IMAGER FOR MARS PATHFINDER (IMP)

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Goals of the Investigation

The major science objectives of the IMP experiment include. (1) mapping the morphology and terrain of the landing site. (2) Determination of the mineralogy of the exposed crustal rocks and soil as well as the mineralogy of the weathering products in the soil, dust, and on the surface of the rocks. (3) Observation of time-variable phenomena at the landing site including cloud formation, wind velocity and direction, frost, and the formation/evolution of eolian features. (4) Observation of the properties of the martian atmosphere including measurement of the quantity of atmospheric water vapor and the quantity and size distribution of atmospheric dust. (5) Study the magnetic properties of the martian dust by multispectral imaging of dust accumulations on the magnetic arrays. (6) Multispectral studies of the nighttime martian atmosphere by imaging bright stars and the multispectral study of the mineralogy of the martian moons Phobos and Deimos.

Instrument Description

The Imager for Mars Pathfinder is a binocular CCD-based camera using a Loral 512 x 512 pixel CCD. The camera resembles a 4 by 8 inch cylinder with the long axis aligned horizontally to the plane of the lander (Figures 12 and 13). The square eyes are separated by 15 cm to provide good stereo and ranging performance to support rover operations. The dual optical paths are folded by two sets of mirrors to bring the light to the single CCD. To minimize moving parts, the IMP is electronically shuttered and half of the CCD is masked and used as a readout zone for the electronic shutter. The active half is split into two identical 248x256 pixel sub-arrays for each eye separated by a 12 pixel "dead zone" to minimize cross-talk between the eyes. Readout takes approximately a minute and the data is digitized to 12-bits. The field of view of each eye is 14.4° horizontal by 14.0° vertical with a 18 milliradian toe-in in each eye to provide complete viewing overlap at 5 m distance. The toe-in was to assure maximum stereo performance in the zone 2-10 meters from the camera which is the primary area for rover operations, mineralogical observations, and morphological investigations. The lenses are modified Cooke triplets, designed with rad hard glasses and stopped down to f/18 with a 1.04 mm aperture. The effective pixel resolution of these optics is one milliradian per pixel which gives 1 mm per pixel at one meter range. In the optical path of each eye is a twelve-position filter wheel, giving the investigation a total of 24 filters (Figure 12). Both filter wheels are on a common drive shaft so both wheels move together. Four wheel positions (eight filters) are used for atmospheric investigations and eight wheel positions (15 filters and a diopter lens) are used for geological/stereo investigations. The atmospheric filters are designed for direct observations of the sun through the martin atmosphere and include neutral density coatings that reduce transmission to less than 0.1%. The geology positions include three wheel positions for stereo viewing that have the same filter and one position that has a diopter lens to allow close-up viewing of a magnet mounted on the camera tip plate. This provides a total of twelve separate geology filters for visible and near-IR spectroscopy. A listing of IMP filter characteristics and wheel positions is shown in Table 2. The camera cylinder is mounted on gimbals that provide pointability of 360° in azimuth and -67° to +90° in elevation. This assembly is supported by an extendible mast designed and built by AEC Able Engineering. The mast is an open lattice of fiberglass stiffened by wire that pops up 80 cm above its stowed position (Figure 13). This puts the camera at approximately 1.5 meters above the martian surface and extends Pathfinder's horizon to 3.4 kilometers on a featureless plane. A summary of IMP characteristics and specifications is listed in Table 3.

In addition to the camera, the IMP experiment includes two radiometric calibration or photometric targets, a number of magnetic properties targets, three wind socks, four sets of color calibration targets (5 colors each) and one flat field targets (Figure 6). The flat field targets, made of rutile (titanium dioxide paint pigment), are mounted on the tip plate beneath the IMP in view by both eyes of the camera. The radiometric or photometric targets are mounted on top of the electronics box and on the base petal. Each consists of a white (rutile), gray (mixture of rutile and carbon black) and black (carbon black) ring with a shadow post in the center with known reflectances. There are four sets of color targets on the lander (mounted with each photometric and magnetic target) and two on the rover (along the edge of the solar cell). Each set of color targets is composed of 5 silicon squares impregnated with: hematite (red reference), maghemite, goethite, chromium dioxide paint pigment (green) and cobalt blue paint pigment of stable and known spectra. Three types of magnetic targets are mounted on the spacecraft. Two magnetic arrays, each consisting of two blocks of magnesium with permanent "bulls eye" Sm-Co magnets of varying strengths (5, 11, 21, 45, 130 T/m) embedded and a sputtered gray platinum surface. One block contains magnets of Viking strength; the other block carries three of lesser strength (Figure 14). One magnet array is mounted on top of the electronics box, the other on the base petal. The surface of the array is tilted so that only magnetic dust will adhere to the surface. A magnet is also mounted on the tip plate with a magnetic field gradient across it (highest field strength is 130 T/m). A flexible flat magnet is also mounted at the end of each 1 m long rover ramp. The magnets are constructed of thin strips of magnetic material in aluminized Mylar that cover a 10 cm by 10 cm area magnetized to between 23 mT and 49 mT. Three wind socks are mounted at heights of 33.1, 62.4 and 91.6 cm above the petal on the ASI/MET mast. Each windsock (Figure 15) is made of an aluminum cone attached to a steel and aluminum counterweight rod. The 10 cm long socks pivot on gimbal mounts attached to 10 cm long struts extending from the mast.

<u>Data Collection Procedures</u>

Commanding the camera system is accomplished through a sequence of commands that are time tagged and stored in RAM until they are required. These commands can either be from already stored sequences or newly generated sequences that have been unlinked to respond to changed mission conditions. The basic modes follow the operational sequences. The first operation after landing is the release of the launch lock which will allow full operation of all camera functions. Pre-deployed images are taken and stored through the use of the imaging command. The image command includes optional parameters that control the exposure and processing. Everything from the exposure time to the amount and type of data compression are specified and attached to the data set. Sub-framing boundaries and pixel averaging parameters can also be specified. After processing for data compression the packetized images are stored in the telemetry buffer. Several types of data compression are included in the IMP software package. Lossless compression using the Rice algorithm developed at JPL will be the workhorse for the IMP images as long as we have a data rate of several thousand bits per second. For non-science or low data rate scenarios a lossy compression using a modified JPEG compressor developed at the Technical University of Braunschweig will normally be used. Other methods of conserving downlink resources include sub-framing the image. Examples of this are most of the atmospheric science images of the Sun which will be returned as 25x25 pixel blocks centered on the Solar disk. Row and column averages will be used for sky images, as this gives the gradient and the edges of cloud features, but not the high resolution of an image. Pixel averaging can be used where full resolution is not needed. Also, these methods can be used in combinations for highest compression.

<u>Nature of the Available Data Sets</u>

The standard IMP product will be a single image consisting of a header that contains the time-tagged command information, a unique image identifier, and an array of the DN's produced by that image. Although the IMP takes data in a 248x256 pixel format the software can use a variety of tools to compress this data. The major constraint on IMP data sets is the downlink resources available to Pathfinder. Optimistic scenarios put the downlink data rate at approximately 5000 bits per second for several hours per day. As a result large data sets like a color panorama of the landing site will not be returned quickly and many IMP investigations will need to conserve downlink bandwidth by a combination of lossless or lossey compression, subframing, and pixel averaging. Images with the geology filters will be used for panoramas, true color mosaics, multispectral image cubes, and multiple sun angle photoclinometry. Images of the magnetic properties arrays, wind socks, and calibration targets will be subframed to conserve downlink bandwidth. Atmospheric science images of the sun will be sub-framed and averaged. Stereo images will be mosaiced to produce a "virtual reality" scene of the landing site to support rover operations.

<u>Investigations Planned by the IMP Team</u>

Geomorphology, Photoclinometry, and Topography:: Panoramas of the landing site will be taken both before and after the camera mast deployment. These images will map the landing site for rover operations, as well as study the large-and small-scale structure of the landing site, rock and dune features, and any erosional features. Stereo ranging will determine the topography of the landing site and support rover operations. Images of the same areas taken at different solar elevation angels will permit topographic analysis by shadow length and photoclinometry. Additional images will be taken to study the nature of the martian soil. This will include imaging the rover wheel tracks to determine soil strength and compaction properties. Observations of the calibration targets and the lander surfaces will measure the rate of dust outfall.

Geology and Mineralogy: Filter-wheel spectral mapping using 12 filter wavelengths spanning 0.45 to 1.0 μm will determine the compositional variation of the landing site and identify mineralogical units as targets for further investigation using the rover-based Alpha/Proton/X-ray Spectrometer. Spectral mapping will also study weathering processes and products in the dust, soil, and rock. Of particular interest is the possibility of a "grab-bag" of mineralogies at the Ares Vallis landing site. This site was chosen in a catastrophic outwash area to explore the possibility that a range of mineralogies, including ancient martian highlands materials, were deposited in this area by the flood event(s). Nighttime multispectral observations of Phobos and Deimos can enhance the limited spectral data available on these small moons. The IMP should be able to detect bright (0 visual magnitude) stars and use these objects as standards for removal of the atmospheric signature from the Phobos and Deimos observations. These observation can also be used for the nighttime study of the martian atmosphere.

Magnetic Properties of Martin Soil and Dust: The scientific goal of the IMP Magnetic Properties Experiment is to identify the magnetic minerals in the martian soil and airborne dust. Imaging the distribution of magnetic material on the different strength magnets will be diagnostic of material's mineralogy (Figure 14). Spectral images of the accumulated dust on these magnets should provide diagnostic mineralogical identification of these magnetic species. The magnets built into the rover deployment ramps will put the magnets in close proximity to the soil and allow the rover to measure the accumulated magnetic dust with the Alpha Proton X-ray Spectrometer. The magnet mounted on the camera tip plate is less than 10 cm from the camera windows and the IMP will use a diopter lens to allow close-up viewing of this array. This magnet will collect magnetic dust settling from the atmosphere and its proximity to the camera will provide 200 mm per pixel resolution of the dust grains. The dust grains are probably much smaller than 200 mm, but the camera will be able to resolve chains that grains may form in the magnetic force lines of the array. The morphology of these chains can be diagnostic of the mineralogy of the magnetic species.

Atmospheric Water Vapor and Dust: Atmospheric water vapor will be measured by ratioing solar images through two narrow band filters, one at the 0.935 μm water band and one on the continuum at 0.925 μm. Additional solar images using ratios of narrow band filters at 0.45 and 0.925 μm will provide data on the size distribution and quantity of atmospheric dust. These measurements will be made at a number of airmasses from zenith to the horizon to provide an hourly history of water vapor, dust loading, and particle size variability for each sol of the Pathfinder mission. The 12 different geology filter wavelengths can be used to take multispectral sky images for several applications. Sky brightness measured at various angles from the Sun at multiple wavelengths can determine atmospheric particle size and shape. As the sun sets, illumination is restricted to progressively higher zones in the atmosphere and a series of multispectral sky brightness measurements can give us a picture of the vertical structure of the aerosols in the martian atmosphere. Finally multispectral measurements of Phobos and its aureole can be used to detect nighttime condensation and early morning fogs.

Wind Speed, Direction, and Gradient: The IMP Wind Sock Experiment will measure the direction, speed, and the boundary-layer velocity profile of the local martian wind by imaging the deflections and azimuth of the socks. These measurements will allow us to characterize the eolian processes at the Pathfinder landing site including particle threshold and the aerodynamic surface roughness. The socks will be imaged by the IMP every daylight hour to provide a continuous record of wind parameters. The windsock images will be sub-framed, processed on-board, and compressed to minimize the downlink data requirements. The deflections of the socks under wind velocities have been measured to provide quantitative data about the wind speed (Figure 16). The azimuth that the sock "points" indicates the direction of the wind.

Open Areas for Complementary Investigations

It is anticipated that any Participating Scientists attached to the IMP team will contribute to the generation and validation of IMP data products. Additional specialization's that can contribute to the IMP investigation include, but are not limited to, photometry using Hapke or Lummie/Boule methods, petrology/mineralogy of SNC meteorites, and the morphology of impact crater ejecta.

ALPHA-PROTON-X-RAY SPECTROMETER

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General Goals of Investigation

The objective of the Alpha-Proton-X-ray Spectrometer (APXS) for the Mars Pathfinder mission is to provide a complete and detailed chemical elemental analysis of martian soil and rocks near the landing site. The APXS technique is well established, and can measure all major and minor elements except hydrogen. Because all other major elements are determined to high accuracy, even H can often be estimated from stoichiometry. We presently have only coarse soil chemistry of Mars at the two Viking landing sites. Viking, however, had no means of determining C, N, O, and Na which are vital to understanding the history and the evolution of the planet, so the APXS experiment will fill important gaps in our knowledge of Mars.

The primary focus of the APXS investigation is new measurements of the chemistry of martian rocks. The APXS instrument is carried aboard the Pathfinder microrover, which will provide transportation to places of interest on the surface. The possibility to transport the APXS to an arbitrary location, pre-selected on Earth, and to perform in-situ analysis at it, constitutes one of the most exciting scientific aspects of the Pathfinder mission. Chemical analyses of several rocks at the landing site will therefore shed light on a variety of important processes that have operated on Mars.

Measurement Techniques

The principle of the APXS technique is based on three interaction of alpha particles from a radioisotope source with matter: (a) simple Rutherford backscattering, (b) production of protons from reactions with the nucleus of light elements, and (c) generation of characteristic X-rays upon recombination of atomic shell vacancies created by alpha bombardment.

Measurement of the intensities and energy distributions of these three components yields information on the elemental chemical composition of the sample. In terms of sensitivity and selectivity, data are partly redundant and partly complementary: Alpha backscattering is superior for light elements (C, O), while proton emission is mainly sensitive to Na, Mg, Al, Si, S, and X-ray emission is more sensitive to heavier elements (Na to Fe and beyond). A combination of all three measurements enables determination of all elements (with the exception of H) present at concentration levels above typically a fraction of one percent.

Alpha Backscattering (Alpha Mode): Elastic collisions between alpha particles and atoms of a target (sample) material lead to a change in direction and energy of these particles. The energy E of a scattered alpha-particle, in relation to its initial energy E_0 is a function of the mass A of the target atom and the scattering angle ϕ:

$$\frac{E}{E_0} = \left(\frac{4\cos\phi + \left(A^2 - 16\sin^2\phi\right)^{1/2}}{A+4} \right)^2$$

For a scattering angle of ϕ = 180° ("Backscattering") this reduces to:

$$\frac{E}{E_0} = \left(\frac{A-4}{A+4} \right)^2$$

In the case of a thick sample, alpha particles will be scattered at various depth along their path. Before scattering they will have lost energy in the sample and the scattered particle will lose additional energy on its way out of the sample. The resulting energy distribution is a generally flat spectrum, extending from 0 to a sharp cutoff at a maximum energy determined by E/E_0 which is characteristic for the scattering element. The total number of particles registered in the spectrum is a measure for the number of atoms of the scattering element in the sample; i.e. its concentration in the sample. These two facts are the basis for analytical applications of alpha backscattering.

Proton Emission (Proton Mode): Another process important for analytical applications is the nuclear reaction, in which Alpha particles merge with the target nucleus, followed by the emission of a proton and, in some cases, gamma radiation. This process is characterized by the Q-value, i.e. the difference in binding energy of the alpha-particle and the target nucleus on the one side and of the proton and the product nucleus on the other side. This process is energetically possible, when the kinetic energy of the incoming alpha-particle E_a exceeds the difference in binding energy Q; the excess energy is transferred to the kinetic energy of the proton E_p and the energy of an associated gamma transition E_g:

$$E_p + E_g = E_a + Q$$

This process is of particular interest in the case of the light rock-forming elements Na, Mg, Al and Si, where *Q*-values range between -2 MeV and +2 MeV and the reaction cross sections for alpha-particles of 5 to 6 MeV are not too small. This is due to the fact that alpha-particles have to penetrate the Coulomb barrier of the nucleus, before the nuclear reaction can take place, and this is determined by the nuclear charge of the target nucleus.

X-ray Generation (X-ray Mode): The alpha particles from the radiation sources used in the alpha and proton modes are also used as a very efficient excitation source for production of characteristic X-rays from the sample material. Actually, charged particle excitation is preferred to any other kind of excitation since it produces the best signal-to-noise ratio due to absence of any Compton scattering. This advantage significantly improves the performance of the instrument..

The analytical information in the X-ray mode comes from the characteristic X-rays that are emitted when the low electron orbit vacancies (in K and L shells) produced by bombardment of atoms by alpha particles are filled by electrons from higher orbits. The alpha particle sources can excite characteristic X-rays in a sample in two ways. First, the interaction of the alpha particles with the electronic cloud of an atom has a probability of producing a vacuum in the K electronic shell of the target. Second, alpha radioactive sources such as ^{244}Cm are also strong emitters of L X-rays themselves. These have energies of ~0.015 to 0.022 MeV, and can produce characteristic X-rays in the measured sample.

In addition, the X-ray mode of the APXS is very helpful in another way. While the alpha mode has very good resolution for separating the light elements, it starts to have problems in separating the neighboring elements above about the element silicon. The opposite is true for the X-ray mode; it has its best resolution exactly where the alpha mode has the worst resolution.

Instrument Description

The APXS instrument shown in Figure 17 consists of two parts: The sensor head on the right and the electronics box on the left. The sensor head is mounted on a deployment mechanism outside the Pathfinder microrover's Warm Electronics Box (WEB). The electronics box is contained inside the WEB. The sensor head is connected to the electronics box via four coaxial cables (alpha-, proton- and X-ray signals; X-ray bias voltage) and six single wires (power for the X-ray preamplifier and the shutter motor; temperature sensor). Table 4 lists the mechanical and electrical specifications of the instrument.

APXS Sensor Head: The sensor head contains nine ^{244}Cm sources in a ring-type geometry and three detectors for the measurement of the three components: a telescope of two Si-detectors for the measurement of alpha-particles and protons and a Si-PIN X-ray detector with its preamplifier.

Figure 18 shows the geometrical arrangements of all components of the sensor head. Sources are contained in their own holder and are protected by a motor-driven shutter of 0.2 mm thick stainless steel blades and very thin (typically 200 nm thick) foils of alumina and VYNS. Collimators, delineating the area to be analyzed, are placed in front of the detectors, rather than in front of the sources, as this yields a more compact design. These collimators have been designed for a nominal working distance (distance between sample surface and collimator front face) of 4 cm. This distance is, however, not very critical and may in a real situation vary by as much as ±0.5 cm.

Figure 19 is a photograph, showing the APXS sensor head, mounted with the deployment mechanism on the back of the rover. A color camera mounted on the back of the microrover is visible to the right side of the APXS. This camera will provide close up images of all samples analyzed by the APXS. Additional images of the same region in several filters will also be acquired by the IMP.

^{244}Cm Alpha Radioactive Sources: The APXS needs for its operation in alpha, proton and X-ray modes a beam of alpha particles with high intensity and low energy spread. The intensity of the beam determines the total measurement time needed to obtain data with the necessary statistical accuracy; its energy spread directly determines the resolving capability of the alpha mode. The APXS is using 50 mCi of ^{244}Cm, with an alpha particle energy of 5.8 MeV and a half life of 18.1 years. This isotope is readily available in large quantities from several sources, but it must be purified and specially prepared for the APXS instrument. The sources are prepared by evaporation onto silicon backing wafers, and then fired at a high temperature to form silisides that exhibit high stability. To minimize self-absorption and degradation of their monochromatic energy, we use a set of 9 sources, each with 5-7 mCi of activity. A combination of Al_2O_3 and VYNS thin films in front of the sources prevents the contamination of the instrument from the recoils after an alpha decay of a nucleus in the source material. A very light mechanical shutter in front of the sources, controlled by a tiny motor, protects the films between launch and rover deployment, and also provides for the safety of the instrument and personnel.

Electronics for the APX Spectrometer: Basically, the electronics of the APXS consists of three independent analog channels for each of its modes: alpha, proton and the X-ray channel, and the digital electronics to condition signals and handle the data produced by the instrument. All of the APXS electronics, except for the X-ray preamplifier, is inside the rover warm electronic box, the temperature of which will be controlled within a range of -50°C to +50°C, using power from the batteries and auxiliary thermal energy. The temperature of the sensor head, including the X-ray preamplifier will be at Martian ambient temperature, expected to be in the range of -100°C to +10°C.

Fig. 4 shows the block diagram of the electronics system for the APX Spectrometer. Six individual building blocks are indicated by dashed lines. They consist of the sensor head with alpha, proton and X-ray detectors (with the X-ray preamplifier) and five printed circuit boards with the following: (1) the analog section for the alpha- and proton detector, up to and including peak detector/stretcher; (2) the analog section for the X-ray detector, up to and including peak detector/stretcher; (3) serial A/D and D/A converters, voltage reference source and buffer amplifiers; (4) microcontroller with program PROM, data RAM, serial I/O, a watchdog/power monitor circuit and a backup battery; (5) the voltage converter for the X-ray detector bias, power line filters and the interface connectors (not shown). The system performs the tasks of amplifying and conditioning individual pulse signals from three detectors, measuring their amplitude, which in turn is a measure of the energy, a charge particle or an X-ray photon has deposited in the detector, and counting the number of events in 256 pulse height intervals per detector.

APXS Deployment Mechanism

One of the most exciting aspects of the Mars Pathfinder APXS experiment is the way it will be deployed to analyze martian surface soil and rock samples. In contrast to the Russian Mars-96 mission, in which the APXS instrument is deployed after the landing on a one degree of freedom arm enabling it to analyze whatever single sample happens to be under the instrument, the APXS on the Mars Pathfinder is mounted on one end of rover that provides mobility and the opportunity to analyze multiple soil and rock samples. The deployment mechanism was designed at JPL as part of the rover (Figure 5) in a such a way that the APXS can be deployed vertically to the ground or horizontally against any rock that looks interesting and was pre-selected by the lander or rover images. The deployment mechanism is a very ingenious device, being operated with only one motor, but providing compliance to the analyzed sample shape. Contact switches and spring coils makes the design simple and dependable.

APXS Data and Analyses

Flight Software for the APX Spectrometer: The general concept for the flight software is the following. After a power-on reset, the APXS microcontroller performs initialization and then enters a low power "sleep" (idle) mode. From this mode it is "woken up" by external interrupts to perform various tasks in interrupt - service routines. These tasks are: response to commands received through the Serial Interface, response to Timer 0 signals to periodically increment a counter for the measuring time, combined with periodic temperature measurements and the associated readjustment of D/A-settings, and response to signals from the analog electronics to perform signal amplitude analysis and multichannel storage.

Martian Surface Soils and Rock Measurements: The APXS will analyze at multiple rock and soil samples in the vicinity of the landing site. The strategy is to obtain the first soil analysis right after the landing on the first night on the surface. On the second day, after analyzing the images of the landing site, an appropriate rock sample will be chosen and the rover will be commanded to place the APXS to analyze it. Most of the time the APXS will be operating during the night time, when there is no other activity going on. Later in the mission, daylight measurements will be also performed to see if there are any condensation processes happening during the night time. Under nominal rover conditions, it may be possible to obtain a new APXS spectrum every night during the first week of operation.

Data Analysis: Measurements with the APX Spectrometer yield three data sets: (1) a spectrum of backscattered alpha particles, (2) a spectrum of protons generated by nuclear processes and (3) a spectrum of characteristic X-rays emitted from the sample upon excitation with alpha particles and X-rays. Within certain constraints (mainly matrix effects) all three spectra can be considered linear superpositions of spectra of all elements present in the sample, multiplied with an appropriate scaling factor linked to their abundance in the sample:

The alpha spectrum is the sum of back-scatter spectra of all elements with atomic mass greater than 4 (He, this is due to the physics of the back-scattering process); the proton spectrum is the sum of proton spectra emitted by elements, for which nuclear reactions take place (mainly Na, Mg, Al, Si and S) and the X-ray spectrum is the sum of X-ray spectra emitted by all elements heavier than Na (determined by the type of detector). In principle, abundance figures can be derived from each of the three types of spectra; in practice, a combination of the results is required to overcome certain limitations of each approach and improve the accuracy of the results:

In the alpha spectra, the low resolving power of the instrument for elements heavier than Mg and the statistical counting errors of the data do not permit accurate distinction between the major rock forming elements Mg, Al and Si. On the other hand, these are the main elements contributing to the proton spectra. The X-ray spectra provide information on elements heavier than Na, but matrix effects (absorption and secondary fluorescence) play a more important role, than in the case of alpha and proton spectra. The approach taken is therefore an iterative one, in which the alpha and proton spectra are combined and the complex sample spectrum is decomposed into its individual components, using a least square fitting procedure with a library of standard spectra, and applying appropriate corrections for matrix effects. As the alpha-proton spectra contain information about all elements heavier than He, neglecting the lightest elements, the results can be normalized to add up to 100%. Then the X-ray spectra are analyzed, using a library of standard spectra and added to the results from the first step for matrix corrections. This step yields improved data for the ratios of the elements Na through Ni, which are used in a second least squares fit of the alpha-proton spectra.

Magnetic Target Measurements: During operations on the surface of Mars, the APXS will analyze many samples of martian soil and rocks. It is, however, also anticipated that the APXS will analyze several magnetic targets mounted on the rover ramps to provide information about the magnetic properties of the martian surface material. By analyzing the collected material with the APXS it will be possible to determine if there is any preferential separation of the collected material according to the magnetic properties of the material. The spectra of the magnetic targets obtained will be compared with the laboratory spectra obtained during the calibration of the APXS instrument. From these measurements, it is expected to determine some of the iron mineralogy of the martins surface material.

Investigations Planned by the APXS Team

The APXS team will provide the chemical elemental analyses of all the samples obtained from the surface of Mars utilizing the standard elemental library obtained during the pre-launch calibration of the instrument and computational techniques described above. For each element an associated uncertainty, based on the statistical error and the error of the method will be determined. From the complete analyses obtained by the APXS an attempt will be made to interpret the data and possible mineralogical analogs will be suggested. The data will also be scrutinized to established any resemblance to the SNC rock analyses that would confirm their martian origin.

Open Areas for Complementary Investigations

1. Normative mineralogy derived from a complete elemental analysis.
2. X-ray analysis using fundamental parameter approach.
3. Interpretation and importance of the obtained elemental analyses in understanding the planet Mars.