20 MEV gamma radiation in selected bands.

Measurements	Parameters	Requirements
Structure	Cloud structure and patterns. Possible presence of core, mantle and crust.	To be obtained from images with resolutions to within 0.1 km. Length of fault lines to 1 km. Degree of volcanic activity. (The Earth has approximately 300 active volcanoes.)
Temperature	The temperature of cloud tops, cloud bottom, cloud centers, difference in cloud layers, surface from equator to poles, and from the lowest to the highest altitudes.	Measure all temperature to within 1°K. All temperature changes to 1°K per hour.
Thermal Budget	Both the spectrum and the intensity of all energy sources and sinks is required. The Sun, volcanic activity, radioactivity and the specific heat of the planet contribute to the thermal budget of the planet.	The thermal radiation and the distribution of the sources should be verified to within 10%. Source extent to be determined within 2%. All spectra to be measured within 1%.
Volcanic Activity	IR hot spots in the atmosphere and radar images.	Resolution of the radar for the images and the hot spot spectrum and distribution to within 1%. Correlation of the hot spot to the image to within 0.1%.

Experiment	General Requirement
1. Chemical Analysis	General assay practice sufficient. Samples should be representative of ~10 km^2
a. Representative surface materials	
b. Isotopic Ratios	
c. Radiochemical analysis (U, Th, R, etc.)	
2. Heat Flow and Downhole Temperatures	Accuracies to ±1°K per hour in 10-ft hole.
3. Core Drilling and Logging	Accuracies of 5-10% are desired 300-meter hole desired but 100-meter hole will provide usable information.
a. Elastic wave velocity	
b. Magnetic susceptibility	
c. Electric conductivity	
d. Thermal conductivity	
e. Density	
f. Porosity	
g. Remnant magnetism	
4. Surface Material Transport Studies	Study of existing features to determine modifying forces.
a. Wind velocities	
b. Particle flux and energy	
c. Origin and termination periods or ages	
d. Does or did planet surface react to loading	
e. Evidence of liquid transport	
f. Cratering phenomenon	

Experiment	General Requirements
1. Analysis for CH_4m NH_3, H_2O and H_2 a. The atmosphere b. Rock samples c. Soil samples	Atmospheric trace gases to be determined to 1 part in 10^6. Rock and soil samples to accuracies of microliters per Kg.
2. Determination of Quantity of C^{14} a. Rate of formation in the atmosphere b. Soil samples	Accuracies to 1% are desirable. For soil samples, age dating extrapolations are desirable.
3. Chemical Compositions a. Rocks and soils b. Carbon compounds c. Minerals d. Water	Titration accuracies are sufficient. Emphasis on the carbon compounds.
4. Microscopic Soil Analysis and Fossil Search	Observations for possible cell structures
5. Cultures of Soil Samples	To be determined
6. Exposure of Test Animals to Water and Soil	Two-week incubation period suffices
7. Exposure of Test Plants to Water and Soil	Yeast cultures, grasses and small shrubs. Period of 2 weeks.
8. Study of Mars Life Forms a. Viruses b. Microscopic c. Macroscopic	Growth rates. Assess compatibility and similarities to Earth life forms.
9. Age Dating a. Strontium/Rabidium b. As required	Background radioactivity must be less than 1% of that in the sample
10. Radiation Dose Monitoring	Accuracies to 1 milliroentgen

APPENDIX D

PROJECTIONS OF THE KNOWLEDGE BASE FOR THE WOODS HOLE CATEGORIES

1.1 MARS

1.1.1 GROUND RULES

By 1977 the following missions will have been completed:

1) One unmanned flyby,
2) One orbiter,
3) One soft lander,
4) Two probes or hard landers.

The Woods Hole objectives and priorities apply. These are given in Table D-1. The six major categories are Exobiology, Differentiation, Activity, Composition, History and Atmospheric Dynamics.

The state of knowledge ranges to be assigned are:

Range	Criteria
0 - 1	Data permits ambiguous answers
1 - 2	Data permits "yes" or "no" answer
2 - 3	Permits *correlation* or *degree* conclusions
3 - 4	Verifies theory. Complete.

Percentages may be derived by summing the maxima and the minima of the ranges assigned and dividing these two sums by the maximum permitted in each category, i.e., four times the number of applicable subcategories within each major category.

1.1.2 MARS--PROJECTION

CATEGORY 1 Exobiology

Life Existence

Still do not know if there is or is not life of one form or another. Range from 0 - 1.

Carbon Chemistry

Know that carbon is present but not necessarily its associated with life. Range from 0 - 1.

Table D-1: WOODS HOLE CATEGORIES VS MISSION MODE COMPLETED SCIENTIFIC QUESTIONS IN THE EXPLORATION OF MARS

PRIORITY INVESTIGATIONS	PROJECTED 1975 AVAILABLE KNOWLEDGE MARS EXPLORATION CATEGORY (1)												MISSION MODE COMPLETED (2)			
	Exo-biology		Differ-entiation		Activity		Compo-sition		History		Atmosphere Dynamics		1 Flyby	1 Orbiter	2 Probes	1 Lander
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max				
SPECIFIC QUESTIONS																
Life Existence	0	1	-	-	-	-	-	-	0	1	-	-	X	X		X
Carbon Chemistry	0	1	-	-	-	-	1	2	0	1	-	-				X
Surface Environment	2	3	2	3	2	3	1	2	0	1	-	-	X	X	X	X
Water Geology	-	-	0	1	-	-	0	1	0	1	-	-	X	X		X
Water Chemistry	-	-	0	1	-	-	0	1	0	1	-	-				X
Micrometeorology	0	1	-	-	-	-	-	-	0	1	3	4	X	X		X
BROAD EXPLORATION																
Photo Reconnaissance	0	1	2	3	2	3	3	4	2	3	1	2	X	X		
Thermal Emission Reconnaissance	0	1	1	2	1	2	1	2	1	2	2	3	X	X		
Surface Composition	1	2	1	2	1	2	3	4	2	3	1	2	X	X		X
Atmosphere Composition	4	4	-	-	0	1	1	2	1	2	3	4	X	X	X	X
IMPORTANT QUESTIONS																
Figure of Planet	-	-	3	4	3	4	-	-	0	1	-	-		X		
Magnetic Field	-	-	3	4	3	4	-	-	0	1	-	-	X	X	X	X
Seismicity	-	-	2	3	1	2	-	-	0	1	-	-	X	X		X
Mineral Composition	-	-	1	2	0	1	1	2	0	1	-	-				X
Noble Gases	-	-	-	-	-	-	3	4	1	2	-	-	X	X	X	X
Ion Sheath	-	-	-	-	3	4	3	4	-	-	3	4	X	X	X	X
TOTALS	7 32	14 32	15 40	25 40	16 40	26 40	17 44	28 44	7 60	22 60	13 24	19 24				

(1) Bar Chart Percentages Assigned:

1	0-25%	3	50-75%
2	25-50%	4	75-100%

(2) X connotates measurement made.
Includes one manned flyby.

Surface Environment

Assume the temperature range (3 - 4), moisture availability (1 - 2), food (0 - 1) and atmospheric composition (3 - 4). Gives an average range from 2 - 3.

Water Geology and Water Chemistry

Are taken as physical measurements in this case and hence not applicable.

Micrometeorology

May know the atmospheric dynamics of the planet very well but not necessarily know its relation to life. Hence a range of 0 - 1.

Photo Reconnaissance

A resolution of ±500 meter map will not give a positive answer to presence of macroscopic life. Range is 0 - 1.

Thermal Emission Reconnaissance

Resolution anticipated may permit a good thermal map but not necessarily its relation to life. Range is 0 - 1.

Surface Composition

Will know surface features but not necessarily if they can support life. Range is 1 - 2.

Atmosphere Composition

This will be known adequately. Biggest emphasis. Assign 4.

By summing the maxima and the minima assigned a range of 7 to 14 is established out of an available 32. Hence 22 to 44% of the Woods Hole questions can be answered.

CATEGORY 2 Differentiation

Life Existence

Not applicable

Carbon Chemistry

Not applicable

Surface Environment

The major physiographic and surficial features of the planet may be well identified but little can have been done to determine the permanent and variable features over a significant fraction of the surface. Some degree of permanence or change will be shown, e.g., the meteorite impact rate over the last several hundred million years. Minimum of 2 to a maximum of 3.

Water Geology and Water Chemistry

Presence of H_2O can be established but both the geology and chemistry will be open to ambiguous interpretation until extensive surface and subsurface exploration is completed. Minimum is a 0 to a maximum of 1 for both.

Micrometeorology

Not applicable

Photo Reconnaissance

Same as Surface Environments. Minimum 2 to maximum of 3.

Thermal Emission Reconnaissance

A surface map may exist but the relation to differentiation must be established using orbiter determined radii and gravitational anomalies. Range from 1 - 2 because resolution will be on the order of 1 - 2 km.

Surface Composition

Surface composition will be established but relationship to differentiation will require extensive surface exploration and correlation. Range from 1 - 2.

Atmospheric Composition

It is assumed that this determination does not apply although the case can be argued.

Figure of Planet

Ranges up to a maximum of 4 completely known. Manned flyby obtains what orbiter misses.

Magnetic Field

Again data should substantiate this. Minimum of 3 to maximum of 4.

Seismicity

Even though a natural earthquake will have been recorded the relationship to Differentiation will not have been established. Maximum of 3 and minimum of 2.

Mineral Composition

This will have been established on one spot. Greater sampling of the planet will be required. Maximum of 2 to a minimum of 1.

Noble Gases and Ion Sheath

Although established the assumption is made that these as topics are *not applicable* to differentiation per se.

The sum of the maxima and the minima assigned above establishes a range from 15 to 25 points out of 40. The percentage range is from 38 to 63%

CATEGORY 3 Activity

Life Existence and Carbon Chemistry

Are assumed not applicable.

Surface Environment

The major features will have been established but the degree to which they change will not be known for certain. A range of 2 to 3 is assigned.

Water Geology, Water Chemistry and Micrometeorology

These are not indicative of the activity existing on the planet as discussed in the Woods Hole report.

Photo Reconnaissance

Unless an active volcano is discovered, photographic evidence will not indicate activity. Must await the surface measurement of seismic, volcanic or tectonic activity. A range of 2 to 3 is assigned since some degree of past activity will be established.

Thermal Emission Reconnaissance

Because of the resolution that is anticipated from the equipment will be difficult to establish the present activity on the planet. Resolution will be on the order of 2 km. A range of 1 to 2 is considered accurate.

Surface Composition

A range from 1 to 2 is assigned. A standard for degree of activity has not been established.

Physical composition 1 - 2
Atmospheric compositions 3 - 4 } Average 1 - 2
Chemical composition 0 - 1

Atmospheric Composition

A range from 0 to 1 is assigned. It is assumed that the composition of the atmosphere will have been established but its relationship to activity existing on the planet will require more specific data.

Figure of Planet

This may well establish the degree of activity at least from a tectonic and seismic point of view. A range from 3 to 4 is assigned.

Magnetic Field

The presence of this field will most certainly have been established by this time. Hence the highest range, 3 to 4, is assigned.

Seismicity

Because some form of seismograph will be landed it will be established that seismic activity does or does not exist. The relationship of this activity to degree as related to Earth may not be established. Ranges from 1 - 2.

Mineral Composition

The mineral composition of the surface will have been at least partially established. But without greater emphasis on surface exploration the data will be for the most part ambiguous in establishing the activity of the planet. Range from 0 to 1.

Noble Gases

For the present these are assumed as irrelevant.

Ion Sheath

Since this appears intimately connected with the magnetic field it is assigned the same range, 3 to 4.

The range over which Activity is established is from 16 to 26 points out of a possible 40. The percentage range is therefore from 40 to 65.

CATEGORY 4 Composition

Life Existence

Not applicable

Carbon Chemistry

The total carbon chemistry of the planet will not have been established although yes or no answers will be available in the many categories of carbon compounds. A range from 1 to 2 is assigned.

Surface Environment

The surface environment will be fairly well established but the degree of its relationship to composition will not have been determined. Range from 1 to 2.

Water Geology

The relationship to composition will still be ambiguous, 0 to 1.

Water Chemistry

The relationship to total planet composition will still be ambiguous. A range of 0 to 1 is assigned.

Micrometeorology

Assumed not applicable

Photo Reconnaissance

The broad job will have been essentially completed. Ranges from 3 - 4.

Thermal Emission Reconnaissance

The relationship of the present thermal distribution will have been established but not the degree. Hence a range of 1 to 2 is assigned.

Surface Composition

The determination of surface composition is considered to be one of the prime results of the unmanned program. This is assigned the highest range, 3 to 4.

Atmospheric Composition

This is just a minor portion of composition as a whole and hence its relationship to the planet composition as a whole will not be firmly determined. A range from 1 to 2 is assigned.

Figure of Planet, the Magnetic Field and Seismicity

Not applicable

Mineral Composition

Mineral exploration must proceed from the surface. Hence a range from 1 to 2 is established.

Noble Gases

It is assumed that atmospheric composition will be firmly established by this time period. The relationships of the noble gases and their isotopes will be fairly well established. Noble gases are given a higher range in general because isotopic abundances can establish their relationship to total composition as a whole. Hence the range assigned is from 3 to 4.

Ion Sheath

Since the ion sheath will be fairly well established and the impact of the Earth's ion sheath will be understood it can be predicted that the contribution of the sheath to planet composition will be well understood. The range assigned is from 3 to 4.

The range over which it is anticipated that Composition is established is from 17 to 28 points out of a total of 44. The percentages range from 39 to 64.

CATEGORY 5 History

How, *Life Existence*, *Carbon Chemistry*, the *Surface Environment*, *Water Geology*, *Water Chemistry* and *Micrometeorology* have changed throughout the history of Mars will still be subjects of controversy. Hence all six will be assigned in the range from 0 to 1.

Photo Reconnaissance

Photo Recon will be complete with a resolution of 500 meters. Analysis will show some degree of age dating. (Has already been accomplished to determine the ages of some meteor craters.) Hence a range from 2 to 3 is assigned pending analysis of samples using controlled age dating techniques.

Thermal Emission Reconnaissance

Again this will be essentially complete. But other than to show that some areas are hotter than others it will not be able to draw many conclusions requiring the establishment of relationships. For this reason it has been assigned a range extending from 1 to 2.

Surface Composition

Surface composition will be fairly well established but the relative histories of specific surface areas will not be well understood. Hence a range from 2 to 3 is assigned.

Atmospheric Composition

Even though the composition of the atmosphere will have been fully determined its significance in establishing its own age or that of Mars will still be open to controversy. A landing mission in selected areas will be necessary before atmospheric evolution will be understood. The Martian atmosphere will be only the second analyzed by man. A range of 1 to 2 is assigned.

Figure of Planet, Magnetic Field, Seismicity and Mineral Composition are significant in determining the evolution of Mars. However, until a landing is made and correlation studies completed the contribution of each of these will be ambiguous. A range from 0 to 1 is assigned to each.

Noble Gases

Although well determined the changes which have undergone in determining the ratios of the isotopes and the percentage composition will require further correlation with the radioactive materials on the surface of the planet. For this reason a range of knowledge which extends from 1 to 2 has been assigned.

Ion Sheath

The history of the ion sheath will follow the history of the magnetic field and hence is considered not applicable here.

The sums of the maxima and the minima range from 22 to 7 out of a possible 60 for this category. The percent range is therefore from 12 to 37.

CATEGORY 6 Atmospheric Dynamics

Life Existence, Carbon Chemistry, Surface Environments, Water Geology and Water Chemistry are considered not applicable.

Micrometeorology

The orbiter will have been able to establish the meteorological pattern of Mars. Range is from 3 - 4.

Photo Reconnaissance

Photo recon will not have been able to detail the complicated processes involved with the complete atmospheric dynamics of Mars. It will have established cloud patterns and distribution but the complex upper atmosphere circulation with seasonal and polar-equatorial flows will not have been correlated nor dynamic theories verified. The range assigned here is from 1 - 2.

Thermal Emission Reconnaissance

Although thermal recon will be essentially complete the seasonal correlations will have been insufficient to establish advanced theories based on the information of the first orbiter. The range assigned in this case will be from 2 to 3.

Surface Composition

The correlation between the surface composition and atmospheric dynamics will not have been completed. A range from 1 - 2 is assigned.

Atmospheric Composition

Atmospheric composition models are now being formulated. It should be possible to distinguish between the several models and the effect of composition on atmospheric dynamics will be fairly well established. A range from 3 - 4 is assigned.

Figure of Planet, Magnetic Field, Seismicity, Mineral Composition and the Noble Gases are not applicable.

Ion Sheath

The interaction of the ion sheath, if any, with the Martian atmosphere will be firmly established. A range of 3 - 4 in knowledge is presumed to exist.

The complete range for atmospheric dynamics is from 13 - 19 out of a possible 24 for percentages which range from 57 - 79.

Table D-1 summarizes the projections made in these categories. A bar chart summary of the six categories is presented in Figure D-1. The unmanned planetary explorer program calls for the completion of Mars mapping with a resolution of about 500 meters. This is included for completeness. The range is from 3 - 4 or 75 - 100 percent.

1.2 VENUS

1.2.1 GROUND RULES

By 1977 the following missions will have been completed:

1) Two unmanned flybys,

2) Two probes or hard landers.

The Woods Hole objectives and priorities for Mars apply. They were not developed for Venus at the conference. These and the assigned knowledge state are summarized in Table D-2.

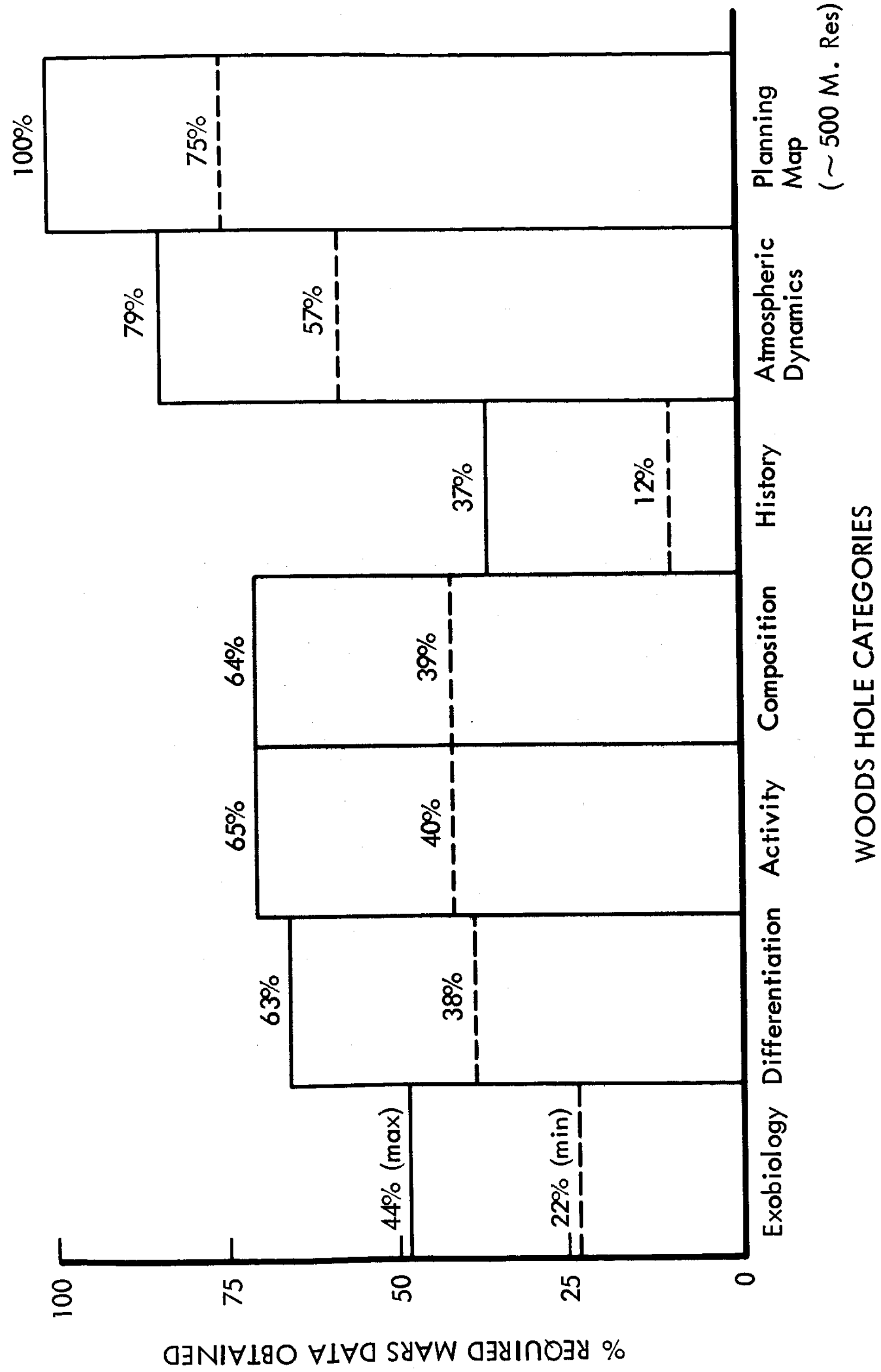


Figure D-1: PREDICTED STATE OF KNOWLEDGE - 1975

Table D-2: WOODS HOLE CATEGORIES VS MISSION MODE COMPLETED—VENUS

PRIORITY INVESTIGATIONS	PROJECTED 1975 AVAILABLE KNOWLEDGE MARS EXPLORATION CATEGORY (1)												MISSION MODE COMPLETED (2)	
	Exo-biology		Differ-entiation		Activity		Compo-sition		History		Atmosphere Dynamics		1 Flyby	2 Probes
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max		
SPECIFIC QUESTIONS														
Life Existence	0	1	-	-	-	-	-	-	0	1	-	-	X	
Carbon Chemistry	0	1	-	-	-	-	0	1	0	1	-	-		
Surface Environment	1	2	1	2	1	2	0	1	0	1	-	-	X	X
Water Geology	-	-	0	1	-	-	0	0	0	1	-	-	X	
Water Chemistry	-	-	0	1	-	-	0	1	0	1	-	-		
Micrometeorology	0	1	-	-	-	-	-	-	0	1	1	2	X	
BROAD EXPLORATION														
Radar Reconnaissance	0	1	1	2	2	3	0	1	1	2	1	2	X	
Thermal Emission Reconnaissance	0	1	1	2	1	2	1	2	1	2	1	2	X	
Surface Composition	0	1	0	1	1	2	0	1	0	1	0	1	X	
Atmosphere Composition	3	4	0	1	0	1	1	2	0	1	3	4	X	X
IMPORTANT QUESTIONS														
Figure of Planet	-	-	0	2	2	3	0	1	0	1	-	-		
Magnetic Field	-	-	3	4	3	4	0	1	0	1	-	-	X	X
Seismicity	-	-	0	1	0	1	0	1	0	1	-	-	X	
Mineral Composition	-	-	0	1	0	1	0	1	0	1	-	-		
Noble Gases	-	-	0	1	-	-	3	4	0	1	-	-	X	X
Ion Sheath	-	-	-	-	3	4	1	2	-	-	3	4	X	X
TOTALS	$\frac{4}{32}$	$\frac{12}{32}$	$\frac{6}{48}$	$\frac{19}{48}$	$\frac{13}{40}$	$\frac{23}{40}$	$\frac{6}{56}$	$\frac{19}{56}$	$\frac{2}{60}$	$\frac{17}{60}$	$\frac{9}{24}$	$\frac{15}{24}$		

(1) Bar Chart Percentages Assigned: 1---0-25% 3---50-75%
2---25-50% 4---75-100%

(2) X connotates measurement made.

The state of knowledge ranges to be assigned are:

Range	Criteria
0 - 1	Data permits ambiguous answers
1 - 2	Data permits "yes" or "no" answer
2 - 3	Permits correlation or degree conclusions
3 - 4	Verifies theory. Complete

Percentages may be derived by summing the maxima and the minima of the ranges assigned and dividing these two sums by the maximum permitted in each category, i.e., 4 times the number of applicable subcategories within each major category.

1.2.2 VENUS--PROJECTION WOODS HOLE CATEGORIES

CATEGORY 1 Exobiology

Life Existence

Still do not know if there is or is not life of one form or another. Range from 0 - 1.

Carbon Chemistry

Know that carbon is present but not necessarily its association with life. Range from 0 - 1.

Surface Environment

Assume the temperature range (1-2), moisture availability (1-2), food (0-1) and atmospheric composition (2-3). Gives an average range from 1 - 2.

Water Geology and Water Chemistry

Are taken as physical measurements in this case and hence not applicable.

Micrometeorology

May know the atmospheric dynamics of the planet very well but not necessarily know its relation to life. Hence a range of 0 - 1.

Photo Reconnaissance

A resolution of ± 500 meter flyby map will not give a positive answer to presence of macroscopic life. Range is 0 - 1.

Thermal Emission Reconnaissance

Resolution anticipated may permit a thermal map but not necessarily its relation to life. Range is 0 - 1.

Surface Composition

Still will not know surface features but not necessarily if they can support life. Range is 0 - 1.

Atmosphere Composition

This will be known adequately. Biggest emphasis. Assign 3 - 4.

By summing the maxima and the minima assigned a range of 4 - 12 is established out of an available 32. Hence 13 - 38% of the Woods Hole questions can be answered.

CATEGORY 2 Differentiation

Life Existence

Not applicable

Carbon Chemistry

Not applicable

Surface Environment

The major physiographic and surficial features of the planet will not be identified and little can have been done to determine the permanent and variable features over a significant fraction of the surface. Some degree of permanence or change will be shown, e.g., presence or absence of a precipitate at the poles will be established. Minimum of 1 to a maximum of 2.

Water Geology and Water Chemistry

Presence of H_2O can be established but both the geology and chemistry will be open to ambiguous interpretation until extensive surface and subsurface exploration is completed. Minimum is a 0 to a maximum of 1 for both.

Micrometeorology

Not applicable

Radar Reconnaissance

Same as Surface Environments. Minimum 1 to maximum of 2.

Thermal Emission Reconnaissance

A partial surface map may exist but the relation to differentiation must be established using orbiter determined radii and gravitational anomalies. Range from 1 - 2.

Surface Composition

Surface physical composition will be partially established but relationship to differentiation will require extensive exploration and correlation. Range from 0 - 1.

Atmospheric Composition

The relation to differentiation will not have been established 0 - 1.

Figure of Planet

Ranges up to a maximum of 2 in this instance. May have established two radii at different angles.

Magnetic Field

Again data should substantiate this. Minimum of 3 to maximum of 4.

Seismicity

No natural earthquakes will have been recorded. The relationship to differentiation will not have been established. Maximum of 1 and minimum of 0.

Mineral Composition

This may have been established on one spot. Greater sampling of the planet will be required. Maximum of 1 to a minimum of 0.

Noble Gases

These will be established but relationship to differentiation is not known. Range assigned is 0 - 1.

Ion Sheath

Not related to this topic.

The sum of the maxima and the minima assigned above establishes a range from 6 to 19 points out of 48. The percentage range is from 13 to 40%.

CATEGORY 3 Activity

Life Existence and Carbon Chemistry

Are assumed not applicable.

Surface Environment

Some major features will have been established but the degree to which they change will not be known for certain. A range of 1 - 2 is assigned.

Water Geology, Water Chemistry and Micrometeorology

These are not indicative of the activity existing on the planet as discussed in the Woods Hole report.

Radar Reconnaissance

Unless an active volcano is discovered, radar evidence will not indicate activity on the surface. Churning clouds may be indicative but surface measurements of seismic, volcanic or tectonic activity are essential. A range of 2 - 3 is assigned since some degree of past activity will be established.

Thermal Emission Reconnaissance

Because of the area coverage and resolution that is anticipated from the equipment it will be difficult to establish the present activity on the planet. A range of 1 - 2 is considered accurate.

Surface Composition

A range from 1 - 2 is assigned. A standard for degree of activity has not been established.

Physical composition 1 - 2
Atmospheric composition 3 - 4 } Average 1 - 2
Chemical composition 0 - 1

Atmospheric Composition

A range from 0 - 1 is assigned. It is assumed that the composition of the atmosphere will have been established but its relationship to activity existing on the planet will require more specific data.

Figure of Planet

This may well establish the degree of activity at least from a tectonic and seismic point of view but two radii are insufficient. A range from 2 - 3 is assigned.

Magnetic Field

The presence of this field will most certainly have been established by this time. Hence the highest range, 3 - 4, is assigned.

Seismicity

Because some form os seismograph has not been landed it cannot be established that seismic activity does or does not exist. The relationship of this activity to degree as related to Earth may not be established. Ranges from 0 - 1.

Mineral Composition

The mineral composition of the surface will have been at least partially established. But without greater emphasis on surface exploration the data will be for the most part ambiguous in establishing the activity of the planet. Range from 0 - 1.

Noble Gases

For the present these are assumed as irrelevant.

Ion Sheath

Since this appears intimately connected with the magnetic field it is assigned the same range, 3 - 4.

The range over which Activity is established is from 13 to 23 points out of a possible 40. The percentage range is therefore from 32 - 58.

CATEGORY 4 Composition

Life Existence

Not applicable

Carbon Chemistry

The total carbon chemistry of the planet will not have been established although yes or no answers will be available. A range from 0 - 1 is assigned.

Surface Environment

The surface environment will be poorly established and the degree of its relationship to composition will not have been determined. Range from 0 - 1.

Water Geology

The relationship to composition will not be established at all, 0 is the highest assignment.

Water Chemistry

The relationship to total planet composition will still be ambiguous. A range of 0 - 1 is assigned.

Micrometeorology

Assumed not applicable.

Radar Reconnaissance

The broad job will have been essentially started only. Ranges from 0 - 1.

Thermal Emission Reconnaissance

The relationship of the present thermal distribution will have been established but not the degree. Hence a range of 1 - 2 is assigned.

Surface Composition

The determination of surface composition is one of the prime results of a surface program. This is assigned the lowest range, 0 - 1.

Atmospheric Composition

This is just a minor portion of composition as a whole and hence its relationship to the planet composition as a whole will not be firmly determined. A range from 1 - 2 is assigned.

Figure of Planet, the Magnetic Field and Seismicity

Ranges from 0 - 1 on all three.

Mineral Composition

Mineral exploration must proceed from the surface. Hence a range from 0 - 1 is established.

Noble Gases

It is assumed that atmospheric composition will be firmly established by this time period. The relationships of the noble gases and their isotopes will be fairly well established. Nobel gases are given a higher range in general because isotopic abundance can establish their relationship to total composition as a whole, hence the range assigned is from 3 - 4.

Surface Composition

Surface Composition will be poorly established and the relative histories of specific surface areas can not be understood. Hence a range from 0 - 1 is assigned.

Atmospheric Composition

Even though the composition of the atmosphere will have been fully determined its significance in establishing its own age or that of Venus will still be open to controversy. A landing mission in selected areas will be necessary before atmospheric evolution will be understood. The Venusian atmosphere will be only the third analyzed by man. A range of 1 - 2 is assigned.

Figure of Planet, Magnetic Field, Seismicity and Mineral Composition are significant in determining the evolution of Venus. However, until a landing is made and correlation studies completed the contribution of each of these will be ambiguous. A range of from 0 - 1 is assigned to each.

Noble Gases

Although well determined the changes which have undergone in determining the ratios of the isotopes and the percentage composition will require further correlation with the radioactive materials on the surface of the planet. For this reason a range of knowledge which extends from 0 - 1 has been assigned.

Ion Sheath

The history of the Ion Sheat will follow the history of the magnetic field and hence is considered not applicable here.

The sums of the maxima and the minima range from 12 - 17 out of a possible 60 for this category. The percent range is therefore from 3 - 28.

CATEGORY 6 Atmospheric Dynamics

Life Existence, Carbon Chemistry, Surface Environments, Water Geology and Water Chemistry are considered not applicable.

Micrometeorology

The flybys will not have been able to establish the meteorological patterns of Venus. Range is from 1 - 2.

Radar Reconnaissance

Radar Reconnaissance will not have been able to detail the complicated processes involved with the complete atmospheric dynamics of Venus. It will have established cloud patterns and distribution but the complex upper atmosphere circulation with seasonal and polar-equatorial flows will not have been correlated nor dynamic theories verified. The range assigned here is from 1 - 2.

Thermal Emission Reconnaissance

Thermal Reconnaissance will be in the initial stages only. The seasonal correlations will have been insufficient to establish theories based on the information of the first flyby. The range assigned in this case will be from 1 - 2.

Surface Composition

The correlation between the surface composition and atmospheric dynamics will not have been completed. A range from 0 - 1 is assigned.

Ion Sheath

Since the ion sheath will be fairly well established and the impact of the Earth's ion sheath will be understood it can be predicted that the contribution of the sheath to planet composition will be partially understood. The range assigned is from 1 - 2.

The range over which it is anticipated that Composition is established is from 6 - 19 points out of a total of 56. The percentages range from 11 - 34.

CATEGORY 5 History

How Life Existence, Carbon Chemistry, the Surface Environment, Water Geology, Water Chemistry and Micrometeorology have changed throughout the history of Mars will still be subjects of controversy. Hence all six will be assigned in the range from 0 - 1.

Radar Reconnaissance

Radar Reconnaissance will be started with a resolution of 500 meters. Analysis will show some degree of age dating. Hence a range from 1 - 2 is assigned pending analysis of samples using controlled age dating techniques.

Thermal Emission Reconnaissance

Again this will be essentially in its initial stages. And other than to show that some areas are hotter than others it will not be able to draw many conclusions requiring the establishment of relationships. For this reason it has been assigned a range extending from 1 - 2.

Atmospheric Composition

Atmospheric Composition models are now being formulated. It should be possible to distinguish between the several models and the effect of composition on atmospheric dynamics will be fairly well established. A range from 3 - 4 is assigned.

Figure of Planet, Magnetic Field, Seismicity, Mineral Composition and the Noble Gases are not applicable.

Ion Sheath

The interaction of the ion sheath, if any, with the Martian atmosphere will be firmly established. A range of 3 - 4 in knowledge is presumed to exist.

The complete range for atmospheric dynamics is from 9 - 15 out of a possible 24 for percentages which range from 38 - 63.

A bar chart summary of the six categories is presented in Figure D-2. The Voyager program calls for the initial radar mapping of Venus with a resolution of about 500 meters. This is included for completeness. The range is from 0 - 1 or 0 - 25%.

1.3 THE SUN

1.3.1 GROUND RULES

By 1977 the following missions will have been completed:

1) The OSO,
2) The Sunblazer,
3) The AAP.

1.3.2 THE SUN--PROJECTIONS

The predicted state of knowledge for the Sun in 1975 has been developed using the Woods Hole categories. In practically every case, our knowledge of the Sun's surface extends to the point where theory and theoretical considerations are meaningful. It should be emphasized that these categories are confined primarily to the surface features of the Sun. This suggests that our knowledge of the Sun cannot be complete until investigations into the central core of the Sun can be made. Neutrino astronomy offers some hope that this will be possible along with instrumentation or telescopic viewing into the Sun spots. The projections for the Woods Hole categories are summarized in Table D-3, and graphed in Figure D-3.

1.4 THE PLANETS

1.4.1 PLANETS--GROUND RULES

The programs completed are:

1) The OAO,
2) The OSO,
3) The AAP.

1.4.2 PLANETS--PROJECTION

The predicted state of the knowledge for 1975 indicates that our knowledge decreases as the distance of the planet from the Sun increases. The categories indicate that for only two planets, Mercury and Jupiter, is there sufficient knowledge to determine which additional measurements should be made to further our investigation of these planets. Saturn, Uranus and Neptune all lie in the 25 - 50% knowledge state. This implies that it may be possible to make meaninful measurements upon which to base theories, origin and evolution. Pluto remains an enigma. Summarized in Table D-4 and graphed in Figure D-4.

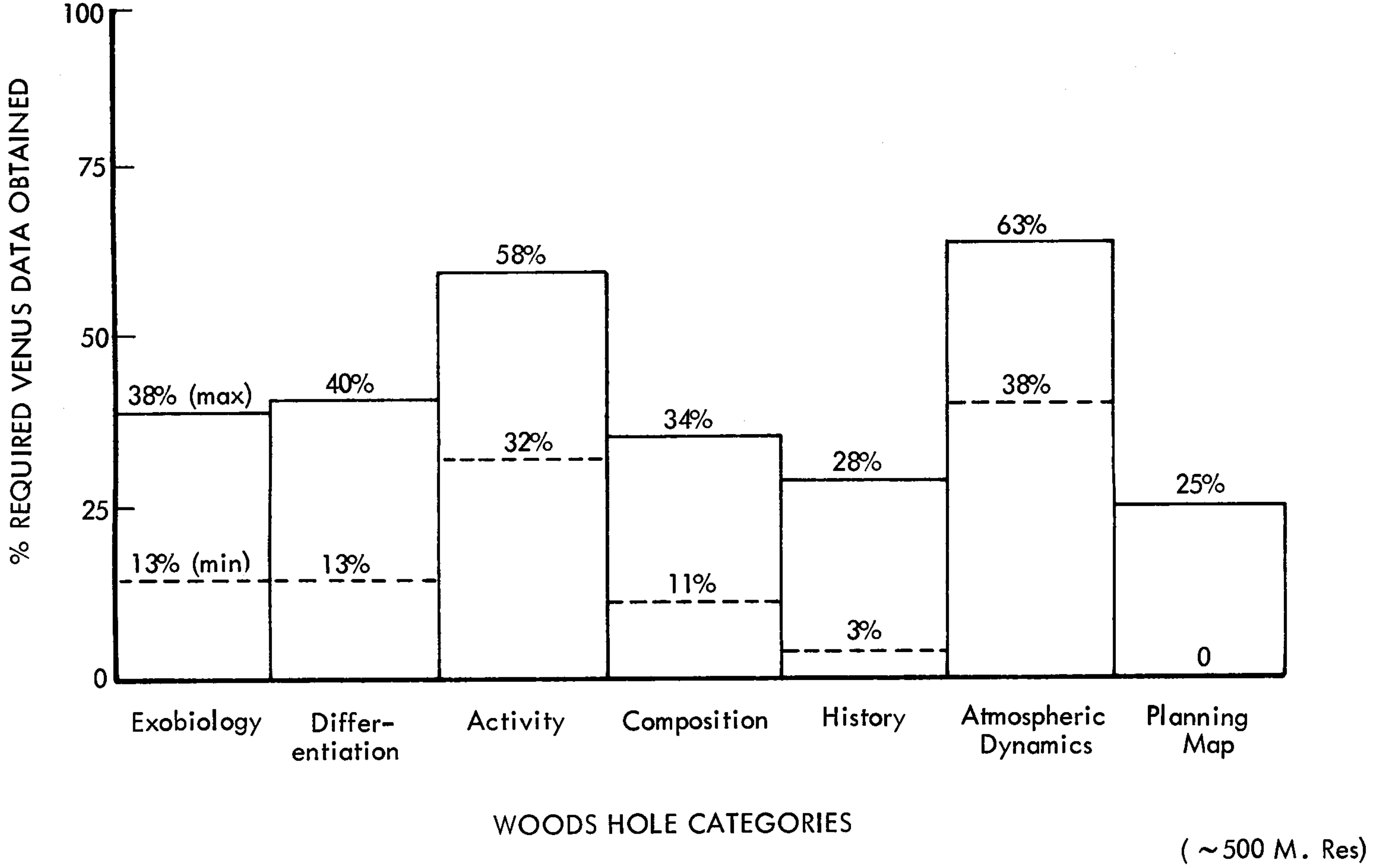


Figure D-2: PREDICTED STATE OF KNOWLEDGE — 1975

Table D-3: PROJECTED 1975 AVAILABLE KNOWLEDGE — SUN (WOODS HOLE CATEGORIES)

IMPORTANT SPECIFIC QUESTIONS	General		Photo-Sphere		Chromo-sphere		Corona		Flares		Sun-Spots		Plages & Faculae		Promin-ences	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Model	2	3	2	3	2	3	3	4							2	3
Size	3	4	3	4	3	4					3	4			3	4
Structure	1	2	3	4	3	4	3	4	3	4	3	4	2	4	3	4
Origin & History	0	2														
Sphetral Interpretation	1	3			2	3	2	3	2	3	1	2			2	3
Aerodynamic Phenomena	1	3	1	2	1	2			3	4	1	2				
Temp. Gradients			1	2	1	2	3	4					1	2	1	2
Sources & Mechanisms	3	4	1	3	1	3	3	4	2	4	1	2			3	4
Energy Transfer Process	1	2			1	2	1	2	1	2	1	2			1	2
Wave & Photon Phenom.	3	4			1	2	3	4			3	4				
Particle Prod & Emiss.	2	3			1	2	1	2	1	2						
Periodicities	3	4			2	3	2	3			3	4	2	3		
Magnetic Relationships	1	2	1	2	2	3	3	4	3	4	2	3	2	3	3	4
Interrelationships	1	2	2	3	2	3	2	3	2	3	0	3	2	3	3	4
Totals	22	38	14	23	22	36	26	37	17	26	18	30	9	15	21	30
Possible Max.	52	52	32	32	52	52	44	44	32	32	40	40	20	20	36	36
Percent	42	73	44	72	42	69	59	84	53	81	45	75	45	75	58	83

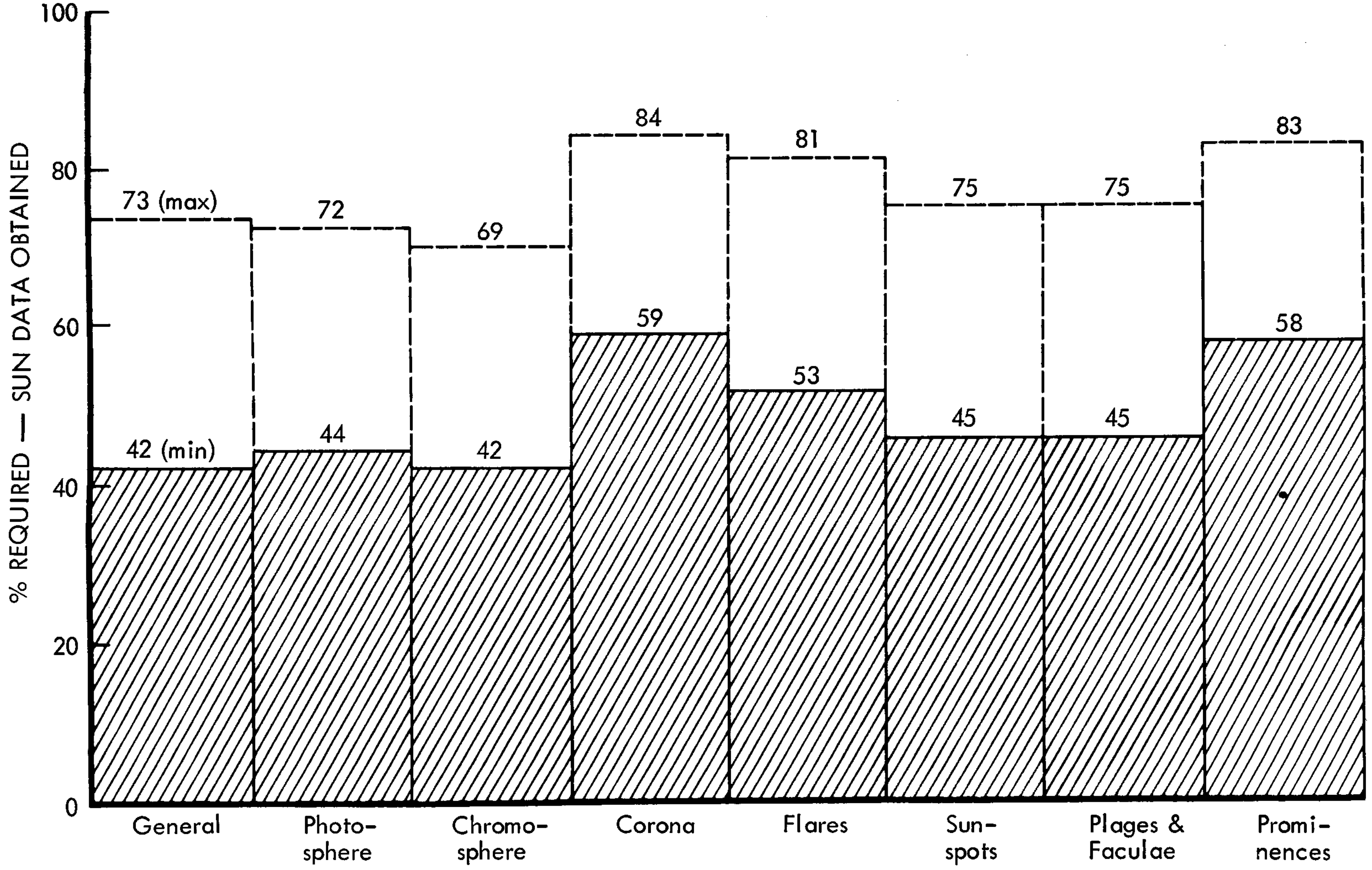
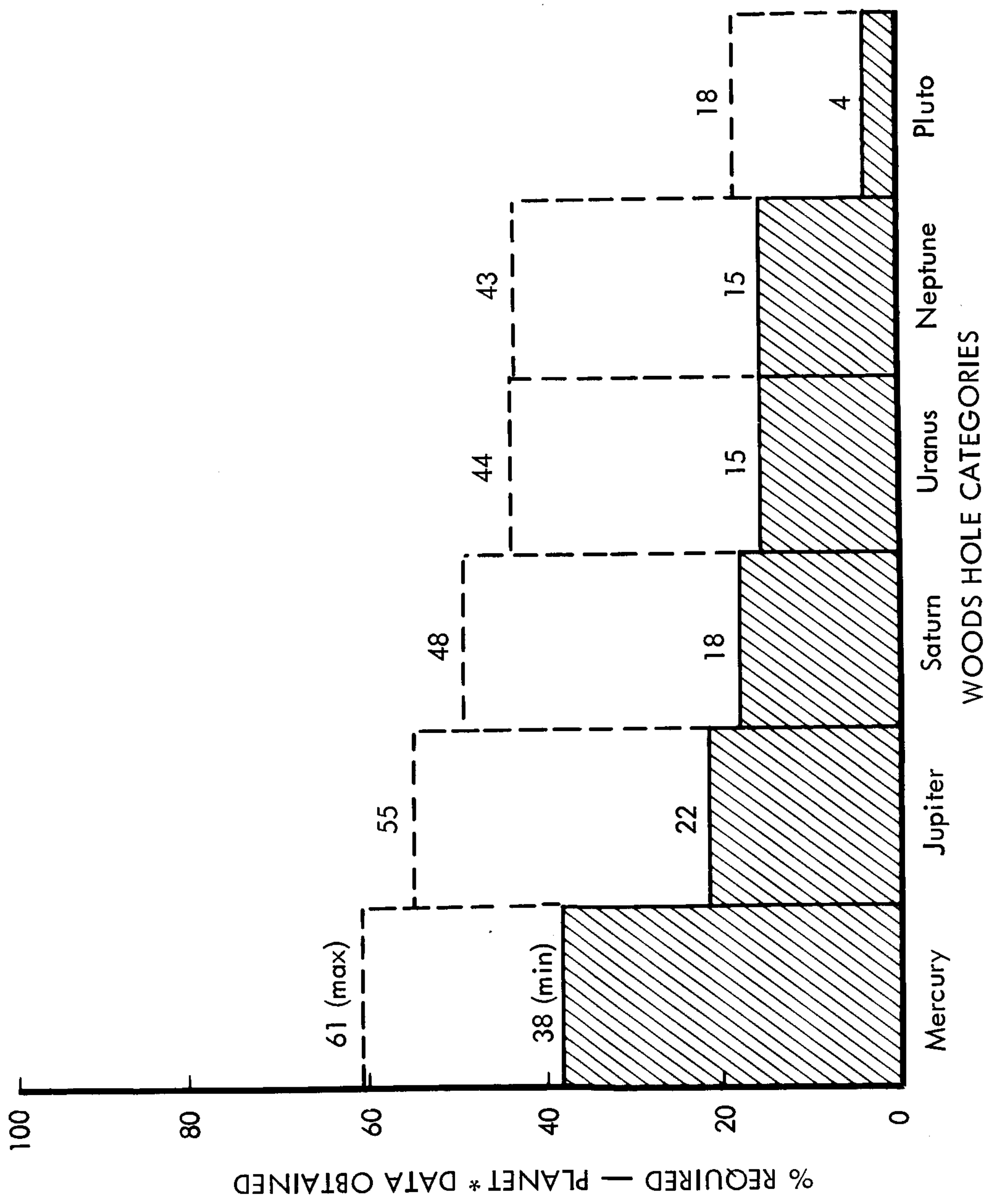


Figure D-3: WOODS HOLE CATEGORIES

Table D-4: PROJECTED 1975 AVAILABLE KNOWLEDGE — PLANETS* (WOODS HOLE CATEGORIES)

SPECIFIC QUESTIONS	Mercury		Jupiter		Saturn		Uranus		Neptune		Pluto	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Composition, Etc.												
Composition	1	2	0	2	0	2	0	2	0	2	0	1
Structure	0	1	0	1	0	1	0	1	0	1	0	0
Chemical Differentiation	0	1	0	1	0	1	0	1	0	1	0	0
Spectral Phenomena	2	3	2	3	2	3	1	2	1	2	0	1
Energy Release Mechanism	2	3	1	2	0	1	0	1	0	1	2	3
Exobiology	0	1	0	2	0	1	0	1	0	1	0	1
Dynamics												
Temperature Gradients	1	2	0	2	0	1	0	1	0	1	0	0
Mass Transport	1	2	0	2	0	1	0	1	0	1	0	0
Atmosphere Circulation	3	4	1	2	1	2	1	2	1	2	0	1
Magnetic Fields												
Mechanism	1	2	1	2	1	2	1	2	1	2	0	0
Structure	1	2	1	2	0	1	0	1	0	1	0	0
Variability	1	2	0	1	0	1	0	1	0	1	0	0
Rad. Belt Mechanisms	2	3	0	1	0	1	0	1	0	1	0	0
Curious Features												
Causes	1	2	0	2	0	2	0	0	0	0	0	0
Uniqueness			2	3	2	3	0	1	0	1	0	1
Satellites												
Origins			0	2	0	2	0	2	0	2		
Orbital Anomalies			0	1	0	1	0	2	0	1		
Interactions			1	2	1	2	1	2	1	2		
Environment												
Solar Wind	3	4	1	2	0	1	0	1	0	1	0	1
Solar Cycle Influence	3	4	1	2	0	1	0	1	0	1	0	1
Photochemistry	3	4	1	2	1	2	1	2	1	2	0	1
General												
Radii	3	4	3	4	3	4	3	4	3	4	1	2
Non-Thermal Radiation	3	4	2	3	2	3	2	3	2	3	0	1
Rotational Causes	2	3	0	1	0	1	0	1	0	1	0	0
Formation by Accretion	0	1	0	1	0	1	0	1	0	1	0	1
Tidal Interactions	2	3	2	3	2	3	2	3	2	3	0	1
Density	3	4	3	4	3	4	3	4	3	4	1	2
Totals	38	61	22	55	18	48	15	44	15	43	4	18
Possible Max.	92	92	108	108	108	108	108	108	108	108	96	96
Percent	35	66	20	50	17	44	14	41	14	40	4	19

*Excludes Venus, Earth & Mars.



* Excludes Venus, Earth and Mars

Figure D-4: PREDICTED PERCENT OF WOODS HOLE QUESTIONS ANSWERED — PLANETS

These states of knowledge are not comparable to those developed for the IMISCD program. Such comparisons in general would only reveal the near ambiguity of our knowledge concerning these planets and the general lack of directed programs with planned experiments within the 1967 to 1975 time period.

1.5 SMALL OBJECTS

1.5.1 SMALL OBJECTS AND FIELDS--GROUND RULES

These will not have had specific missions completed for them. However, some information will be gathered during the in-transit phases of other missions, the OSO, the AAP and several Explorers.

1.5.2 SMALL OBJECTS--PROJECTIONS

The small objects--asteroids, comets, satellites, meteoroids and dust--are on the whole better understood than the planets themselves. The reason for this is that meteoroids and dust enter the atmosphere of the Earth. We have a satellite, and the planet Mars has two satellites, permitting us to study these at close hand; while comets enter the inner part of the solar system periodically. Least is known about the asteroids which, in general, range from a few feet in diameter to several hundreds of miles. For the most part, these irregularly shaped objects have unknown parameters and appear to excite little general interest. The projections for these are summarized in Table D-5 and Figure D-5.

1.6 FIELDS

The fields in the solar system are the only measurements and observations which tie the solar system together as a whole. The functions of the gravitational field were the first to be measured and defined, and our state of knowledge is indicative of the effort in this area (see Table D-6 and Figure D-6). The interplanetary magnetic field is the second of these to be discovered and our knowledge of it indicates this fact. The elevtric field itself--and we can't have the magnetic field with the potential--shows the lack of attention in this case. The interactions between electromagnetic radiation and gravity have been established; however, the interactions have not been sufficiently investigated to determine the evolution of these fields. Note that these projections are based on the questions documented during the Woods Hole conference and the unmanned interplanetary programs proposed to answer these.

Table D-5: PROJECTED 1975 AVAILABLE KNOWLEDGE — SMALL OBJECTS (WOODS HOLE CATEGORIES)

SPECIFIC QUESTIONS	Asteroids		Comets		Satellites		Meteoroids		Dust	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Class	2	3	2	3						
Size, Distr. & Shape	2	3	2	3			1	2	1	2
Struct. & Mech. Prop.	1	2	1	2	1	2			2	3
Age	0	1	0	1	1	2				
Origin & History	0	1	0	1	1	2	0	1	0	1
Optical Properties	1	2							1	2
Orbital Parameters	3	4	2	3	3	4	2	3	2	3
Rotational Parameters	0	1	0	1	1	2				
Composition-Physical	0	1	0	2	1	2	3	4	3	4
-Chemical	0	1	1	3	0	1	2	4	3	4
-Mineral	0	1								
-Isotope	0	1	0	1						
Encounter Data	0	1			0	1			0	2
Energy Change	1	2	0	2	2	3	1	3		
Temperatures			0	2						
Fields			0	2					1	2
Ionization Process			1	3						
Changes of State			1	2						
Tidal Interactions	1	2	2	3						
Totals	11	26	12	34	10	19	9	17	13	23
Possible Max.	60	60	64	64	36	36	24	24	36	36
Percent	18	43	19	53	28	53	38	71	36	64

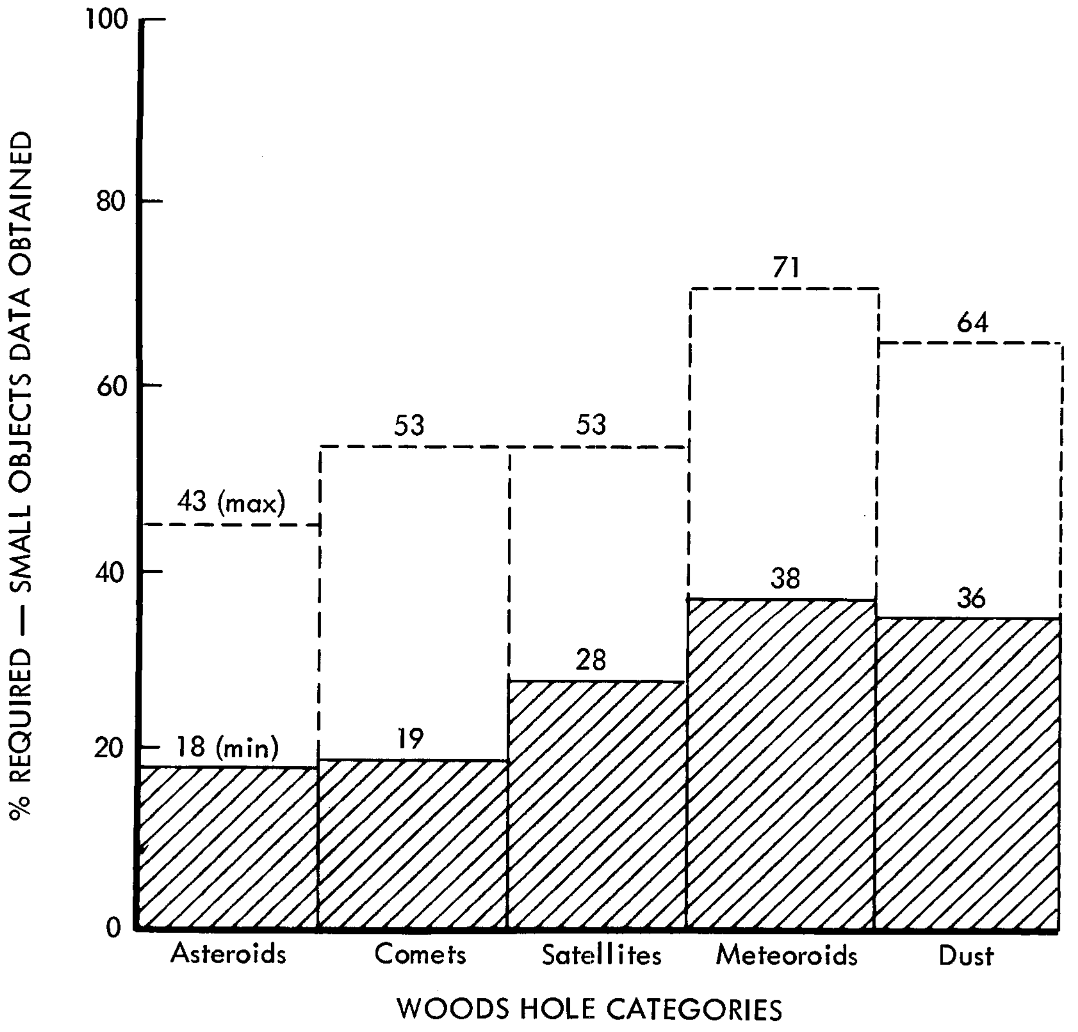


Figure D-5: PREDICTED PERCENT OF WOODS HOLE QUESTIONS ANSWERED — SMALL OBJECTS

Table D-6: PROJECTED 1975 AVAILABLE KNOWLEDGE — FIELDS (WOODS HOLE CATEGORIES)

SPECIFIC QUESTIONS

	Magnetic		Electric		Gravita-Tional		Inter-Actions	
	Min	Max	Min	Max	Min	Max	Min	Max
Solar	1	2	1	2	3	4		
Planetary								
Mercury	0	2	0	0	2	3	0	1
Venus	1	2	0	0	2	3	0	1
Earth	3	4	2	3	3	4	3	4
Mars	2	3	0	0	2	3	3	4
Jupiter	1	2	0	0	2	3	0	1
Saturn	1	2	0	0	2	3	0	1
Uranus	0	2	0	0	2	3	0	1
Neptune	0	2	0	0	2	3	0	1
Pluto	0	2	0	0	1	2	0	1
Satellites	1	2	0	0	1	2	0	1
Interplanetary	2	3	0	0	1	2	0	1
Galactic	1	2	0	0	0	1	0	0
Extra-Galactic	1	2	0	0	0	1	0	0
Totals	14	32	3	5	23	37	6	17
Possible Max.	56	56	56	56	56	56	52	52
Percent	25	57	5	20	41	66	12	33

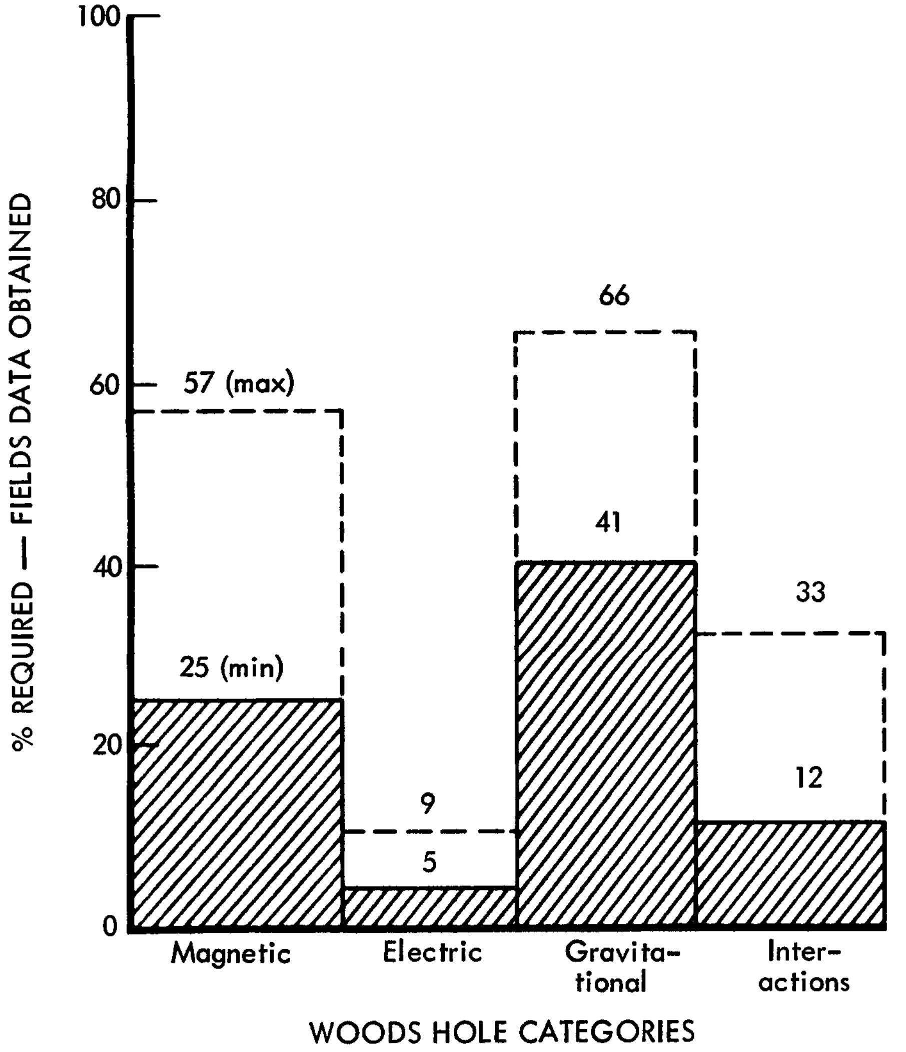


Figure D-6: PREDICTED PERCENT OF WOODS HOLE QUESTIONS ANSWERED — FIELDS

APPENDIX E

BACK CONTAMINATION

1.0 INTRODUCTION

Back contamination can be defined as contamination of the terrestrial environment by extraterrestrial organisms or biologically active materials. The potential hazards of such contamination are caused by the possible introduction of pathogenic agents or hazardous materials that can adversely modify the earth's ecological system. While this potential contamination problem appears most critical for planetary missions due to the planetary environments, it should not be ignored when considering Lunar exploration. The latter statement is supported by many of the advisory groups that have been established to consider back contamination. The following is an excerpt from a report submitted by Space Research, Directions for the Future, 1965, Woods Hole, Massachusetts.

> The Working Group agreed with the recommendations of the 1964 study group (Space Science Board Conference on Potential Hazards of Back Contamination from the Planets, February 19, 1965). Like the previous study group, the 1965 Group believes that the hazards are small but the consequences of misjudgment are potentially catastrophic. The Group agrees that safeguards should be incorporated into the Apollo operation.
>
> Quarantine regulations should be designed to be compatible with the scientific goals of extraterrestrial missions. Samples to be tested for biological activity must not be treated so drastically as to destroy that activity for research purposes. Provision must be made to give experimenters access to the samples as soon as possible. *Screening procedures for biological study and pathogenicity should be confined to modest aliquots of the samples.* Thus, stringent precautions can minimize the hazard of back contamination, yet remain compatible with scientific needs for access to samples. Close consultation between the NASA and the U. S. Public Health Service will be required.

The problems of developing appropriate screening procedures to insure the safety of terrestrial life are many. Although it is generally felt that, on a molecular level, more similarities than differences exist among life forms, it is recognized that differences do exist. Therefore, one is faced with the problem of selecting a test program that will include a representative sample of terrestrial life. If, armed with the information available today, we admit to the difficulty of such a task, we can then proceed to outline a program that will provide some answers and some insight into the biological activity of an extraterrestrial sample.

We assume that anything macroscopic can usually be controlled or avoided because we can see it and, therefore, exercise "stay away" action if we know it to be dangerous. This avoidance action applies to both terrestrial and extraterrestrial material. Most danger--in the form of biological antagonism--is found in cases of microscopic invaders--we can't see them and therefore, recognition is difficult. This microscopic threat is usually posed to man and other animals and plants in the form of microorganisms. If the above assumptions are correct, then it appears that the best approach to the back contamination problem is to consider the biological activity of any extraterrestrial life form in terms of microorganisms since they appear to be the most critical case.

2.0 SIGNIFICANT PROBLEM AREAS

Four significant problems have been identified that must be solved in order to assure a successful mission, obtain and maintain extraterrestrial samples and prevent back contamination.

A. The determination of the biological activity of extraterrestrial samples on terrestrial life.

   The biological activity of any extraterrestrial sample must be shown not to be harmful by screening a representative spectrum of terrestrial life.

B. Prevention of pathogenic effects on scientists while obtaining samples.

   Techniques need to be developed that will insure no contamination of scientists by extraterrestrial samples. A worst-case situation should be assumed about the biological nature of the samples.

   1. Isolation: use of mechanical device to keep the sample and the collector separated; improvement of techniques such as now found in remote handling of radioactive material.

   2. Disinfection: the sterilization of any mechanical collecting device will be required before reentering the spacecraft; sterilization of anything that has come in contact with extraterrestrial samples.

   But, what kills extraterrestrial life? It will be necessary to establish methods to insure sterilization of extraterrestrial life. (Determining sterility of unknown systems may be difficult since the detection of exotic life under all conditions is difficult. Methods based on the destruction of molecular organization--such as heat treatment--are suggested.)

C. Maintenance of samples in an environment that simulates the environment from which the samples were obtained.

Correct storage facilities will have to be available so that samples will remain in their "natural condition" until being tested.

Although we are only concerned with the effects of any extraterrestrial sample on terrestrial life, and this effect will be measured in a terrestrial environment, it is desirable to prevent any alteration in the sample before exposure to a life test system.

Reliable measurements of extraterrestrial environments will be necessary in order to establish environmental parameters for maintaining biological samples.

D. Prevention of pathogenic effects on experimenters while performing initial screening tests.

Initial testing should be conducted assuming, again, a worst-case situation. As stated above, isolation and disinfection is the safest approach. Until reliable data from initial screening research is obtained, *all samples must be approached as if they were highly infectious and pathogenic.*

If the initial data demonstrates the relative safety of the samples, then the additional testing may be conducted using standard biological procedures followed by decontamination practices. Standard biological handling procedures will greatly decrease the amount of time investigators will need to test the effects of extraterrestrial samples on terrestrial life.

3.0 BIOLOGICAL SCREENING CONSIDERATIONS

The virulence of any organism for a particular animal--and the nature of the symptoms produced in such infections--often are characteristics of great differential value. The isolation of many human pathogens is facilitated by the inoculation of susceptible animals and the recovery of the organism from the blood or from the specific lesions produced in the various organs. An outline of the types of tests that may be used is presented in Figure E-1.

A. In Vivo Testing

1. Test Considerations for Animals:

   a) Selection of test animals - must be an established strain so that normal and abnormal responses are able to be distinguished. Experimental animals used successfully in terrestrial laboratories for elucidating pathogenic responses are white mice, rabbits, guinea pigs, and monkeys. It is desirable to include animals that have a short gestation period in order to test the effects of an infectious agent on embryonic development.

   b) Portal of entry - method of sample inoculation. VERY IMPORTANT! The communicability, invasiness, and killing power of an organism may be profoundly altered by the portal of entry into the body.

      Injections - cutaneous, subcutaneous, intraperitoneal, intravenous, intramuscular

      Inhalation - aerosols

      Ingestion

   c) Symptoms - dermatological changes; rashes, inflamation, lesions.

      Physiological - respiration, senses, weakness, fever, chills, paralysis, nausea, etc.

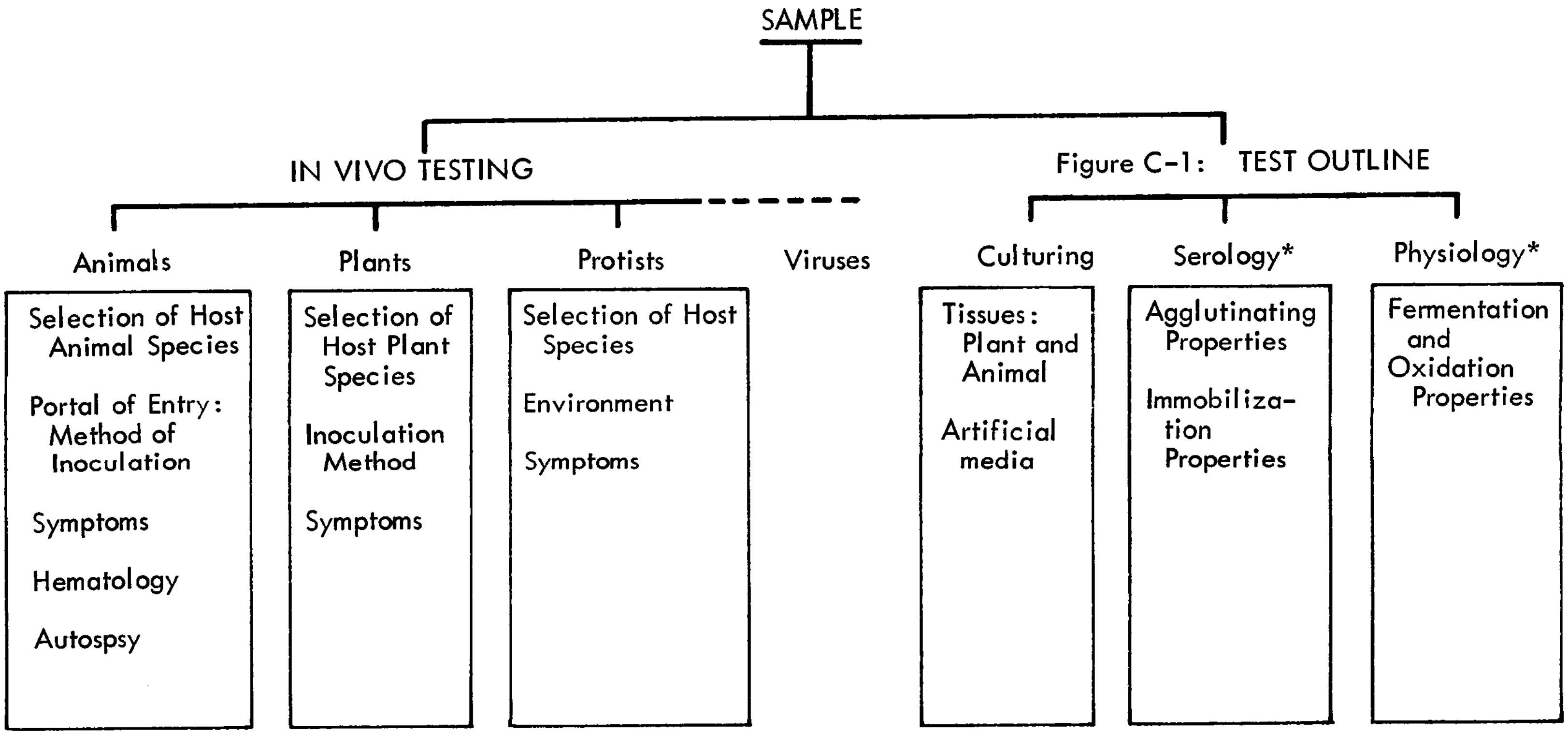
      Pain, sensitive areas...Death.

   d) Hematology

      Blood - cellular balance, any shift in the ratio of blood cell types is indicative of a disease state.

      Blood - humeral balance, abnormal levels (or absence of) of complement, properdin, etc. Compounds of the liquid portion of the blood are used to measure pathological changes.

   e) Autopsy - organis involved, presence of necrotic lesions.



* Not Necessary for Immediate Testing to Determine Pathogenicity.

Figure E-1: TEST OUTLINE

2. Test Considerations for Plants

   a) Selection of Test Plants

      As in animal selection, the choice of the plant species for testing must be based on a thorough knowledge of the responses made by the plant under normal conditions and how well the responses typify major groups of plant material.

      Commonly used test plants are corn, tomato, cereals, and potato. It is necessary in any in vivo system (test) that adequate controls be maintained over the test system so that no changes occur and thus confuse the expression of symptoms.

   b) Inoculation Method

      Although it is common in plant pathology to use the abrasive method for the introduction of infectious agents, other techniques are available. These include direct inoculation through stomata, root absorption, and injection into the fluid transport system.

   c) Symptoms

      Among the common external symptoms of plant diseases are wilts, scabs, blotches, hypertrophies, leaf spots, rot, cankers, blight, chlorosis, mosaics, and blisters.

3. Test Considerations for Protists

   a) Selection of host species - representative samples of Protists (protozoa, fungi, algae, and bacteria - the latter including autotrophes and heterotrophes.)

   b) Selection of environment - cultural conditions (nutrients, temperature, etc.) would be such that they would afford the introduction of extraterrestrial samples into the closed, controlled microenvironment.

   c) Symptoms - changes in colonial morphology, pigmentation. Lysis; inability to reproduce; death.

4. Test Considerations for Viruses

   Discussion of the inclusion of terrestrial viruses in a life test system for extraterrestrial samples:

   a) The cell is the minimum organization of matter that is capable of all those processes we collectively refer to as "life".

b) Virus reproduction is dependent on the existence and organized abilities of the living cell.

c) Viruses are obligate intracellular parasites.

d) A virus never arises directly from a pre-existing virus. A cell always arises directly from a pre-existing cell.

e) Due to their manner of reproduction, all viruses known today are harmful to their host.

B. In Vitro Testing

1. Test considerations utilizing tissue culture.

The tissue culture technique has been established as a reliable and fairly simple procedure. The use of cell lines obtained from various animal species and of different organs from the animals is well documented in the study of viruses and virus-like particles. Tissue response to disease causing organisms will result in observable pathological changes.

Although, to date, tissue cultures of plants have not reached the stage where they may be used with reliability, it is only a matter of time before the situation is corrected.

2. Developing Embryos

Developing embryos provide a unique culture medium for infective agents. However, this type of test would probably not be practical for use due to the difficulty of obtaining embryos while in space.

3. Artificial Media

Animal body fluids incorporated into nutrient media will give a good picture of the potential invasive powers of microorganisms. This technique is especially useful in isolation and characterization studies.

Blood and serum agars are commonly used.

The in vitro approach to determining pathogenicity on a "common denominator" basis potentially appears to hold the most promise. Such techniques are not currently available. The expansion of this area of biology is definitely needed.

4.0 EXAMPLE EXPERIMENTS

How are terrestrial diseases transmitted?

1. Aerosols, droplet infection--inhalation into the respiratory areas.
2. Ingestion of contaminated milk, food--infection in the intestinal area.
3. Arthropod vectors--injections into blood stream or tissues with eventual uptake by lymphatic/vascular systems.
4. Foamites (any inanimate object used to transfer disease producing organisms). Puncture wounds, cuts, abrasions.
5. Direct contact--dermal infection. Sexual contact--uro-genital region.

Therefore, in order to cover all possible routes of infection, four categories for animal experimentation are suggested.

1. Inhalation into respiratory areas.
2. Ingestion into intestinal region.
3. Injections into various tissue layers.
4. Direct contact with specific anatomical regions.

The recommendation is made to repeat all animal experiments three times. Also, experiments will be performed in transit to verify orbital data to insure animals are responding in the predicted manner with regard to physiological measurements.

A. Animal Experiment

1. Inhalation

Experiment Title---The effects of the inhalation of an extraterrestrial sample by a white mouse.

Objective and Significance---The objective of this experiment is to determine possible harmful effects of an extraterrestrial sample on a mammalian organism.

This experiment will provide information as to the potential invasiveness of an extraterrestrial sample when introduced into the respiratory area of a white mouse.

Experiment

1. Two groups of 6 white mice each will be exposed to the extraterrestrial samples. A third group will serve as a control.
2. An aerosol of the extraterrestrial sample will be directed into the nasal and throat passages of one test group.
3. Dried and powdered extraterrestrial sample will be blown into the nose and throat areas of the second test group.

4. All three groups will be maintained in separate cages.
5. Take rectal temperatures daily.
6. Observe for any respiratory or other abnormality that could be interpreted as indicative of disease--such as runny eyes, difficulty in breathing, ruffled fur, chills, etc.
7. At 2 week intervals, sacrifice 2 mice from both test groups and perform an autopsy--paying particular attention to lung disorders.
8. Prepare histological slides of the lungs and any other organs that exhibit abnormalities.
9. Freeze remains of autopsied mice.

Equipment

1. Eighteen white mice--three groups of 6 each in three separate cages.
2. Aerosol generator fitted with a capillary tube (for inertion into nasal area).
3. Drying and powdering apparatus for extraterrestrial samples.
4. Rectal thermometer.
5. Autopsy instruments, pan sterilizer.
6. Microtome, slides, stains.
7. Freezer.

2. Ingestion

Experiment Title---The effects of the ingestion of an extraterrestrial sample on mammals.

Objective and Significance---The objective of this experiment is to determine possible harmful effects of an extraterrestrial sample in a mammalian organism.

This experiment will provide information as to the potential pathogenicity of an extraterrestrial sample when ingested by a terrestrial mammal.

Experiment

1. Expose 6 white mice to an extraterrestrial sample by mixing a portion of it with their food.
2. Maintain a control group of 6 white mice that receive no inoculated food and are kept separated from the test group.
3. Observe any changes in water and food uptake by either group.
4. Observe any abnormal physiological symptoms such as diarrhea, lethargy.
5. Collect a urine sample daily from each mouse and, using Clinistiks, perform urinalysis.
6. Take rectal temperature daily.

7. At intervals of 1 week, sacrifice a mouse from the test group and perform an autopsy; after noting any abnormalities, the animals will be frozen for future, more detailed, examination.

Equipment

1. Twelve white mice of an established laboratory strain, preferably litter mates.
2. Two cages with feeding trays and water source.
3. Clinistiks for urinalysis--glucose, albumen, ketone, blood.
4. Rectal thermometer.
5. Autopsy instruments, autopsy pan, method for sterilizing them. Freezer for dead animals.

3. Injection

Experiment Title---The effects of the injection of an extraterrestrial sample into a white mouse.

Objective and Significance---The objective of this experiment is to determine possible harmful effects of an extraterrestrial sample on a mammalian organism.

This experiment will provide information as to the potential pathogenicity of an extraterrestrial sample when introduced into various tissue layers by means of hypodermic injection.

Experiment

1. Four groups of 6 mice each will be injected with the extraterrestrial sample. A fifth group will serve as a control. Each group will be shaved where injected.
2. One group will receive subcutaneous injections in the front limb area.
3. The second group will be injected intraperitoneally.
4. The third group will be injected intramuscularly in the hind haunch area.
5. The fourth group will be injected intravenously.
6. Each group will be maintained in isolated cages.
7. Take rectal temperatures daily.
8. Observe for any dermatological changes at the site of injection--such as rash, inflammation, or necrosis. Also note any physiological changes that may be symptomatic of an infectious process.
9. Every week, sacrifice one mouse from each test group and perform autopsy.
10. Prepare and examine histological slides from the site of injection, lymphatic areas, spleen, liver, etc.
11. Freeze animals.

Equipment

1. Thirty mice--5 groups of 6 each in 5 separated cages.
2. Hypodermic syringes
3. Shaver
4. Thermometer
5. Autopsy materials, freezer
6. Microtome, stains, slides

4. Contact

Experiment Title---The effects of mammalian contact with an extraterrestrial sample.

Objective and Significance---The objective of this experiment is to determine possible harmful effects upon mammalian organisms as the result of contact exposure to an extraterrestrial sample.

This experiment will provide information as to the potential pathogenicity of an extraterrestrial sample when brought into contact with specific anatomical regions.

Experiment

1. Four groups of 6 mice each will be exposed to the extraterrestrial sample. A fifth group will serve as a control.
2. One group will have their belly region scarified and the extraterrestrial sample rubbed on the abraded area.
3. The second group of test mice will receive drops of an extraterrestrial solution on their conjunctiva of the left eye.
4. The third group, all male mice, will be inoculated in the urogenital region with an inoculation device.
5. The fourt group, all female mice, will also be inoculated in the urogenital area.
6. Each group will be maintained in cages separated from the other test groups.
7. Take rectal temperatures daily.
8. Observe group one for any dermatological changes such as loss of hair, rash, inflammation, lesions, etc. Periodically, remove small bits of fur at the site of contact and examine microscopically for changes in hair integrity.
9. Observe group two for the appearance of runny eyes, inflammation, swollen conjunctiva, lesions on the eye, etc.
10. Groups three and four will have their urine microscopically checked weekly for the presence of pus cells. Gross symptoms such as inflammation, tenderness, or lesions of the urogenital area should be noted if observed. At weekly intervals, one mouse from group three and

one from group four will be sacrificed and an autopsy performed. Particular attention will be paid to the organs of reproduction. Histological slides of these tissues will be prepared and examined.

11. At the end of 6 weeks, all the mice in group one should be reinoculated and again, observed for 6 weeks.

    If time and space permit, continuation of this test group will be beneficial to check for effects of long term contact with an extraterrestrial sample.

Equipment

1. Thirty mice--5 groups of 6 each in 6 cages.
2. Abrasive device for scarification.
3. Urogenital inoculation device.
4. Rectal thermometer
5. Microscope, slides, stains, forceps.
6. Autopsy instruments, freezer.
7. Microtome.

ANIMAL EXPERIMENTS--TOTAL EQUIPMENT

1. Mice--90 (24 of which will remain alive after completion of the experiments. They will be used for breeding purposes to repopulate the mouse stock for further repeat runs of the experiments)
2. Cages, water bottles, feeding trays--15
3. Sterilizer
4. Autopsy instruments
5. Freezer
6. Microtome, stains, slides
7. Microscope
8. Aerosol device
9. Drying and Powdering device
10. Rectal thermometer
11. Syringes
12. Shaver
13. Abrasive device for scarification
14. Urogenital inoculating device
15. Clinistiks

Table E-1 summarizes the equipment requirements for animal requirements

Table E-1: EQUIPMENT REQUIREMENTS FOR ANIMAL EXPERIMENTS

Item	Weight	Volume	Power	Time
Mouse cage and feeders	15 lb	3 ft^3	0	
Life Support	15 lb	1 ft^3	Small bleed from main ECS	6 hr per day for 6 wk
Freezer	5 lb	5 ft^3	5 W continuous	
Food and Water	200 lb	3 ft^3	0	
Lab Equipment	25 lb	2 ft^3	0	

A. Animal Experiments

Note: While white mice may suffice as test organisms to screen for possible hazards due to back contamination, it is highly recommended that additional diverse life test systems be used. Two examples of these systems (plants, protists) are outlined in the following experiments.

B. Plant Experiment

Experiment Title---Effects of extraterrestrial sample material on survival and growth of duck weed.

Objective and Significance---The objective of this experiment is to determine the response of plant material to extraterrestrial sample material.

This experiment will provide data on adverse effects of extraterrestrial sample material on terrestrial plants.

Experiment

1. Three cultures of duck weed will be grown.
2. One culture will be exposed to the extraterrestrial sample in the soil through the roots.
3. The second culture will be exposed to the sample by means of incisions in the leaves.
4. The third culture will be maintained as control with no exposure.
5. Comparisons will be made between the exposed cultures and the control with respect to growth rate and morphological characteristics.
6. Comparisons will be made weekly.

Equipment

1. Three growth chambers
2. Nutrients
3. Microscope
4. Light Source
5. Micratome, slides, stains

Table E-2 summarizes the plant experiment equipment.

Table E-2: EQUIPMENT REQUIREMENTS FOR PLANT EXPERIMENT

Item	Weight	Volume	Power	Time
Growth Chamber	10 lb	2 ft^3	0	8 hr
Nutrients	1 lb	0.1 ft^3	0	per
Microscope	10 lb	1 ft^3	0	week
Light Source	10 lb	1 ft^3	1000 W continuous	for 24 wk
Lab Equipment	15 lb	2 ft^3	0	

C. Protists Experiment

Experiment Title---Effects of exposure to extraterrestrial sample on microorganisms.

Objective and Significance---The objective of this experiment is to determine possible inhibition by an extraterrestrial sample upon the growth response of a microorganism.

This experiment will provide information as to the potential pathogenicity of an extraterrestrial sample to a terrestrial microorganism.

Experiment

1. Addition of an extraterrestrial sample to a liquid culture of *Escherichia coli* in the lag phase of its growth cycle.
2. Maintenance of a control culture of *E. coli* in the lag phase that is not exposed to an extraterrestrial sample.
3. Incubation of both cultures at 35°C.
4. Measurement of growth response.
5. Microscopic examination of bacteria in both cultures.
6. Removal of aliquot, centrifugation, washings, etc., to remove all traces of old medium and extraterrestrial sample--from both cultures.

7. Inoculation of fresh liquid media with washed bacteria.
8. Observation of growth response.

Equipment

1. Culture of *E. coli*
2. Liquid culture media in bottles.
3. 35°C incubator
4. Spectrophotometer for measuring growth response
5. Microscope, slides, stain
6. Pipettes
7. Centrifuge, tubes.

Table E-3 summarizes the Protist Experiment Equipment.

Table E-3: EQUIPMENT REQUIREMENTS FOR PROTIST EXPERIMENT

Item	Weight	Volume	Power	Time
Incubator	8 lb	$.5\ ft^3$	5 W Continuous	2 hr per day for 4 days
Media	5 lb	$.2\ ft^3$	0	
Microscope	10 lb	$1\ ft^3$	0	
Lab equipment	10 lb	$1\ ft^2$	0	
Centrifuge*	5 lb	$.5\ ft^3$	0	

*Hand turned

5.0 EARTH ORBIT CONTROL EXPERIMENTS

If the mouse is going to be used as a test system for extraterrestrial pathogenicity then its normal physiological and immune responses to disease must be established for the space environment.

a. Does the new environment select for any genetic change?

b. Is the reproductive capacity altered--is the gestation period changed?

c. Is the normal life expectancy of the mouse altered?

d. Is the mouse able to elicit the same immune responses as on Earth?

e. Will a change in environment render the mouse "immune" to normally infectious organisms?

f. Or will the change in environment produce a change in the mouse with a resultant change in host specificity for certain normally nonpathogenic microorganisms?

These questions could be answered by maintaining a mouse colony in Earth orbit and observing their biological patterns of reproduction, etc. Test groups also would be challenged with microorganisms that are: a) normally nonpathogenic, b) pathogenic, or c) pathogenic for animals other than mice. It may also be feasible to attempt to change the immunity of the mouse by administering drugs or chemicals and then challenging it with microorganisms.

If the space environment, alone or coupled with chemical suppressors, can be shown to encourage infection with normally host specific microorganisms, then more confidence in the use of the mouse as a test system for extraterrestrial pathogenicity will be established.

A research program such as the one outlined above would provide information that would prevent misinterpretation of data obtained when subjecting space animals to extraterrestrial samples.

6.0 RECOMMENDATIONS

Numerous "best" estimates have been made of the weight, volume, power and time required to conduct experiments in space. Estimates of this type have been made for MOL, AAP and other related programs. While the estimates are adequate for gross preliminary planning, they may be in error by an order of magnitude or more. More accurate data on these parameters are now required to establish meaningful engineering numbers. An approach is outlined here that will provide these data for the type of experiments proposed to evaluate back contamination.

Representative biological "space" experiments should be designed, conducted, and the results evaluated. Information obtained from doing the complete experimental sequence will determine:

1. Experimental Protocol
    a. Feasibility of selected experiments for space application.
    b. Experimental procedures
    c. Time line requirements
    d. Experimental level of technical competence and experience.
2. Terrestrial Physiological Requirements for Test Organisms
    a. Organism's normal response to experimental environments.
    b. Organism's response to experimental treatments.
    c. Applicability of test measurements.
3. Equipment Requirements
    a. Type and quantity of equipment required.
    b. Establish equipment specifications for space hardware.

A final test should be conducted upon completion of the outlined tasks. All equipment and personnel necessary to conduct the experiments should be placed in a simulated space laboratory. The experiments should be conducted as programmed for space. Any omissions of equipment, technique, interpretation, etc., can then be observed. This method of evaluation should be used for all space experiments to obtain accurate data and eliminate errors inherent in "dry-lab" estimates.

7.0 STANDARD TERRESTRIAL SCREENING TECHNIQUES

Most human beings, indeed probably all living things, carry throughout life a variety of microbial agents potentially pathogenic for them. Under most conditions these pathogens do not manifest their presence by either symptoms or lesions; only when something happens which upsets the equilibrium between host and parasite does infection evolve into disease. In other words, infection is in many cases the normal state; it is only disease which is abnormal.

Under natural conditions different animal species show a widely differing incidence of certain infections (diseases). Thus, anthrax is in the main a disease of herbivora. Of the animals dying of anthrax in this country in 1914, 733 were cattle, 5 were sheep, 32 were swine, and 25 were horses. In Australia and South America sheep are more commonly affected; but Algerian sheep are highly resistant. Tuberculosis is one of the commonest natural infections of man and cattle. It is common in pigs and in fowl. It is relatively uncommon in sheep, goats, horses, cats, and dogs; and very uncommon as a natural disease in rabbits, guinea pigs, hamsters, rats, and mice. Among mankind there are marked racial differences in its incidence and severity.

In any infective disease we are confronted with a wide variety of circumstances in which some patients die and some recover. The explanation of this in biological terms is not known.

The following brief list of diseases and susceptible animals is submitted as evidence against the case for one test system to measure for potential pathogens. As will be noted, many organisms are host specific--that is, only one host has ever been infected.

BACTERIAL DISEASES

Test Animal	Disease or Organism
Man is most susceptible, rabbit next, guinea pig not	Staph. aureus
Man is more susceptible--no organ is immune. White mice, rabbits; bird are immune	Streptococci
White mouse--intraperiotoneally--death	Pneumococci
White mouse--intraperiotoneally with mucin--death	Hemophilus influenzae--meningitis
Man, mice	Haverhill fever
Mice--intranasal instillations, or intracerebral inoculation	Whooping cough
Rabbits; mice are not susceptible	Bronchiseptica
Most laboratory animals are resistant--monkeys may have been infected	Soft chancre
Man	Conjunctivitis
Monkeys, rabbits--by intrathecal injection	Epidemic meningitis
Mice--if also injected with mucin	Meningitis
None--other than man	Gonorrhea
Guinea pig, cat, dog; mice--no. use subcutaneous injections	Diphtheria
Monkeys, guinea pigs--for human TB, rabbits for bovine TB	Tuberculosis
Man	Leprosy
Rats, calves, field mice	Rat leprosy, Johne's disease, Volves disease
Rabbits, guinea pig, hamster	Glanders
Guinea pigs	Actinomycosis
Chimpanzees	Typhoid fever

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GLOSSARY

AA	A dark-colored, jagged clinkery lava, occuring in angular broken blocks formed by the cracking of a hardened lava crust by molten rock running underneath. Compare with "pahoehoe."
Adiabatic Process	A thermodynamic change of state of a system in which there is no transfer of heat or mass across the system's boundaries.
Albedo	The ratio of electromagnetic radiation reflected by a body to that incident upon it.
Alluvial Fan	A river deposit having a fan-shaped outline. Built by a mountain stream when it loses velocity at the foot of a steep slope. The land counterpart of a delta.
Anticline	An upfold or arch in layered rocks. The opposite of a syncline, with which it usually appears in alternation.
Anticyclone	An area of relatively high pressure from which the wind blows spirally outward in a clockwise direction in the northern hemisphere and counterclockwise in the southern hemisphere.
Aphelion	The point on a heliocentric elliptical orbit farthest from the Sun.
Apparition (of a planet)	The indefinite period to time centered at opposition (or inferior conjunction) during which a planet is favorably located for observation.
Aquifer	A water-bearing layer of earth, gravel, or rock.
Arete	A sharp, jagged mountain ridge between glaciated valleys.
Ascending Node (of an orbit)	That point on an orbit at which a body (planet or satellite) crosses from south to north the reference plane (e.g., the cliptic for the planets) on the celestial sphere. The opposite point, separated by 180° of longitude, is the descending node.

Astronomical Unit (A.U.)	A fundamental unit of length used in astronomy. Originally, the astronomical unit was defined as the mean distance of Earth from the Sun. In celestial mechanics, it is defined as the radius of an idealized circular and unperturbed orbit of Earth around the Sun. The recent radar determination of Muhleman (1964) is 1 astronomical unit = 149,598,900 ± 600 kilometers.
Badland	A region consisting of a maze of deep gullies, with intervening sharp ridges and pinnacles. Erosion is so rapid and the slopes so steep that vegetation has not been able to take hold.
Basalt	Dark-colored, fine-grained igneous rock. Usually occurs in lava flows.
Bombs, Volcanic	Spindle or tear-shaped masses of porous lava varying in length from a few inches to a foot or more. Formed from liquid gouts of magma blown out of a volcano and hardened in flight.
Bond Albedo (or Russell-Bond albedo)	The ratio of the total flux, reflected in all directions by a sphere (planet), to the total flux incident in parallel rays from a distant source (Sun) and expressed as the product, $A = p.q$, of a full-phase albedo factor p (geometrical albedo) and a phase-varying factor q (phase integral).
Brilliancy (of a disk)	A geometrical measure of disk brightness, independent of albedo, that is determined only by phase k, the apparent semidiameter s, and solar distance r according to the defining formula: $L = k \frac{s^2}{r^2}$
Butte	A term commonly used in the West and Southwest for conspicuous steep-sided isolated hills. Most commonly an erosional remnant in a plateau area; applied also to various other features, such as isolated cinder cones.
Caldera	A large basin-shaped depression at the top of a volcano many times larger than the average crater.
Cinder Cone	A small volcano constructed primarily of ash and cinders. See also "strato volcano; shiled volcano."
Cirque	A bowl-like amphitheater cut into the side of a mountain by glacial erosion. Formed at the head of a valley glacier.

Coastal Plain	A plain, underlain by horizontal or gently sloping sediments, bordering the ocean. It generally represents a recently emerged section of the sea floor.
Columnar Jointing	Parallel rock fractures, usually vertical, associated with basalt lava flows or sills. Such jointing results from the shrinkage of lava on cooling.
Composition	
Charged Particles	All charged corpuscular entities or chemical species.
Atomic Elements	All monotomic chemical elements.
Molecular Elements	All diatomic or triatomic elements.
Minerals	The chemical elements, compounds, or their aggregates occuring naturally as a product of inorganic processes.
Chemicals	Chemical elements and compounds which are in a state of unequal equilibrium with their environment.
Isotopes	Any two or more forms of the same element with different masses.
Concretion	An irregular nodular or disc-shaped body found in sedimentary rocks. Formed by local concentration of cementing materials, such as silica, calcite, or iron oxide, some concretions measure a foot or more across.
Conglomerate	A sedimentary rock formed of more or less rounded pebbles cemented together.
Conjunction	The configuration of the Sun, a planet, and Earth when the heliocentric longitudes of the latter two are equal. The three bodies then lie most nearly in a straight line. When the planet is between the Sun and Earth, the planet is said to be in inferior conjunction; when the Sun is between Earth and the planet, the planet is said to be in superior conjunction.
Continental Glacier	An ice sheet which covers an appreciable part of a continent, overriding hills and valleys alike. Continental glaciers exist today in Greenland and Antarctica. Compare with "valley glacier."
Cuesta	An asymmetric ridge sloping steeply on one side and very gently on the other, capped by a resistant layer.
Cyclone	An area of relatively low atmospheric pressure from which the wind blows spirally inward: counterclockwise in the northern hemisphere, clockwise in the southern.

Cyclotron Radiation	Radiation emitted from the Van Allen belts of a planet; the emission results from the acceleration of trapped electrons to nonrelativistic energies. The electrons spiral along magnetic lines of force and accelerate in a manner similar to that of a cyclotron.
Day (ephemeris)	Average value of the mean solar day taken over the last three centuries.
Day (sidereal)	Time interval between two successive transits of the vernal equinox over the same meridian.
Day (solar)	Time interval between two consecutive transits of the Sun over a meridian. Since this time interval varies with Earth's orbital motion, a mean solar day was chosen, based on a mean annual motion of Earth (assuming an equivalent circular orbit) or a fictitious mean Sun.
Declination (of a celestial point)	The angle between a point and the celestial equator, measured along the hour circle through the point and counted as north (+) or south (-) of the equator.
Decomposition	The chemical breakdown of the minerals in a rock. Synonymous with chemical weathering.
Delta	The deposit formed by a stream as it enters a body of water and drops its load of sediments. Many deltas are roughly triangular in plan resembling the Greek letter delta with the apex pointing upstream.
Diastrophism	The process by which the crust of the Earth is deformed. It includes folding and faulting, and is one of the three major processes which affect the Earth's crust. The other two processes are igneous activity and gradation (weathering and erosion).
Dike	A tabular body of igneous rock which cuts across the structure of pre-existing rocks into which it has been intruded.
Disintegration	The mechanical, as opposed to the chemical, breakup of rocks under weathering conditions. It results from such factors as frost action, the wedging effect of plant roots, and changes in temperature.
Disk	The flattened appearance of a celestial body as it is observed, or the projection on the celestial sphere of that portion of the observed body which is visible.
Drift	A general term for all glacial deposits, whether deposited directly from the ice or by meltwater.

Dripstone	Any calcium carbonate deposit formed in a cave. See also "stalactite" and "stalagmite."
Drowned Coast	Characterized by many estuaries and islands; results from the sinking of land relative to the sea and the subsequent inundation of coastal areas.
Drumlin	An elongated hill composed of till deposited by a continental glacier. The longer dimension varies generally from one quarter to one half mile, and the height from 50 to 1000 feet.
Dry Adiabatic Lapse-Rate	The rate of decrease of temperature with height of a parcel of dry air lifted adiabatically through an atmosphere in hydrostatic equilibrium.
Ecliptic	The annual, apparent path of the Sun's center on the celestial sphere, as seen from Earth, or the intersection of Earth's orbital plane with the celestial sphere.
Elongation (of a planet)	The angle between the Sun and a planet and Earth with the vertex at the center of Earth. Elongation is measured east or west of the Sun.
Environment	
Diurnal	Recurring with each planetary axial revolution.
Seasonal	Recurring with each planetary revolution about the Sun.
Latitude	Environment as it varies from the planet's equator to its spin axis poles.
Magnetic Field	The local magnetic field on the surface of the planet. Magnetic field in space and resulting Van Allen belts.
Micrometeorology	Atmospheric phenomena occuring near the surface of the planet.
Meteoroid	The dust, micrometeoroids and meteoroids in the vicinity of the orbit of the planet and its satellites.
Radioactive Decay	The flux and spectrum produced by the unstable isotopes (includes alpha beta and gamme emissions).
Solar Radiation	The complete spectra, flux and variations of the Sun's emissions (includes magnetic field and solar wind).
Ephemeris (fundamental)	An astronomical table predicting the positions of celestial bodies at regular intervals of time (also called almanac).
Ephemeris Time	Uniform or Newtonian time based on the mean rotation of Earth during the year 1900.
Epoch	An arbitrary instance of time at which positions are measured or calculated.

Erosion	The wearing away of the land by any one or a combination of the following five agents: streams, glaciers, wind, underground water, or ocean waves and currents.
Erratic Boulder	A boulder transported and dumped by a glacier.
Esker	Associated with glaciation, a sinuous ridge, 10 to 100 feet high, composed of roughly sorted sand and gravel; often resembles a railroad embankment.
Estuary	A tidal inlet by which a stream enters the sea. Formed as the result of a rise in sea level and the consequent drowning of the seaward end of a former stream valley.
Exfoliation	The peeling off of layers of rock. It produces round domal rock forms.
Extrusive	Applied to an igneous rock consisting of lava which has flown out at the surface of the Earth.
Fault	A fracture in a rock along which adjacent blocks have shifted with respect to each other.
Fault Block Mountain	A mountain bounded on one or both sides by faults. Examples are the Sierra Nevada, the Grand Tetons, and many ranges in the Basin and Range region of the United States.
Fiord	A deep, narrow, steep-walled inlet of the sea; the result of the partial submergence of a glaciated valley.
Flatiron	A portion of a hogback ridge eroded into a triangular shape; occurs in series on the flanks of mountains.
Floodplain	The flat area adjoining a mature or old stream; may become flooded at times of high water.
Fumarole	A vent in a volcanic area emitting various gases and fumes.
Geometrical Albedo	The ratio of the actual brightness of a reflecting body (planet or satellite) at full solar phase to that of a self-luminous body of the same size and position and radiating a flux of light equal to that incident on the first body.
Geosyncline	A large area on the Earth's crust which has slowly subsided throughout long periods of time and in which thick layers of sediments have been deposited, often to a depth of many thousands of feet.
Geyser	A periodically eruptive hot spring.

Gradation	The process of weathering and erosion by which the Earth's surface is worn down. This is one of the three major processes affecting the Earth's surface. The other two are igneous activity and diastrophism.
Granite	A coarse-grained, light-colored instrusive igneous rock.
Graybody	A hypothetical body that absorbs, independently of wave-length, some constant fraction between zero and one of all electromagnetic radiation incident upon that body.
Gregorian Date	A date on the official calendar in use throughout the Christian world. The Gregorian calendar was instituted in 1582 by Pope Gregory XIII to correct errors accumulating in the Julian calendar.
Hanging Valley	A valley tributary to a U-shaped glacial trough. Left "hanging" as the result of the rapid deepening and widening of the principal valley by glacial erosion.
Heliocentric	Sun centered; term derived from helios, the Greek word for Sun.
Hogback	A ridge formed of a resistant, steeply dipping layer between less resistant material. It is an erosional remnant resulting from the removal of material from either side.
Igneous Activity (Vulcanism)	One of the three major processes affecting the Earth's surface. This includes the production of lava flows, volcanoes, sills, and dikes.
Igneous Rock	A rock formed by the solidification of either magma or lava.
Incised (or entrenched) Meanders	Formed when a rejuvenated meandering stream cuts a deep valley for itself through flood-plain material and into underlying bedrock. The path of such a stream is inherited from the former meandering path.
Intrusive	A body of igneous rock formed beneath the surface of the Earth by the solidification of a mass of magma which has penetrated into or between other rocks.
Joint	A fracture or crack in a rock; generally occurs as one of a set of more or less parallel cracks. A joint differs from a fault in that there is no relative motion of the rock masses on either side of the fracture.
Julian Date	The number of mean solar days that have elapsed since the adopted epoch of Greenwich mean moon on January 1, 4713 B.C.

Kame	A small conical hill composed of roughly sorted sand and gravel, deposited by melt waters from a glacier in a hole in a mass of stagnating ice or as a very steep fan-shaped deposit at the edge of the ice.
Kame Terrace	A terrace deposit of stratified sand and gravel laid down between a mass of stagnating ice and a valley wall.
Karst Topography	A type of landscape developed in a limestone country, consisting of many sink holes and disappearing streams and caves, where the drainage is primarily underground.
Kepler's Laws	Three laws of undisturbed planetary motion formulated by Kepler: 1st law: The orbits of the planets are ellipses with the Sun at one focus. 2nd law: The radius vector Sun-to-planet sweeps equal areas in equal times. 3rd law: The squares of the planets' periods of revolution are proportional to the cubes of their mean solar distances (semimajor axes of ellipses).
Kettle Hole	A bowl-shaped depression, usually from 20 to 50 feet deep and up to a few hundred feet in diameter, found in a glacial deposit. It is produced when a detached block of ice buried in the deposit eventually metls, causing a collapse of the surface.
Lava	Liquid rock as it emerges at the Earth's surface from a volcano or fissure. While still underground it is called magma.
Laplacian Plane (or proper plane)	A plane that is fixed relative to the planet's equator, and upon which the precessing orbital plane of a satellite maintains a nearly constant inclination. The plane's position is determined by the balance of the orthogonal components of the disturbing forces (e.g., from the planet's oblateness or the Sun's attraction).
Libration	Periodic oscillation about a mean position as, for example, caused by perturbations.
Life	
Macroscopic	Life easily discernible by eye--plants and animal.
Microscopic	Cellular aggregates or unicelled--plants and animals.
Proto-organic	Gases such as H_2O, NH_4, CH_4, N_2, LO_2, etc.
Fossil	Any evidence of the remains of past life.
Limb	Edge of the illuminated part of a disk.

Limestone	A sedimentary rock composed of calcium carbonate.
Line of Apsides	A straight line infinitely extending the major axis of an elliptical orbit. This line passes through those points closest (periapsis) and farthest (apoapsis) from the dynamical center.
Line of Nodes	A straight line that joins the intersection points (nodes) of the two great celestial circles that determine the orbital plane and the reference plane used to describe the motion of a planet or satellite.
Loess	A wind deposit of dust produced by glacial erosion; characterized by its ability to stand in steep cliffs.
Magma	Liquid rock under the Earth's surface. When magma emerges from a fissure or a volcano, it is called lava.
Magnitude (stellar)	An inverse logarithmic measure of the brightness of a celestial body such that an increase of five magnitudes represents a hundred-fold decrease in the body's brightness.
Matterhorn Peak (horn)	A high pointed peak left as a residual feature by mountain glaciers.
Mature River Valley	A valley with a wide flat floor or floodplain veneered with sediments over which a meandering stream flows. When the valley is many times the width of the meander belt, it may be considered old.
Meander	A rounded loop-like bend in the course of a mature or old river.
Mesa	A flat-topped mountain or tableland, bounded on at least one side by a steep cliff. A partially detached part of a plateau.
Metamorphic Rock	A rock formed by physical or chemical changes in some previous igneous or sedimentary rock.
Mie Scattering	That scattering of radiation which is produced by spherical particles of any size (for comparison see "Rayleigh scattering").
Mixing Ratio	The ratio of the mass of the gas considered to that of the remaining gases in a given atmospheric mass.

Modifying Forces	
Solar Radiation	Forces produced by the complete electromagnetic radiation from the Sun including the solar wind and its constituents.
Meteoroid Impacts	The number, size, distribution and frequency of meteoroid collisions with a planet.
Isostatic Forces	The balancing gravitational forces tending to level different altitudes or topographic reliefs on basis of gravity.
Seismic Activity	The forces associated with seismicity, including their frequency, intensity or duration.
Diastrophism	The general forces tending to deform the crust of a planet. Includes mountain and continental uplifting forces.
Volcanic Activity	The activity associated with release of solids, liquids and gases from the interior of a planet to its surface.
Surface Winds	The air forces transporting surface material.
Temperature Changes	The forces of temperature associated with changes in energy such as the expansion or contraction of a solid.
Chemical Reactions	The combining and recombining forces associated with chemical compounds reacting with each other.
Life	The life forces which extract minerals and chemicals from the soil as well as react with it. (Includes all life forms and systems.)
Phase Changes	The forces exerted when chemicals and their compounds change from plasma to gases, from gases to liquids, from gases to solids, from liquids to solids or from solids to superdense matter.
Gravity	The force exerted by the gravitational field on material which can be deformed or shifted from a high to a lower potential energy field.
Hydraulic Action	The forces exerted by a liquid impinging on a surface. This force is a result of a kinetic or frictional energy produced by gravity.
Glacier Action	The forces produced by the presence and movement of glacier ice.
Nuclear Reactions	The forces produced as a result of the disintegration of a nucleus or of the integrated energy in the form of heat.
Monadnock	A hill rising above the level of a peneplain; an erosional remnant.
Moraine	A glacial deposit of till, or unsorted mud, sand, and gravel. Such a deposit may form an extensive ridge which marks the terminus of a glacier (terminal moraine); it may be spread out over the land as a thin widespread deposit (ground moraine); it may show up as a pile of debris riding on or in the middle part of a valley glacier (medial moraine); or it may have been left at the side of a valley glacier (lateral moraine).

North Celestial Pole	The northern point of intersection of Earth's rotation axis with the celestial sphere.
Obsidian	A volcanic glass, generally black in color.
Occultation	The obscuring of an observed body by a larger body passing in front of it.
Opposition	The configuration of Sun, Earth, and planet when the heliocentric longitudes of the latter two are equal. The three bodies, with Earth in the middle, are then most nearly in a straight line.
Osculating Orbit	The instantaneous elliptical orbit that a planet or satellite would follow at the date considered (epoch of osculation) if all disturbing forces were removed.
Outwash Plain	A very gently sloping plain composed of stratified layers of sand and gravel deposited by meltwater from a glacier.
Ox-bow Lake	A crescent-shaped lake on a flood plain, which fills an abandoned meander.
Pahoehoe	A dark colored lava showing a billowy or ropy surface. Compare with AA.
Pegmatite	A dike-like body of igneous rock composed of very large minerals, which may be many feet across. Most pegmatites are composed primarily of quartz and feldspar with some mica.
Peneplain	An extensive nearly flat surface or erosion.
Pericenter (or, perifocus)	That point on an orbit which is closest to the attracting center.
Perihelion	That point on a heliocentric elliptical orbit which is closest to the Sun.
Permeability	The capability of a rock for transmitting a fluid.
Phase	The fraction illuminated of the disk area.
Phase Angle	The angle between the Sun and Earth, as observed from a planet whose center is the vertex.
Phase Curve or Law	The plot or mathematical law of the phase function $\phi(\alpha)$ of a planet versus phase angle α.
Phase Function	The ratio of the brightness of a planet at any phase angle α to that at full phase ($\alpha = 0$), assuming the planet at unit distances from the Sun and Earth.

Phase Integral	The phase varying factor that modifies the geometrical albedo (or, full-phase factor) that enters into the definition of the Bond albedo of a planet. It is expressed as the integral: $a = \int_0^{2\pi} \phi\ (\alpha)\ \sin\ \alpha d\alpha$ of the phase function $\phi\ (\alpha)$.
Piedmont Glacier	A mass of ice at the foot of a mountain formed by the coalescence of several valley glaciers.
Placer Deposit	A deposit of heavy minerals concentrated by running water; found in the lower layers of gravel in a stream channel.
Plain	A level area of low relief underlain by essentially horizontal rock layers.
Planetology	
Orbital Parameters	The six elements required to describe the path of a planet around the Sun or its satellites about the planet and any precession of these.
Rotational Parameters	The period, axis of rotation and axial inclination to the reference plane, including any precession or nutation.
Figure of Planet	The geometrical outlines of the planet in three dimensions accurate to 0.1 km.
Moments of Inertia	The moments associated with the rotational and orbital parameters of the planets as well as of their satellites.
Gravitational Field	The inverse square field associated with a planet and its satellite as well as the resultant harmonics.
Magnetic Field	The vector function field described by the magnetic induction associated with some planets. Include nonuniformities and time variations.
Structural Features	The arrangement or rearrangement of the materials and gases which form the body of the planet and its atmosphere including its ionosphere.
Thermal Budget	The net influx or efflux of radiant energy associated with a planet or its satellites.
Physical Properties	The properties of a planet dealing with things measurable such as conductivity, density, pressure, mass, volume, etc.
Seismicity	The property of having earthquakes or earth tremors and the frequency with which these occur.

Physical Features	The make, form or appearance of the solid and liquid surface of planets. The distribution of these features and their inferred depth and extent.
Isotope Ratios	The % composition of the isotope of a chemical element to the % composition of a second isotope of the same chemical element.
Mineral Composition	The chemical compounds and their combinations and distribution of a planet.
Age	The age in years of the planet as a whole as well as of its features, properties, structure, etc.
Atmosphere	The gaseous envelope surrounding a planet including the charged constituents and the atmosphere.
Satellites	Bodies orbiting the planets whether the size of observable moons or cosmic dust.
Plateau	A region of horizontal rock layers at a high elevation which have been dissected by deep canyons or river valleys.
Playa Lake	A temporary lake found at the center of an undrained desert basin. On drying out such a lake will commonly leave a salt deposit.
Plug Dome	A steep-sided protrusion of lava in a volcania crater.
Plunge Pool	A large pothole formed at the foot of a waterfall.
Polarization (amount or degree of)	The proportion of polarized light to total light; it is defined by: $P = \frac{I_1 - I_2}{I_1 + I_2}$ where I_1 is the component of intensity perpendicular to the plane of vision (defined by directions of illumination and observation) and L_2 is the intensity component contained in this plane.
Polarization Curve	The plot of degree of polarization versus phase angle of a planet.
Porosity	The percentage of open space in a mass of rock or sediments.
Pothole	A roughly circular hole ground into the bedrock of a stream channel by the abrasive action of swirling sand and gravel.

Procession	The very slow (long period) motion (26,000 hears for Earth) of a planet's rotation axis about the north pole of the ecliptic, caused by the action of the Sun and any large satellite upon the planet's equatorial bulge; resembles the motion of a spinning top.
Pumice	A light-colored, porous lava, very light in weight.
Rayleigh Scattering	That scattering or radiation which is produced by spherical particles of radii smaller than about one-tenth the wavelength of the radiation (Rayleigh limit). Also called "molecular scattering."
Refraction	Change in direction of wave motion. On approaching an irregular coast, ocean waves bend so as to hit the shore more directly along their entire length.
Relief	As applied to a region it refers to the difference in elevation between the highest and lowest points.
Retrograde Sense	The opposite of direct sense of rotation; that is, clockwise.
Right Ascension	The angular arc measured along the celestial equator from the vernal equinox eastward (i.e., counterclockwise) to the intersection with the hour circle of the point (semigreat circle passing through the north celestial pole and the point).
Rotational Lines	Spectral lines caused by rotational energy changes in a molecule.
Sandstone	A sedimentary rock composed of cemented sand grains.
Scale Height (of an atmosphere)	The distance in which an isothermal atmosphere decreases in density from 1 to 1/e.
Schist	A finely foliated metamorphic rock. A common variety is mica schist, in which parallel flakes of mica are predominant.
Scoria	A dark-colored, very porous igneous rock. Occurs only in lava flows.
Sediment	Applied to any layer of loose material, such as mud, sand, or gravel, dumped by one of the erosional agents.
Sedimentary Rock	A rock formed by the solidification or consolidation of sediments. Layering or stratification is the most obvious characteristic of such rocks.

Shadow Transit of a Satellite	The passage of a satellite's shadow, umbra, across the primary's illuminated disk.
Shale	A sedimentary rock resulting from the consolidation of mud.
Shield Volcano	A broadly convex volcanic cone, built up almost entirely of rather fluid basaltic lava. Slopes are generally from 2 degrees to at most about 10 degrees. The volcanoes of Hawaii are examples.
Sill	A tabular igneous rock body intruded between pre-existing sedimentary layers.
Sink Hole	A funnel-shaped depression in a limestone region, resulting from the collapse of the surface into an underground hollow.
Snowline	The elevation at which snow exists throughout the year.
Spatter Cone	A low steep-sided volcanic cone built up of spattering gouts of lava emitted spasmodically from a vent.
Spit	A hooked shaped peninsula of sand built by waves and currents.
Stack	An offshore rocky islet. A residual feature isolated from the land by the removal of the surrounding material by wave action.
Stalactite	A cave deposit of calcium carbonate hanging icicle-like from the ceiling.
Stalagmite	A conical, post-like deposit of calcium carbonate growing upward from the floor of a cave.
Strato Volcano	A volcano composed of alternating layers of lava and ash. The slopes of the cone are a great deal steeper than those of a shield volcano.
Striations, Glacial	Scratches found on rock ledges in glaciated regions. Formed by the abrasive action of boulders and pebbles frozen into the base of moving ice.
Synchronous Rotation	Rotation of a planet or satellite such that the rotation period is equal to the period of revolution around the Sun or primary; thus, the same side of the rotating body always faces the attracting body (for example, the Moon).
Synchrotron Radiation	That radiation emitted from a planet's Van Allen belts wherein trapped electrons are accelerated to relativistic energies (i.e., with velocities approaching that of light) as in a synchrotron.

Syncline	A downfold or trough-like feature in folded rocks. The opposite of an anticline, with which it usually appears in alternation.
Synodic Period of Revolution (of two planets or satellites)	The time interval between consecutive oppositions or conjunctions of two bodies revolving around the same center.
Talus	A slope of broken rock fragments at the base of a cliff.
Tarn	A small mountain lake, especially that found in the scooped out bottom of a cirque.
Terminator	The line separating the illuminated from the nonilluminated portions of a planet or satellite; one observes a morning or evening terminator on the disk.
Till	A glacial deposit of unsorted material composed of mud, sand, and gravel laid down directly by the melting ice.
Tombolo	A sand bar which connects an island with the mainland.
Twiligh Arc	The planetocentric angular arc that measures the displacement, resulting from atmospheric scattering of light on the planet, of the actual terminator from the theoretical terminator.
Unconformity	An erosion surface which separates two masses of rock. A common type of unconformity shows an angular relationship between an older tilted or folded sequence which was eroded and a newer sequence of rocks deposited on the erosion surface.
U-Shaped Valley	A valley showing a U-shaped cross profile; formed by glacial erosion.
Valley Glacier	Sometimes called alpine or mountain glacier. It is a stream of ice confined to a valley and usually starts in a growing cirque.
Vernal Equinox	The point at which the Sun in its annual apparent path around Earth appears to cross the celestial equator from south to north at a certain time of the year (approximately on March 21), or the ascending nose of the ecliptic on the equator.
Volcanic Neck	An isolated column or hill of igneous material, representing the solidified filling of the pipe or vent up which lava came to form a volcano. Its presence obviously implies deep erosion.

V-Shaped Valley	A valley having a V-shaped cross profile; characteristic of youthful stream valleys.
Volcanism	See igneous activity.
Water Table	The upper surface of the zone of saturated rocks under the Earth's surface. It is usually at a higher elevation under hills and lower under valleys.
Weathering	The decay and breakup of solid rocks at the Earth's surface.
Year, Julian	The mean length of the year on the Julian calendar; it is equal to 365.25 mean solar days, or $365^{d}6^{h}$ exactly.
Year, Sidereal	The time interval between two successive returns of the Sun to a fixed celestial point (fixed star); it is the true period of revolution of Earth and is equal to 365.25636 mean solar days, or $365^{d}5^{h}9^{m}10^{s}$.
Year, Tropical	The time interval between two successive returns of the Sun to the vernal equinox. Because of precession, it is shorter than the sidereal or true year. It is equal to 365.24220 mean solar days, or $365^{d}5^{h}48^{m}6^{s}$.
Young River Valley	A valley in its early stages of development; characterized by a V-shaped cross profile. A stream in such a valley may possess falls and rapids, and flows on bedrock for much of its length.