ANNOUNCEMENT OF OPPORTUNITY

AO 96-OSS-01

# MARS PATHFINDER AND MARS'96 LANDER SCIENCE OPPORTUNITIES

PROPOSAL INFORMATION PACKAGE (PIP)

for the

**Mars Pathfinder Participating Scientist Program**

**Mars Pathfinder Atmospheric Structure Instrument/Meteorology Package Facility Instrument Science Team**

portions of the AO

Office of Space Science
National Aeronautics and Space Administration
July 25, 1996

This PIP contains Information about the Mars Pathfinder Mission for use with the above stated AO. The PIP includes a description of: the mission, the spacecraft, mission operations, science teams, and the instruments on the Mars Pathfinder Mission. Information about the Mars'96 Mission and the Mars Oxidation Experiment can be found in a different location.

All requests for additional information on Mars Pathfinder not contained in this document or associated documents must be made in writing at this location. No oral responses will be given and any attempt to obtain information through another channel will be considered as a conflict. All questions must be written at this location, with questions and answers posted for viewing by all.

E-mail questions should be addressed to: mpfao@jpl.nasa.gov.

NRAs and AOs will be made available in several formats described below. There are many computer platforms and software packages and we cannot provide files in all possible formats. We have chosen a few widely useful formats.

Text is the only universal format; it can be read by any computer capable of connecting to this page. Text files don't have attractive layouts and fonts.

Postscript files can be printed by any postscript printer and don't require word processor software. The printout will be a true copy of the document.

Rich Text Format can be read by many, but not all, word processors. It is easy to capture, complete, and print the forms contained in rich text documents.

IMPORTANT NOTE: Some browsers will display the postscript file on the screen after retrieving it. Unless you have a postscript reader installed, the displayed file will be generally dense and unintelligible. However you can still print the retrieved file on a postscript printer and get a true copy of the original document. The rtf file may behave similarly. If you obtain an unintelligible screen display after a point and click operation, this does not necessarily mean that anything is wrong. It probably means simply that your web browser is not configured to read the file format. By clicking on a file choice you are automatically acquiring a copy of the file in your computer in whatever directory has been set up to receive it, for example c:\netscape or c:\mosaic Once you have found the file(s) you should be able to read or print them if you have the appropriate software, i.e. text editor, or word processor, or postscript driver and printer.

IMPORTANT NOTE FOR UNIX USERS: The postscript files we provide work on PC and Mac systems with network and stand-alone printers. The files have a ^D at the beginning and at the end of the file. These are printer control characters. We have learned that they do not work on Unix systems. To solve this problem use a text editor to remove the ^D characters from the beginning and the end of the file. Once the ^Ds are removed the file will not work on PC and Mac systems.

# MARS PATHFINDER

## PROPOSAL INFORMATION PACKAGE (PIP)

## TABLE OF CONTENTS

# LIST OF FIGURES

LIST OF TABLES

# LIST OF ABBREVIATIONS

| | |
|---|---|
| A/D | analog to digital |
| AIM | Attitude and Information Management |
| AIP | Aeroshell Instrumentation Package |
| AO | Announcement of Opportunity |
| APXS | Alpha Proton X-ray Spectrometer |
| ASI/MET | Atmospheric Structure Instrument/Meteorology Package |
| bps | bits per second |
| CCD | Charged Couple Device |
| CD ROM | Compact Disc Read-Only-Memory |
| cm | centimeter |
| Co-I | Co-Investigator |
| D/A | digital to analog |
| DMD | Data Management and Display |
| DPT | Data Priority Tables |
| DSN | Deep Space Network |
| DSOT | Data System Operations Team |
| EDL | Entry, Descent and Landing |
| EDR | Experiment Data Record |
| EEPROM | Electrically Erasable Programmable Read Only Memory |
| EH&A | Engineering, Health and Accountability |
| EOPG | Experiment Operations Planning Group |
| EST | Eastern Standard Time |
| g | gee |
| Gbits | Gigabits ($10^9$ bits) |
| HEF | High Efficiency antenna |
| HGA | High-Gain Antenna |
| Hz | hertz |
| IDL | Interactive Display Language |
| IEM | Integrated Electronics Module on Lander |
| IMP | Imager for Mars Pathfinder |
| IMPSoft | Imager software |
| JPL | Jet Propulsion Laboratory |
| K | Kelvin degree |
| Kbps | kilobits per second |
| kg | kilograms |
| km | kilometers |
| LIF | Lander Interface Assembly |
| LREU | Lander Remote Engineering Unit |
| LST | Local Solar Time |
| m | meter |
| m | meters |
| mA | milliamps |
| μb | microbar |

| | |
|---|---|
| mbar | millibar |
| mCi | millicurie |
| MeV | million electron volts |
| μg | microgee |
| mg | milligee |
| MHz | megahertz |
| MIPL | Multimission Image Processing Laboratory |
| μm | micrometer |
| mm | millimeter |
| msec | milliseconds |
| mT | millitesla |
| N | North |
| nm | nanometer |
| PC | Personal Computer |
| PDB | Project Data Base |
| PDS | Planetary Data System |
| PI | Principal Investigator |
| PICS | Planetary Image Cartography System |
| PROM | Programmable Read Only Memory |
| PRT | platinum resistance thermometer |
| PSG | Project Science Group |
| RAM | Random-Access Memory |
| rpm | revolutions per minute |
| s | seconds |
| SNC | Shergottites, Nakhlites and Chassigny meteorites |
| SOG | Science Operations Group |
| sol | one martian day (24.62 hours) |
| SRA | Sequential Ranging Assembly |
| T | tesla |
| TCM | Trajectory Correction Maneuvers |
| TWNC | two-way non-coherent |
| VICAR | Video Image Communication and Retrieval |
| W | watts |
| W | West |
| WEB | Warm Electronics Box on Rover |
| WWW | World Wide Web |
| °C | degrees Celsius |

**MISSION DESCRIPTION**

Pathfinder will be launched on a McDonnell Douglas Delta II 7925 expendable launch vehicle in December 1996 from the Cape Canaveral Air Station in Florida. The launch window opens at 2:10 am EST on December 2, 1996 and remains open for about 30 days, with one opportunity per day (about one minute duration) available for launch. The spacecraft is injected into a Type 1 Earth-Mars transfer trajectory on a PAM-D upper stage within one Earth orbit. Arrival at Mars is fixed on July 4, 1997.

The 6-7 month cruise phase includes periodic attitude control maneuvers required to remain Earth pointed, four trajectory correction maneuvers needed to insure accurate arrival targeting at Mars and two instrument health check sequences; one 7 days after launch and the other 15 days before arrival at Mars. The spacecraft is spin stabilized (about 2 rpm); the solar arrays remain within 40° of perpendicular to the sun, except near the Earth and during TCMs. Spacecraft engineering status data is transmitted by a medium gain antenna throughout cruise. No science investigations are conducted during cruise as all instruments are enclosed within the folded-up lander.

At Mars arrival, the cruise stage is jettisoned and the spacecraft properly orients itself for atmospheric entry (entry angle is 14.2° from horizontal) directly from the hyperbolic approach trajectory at a velocity of 7.65 km/s (Figure 1). The lander enters the atmosphere behind the aeroshell which slows the vehicle (peak deceleration's at about 20 g's at 30 km altitude). The aeroshell is jettisoned just prior to parachute deployment (at mach 1.8 at about 6-10 km altitude). During descent on the parachute at a terminal velocity about 65 m/s, the lander is lowered beneath the back cover on a 20 m long bridle. Signals from a radar altimeter, mounted in one of three triangular openings at the base of the lander, are used to initiate the firing of three small solid tractor rockets at about 50 m above the surface, reducing the vertical component of velocity to near zero. A significant horizontal velocity component, estimated at up to 20 m/s may remain. Large six-lobed airbags inflate around each face of the lander and the bridle is cut prior to final rocket burn, insuring that the parachute and back cover are carried away. The airbags, which provide about 0.5 meters of energy absorbing stroke, are not vented during landing. Peak decelerations of 40 g's will be experienced as the lander makes several bounces before coming to rest. The random nature of these bounces will likely carry the lander to a location uncontaminated by solid rocket exhaust (mostly aluminum oxide).

The atmospheric structure experiment (the ASI/MET instrument and the science accelerometers) is activated prior to encountering the sensible atmosphere and collects 3-axis accelerations, pressure and temperature data throughout the EDL sequence. Pressure and temperature data are influenced by the surrounding spacecraft structures; accordingly their utility will be limited to the period after the release of the aeroshell; namely, the lower atmosphere.

Accelerometers signal that the lander has come to rest, at which time interior, filtered, peal-away patches vent the airbags, with minimal surface contamination. The lander accelerometers determine which petal is down and automatically initiate the lander deployment sequence in which the upper airbags retract (internal tendons pull the airbags close to the petals) and the petals open in the proper sequence to assure an upright configuration.

Key entry, descent and landing events are signaled by modulating the transmitted spacecraft signal. In addition, all engineering and science data obtained during the entry, descent, and landing phase are recorded for playback at the initiation of lander surface operations. The duration of the entry phase is approximately 5 minutes. Landing occurs in darkness, very early in the morning at about 3 am local Mars time, just after Earth rise. Opening of the lander takes a few hours before the spacecraft can be commanded from the earth (about 7 am local Mars time).

The events to be accomplished on the landing sol are to achieve an upright landed configuration, to return the recorded entry science and engineering data, to establish a high rate telecommunications link, to acquire and return a panoramic image of part of the surrounding terrain, and to drive the rover off its petal. Constraints on the operation of the lander during this period include limited power (the batteries have been partially depleted by the entry descent and landing operations), limited telemetry capability, and the need for flight controllers on Earth to verify key events before proceeding with subsequent operations. Surface operations for the remainder of the mission are focused on extensive use of the rover and science instruments. The rover will explore a region within ten or a few tens of meters from the lander during the first week of the rover mission After that time the rover may be commanded to acquire APXS spectra from magnetic targets on the rover ramps and to explore regions of the surface up to 500 meters from the lander (the approximate limit of its communication range).

Mars Pathfinder will land in Ares Vallis, Chryse Planitia (19.5°N, 32.8°W), within a 100 km by 200 km error ellipse determined by navigational uncertainties during cruise and variable atmospheric entry conditions. This site lies near the mouth of the catastrophic outflow channels Ares Vallis (and Tiu Vallis), which drained from the highlands to the south. Selection of this site was made after an exhaustive search and selection process involving engineering analyses of site safety and an assessment of the science potential of the several candidate sites. Landing at this site may permit sampling a diversity of rock types that make up the ancient cratered terrain on Mars (some of which may reflect primary differentiation and early evolution of the crust), the ridged plains and a variety of reworked channel materials (reflecting later crustal evolution and the development of weathering products). Even though the exact provenance of the samples would not be known, data from subsequent orbital remote sensing missions could then be used to infer the provenance for the "ground truth" samples studied by Pathfinder.

## FLIGHT SYSTEM DESCRIPTION

The Pathfinder flight system (Figures 2, 3, 4, 5 and 6) consists of four major elements: the cruise stage, the deceleration subsystems, the lander and the rover. Two of the three flight science experiments are contained on the lander (Figure 6) -- the Imager for Mars Pathfinder (IMP) and the Atmospheric Structure Instrument / Meteorology package (ASI/MET).The other experiment, the Alpha Proton X-ray Spectrometer (APXS) is mounted on the rover by means of a deployment mechanism which allows the instrument to be placed in contact with rock or soil samples. The flight system launch mass is approximately 890 kg (100 kg of this is cruise stage fuel), including about 25 kg of payload (science instruments, rover, and lander-mounted rover support equipment).

### Cruise Stage

The cruise stage (Figures 2 and 3) is used to perform launch vehicle separation, spin-stabilized attitude control, trajectory correction maneuvers, cruise telecommunications, and final Mars entry attitude placement. The cruise stage is jettisoned prior to entry into the martian atmosphere. Cruise stage hardware consists of a gallium arsenide solar array (4.4 $m^2$ generating 250-450 W of power) and additional related power equipment, a medium gain X-band antenna, propulsion valves, tanks, and thrusters, and attitude determination sensors (Magellan star scanner): it weighs 210 kg without fuel.

Deceleration Subsystem

Deceleration subsystems are required to reduce Pathfinder's entry velocity and allow a safe and survivable landing on the martian surface. The deceleration subsystems consist of a 2.65 m diameter aeroshell, engineering instrumentation used to characterize the performance of the aeroshell during entry, a Viking heritage disk-gap-band parachute, an incremental bridle, three small solid retrorockets, a radar altimeter, and airbags; all of which weigh 330 kg. The retrorockets and airbags are designed to minimize surface and atmospheric contamination due to propellant effluence.

Lander

The lander (250 kg mass) is a tetrahedron shaped structure containing the science instruments, rover, and all electronic and mechanical devices required to operate on the surface of Mars (Figure 4). The tetrahedron consists of four, similarly-shaped, 1 m triangular panels. All lander equipment except the solar arrays, rover and meteorology mast are attached to a single center panel. The other three panels are attached to the edges of the center panel by actuators that are used to right the lander after touchdown. This active self-righting mechanism is needed because of the passive nature of the Pathfinder deceleration subsystems. All thermally sensitive electronics are contained in an insulated enclosure on the center panel. Specific hardware components inside this enclosure include a high performance central computer that controls the spacecraft during cruise, entry, descent, landing and surface operations (a 32 bit, radiation-hardened work station-RAD 6000 with roughly a gigabit of memory, programmable in C with a VxWorks operating system), a Cassini heritage transponder, a solid state power amplifier for telecommunications, and a high capacity rechargeable battery (40 amp-hr). Hardware outside the thermal enclosure includes a steerable high gain X-band antenna capable of approximately 5.5 kilobits per second into a 70 m Deep Space Network antenna and solar arrays (3.3 $m^2$ gallium arsenide array generating 1100 W-hr/day) capable of providing enough power to transmit for 2-4 hours per sol and maintain 128 megabytes of dynamic memory through the night. The lander is designed to survive for a minimum of 30 sols, with an extended mission lifetime of up to a year.

Rover

The Mars Pathfinder rover (named Sojourner) is a six wheel drive rocker bogie design vehicle, which is 65 cm long by 48 cm wide by 30 cm high (Figure 5). Total mass of the rover is about 10.5 kg (including payload), lander-mounted support equipment is an additional 5.5 kg. The rocker bogie chassis has demonstrated remarkable mobility, including the ability to climb obstacles that are a full wheel diameter in height and the capability of turning in place. The vehicle communicates through the lander via a UHF antenna link and is intended to operate entirely within view of the lander cameras, or within a few tens of meters of the lander (extended mission traverses up to 500 m from the lander are possible, limited by the UHF link). It is a solar powered vehicle, generating 16 W peak power, with a (non-rechargeable) primary battery back-up (~300 W-hr). The rover moves at 0.4 m/min, and carries 1.5 kg of payload. The payload consists of monochrome stereo forward cameras for hazard detection and terrain imaging and a single rear color camera. The alpha proton x-ray spectrometer (APXS) is mounted on a deployment device on the rear of the vehicle (Figure 5) that enables placing the APXS sensor head up against both rocks and soil in a continuum of orientations (from horizontal on the ground to vertical rock faces at rover height). The rear facing camera will image the APXS measurement sites at slightly better than 1 mm per pixel resolution. The rover control system includes a variety of autonomous hazard detection systems for safing the vehicle in potentially hazardous situations (forward laser light stripers for detecting obstacles or crevasses, potentiometers for detecting bogie tilts).

The rover will also perform a number of technology experiments designed to provide information that will improve future planetary rovers. These experiments include: terrain geometry reconstruction from lander/rover imagery; basic soil mechanics by imaging wheel tracks and wheel sinkage; dead reckoning, path reconstruction and vision sensor performance; vehicle performance; rover thermal characterization; UHF link effectiveness; material abrasion by sensing abrasion of different thicknesses of paint on a rover wheel; and material adherence by measuring dust accumulation on a reference solar cell with a removable cover and by directly measuring the mass of the accumulated dust on a quartz crystal microbalance.

## LANDER AND ROVER OPERATIONS CONSTRAINTS

### Lander

Characteristics of the lander described below affect its ability to support science instrument operation, to acquire data and to transmit that data to earth.

*Commanding*. During surface operations the lander can be commanded as often as several times per day. Because of the interactive nature of the surface mission it is planned to update each sol's activities based on the observations returned as recently as the preceding sol. Accordingly the mission planning activities on the Earth are scheduled to accomplish rapid responses to spacecraft observations. The time schedule is particularly tight on sol 1 because of the need to verify proper deployment of the lander, to verify the deployment of the rover ramps, to verify the acquisition of the high gain antenna link, to assess the terrain in the immediate vicinity of the lander and to command the deployment and initial traverse of the rover. After the first several sols of operation, a single command period per sol is scheduled.

*Power*. The lander power is supplied by a combination of solar cells and rechargeable batteries. During the daylight hours the solar cells supply power for routine operations (including the major power consumer, the telecommunications subsystem) and for recharging the batteries. The batteries supply additional power during times of peak loads. During nighttime hours the batteries provide power for heating critical subsystems, for maintaining the computer and its memory in a low power state and for conducting limited experiment operations (meteorological measurements and selected night imaging experiments). The transmitter is the largest power user; thus, under certain circumstances, transmission time (and consequently data volume) are constrained by the state of discharge of the battery.

*Thermal*. During daylight hours, operation of the lander subsystems, particularly the transmitter, results in heating of subsystem elements within the lander thermal enclosure. Under certain circumstances these elements may approach their flight temperature limits, necessitating that data transmission periods be limited. Thus thermal constraints may limit the volume of data returned.

*Data rates*. The choice of data rate is influenced by many factors including the Earth-Mars range, elevation angle of Mars as seen from a Deep Space Network (DSN) station, DSN antenna size and performance, and lander antenna choice (high or low gain antenna) and antenna pointing accuracy. Data rates from a few tens of bits per second to greater than 10 Kbps are selectable by ground command. The sample scenario described later in this document is based on a data rate of 4740 bps, a rate achievable under nominal performance for all subsystems.

*Memory*. The Pathfinder lander computer contains roughly 128 megabytes of RAM and 6 megabytes of EEPROM. EEPROM is used to store critical EDL science and engineering data and a copy of the flight software. After verified receipt of the EDL data on the ground, EEPROM will be available to store key data sets (protection against data loss in the event of RAM power loss). Normally science data will be stored in RAM for playback during scheduled transmission periods.

*Data Management*. Data are played back during scheduled transmission periods in accordance with its priority assignment. Priorities are assigned using Data Priority Tables (DPTs) which are uplinked to the spacecraft and which can be modified for different portions of the mission. Ground software tools are used to predict the content of the scheduled telemetry sessions. Data are commanded to be deleted from the lander memory only after they have been received successfully on the ground.

Rover

Characteristics of the rover described below affect its ability to support science instrument operation, to acquire data and to transmit that data to earth.

*Power*. The rover is designed to perform a minimum seven day mission using either solar power from its own solar arrays or battery power provided from its internal primary (non-rechargeable) battery. Normally the rover will use solar power for daytime operations and limit its use of the battery to peak loads and limited night-time operations (health checks and APXS data acquisition). The design of rover traverses will include consideration of the rover orientation at stopping points to the extent that it affects solar panel performance.

*Communications*. The rover communicates to Earth through the lander. Commands are transmitted from Earth to the lander and stored for forwarding to the rover by modem, when requested by the rover. Similarly rover data is stored on the rover, transmitted to the lander and queued for transmission to earth using the same downlink priority process used by the other lander subsystems. Typical imaging scenarios provide for the return of one monochrome stereo image, one monochrome monoscopic image and one three-color image per sol from the rover cameras. In addition, approximately one megabit of non-imaging data including APXS spectra, rover technology experiments and other rover engineering data are returned each sol.

*Rover Imaging Operations*. The primary function of the rover cameras is to sense hazards in the rover's path. In this mode they are part of the rover's control system and do not transmit images to earth. They will also be used to image the terrain immediately in front of the rover at the end of each sol's traverse, to assist the rover in approaching a rock (for the APXS experiment) and to image the lander.

*Technology Experiment Operations*. Some of the rover technology experiments are inherently conducted as a part of normal rover operations; for example, trafficability is assessed by determining rover positions and by analyzing the standard engineering data. Other experiments (for example, the Material Adherence Experiment) are performed repeatedly when the rover is operated and their results are also incorporated in the engineering data.

*APXS Operations*. The acquisition of APXS data depends on the rover's ability to position the APXS for soil or rock observations. Current scenarios provide at least two soil samples and one rock sample during the first seven sols of operation (the rover's nominal mission). Standard APXS data acquisition sequences provide for ten hours of integration at a single site. Normally these data are acquired using battery power at night when other rover subsystems are off, thereby providing the lowest noise environment for the observations. Positioning the APXS on a rock sample may require two or three iterations, using both lander and rover images to navigate the rover to the desired position and to achieve the desired APXS positioning with its deployment mechanism. Each iteration normally requires one sol because of downlink and uplink cycle times combined with time for analysis and decision making on Earth. The APXS deployment mechanism is designed to position the APXS sensor head axis normal to surfaces with slopes from 0-90 degrees and heights relative to the surface from -2 to about 15 cm. The actual time required to position the APXS will depend on the specific choice of a target rock, the nature of the intervening terrain and the uncertainties in rover position.

## MISSION OPERATIONS

### Overview

The basic requirements of operating the lander and rover on the surface of Mars for a short period of time (one week to a month), with daily uplinks that are dependent on the previous days downlinks, requires streamlined and efficient mission operations and ground data systems. This is made possible by an extremely capable central computer on the lander, a simplified set of spacecraft commands, some autonomous aspects of the rover and instruments, and development of integrated software packages that streamline generation of uplink commands. During operations the project management structure will be simplified considerably to include a group of spacecraft engineers (experts in navigation, propulsion, thermal control, power and pyros, telecommunications, etc.) and an Experiment Operations Team that includes all science instrument and the rover team members, directly under a single mission director.

### Organization

The Pathfinder mission operations activities are led by the Project Manager as shown in Figure 7. The project Manager is supported by a small staff, including the Project Scientist. Daily Operations are conducted under the leadership of the Mission Director. The execution of the science and rover operations activities is the responsibility of the Experiment Operations Team. Responsibility for operation, health and safety of the spacecraft (cruise stage, entry vehicle and lander) rests with the Flight Engineering Team. These two teams are supported by specialists in the operation and analysis of the several spacecraft subsystems and by three JPL organizations external to the Pathfinder project, the Multimission Image Processing Laboratory (MIPL) , the Data System Operations Team (DSOT) and the Deep Space Network (DSN) Operations team.

With the exception of the Project Science Group (PSG) all science and rover activities are conducted within the Experiment Operations Team. The PSG serves as an advisory body to the Project Scientist who, in turn, reports directly to the Project Manager. The roles of the individual groups and subteams are described below.

The planned organization for the Experiment Team is shown in Figure 8. This team is led by the Experiment Team Chief. The Deputy Experiment team Chief position is held by the Project Scientist as an additional duty. The Rover Team, the IMP Team, the ASI/MET Team and the APXS Team are designated as “instrument teams” for the purpose of this discussion. These instrument teams are led by the respective PIs or Team Leaders and have the principal responsibility for operating the instruments (and rover) and producing a validated data record for the mission.

The Rover Technology Working Group is responsible for conducting the technology investigations, working closely with the Rover Operations Team for implementation of the rover activities. An Instrument Engineering Team monitors the health of the instruments (exclusive of the rover), reviews instrument command files and analyzes the engineering and housekeeping data as well as relevant portions of the science data. Flight Engineers, while not formally a part of the Experiment Team work closely with the team members involved in sequence planning to resolve conflicts, to comply with constraints and to ensure the feasibility of the planned observations.

The Experiment Operations Planning Group (EOPG), a subset of the Experiment Team provides coordination and approval of the science mission plan and science mission plan changes. The planning process is illustrated in Figure 9. The EOPG issues planning guidelines for each planning interval (normally, one sol, during the landed mission), integrates the mission plans and changes generated by the Instrument Teams and resolves conflicts between those plans. The EOPG is jointly chaired by the Experiment Team Chief and one of the Flight engineers (representing the Mission Director) and includes the Project Scientist, the Experiment Planner, the Instrument Team Leaders, the Lead Instrument Engineer and the EOPG Administrator. Representation from the Science and Technology Operations Groups is provided as needed.

Virtually all of the scientific investigations and many of the rover technology investigations described earlier can be addressed by data from more than one instrument. The use of data from one or more instruments to address a particular science topic has driven the experiment mission operations to be organized around scientific investigations. Science Operations Groups will interface with the appropriate science instrument and rover teams to obtain the observations needed (each group may obtain data from more than one source). In addition, rover technology experimenters will also participate in these groups as appropriate. Example Science Operations Groups, the data sources they might use and participation of rover technology experimenters is described below.

*Surface Morphology and Geology Science Operations Group* would be interested in understanding the physiography of the landing site, including surface features, slopes and physical characteristics. This group would use imaging from both the IMP and rover and might include participation of the Terrain Geometry Reconstruction technology experiment.

*Petrology and Geochemistry Science Operations Group* would use IMP spectral imaging to target APXS elemental composition measurements of rocks, soil and surface materials. Close up imaging by the rover (forward stereo and rear color) cameras should help identify the rock type and can be used to help constrain the mineralogy of rocks.

*Magnetic Properties Science Operations Group* would use multispectral imaging of magnetic targets, magnified close up imaging of the tip plate magnet and APXS measurements of the ramp magnets to better understand the magnetic phase of the dust, its chemical composition and ultimately help constrain its mineralogy and mechanism of formation.

*Soil Mechanics and Properties Science Operations Group* would use stereo and close up lander and rover imaging of rover wheel tracks and terrain disturbances and vehicle performance information such as motor torque and bogie positions to estimate the mechanical and physical properties of the soil. Information relevant to this topic might also include data from the Material Abrasion and the Soil Mechanics and Sinkage Technology Experiments.

*Atmospheric Science Operations Group* might be broken down into a number of subgroups according to their main focus. One group would be interested in reconstructing the atmospheric profile during entry and descent. Another group would characterize the diurnal and seasonal variations in the boundary layer by regular meteorology measurements including pressure, temperature, wind and opacity from the ASI/MET and IMP images (opacity and wind socks). A group focusing on atmospheric aerosols might use data from the IMP to investigate dust particle size and shape, refractive index, vertical aerosol distribution and water vapor abundance in the atmosphere and might use data from the Material Adherence Technology Experiment. Finally an aerodynamic roughness subgroup might use data from the wind socks, wind sensors and terrain imaging by the lander and rover to better understand how material is lifted from the surface and carried by the wind.

*Rotational and Orbital Dynamics Science Operations Group* would use two-way ranging and Doppler tracking data from the Pathfinder telecommunications subsystem and Deep Space Network to determine the location of the Pathfinder lander on Mars, the pole and rotation of the planet and the precession constant.

<u>Organizational Roles and Responsibilities</u>

NASA Headquarters has program-level responsibility for the Mars Pathfinder Mission and has appointed a Program Manager and Program Scientist to provide program-level guidance to the Project. The Program Scientist is the vice-chair of the PSG.

JPL is the Project Manager for Mars Pathfinder and is responsible to NASA for the technical performance, schedule and cost of the mission. JPL provides the facilities and support services for mission operations, including the DSN.

Science Team Member and Participating Scientist Institutions provide the institutional support for their respective scientists, including contract administration and other services, as negotiated with each individual scientist.

NASA Centers provide support elements of the Pathfinder Mission, including, but not limited to, launch support, data distribution, technical support in a variety of areas and support of selected Science Team members or Participating Scientists.

Portions of existing instruments on Pathfinder are provided by foreign institutions. A major portion of the APXS instrument and the magnetic target investigation (part of IMP) are foreign-provided. Foreign participants are funded by their own space program entities (no exchange of funds). Participation of existing foreign PIs and Co-Is is described in a Letter of Agreement between NASA and the respective national space organizations.

Key Schedule Items

An overview of the Mission Operations Schedule activities is given in Figure 10. It is anticipated that the Science Team Members and Participating Scientists will be selected in December 1996. Following negotiations and award of contracts, funding to support the selected proposals can be expected to be available in February 1997. A series of test and training activities are scheduled during the cruise phase. The particular training sessions and the amount of training required will vary according to the role of each investigator. Proposers should anticipate spending approximately two weeks at JPL for test and training activities.

A meeting of all selected and existing Pathfinder scientists is scheduled for early February 1997 to initiate organization into effective Science Operations Groups and schedule training. This meeting will include introductions to the mission and operations plans. In addition, all scientists will discuss the science investigations being planned to allow organization into Science Operations Groups and to revise operations plans to ensure that data necessary for their investigation will be obtained and downlinked.

The prime landed mission duration is one month, starting on July 4, 1997. The prime Rover mission duration is one week, starting on the same date. There are no expendables to fix the actual length of the mission operations; the operations team staffing plan will support operations for about a year. However, the amount of 70-meter DSN station time is sharply reduced after the first month of operations; thus the rate of data return will diminish accordingly. The end of the Pathfinder Project is September 30, 1998.

Science teams have the obligation to produce an archival data record for the mission. In accordance with the data release policy (described in more detail below) the Principal Investigators and Team Leaders have up to six months from the time of acquisition to complete the validation process and deliver products to the Planetary Data System (PDS). All funding for mission data processing and validation activities ends by the end of Project date given above.

Experiment Operations Processes

Planning and executing the Pathfinder mission is a large part of the responsibility for the Science Teams and Participating Scientists. The two processes - “Planning” and “Data Analysis,” described below constitute the major activities for the Experiment Operations Team. This description follows the content of the Experiment Operations Plan.

*Planning*. The “Planning” process occurs on several time scales. Long range planning, already underway will produce a set of mission scenarios and detailed sequence designs for most of the nominal mission. These scenarios and sequences are being generated in response to the Science and Instrument Requirements Document, the Rover Technical Design Document (these documents are available online at URL http://mpfwww.jpl.nasa.gov/nasa/science and at http://mpfwww.jpl.nasa.gov/nasa/rover) and inputs from the science and Rover teams. Many of them have been executed on the Flight System Test Bed and on the Pathfinder flight vehicle. The long range planning process results in a baseline mission plan with which the operations team begins the landed mission.

Built into the baseline mission plan is the recognition that sequences will be updated in response to the health and behavior of the flight systems and the nature of the environment in which Pathfinder lands. Short range planning is the set of activities that produce updates to the baseline mission plan in response to changes in spacecraft operating constraints or observations from the spacecraft. This short range planning process has the capability of responding within one sol to changing conditions and in some cases making changes in as little as a few hours.

Medium-range planning addresses more major changes to the baseline mission plan on a time scale of a few days to weeks. An example would be the modification of the planned rover traverses to observe a particularly interesting scientific site at some significant distance from the lander.

A flow diagram for the Planning Process is provided in Figure 9. For short-range planning this process is completed in a single working shift. The process begins with a planning guidelines meeting at which current spacecraft constraints, recent science data products and desired changes to the mission plan are discussed. The result of this meeting is a coordinated set of planning guidelines for the Instrument Teams, Science Operations Groups, Flight Engineers and Instrument Engineers. These groups then do the detailed planning and coordination to implement the changes. Approval of the individual instrument and rover changes is the responsibility of the Instrument Team Leaders. Final integration and approval of all changes to the mission plan takes place at the Mission Plan Approval meeting, late in the planning cycle, at which any remaining conflicts are resolved. The Flight Engineers and mission planners implement the sequences and command files in preparation for transmission to the spacecraft.

*Data Analysis* Data analysis functions on multiple time scales. At the long extreme, Science Teams have up to six months to validate data sets and release them to the archives. At the short extreme, products must be analyzed within a few tens of minutes or hours of receipt to support operational decisions, particularly on the first few sols.

The Data Analysis process is shown in Figure 11. Science and engineering data from the spacecraft are processed and placed in a large file server, the Project Data Base (PDB). Members of the Experiment Team may access data from the PDB, process the data in the Mission Support Area using a number of workstations and available software tools and store their results in the PDB. Analysis of data may result in proposed changes to subsequent sequences or the request for new observations. To support a regular schedule of press briefings, current data products will be selected for processing, annotation and immediate release. These products will also be made available through the World Wide Web. Products for publications and for extended study may be produced either at JPL or externally; however, the Pathfinder Project will not support high data rate interfaces with external institutions. Mission data products will be produced periodically and distributed via CD ROMS.

Summary of Example Mission Scenario

Operating the lander immediately after landing on the first sol is particularly challenging. Entry, descent and landing data are sent back on the low-gain antenna after landing and attaining an open operational configuration (including deployment of the ASI/MET mast). After sunrise (7-8 local time) and uplink from the Earth, the IMP camera is unlatched and searches for the sun, provides the coordinates to the central computer, which determines the orientation of the lander and instructs the high-gain antenna to unlatch, point towards the Earth, and establish communications. The IMP also takes a series of images of a portion of the lander with the rover and a partial color panorama. After receipt of these data on Earth the ramps are instructed to unfurl. Images are taken to confirm deployment of the ramps, and the rover is detached from the petal and instructed to drive off the lander on one of the ramps. The rover will obtain an APXS measurement of the soil during the night of the first day. The final downlink of the day includes IMP images of the rover and rover images of the lander on the surface of Mars. After obtaining a pre-deployment panorama, images of the surface and calibration data, the IMP will be deployed to its full elevation, approximately one and one-half meters above the local surface.

Operation of the lander and rover during the first week involves daily uplink and downlink sessions and involves obtaining data to support virtually all scientific and rover technology experiments and investigations. IMP stereo images provide a data base to drive the rover. IMP stereo and multispectral images are used to help select APXS measurement sites. However, because the IMP can generate data much faster than it can be downlinked, careful choices must be made between full panoramic imaging desired to characterize the landing site and more spatially limited spectral data to select interesting targets for the APXS near the lander early in the mission. A significant storage capability in the central computer (about a gigabit) allows sophisticated data acquisition and playback strategies for obtaining time-critical engineering and science data during the mission.

After the initial one or two days of surface operations, the spacecraft is expected to settle into a routine schedule of events; the exact schedule is dependent upon conditions only discoverable after landing. The scenario is based upon a Lander-centric time system (Local Solar Time, LST) which assigns times according to the position of the Sun over our landing site.

Early morning activities begin shortly before the Earth rises over the horizon at 02:30 as the lander warms the actuators which move the high-gain antenna allowing it to track Earth. Tracking continues through earthset at 16:00 during which time the lander is capable of receiving a signal from the DSN. The first communications session with the ground does not usually occur until about 06:00, when the lander transmits data collected overnight and receives that days' command load for the rover. Changes planned for the day's Lander activities are also received. Meteorology data is also being collected overnight, and continues throughout the day on a 24-hour repeating schedule.

At sunrise the level of activity increases. The primary battery heaters are turned on in order to heat the battery to its optimum charging temperature in time for the moment when the incoming solar power exceeds the baseline power draw. The lightening sky provides the opportunity to take images to characterize the dust in the atmosphere. After sunrise images that characterize the aerosol opacity of the atmosphere are acquired. These imaging campaigns are repeated after sunset and before sunset, respectively. During the day, the lander takes repeated images of a radiometric calibration target to aid in the color calibration of any additional imaging done during that day. Images of the magnetic targets located in various areas of the lander may also be taken during the day. During daylight hours, meteorology data collection is accompanied by images of the wind socks attached to the ASI/MET mast, and every three days images of the Sun are acquired in order to measure the abundance of water vapor in the atmosphere.

The rover begins operating at about 07:30 each day. Its daily operation is more varied than the lander's, but usually involves some traversal, imaging, and material abrasion measurement. Many days include an APXS analysis of rock or soil. After completing an APXS, the rover will move forward and take a color image of the sample site as documentation of the analysis. The rover next performs a soil mechanics test by repeatedly navigating from place to place, stopping in each location to spin one of its six wheels and document the effect on the soil through images and other data. At the end of each day's traverse, the rover will measure current through a special cell on its solar panel to document the adherence of dust to the cell cover. The rover (in coordination with the lander) will also take some images to document its location on the surface. These images, along with other data collected during the day, are downlinked in an afternoon communications session (15:00 to 17:00) and are used by the rover team in producing the next day's schedule of activities. After completing its day's activities, the rover will periodically communicate health data to the lander until the next day's activities are available.

Estimated Science Data Return

Pathfinder has a minimum of 4 hours per day use of the 34 and 70 m DSN antennas for uplink and downlink, respectively, during the prime mission (first month). For expected high-gain antenna links, Pathfinder can expect roughly 20 megabits of data per day returned, with a total data return over the first month of order 1 gigabit. Data return of this magnitude is capable of providing virtually all the science, technology experiment and engineering data needed to fully satisfy all the science objectives and investigations (Table 1) discussed earlier (although a few months of tracking is required to determine the precession constant). The rover, with all its engineering, technology and science sensors is likely to produce of order a few megabits of data per day. In the extended mission, Pathfinder will have use of the 34 m antennas (supporting roughly a factor of 4 lower data rates), which should provide at least 3 uplink sessions per week and significant downlink capability (a few hours per day), thereby augmenting the prime mission data return significantly by a few megabits per day.

As a hedge against possible failure of any of the Pathfinder instruments, the present mission scenario calls for the acquisition and onboard storage of large volumes of data early in the mission. These data are assigned varying downlink priorities so that playback of higher priority data acquired later will supersede some of the earlier "contingency observations." Table 1 shows a data acquisition and playback summary for a relatively ambitious science scenario. Assumptions include the use of relatively high data rates (implying nominal pointing for the high gain antenna), nominal thermal control of the spacecraft and nominal power management (permitting full use of the data transmission periods). The total data acquisition is 1.735 Gbits. The total data downlinked during the 28 sols is 1.280 Gbits. The difference of 0.455 Gbits represents data that have either been overwritten or remain in the memory at the end of sol 28.

To illustrate this data management strategy, a full multispectral panorama in all of the geology filters is acquired before the IMP mast is deployed from its stowed position. As a minimum, panoramas from four filters of this set will be returned. If the IMP is performing well after deployment, a complete multispectral data set will be acquired from the deployed position and eventually downlinked. The panoramas acquired in the stowed position (in other than the four filters) are considered "contingency frames" and will be overwritten to conserve space in the lander memory.

The data in Table 1 describes a sample mission scenario which is responsive to the Science and Instrument Requirements Document and has had several iterations with the existing instrument teams. It is also consistent with the currently-understood capabilities of the flight system. It is provided to indicate the approximate capabilities of the Pathfinder mission. Changes can be expected as a result of more detailed planning as well as improved understanding of the spacecraft capabilities at the conclusion of the environmental test program.

### Requirements on Science Team Members

The following paragraphs describe the expectations of the Pathfinder Project with respect to the Experiment Team, both the continuing members and those selected through this announcement. It is understood that the conduct of a complex, interactive mission requires coordination of the expertise of a number of individuals and that the various elements of the Experiment Team (Instrument teams, Rover Teams Science Operations Groups, etc.) will have to organize their activities to utilize effectively the talents of their members.
Experiment Team members should expect to:

1. Be assigned to a science operations group or an instrument team.
2. Participate in planning observations.
3. Participate in analyzing data to support operational decisions or activities.
4. Assist in the preparation of data products for deposit in the PDB and eventually a well calibrated and described data set for the Planetary Data System (PDS). Some of these materials will be used for press briefing, outreach activities, scientific publications, etc.
5. Adhere to the data rights policy.
6. Participate in the preparation of team-authored papers (e.g.. 30-day report).
7. Participate in general and specific training activities as negotiated with their assigned Science Operations Group or Instrument Team

## SCIENCE DATA MANAGEMENT

### Data Release Policy

With the approval of the Mars Pathfinder PSG, the project has negotiated the following data release policy with NASA headquarters:

“Mars Pathfinder Data Release Policy. Because of the expected widespread scientific and public interest in new results from Mars, and the strong commitment of Mars Pathfinder scientists to releasing data on a timely basis, it is important to establish clear release policies. These policies are summarized as follows:

“1. There is no proprietary period for any scientific or engineering data to be returned by the Mars Pathfinder spacecraft. The generation/validation time period for standard data products (see below) is defined to be the period from receipt of science packets containing raw data at instrument processing facilities to release of archive volumes to the Planetary Data System. The archive volumes will include standard data products, science data packets from which the standard products were generated, and documentation describing the generation of the products. Instrument Teams are expected to extract raw data from the Project Data Base, generate standard products and archive volumes, and validate the products and volumes, during the generation/validation period. Efforts involving all the various Mars Pathfinder investigators are expected to be underway during this period, including product validation and generation of special data products for analysis. Generation/validation of products and archive volumes will require six months from time of receipt of raw data at instrument processing facilities in order to produce and validate useful archive volumes.

“2. Each Team Leader and Principal investigator will also release a significant subset of data earlier as a form of public outreach and education to ensure rapid dissemination of new and significant information. These early releases will consist of special products and will typically be available within a week of data receipt. Postings on Internet (e.g., World Wide Web) will be used as a cost-effective way for widespread dissemination of these special products. The posted data will include images, rock and soil spectra, weather information, and other forms of data that illustrate new and significant results. Postings will include documentation.

“3. Any use and analysis of raw and standard products from a particular instrument or use of the results of unpublished papers derived from such analysis shall require the agreement of the relevant Principal Investigator or Team Leader during the generation/validation period.

“ 4. After the six month generation/validation period, the relevant archive volumes and posted special products will be transferred to the Planetary Data System.

“5. Individual Instrument Teams may make their own data available earlier and they may decide to make a number of versions available on a more timely basis than the typical six-month period. They may not release data from other instruments.

“The Mars Pathfinder Project will subsequently specify the standard data products to be generated, and archive volume generation, validation, and delivery schedules as well as the types of data to be posted on World Wide Web for immediate release, along with posting schedules.

“Note that this release policy may be amended when NASA releases its agency-wide policy on timely release of data sets.”

(End of Pathfinder Data Release Policy)

Hardware

A number of workstations will be provided for the use of Experiment Operations Team members during the mission, including: at least five Sun SPARX 10 or 20 workstations (UNIX Operating System); at least one Silicon Graphics Inc. workstation; and several Macintosh and IBM-equivalent PCs. Team members may bring their own personal computers to support their data analysis activities.

Software

The Pathfinder Project will make all data product types available through the Project Data Base (PDB). Software will be available to produce the standard and special products listed below. In addition VICAR, PICS and IDL image processing packages will be supported.

Standard Products

The following science standard products will be provided:

*Imager for Mars Pathfinder (IMP) Products:*
Realtime display -- up to 3 X-devices simultaneously, closed-circuit TV distribution
Image files -- obtained via browser, in color, monochrome, with label conversions VICAR to/from PDS/IMPSoft/PICS.
Single frames -- stereo, monocular, geometrically corrected
Mosaics -- stereo, monocular projections in cylindrical and polar coordinates, digital terrain map
PDS compliant CD-ROMS in single frame monochrome (EDR)
Film products -- "naked" image files, masked images in stereo, monoscopic (including color) and mosaics; for two different versions of each frame, one original positive transparency, one copy negative, one contact print and up to ten photographic prints per day.
Hard copies on demand from high-quality color printer

*Rover products:*
Realtime display -- up to 3 X-devices simultaneously, closed-circuit TV distribution
Image files -- obtained via browser, in monochrome (color for rear camera only)
Single frames -- stereo, monocular, geometrically corrected
PDS compliant CD-ROMS in single frame monochrome (color for rear camera)
Film products -- "naked" image files, masked images, monoscopic (including color for rear camera) and mosaics; for two different versions of each frame, one original positive transparency, one copy negative, one contact print and up to ten photographic prints per day.
Hard copies on demand from high-quality color printer

*APXS Products:*
Realtime display -- up to 3 X-devices simultaneously, closed-circuit TV distribution
Experiment data record provided as image files

*ASI/MET Products:*
Data files stored in the PDB
Custom displays of data extracted from the PDB

Special Products

Within the resources available to the Mars Pathfinder Project special products will be created to support science data analysis, operational needs, outreach and public information. These will include the preparation and maintenance of data sets on the World Wide Web for all of the experiments including the rover.

Publications Plan

Although a detailed plan for publications has not been developed, team members should expect to participate in the preparation of two or three refereed science papers, including a 30-day report and a six-month's and/or one year report.