NASA Conference Publication 10093

Electrical and Chemical Interactions at Mars Workshop

Part II–Appendix

Proceedings of a workshop
held at the NASA Lewis Research Center
Cleveland, Ohio
November 19 and 20, 1991

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National Aeronautics and
Space Administration

Office of Management

**Scientific and Technical
Information Program**

1993

PREFACE

The Electrical and Chemical Interactions at Mars Workshop, hosted by NASA Lewis Research Center on November 19 and 20, 1991, was held with the following objectives in mind: (1) to identify issues related to electrical and chemical interactions between systems and their local environments at Mars, and (2) to recommend means of addressing those issues, including the dispatch of robotic spacecraft to Mars to acquire necessary information. The workshop began with presentations about Mars' surface and orbital environments, Space Exploration Initiative (SEI) systems, environmental interactions, modeling and analysis, and plans for exploration. Participants were then divided into two working groups: one to examine the surface of Mars; and the other, the orbit of Mars. The working groups were to identify issues relating to environmental interactions; to state for each issue what is known and what new knowledge is needed; and to recommend ways to fulfill the need. Issues were prioritized within each working group using the relative severity of effects as a criterion. The contributions of the two working groups are described in Part I, published as a separate document. When materials were available in viewgraph form, the presentations given at the outset of the workshop are included in this appendix.

Joseph C. Kolecki and G. Barry Hillard
Space Environment Effects Branch
NASA Lewis Research Center

CONTENTS

INTRODUCTORY INFORMATION

WORKSHOP PRESENTATIONS

INTRODUCTORY INFORMATION

Executive Summary:

SYNOPSIS OF WORKSHOP CONCLUSIONS/RECOMMENDATIONS

I.) SURFACE

1.) No hard knowledge exists of the Martian subsurface, and while structures in Martian bases must interact with the subsurface, no missions are currently being planned to explore into this realm. The following information about the subsurface is required:

- i.) The presence or lack of subsurface water and its state (liquid or solid, fresh or brine)
- ii.) Subsurface soil mechanics and mineralogy
- iii.) Mechanical, thermal, electrical, and chemical properties of subsurface rocks and soil
- iv.) The nature and distribution of volatiles and their chemical properties.

Therefore, surface rovers should include instrumented probes to characterize the subsurface whenever and wherever such inclusion is feasible.

2.) On the martian surface, dust plays a major role in just about all of the surface interactions considered. The following information on Martian surface dust is required:

- i.) Surface soil mechanics and mineralogy
- ii.) Mechanical, thermal, electrical, and chemical properties of surface rocks and soil
- iii.) The explosion potential of suspended dust in confined volumes
- iv.) The nature and distribution of volatiles and their chemical properties.

Therefore, robotic missions (whether surface rovers/landers for in situ observations or orbital for remote global reconnaissance) are recommended to characterize the surface.

3.) The Martian atmosphere also is reactive, and capable of sustaining Paschen type electrical breakdowns. At a minimum, such breakdowns are a source of EM noise to instruments operating on the Martian surface. The following about the Martian atmosphere information is required:

- i.) The thermal and electrical breakdown characteristics of the Martian atmosphere in the presence and absence of dust, with and without wind, and the magnitude and direction of the ambient electric field.

Therefore, surface robotic missions must include appropriate instrument and experimental packages to characterize the martian atmosphere.

4.) The surface radiation environment will impact all aspects of a Mars mission, human and systems related. Knowledge of Mars specific environments is lacking. The following information about the surface radiation environment is required:

- i.) Solar flare and galactic cosmic ray radiation spectra
- ii.) Models to estimate levels of induced radiation
- iii.) Surface mapping of induced radiation levels.

Therefore, surface robotic missions must include appropriate instrument and experimental packages to achieve these objectives whenever it is feasible for them to do so.

While the planned Mars Observer, MESUR, MAO, and Mars 94/96 missions will provide much needed data on conditions at the planet, it was agreed that additional information must be sought on:

- i.) Surface conditions such as composition and distribution of native materials
- ii.) Dust processes associated with disruption and reformation of the duricrust
- iii.) Chemical activity, nature and distribution of volatiles
- iv.) Chemical composition and breakdown characteristics of the atmosphere in its various states of rest and motion, dustiness and relative clarity
- v.) Reactivity of soil and atmosphere in the presence of heat and fluids
- vi.) Solar and galactic cosmic ray radiation spectra and induced surface radiation levels
- vii.) Abrasive properties, electrical properties (including electret and dipole formation), and melting/decomposition properties of dust
- viii.) Explosion characteristics of Martian dust suspended in closed volumes.

II.) ORBIT

The orbital working group defined issues in the spatial regime extending from 100 km altitude upwards. These issues include:

- i.) Atomic oxygen erosion of materials
- ii.) CO_2 damage to refractory metals
- iii.) CO chemical reactions
- iv.) Plasma interactions in the ionosphere
- v.) Erosion and charging due to a hot O^+ tail (≤ 60 KeV) extending behind the planet
- vi.) Dust erosion
- vii.) Penetration by particulates like meteoroids and ejecta from the moons
- viii.) Man-made debris including particulates from propellants
- ix.) Radiation (optical and ionizing) and solar UV damage to materials
- x.) Aerocapture related effects including those due to locally generated plasma and dust erosion, and effects of such atmospheric anomalies as gravity waves
- xi.) Transport of surface dust into orbit by ascent vehicles
- xii.) System generated environments and their effects

These twelve issues break into four broad groups:

i.) Electrical interactions with plasmas and neutrals which include spacecraft charging, spacecraft potential variations, structural currents, and erosion due to local sputtering

ii.) Interactions with particulates (solid materials like meteoroids and debris) in low Mars orbit (LMO) which include mechanical erosion or penetration of spacecraft surfaces

iii.) Chemical interactions which include erosion by atomic oxygen and/or species liberated from local CO and CO_2, and photochemical reactions on surfaces and degradation within materials due to the presence of solar UV

iv.) Radiation interactions including the effects of cosmic ray and solar flare particles on humans and on system components.

Recommendations were made for robotic precursor missions to:

i.) Comprehensively map the atmosphere in LMO, including the spatial and temporal characteristics which affect orbital mechanics, and ascent/descent maneuvers (including g-wave characteristics and drag uncertainties), diurnal and solar cycle variations in the temperatures and densities of atomic oxygen, the hot O^+ tail, CO, and CO_2 populations

ii.) Determine the effects of high energy impacts with all of these species upon spacecraft structures and materials

iii.) Evaluate and define the Mars specific radiation environment including solar wind, solar flare, and galactic cosmic ray components

iv.) Measure suspended dust populations and size distributions over time

v.) Understand impact cloud characteristics corresponding to aerocapture altitudes, velocities and densities

vi.) Evaluate system generated effects such as those due to the addition of effluents or solid debris.

It was proposed that several of these test and measurement functions might be combined in one spacecraft or platform like the Aeronomy Observer with time varying orbital parameters and sufficiently diverse instrumentation. Additionally, it was recommended that ground tests and model development either be continued or begun. Specific areas of opportunity include:

i.) Subsystem laboratory tests and analytic modeling of spacecraft plasma interactions in a martian cold plasma environment

ii.) Laboratory measurements of sputtering and erosion interactions at 60 KeV energies.

These activities must keep pace with SEI program development and ensure timely availability of design tools for SEI system engineers.

INTRODUCTION to the APPENDICES

The workshop began with a series of presentations on Mars surface and orbital environments, SEI systems, environmental interactions, modeling and analysis, and plans for future exploration.

STRAWMAN QUESTIONS/CONCERNS	Joseph C. Kolecki, NASA/Lewis
CONDITIONS AT THE MARTIAN SURFACE*	Jeffrey B. Plescia, JPL
THE MARTIAN ATMOSPHERE	Robert Haberly, NASA/Ames
THE MARTIAN IONOSPHERE	Lawrence Brace, U. of Mich.
SEI/SYNTHESIS REPORT SYSTEMS SUMMARY	Scott R. Graham, NASA Lewis
SUMMARY OF ENVIRONMENTAL INTERACTIONS	Dale C. Ferguson, NASA Lewis
MODELING AND ANALYSIS TOOLS	Gary Jongeward, S-Cubed Div. of Maxwell Labs, Inc.
NASA MARS EXPLORATION: CODE SL	Tammy Dickinson, NASA/HQ/SLC

The above presentations are included in this appendix.

* This presentation was not available in viewgraph form.

WORKSHOP AGENDA

19 NOVEMBER 1991:

8:30 AM TO 12:00 NOON:	TALKS AND DISCUSSION
12:00 NOON TO 1:00 PM:	LUNCH
1:00 PM TO 5:00 PM:	TALKS CONTD. / WORKING GROUPS

20 NOVEMBER 1991:

8:30 AM TO 12:00 NOON:	WORKING GROUPS
12:00 NOON TO 1:00 PM:	LUNCH
1:00 PM TO 2:30 PM:	WORKING GROUPS CONTD.
2:45 TO 4:00 PM:	CHAIRMEN PRESENT RESULTS

WORKSHOP OBJECTIVE

I.) Subject: Electrical and Chemical Systems-Environmental Interactions at Mars.

II.) Context: Systems for the Exploration Initiative; Environmental Interactions on the Surface and in Orbit.

III.) Objective: Review what we already know, ascertain what we need to know, find the holes, and recommend ways to fill them via models, laboratory experiments, or robotic precursor missions.

WORKSHOP ATTENDEES

WORKSHOP CHAIRMEN:

Joseph C. Kolecki, NASA Lewis Research Center
G. Barry Hillard, NASA Lewis Research Center

PARTICIPANTS:

Larry Brace, University of Michigan
Tammy Dickinson, NASA Headquarters, Code SL
Dale Ferguson, NASA Lewis Research Center
Robert Haberle, NASA Ames Research Center
Daniel Hastings, MIT, Department of Aeronautics and Astronautics
Mark Hickman, NASA Lewis Research Center
Gary Jongeward, S-Cubed, Inc.
Ira Katz, S-Cubed, Inc.
Gerry Murphy, JPL
Gary Olhoeft, USGS
Maria Perez-Davis, NASA Lewis Research Center
Jeffery Plescia, JPL
Carolyn Purvis, NASA Lewis Research Center
Frank Rose, Auburn University, Space Power Institute
Ralph Tapphorn, Lockheed Engineering & Sciences Co., c/o NASA/WSTF
Tim Van Sant, NASA Goddard Space Flight Center
Alan Willoughby, NASA Lewis Research Center

WORKSHOP PRESENTATIONS

ELECTRICAL AND CHEMICAL INTERACTIONS AT MARS

Joseph C. Kolecki and G. Barry Hillard
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135

AGENDA

19 NOVEMBER 1991:

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2:45 TO 4:00 PM:	CHAIRMEN PRESENT RESULTS

SPEAKER AND BREAK SCHEDULE

7:30 - 8:30 am:	Breakfast and Registration
8:30 - 8:45 am:	J. Kolecki, B. Hillard
8:45 - 9:15 am:	J Plescia
9:15 - 9:45 am:	R. Haberly
9:45 - 10:15 am:	L. Brace
10:15 - 10:30 am:	BREAK
10:30 - 11:00 am:	S. Graham
11:00 - 11:30 am:	D. Ferguson
11:30 - 12:00 noon:	G. Jongeward
12:00 - 1:00 pm:	LUNCH
1:00 - 1:30 pm:	T. Dickinson
1:30 - 1:45 pm:	J. Kolecki, B. Hillard
1:45 - 5:00 pm (or beyond ...):	WORKING GROUPS

OBJECTIVE OF THIS MEETING

- Subject: Systems/Environmental Interactions at Mars.
- Context: Systems as described in the Synthesis Report; Environmental interactions on the surface and in orbit, electrical and chemical.
- Objective: Review what we already know, ascertain what we need to know, find the holes, and recommend ways to fill them.

DEFINITION: SPACE SYSTEM/ENVIRONMENT INTERACTIONS

SPACE SYSTEM/ENVIRONMENT INTERACTIONS COMPRISE A SET OF PHENOMENA WHICH OCCUR WHEN A SYSTEM IS PLACED INTO AN ENVIRONMENT WHOSE LOCAL CHARACTERISTICS ARE SUCH THAT THE SYSTEM AND THE ENVIRONMENT ARE ABLE TO EXCHANGE "INFORMATION" IN SOME WAY AND THEREBY MODIFY EACH OTHER.

ENVIRONMENTAL INTERACTIONS WORKING GROUP

THE ENVIRONMENTAL INTERACTIONS KNOWLEDGE REQUIREMENTS WORKING GROUP REPRESENTS AN INTEGRATED NASA-WIDE ACTIVITY IN SPACE EXPLORATION ENVIRONMENTAL INTERACTIONS. THE FIRST YEAR OBJECTIVE OF THE ENVIRONMENTAL INTERACTIONS WORKING GROUP IS TO IDENTIFY ENVIRONMENTAL INTERACTIONS ISSUES, AND FORMULATE AND DOCUMENT ROBOTIC PRECURSOR MISSION REQUIREMENTS BASED ON THESE ISSUES.

AD HOC ORGANIZATIONAL STRUCTURE

PROGRAM REQUIREMENTS

ROBOTIC MISSION WORKING GROUP

ENGINEERING REQS. SUBGROUP

SCIENCE REQS. SUBGROUP

(WORKING GROUPS)

WORKING GROUPS in the ENGINEERING REQUIREMENTS SUBGROUP

- ENGINEERING TEST AND DEMONSTRATION
- LUNAR SURFACE KNOWLEDGE REQUIREMENTS
- MARS SURFACE KNOWLEDGE REQUIREMENTS
- MARS ATMOSPHERE KNOWLEDGE REQUIREMENTS
- **ENVIRONMENTAL INTERACTIONS**
- HUMAN SUPPORT
- NAVIGATION REQUIREMENTS

SOME "STRAW MAN" ENVIRONMENTAL INTERACTIONS CONCERNS/QUESTIONS

1.) PASCHEN ELECTRICAL BREAKDOWN IN THE LOW PRESSURE MARTIAN ATMOSPHERE

The Paschen curve for carbon dioxide shows a minimum at the 7-9 torr Martian surface pressure, which means that Paschen electrical breakdown will occur readily on Mars. At this pressure, millimeter to centimeter long discharges are possible at voltages up to a few hundred volts, and centimeter to meter discharges at voltages from a few hundred to a few kilovolts. What role does Paschen breakdown play in production of E.M. noise, electrical power loss, astronaut safety? Will Paschen breakdown be a "major concern" or a "minor annoyance" to unmanned robotic systems? larger manned systems? powered permanent habitations? multikilowatt surface power systems? What can be done to deal with Paschen breakdown in systems designs?

2.) CHARGED OR POLARIZED SAND AND DUST

Electrical forces are believed to play a role in Martian dust physics, specifically in the formation of soil agglomerates and possibly dunes. Also, electrical power system grounding is difficult on Mars because of extremely dry conditions. What role does electrically charged dust play in contamination? Astronaut safety? Do Martian soil grains form electric and/or magnetic dipole structures? What role do these structures play? Will dust charging (a triboelectric effect) occur during dust storms? Will differential dust settling after dust storms result in electrical fields and set up conditions for Mars "lightning?" Will vehicles on excursion across the Martian soil become electrically charged? What can/should be done to deal with charged dust in systems designs?

3.) ELECTRICAL DISCHARGES ACCOMPANYING ASCENT/DESCENT ENGINE FIRING

Observation of electrical discharges associated with launch operations on Earth coupled with the surface characteristics of Mars (high probability of Paschen breakdown, charged dust, etc.) make this scenario a possibility for Mars. What mechanisms might be involved? How great a problem is posed? Should provisions be made to eliminate discharges during engine firings?

4.) ATOMIC OXYGEN and CO_2 IN LOW MARS ORBIT (LMO)

Mars has an atomic oxygen and carbon dioxide environment comparable in density to that found in LEO. The LEO atomic oxygen is known to pose an erosion hazard to objects placed in long term orbit. Should similar hazards be assumed for objects placed in long term LMO?

5.) MARS PLASMA ENVIRONMENT

Mars has an ionosphere roughly an order of magnitude lower in density than LEO. The LEO plasma interacts electrically with all objects placed into it and must be taken into careful consideration in spacecraft design. Should similar interactions be assumed to occur in LMO? Are existing LEO models appropriate to use?

6.) DUST, METEOROIDS, AND DEBRIS ENVIRONMENT

Although dust, meteoroids, and debris may not be a major problem now, human presence in LMO may quickly alter this condition. Will landings on the Martian moons contribute to the orbiting dust environment? What reentry rates should be assumed for orbiting dust, meteoroids, and debris? How do Martian atmospheric parameters (such as scale height) vary with the martian year? What role does this variation play in the maintenance of an orbital dust, meteoroid, and debris environment?

7.) RADIATION AT THE MARTIAN SURFACE AND IN LMO

Mars does not have a significant magnetic field to trap particle radiation and/or shield astronauts from energetic particle fluxes from the sun and from space. What radiation hazards exist in LMO and at the surface? How should these hazards be addressed?

8.) PLASMA GENERATION DURING AEROBRAKING

Aerocapture has been considered for use at Mars. The atmosphere around the aeroshell will be heated and excited to form a thermal plasma. What issues surround this plasma? Do such phenomena as communications blackout during the aerobraking maneuver pose a problem to spacecraft? What issues (charging, electrical currents, etc.) are associated with plasma moving around the aeroshell and/or streaming back past the spacecraft? How should designers take these issues into account?

LIST OF SPEAKERS AND TOPICS

Dr. Jeffrey B. Plescia, JPL:	CONDITIONS AT THE MARTIAN SURFACE
Dr. Robert Haberly, NASA Ames:	THE MARTIAN ATMOSPHERE
Dr. Lawrence Brace, GSFC/Univ. of Mich.:	THE MARTIAN IONOSPHERE
Dr. Scott R. Graham, NASA Lewis:	SEI/SYNTHESIS REPORT SYSTEMS SUMMARY
Dr. Dale C. Ferguson, NASA Lewis:	SUMMARY OF ENVIRONMENTAL INTERACTIONS
Dr. Gary Jongeward, S-Cubed, Inc.:	MODELING AND ANALYSIS TOOLS
Dr. Tammy Dickinson, NASA/HQ/SLC:	NASA MARS EXPLORATION: CODE SL

WORKING GROUPS AND CHAIRS

THE MARTIAN SURFACE — CHAIR: Dr. Ira Katz, S-Cubed, Inc.

MARS ORBIT — CHAIR: Dr. Carolyn Purvis, NASA Lewis Research Center

DOCUMENTS RECEIVED BY MAIL

1.) "America at the Threshold," The Synthesis Group Report to the President, Executive Summary

2.) NASA Technical Memorandum 100470, "Environment of Mars, 1988"

3.) NASA CP 10074, "Sand and Dust on Mars"

4.) JPL, "Viking 2 Landing Site/Site Description and Material Properties"

5.) "Electrical and Chemical Interactions at Mars" (My opening remarks including agenda and other things).

ADDITIONAL DOCUMENTS AVAILABLE TO WORKING GROUPS

1.) "America at the Threshold," The Synthesis Group Report to the President

2.) NASA M75-125-3, "Viking 75 project"

3.) ESA SP-1117, "Mission to Mars"

4.) NASA Ames, "MESUR Mars Environmental Survey"

5.) NASA TM 82478, "Space and Planetary Environment Criteria Guidelines for Use in Space Vehicle Development, Section 6, MARS"

WORKING GROUP OPERATING RULES

Identify ISSUES in the form of ENVIRONMENTAL INTERACTIONS. State WHAT WE KNOW, WHAT WE NEED TO KNOW, and HOW WE GET THERE. PRIORITIZE issues within your group using relative SEVERITY OF EFFECTS as your criteria. The following forms should help you on your way.

INTERACTION

WORKING GROUP: Surface
INTERACTION #________
DESCRIPTION:

SEVERITY:

CURRENT KNOWLEDGE:

NEW KNOWLEDGE REQUIREMENTS:

RELATIVE PRIORITY:__________________

RECOMMENDATIONS

WORKING GROUP: Surface
INTERACTION #________:
APPROACH TO FILLING KNOWLEDGE REQUIREMENT:

JUSTIFICATION:

ESTIMATED COST AND TIME: COST:____________________

TIME:____________________

SUPPORTING DATA, REFERENCES, CURVES, PICTURES (ETC.)

WORKING GROUP: Surface
ISSUE #________

INTERACTION

WORKING GROUP: Orbit
INTERACTION #________
DESCRIPTION:

SEVERITY:

CURRENT KNOWLEDGE:

NEW KNOWLEDGE REQUIREMENTS:

RELATIVE PRIORITY:____________________

RECOMMENDATIONS

WORKING GROUP: Orbit
INTERACTION #________:
APPROACH TO FILLING KNOWLEDGE REQUIREMENT:

JUSTIFICATION:

ESTIMATED COST AND TIME: COST:______________________________

TIME:______________________________

SUPPORTING DATA, REFERENCES, CURVES, PICTURES (ETC.)

WORKING GROUP: Orbit
ISSUE #________

N93-26393

The Upper Atmosphere and Ionosphere of Mars

Larry H. Brace
Space Physics Research Laboratory
The University of Michigan
Ann Arbor, MI 48109.

Presented at the Workshop on Electrical and Chemical Interactions of Mars.
November, 19-20, 1991
Lewis Research Center, Cleveland, Ohio.

SUMMARY

The Dynamic Atmosphere of Mars

The Martian atmosphere is believed to be highly variable and dynamic, much more so than the atmosphere of Earth. Figure 1 illustrates certain aspects of this dynamic behavior. High winds blowing over high relief surface features produce density variations, usually identified as gravity waves, having peak to peak amplitudes of 15 to 20%, as is evident from the Viking 1 and 2 Lander measurements shown in Figure 2. These structures grow as they propagate upward into the thermosphere and ionosphere (>80 km) where they deposit energy and momentum that should drastically affect the thermal and chemical structure of Low Mars Orbital (LMO) environment; i.e, the region between about 100 and 400 km.

Possible Similarities with Earth and Venus

The upper atmospheres of the terrestrial planets are all known to be highly dynamic. Knowledge of this behavior at Mars is very meager, but the upper atmospheres of the other two (Earth and Venus) have been rather thoroughly measured. Earth satellites like the Atmosphere Explorers[1] have shown that upper atmosphere density disturbances are most prevalent at high latitudes (Figure 3). At Venus, the Pioneer Venus Orbiter[2] Neutral Mass Spectrometer has shown that high amplitude gravity wave structure is common at the terminators, and that this behavior is not associated with any particular surface features (Figures 4 and 5). Many Space Shuttle flights carrying sensitive accelerometers have measured similar features between 60 and 160 km during reentry (Figures 6). A new Earth upper atmospheres mission, called TIMED[3], is now being planned to study more carefully the coupling between the upper atmosphere and the thermosphere/ionosphere. The comparable regions at Mars have yet to be explored globally.

The Atmosphere and Ionosphere of Mars

Much more is known about the lower and middle atmosphere of Mars than about its upper atmosphere, including the thermosphere and exosphere. More is known about the electron density in the ionosphere, since that parameter can be measured by radio occultation measurements without passing into the ionosphere. Temperature profiles of the lower atmosphere up to about 30 km were obtained in 1970 and 1971 by the Mariner 9 IR limbscanning experiment[4], and radio occultation measurements of the ionosphere provided hundreds of electron density vs height profiles of the ionosphere between about 100 km and 400 km[5] (Figure 7). A striking result was the great orbit to orbit variability of the altitude of the ionospheric peak (Figure 8), a result that is believed to reflect the great variability of thermospheric density that is to be expected from the variability seen at lower altitudes.

Solar Wind Interactions

The Phobos-2 spacecraft did not penetrate the ionosphere or thermosphere of Mars (periapsis ~ 870 km), but did perform many valuable measurements[7] that shed light on the nature of solar wind interactions with the planet and on its energetic particle environment at its circular orbit altitude of about 6000 km. Figure 9 is a cartoon showing the suspected escape of O^+ ions down the Martian tail as a result of solar wind interactions. Figure 10 shows the measurements of the energetic O^+ ion fluxes measured some 6000 km down the tail, apparently escaping the planet. These energetic ions represent part of the energetic particle environment to be expected in Mars orbit.

Future Approved Missions

Mars Observer is expected in 1993 to extend the gas temperature measurements to somewhat higher altitudes than those achieved by Mariner 9 limbscanning, but its sun-synchronous orbit will provide measurements at only two opposing local times (02 and 14 hrs). MO will leave the thermosphere largely unexplored, since it will have no related in situ measurements, but it will obtain additional electron density profiles via radio occultation. The Soviet Mars-94 mission provides the only hope of learning more about the composition and temperature of the Martian ionosphere, but its perigee altitude (>300 km) will probably only an occasionally dip into the upper ionosphere, and this will not be low enough to permit in situ measurements of the thermosphere itself. A topside sounder should provide additional electron density profiles down to the altitude of the peak density.

Possible Future Mission

Past missions, and the missions now being implemented will have left unaddressed most of the important questions about the nature of the LMO environment. The global variations of thermospheric and ionospheric composition and temperature will remain unknown. The temporal variations of the density, temperature, composition and winds in the thermosphere and ionosphere (local time, seasonal, solar cycle, response to local and global dust storms) remain almost totally unknown. Nor are the amplitudes and scale sizes of smaller scale structures (such as gravity waves) known for the upper atmosphere and thermosphere. Viking 1 and 2 confirmed their existence but their global distribution, local time distribution, and frequency of occurence is completely unknown. The martian contribution to the energetic particle environment in LMO is also almost completely unknown.

As for new missions that will help cure our ignorance of the LMO environment, none are currently approved. A long advocated Mars Aeronomy Orbiter[8] has been proposed to study this region. In its initial elliptical orbit phase, it would be a deep diver capable of making both in situ measurement of the height variations down to the vicinity of 120-130 kilometers and remote measurements of the middle and lower atmosphere, including dust. Figure 11 shows a low passage of MAO through such a wave train The path of an entry probe which could be deployed from such a satellite is also shown traversing the same wave train at lower altitudes. Such measurements will also reveal the amplitude of the density enhancements that are believed to accompany local or global dust storms. Figure 12 illustrates an MAO and entry probe traversal of a region perturbed by an underlying local dust storm. Figure 13 shows the Strawman payload recommended for MAO to make such measurements.

Later in the MAO mission, aerobraking maneuvers will be used to circularize the orbit to provide a more global view of the atmosphere, ionosphere, and particles and fields environment at altitudes above about 130 km. Ion and neutral mass spectrometers and various cold plasma probes would measure the altitudinal and global variations in the ionosphere and thermosphere, as well as define the amplitude and scale sizes of the gravity wave structures. They will also be able to determine whether such structures are associated with specific surface features or are locked into a diurnal pattern, as found at Venus[2]. MAO fields and particles instruments would illucidate the role of solar wind interactions as a source of energy and dynamics of the ionosphere and thermosphere and the importance of atmospheric escape in the continuing evolution of the Martian atmosphere.

The MAO mission, while essentially focused on scientific questions about planetary atmosphere processes, will have important spinoffs for future manned and robotic explorations of the planet[9]. It will define the atmospheric drag environment to be encountered in LMO. It will identify the most dynamic atmospheric regions that perhaps should be avoided when selecting potential targets for aerobraking or aerocapture maneuvers. It will add to our meager knowledge of the energetic particle environment in LMO.

Specific MAO Spinoffs for Knowledge of the LMO Environment

- Chemical erosion of s/c surfaces:	Define the spatial and temporal variations of atomic oxygen, the major constituent above about 200 km.
- Electrical design of spacecraft:	Define the ionospheric medium to evaluate the need for isolation of future s/c power systems from the conducting plasma to avoid unnecessary s/c charging and leakage currents.
- Orbital lifetimes:	Define the atmospheric densities and their variations to permit accurate orbital lifetime predictions and propulsion requirements to offset drag effects.
- Aerobraking and Aerocapture:	Identify dynamic regions of the Martian atmosphere that should be avoided as aerocapture targets to assure a safer, smoother ride and a more predictable initial orbit.
- Impact Ionization Effects	Measure the electrons, ions, and airglow produced by the spacecraft as it dives deeply into the lower thermosphere (~100-130 km).

References

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11. Zhang et al., "An Observational Study of the Nightside Ionosphere of Mars and Venus with Radio Occultation Methods," *J. Geophys. Res.*, 95, No. A10, 17,095-17,102, 1990.

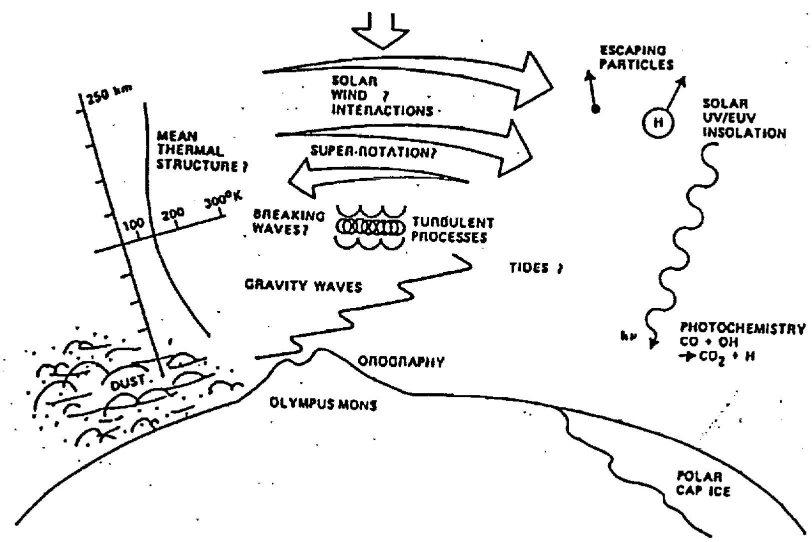
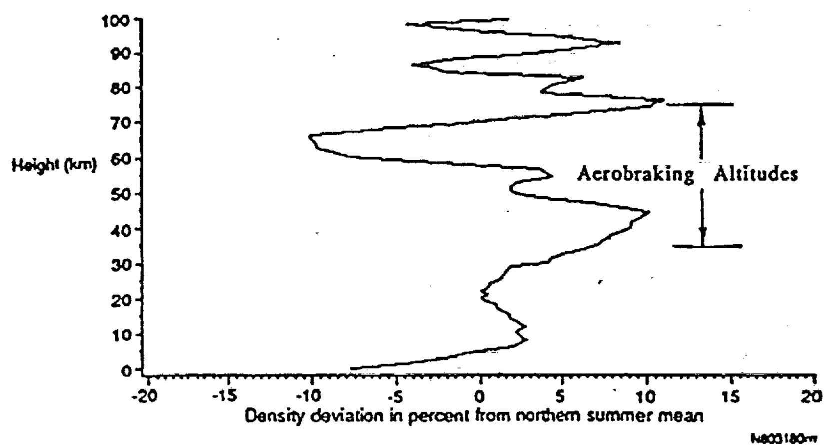


Figure 1. A cartoon showing the dynamic atmospheric processes that would be invest igated by the Mars Aeronomy Orbiter. (from the MAO Science Team Report, NASA Tech. Memo 89202).



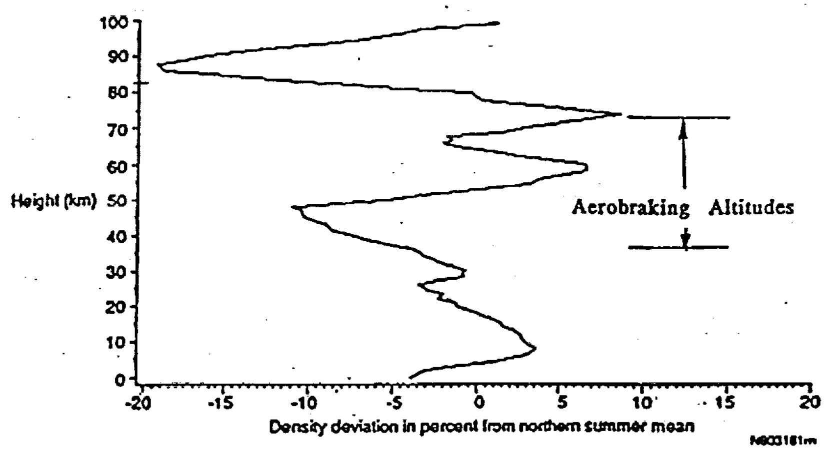


Figure 2,Viking 1 and 2 Lander measurements of density normalized by the COSPAR model atmosphere. Large waves were present at aerobraking altitudes. This is the only hard information we have about the wave structure at these altitudes. (from Environment of Mars, 1988)

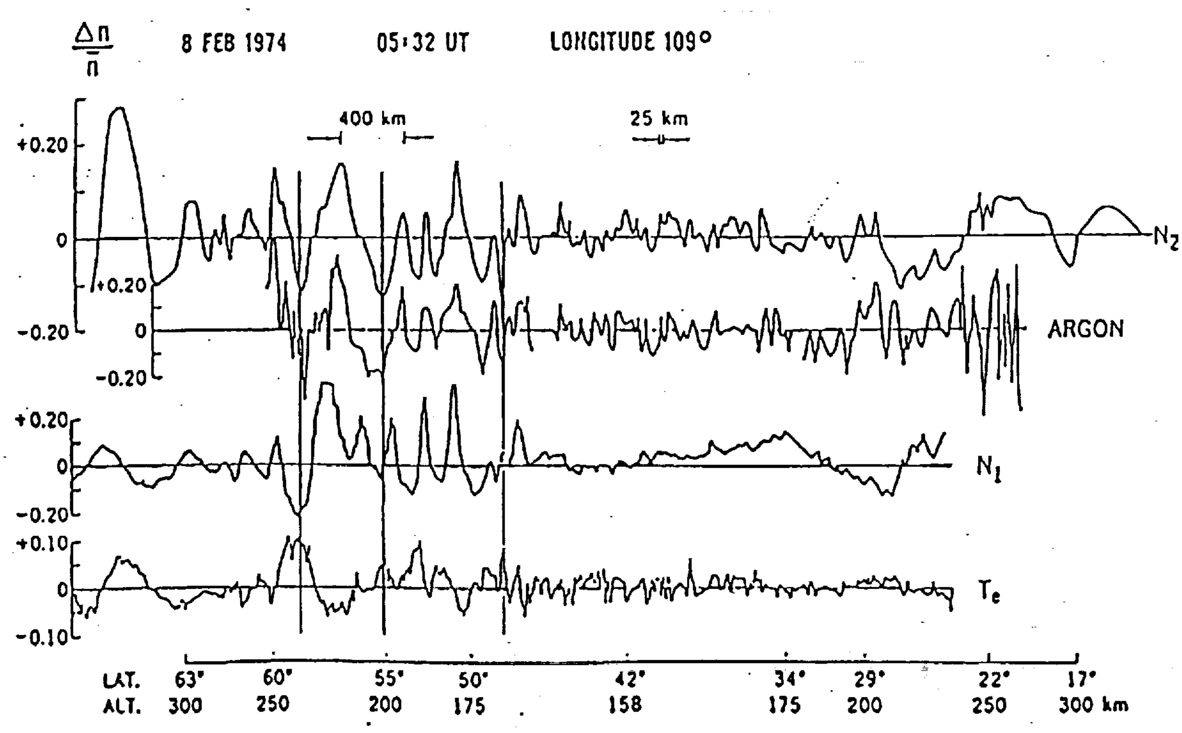


Figure 3. Density variations (upper panel) in the Earth's themosphere measured by Atmosphere Explorer-C. The greatest wave amplitudes are found at higher latitudes where auroral energetic particles heat the atmosphere.

C.A. Reber et al., J. Geophys. Res., Vol. 80, No. 34, 4576-80, 1975, copyright by the American Geophysical Union.

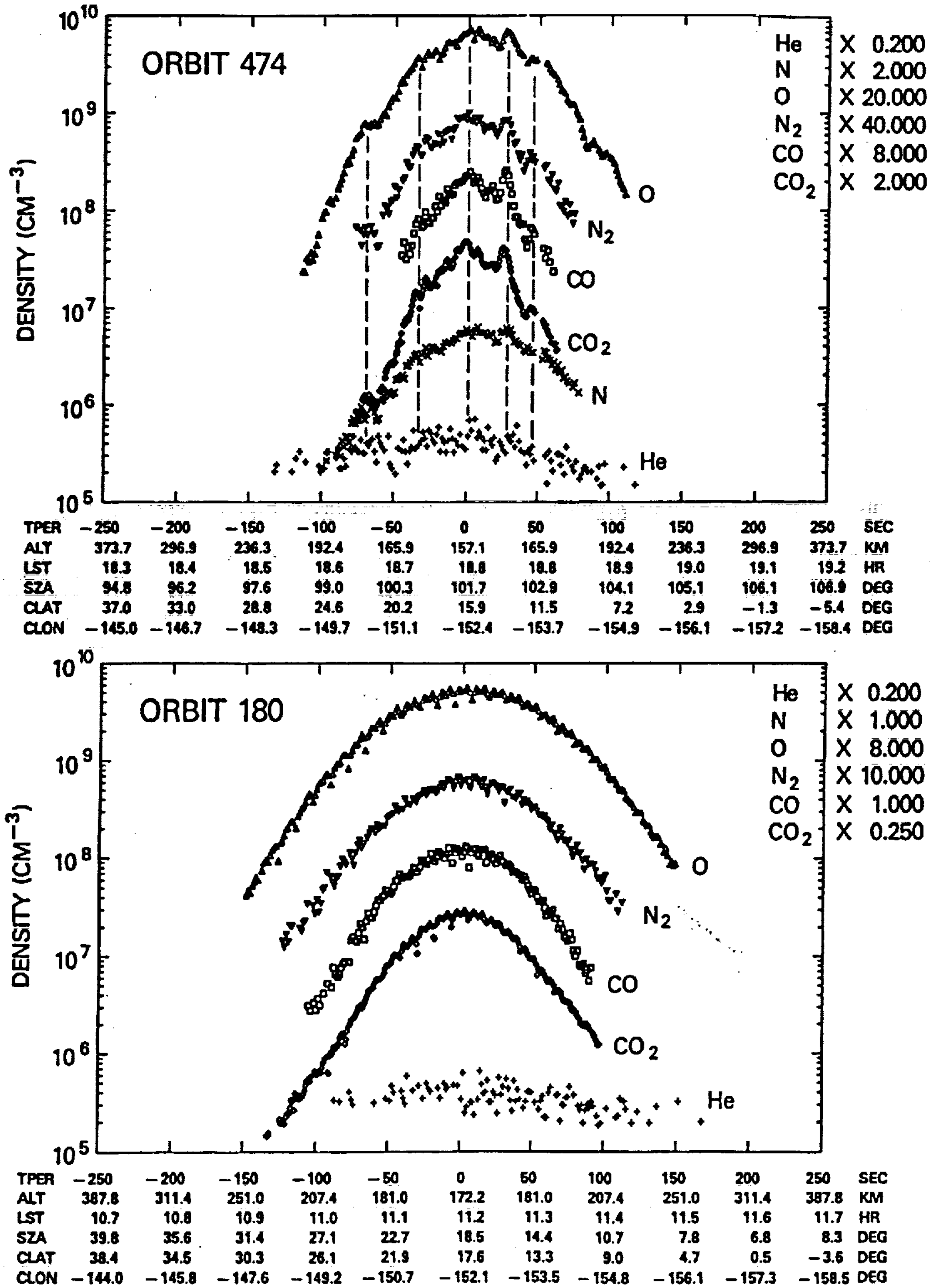


Figure 4 Plot of ambient density versus time from periapsis for He, N, O, N_2, CO, and CO_2 measured on orbits (bottor 180, near noon, and (top) 474, near the terminator. The densities have been scaled by the factors shown. Atomic nitroge was not routinely measured prior to orbit 190. The points below the main data line in orbit 180 for O, N_2, CO, and CC are due to a partial shadowing of the ion source by the spacecraft antenna at extreme angles of attack.

W.T. Kasprzak et al., Geophys. Res. Letts., 7, 106, 1988, copyright by the American Geophysical Union.

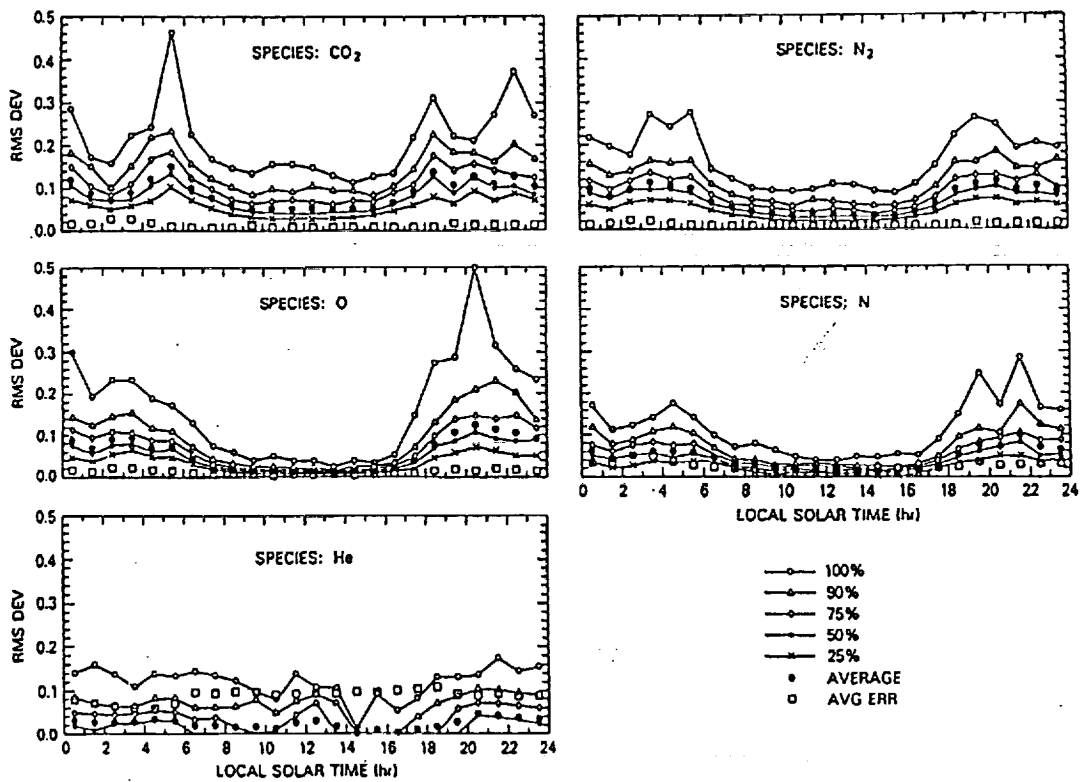


Figure 5. The statistical amplitudes of density waves in the Venus thermosphere shows that the atmosphere is most dynamic near dawn and dusk, and on the night-side in general. The dayside is quite smooth. Similar information is not available for Mars.

W.T. Kasprzak et al., Geophys. Res. Letts., 7, 106, 1988, copyright by the American Geophysical Union.

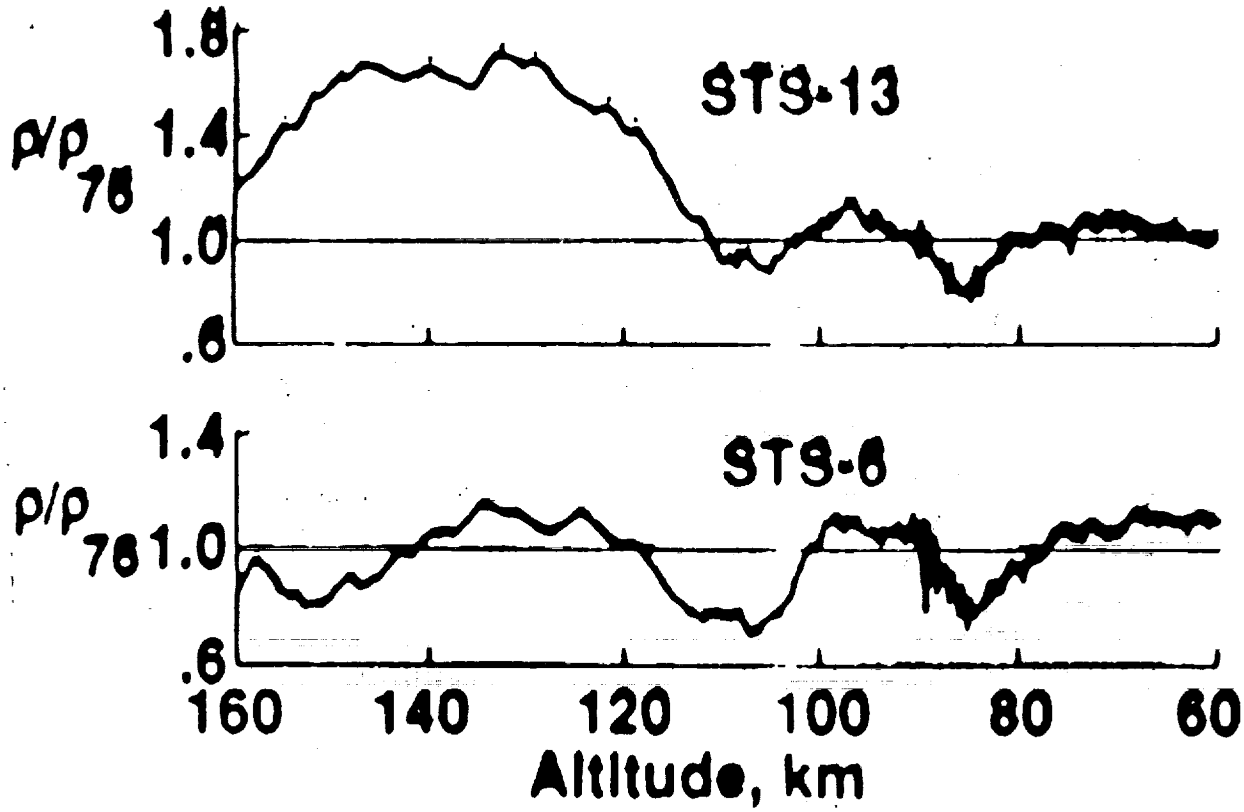


Figure 6. The ratio of the atmospheric density (ρ) to a 1978 model density based on STS-13 and 6 accelerometer measurements. These measurements reveal large amplitude gravity wave structure at aerobraking altitudes in the Earth's upper atmosphere.

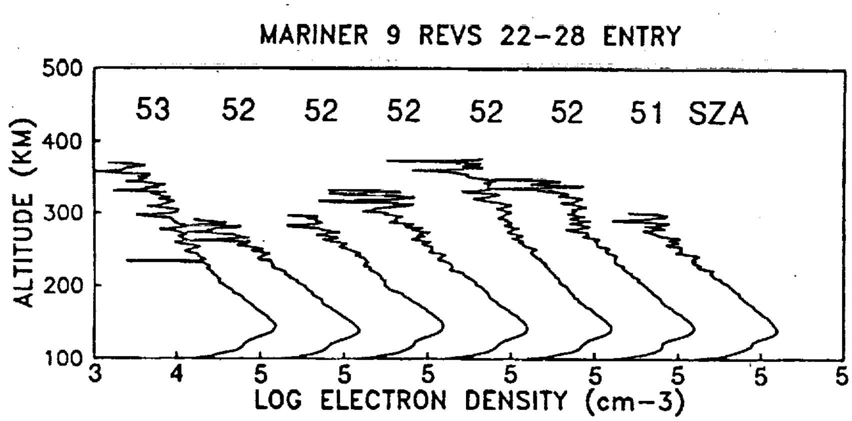


Figure 7. Examples of altitude profiles of dayside ionospheric electron density at Mars, derived from the radio occultation experiment on Mariner 9 [from *Zhang et al.*, 1990*a*]. SZA is the solar zenith angle at which the profile was obtained (subsolar is SZA = 0; SZA = 90 is the terminator).

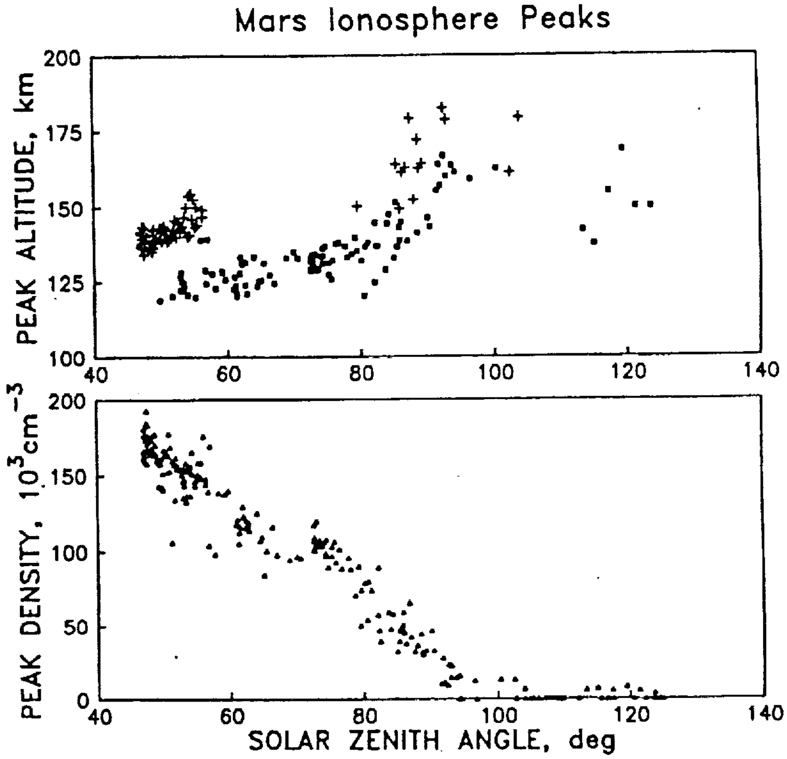


Figure 8. Plots of the density (bottom) and altitude (top) of the peaks in the electron density profiles observed at Mars as a function of solar zenith angle (adapted from *Zhang et al.* [1990*b*]).

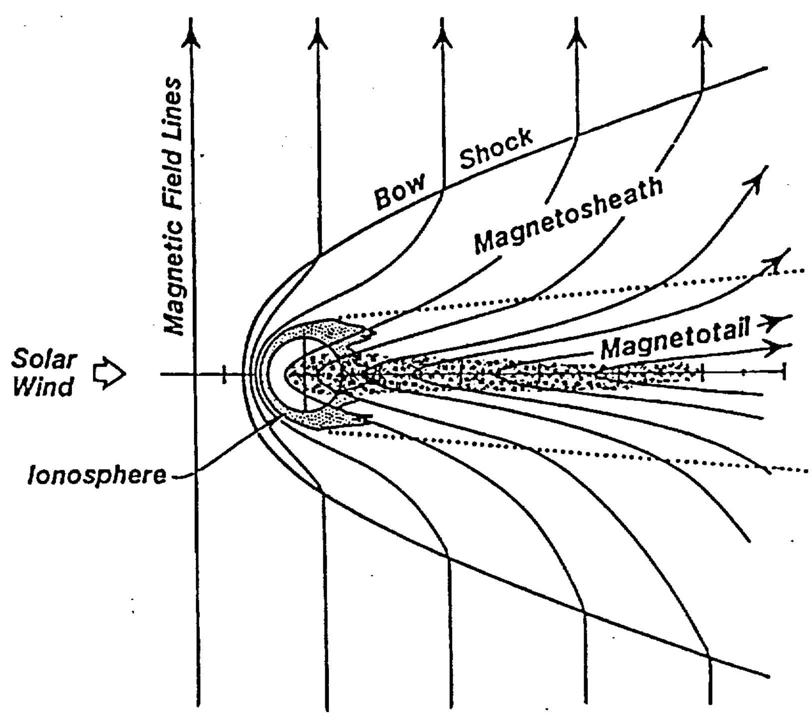


Figure 9. A cartoon illustrating the escape of energetic O+ ions from Mars, based on Phobos 2 measurements such as those shown in Figure 10.

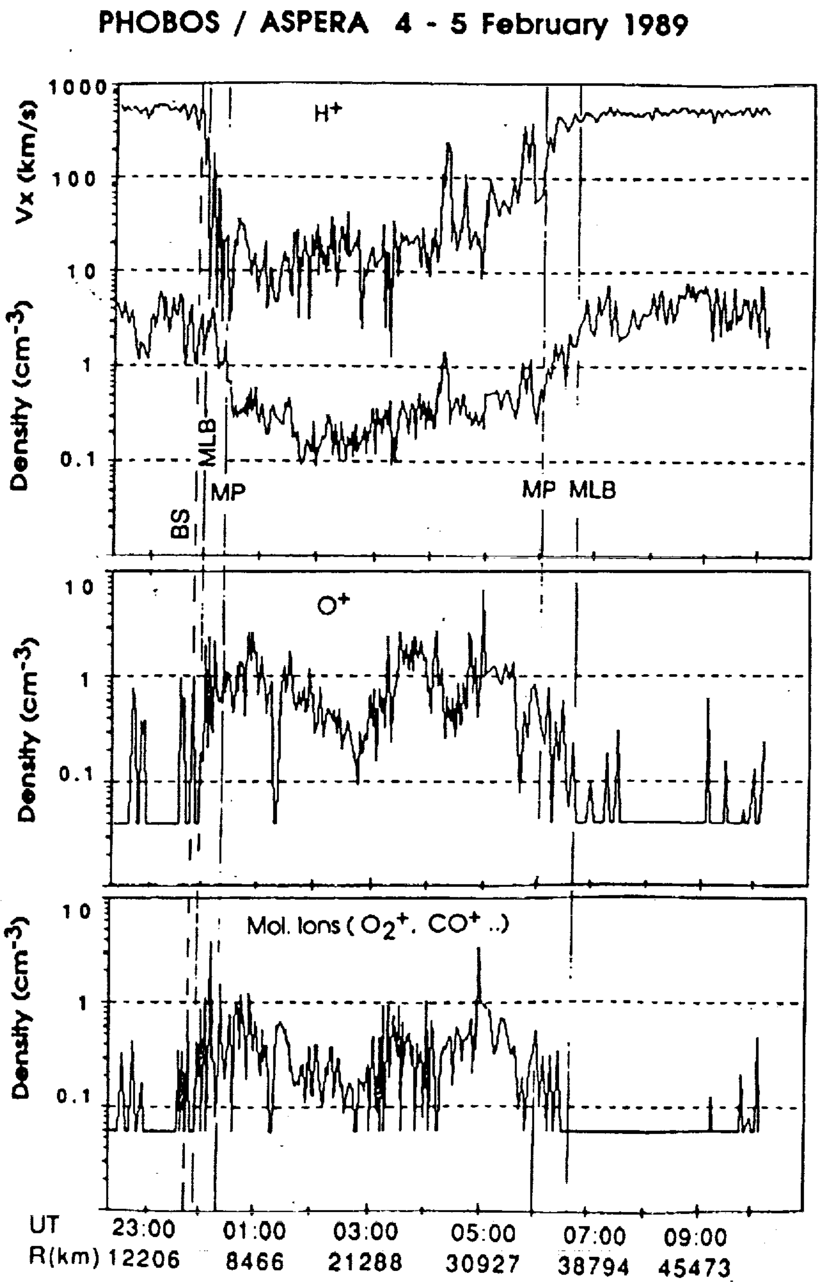


Figure 10. ASPERA measurements from Phobos 2 showing energetic ions escaping down the Martian tail. These ions contribute to the energetic particle environment to be encountered in Mars orbit.

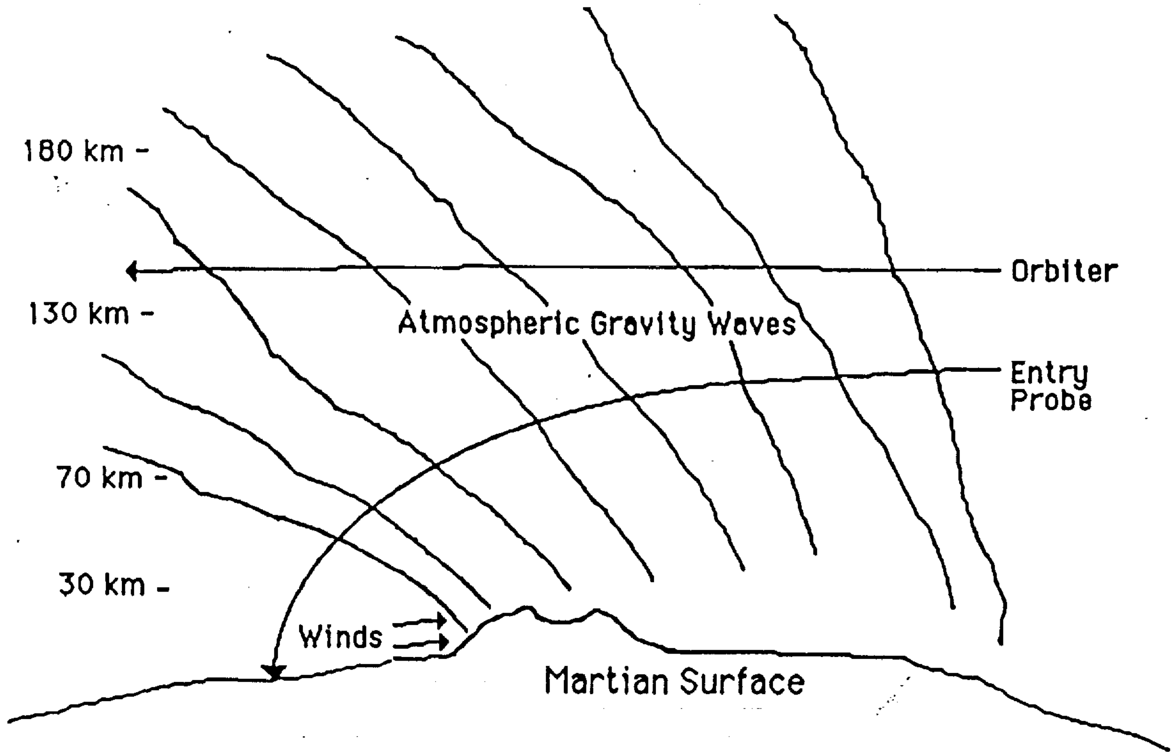


Figure 11. The trajectory of MAO, and an entry probe, through a series of gravity waves propagating upward out of the Martian lower atmosphere.

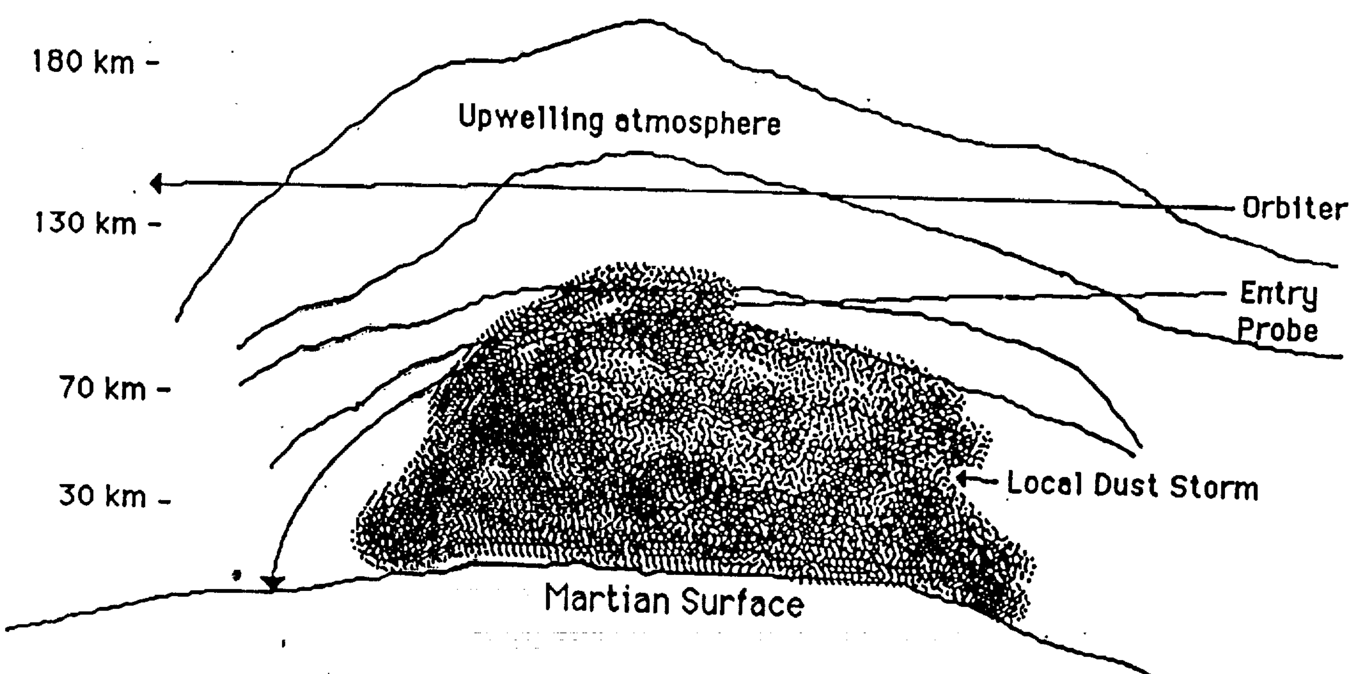


Figure 12. The trajectory of MAO, and an entry probe, through the upwelling atmosphere produced by heating associated with a local dust storm at Mars.

TABLE V.1 MAO SWT RECOMMENDED INSTRUMENTS

	MASS	POWER	TELEMETRY[1]
CORE PAYLOAD			
Neutral Mass Spectrometer[2] (NMS)	10.0	8.5	180
Fabry-Perot Interferometer (FPI)	13.5	5.5	30
UV + IR Spectrometer (UV + IRS)	5.0	7.0	130
Ion Mass Spectrometer (IMS)	2.5	1.5	60
Retarding Potential Analyzer + Ion Driftmeter (RPA + IDM)	4.5	4.0	80
Langmuir Probe (ETP)	2.0	4.0	30
Plasma + Energetic Particle Analyzer (PEPA)	10.0	9.0	320
Magnetometer (MAG)	3.0	3.5	200
Plasma Wave Analyzer (PWA)	5.5	3.5	130
Radio Science[3] (RS)	4.5	12.5[4]	-
	60.5 kg	59.0 W	1160 bps
SECONDARY PAYLOAD			
Infrared Atmospheric Sounder (IAS)	8.0	7.5	260
UV + Visual Synoptic Imager (UV + VSI)	9.0	8.0	1000
Neutral Winds/Temperature Spectrometer (NWTS)	10.0	9.0	180
	27.0 kg	24.5 W	1440 bps
TOTAL	87.5 kg	83.5 W	2600 bps

1 Individual instrument rates can be highly variable and will depend upon the final payload and orbit selection. The rates listed are based upon typical duty cycles for each experiment and they have been averaged over the orbit (i.e., 6,000 x 150 km orbit has been assumed).

2 Includes limited wind measuring capability.

3 Consists of S-band transponder and stable oscillator.

4 10 W (continuous) for the stable oscillator and 25 W (10% duty cycle) for the S-band transponder.

Figure 13. The MAO Recommended Instrument Payload (from the MAO Pre Phase A Study)

N93-26394

THE MARTIAN LOWER ATMOSPHERE

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Moffett Field, California 94035

Topics:

- Mass and composition
- Photochemical processes
- Temperatures and winds
- General Circulation
- Dust storms

BASIC PROPERTIES OF MARS AND EARTH

PLANETARY PROPERTIES	MARS	EARTH
MASS, kg	6.46×10^{23}	5.98×10^{24}
RADIUS, m	3394	6369
ACCELERATION OF GRAVITY, m/sec^2	3.72	9.81
ORBIT ECCENTRICITY	0.093	0.017
SPIN-AXIS INCLINATION, deg	25.2	23.5
LENGTH OF YEAR, Earth days	687	365
LENGTH OF SOLAR DAY, sec	88,775	86,400
SOLAR CONSTANT, W/m^2	591	1373

ATMOSPHERIC PROPERTIES	MARS	EARTH
PRINCIPAL CONSTITUENTS, by volume	CO_2 (95.3%) N_2 (2.7%) Ar^{40} (1.6%) O_2 (0.13%)	N_2 (78.1%) O_2 (20.9%) Ar^{40} (0.9%) CO_2 (0.03%)
MEAN MOLECULAR WEIGHT	44	29
TOTAL MASS, kg	2.4×10^{16}	5.3×10^{18}
MEAN SURFACE PRESSURE, mbar	6	1013
NEAR-SURFACE TEMPERATURE RANGE, K	145-245	220-310

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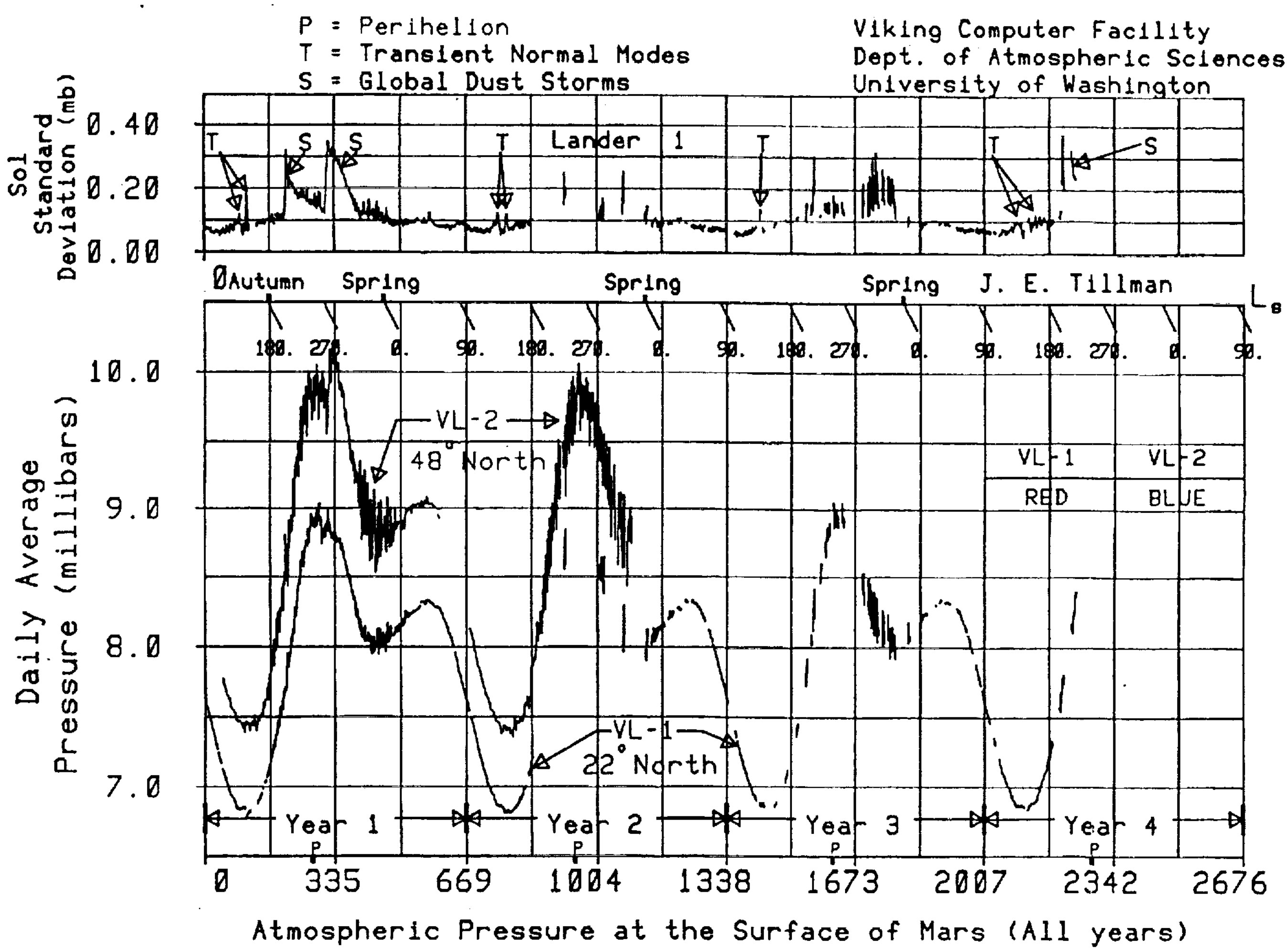

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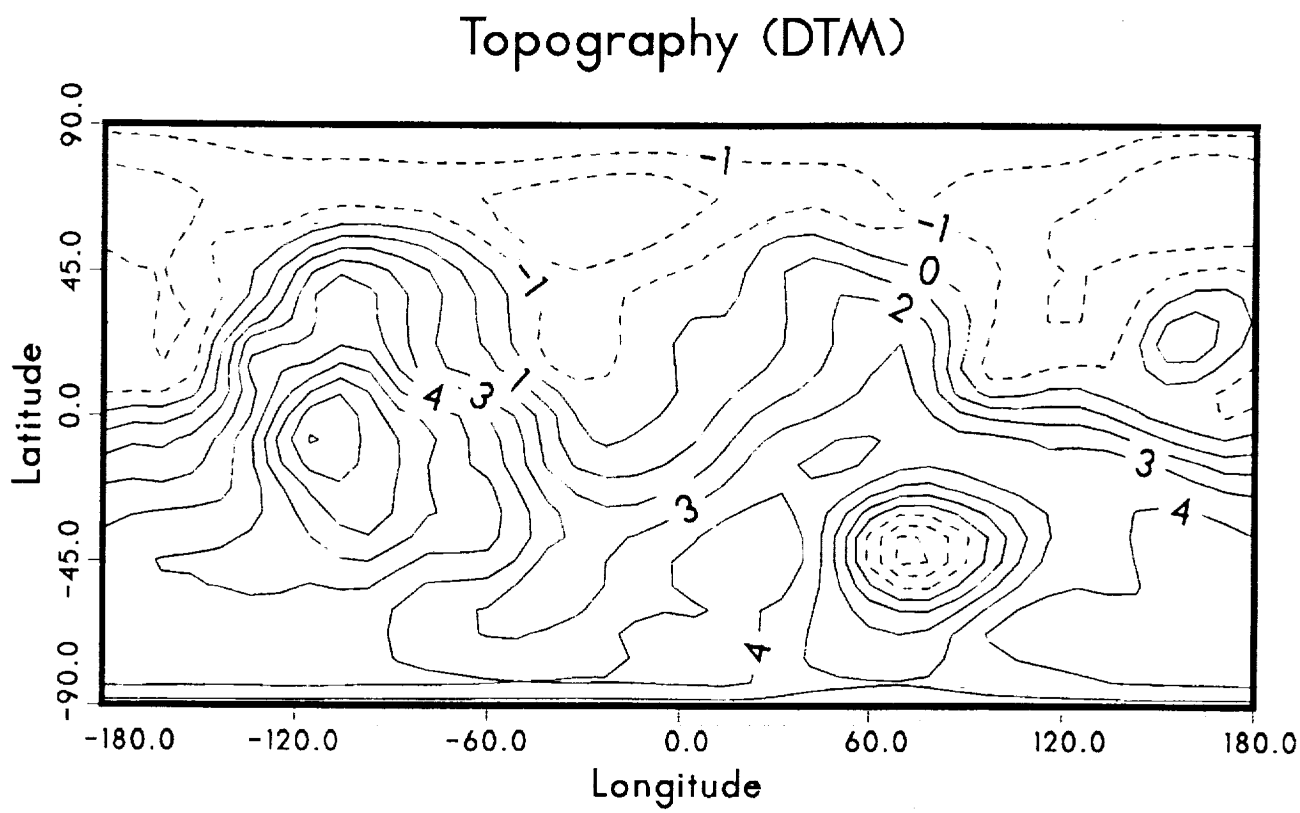
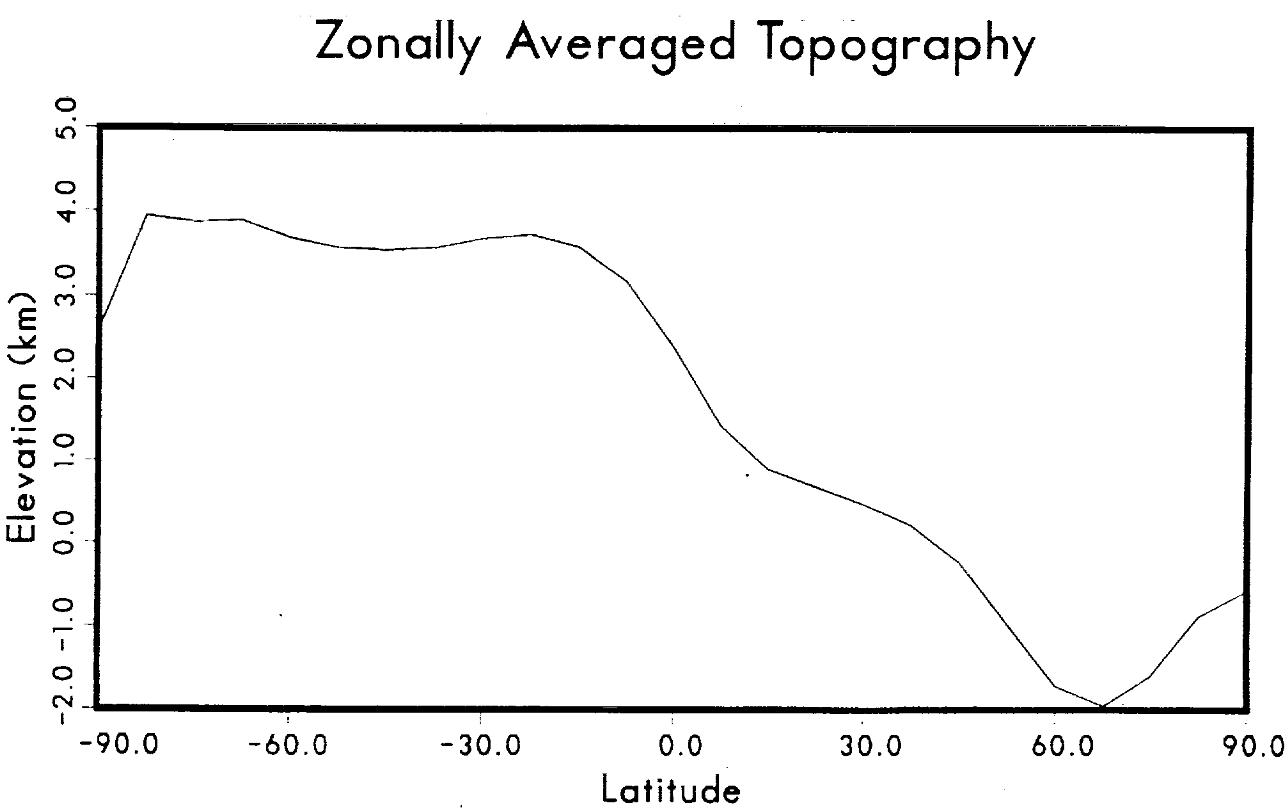
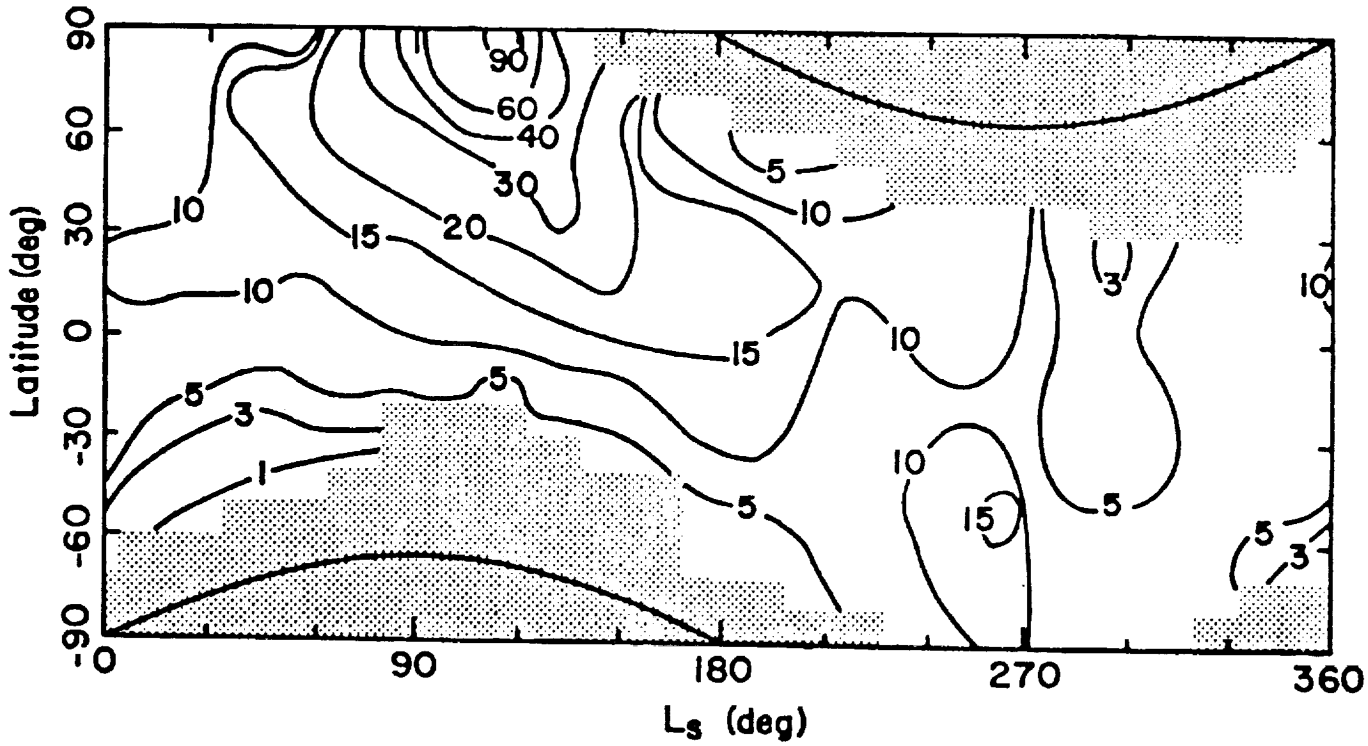
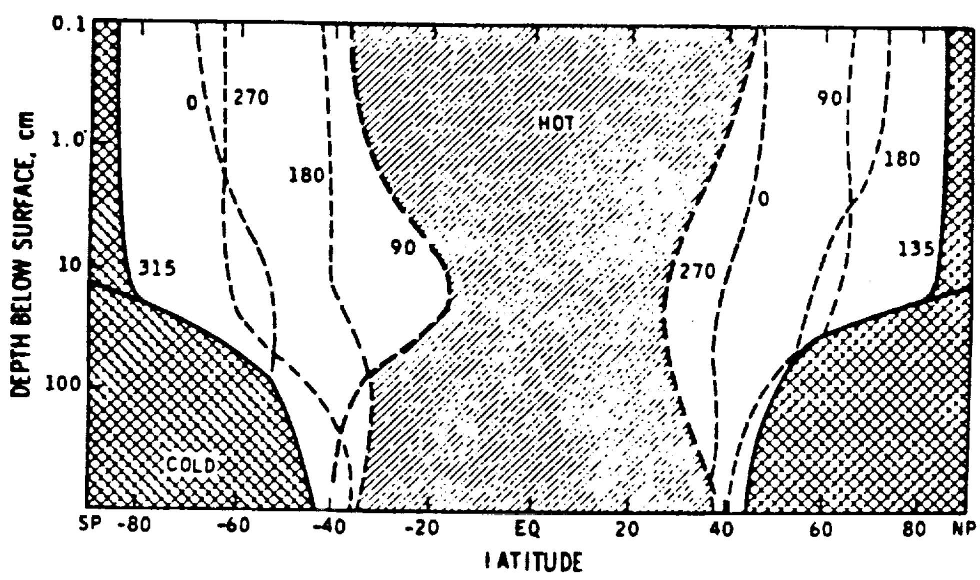

Topography (DTM)
90.0
45.0
0.0
-45.0
-90.0
Latitude
-1
0
2
4
3
1
3
4
-180.0
-120.0
-60.0
0.0
60.0
120.0
180.0
Longitude


Zonally Averaged Topography
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
Elevation (km)
-90.0
-60.0
-30.0
0.0
30.0
60.0
90.0
Latitude



Jarosky, B.M. and Farmer, B., J. Geophys. Res., 87, 2999-3019, 1982, copyright by the American Geophysical Union.



Farmer, C.B. and Doms, P.E., J. Geophys. Res., 84, No. B6, 2881-2888, 1979, copyright by the American Geophycial Union.

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Particles in the atmosphere	Measurement	Model	Ideas	Notes
composition		< 60% SiO_2 1% magnetite		SiO_2 measurement based on inferences from Mariner 9 IRIS spectra - loosely constrained. Value quoted is higher than Viking lander soil elemental composition measurements.
density			ρ = 2-3 gm/cm^3	Based on typical silicate rock densities. Considered a good estimate.
size distribution		range: r = 0.1 - 10 μm mean: r = 0.4 - 2.5 μm		Measurements based on inferences from Mariner 9 IRIS spectra, and Viking Lander Sun Diode images. Considerable uncertainty in concentrations of sub-micron particles. Means are cross-sectional weighted.
concentration		$N \sim N_0 \tau \exp(-z/H)$ where N_0 = 6 particles/cm^3, τ is the visible optical depth, z is height (km), and H = 10 km is an atmospheric scale height.		Based on the Mariner 9 inferred particle size distribution assuming r = 2.5 μm and ρ = 3 gm/cm^3. See Appendix A.

vertical distribution	Background dust haze extends 30-70 km above the surface. During great dust storms, particles can reach 70 km.		Background dust haze: particles are unifromly distributed with height. Developing storms: particles are concentrated near the surface in source regions; aloft elswhere. Particles with radii >> 5 μm fall out quickly.	Consistent with twilight observations and sky brightness measurements. Loosely constrained.
geographical distribution	Dust storm periods: regional to global. Non-dust storm periods: localized storms can occur anywhere.		Maximum concentrations tend to occur in tropical regions.	Highly variable.
seasonal variability	Maximum dust loading occurs during southern spring and summer.			
optical properties	Solar optical depth varies from 0 to 6 or above.	$\tau_{vis}/\tau_{ir} \sim 2$ solar transmissivity ~ $\left(1+\frac{\tau}{2\mu}\right)^{-1}$		Optical depth always > 0.2 at the Viking lander sites. Solar transmissivity is that for purely scattering dust particles, and is therefore an approximation.
ground visibility		Visual Range (km) ~ 10 / τ		Visual range for distinguishing a black target against a diffuse white background.
space-to-ground visibility	No surface features were visible from orbit during the first half of the 1971 storm.			

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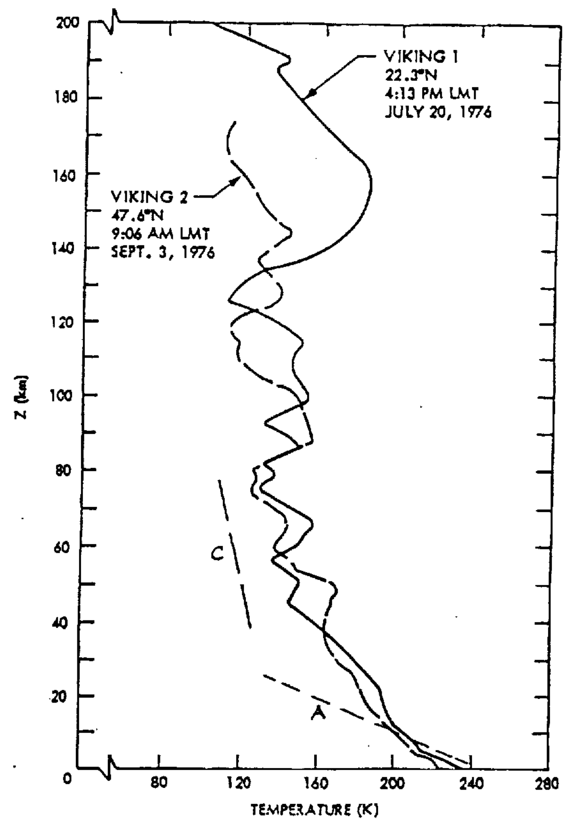
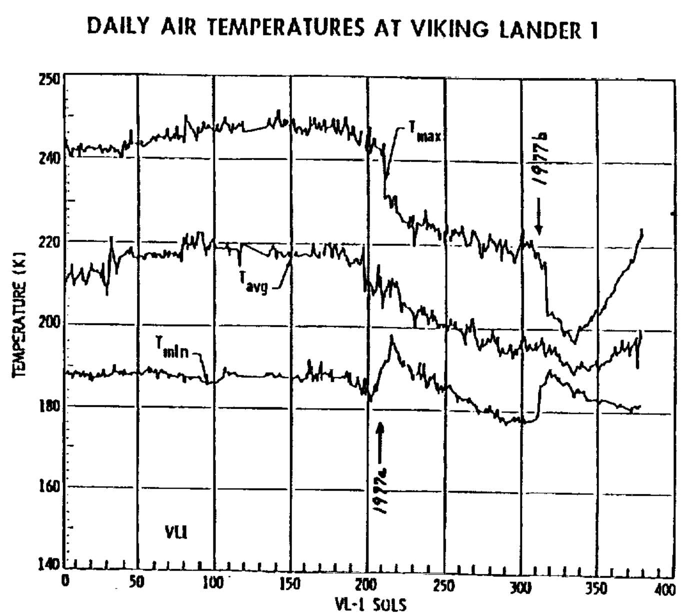


Seiff, A. and Kirk, D.B., J. Geophys. Res., 82, No. 28, 4364-4378, 1977, copyright by the American Geophysical Union.



Ryan, J.A. and Henry, R.M., J. Geophys. Res., 84, No. B6, 2821-2829, 1979, copyright by the American Geophysical Union.

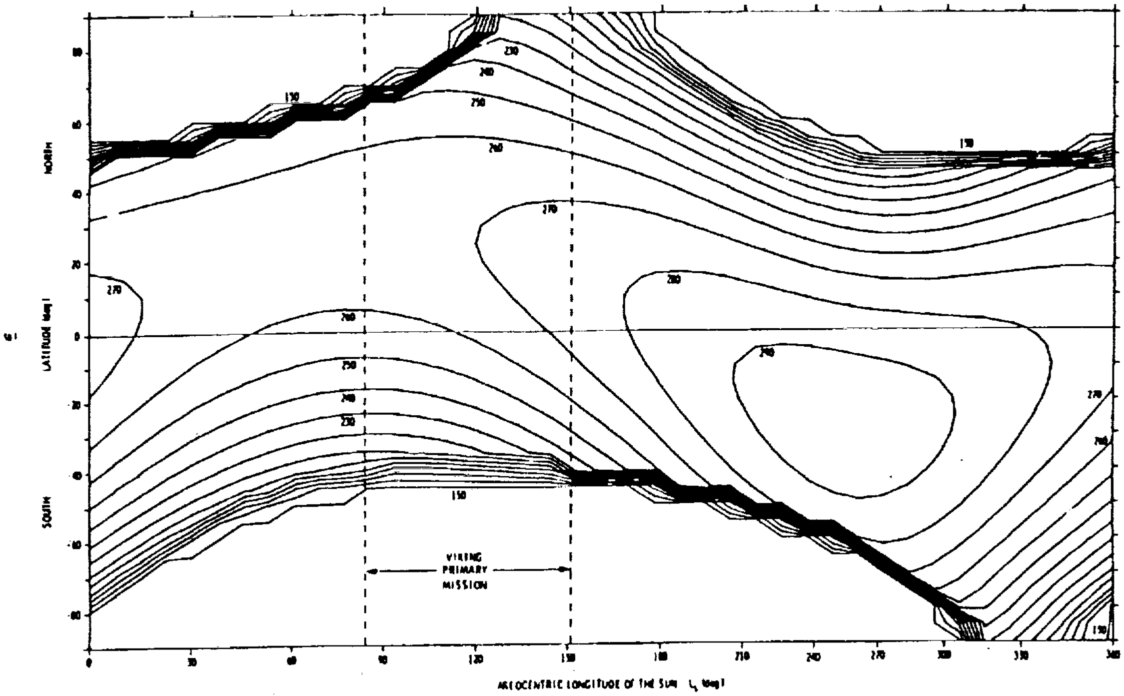


Fig. 18*a*

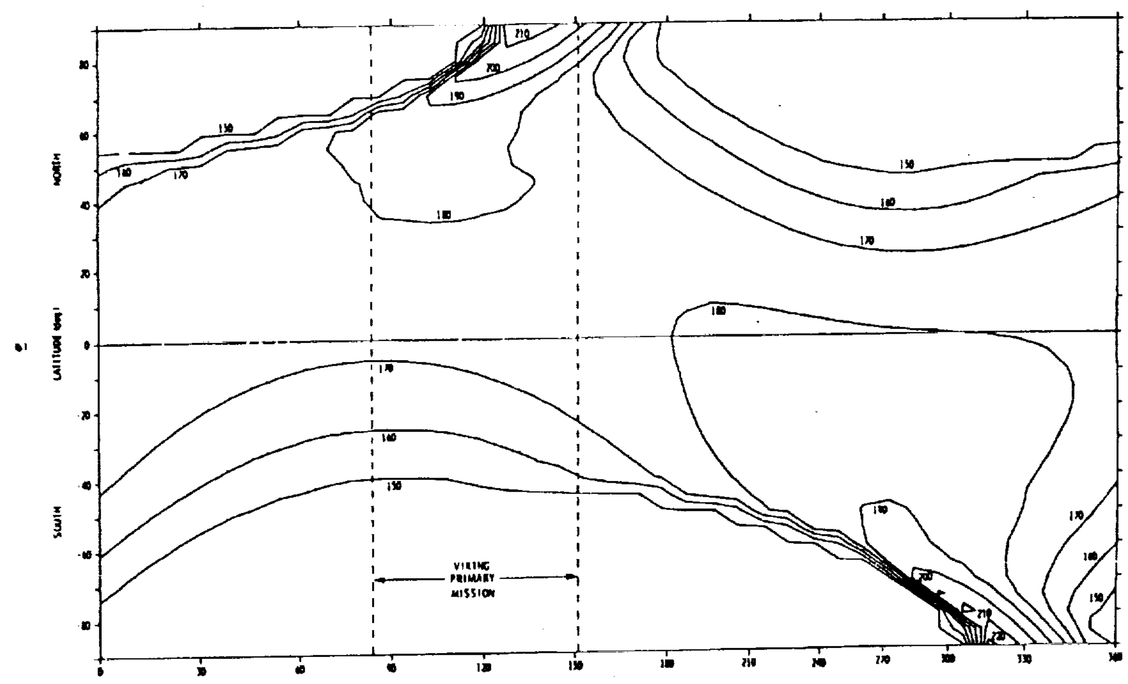
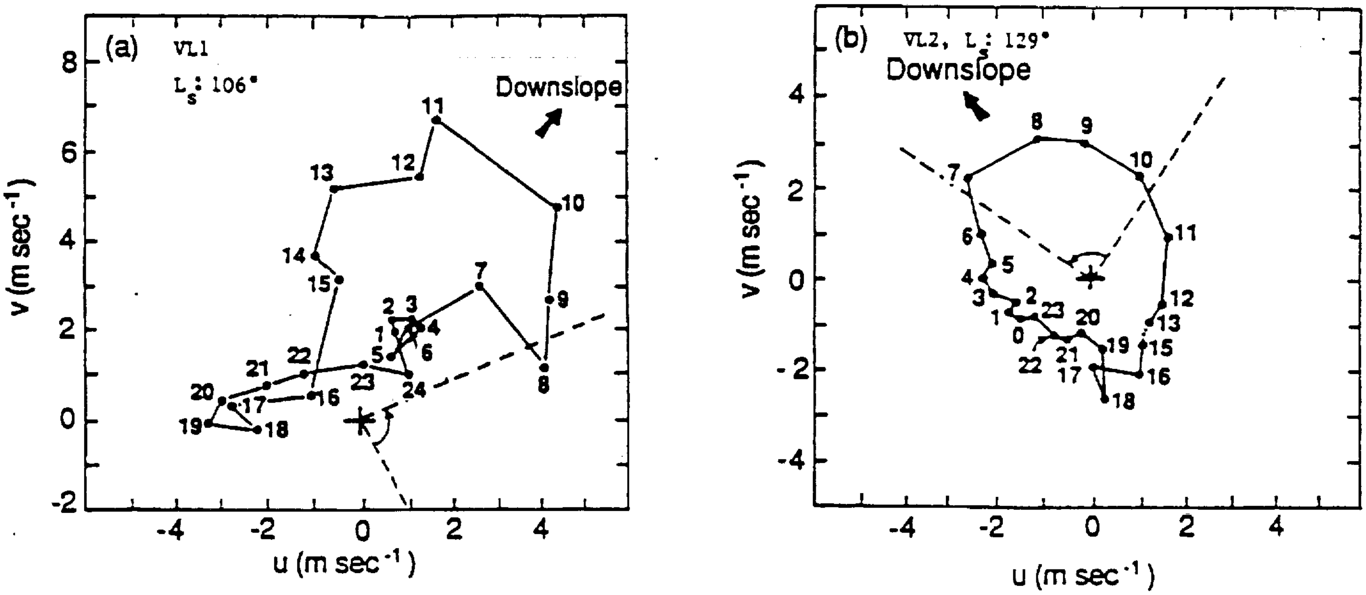
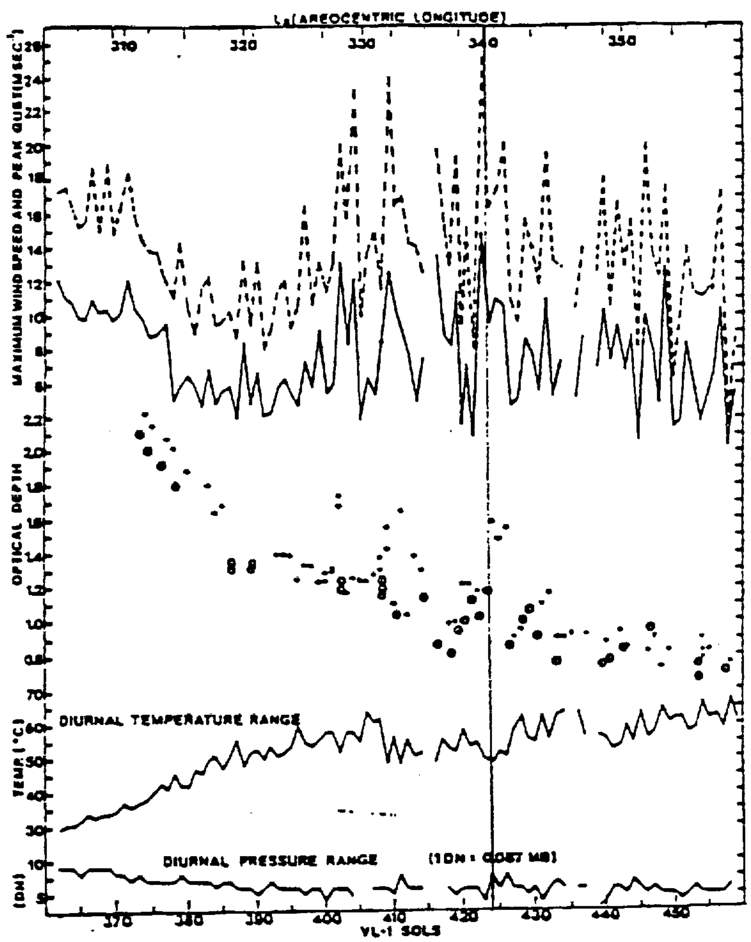


Fig. 18*b*

Fig. 18. Diurnal surface temperature mean and extremes for the primary Viking thermal model ($A^* = 0.25$ and $I = 6.5$). The dashed lines indicate the seasonal range of the primary mission. (*a*) Maximum temperatures. (*b*) Minimum temperatures. (*c*) Mean temperatures.



Hess, S.M., et al., J. Geophys. Res., 82, No. 28, 4559-4574, 1977, copyright by the American Geophysical Union.



Ryan, J.A. et al., J. Geophys. Res., 87, No. C9, 7279-7284, 1982, copyright by the American Geophysical Union.

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Dust Storm Characteristics

- Require strong near-surface winds (> 30 m/s)
- Occur on a variety of scales
- Local dust storms
  - last a few days
  - spatially confined (< 25 km, < 10**6 km**2)
  - occur every year and probably in every season
  - there are preferred locations, but can occur anywhere
  - visible opacities vary: $\tau \sim 1\text{-}6$
- Regional dust storms
  - last from days - months, cover large areas, extend to great heights
  - start small then expand
  - tend to occur during southern spring and summer
  - may envelop much of the planet
  - visible opacities vary: $\tau \sim 2\text{-}6$

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N93-26395

REPRESENTATIVE SYSTEMS FOR SPACE EXPLORATION

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Cleveland, Ohio 44135

OUTLINE

- OVERVIEW OF THE SYNTHESIS REPORT

- SPECIFIC ARCHITECTURE IV IMPLEMENTATIONS

- SPECIFIC POWER SYSTEM/ENVIRONMENT ISSUES

BACKGROUND

- **Synthesis Group was created in June 1990 to evaluate Outreach results and to establish a politically viable foundation**
  - — Architectures
  - — Technology priorities
  - — Early milestones

- **Synthesis Report architectures are an excellent basis from which to proceed (appropriate framing parameters and range)**
  - — Associated priority technologies appear appropriate; assessment underway

 53, 54

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RECOMMENDATIONS

(1) Establish within NASA a long range strategic plan for the nation's civil space program, with the Space Exploration Initiative as its centerpiece.

(2) Establish a National Program Office by Executive Order.

(3) Appoint NASA's Associate Administrator for Exploration as the Program Director for the National Program Office.

(4) Establish a new, aggressive acquisition strategy for the Space Exploration Initiative.

(5) Incorporate Space Exploration Initiative requirements into the joint NASA-Department of Defense Heavy Lift Program.

(6) Initiate a nuclear thermal rocket technology development program.

(7) Initiate a space nuclear power technology development program based on the Space Exploration Initiative requirements.

(8) Conduct focused life sciences experiments.

(9) Establish education as a principal theme of the Space Exploration Initiative.

(10) Continue and expand the Outreach Program.

PRIORITY TECHNOLOGIES

- Heavy lift launch with a minimum capability of 150 metric tons with designed growth to 250 metric tons
- Nuclear thermal propulsion
- Nuclear electric surface power to megawatt levels
- Extravehicular activity suit
- Cryogenic transfer and long-term storage
- Automated rendezvous and docking of large masses
- Zero gravity countermeasures
- Radiation effects and shielding
- Telerobotics
- Closed loop life support systems
- Human factors for long duration space missions
- Light weight structural materials and fabrication
- Nuclear electric propulsion for follow-on cargo missions
- In situ resource evaluation and processing

SYNTHESIS REPORT OVERVIEW OF ARCHITECTURES:

MARS EXPLORATION

The major objective of this architecture is to explore Mars and provide scientific return. The emphasis of activities performed on the Moon is primarily as a preparation for the Mars mission, to test Mars equipment, systems and operations. This permits meaningful scientific return from the Moon.

Precursors		
		Moon: None Mars: Scout territory before committing to landing site
Lunar IOC	6 crew * 14 days 2006	Return safely to Moon, check equipment with second mission
Lunar NOC-1	6 crew 45-60 days 2007	Demonstrate extended operations through lunar night using Mars prototype equipment
Lunar NOC-2	6 crew 30 days 2009	Perform complete dress rehearsal for Mars; extended stay time in lunar orbit; obtain significant life sciences data
Mars IOC	6 crew 30-100 days 2014	Arrive at Mars and accomplish scientific exploration
Mars NOC	6 crew 600 days 2016	Achieve long surface stay to perform extensive field exploration, including addressing difficult and complex scientific problems; ISRU demonstrations

* Number of crew, surface stay time, launch date

- The dates are notional and depend upon available resources and technological development. (16)

SCIENCE EMPHASIS FOR THE MOON AND MARS

Balanced scientific return from the Moon and Mars. Emphasized throughout are exploration and scientific activities, including complementary human and robotic missions required to ensure optimum return.

Precursors		
		Moon: Global reconnaissance; landing site selection Mars: Global reconnaissance; geophysical and environmental measurements; site selection
Lunar IOC	6 crew * 14 days 2003	Demonstrate safe return with significant exploration capability; explore three complex sites; emplace experiments
Lunar NOC-1	6 crew 90 days 2006	Extend length of human presence; permanent crew-tended outpost; begin construction of lunar observatory
Lunar NOC-2	6 crew 180 days 2007	Longer stays; surface exploration; increase capability of observatory; experiment with life support system closure
Lunar NOC-3	6 crew 30 days 2008	Dress rehearsal for Mars mission; 200 day lunar orbit stay time (same as Architecture I)
Lunar NOC-4	18 crew extended 2010	Expand surface exploration and observatory capability
Mars IOC	6 crew 30-100 days 2014	Arrive at Mars and accomplish scientific exploration (same as Architecture I)
Mars NOC-1	6 crew 600 days 2016, 2018	Expand capability to conduct human field work
Mars NOC-2	12 crew 600 days 2020	Establish permanent base; emphasize exploration and science
Asteroid Option	6 crew 10-100 days (open)	Science includes mapping, sampling, emplacing; ISRU experiments

* Number of crew, surface stay time, launch date

- The dates are notional and depend upon available resources and technological development. (16)

MOON TO STAY AND MARS EXPLORATION

Permanent presence on the Moon and Mars exploration. Long term human habitation and exploration in space and on planetary surfaces provide terrestrial spinoffs to improve our life on Earth and increase knowledge of solar system and ourselves.

Precursors		
		Moon: Landing site selection; surface site characterization Mars: Global reconnaissance; site selection
Lunar IOC	6 crew * 14 days 2004	Establish crew-tended site and conduct survey work for a future permanent habitat; detailed site characterization
Lunar NOC-1	6 crew 40 days 2005	Remain for complete day/night cycle; establish infrastructure for permanent habitat
Lunar NOC-2	12 crew 90 days 2006	Emplace multiple habitats, accumulate life science data; demonstrate resource use, food production, recycle waste
Lunar NOC-3	18 crew 360 days 2007	Permanent presence; food production and life support system closure; in situ gas production; regular resupply and crew rotation
Lunar NOC-4	18 crew 30 days 2009	Mars dress rehearsal (same as in Architecture I)
Mars IOC	6 crew 30-100 days 2014	Arrive at Mars and accomplish scientific exploration (same as Architecture I)
Mars NOC	6 crew 600 days 2016	Achieve long surface stay to perform extensive field exploration, including addressing difficult and complex scientific problems; ISRU demonstrations (same as Architecture I)

* Number of crew, surface stay time, launch date

- The dates are notional and depend upon available resources and technological development. (16)

SPACE RESOURCE UTILIZATION

Make maximum use of available resources to support SEI missions. Seek to develop resources for transportation, habitation, life sciences, energy production, construction, etc. Reduce costs and approach self-sufficiency.

Precursors		
		Moon: Landing site selection for resource potential Mars: Site selection; surface characterization
Lunar IOC	6 crew * 14 days 2004	Select a resource-rich site and demonstrate in situ fuel production for use in rover and ascent vehicle.
Lunar NOC-1	6 crew 45-180 days 2006-2010	Small base, capable of expansion; demonstrates production of fuel, power beaming, etc.; build infrastructure
Lunar NOC-2	6 crew 40 days 2011	Dress rehearsal for Mars mission: extended lunar orbit stay time (500 days)
Mars IOC	6 crew 30-100 days 2016	Arrive at Mars and accomplish scientific exploration and ISRU experiments (same as Architecture I)
Mars NOC	6 crew 30-100 days 2018	Achieve long surface stay to perform tests and demonstrations of in situ resource use to support long term human presence
Asteroid Option	6 crew 10-100 days (open)	Emphasis on characteristics and examination of asteroid as a source of valuable, useful material

* Number of crew, surface stay time, launch date

- The dates are notional and depend upon available resources and technological development. (16)

SPECIFIC ARCHITECTURE IV IMPEMENTATIONS

- PRECURSORS
- TRANSPORTATION SYSTEMS
- SURFACE SYSTEMS

Space Resource Utilization Architecture
- Objective and Strategy -

ARCHITECTURE OBJECTIVE

Make maximum use of available resources to support the space exploration missions directly.

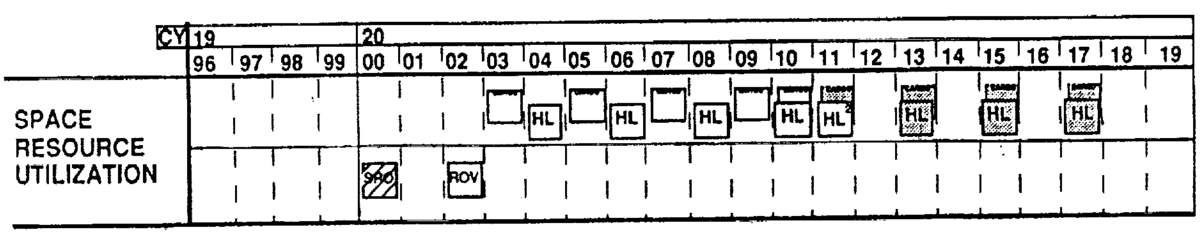
STRATEGY

"The goal is first to reduce the direct expense of going to the Moon and Mars, then to build toward self-sufficiency of long-duration space bases, and eventually to return energy and resources to Earth."

Space Resource Utilization Architecture
- Lunar Precursors and Robotics: Mission Strategy -

Strategy:

"...the location and quantities of resources on the Moon ... must be assessed. Some of this characterization is done remotely from Earth, but the general plan is to conduct robotic missions to map the Moon ... emphasizing resource location and quantification."



Reconnaissance orbiter (2)

- quantify mineralogy and chemistry
- surface topography (stereo visual imagery)
- regolith structure (electromagnetic sounder)
- electromagnetic noise background

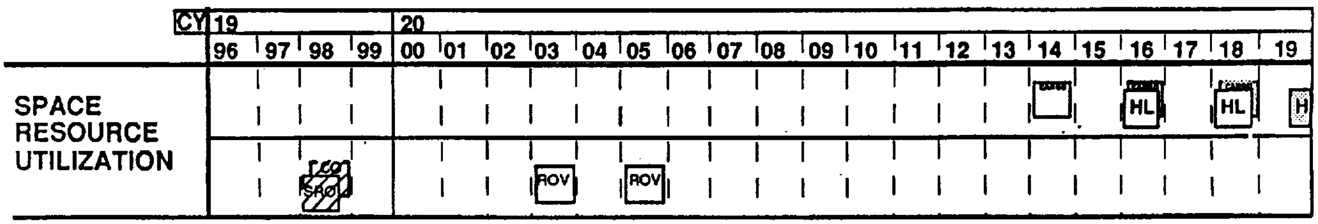
Telerobotic rover (1)

- locate resource deposits
- chemical and evolved gas analysis
- physical properties

Space Resource Utilization Architecture
– Mars Precursors and Robotics: Mission Strategy –

Strategy:

"The overall approach is to achieve knowledge of Mars from robotic missions and then to follow up with detailed field science by humans. ...robotic precursor missions are used to scout the territory before committing to a landing site. ... A minimum set of precursors is flown to gather the data necessary for selecting Mars landing sites.



Reconnaissance orbiter / Comm orbiter (2 each)
- image 12 candidate landing sites for certification
  - identify and map hazards
- chemical and physical properties
  - strategic science and resource data to aid site selection

Automated rover (2)
- test for toxicity
- chemical and mineral analysis
- image surface and subsurface

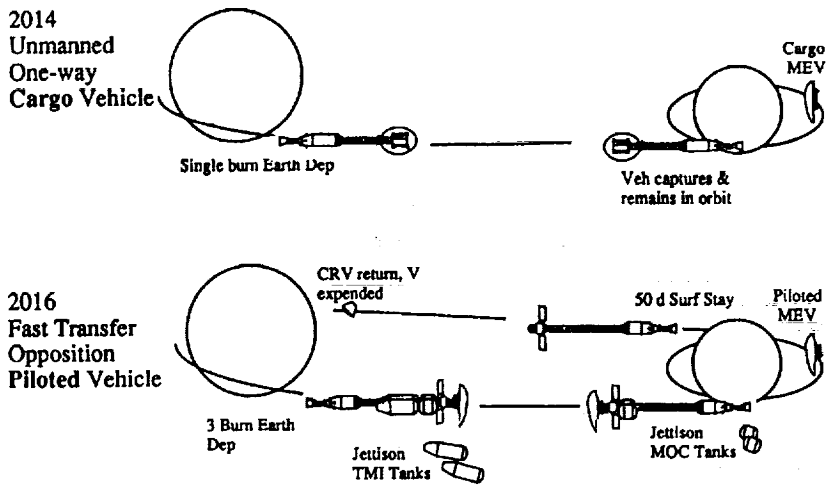
Mars Transportation System (MTS)

Assumptions & Approach

- **Mission Concept is a Split-Sprint Type**
  - **Piloted Flights in 2016 & 2018**
  - **Cargo-Only Flights in 2014 & 2016**
- **Earth-to-Orbit (ETO) Launch Capability is 250t Class**
  - **Cargo-Only MTS Flights Sized for Single ETO (Multiple Cargo Flights/Mission)**
  - **Piloted MTS Flights Utilize Multiple ETO's**
- **MTS Comprised of Transfer Vehicle (MTV) & Lander Vehicle (MEV)**
  - **MTV Uses Nuclear Thermal Propulsion (Isp = 925s)**
  - **MEV Uses Lox/Methane Propellant (Descent/Ascent Stages) & Descent Aerobrake**
  - **MEV Sized to Land 45t on Mars Surface**
  - **MTS is Zero-g Vehicle**
  - **MTS Elements are Expended on Each Mission - Except MEV is Reusable**
- **MTS Crew Modules Sized for Crew of 6**
  - **Ballistic Crew Recovery at Earth**
  - **Separate Transfer & Lander Crew Modules**
  - **Crew Launched By Shuttle**

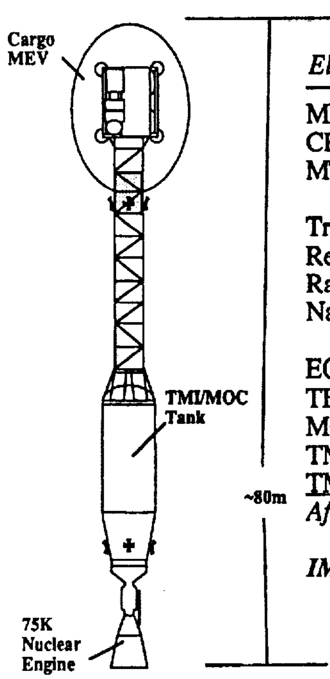
Space Resource Utilization Architecture

Split Sprint Mission Profile
2014/2016 First Mars Mission



Space Resource Utilization Architecture
2014 & 2016 One Way Cargo Mars Transfer Vehicles

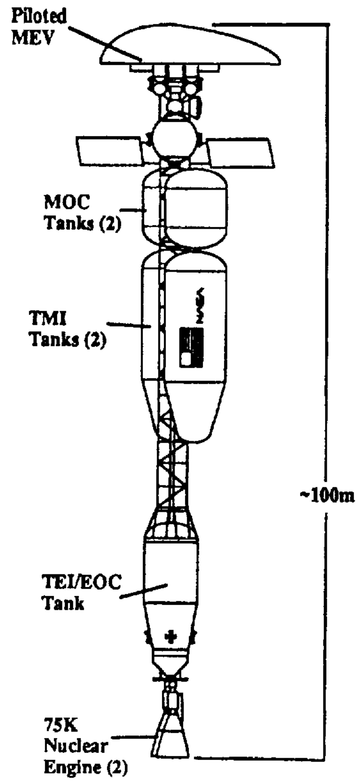
Single MEV delivery



Element	*Mass (kg)*	*2014*	*2016*
MEV		78900	78900
CRV		0	0
MTV crew habitat system		0	0
Truss strongback, struts & RCS		5521	5521
Reactor/engine mass		3402	3402
Radiation shadow shield mass		0	0
Navigation pack mass		2000	2000
EOC propellant		0	0
TEI propellant		0	0
MOC propellant		22925	22630
TMI propellant		79236	75514
TMI/MOC common tank (1)		17797	17235
Aft tank total mass		119958	115379
IMLEO		**209781**	**205202**
		x2	**x3**
		419562	**615606**

* 2018 manned long stay conjunction requires 3 cargo MEVs,
2016 cargo: 3 NTR vehicles carrying 1 MEV each

Space Resource Utilization Architecture
2016 Opposition & 2018 Conjunction Piloted Mars Transfer Vehicles
2016 - 425 d transfer time, 50 d stay   2018 - 188 d transfer, 678 day stay



Element	*Mass (kg)*	*2016*	*2018*
MEV		78900	78900
CRV		5808	5808
MTV crew habitat system		58000	58000
Truss strongback, struts & RCS		5521	5521
Reactor/engine mass		6804	6804
Radiation shadow shield mass		5598	5598
EOC propellant		0	0
TEI propellant		95281	80090
TEI/EOC common tank (1)		16873	14705
Aft tank total mass		112154	94795
MOC propellant		155260	116030
MOC tanks (2)		25002	20103
MOC tankset total mass		175620	136133
TMI propellant		314870	353880
TMI tanks (2)		49035	54360
TMI tankset total mass		363905	408240
IMLEO		**816943**	**796799**

Space Resource Utilization Architecture

Methane Lander Characteristics

Propellent Type: Cryogens, liquid oxygen, liquid methane

Rated Thrust: 30,000 lbf each

Number of descent engines: 5

Number of ascent engines: 3

Specific Impulse (vacuum): 380 sec

Total Loaded Mass: 78.9 metric tonnes

Landed Payload Capability: 45 metric tonnes

Space Resource Utilization - Mars IOC

Synthesis Group

- Similar to Mars IOC of Mars Exploration Architecture

> - Arrive at Mars and successfully accomplish scientific exploration of its surface.
> - Predeployment of much of the needed equipment on the Martian surface and remote testing prior to crew launch
> - 30 - 100 day surface stay
> - Specified implementation utilizing:
>   - habitat (same design as the one tested on the lunar surface)
>   - pressurized rover
>   - nuclear power system
>   - minimal photovoltaic emergency backup
>   - unloader/mover
>   - scientific exploration equipment
>   - communications equipment

- Addition of resource utilization experiments on the Martian surface
  - Methane
  - Oxygen
- Specified implementation utilizing:
  - pressurized rover
  - habitat
  - atmosphere reduction plant

PSS Implementation

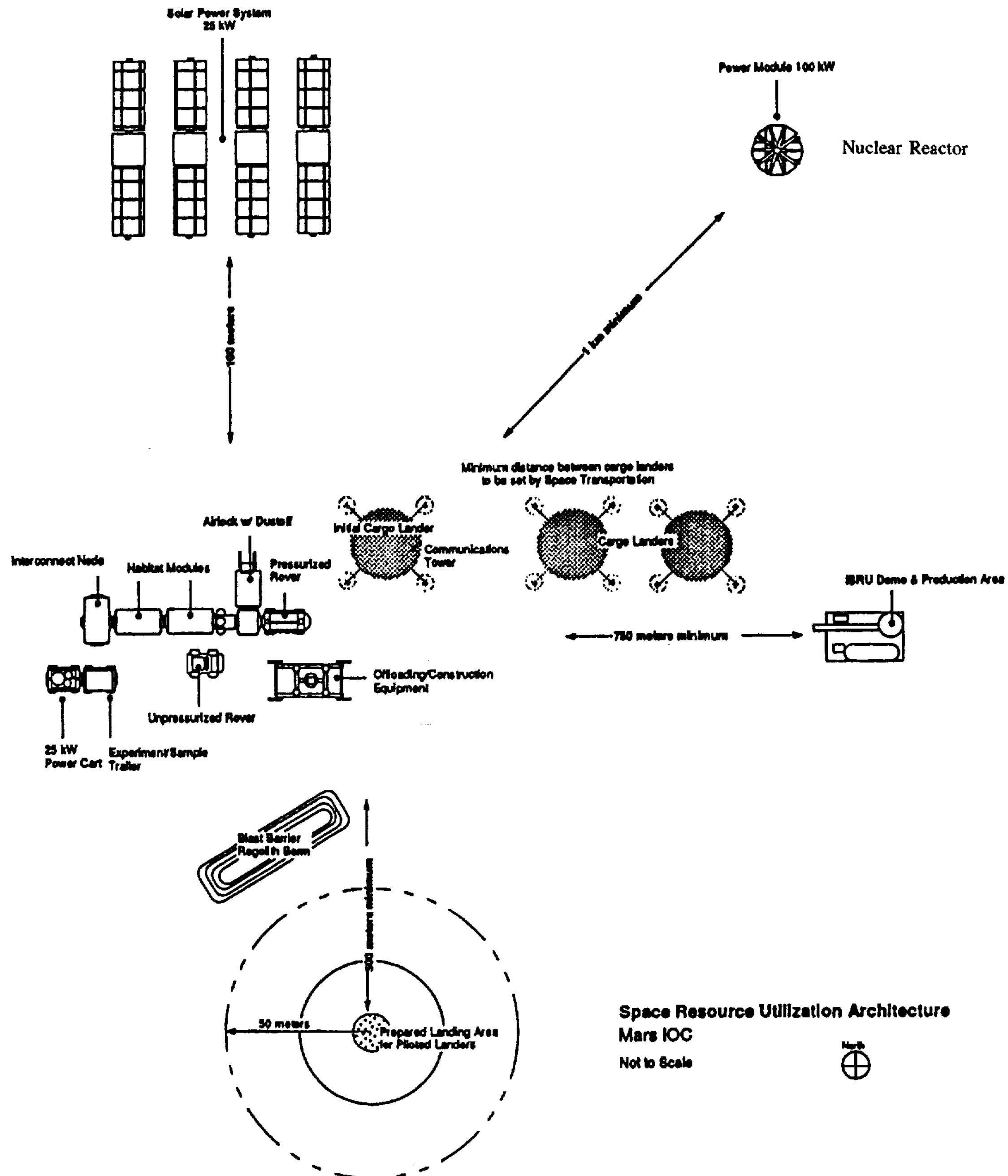
- PSS Objective

  Mars IOC establishes the infrastructure to support a crew of 6 on the Martian surface for up to 90 days.
- Major Elements Delivered

  Offloading/Construction Equipment
  Habitat Modules/Airlock
  Interconnect Node
  100 kW Power Module
  PVA/RFC Backup Power System
  Pressurized Rover
  CH_4/O_2 Unpressurized Rover
  ISRU Demonstration Unit
  Science
- Capabilities Provided
  - Habitat for a Mars surface crew of 6 for up to 90 days
  - Continuous power of 100 kW, with PVA backup
  - Pressurized transport on the surface with 100 km range
  - Payload unloading
  - Site preparation
  - Local unpressurized transportation capable of using locally produced fuel
  - Warning system for solar flares
  - Production of small quantities of CH_4, H_2O, O_2
- Issues

  Required habitat mass
  The required habitat mass exceeds payload constraints of Space Transportation, so habitat is delivered in multiple modules

  Delivery of elements 2 years prior to crew arrival
  Elements required to sit on the surface of Mars for 2 years before crew arrives



Cartoon—not based on any specific system's study.

Space Resource Utilization - Mars NOC

Synthesis Group

- Emphasizes tests and demonstrations of in situ resource use on the Martian surface to support long term human presence
- Return to original site of Mars IOC
- Specified implementation utilizing:
  - resource plant expansion
  - small greenhouse

PSS Implementation

- PSS Objective

  Mars IOC objective is to carry out a 600 day crew stay at the site of the Mars IOC mission.

- Major Elements Delivered

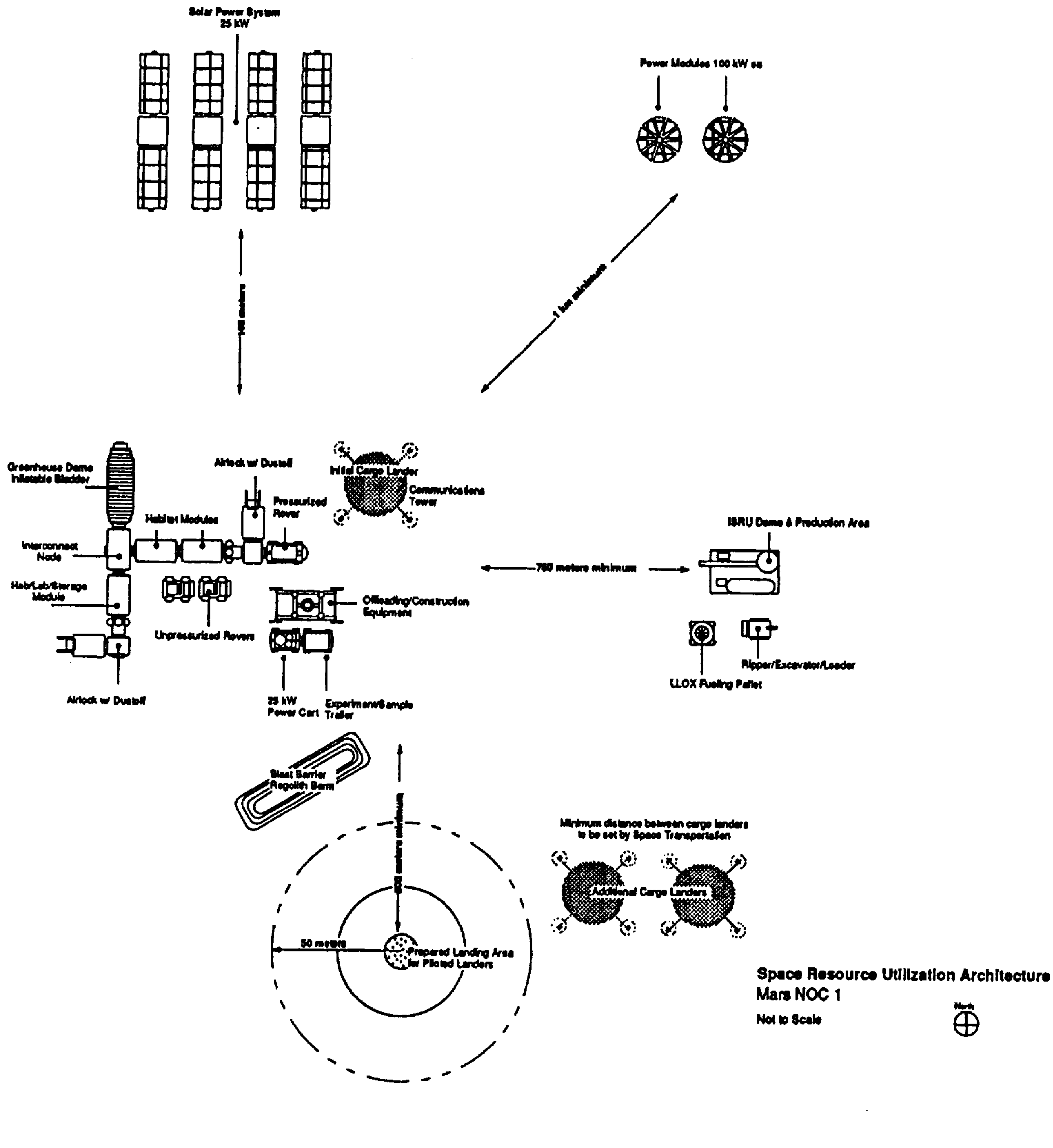
  Hab/Lab/Storage Module
  Airlock
  100 kW Power Module
  Greenhouse
  Mars Atmosphere Processing Plant
  Integrated Mining Vehicle
  Fueling Pallet
  Unpressurized Rover
  Consumables
  Science

- Capabilities Provided
  - Habitat for a Mars surface crew of 6 for 600+ days
  - Continuous power of 200 kW, with PVA backup
  - Mining
  - Food production
  - Increased CH4 production

- Issues

  Consumables

  The mass of the consumables needed (plus pallet) exceeds the allowable down mass for piloted flights. Consumables must have a "shelf-life" of 2 yrs.



Space Resource Utilization Architecture
Mars NOC 1
Not to Scale

SPECIFIC POWER SYSTEM/ ENVIRONMENT ISSUES

- WHAT SHOULD WE CONSIDER TO BE OUR MAXIMUM OPERATING VOLTAGES FOR SURFACE AND ORBITING POWER SYSTEMS? WHAT INCREASE IN VOLTAGE CAN BE ACHIEVED WITH INSULATION OF EXPOSED PARTS?

- WHAT CONCERNS ARE THERE WITH COPPER OR ALUMINUM CONDUCTORS, ON THE SURFACE? - OR IN ORBIT? (PROBABLY UPPER BOUNDED BY AREOSYNCHRONOUS ORBIT).

- WE ARE AWARE OF CO_2 AND REFRACTORY METALS INCOMPATABILITY- WHAT OTHER MATERIALS MAY EXPERIENCE EITHER CHEMICAL OR ELECTROCHEMICAL DECOMPOSITION?

- WILL A.C. (AS COMPARED TO D.C.) POWER TRANSMISSION REDUCE POSSIBLE STATIC BUILD UP AND SUBSEQUENT DUST BRIDGING ON EXPOSED POWER SYSTEM COMPONENTS SUCH AS, ARRAYS, CABLES, CONNECTORS OR INSULATORS? (MOON)

- WHAT SPECIAL GROUNDING TECHNIQUES MAY BE REQUIRED FOR SURFACE POWER SYSTEMS? (MOON)

CLOSING REMARKS

- CONCEPTUAL DESIGNS ARE CURRENTLY BEING DEVELOPED FOR LUNAR AND MARS POWER SYSTEMS.

- BOTH SOLAR AND NUCLEAR BASED SYSTEMS ARE VIABLE CANDIDATES PREDICATED PRIMARILY ON POWER LEVEL AND APPLICATION.

- SPECIFIC DESIGN DETAILS ARE SOMEWHAT LACKING BECAUSE ONLY TOP LEVEL INFORMATION IS AVAILABLE ON EACH ARCHITECTURE AT THIS TIME.

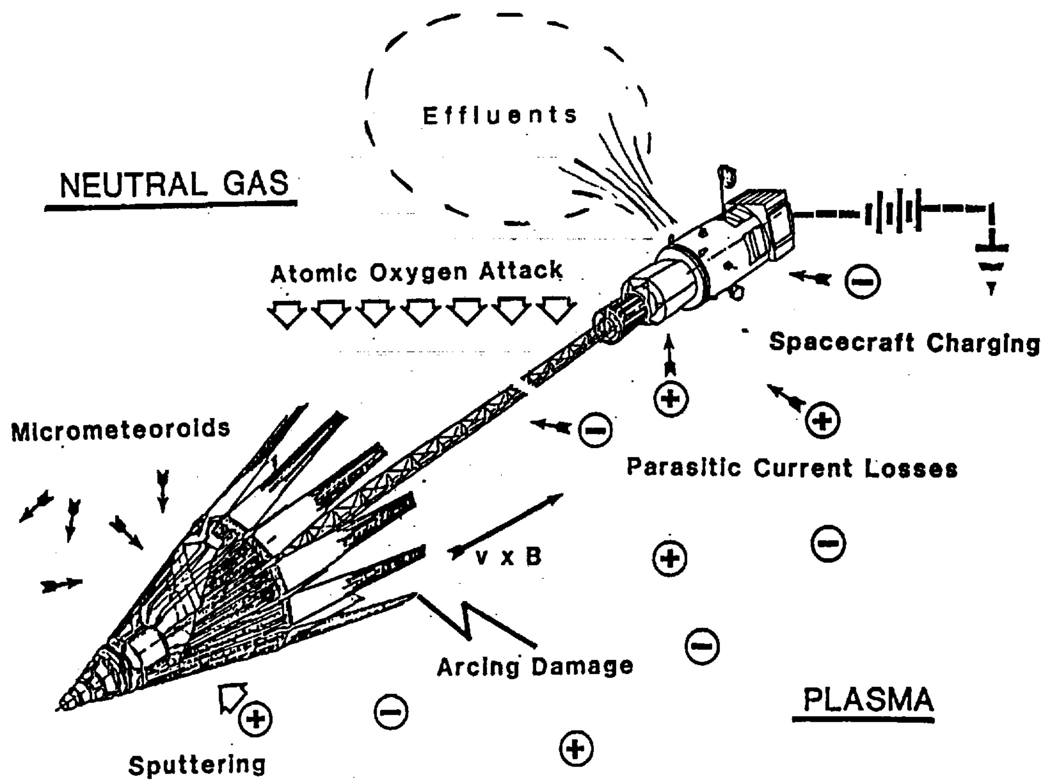
- A SYSTEMS APPROACH TO DESIGNING POWER SYSTEMS HAS BEEN ADOPTED AND WE CONSIDER THE EFFECTS OF VARIOUS <u>SPACE ENVIRONMENTS</u> TO BE A KEY FACTOR IN THAT APPROACH.

N93-26896

SPACE ENVIRONMENTAL INTERACTIONS FOR THE SPACE EXPLORATION INITIATIVE

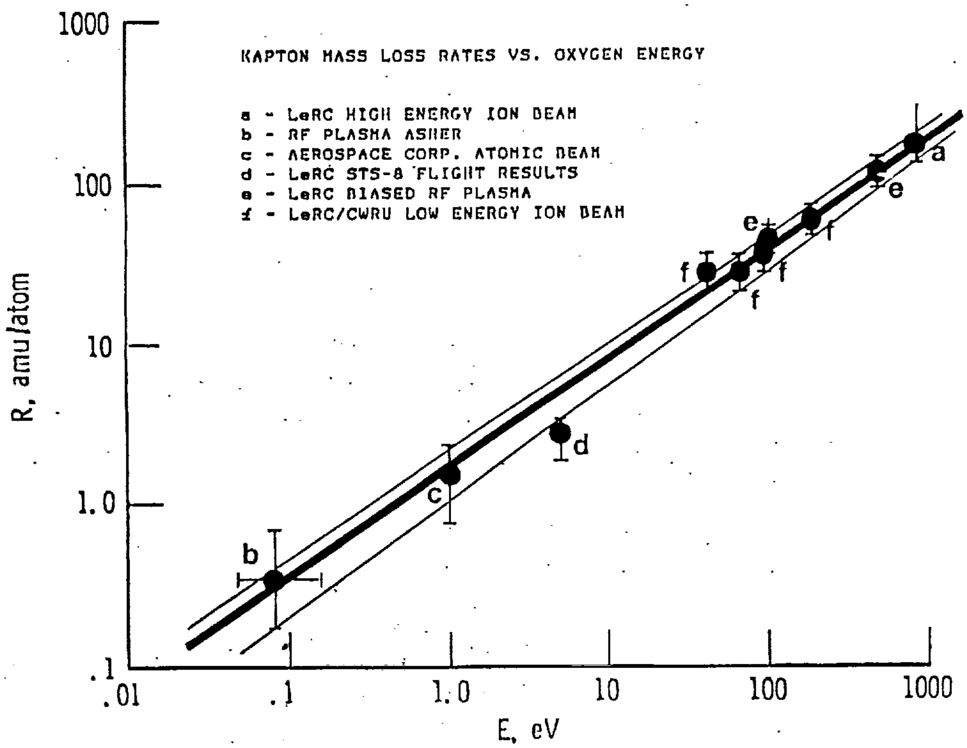
Dale C. Ferguson
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135

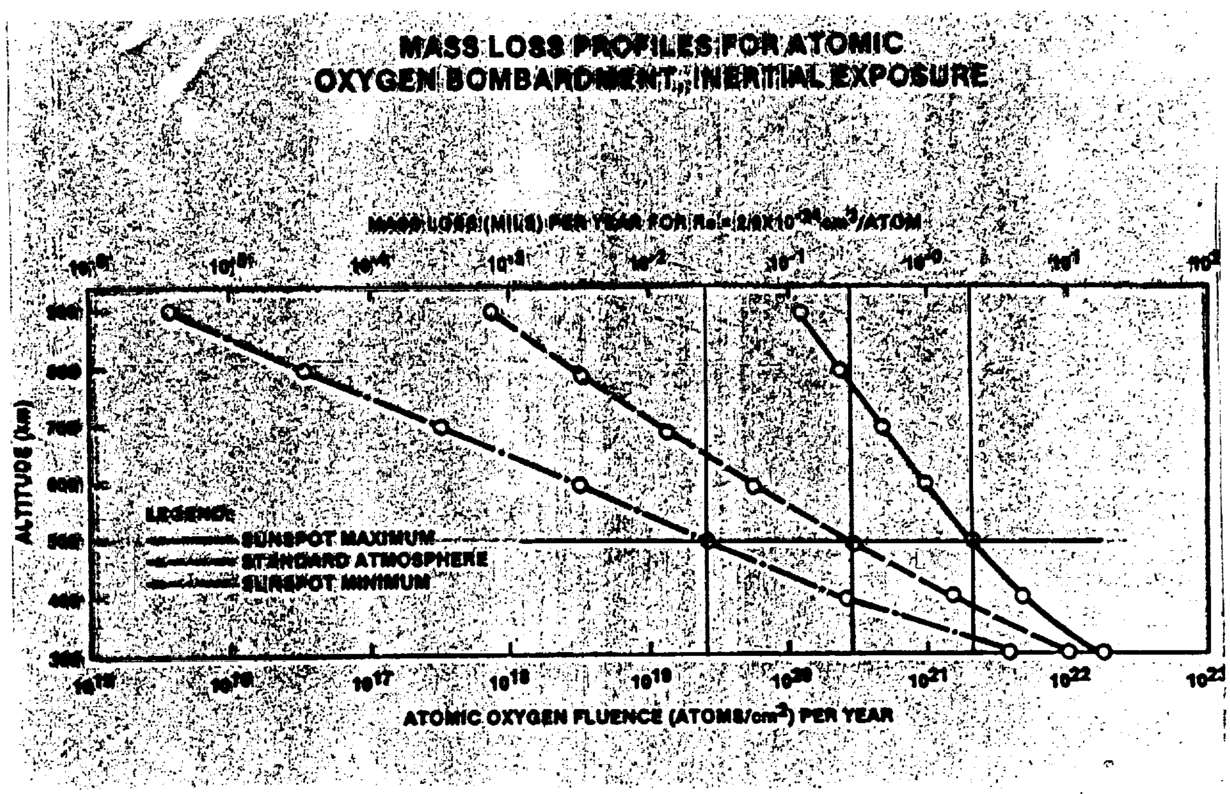
SPACECRAFT ENVIRONMENTAL EFFECTS



Space Environmental Interactions
Atomic Oxygen Attack

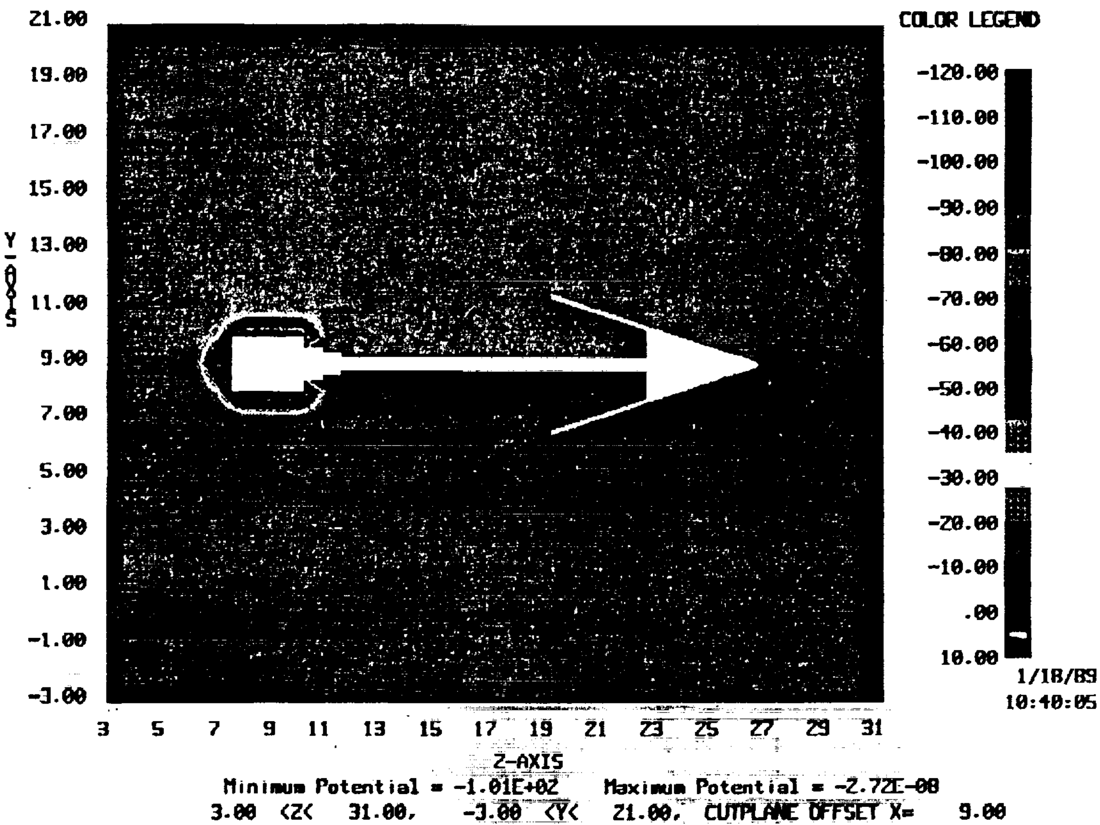
- LOW PLANETARY ORBITS ONLY
  - Material Specific
  - Preferentially in Ram
  - Low Mars Orbit Also Contains AO
  - For Some Materials, Synergy w/ UV
  - Ionized AO Also Reactive.
- CHANGES MATERIAL SURFACE PROPERTIES
  - Optical and Thermal Properties
    Surface Conductivities
    Strength of Exposed Fibers





 Visentine, J.T. and Leger, L.J., A Consideration of Atomic Oxygen Interaction with the Space Station, J. Spacecraft and Rockets, 23, 5, 505-511, 1986.

Load Biased to 100V Neg. w.r.t. Body



Space Environmental Interactions
Arcing and Discharges

- GEOSYNCHRONOUS ENVIRONMENT
  - Differential Charging in Geo Substorms
  - Solar Flares in Interplanetary Space
- LOW PLANETARY ORBITAL ENVIRONMENTS
  - Arcing To or Thru Ionized Plasma
  - Dielectric Breakdown of Anodized Surfaces
  - Arcing at Conductor-Insulator Junctions
- PASCHEN BREAKDOWN - PLANETARY SURFACE
  - Martian Atm Pressure Ideal for Discharges
  - Lunar Camps Create Local Atmospheres

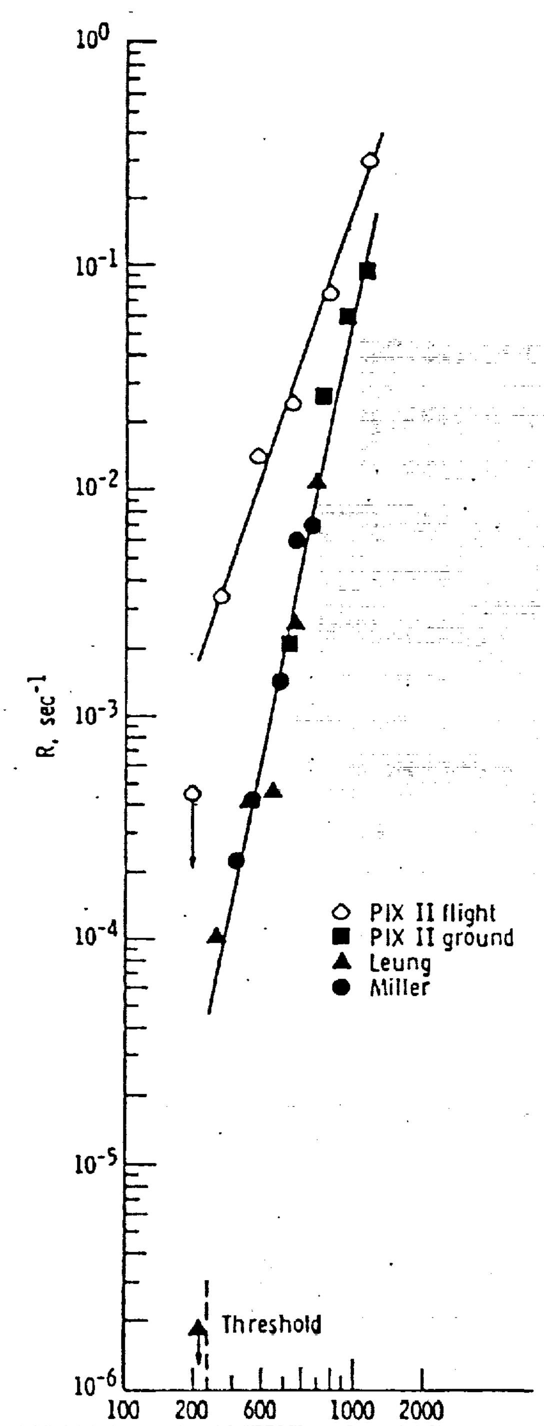
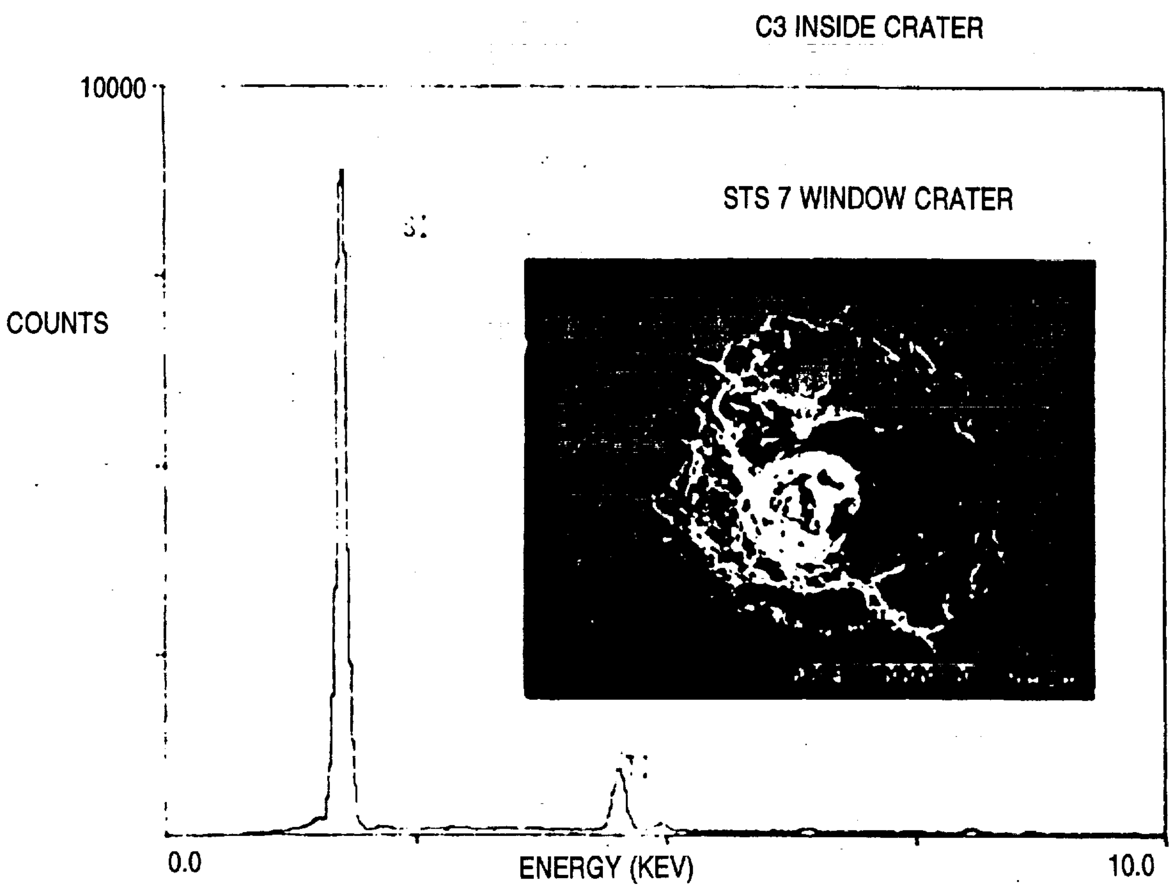


Figure 7. - Arc rate versus voltage for standard interconnect cells. Normalized to LEO ram conditions (see text).

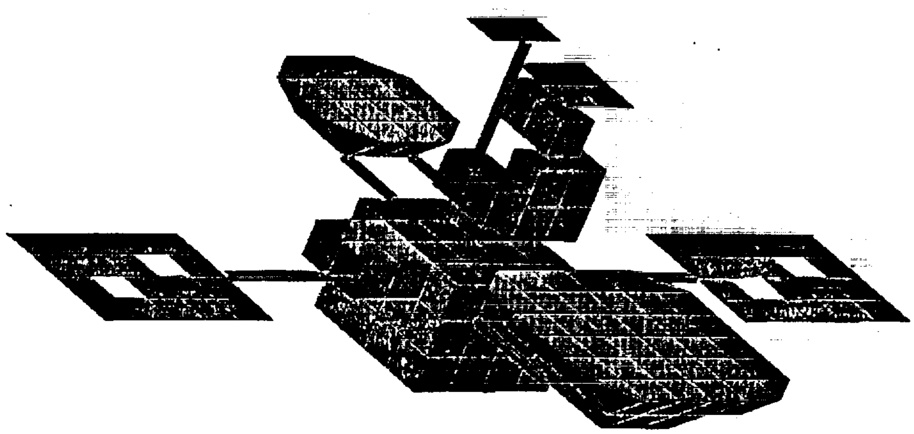
Space Environmental Interactions
Micrometeoroids and Debris

- SURFACE DAMAGE
  - Pinholes in Insulators
  - Change of Thermal Properties
  - Sites for Arcing, Sputtering
  - Possible Site of Kapton Pyrolysis
- NEED FOR REDUNDANCY OR HEALING
  - Fluid Lines and Heat Pipes
- LOCAL PLASMA CREATED AT SITE
  - May Produce Prompt Arcing
  - Arcs Enlarge Damaged Area
- DEBRIS PROBLEM IN PLANETARY ORBITS



Space Environmental Interactions
State-of-the-Art Computer Tools

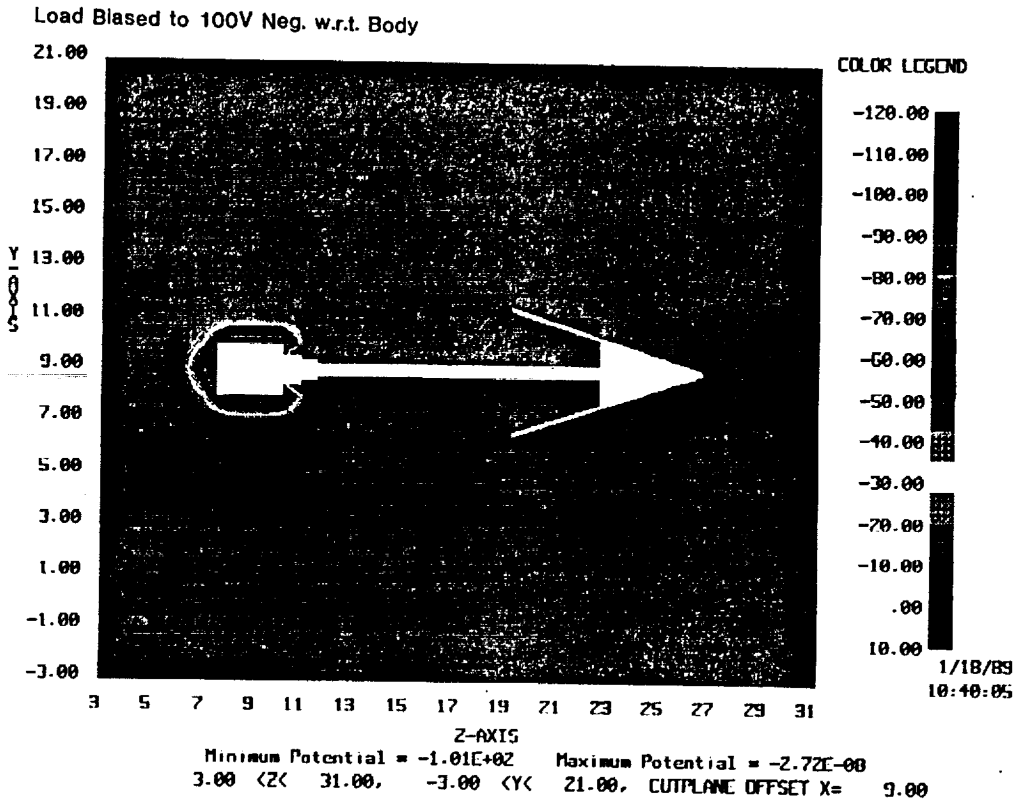
- S-CUBED DIV. OF MAXWELL LABORATORIES
- NASCAP (3-D, Particle Tracking)
  - Calculates Charging in GEO
  - Obtainable thru COSMIC
  - Mature Code, Industry Standard
- NASCAP/LEO (3-D, Particle Tracking)
  - Calculates Charging, Currents in LEO
  - Release thru COSMIC This Year
  - Under Final Testing
- EPSAT, EWB (1-D, Systems Tools)
  - Evaluate Multiple Interactions
  - Quick, Approximate
  - Under Beta Testing
  - May Be Ideal Starting Point for SEI

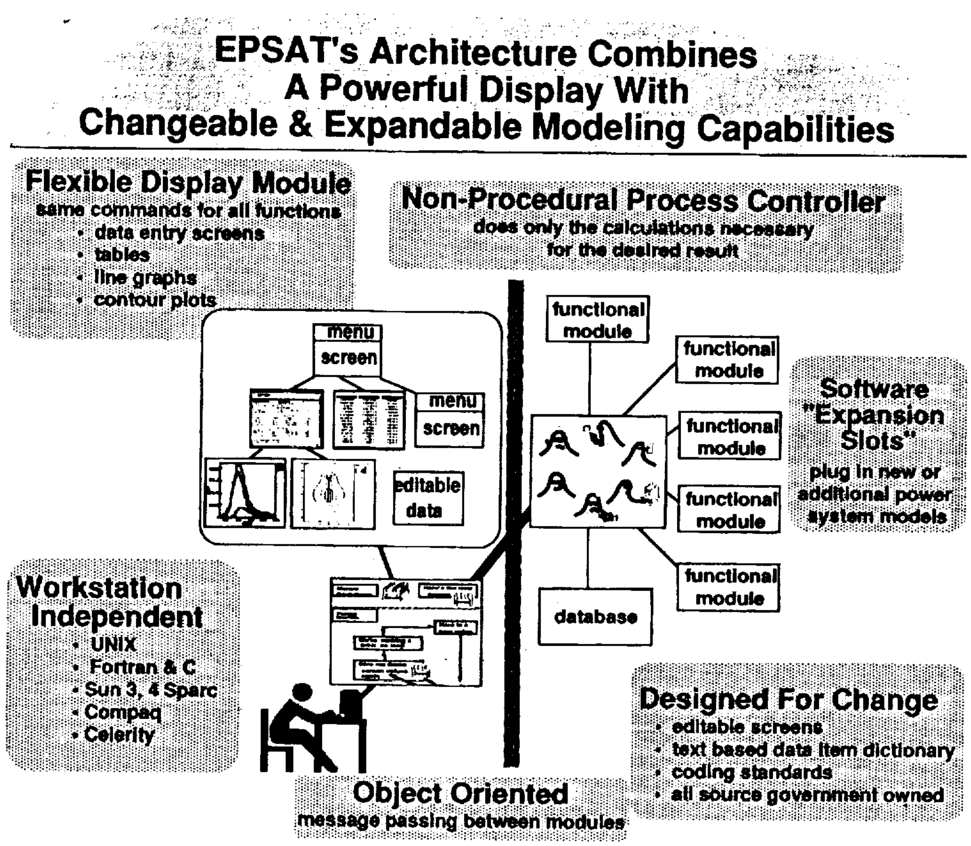


NASCAP model of NASA's
Advanced Communications Technology Satellite.

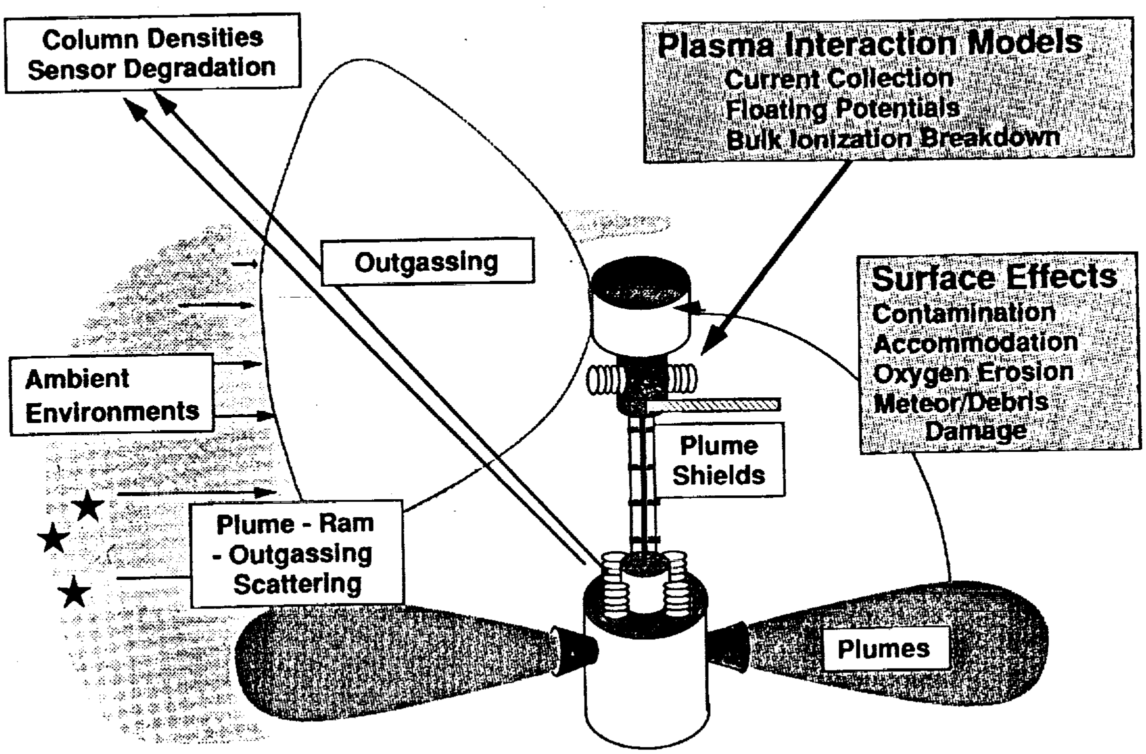
Figure 6

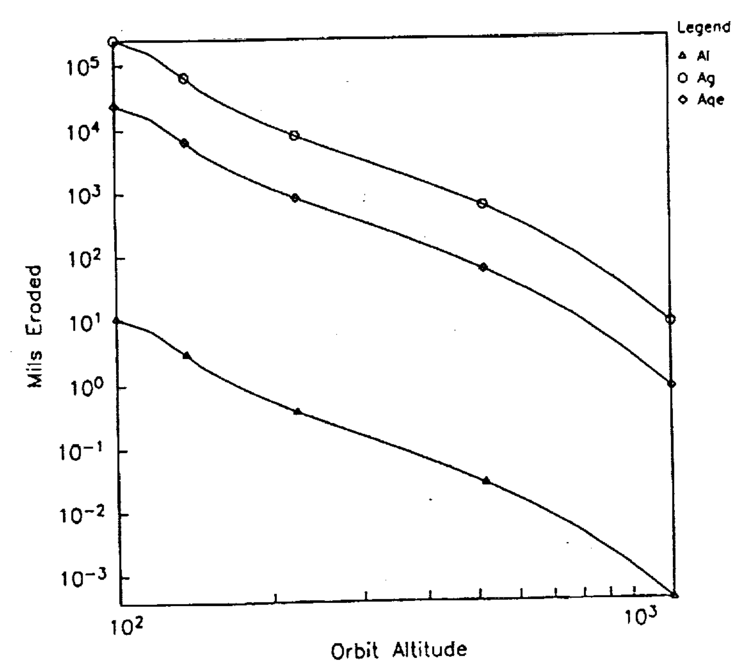
SP-100 Floating Potential





EPSAT
Power System Models





Total atomic oxygen erosion during a 10-year mission life for three conductive coatings as a function of altitude for 60° inclination circular orbits.

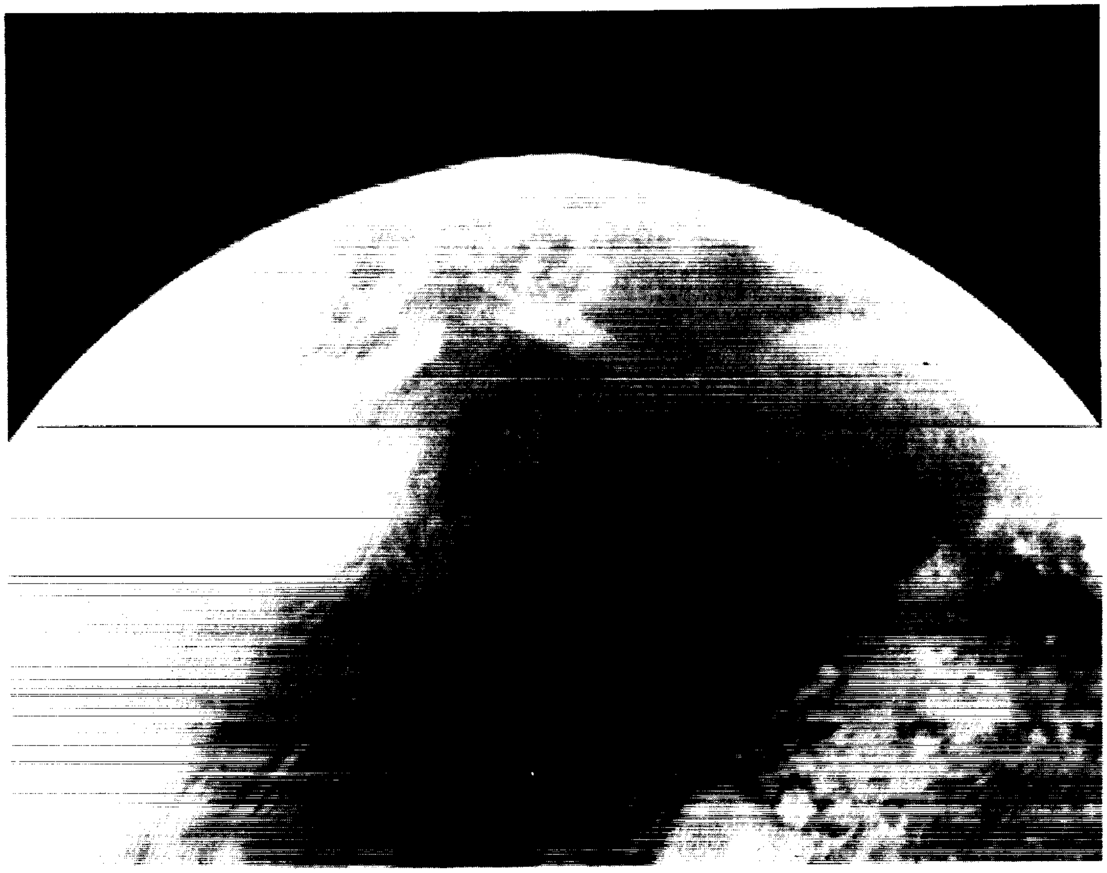
KAPTON 41 HOURS EXPOSURE TO ATOMIC OXYGEN ON STS-8

STS-8 FLIGHT SAMPLES

LeRC PRELIMINARY MASS LOSS MEASUREMENTS
(Corrected for mass change of control due to moisture, etc.)

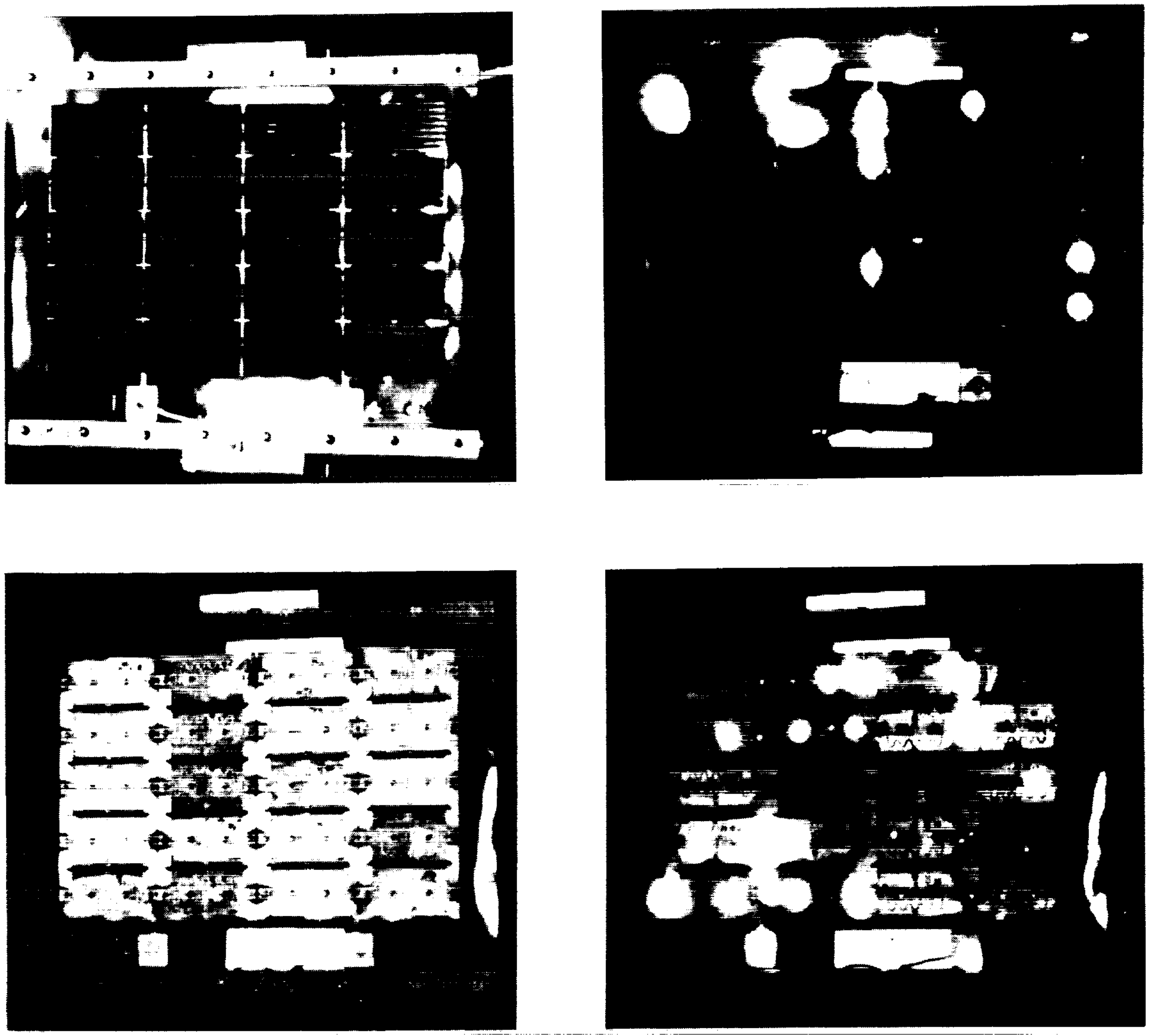
(Assumes 3.87×10^{20} atoms/cm^2)

SAMPLE #	DESCRIPTION	MASS CHANGE (g) ERROR	[redacted] ERROR	COMMENT
1	5 mil Kapton, Al backed	-0.0050200 99	-3.88×10^{-24} 01	
2	5 mil Teflon, Al backed	-0.0000820 91	-6.34×10^{-26} 01	Low loss rate
3	5 mil Mylar, Al backed	-0.0056081 118	-4.34×10^{-24} 01	HIGHEST MEASURED
4	MgF_2 anti-reflection on glass	-0.0000204 259	-1.58×10^{-26} 2.01	No sig. change
5	ITO on glass	-0.0000190 359	-1.46×10^{-26} 2.78	No sig. change
6	96% SiO_2 + 4% PTFE on 5 mil Kapton	-0.0000103 52	-7.98×10^{-27} 4.04	Very low loss rate
7	Al_2O_3 on 5 mil Kapton	-0.0005674 52	-4.40×10^{-25} 04	LOWEST MEASURED
8	SiO_2 on 5 mil Kapton	-0.0000058 52	-4.50×10^{-27} 4.04	No sig. change
9	TiO_2 on quartz	+0.0000437 147	$+3.38 \times 10^{-26}$ 1.14	Low gain rate
10	Mo on sapphire	+0.0000760 235	$+5.88 \times 10^{-26}$ 1.81	Low gain rate
11	Copper on sapphire	+0.0000764 767	$+5.91 \times 10^{-26}$ 5.93	No sig. change
12	Chromium on Kapton, Al backed	-0.0000492 147	-3.81×10^{-26} 1.14	Low loss rate



Space Environmental Interactions
Current Collection and Snapover

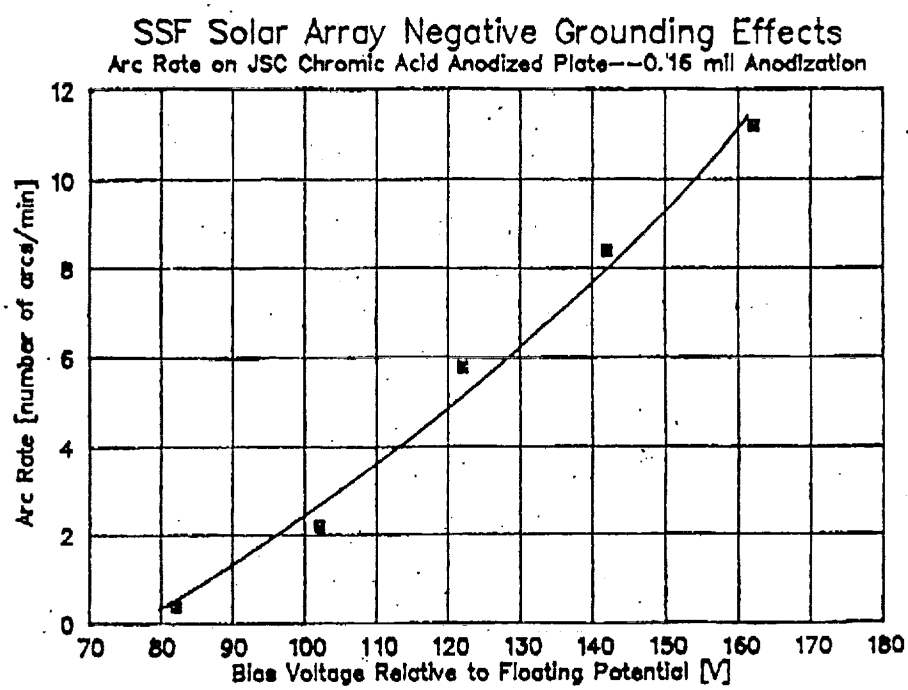
- ELECTRON COLLECTION AND SNAPOVER
  - Snapover at Potentials > +100 V
  - Insulators Act as Electron Conductors
  - Large Power Drains
- ION COLLECTION AND SPUTTERING
  - Ions Focused Onto Insulation Defects
  - Sputtering at Potentials < -100 V
- FLOATING POTENTIALS
  - Ion and Electron Currents Must Balance
  - Ease of Electron Collection Makes Systems Float Negative
- POWER SYSTEM GROUND IMPORTANT
  - Grounds on Moon, Mars Difficult?

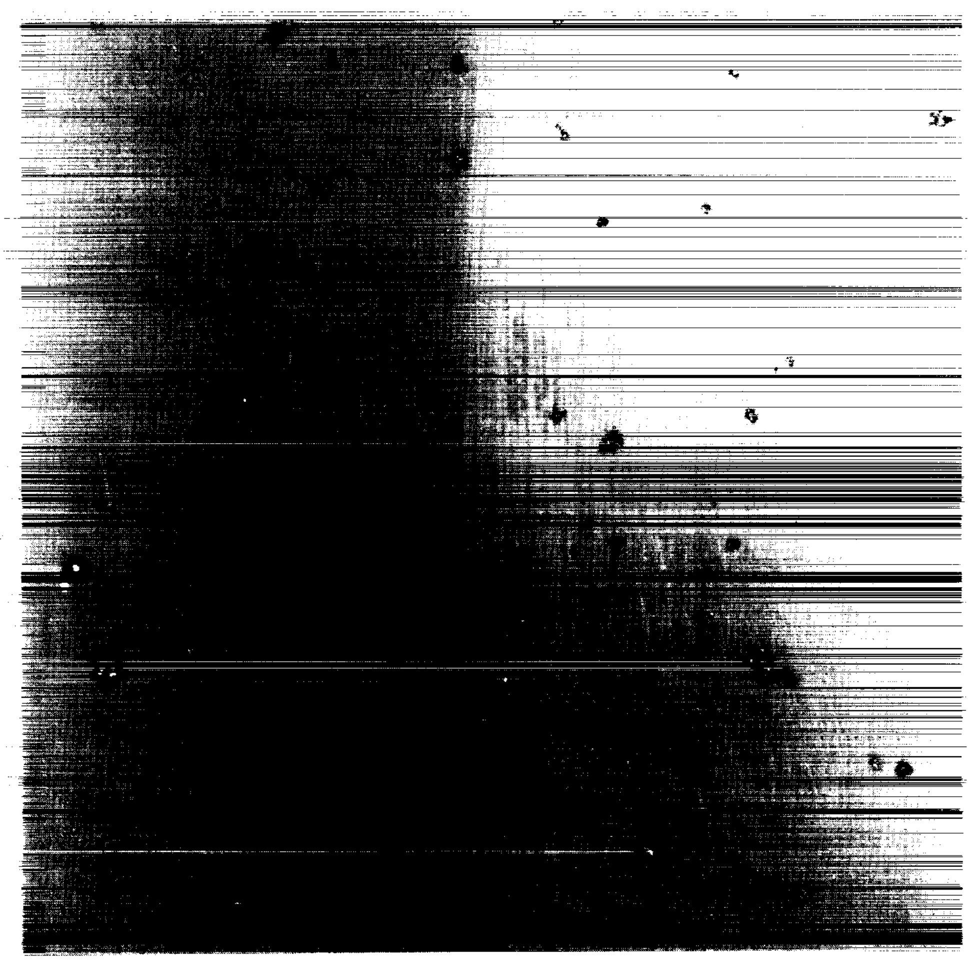


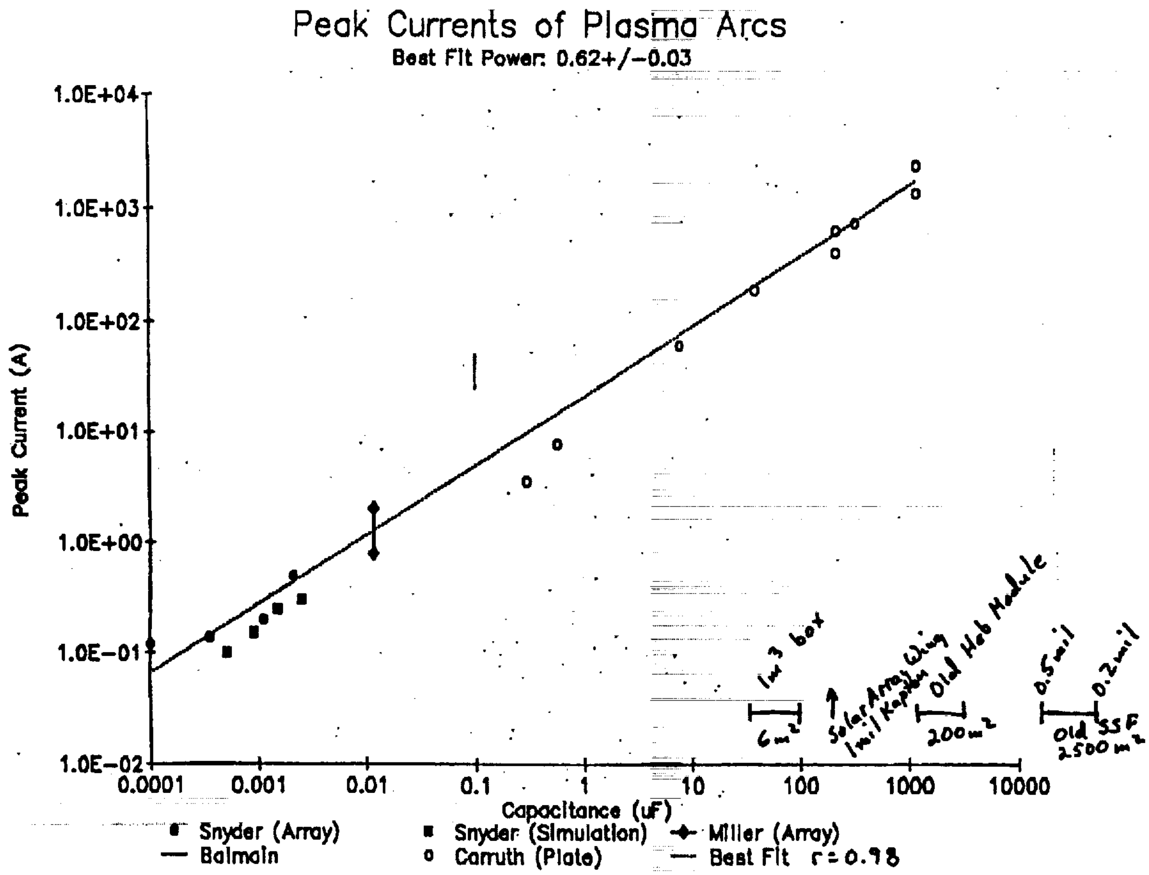
ARCING ON SOLAR CELL ARRAY SAMPLES
2x4 cm WRAPAROUND CELLS ON KAPTON
-1 kV BIASED ARRAY CIRCUIT
10^5 cm^{-3} N PLASMA (25 eV IONS, 3 eV e^-)

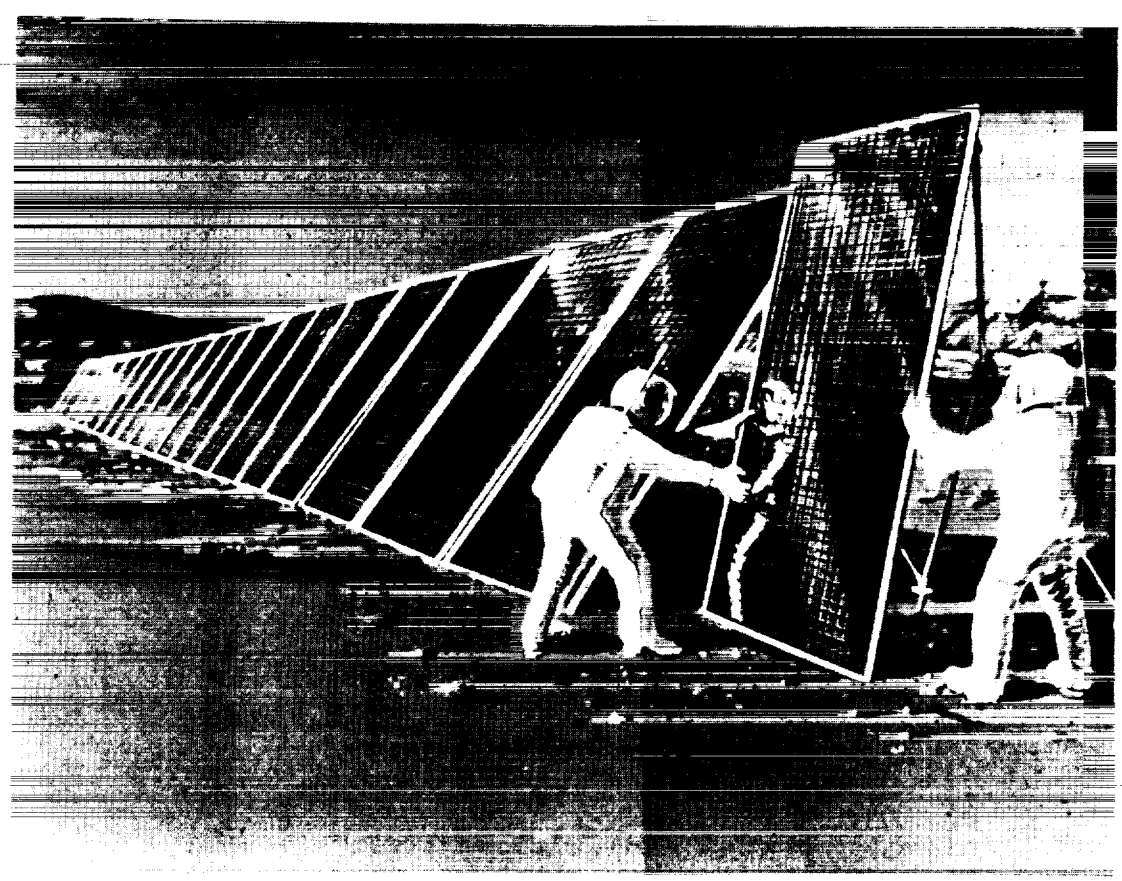
NASA/LEWIS RESEARCH CENTER
ENVIRONMENTAL INTERACTIONS PROGRAM

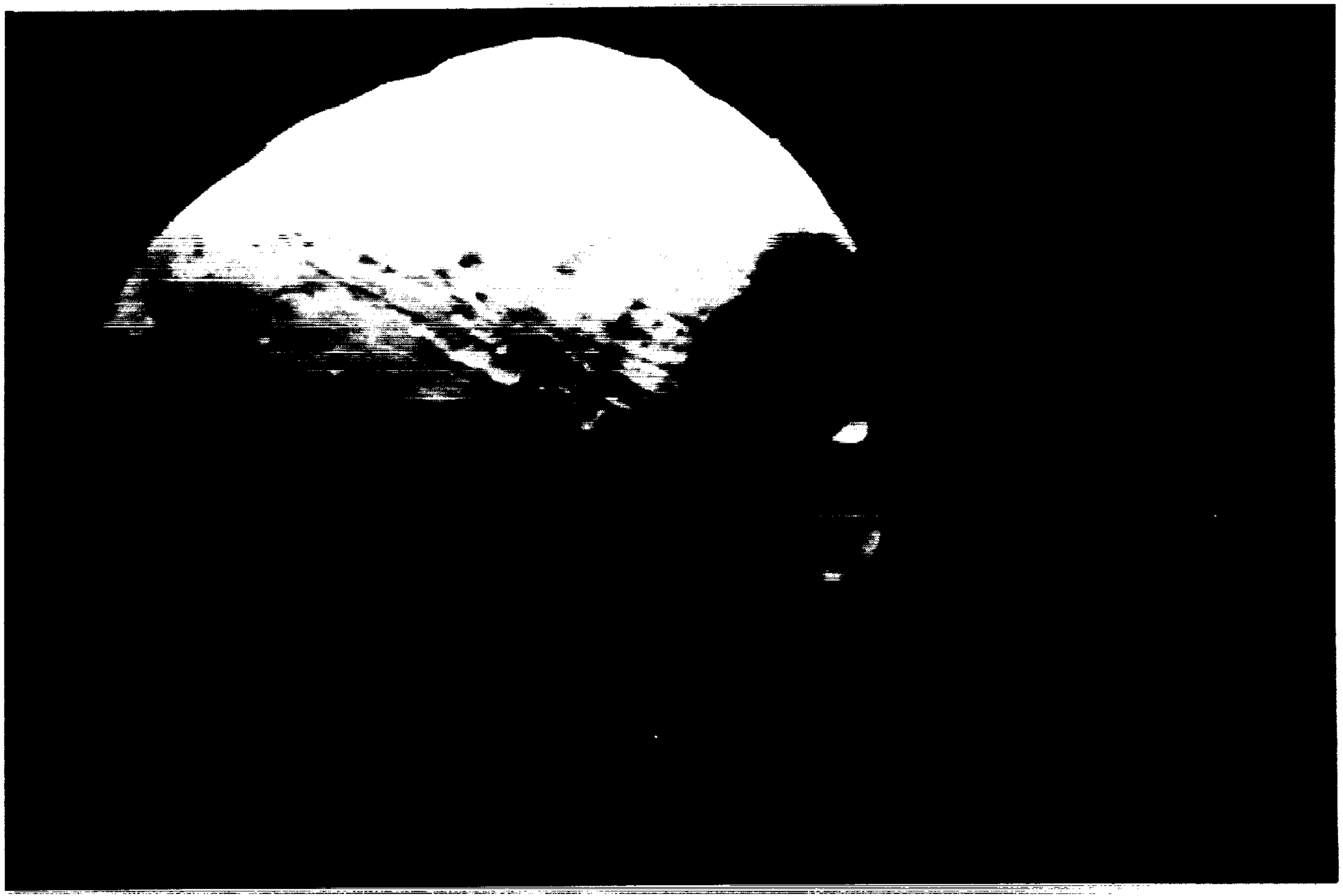
DIELECTRIC BREAKDOWN OF ANODIZED SURFACES IN A PLASMA





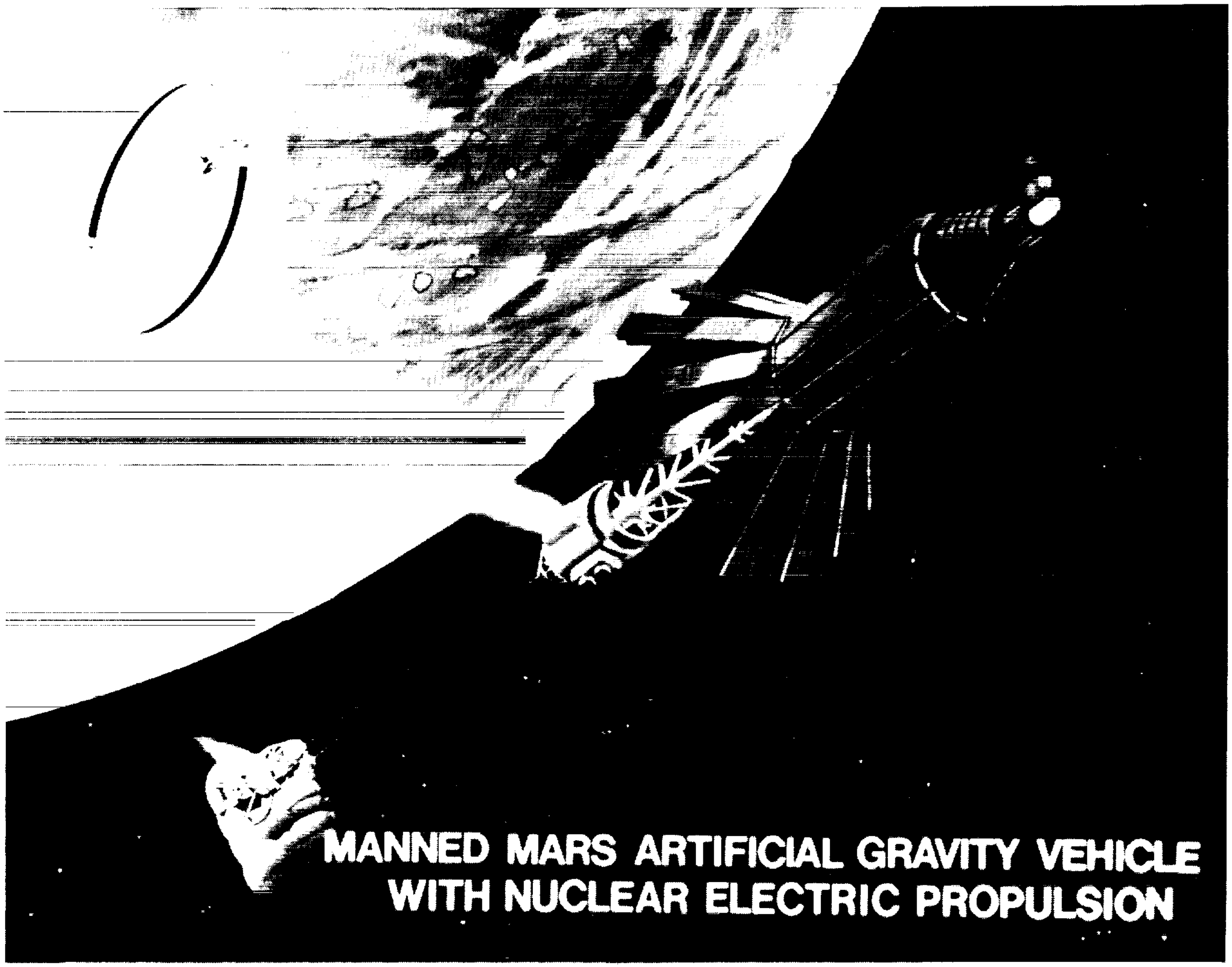

Peak Currents of Plasma Arcs
Best Fit Power: 0.62+/-0.03
Peak Current (A)
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
1.0E-01
1.0E-02
0.0001
0.001
0.01
0.1
1
10
100
1000
10000
Capacitance (uF)
1m³ box
6m²
Solar Array Wing 1mil Kapton
Old Hab Module
200m²
0.5mil
0.2mil
Old SSF 2500m²
Snyder (Array)
Snyder (Simulation)
Miller (Array)
Balmain
Carruth (Plate)
Best Fit r=0.98





Space Environmental Interactions
Effluents, Neutral and Ionized

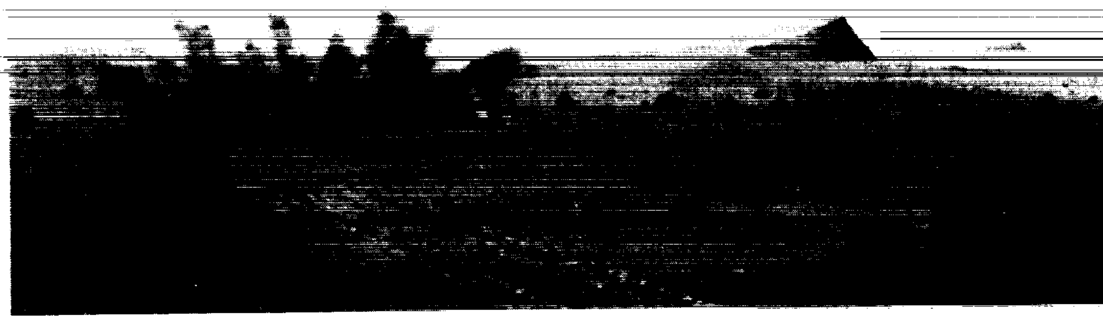
- NEUTRAL EFFLUENTS
  - Thruster Firings and Gas Dumps
  - Change Vehicle Floating Potential
  - May Interact Chemically with Surfaces
  - May Become Ionized by UV, Critical Ionization Velocity, Charge Exchange
  - Source of Contamination
- IONIZED EFFLUENTS
  - Ion Thrusters, Radioactive Sources
  - May Be Attracted Back by E Fields
  - Change Vehicle Potential
  - Increase Local Plasma Density, Arcing, Sputtering, etc.

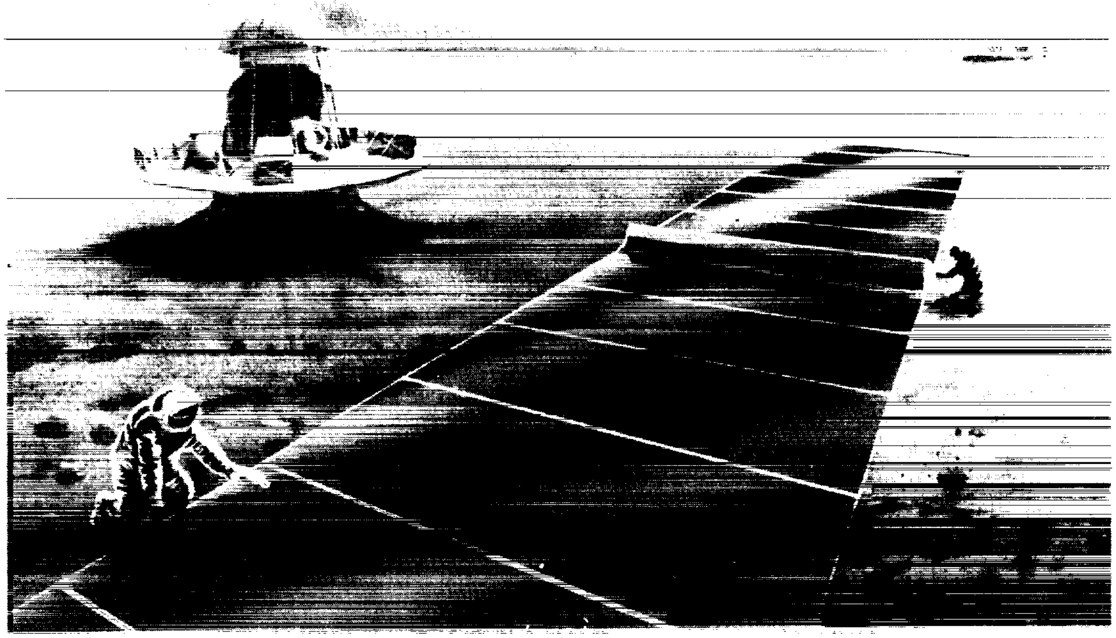


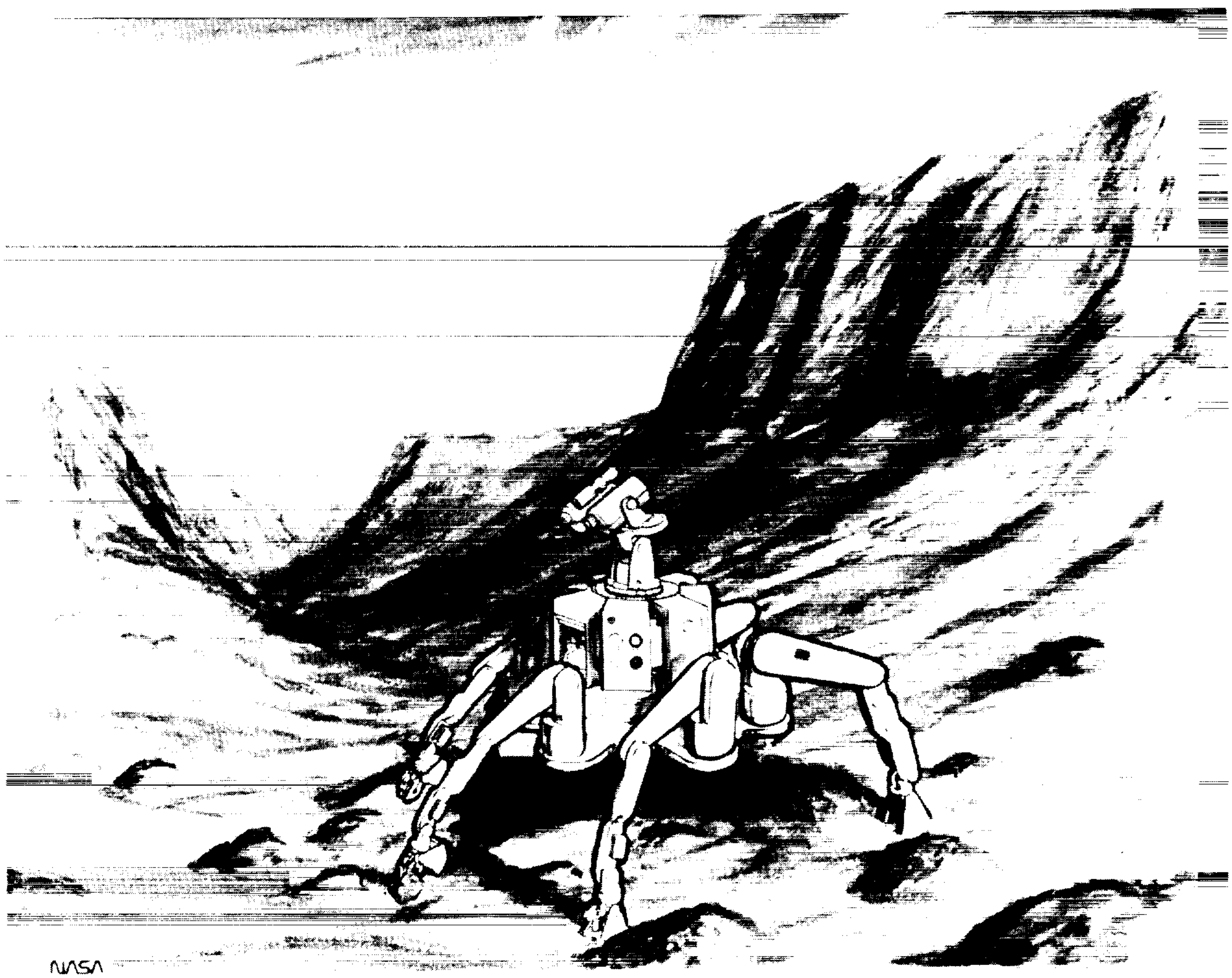
Space Environmental Interactions

Winds, Dust, and Contamination

- NEUTRAL DUST CONTAMINATION
  - Propelled by Winds or Rocket Exhausts
  - May Have High Sticking Factors
  - Can Change Thermal, Optical Properties
  - Attracted to Charged Surfaces by Dipole Attractions
- CHARGED DUST
  - Mars, Moon - Photoelectric Effect
  - Mars - Triboelectric Charging
  - Attracted Strongly to Charged Surfaces






NASA

N93-26397

MODELING AND ANALYSIS TOOLS

Gary Jongeward
S-Cubed Division of Maxwell Labs
3398 Carmel Mountain Road
San Diego, California

Modeling and Analysis Tools

The Objective

Help SEI Become Reality By Providing Environment Interactions Information To SEI Planners, Designers, & Engineers

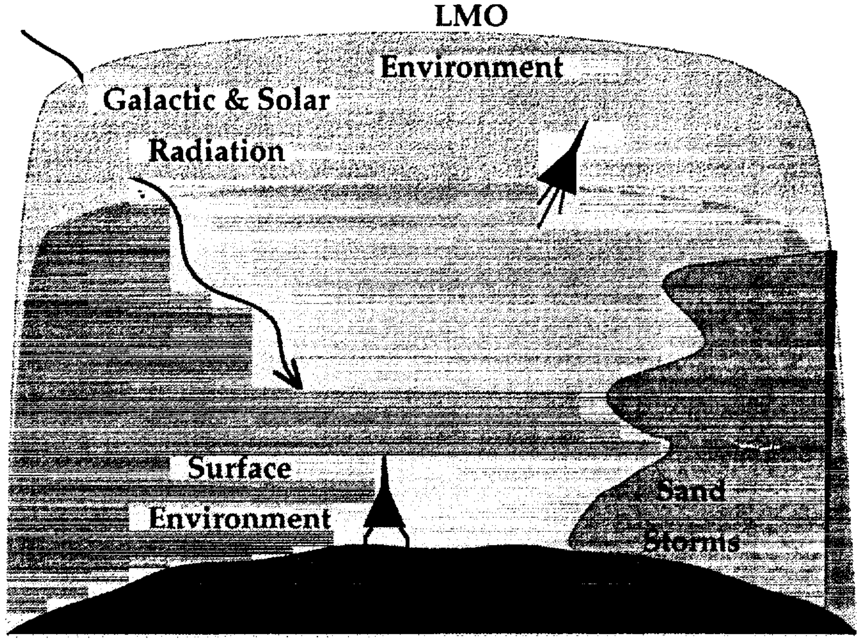
The Reason

- **SEI designers need information for preliminary designs**
- **SEI designers need the latest knowledge as early as possible**
- **The legacy of SEI should be retained knowledge, not lost expertise**

The Method

- **Coordinate model development & identify gaps in the data**
- **Integrate models and data into a software package for SEI**
- **Develop the tool now in time to impact SEI conceptual designs**

Mars Environments Will Affect Systems In Many Ways



Transit Effects
O Erosion
Radiation Dose
Heating
Drag

Surface Effects
Degradation
Contamination
Operability
Survivability

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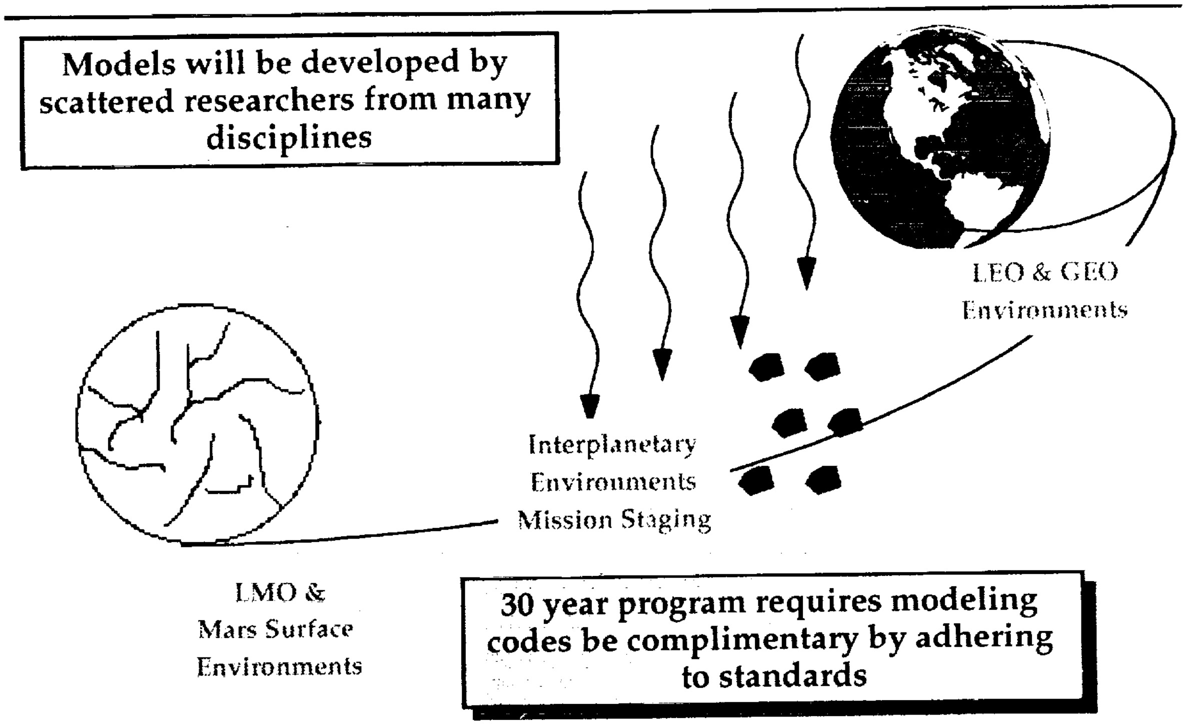
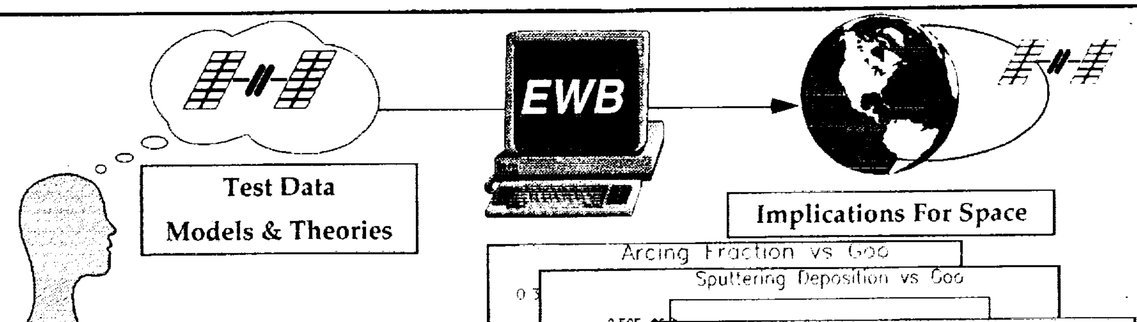
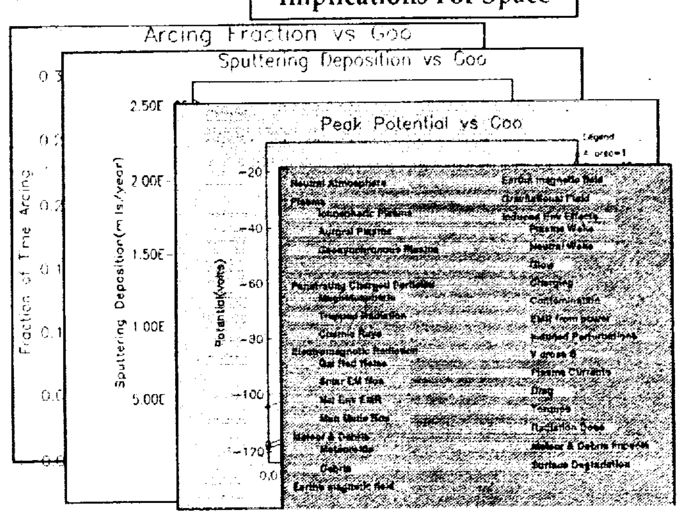
Models and Modeling Tools Must Be Designed With the Entire SEI Mission in Mind



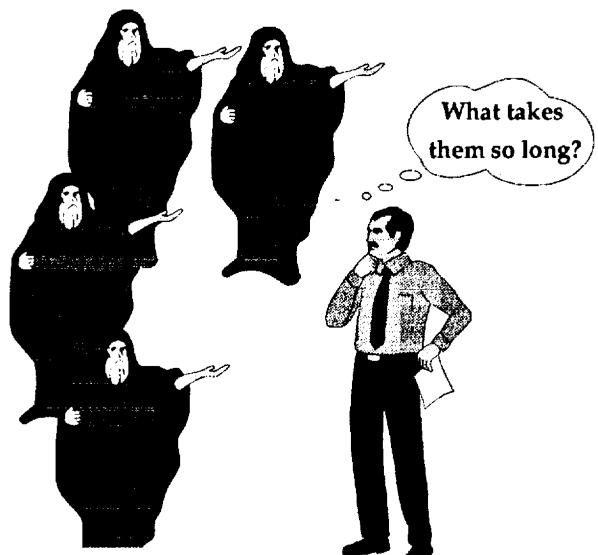
Space Station Designers Did Not Have Integrated Environment Interaction Tools



- EWB is being developed by NASA/LeRC & S-Cubed to fill this need.
- Had EWB been available early in the program, the array grounding issue & others would have been avoided!



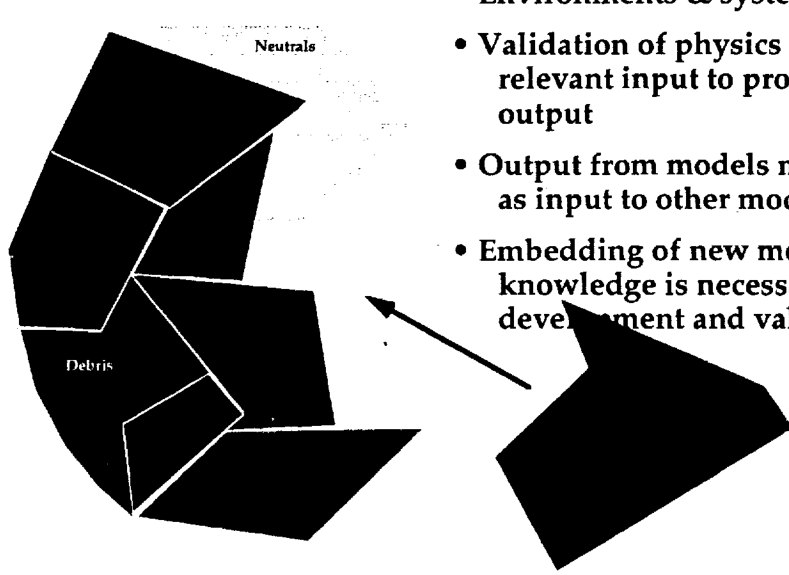
Environment Interactions Information Must Be Provided To SEI Planners, Designers, And Analysts In A Timely Fashion



Presently, integral knowledge is scattered among a few Gurus and is inaccessible, incomplete, and unreliable.

This knowledge and expertise can be transferred to mission planners through models, databases, and tools.

Tools Are Needed To Aid In The Development And Validation Of Models



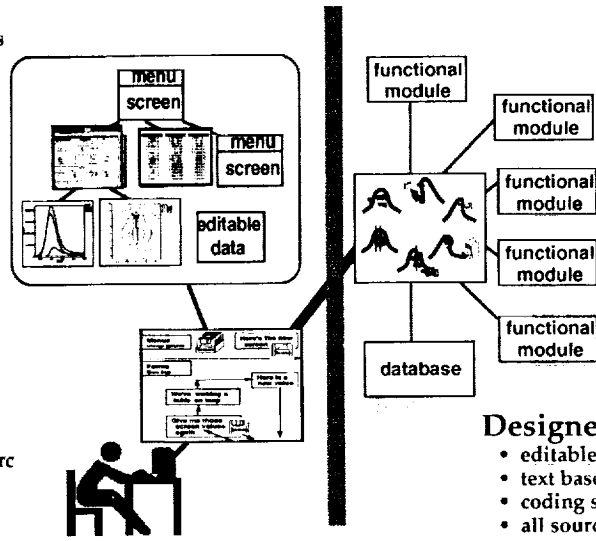
Each model is one piece of the puzzle

- **Environments & systems interact**
- **Validation of physics models requires relevant input to produce relevant output**
- **Output from models must be available as input to other models**
- **Embedding of new models in existing knowledge is necessary for development and validation**

SEI Workbench Builds On Proven Technology

Flexible Display Module
same commands for all functions
- data entry screens
- tables
- line graphs
- contour plots

Non-Procedural Process Controller
does only the calculations necessary for the desired result



Software "Expansion Slots"
plug in new or additional environment & system models

Workstation Independent
- UNIX
- Fortran & C
- Sun 3, 4 Sparc
- Compaq
- Celerity
- IBM 6000
- Decstation

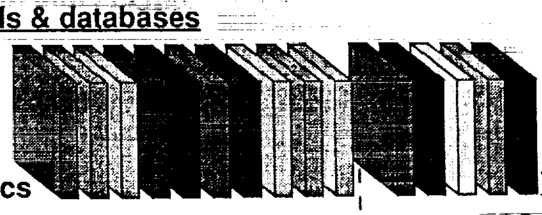
Designed For Change
- editable screens
- text based data item dictionary
- coding standards
- all source government owned

Object Oriented
message passing between modules

An SEI Workbench Based On The EWB Will Satisfy Both The Needs Of Researchers And SEI Mission Planners

<u>Library of models & databases</u>

Environments
Interactions
Systems
Orbital mechanics



<u>Proven Technology</u>

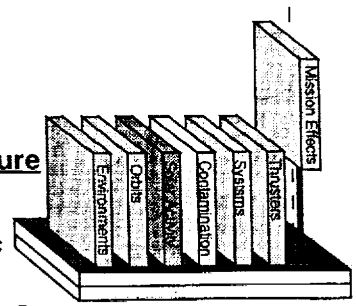
EPSAT
NASA/LeRC SDIO Space Systems

EWB
NASA/LeRC SSF

SSAM
Space Nuclear Power

LIWB
LDEF

SEISAT
SEI IR&D Prototype



<u>MIRIAD</u>

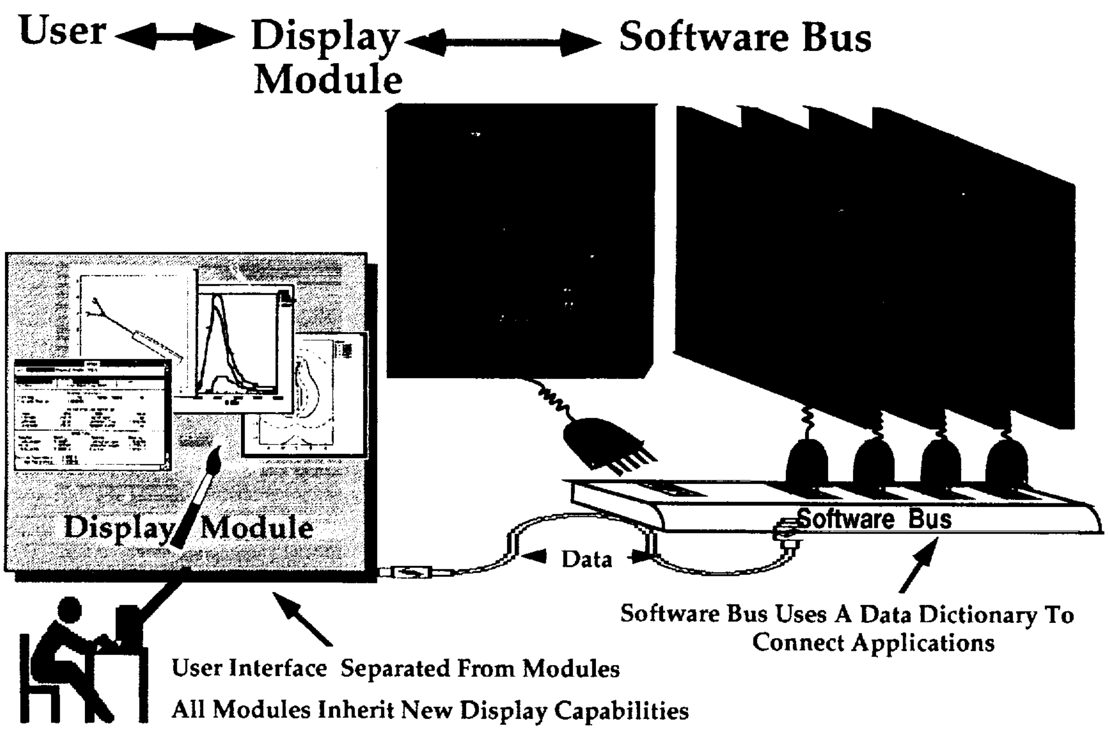
<u>Integrating Architecture</u>

Expandable

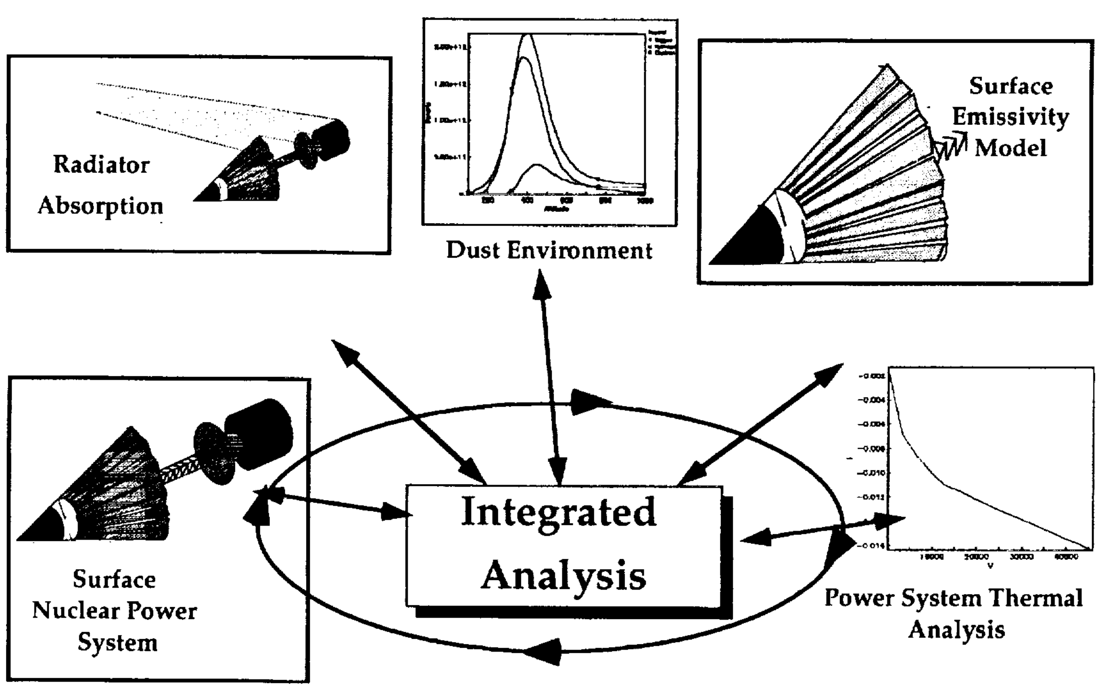
Tailorable to specific needs

Transfers knowledge & technology to the users

Miriad Architecture
The Core Of An Integrated SEI Workbench



SEI Mission Planning
Needs Integrated Assessment Tools



Summary
Modeling And Analysis Tools

- SEI mission will be the most intricate & longest running project ever attempted
  - Over 30 years
  - Moon, Mars, & interplanetary environments

- SEI designers must have mission design tools in time
  - To impact the conceptual design
  - To identify gaps in the knowledge
  - To aid in the design of precursor missions
  - To provide a vehicle to retain acquired knowledge

- The SEI workbench must be an integral part of the SEI
  - Provides the vehicle for knowledge and technology transfer
  - Is the nucleus for permanent retention of knowledge

N93-26898

ENVIRONET

Tim VanSant
National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

SPACE ENVIRONMENT INFORMATION

EnviroNET is a service/facility that provides users with on-line, dial-up technical information concerning environmental conditions likely to be encountered by instruments and experimental arrangements carried aboard spacecraft.

EnviroNET incorporates at present a combination of expository text and numerical tables amounting to about two million characters (bytes), plus FORTRAN programs that model the space environment.

ADVANTAGES OF ENVIRONET

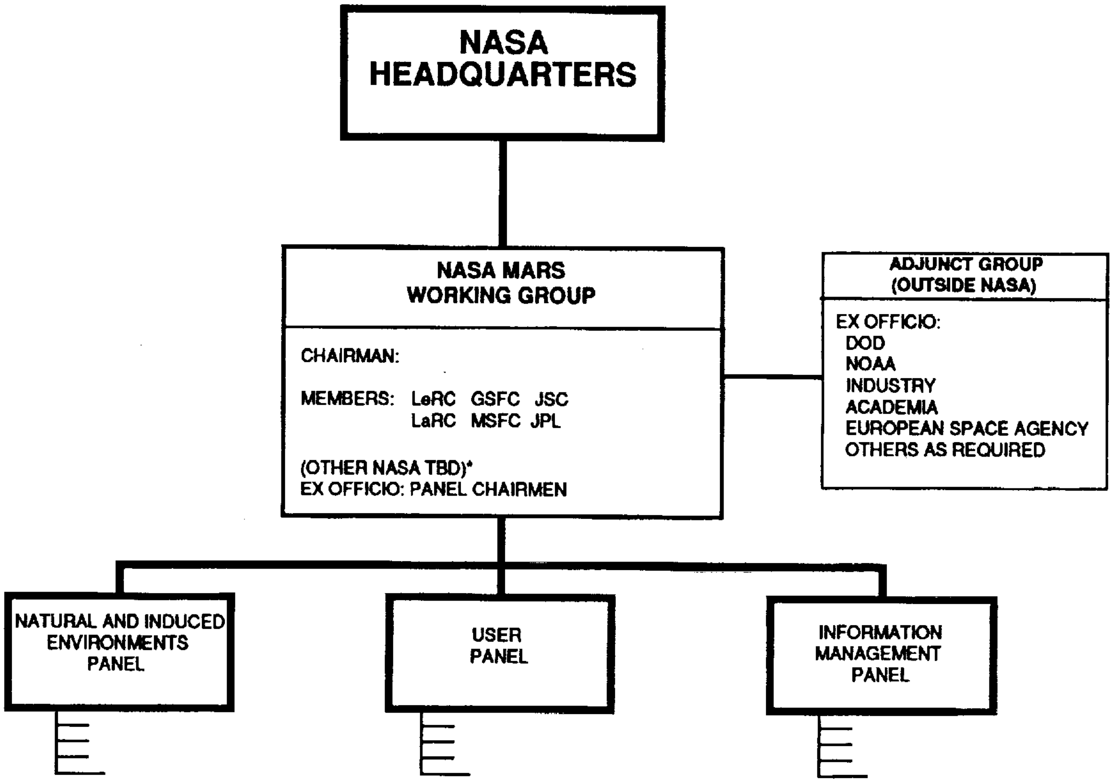
- CENTRALIZED COMPUTER-BASED INFORMATION ON NATURAL AND INDUCED ENVIRONMENTS
- BASED ON MEASURED DATA (SHUTTLE) AND EMPIRICAL MODEL VALIDATED BY DISCIPLINE PANELS
- FOR SCIENTISTS' AND ENGINEERS' USE IN THE DESIGN AND DATA ANALYSIS OF FLIGHT HARDWARE
- CURRENCY MAINTAINED BY NASA THROUGH COOPERATIVE EFFORTS OF INDUSTRY, OTHER GOVERNMENT AGENCIES, THE EUROPEAN SPACE AGENCY, ACADEMIA, AND THE NASA COMMUNITY

AREAS OF CONCERN FOR USERS ARE INCLUDED
IN THE MAIN TOPICS

MAIN TOPICS

- **INTRODUCTION**
- **THERMAL AND HUMIDITY**
- **VIBRATION AND ACOUSTICS**
- **ELECTROMAGNETIC INTERFERENCE**
- **LOADS AND LOW FREQUENCY DYNAMICS**
- **MICROBIAL AND TOXIC CONTAMINANTS**
- **MOLECULAR CONTAMINATION**
- **NATURAL ENVIRONMENT**
- **ORBITER MOTION**
- **PARTICULATE ENVIRONMENT**
- **SURFACE INTERACTIONS**
- **SPACECRAFT ANOMALIES**
- **INTERACTIVE GRAPHICS FACILITY**

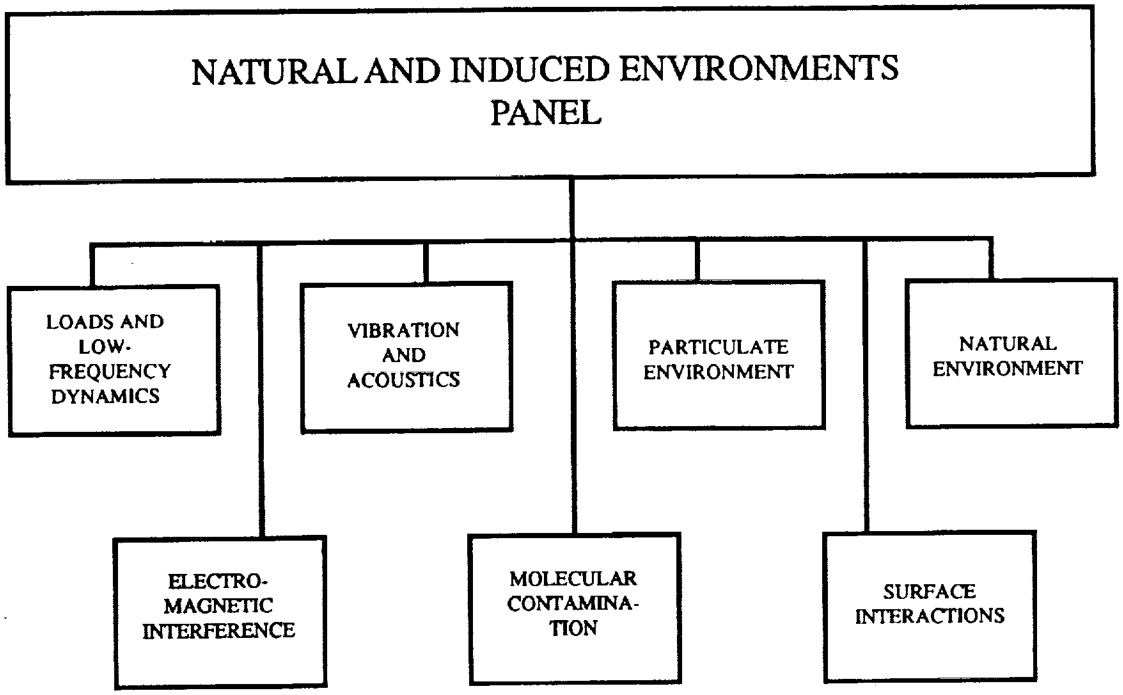
NASA MARS WORKING GROUP



FUNCTIONS OF THE NATURAL AND INDUCED ENVIRONMENTS PANEL

- GATHER DATA
- MAKE PRELIMINARY ASSESSMENTS OF RELIABILITY AND TRACEABILITY OF DATA
- PROVIDE GUIDELINES FOR MEETING PAYLOAD INTEGRATION REQUIREMENTS
- ACCESS STATE-OF-THE-ART-DATA FOR FEASIBILITY

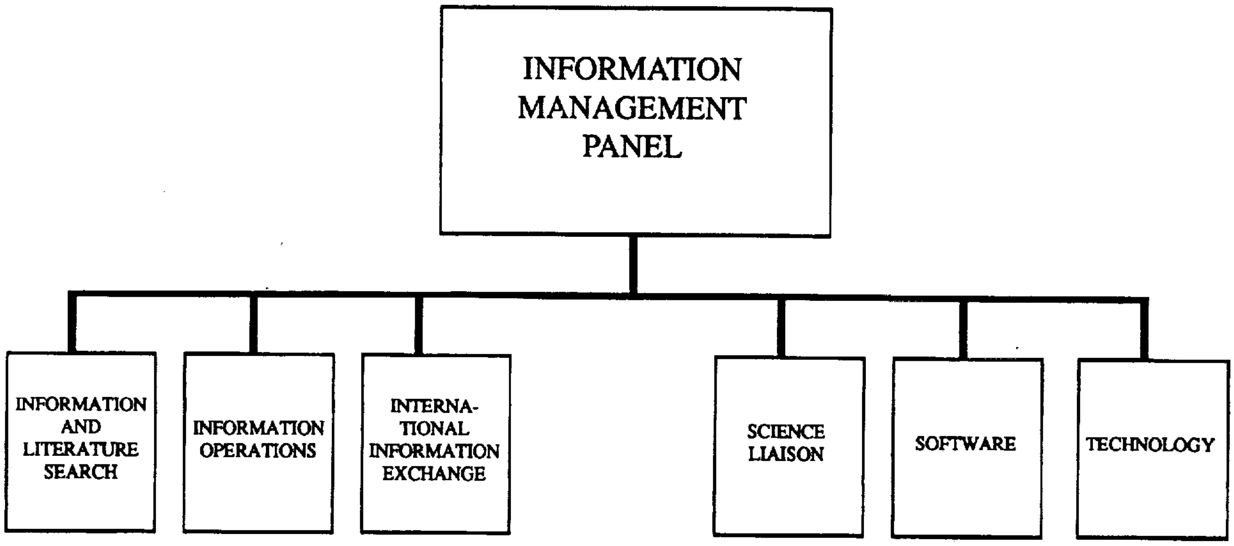
THE NATURAL AND INDUCED ENVIRONMENTS PANEL



INFORMATION MANAGEMENT

The Information Management Panel provides the database structure and manages the database. Duties: Create a system for compiling, storing, and cataloging the information in the database; edit information; and coordinate network activities.

INFORMATION MANAGEMENT PANEL



The scope of the interactive models is shown below. This activity has been advanced by adding interactive models of the natural environment. The models include neutral atmosphere density and temperature, ionosphere, electron temperature and density, the magnetic field vector, and energetic particle or radiation flux. These models are based on data from satellites which orbit the earth in the thermospheric and exospheric regions of the atmosphere.

INTERACTIVE MODELS

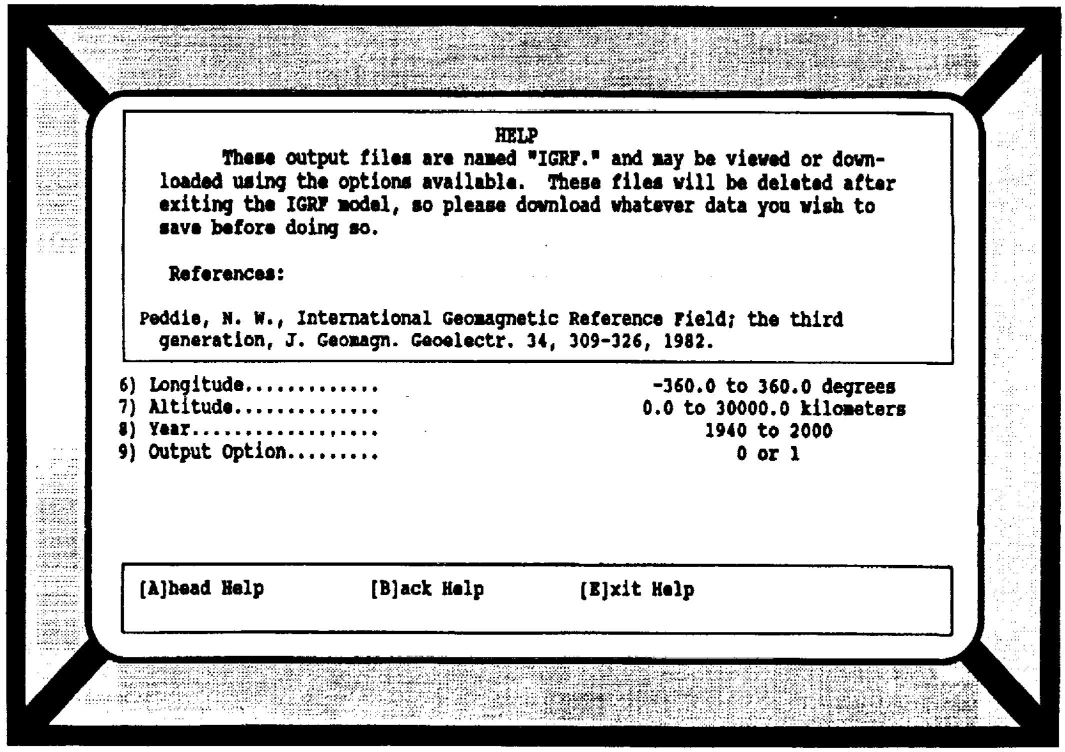
MARSGRAM*	(Mars Global Reference Atmospheric Model)
MSIS*	(Mass Spectrometer Incoherent Scatter
MET*	(Marshall Engineering Thermosphere)
IRI*	(International Reference Ionosphere)
IGRF*	(International Geomagnetic Reference Field Model)
CREME	(Cosmic Ray Effects on Microelectronics)
TOTAL DOSE*	(Orbital Radiation Dose Analysis Package)
ENERGETIC PARTICLES*	
RADIATION BELTS	
SOLAR FLUX	
ORBITAL DEBRIS*	
METEOROID*	
ORBITAL DECAY	
THERMAL ANALYSIS	

*Suitable for orbit integration

ENVIRONMENT MODELS

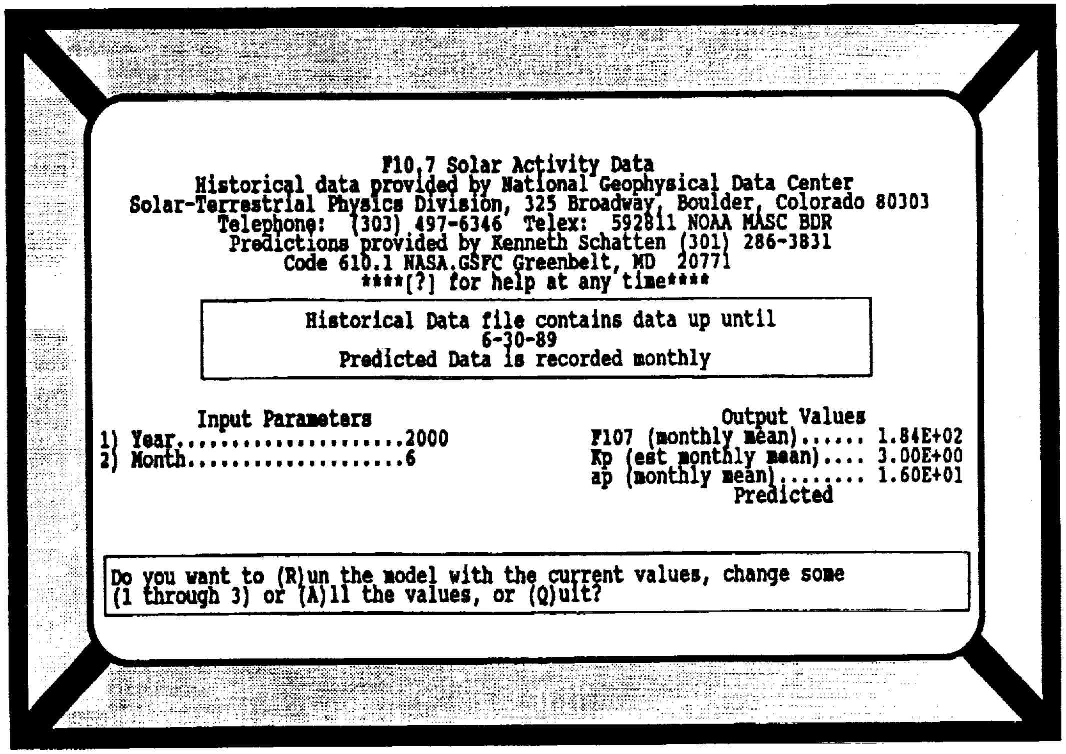
- PROVIDE A READILY ACCESSIBLE METHOD TO DO QUICK, ACCURATE CALCULATIONS.
- ENCOMPASS MANY IMPORTANT ENVIRONMENTS FOR ENGINEERS.
- A USER-FRIENDLY, INFORMATIVE INTERFACE IS STANDARD ON ALL ENVIRONET MODELS.
- ALL MODELS HAVE A POP-UP HELP WINDOW WHICH GIVE MORE INFORMATION ON MODEL INPUTS, OUTPUTS AND CAVEATS.
- PERMIT UPLOADING AND DOWNLOADING OF LARGE DATA FILES.

MODEL HELP WINDOW



SOLAR ACTIVITY DATA AND PREDICTIONS

- PRODUCES DAILY AVERAGES OF Ap AND Kp ACTIVITY WHICH ARE NEEDED FOR MOST ATMOSPHERE AND MAGNETOSPHERE MODELS.
- DATA FILES SPAN FROM 1940 TO 2011 AND ARE PERIODICALLY UPDATED.
- HISTORICAL DATA SUPPLIED BY ARRANGEMENT WITH NOAA.
- PREDICTIONS SUPPLIED BY ARRANGEMENT WITH NASA/GODDARD SCIENTIST DR. KENNETH SCHATTEN.



COSMIC RAY EFFECTS ON MICROELECTRONICS MODEL

- CALCULATES THE LINEAR ENERGY TRANSFER (LET) SPECTRA FOR A CHOSEN RANGE OF ELEMENTS, FOR ANY ORBIT.
- CALCULATES THE SINGLE-EVENT UPSET (SEU) RATE DUE TO THE LET SPECTRA AND PROTON REACTIONS OUTSIDE THE SPACECRAFT, GIVEN PARAMETERS OF THE PART OF INTEREST.
- INCLUDES THE EFFECTS OF SOLAR FLARES, GEOMAGNETIC CUTOFF, AND TRAPPED PROTONS.

CREME MODEL

```
                Cosmic Ray Effects on Microelectronics (CREME) Model
                   by James H. Adams, Jr., N.R.L., (301) 767-2747
                                  Geomag2 Submodel
This program computes the geomagnetic transmission function for a given orbit.
                             [?] for help at any time

          Input Parameters                                Input Range
1) Include Earth shadow?....y                          (Y)es or (N)o
2) Magnetic weather cond....s                        (S)tormy or (Q)uiet
3) Alt. at apogee...........550                        in kilometers
4) Alt. at perigee..........550                        in kilometers
5) Orbital inclination......28.5                     -90 to 90 degrees
6) Initial long of asc node.0                         0 to 360 degrees
7) Init. disp. of asc node..0                         0 to 360 degrees
8) Perig displ. fr asc node.                          0 to 360 degrees

Do you want to (R)un the model with the current values, change some
(1 through 8) or (A)ll the values, or (Q)uit?
```

MARSGRAM

- AN ENGINEERING MODEL ATMOSPHERE FOR MARS.
- LOWER ATMOSPHERE DATA BASED ON ACTUAL MEASUREMENTS MADE BY MARINER AND VIKING SPACECRAFT.
- SIMULATES EFFECTS OF SEASONAL AND DIURNAL VARIATION, DUST STORMS, AND CO_2 SUBLIMINATION/CONDENSATION ON SURFACE PRESSURE.
- RANDOM PERTURBATION PROFILES FOR DENSITY VARIATIONS ALONG SPECIFIED TRAJECTORIES.

MARSGRAM MODEL

THE MARS GLOBAL ATMOSPHERIC MODEL
VERSION 2.22 — NOVEMBER 16, 1989
*** Hit [?] for help at any time ***

	Input Parameters		Input Ranges
1)	Year..	1997	1900 to 2100
2)	Month..	10	1 to 12
3)	Day...	20	1 to 31
4)	Hour...	10	0 to 23
5)	Minute...	20	0 to 59
6)	Second...	0	0.0 to 59.0
7)	LS = 201.79 degrees..........	200	180.0 to 320.0 degrees
8)	Storm Intensity......................	2	0.0 to 3.0
9)	F10.7 cm flux at 1AU...........	100	50.0 to 450.0 (10^-22W / m^2) / Hz
10)	Standard Deviation...............	0	-3.0 to 3.0 (10^-22W / m^2) / Hz
11)	Random Number Seed...........	1	1 to 29999

```
12)  X-Code   13)  Y-Code   14)  Scale   15)  Positions   16)  Lat   17)  Lon
18)  Height   19)  Height inc.   20)  Lat inc.   21)  Lon inc.   22)  Time inc.
```

```
Do you want a dust storm?  [Y \ N]
LS is the measure of the seasonal period of Mars.
```

MARSGRAM MODEL

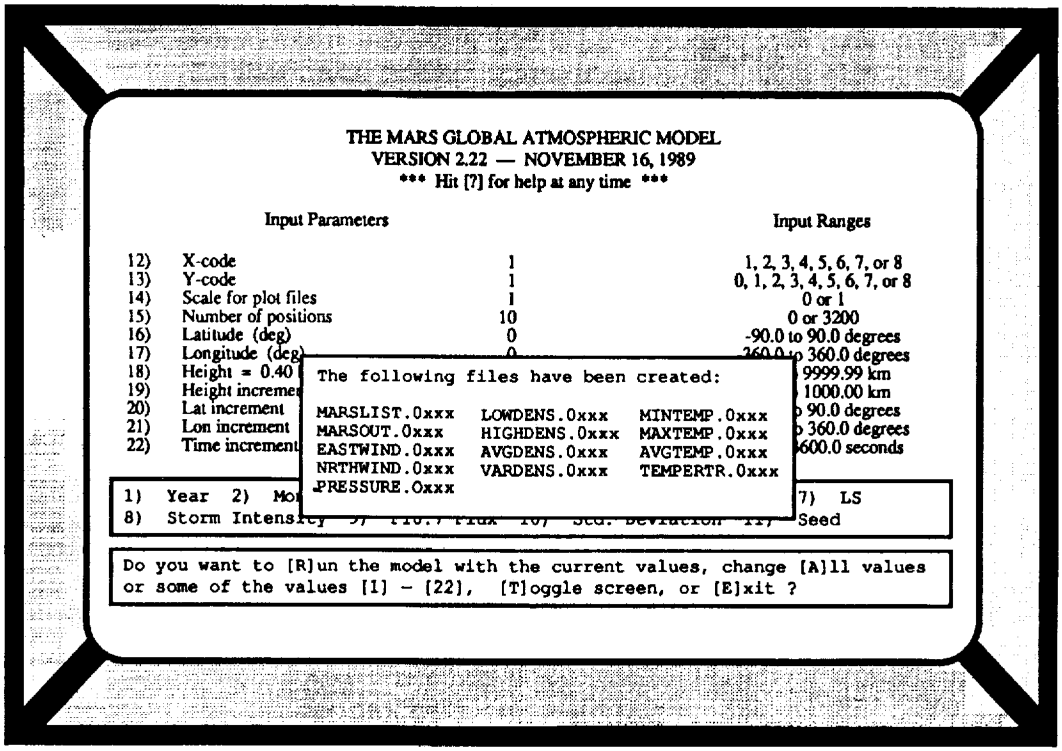
THE MARS GLOBAL ATMOSPHERIC MODEL
VERSION 2.22 — NOVEMBER 16, 1989
*** Hit [?] for help at any time ***

	Input Parameters		Input Ranges
12)	X-code	1	1, 2, 3, 4, 5, 6, 7, or 8
13)	Y-code	1	0, 1, 2, 3, 4, 5, 6, 7, or 8
14)	Scale for plot files	1	0 or 1
15)	Number of positions	10	0 or 3200
16)	Latitude (deg)	0	-90.0 to 90.0 degrees
17)	Longitude (deg)	0	-360.0 to 360.0 degrees
18)	Height = 0.40 km	50	0.0 to 9999.99 km
19)	Height increment	10	0.0 to 1000.00 km
20)	Lat increment	1	-90.0 to 90.0 degrees
21)	Lon increment	0	-360.0 to 360.0 degrees
22)	Time increment	10	0.0 to 3600.0 seconds

```
1)  Year   2)  Month   3)  Day   4)  Hour   5)  Minute   6)  Second  7)  LS
8)  Storm Intensity   9)  F10.7 Flux   10)  Std. Deviation   11)  Seed
```

```
Do you want to [R]un the model with the current values, change [A]ll values
or some of the values [1] - [22],  [T]oggle screen, or [E]xit ?
```

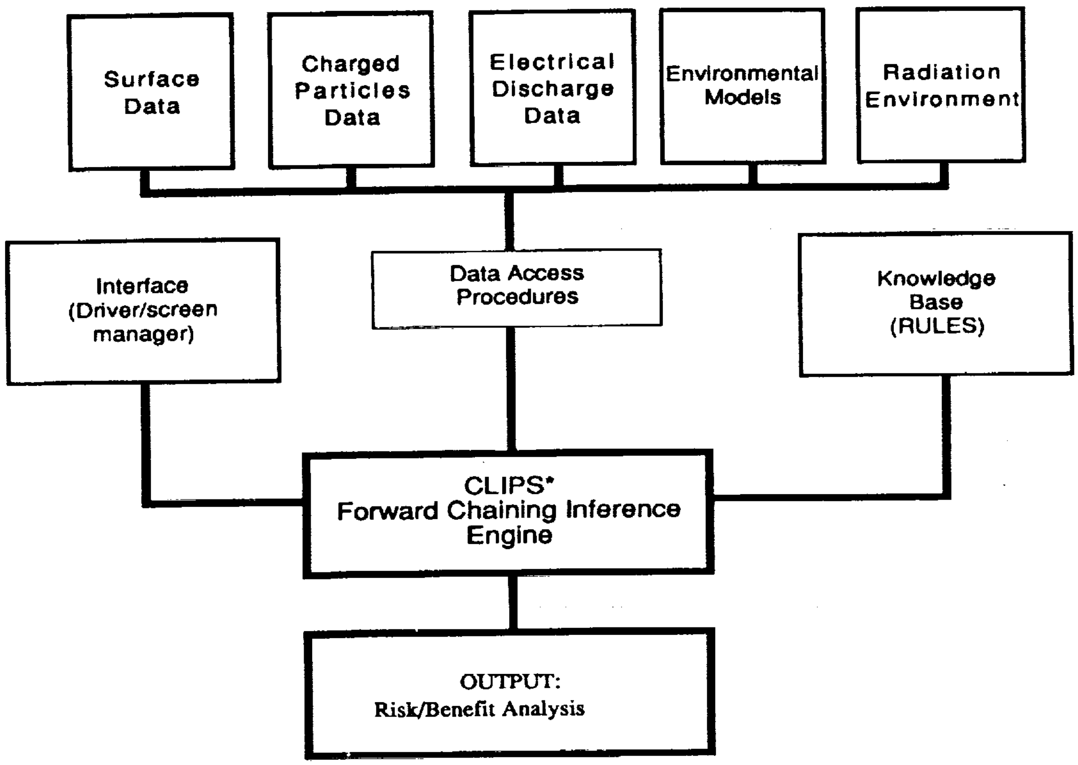
MARSGRAM MODEL



EXPERT SYSTEMS

- Provide an effective method of saving corporate knowledge.
- Allow computers to sift through large amounts of data and pinpoint significant parts.
- Use heuristics for predictions instead of algorithms.
  - Approximate reasoning and inference.
  - Able to attack problems not rigidly defined.

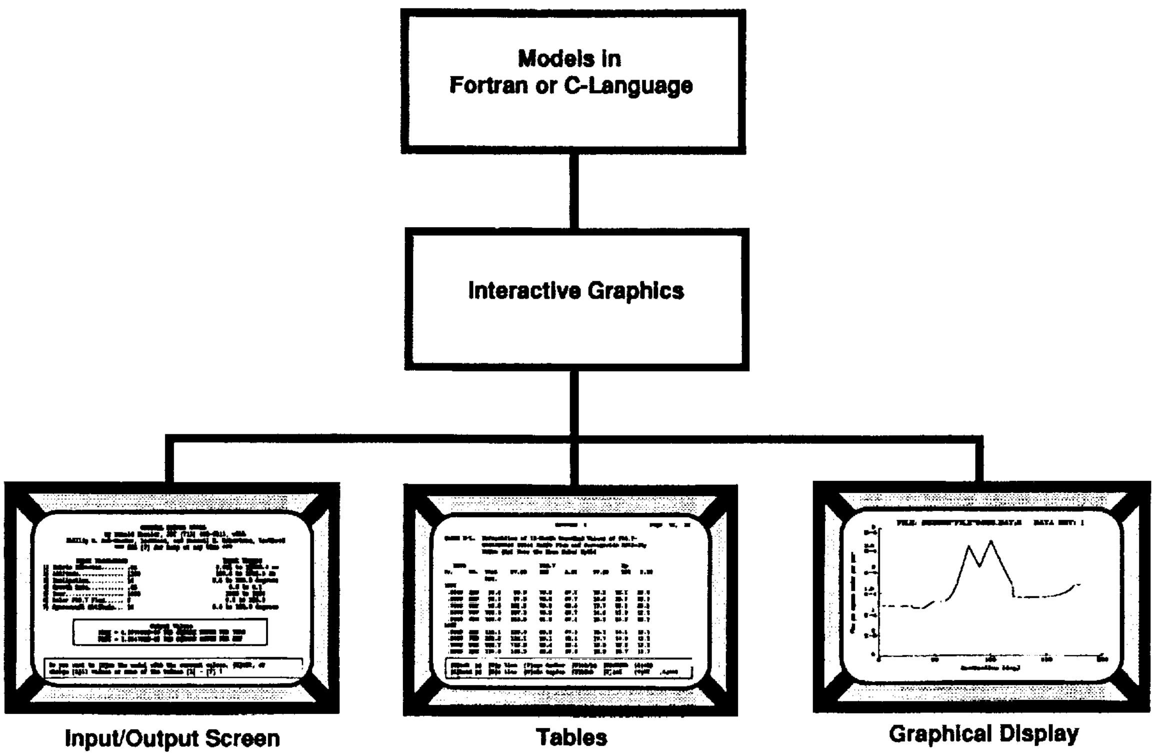
PROPOSED EXPERT SYSTEM FOR ELECTRICAL AND CHEMICAL INTERACTIONS ON MARS



*C-Language Integrated Production System (NASA/JSC)

The proposed model access and organization is shown below

MODEL ACCESS



MARS EXPLORATION PLANNING

Tamara L. Dickinson
National Aeronautics and Space Administration
Washington, DC 20546

Mars Exploration Planning

- Mars Observer
- MESUR
- Small Rovers and Sample Return Missions

Mars Exploration Planning

➢ Mars Observer

MESUR

Small Rovers and Sample Return Missions

Mars Observer: Mission Rationale

While Knowledge of Mars is Extensive, It Contains Significant Gaps. More Importantly, There Are a Number of First Order Scientific Questions That Can be Best Addressed From an Orbital Platform. The Geoscience/Climatology Orbiter Will Provide New Observations and Complement Existing Measurements, and Provide an Improved Basis for Future Intensive Investigations.

SSEC Report

Mars Observer

- Low Altitude Polar Orbit
- 1 Martian Year Mission Duration
- Simple Repetitive Geological/Climatological Mapping Mission
- Spacecraft Based on Derivative of Earth Orbital Spacecraft
- Experiments Selected Concurrent with Spacecraft

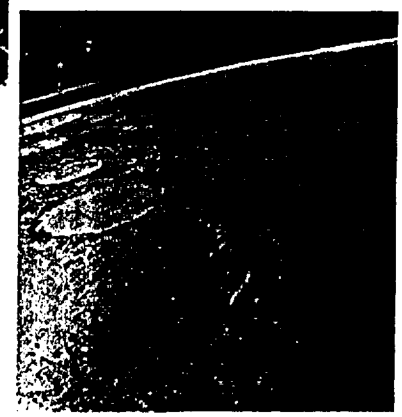
SCIENCE OBJECTIVES

MARS OBSERVER WILL . . .

DETERMINE THE GLOBAL ELEMENTAL AND MINERALOGICAL CHARACTER OF THE SURFACE MATERIAL

DEFINE GLOBALLY THE TOPOGRAPHY AND GRAVITATIONAL FIELD

DETERMINE THE TIME AND SPACE DISTRIBUTION, ABUNDANCE, SOURCES, AND SINKS OF VOLATILE MATERIAL AND DUST OVER A SEASONAL CYCLE



EXPLORE THE STRUCTURE AND ASPECTS OF THE CIRCULATION OF THE ATMOSPHERE

ESTABLISH THE NATURE OF THE MAGNETIC FIELD

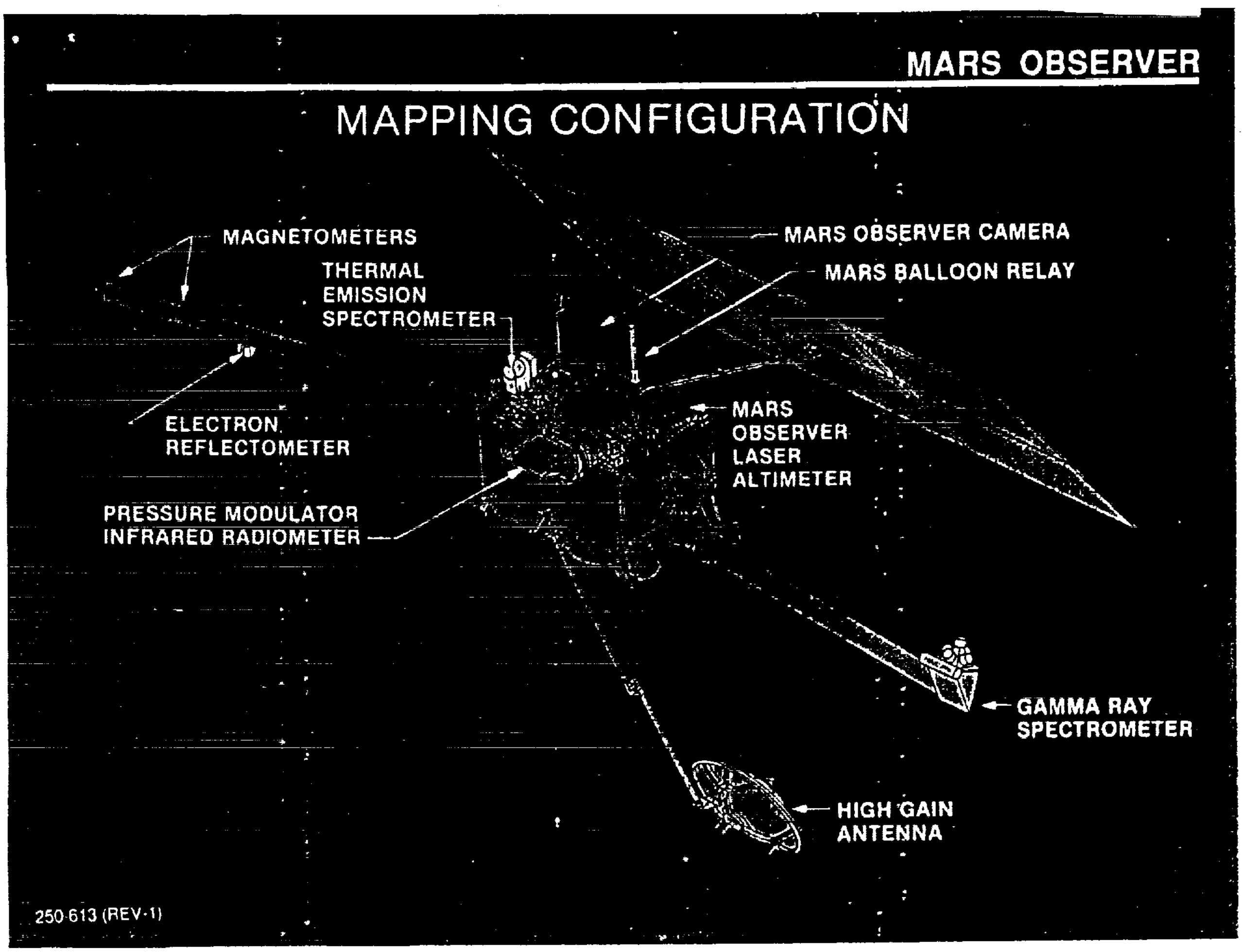
Mars Observer

Science Instrument Measurement Objectives

Gamma Ray Spectrometer	Elemental Composition of Surface
Magnetometer	Intrinsic and Local Magnetic Field
Mars Observer Camera	Global Synoptic Views, Selected Moderate and Very High Resolution Images of Surface and Atmosphere
Pressure Modulator Infrared Radiometer	Profiles of Temperature, Water, Dust, and Radiation Budget Measurements
Radar Altimeter	Topography, Microwave Radiometry
Radio Science	Gravitational Field; Atmospheric Refractivity Profiles
Thermal Emission Spectrometer	Surface Mineralogy; Atmospheric Dust and Clouds: Radiation Budget

Mars Observer Status

- Spacecraft Assembly and Test Nearing Completion
- Five of 7 U.S.-Supplied Instruments Delivered and Integrated
  - Remaining 2 to be Delivered in February
  - Gamma-Ray Spectrometer Electrically Integrated with Spacecraft and Functional Testing Completed
    - Excellent Instrument Performance
  - Thermal Emission Spectrometer Successfully Completed Acceptance Tests and Was Delivered
  - Pressure Modulator Infrared Radiometer (PMIRR) Integrated Systems Testing Successfully Completed



Mars Observer Status

- Instrument and Spacecraft Integration and Test Schedules Remain Challenging
  - Mars Balloon Relay Delivered and Integrated
  - Mars Observer Camera Electronics Completed and System Performance Testing Underway
- All Titan III Major Design Reviews Completed
  - TOS Completed and in Storage
  - Launch Complex Behind Schedule, but on Recovery Plan

Mars Exploration Planning

Mars Observer

➢ MESUR

Small Rovers and Sample Return Missions

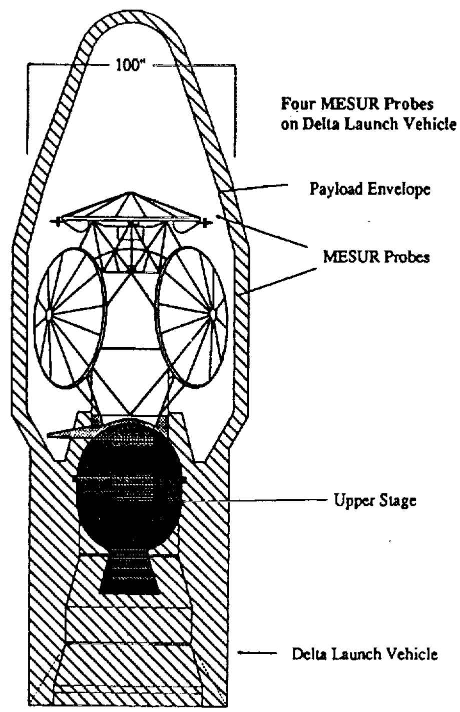
MESUR Philosophy

- "Grow" a Survey Network Over a Period of Years (a Series of Launch Opportunities)
- Develop a Level of Effort Which is Flexible and Responsive to a Broad Set of Objectives
- Focus on Science Return While Providing a Solid Basis for SEI (e.g., Site Selection Data)
- Minimize Cost and Complexity Wherever Possible

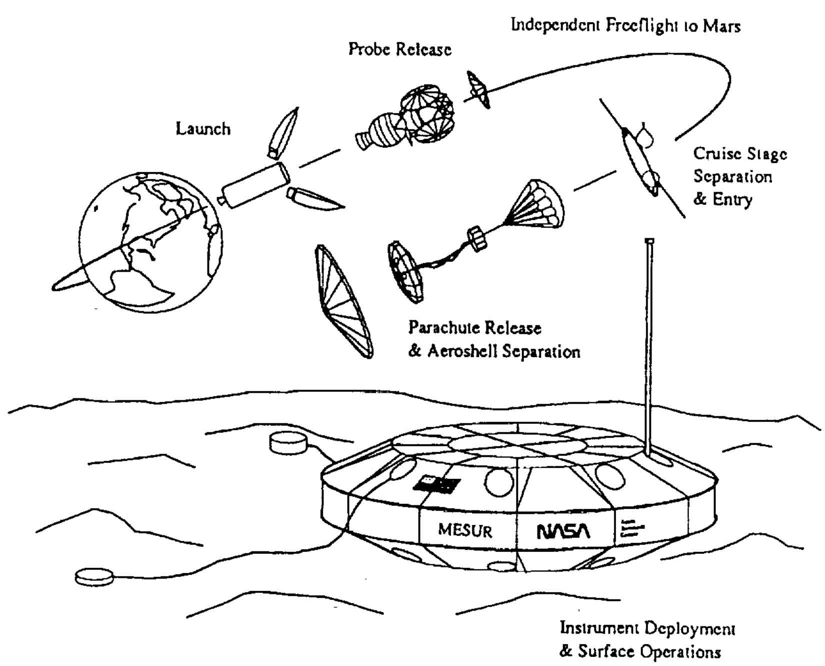
Baseline Mission Profile

- 16 Landers
- Delta II Launches at Every Opportunity
  - 2001, 2003, 2005
  - 4 Probes per Launch
- Small Free-Flyer Spacecraft, Spin Stabilized
  - Probes Designed as Cruise Stage, Entry System, Lander
  - Design Based on Pioneer & Viking Heritage
    - "Hard" Landing of <40 g's
    - RTGs
  - Communications Orbiter
    - Launch 2003

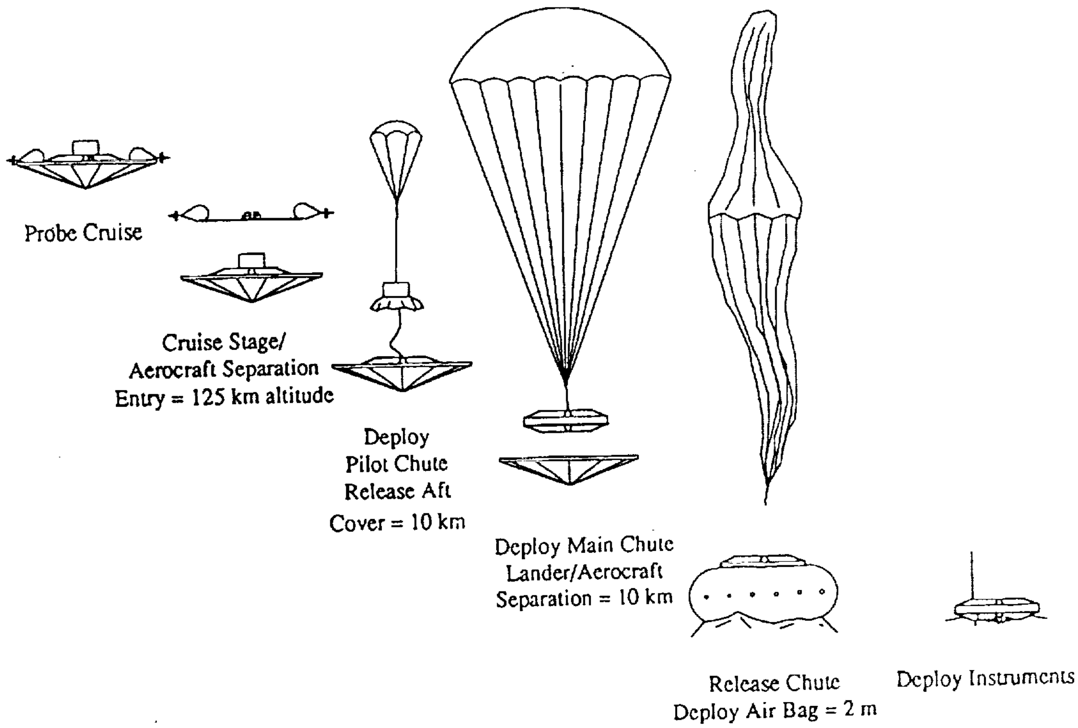
Launch Configuration



MESUR Mission Summary



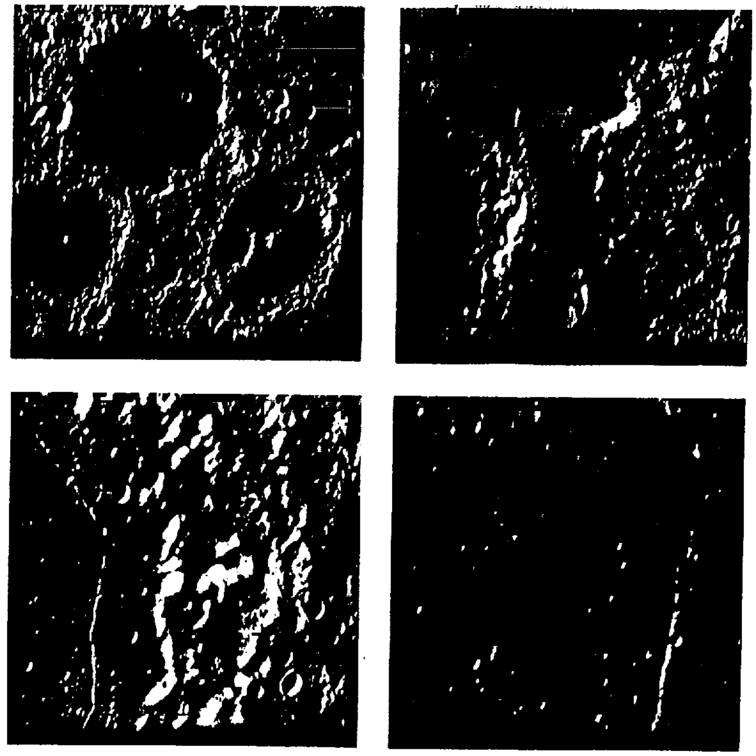
MESUR Descent and Deployment



Detailed Mission Objectives and Assumptions from MarsSWG

- Descent and Surface Imagery (Multiband)
  - Nested Images Desirable but Not Required
- Landing Accuracy on the Order of 100 km
  - Knowledge of Relative Lander Position to 1 km
- Entry Science Performed
  - Atmospheric Structure Experiment

RANGER DESCENT IMAGING



Descent Imaging Concerns

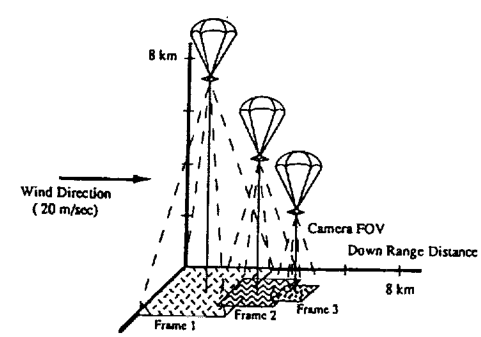
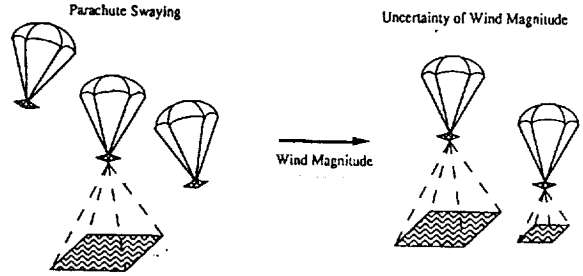


Figure V-2. Descent Imaging Concept



- Choose a more stable parachute
- Use an accelerometer to take pictures when pointing vertically down.

- Increase the field of view of the camera
- Increase the number of frames stored

Detailed Mission Objectives and Assumptions from MarsSWG

- Meteorology Measurements
  - Long Station Life (Simultaneous Measurements for 1-3 Mars Years)
  - Large Number of Widely Dispersed Stations (15-20)
  - Pressure, Opacity, Temperature, Winds and Humidity if Possible

Detailed Mission Objectives and Assumptions from MarsSWG

- Seismology Measurements
  - Short Period Seismometer, Single 3-Axis, as Broad Band as Possible
  - Surface Emplaced Seismometer
  - Long Station Life (>1 Mars Year)

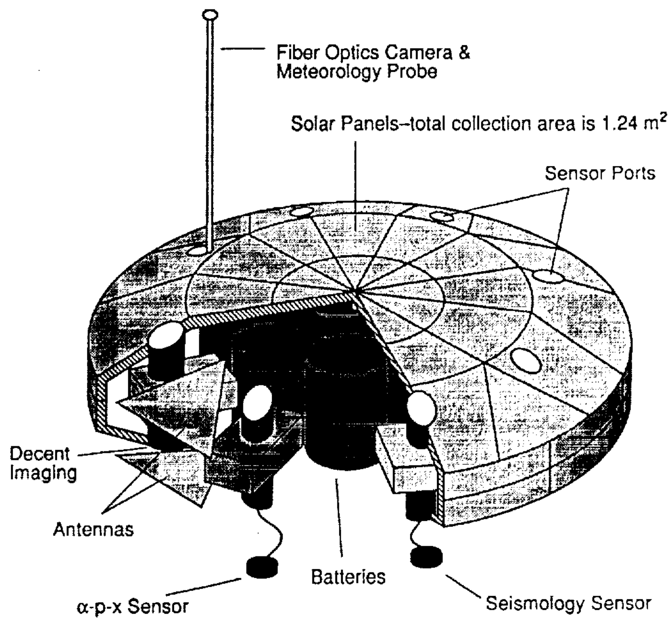
Detailed Mission Objectives and Assumptions from MarsSWG

- Geochemistry Measurements
  - Instruments Placed on Surface
  - Elemental Composition Instrument (α-p-x) Deployed at Each Station
  - Thermal Analyzer and Simple Evolved Gas Analyzer

Strawman Lander Science Payload

- Atmospheric Structure Experiment
  - Determination of Winds
- Descent/Surface Imager (CCD/CID Array)
- Meterology Package
  - Atmospheric Pressure
  - Atmospheric Opacity
  - Temperature, Humidity, and Winds (at 1m Above Lander)
- Surface Composition (α-p-x)
- Seismometer
- Impact Accelerometer
- Thermal Analysis Instrument (e.g., DSC)

MESUR Lander



MESUR Strawman Science Payload

INSTRUMENT	MASS (kg) •	POWER (W)	DATA	DIMENSIONS (cm)	LATITUDE DEPENDENCY	HERITAGE	MAX. 'g' LOAD (peak)	OPERATIONS DUTY CYCLE
METEOROLOGY PACKAGE Note (1)	0.66 •	0.021	10 kbits per day	Not Available		NEW	<40	continuous - wind, temp point measurements, humidity, pressure
3-AXIS SEISMOMETER (Sensor package)	1.5 • Note 2	2	10 Mbits/day			NEW		continuous
ATMOSPHERIC STRUCTURES INSTRUMENT, Note (1)	1.5	6.2	65 bps	4 x (5-10) long (5 sensors) 10 x13 x 13 (elec box)	Note (1)	Galileo, PV, Viking	<500	5.5 minutes
ELEMENTAL COMPOSITION INSTRUMENT, (alpha/proton/x-ray)	0.6 •	0.5	100 kbits for 3 spectra	need elect dimensions (4.5 x 3.2)	primarily site dependent	NEW, Viking	<40	600 minutes
IMAGERS:								
DESCENT	0.22 •	4	12 Mbits to store 12 images	6 x 6 x 3 (head) 10 x 10 x 3 (internal elec)		NEW	<40	continuous during descent
SURFACE	1.36 •	21	25Mbits per 360 deg scan	10 x 15 x 6 (camera/drive) 1000 x 1 dia (Mast) 3 x 2 x 5 (Head)		NEW	<40	10 minutes
COMMON ELECTRONICS	0.26	Note 3		included w/ imagers		NEW		included w/ imagers
THERMAL ANALYZER & EVOLVED GAS ANALYZER ANALYSER	2	12	3M bits per sample	12 x 12 x 12	primarily site dependent	NEW	<40	60 minutes (4 samples per martian year)
TOTAL	8.10							

Notes:
- • mass estimate does not include deployment hardware
- (1) may share common sensor
- (2) mass estimate for sensor only
- (3) mass estimate included in descent and surface imagers mass estimate

Mars Exploration Planning

Mars Observer

MESUR

➢ Small Rovers and Sample Return Missions

Science Drivers: Sample Return Mission

- Return Martian Samples to Earth Laboratories for Analysis
  - Highest Priority Science Objective for Mars
- Geology of Mars
  - Based on Geologic Mapping from Viking Images (Defined Units kms Scale)
- Defined 10 Different Units
  - Need ~10 Different Types of Samples Returned

Science Drivers: Sample Return Mission

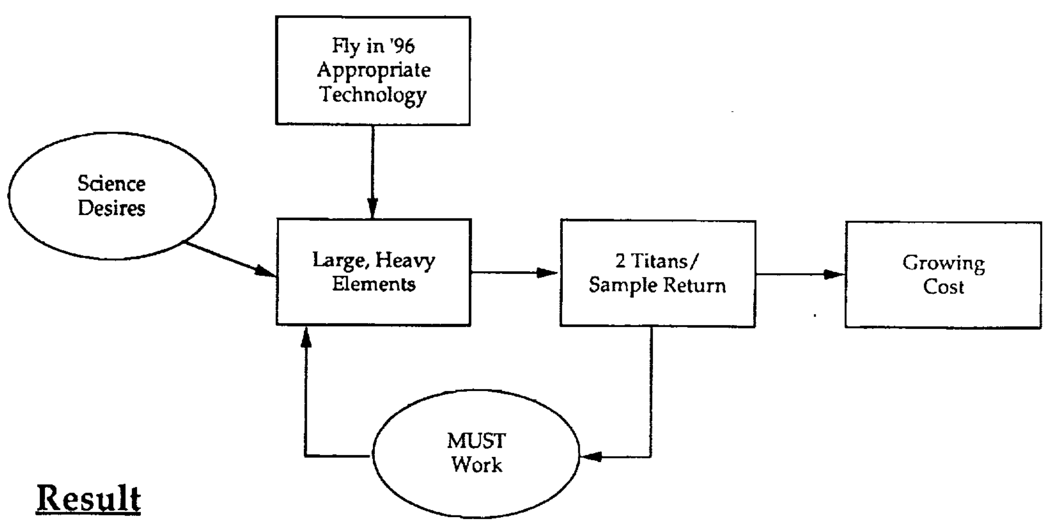
Heavily Cratered Material → Early History of Planets

Volcanic Rocks → Age and Composition of Planet

Sedimentary Rocks → Climatologic and Biologic (?) Conditions

Drift Material, Soil, Salts, Ice, Atmosphere → Volatile Inventory

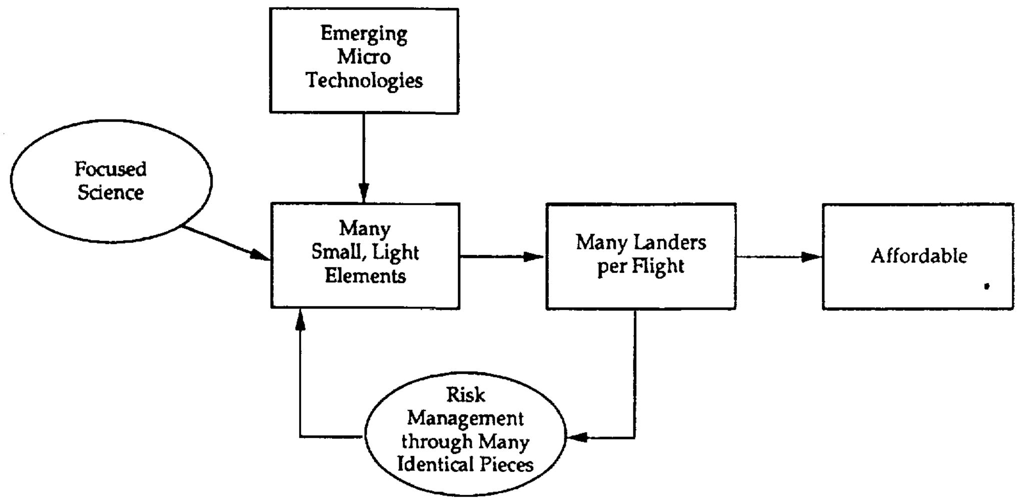
MSRS "Old Think"



__Result__

- Many interacting elements, complex operation
- Extremely Capable Rover
- Two Titan 4 Launches for One Sample Return
- Risk management through very high reliability, single items
- Cost ~$10B

Micro Technology Based Approach
"New Think"



Result

- Much smaller pieces - few on a Delta or Atlas
- Risk Management through many tries
- Cost goal ~$1.5 - 2 B

Key Concepts to "New Think"

- Take Advantage of Emerging Micro Technologies
  - Most Develop Outside NASA, Particularly for SDI
  - Includes Integrated Electronics, Power, Processors, Propulsions, Software...
- Focused Science
  - Limited Access from Lander and Constrained Landing Regions
  - Less Capable Rover
  - Less Elaborate Sampling
  - Less in-situ Science
  - No Traverse Science
  - Less Stringent Sample Preservation

Key Concepts to "New Think"

- Simplify Missions to Absolutely Essential Elements
- Commit to Many Small Landers
  - Accept that Some Fraction (~20%?) Will Fail
  - Manage Risk by Increased Number of Independent Landers
  - Mission Success Achieved with a Fraction (<1) of Landers Successful

Comparison of Approaches

- Returned Samples
  - Both ~8-10 Different Sample Types
  - Similar Total Mass
  - MRSR Samples from 2 Areas
  - Small SR Samples from Diverse Areas

Comparison of Approaches

- Rovers/Landers
  - MRSR
    - Large Complex Rover
    - Many in-situ Instruments on Rover
    - Traverse Science
    - Sample Packaging/Preservation on Rover
  - Small SR
    - Small Simple Rover
    - No Traverse Science
    - Most in-situ Instruments on Lander
    - Sample Preparation on Lander
    - Different Instruments on Different Landers

Small SR

- Satisfies All Major Science Objectives
- Simple Approach
- Flexible
- Less Expensive
- Failure Tolerant

Key Technologies

- Mini RTGs
- Advanced Propulsion Systems
- Small Rover 'Behavior' Control
- Micro Sensors and Instruments
- In-situ Instruments
- Micro Spacecraft Subsystems
- Long Life Electronics

Small Rover Mission Strategies

- Many Landing Options (Propulsive Lander to Ranger-Style Impact Capsule)
- Use Beacons and INS to Guide Rovers
- Reliability Through Redundancy
- Many Small Rovers Mean Smaller Traverses and Shorter Required Lifetimes
- Many Landings Allow Rovers to be Targeted at Individual Geologic Units

Mission Options

- Direct Return from Surface to Earth Entry
  - No Sample Transfer After MARV Lift-off
  - JPL Design Emphasis
- Mars Orbit Rendezvous
  - Sample Transfer MAV to ERV/SRC in Mars Orbit
  - Previous JSC Design Emphasis
- Earth Orbit Rendezvous
  - Sample Transfer MARV to ERV/SRC in Earth Orbit
  - Martin Marietta Corporation Design Emphasis

Micro MAV Sample Return Options

Option	Direct Return	Mars Orbit Rendezvous	Earth Orbit Rendezvous
Design	Current JPL	Old JPL/JSC	Current MMC
MARV Mass	380 kg	62	311
MARV Delta-V	6339 m/s		7235
Sample Mass	0.5 kg	0.5	0.5
Other Elements	SRC+Lander+Aeroshell+ Minirover (6 elements)	Lander+Aeroshell+ Minirover (5 elements)	Lander+Aeroshell+ Minirover (5 elements)
Flight System Mass	790 kg	238	715
Aeroshell Diameter	3.6 m	2.0	3.7
Beta	46 kg/m2	46	41
Launch Vehicle	Atlas IIAS (4)	Delta 7925 (4)	Atlas IIAS (4)
C3	11.1 km3/s2 (2009)	17.7 (2005)	11.1 (2009)
Flight Systems per Launch	2	2	2
Mass Margin	20%	85%	33%
Other Launched Elements	CO+Delta (2)	R/CO+Atlas (2) SRC+ERV+Delta (4)	CO+Delta (2) SRC+ERV+Delta (3)

Interactions with SEI

- New Associate Administrator Named
- Huntress/Griffin Agree on Science Objectives and Priorities for Moon and Mars
- Who Will Implement Moon/Mars Missions?
- Discussions Continue

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13. ABSTRACT ***(Maximum 200 words)***

The Electrical and Chemical Interactions at Mars Workshop, hosted by NASA Lewis Research Center on November 19 and 20, 1991, was held with the following objectives in mind: (1) to identify issues related to electrical and chemical interactions between systems and their local environments at Mars, and (2) to recommend means of addressing those issues, including the dispatch of robotic spacecraft to Mars to acquire necessary information. The workshop began with presentations about Mars' surface and orbital environments, Space Exploration Initiative (SEI) systems, environmental interactions, modeling and analysis, and plans for exploration. Participants were then divided into two working groups: one to examine the surface of Mars; and the other, the orbit of Mars. The working groups were to identify issues relating to environmental interactions; to state for each issue what is known and what new knowledge is needed; and to recommend ways to fulfill the need. Issues were prioritized within each working group using the relative severity of effects as a criterion. The contributions of the two working groups are described in Part I, published as a separate document. When materials were available in viewgraph form, the presentations given at the outset of the workshop are included in this appendix.

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