SMART-1 LUNAR SCIENCE PLANNING

D. Koschny, B.H. Foing*, D. Frew, M. Almeida, M. Sarkarati, J. Volp, M. Grande, J. Huovelin, J.-L. Josset, A. Nathues, A. Malkki, G. Noci, B. Kellett, S. Beauvivre, D. Heather, J.Zender, P. McMannamon, G. Schwehm, O. Camino, R. Blake, and *SMART1 Operations and Science Technology Working Teams, ESTEC/SCI-S, postbus 299, 2200 AG Noordwijk, NL, Europe*, (Detlef.Koschny@esa.int)

Introduction: The SMART-1 spacecraft reached lunar capture on 17 November 2004, and on 15 March 2005 a lunar orbit 400-3000 km for a nominal science period of six months, with 1 year science extension. We report on the SMART-1 science planning methods, tools and lessons learned.

SMART-1 operations

The SMART-1 spacecraft [1-3] is operated from ESOC in Darmstadt. The Mission Operations Centre (MOC) includes the Main Control Room (MCR) augmented by a Flight Dynamics Room, Dedicated Control Rooms, and Project Support Rooms. During the Launch and Early Orbit Phase (LEOP) and during the Moon Capture Phase, the MCR was used for SMART-1 mission control. During the routine operations phases, a Dedicated Control Room has been used.

SMART-1 science operations and coordination:

The planning and co-ordination of the Technology and science experiments operations was carried out at ESA/ESTEC at the SMART-1 Science and Technology Operations Coordination (STOC). STOC interfaces to the MOC to which it provided inputs to the Flight Operation Plan for the payload commanding at spacecraft level. The STOC implements joint payload operations, following overarching priorities defined by science themes. The coordination of the scientific activities was carried within the Science and Technology Working Team (STWT) chaired by the Project Scientist, and via the STOC. Experiment requests for operations, commands and data delivery are routed via the STOC.

The Experiment Operation Facilities are located at each Principle Investigator site. They are connected to the STOC and MOC via the network and remotely operate the experiments.

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. Different operation modes for the camera have been used (see Figs 1 & 2) .

Highlights from instruments performances, operations and results can be found in [4-12].

The data archiving at ESA Planetary Science Archive is based on the PDS (Planetary Data System) Standard.

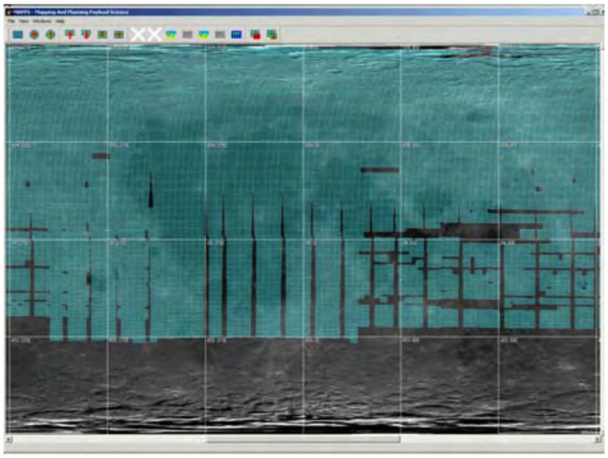

Fig. 1: Lunar coverage obtained with the AMIE camera in synoptic survey mode in May 2005.

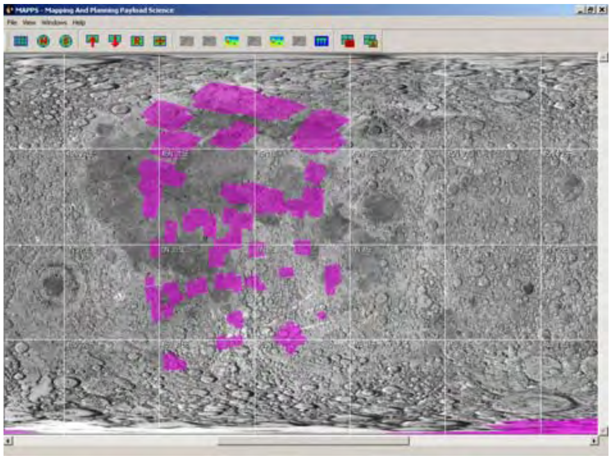

Fig. 2: Coverage for specific targeted observation during an operation week 2 in January 2006. A specific push broom mode in Oct-Dec 05 and April-May 06 is used for high resolution colour targeted imaging.

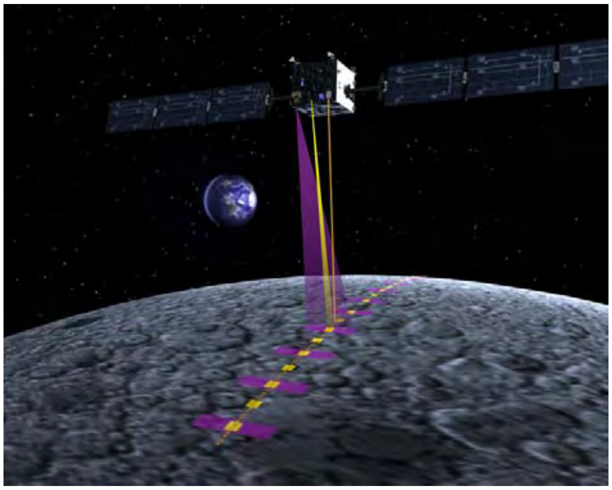

Fig. 3: Comparison between the swaths of the SMART-1 remote sensing instruments in lunar orbit: D-CIXS (32 x 12 deg), AMIE (5x5 deg or 2.5x1.25 deg colour frames) and SIR (4 arcmin point spectral continuous mapping)

Push-broom colour imaging. The pushbroom mode technique is particularly suited for colour imaging of the lunar surface. In push-broom mode, AMIE takes images along a line on the Moon's surface perpendicular to the groundtrack of the spacecraft. It relies on the orbital motion of the spacecraft to reposition it as it records a sequence of images known as an image swath. The AMIE camera on board SMART-1 has fixed-mounted filters which see the Moon in different colour bands. The spacecraft is moving over the Moon's surface. This supports studies of the mineralogical composition on the lunar surface, which in turn lets scientists deduce details of the formation of our celestial companion.

Multi-phase angle imaging and target tracking. Most of the time, the SMART-1 spacecraft pointing direction is exactly downwards to the Moon, the so-called 'nadir-pointing', even during pushbroom operations. But on occasion SMART-1 adopted another special pointing mode, the so-called target-tracking mode. As the spacecraft moves around the Moon, it is commanded such that even though it moves over the lunar surface with several 100 metres per second, it keeps pointing to the same target for a certain period of time.

SMART-1, for example, observed the lunar crater Lichtenberg using the target-tracking mode (see Figure 4). In this particular case, the distance between the target and the spacecraft changes over approximately 6 minutes by 100 km. The prominent crater in the lower right of the image is crater Lichtenberg, with a diameter of 20 km. The actual target of this observation was the ghost crater on the lower left of Lichtenberg. It is almost hidden by overflown lava from Oceanus Procellarum in which it is located. This area is of high geological interest as it is thought to contain the youngest basalts on the Lunar surface, with an age of only 1 Ga. The infrared spectrometer on board SMART-1, SIR, was measuring the composition of this area during these measurements. Whereas the multi-spectral camera aboard the US Clementine mission had constant illumination conditions, SMART-1's orbit offered different viewing angles. AMIE's views correlated with other measurements of the same lunar areas will allow scientists to better interpret imaging and spectral data.

Fig. 4 : One of the images taken during the target tracking of a ghost crater just next (lower left) to the prominent crater Lichtenberg with a diameter of 20 km. Copyright: ESA/SMART-1/ Space-X

We reported on some of the SMART-1 lessons learned in lunar science planning, and applicable to future missions [12]. (see also http://sci.esa.int/smart-1/).

References: [1] Foing, B. et al (2001) Earth Moon Planets, 85, 523 . [2] Racca, G.D. et al. (2002) Earth Moon Planets, 85, 379. [3] Racca, G.D. et al. (2002) P&SS, 50, 1323. [4] Grande, M. et al. (2003) P&SS, 51, 427. [5] Dunkin, S. et al. (2003) P&SS, 51, 435. [6] Huovelin, J. et al. (2002) P&SS, 50, 1345. [7] Shkuratov, Y. et al (2003) JGRE 108, E4, 1. [8] Foing, B.H. et al (2003) AdSpR, 31, 2323. [9] Grande, M. et al (2006) PSS, [10] Pinet, P. et al (2005) P& SS, 53, 1309. [11] Josset J.L. et al (2006) Adv Space Res 37, 14. [12] Foing B. et al (2006) Adv Space Res. 37 , 6.