A WIDE-ANGLE CAMERA FOR THE MOBILE ASTEROID SURFACE SCOUT (MASCOT) ON HAYABUSA-2.
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Introduction: MASCOT, a Mobile Asteroid Surface Scout, will support JAXA's Hayabusa-2 mission to investigate the C-type asteroid 1999 JU3 *[1]* that is expected to be a rubble-pile, with a size slightly larger than Itokawa. Hayabua-2 is scheduled for launch in the 2014/2015 time frame for a rendezvous with 1999 JU3 in 2018. The German Aerospace Center (DLR) develops MASCOT with contributions from CNES (France) *[2]*. Main objective is to in-situ map the asteroid's geomorphology, the intimate structure, texture and composition of the regolith (dust, soil and rocks), and the thermal, mechanical, and magnetic properties of the surface in order to provide ground truth for the orbiter remote measurements, support the selection of sampling sites, and provide context for the returned samples. MASCOT comprises a payload of four scientific instruments: camera, radiometer, magnetometer and hyperspectral microscope. The camera (MASCOT CAM) was designed and built by DLR's Institute of Planetary Research, together with Astrium Germany.

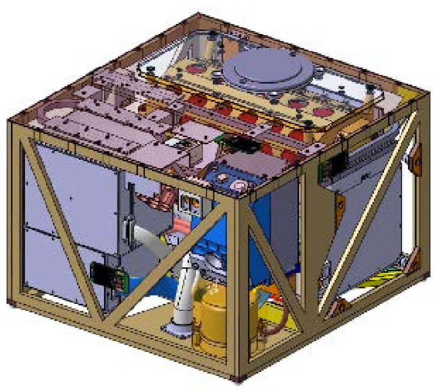

Figure 1: MASCOT lander, with the camera (in blue) mounted inside.

MASCOT CAM Science Objectives: The Hayabusa-2 mission will perform the first in-depth and up-close examination of a C-type asteroid. It is hoped that the Hayabusa 2 mission will shed more light on the nature and origin of this enigmatic class of asteroids. The MASCOT camera will provide the ground truth for the orbiter remote sensing observations. In addition, it will provide context for measurements by the other lander instruments (radiometer, spectrometer), and the orbiter sampling experiment. By imaging during the descent and on the surface, it will characterize the geological context, mineralogy and physical properties of the surface (e.g. rock and regolith particle size distributions). During the day, clear filter images will be acquired. During the night, illumination of the dark surface by means of an illumination device (consisting of four arrays of monochromatic light emitting diodes working in four spectral bands) will permit color imaging. This may allow to identify minerals, organics, and, possibly, ices. Continued imaging during the surface phase and the acquisition of image series at different sun angles over the course of a day will also contribute to the physical characterization of the asteroid surface by allowing to characterize time-dependent processes and the photometric properties of the regolith. Combined Hayabusa-2 and MASCOT visual and spectral observations will cover a wide range of observational scales. The MASCOT camera observations, combined with the MASCOT hyperspectral microscope and radiometer spectral observations, will serve as a strong tie point between Hayabusa-2's remote sensing science (10^3-10^{-3}m) and sample science (10^{-3}-10^{-6}m). *[3,4]*

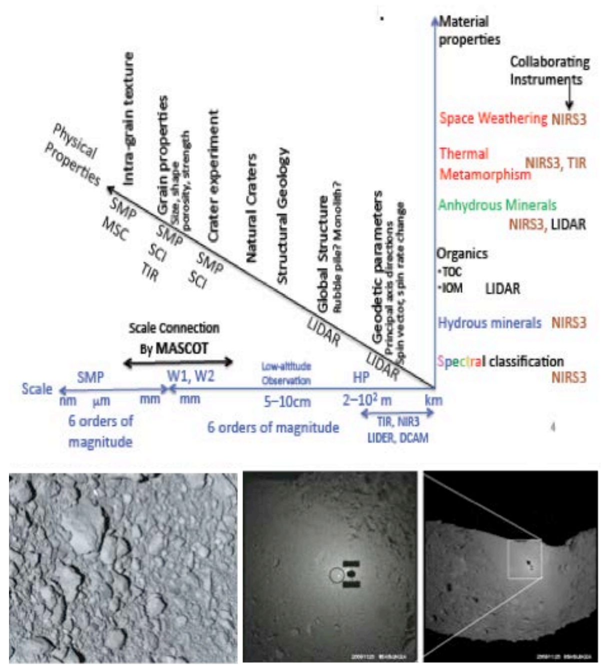

Figure 2: Hayabusa 2/MASCOT combined measurement scales.

Instrument Description: The MASCOT camera, a highly compact CMOS camera, is designed to cover a large part of the surface in front of MASCOT. It is mounted inside the lander slightly tilted, such that the center of its 55° square field-of-view is aimed at the surface at an angle of 22° with respect to the surface plane. This means that both the surface close to the lander and the horizon are in the FOV, when the lander rests on an even surface. The camera is designed according to the Scheimpflug principle, which ensures that the entire scene along the camera's depth of field (150mm to infinity) is in focus. The camera is equipped with a 1024x1024 pixel CMOS sensor sensitive in the 400-1000 nm wavelength range, peaking at 600-700 nm. Together with the f-16 optics, this yields a nominal ground resolution of 150 micron/px at 150 mm distance (diffraction limited). An LED array, equipped with 4x36 LEDs of different colors (centered at B:470nm, G: 530nm, R: 624nm, IR: 805nm), is available to illuminate the surface at night for color imaging. To fit in the limited payload mass allocation for MASCOT, the camera optical head including illumination unit and electronics is designed as a highly compact camera with a low mass of 403g. The power consumption is less than 6.4W (during multiband night-time imaging).

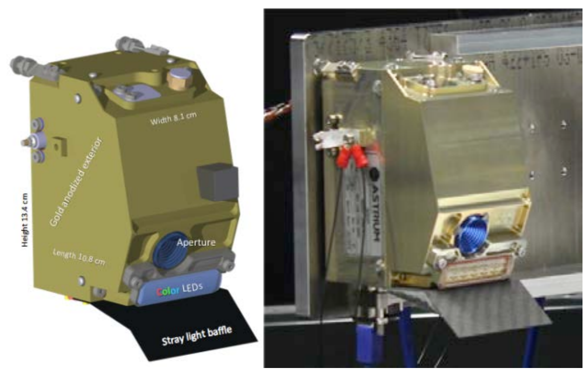

Figure 3: Engineering drawing and photo of the MASCOT camera flight model.

Instrument Performance and Calibration: The MASCOT camera was geometrically calibrated at Astrium, where the focus was established. Geometric distortion, thermal focus stability, as well as in- and out-field straylight were also measured and confirmed to be within the design limits.

Radiometric calibration was performed at DLR Berlin. This campaign included an absolute radiometric calibration of the flight model, including flat field and linearity characterization for different exposure times, a characterization of the camera spectral sensitivity, a complete spectral characterization of the LEDs, as well as a characterization of the LED illumination spatial distribution (figure 5).

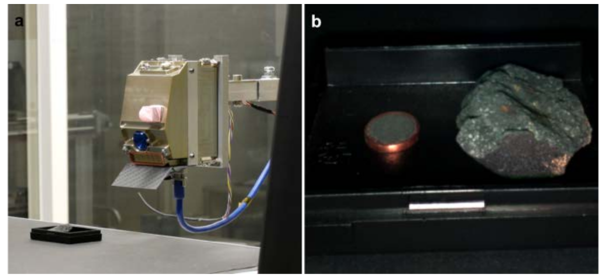

Figure 4: Color imaging of a powder-pressed pellet and a slab of the Murchison meteorite.

Part of the radiometric calibration campaign was also the spectral measurement of samples of the Murchison meteorite. This was part of a cross-calibration of the MASCOT camera with the Hayabusa-2 ONC camera. Figure 4a shows the experimental setup at DLR with the MASCOT camera on a gimbal. In front of the camera is a tableaux with a powder-pressed pellet and a slab of the meteorite, positioned to get a visual impression of the image spatial resolution. Figure 4b shows the aquired RGB image, which is a combination of images in three spectral bands (R,G,B), corrected for dark current.

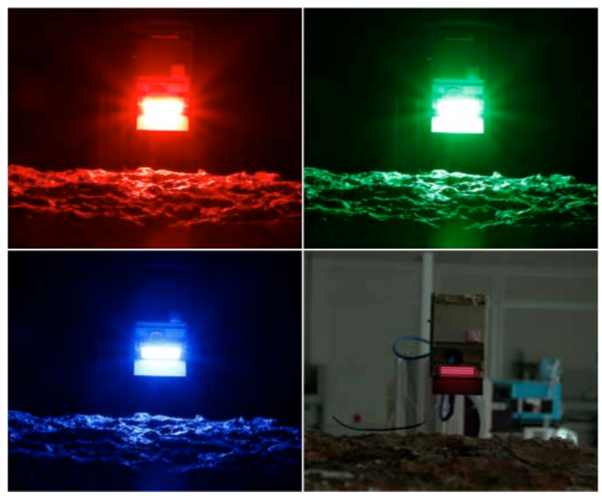

Figure 5: MASCOT/CAM spectral characterization during radiometric calibration of the flight model.

References: *[1] Vilas, F., Special Analysis of Hayabusa-2 Near Earth Asteroid Targets 162173 1999 JU3 and 2001 QC3, Astronomical J. 1101-1105, 2008; [2] Ulamec, S., et al., Landing on Small Bodies: From the Rosetta Lander to MASCOT and beyond; Acta Astronautica, Vol. 93, pp. 460-466, 2014; [3] Jaumann, R. et al., A Mobile Asteroid Surface Scout (MASCOT) for the Hayabusa 2 Mission to 1999 JU3: The Scientific Approach, 44th LPSC, abstract #1500, 2013; [4] Schroeder, S. et al., A Camera for the MASCOT Lander on-board Hayabusa-2, EPSC Abstracts,Vol. 8, EPSC2013-588, 2013.*