SMART-1 LUNAR HIGHLIGHTS

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Abstract: The SMART-1 spacecraft reached on 15 March 2005 a lunar orbit 400-3000 km for a nominal science period of six months, with 1 year extension until impact on 3 September 2006. We shall report at LPSC2008 on SMART-1 lunar highlights relevant for science and exploration.

Overview of SMART-1 mission and payload: SMART-1 is the first in the programme of ESA's Small Missions for Advanced Research and Technology [1,2,3]. Its first objective has been achieved to demonstrate Solar Electric Primary Propulsion (SEP) for future Cornerstones (such as Bepi-Colombo) and to test new technologies for spacecraft and instruments. The SMART-1 spacecraft has been launched on 27 Sept. 2003, as an Ariane-5 auxiliary passenger and injected in GTO Geostationary Transfer Orbit. SMART-1 science payload, with a total mass of some 19 kg, features many innovative instruments and advanced technologies [1], with a miniaturised high-resolution camera (AMIE) for lunar surface imaging, a near-infrared point-spectrometer (SIR) for lunar mineralogy investigation, and a very compact X-ray spectrometer (D-CIXS) [4-6] for fluorescence spectroscopy and imagery of the Moon's surface elemental composition. The payload also included two plasma experiments: SPEDE (Spacecraft Potential, Electron and Dust Experiment, PI. A. Malkki) and EPDP (Electric propulsion diagnostic Package, PI G. Noci), an experiment (KaTE) that demonstrated deep-space telemetry and telecommand communications in the X and Ka-bands, a radio-science experiment (RSIS), a deep space optical link (Laser-Link Experiment), using the ESA Optical Ground station in Tenerife, and the validation of a system of autonomous navigation (OBAN) based on image processing.

SMART-1 lunar science results: A package of three spectroscopy and imaging instruments has performed science at the Moon.

SIR (Smart-1 Infra-Red Spectrometer) has been operating in the 0.9-2.6 µm wavelength range and carrying out mineralogical survey of the lunar crust. SIR had high enough spectral resolution to separate the pyroxene and olivine signatures in lunar soils.
SIR data with spatial resolution as good as 400 m permitted to distinguish units on central peaks, walls, rims and ejecta blankets of large impact craters, allowing for stratigraphic studies of the lunar crust.

AMIE (Advanced-Moon micro-Imager Experiment, PI J.L. Josset) is a miniature high resolution (35 m pixel at 350 km perilune height) camera, equipped with a fixed panchromatic and 3-colour filter, for Moon topography and imaging support to other experiments [7,10,11]. The micro camera AMIE has provided high-resolution CCD images of selected lunar areas. It included filters deposited on the CCD in white light + three filters for colour analyses, with bands at 750 nm, 900 nm and 950 nm (measuring the 1 µm absorption of pyroxene and olivine). AMIE images provided a geological context for SIR and D-CIXS data, and colour or multi-phase angle complement. AMIE has been used to map sites of interest, such as Oresme (see Fig. 1) in the South Pole –Aitken basin that are relevant to the study of cataclysm bombardment, and to preview future sites for sampling return.

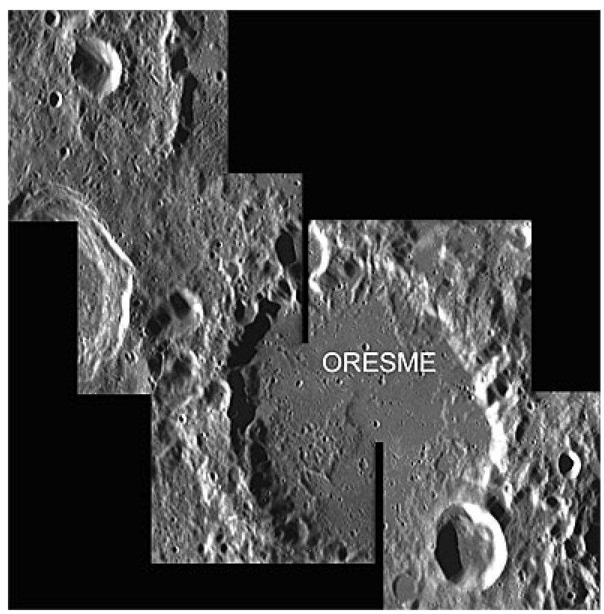

Fig. 1: SMART-1/AMIE image mosaic around the 76 km diameter Oresme crater. Oresme that originated in the Nectarian age, is located on the far-side of the moon, across the northwest part of lunar South Pole-Aitken Giant Impact Basin.

Lunar North polar maps (Fig 2) and South pole repeated high resolution images have been obtained, giving a monitoring of illumination to map potential sites relevant for future exploration .

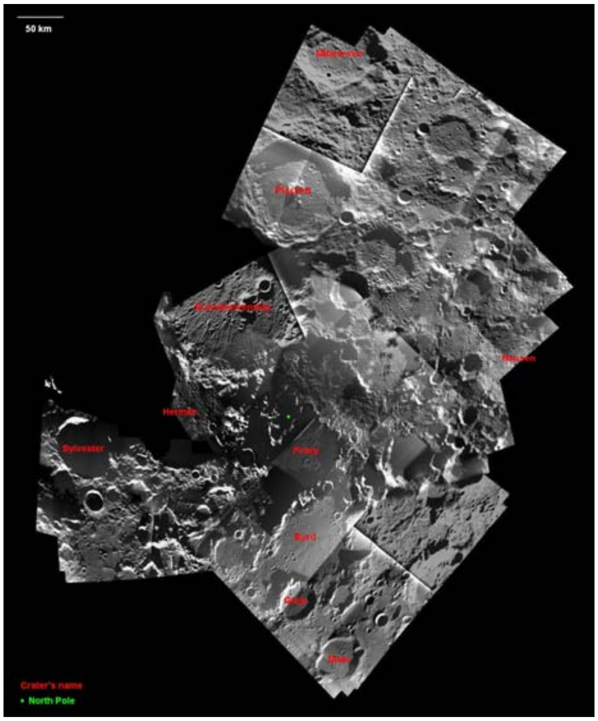

Fig. 2: SMART-1 /AMIE mosaic of the lunar North pole. The pictures were taken between May 2005 and February 2006, during different phases of the mission. The mosaic, composed of about 30 images, covers an area of about 800 by 600 km. The lunar near-side facing Earth is at the bottom of the map, while the far-side is at the top. When obtaining the images, SMART-1 was flying over the North pole at a distance of about 3000 km, allowing large-field (about 300 km across) and medium-resolution views (300 m/pixel). Each individual image includes areas imaged with colour filters and a more exposed area. The differences have been corrected accordingly to obtain this mosaic.

D-CIXS (Demonstration of a Compact Imaging X-ray Spectrometer, PI M. Grande) is based on novel detector and filter/collimator technologies, and has performing the first lunar X-ray fluorescence global mapping in the 0.5–10 keV range [4,5,9], in order to map the lunar elemental composition. It was supported in its operation by XSM (X-ray Solar Monitor) which also monitored coronal X-ray emission and solar flares [6]. For instance, D-CIXS measurements of Si, Mg, Al, Si, Ca & Fe lines at 1.25, 1.49, 1.74, 3.7 & 6.4 keV, were made over North of Mare Crisium during the 15 Jan 2005 solar flare, permitting the first detection of Calcium from lunar orbit [9].

Bulk crustal composition has bearing on theories of origin and evolution of the Moon. D-CIXS produced the first global view of the lunar surface in X-ray fluorescence (XRF), elemental abundances of Mg, Al and Si (and Fe when solar activity permitted) across the whole Moon. The South Pole-Aitken Basin (SPA) and large lunar impact basins have been also measured with D-CIXS.

SMART-1 overall planetary science: SMART-1 science investigations include studies of the chemical composition of the Moon, of geophysical processes (volcanism, tectonics, cratering, erosion, deposition of ices and volatiles) for comparative planetology, and high resolution studies in preparation for future steps of lunar exploration. The mission can address several topics such as the accretional processes that led to the formation of rocky planets, and the origin and evolution of the Earth-Moon system [8].

SMART-1 operations and coordination: The Experiments have been run according to illumination and altitude conditions during the nominal science phase of 6-months and 1 yr extension, in elliptical Moon orbit. The planning and co-ordination of the Technology and science experiments operations was carried out at ESA/ESTEC (SMART-1 STOC). The data archiving is based on the PDS (Planetary Data System) Standard. The SMART-1 observations have been coordinated with upcoming missions. SMART-1 has been useful in the preparation of Selene Kaguya, the Indian lunar mission Chandrayaan-1, Chinese Chang'E 1 , the US Lunar Reconnaissance Orbiter, LCROSS, and subsequent lunar landers. SMART-1 is contributing to prepare the next steps for exploration: survey of resources, search for ice, monitoring polar illumination, and mapping of sites for potential landings, international robotic villages and for future human activities and lunar bases.

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