The Alpha-Particle-X-ray-Spectrometer (APXS) for the Mars Science Laboratory (MSL) Rover Mission.

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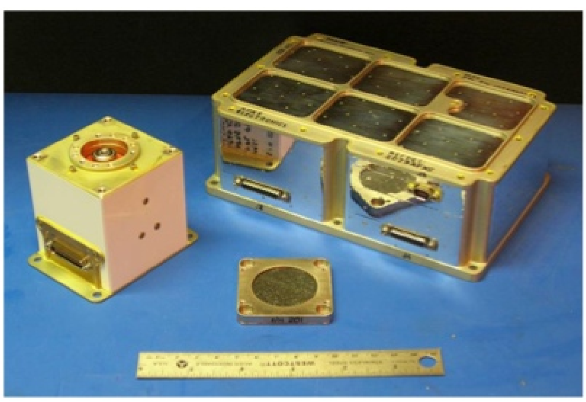
Introduction: The MSL APXS was selected by NASA as a Canadian contribution for the Mars Science Laboratory, now scheduled for launch in 2011. It follows the Pathfinder and Mars Exploration Rover APXS instruments [1] and was significantly improved in many ways. The APXS in-situ method of determining the chemistry with x-ray spectroscopy proved to be very significant and reliable over the 5 year MER mission. The APXS on both MER rovers documented the overall geological context of the landing sites, identified stratigraphic sequences along the traverse and identified local anomalies, many of them were pointing towards interactions with water in the past.

For the upcoming MSL rover mission the APXS method was further improved and now is able to take a full chemical analysis within about 3 hours, an improvement over the MER APXS by a factor of 3. Furthermore the temperature range for good resolution x-ray spectra was extended upwards to approximately -5C, whereas the MER APXS is only capable of functioning sufficiently below -40C.

The MSL flight instrument underwent all qualification tests and a final science calibration before being delivered to NASA/JPL in November 2008. The Main electronics, the sensor head, as well as the basaltic calibration target are shown below.



Method and design changes vs MER: The APXS uses ^{244}Cm sources to irradiate a sample with alpha particles and x-rays. It determines the abundance of the elements Na to Br and beyond with x-ray spectroscopy.

The MSL APXS uses the same 10 mm^2 SDD x-ray detector as MER. The FWHM(5.9 keV) at low temperatures improved from ~155eV to ~140eV at MSL. A major improvement of an overall factor of 3 in sensitivity (signal per second) was achieved by a closer proximity of sample and detector. MER used ~30mm distance, mainly due to the alpha detectors for RBS mode, whereas MSL uses ~19mm. The MSL instrument abandoned the alpha detectors due to the experienced limited sensitivity on light elements in the 10 mBar Martian CO_2 atmosphere. MSL uses 30 mCi conventional sealed ^{244}Cm sources in addition to the alpha emitting 30mCi ^{244}Cm to further boost the high z elements above Fe by a factor of 2. The internal Peltier cooler of the SDD can now be activated, delivering a cooling of the x-ray detector by -35C, allowing much improved Martian day time operation compared to MER.

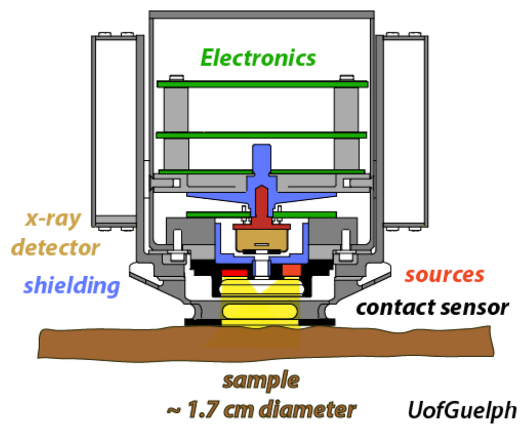


Figure 1: Sketch of the new APXS sensor head geometry. The opening of the contact sensor plate is wide enough to measure either in contact or with a standoff.

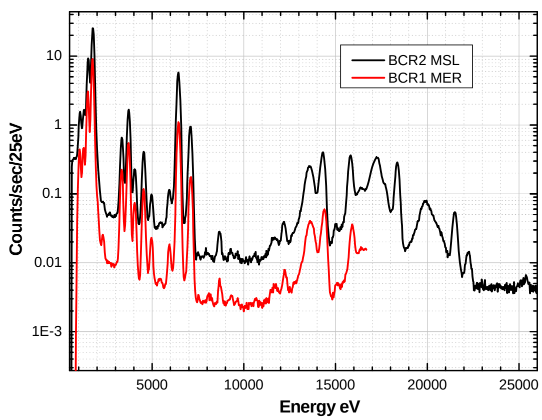
Calibration approach: We followed a similar calibration approach for MSL as was done for MER. In October 2008 the MSL flight instrument underwent its calibration with selected geology standard powders and the basalt calibration target. The main purpose was to characterize the instrument and to get a reliable cross calibration with the MSL lab instrument as well as with the MER instruments.

The calibration is done in vacuum, at sensor head temperatures around +5C and with standard geometry conditions. The extended calibration has been started with a broader collection of samples, including various basalts, minerals, sediments and chemical compounds. It will include also the calibration of influences like sample distance and atmospheric pressure.

The flight calibration target will be used to periodically check the calibration on Mars during operations.

Data analysis: The same data analysis approach used for MER can be applied immediately due to the cross calibration with the existing MER laboratory data [2]. The APXS method is well understood. The dependency of the response of each element is a smooth function of the x-ray energy, determined by the instrument properties and the Physics of the x-ray excitation processes in the sample.

The development of a fundamental approach for the data analysis is in progress. The same holds for the calibration and analysis of the scatter peaks beyond 12 keV, which can be used to extract excess of light elements like bound water [3].



Calibration results: A comparison of a MER and MSL spectrum of BCR is shown in the above figure. The major scientific design improvements, which were already verified with MER components for the MSL proposal, worked as expected. The acquisition time needed for a full analysis including trace elements like Ni and Br was decreased by a factor of ~3 for low z elements and ~6 for higher energies. This gives enough margin to fulfill all set requirements and leaving margin for MMRTG background.

With the new geometry the FOV in contact is about 15 mm in diameter, roughly half the sample size of MER. This will allow the better separation of localized features. It also accommodates the small amounts of processed powder the APXS will analyze in the MSL observation tray.

The x-ray energy range was extended to ~ 700eV to ~ 25 keV with 1024 channels. This allows additionally recording the ^{240}Pu Lβ and Lγ scatter peaks of our excitation source beyond 16 keV. The statistics, as well as the information depths are significantly increased by the extension of the energy range.

Neutron damage of SDD: When we first installed the total of 60 mCi ^{244}Cm sources, we observed a dramatic, nearly linear decrease of FWHM performance. Within a week of 24/7 exposure the FWHM degraded from 190eV to about 300eV.

Tests performed at TRIUMF with proton irradiation and tests with MER spare instruments confirmed that the degradation is due to neutron damage caused by the small spontaneous fission rate of ^{244}Cm.

However, the damage is electrically active only at chip temperatures above ~-40C. The long term stability and performance at lower temperatures is not challenged by this effect as 5 years of MER operation and a total MSL dose irradiation at TRIUMF revealed. We limited the amount of additional sealed ^{244}Cm partly for these reasons. During Martian operations we showed that the APXS will have an acceptable FWHM below ~ -5C during the overall MSL mission and have optimal FWHM below ~-20C.

Operational Improvements: The MSL APXS is equipped with an adjustable parameter table and uploadable software. The extensive experience from MER operations led to a new feature to enhance the placement of the sensor head with the rover arm using short spectra during deployment. The overall count rate varies from ~3 Hz background to ~400 Hz in sample contact and is quite independent of the actual composition. During deployment the count rate will increase determined by the solid angle. The APXS SW is able to take and sum up short spectra and return this value to the rover software controlling the sensor head placement. The method is an addition to the mechanical contact switch and will be investigated on Mars prior to its usage. It will also allow scanning a larger target area for significant changes in elemental ratios, for example Si to Fe ratio or Fe to S ratio and quickly selecting the most distinctive spots for longer measurements.

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References: [1] Rieder et al (2003), *JGR 108*, JE002150,[2] Gellert et al (2006), *JGR 111,JE002555*, [3] Campbell et al (2007),JGR113 *JE002989*