# The X-ray Solar Monitor XSM on SMART-1

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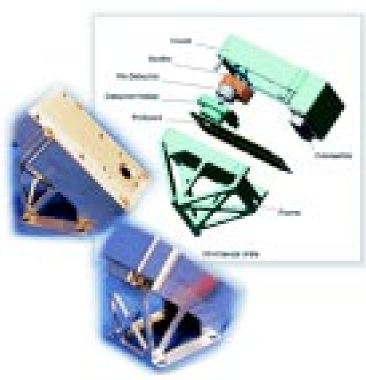
Despite its vicinity, the Moon, and even the surface of the Moon, is not very well known. Global mapping of the lunar surface and mapping of the elemental composition of it are still tasks to be properly accomplished. SMART-1 is the first European space probe aiming to a lunar orbit. It carries a small scientific and technology payload with several instruments prepared for this task. Being a technology demonstration mission of the ESA, SMART-1 has a main task of testing the capabilities of the very small power of a Solar Electric Propulsion engine to manoeuvre the spacecraft and take it from an orbit around one solar system body to another. It has therefore instruments for also monitoring the effects of the engine to the spacecraft and its environment.

SMART-1 will spend almost one and a half years to get from the Earth to an orbit around the Moon. During that period this cubic meter satellite circles the Earth numerous times, spiralling slowly out towards more distant orbits. It will eventually be caught by the gravity of the Moon, and start orbiting it for the next half-year period. An instrument combination with two components, D-CIXS (Demonstration of a Compact Imaging X-ray Spectrometer) and XSM (X-ray Solar Monitor), are designed to make measurements of X-rays from the Sun, the Moon, and also other celestial bodies during the whole SMART-1 mission. D-CIXS has been designed and built by Rutherford Appleton Laboratory in the UK, and the XSM by the University of Helsinki and Metorex International in Finland. The XSM will be able to monitor solar X-rays in the energy range 1 – 20 keV with high spectral and time resolution for almost two years, providing new and versatile observations of the solar corona and solar flares.



**Different views of XSM (engineering model). Explosion view shows the main ingredients. The dimensions of the sensor unit are 80 mm x 40 mm x 26 mm, and the purpose of the frame is to interface the unit to the panel of SMART-1 at the desired 45 degree angle for optimal field-of-view usage.**

Juhani Huovelin is working as a senior researcher at the Department of Astronomy, University of Helsinki. He has been involved in several space projects, most recently on the ESA Gamma-ray satellite INTEGRAL (2002), and development of new technologies for X-ray and gamma-ray detection in space.

## Science with the XSM

The X-ray Solar Monitor will have two major tasks during SMART-1 mission. First task is to provide information on the incident solar X-rays, to enable quantitative analysis of the fluorescence spectra of the Moon measured by the D-CIXS imaging spectrometer. Second task of XSM is to provide valuable data to be used independently, for science of the solar corona.

## X-ray fluorescence of the Moon

What is the use of an X-ray instrument combination like D-CIXS/XSM in a Moon mission? The Moon glows, albeit weakly, also in X-rays. The Moon does not radiate X-rays spontaneously, but all X-rays from it essentially originate from the Sun, and are just scattered and reradiated on the lunar surface.

The elemental composition of the rock and dust on the Moon give a signature to the reflected X-ray spectrum in the form of fluorescence emission lines. The strength of fluorescence at various energies depends on the intensity and shape of the input spectrum, and this is why an investigation like this requires simultaneous measurements with two instruments, one focusing at the Moon surface, and another looking directly to the Sun. Simultaneity of these two measurements is important, since the Sun is very unpredictable and highly variable in X-rays, and yesterday's spectra from the Sun are useless for analysing today's fluorescence spectra.

The origin of the Moon is a big question and a proper answer to it will lead us to what happened with the Earth and the Moon in the dawn of the solar system five billion years ago. One way to find out is to study the elemental composition of the Moon. If the ratio of the abundances of magnesium and iron on the Moon is the same as we know is deep inside the Earth, it is probably due to a collision of a massive, perhaps Mars size solar system body with the Earth in the early days of the solar system. In this scenario, the Moon was formed from the material that was torn apart from the inner parts of our home planet in this devastating catastrophe. D-CIXS/XSM aims at measuring the needed abundance ratio on the Moon, and may help us to find out, if the above really happened.

## X-rays from the solar corona

During its operation the XSM will collect an X-ray spectrum from the Sun in each 16 seconds. Taken from the operation timeline plan of SMART-1, it will be able to have the Sun in its very wide field-of-view (103 degrees across) for more than 300 full days during the mission. Although SMART-1 will not fly during the most active phase of the solar cycle, the XSM will see the rise and decay of hundreds of individual flare events. This data can be utilised for solar science independently of its usage for calibration of D-CIXS data.

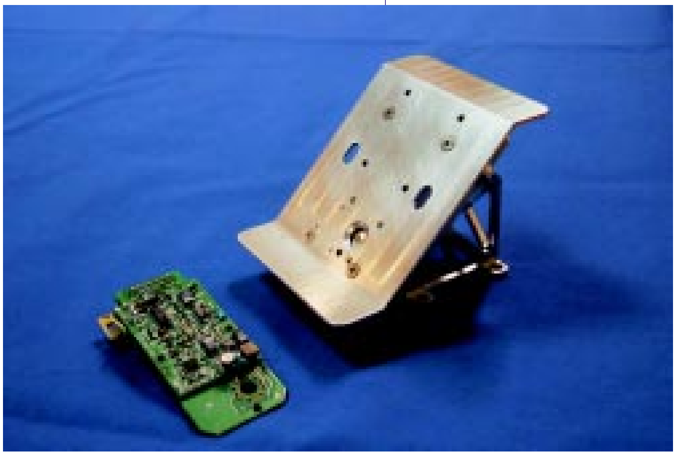
A flare explosion is the most intense local phenomenon on the surface of the Sun, and it causes significant increase of radiation all through the electromagnetic spectrum from radio waves to gamma rays. It is a manifestation of electromagnetic energy release, a consequence of short-circuiting of a magnetically charged coronal loop much bigger in size than the Earth. Most frequently, a flare is also the reason for the aurora (i.e. Northern Lights) on the Earth. A solar flare can last from a few minutes to more than one day, depending on its size and intensity.

In the X-rays, a flare can be more than thousand times brighter than its environment on the Sun. The XSM will measure the X-ray spectrum of flares, and it will be able to track the changes in the spectrum along with the evolution of each flare. Astronomers and physicists are able to derive important knowledge on the properties of the flare explosion by analysing the evolution of the X-ray spectrum. Thus, via the data provided by the XSM, we will be able to dig deeper in the origin and reason of the “mega-lightning” on the Sun.

## The XSM instrument

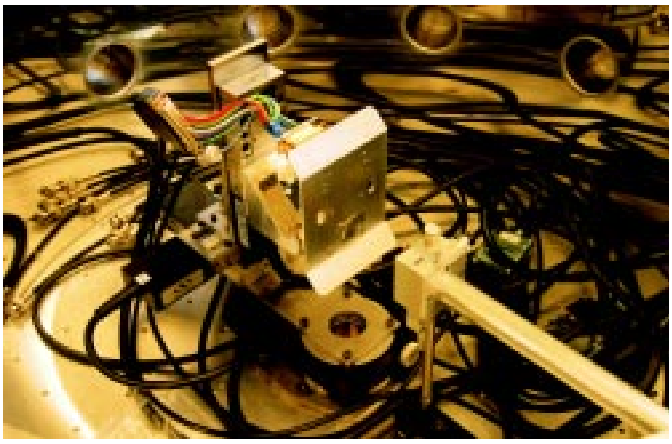
XSM is a very small instrument, with design as simple as possible to accomplish its tasks. Being less than 10 cm long and weighing about 200 grams, the aluminium box including the XSM detector is comparable to an average model 1999 mobile phone. In that very year, the main design parameters of the XSM were actually also determined. As a mobile phone, it comprises very advanced technology and electronics. However, similarities and analogy end at that point. The XSM is designed to measure X-ray spectra with about 250 eV or better energy resolution over the interval 1- 20 keV, and survive in the very hostile space radiation and thermal environment of SMART-1 mission for 2 years or longer without service. In space, a standard mobile phone would probably stay operable for very short time, as the energetic space particles would destroy the sensitive parts of the electronics, which are not shielded or qualified for use in outer space, perhaps in a few days or even faster.

The core of XSM sensor unit comprises of a silicon (HPSi) PIN detector 2 mm in diameter and 0.5 mm in thickness, enclosed in a hermetically sealed stainless steel entry, which is no bigger than a button of your shirt. The detector package sits on a small electronics board, and the window side is covered by a programmable command with an electromagnetic Tungsten plated shutter to shield it from unwanted proton radiation via the entrance hole of the sensor box. The temperature of the silicon detector is regulated by a Peltier cooler. The two-sided electronic board in the sensor box includes front end detector electronics with pulse readout, pre-amplification, and shaping stages. The sensor box is connected with a 3-meter cable to a main electronics board in the D-CIXS system entry.



**XSM flight model with the final design, and the front end electronics board separated. The enlarged front plate of the sensor box was designed for additional passive cooling of the system due to the very demanding thermal requirements of SMART-1 mission.**

The operation of XSM is simple, with only one measurement mode that collects 512 energy channel spectra in 16-second intervals, and repeats this sampling for the active measurement programme. When the shutter is open, XSM can view the Sun for most of SMART-1 operation time, since it has a circularly symmetric field-of-view with 103 degrees of diameter. There is no telescope needed, since the Sun is overwhelming in X-rays compared to all the rest of the sky. XSM uses the time when the shutter is closed also effectively, since the inside of the shutter, towards the XSM detector, is covered by a radioactive Fe55 source. The source emits an X-ray spectrum, which is used for spectral calibration of the XSM.



**XSM flight model attached in a turnable arrangement inside a small vacuum chamber at the Department of Physical Sciences, University of Helsinki. This is the facility specially built for XSM ground calibrations. With accurate adjustment of position and attitude of the detector with respect to the incoming X-ray beam, the arrangement enables measurements of the detector response and effectivity over the full field-of-view of XSM.**