Alpha Particle X-Ray Spectrometer (APXS)

The Athena Alpha Particle X-ray Spectrometer works by exposing martian materials to energetic alpha particles and x rays from a radioactive ^{244}Cm source, and then measuring the energy spectra of backscattered alphas and emitted x rays. The instrument is conceptually similar to the APXS instrument that flew on the Mars Pathfinder mission. However, there are several differences that improve the instrument's reliability and performance. Unlike the Pathfinder APXS, the Athena APXS does not have a proton mode. The proton mode has been dropped because recent increases in the spectral resolution and sensitivity of the x-ray mode have made it unnecessary. Significant modifications have also been made to the instrument to reduce the CO_2-induced background that was observed on Pathfinder, to improve x-ray spectral resolution, and to decrease susceptibility to electromagnetic interference. In addition, the Athena APXS will undergo extensive preflight calibration under Mars-ambient conditions, and will have two onboard reference targets for post-landing calibration on Mars.

The APXS instrument consists of a sensor head mounted on the rover's Instrument Deployment Device, and electronics mounted in the rover's Warm Electronics Box.

The sensor head contains six ^{244}Cm alpha radioactive sources with a total source strength of about 30 mCi. The sources are each covered with 3-µm aluminum foils that reduce the energy of emitted alpha particles from the initial value of 5.8 MeV to about 5.2 MeV. At this energy, the alpha particle scattering cross section of carbon is significantly reduced. The reduction is accompanied by a slight degradation of the alpha spectral resolution caused by broadening of the excitation spectrum, but the net result is a significant suppression of atmospheric background in the alpha spectra. Collimators in front of the sources define the instrument's field of view, which is about 38 mm in diameter at the nominal working distance of 29 mm.

Surrounding the sources are six thin alpha detectors. The FWHM for the alpha mode of a ^{244}Cm peak at 5.8 MeV is less than 100 keV. Interior to the ring of sources is a single high-resolution silicon drift x-ray detector with a 5-µm beryllium entrance window. The FWHM of this detector at 6.4 keV is about 160 eV, compared to 260 eV for the Pathfinder APXS. The noise level in the x-ray mode will be less than 600 eV at temperatures below –30°C, and the efficiency at the 1.24 keV line of Mg will be at least 20%.

Preamplifiers for both detector channels and a circuit to generate detector bias voltages are also mounted on the sensor head, significantly reducing the instrument's susceptibility to electromagnetic interference.

The entrance to the detector head is normally protected from martian dust and other potential contaminants by a pair of doors. These doors swing inward and lock open when the sensor head is pressed against a target or other hard surface. They can be closed again by actuation of a release mechanism. The inner surfaces of the doors provide a calibration reference surface for the instrument. The sensor head can also, if desired, be brought into contact with the magnetite-rich calibration target designed for the Mössbauer spectrometer.

Signals from both detector channels are processed by electronics mounted in the rover WEB. Alpha signals from charge-sensitive preamplifiers –and similarly-x ray signals from a customized voltage-sensitive preamplifiers in the sensor head –are further amplified and filtered

(semi-Gaussian pulse shapes) and then routed to peak detectors, a multiplexer, and into a 16-bit A/D converter for digitization. Signals from comparators that trigger if signals exceed a preset level initiate a sequence of logic signals necessary for peak detection (sample gate and signal hold) and the conversion process (program interrupt, alpha/x-ray flags). A microcontroller selects the appropriate input to the multiplexer and controls analog-to-digital conversion. The analyzed events are stored in the microprocessor buffer memory, building up alpha- and x ray-spectra

The rover can place the APXS sensor head in contact with rock surfaces or soil surfaces at inclinations within the range of 0 to 90°. Under normal conditions, it should be possible to position the instrument centerline within 0.4 cm of a target location that has been observed by another IDD instrument.

Proper preflight calibration is essential to analysis of APXS data, so the Athena APXS will undergo an extensive calibration program. All calibration measurements will be made in a chamber filled with a mixture of gases that closely matches the composition of the martian atmosphere, at the appropriate atmospheric density. Calibration measurements will include:

- spectral "library" measurements of pure elements and oxides;
- geochemical standards that span the full range of plausible martian surface compositions;
- standard targets under a range of atmospheric densities and measurement geometries;
- standard targets in both natural and powdered form, to investigate texture effects;
- the APXS flight calibration target;
- the magnets of the magnet array;
- several blind certified geochemical reference standards, for independent assessment of the accuracy with which compositions can be measured.

All of these measurements will be made using the flight radiation sources.

The accumulation time for the APXS will typically be at least 10 hours per sample analysis, although significantly shorter durations are possible when only the x-ray mode is used. Most data accumulation will take place during the night when the ambient martian temperature is the lowest, giving the best energy resolution on all spectra. However, it is desirable to break the total accumulation time into several shorter accumulation periods. The APXS can store up to 12 sets of accumulated spectra and can transmit the data to the rover either after each accumulation period, or all sets of spectra at the end of the final accumulation period.

The x-ray mode is sensitive to major elements, such as Mg, Al, Si, K, Ca, and Fe, and to minor elements, including Na, P, S, Cl, Ti, Cr, and Mn. The alpha mode is sensitive to lighter elements, particularly C and O. The depth of analysis varies with atomic number, ranging from approximately 10 to 20 micrometers for sodium, to approximately 50 to 100 micrometers for iron. The detection limit is typically 0.5 to 1 weight percent, depending on the element. The APXS is insensitive to small variations of the geometry of the sample surface because all major and minor elements are determined, and can be summed to 100 weight percent.