The MASCOT Camera on Hayabusa-2's asteroid lander MASCOT (Mobile Asteroid Surface Scout). N. Schmitz[1], A. Koncz[1], R. Jaumann[1], H. Hoffmann[1], D. Jobs[1], J. Kachlicki[1], H. Michaelis[1], S. Mottola[1], B. Pforte[1], S. Schroeder[1], R. Terzer[1], F. Trauthan[1], M. Tschentscher[1], S. Weisse[1], T.-M. Ho[2], J. Biele[3], S. Ulamec[3], B. Broll[4], A. Kruselburger[4], L. Perez-Prieto[4]. [1]DLR, Institute of Planetary Research, Berlin, Germany, Nicole.Schmitz@dlr.de, [2]DLR, Institute of Space Systems, Bremen, Germany, [3]DLR-MUSC, Linder Höhe, Cologne, Germany, [4]Airbus DS, Germany.

Introduction: The MASCOT Camera (MSC CAM) is part of the MASCOT lander's science payload. The MASCOT lander (Mobile Asteroid Surface Scout) has been launched to asteroid 1999JU3 onboard JAXA's Hayabusa-2 asteroid sample return mission on Dec 3rd, 2014. It is scheduled to arrive at 1999JU3 in 2018, and return samples to Earth by 2020.

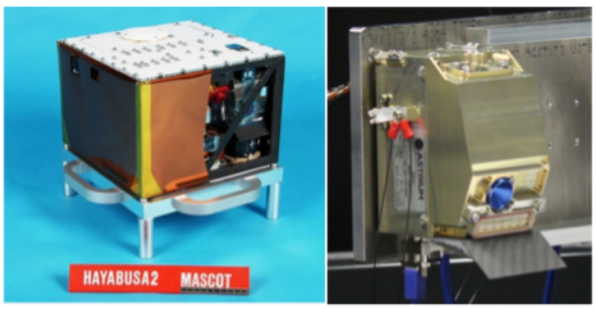

Figure 1. Left: MASCOT lander (camera mounted in the upper left corner). Right: MSC CAM flight model.

MASCOT, developed by DLR with contributions from CNES (France), will support Hayabusa-2's 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. After an initial phase of asteroid characterization, MASCOT will be deployed from the main spacecraft, and then investigate multiple surface sites by means of a hopping mechanism. MASCOT comprises a payload of four scientific instruments: camera, radiometer, magnetometer and hyperspectral microscope. MSC CAM was designed and built by DLR's Institute of Planetary Research, together with Airbus DS Germany. The scientific goals of the MSC CAM investigation are to: a) provide the ground truth for the orbiter remote sensing observations, b) provide context for measurements by the other lander instruments (radiometer, spectrometer), and the orbiter sampling experiment, and c) 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. The MASCOT camera observations, combined with the MASCOT hyperspectral microscope and radiometer spectral observations, will cover a wide range of observational scales and 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]

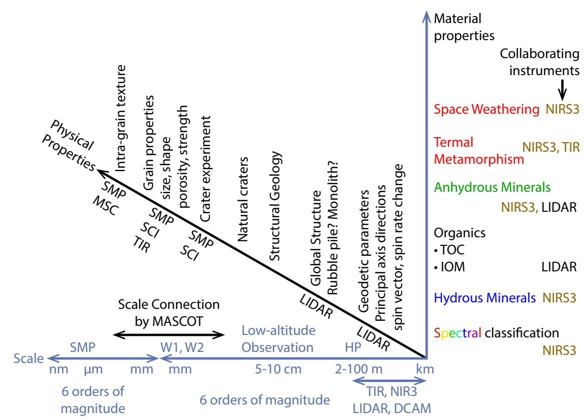

Figure 2. Hayabusa 2/MASCOT combined measurement scales.

Instrument Design: The MASCOT camera, a highly compact wide-angle 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 54.8° square field-of-view is aimed at the surface at an angle of 22° with respect to the surface plane. This is to ensure 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's boresight has been calibrated with the MARA radiometer. The camera is designed according to the Scheimpflug principle, so that the entire scene along the camera's depth of field (150mm to infinity) is in focus, if the lander rests on an even surface. The camera utilizes 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 4 different colors (cf. table 1) is available to illuminate the surface at night for color imaging.

The camera flight model has undergone standard radiometric and geometric calibrations both at the component and system (lander) level. MSC CAM uses a CNES-provided wavelet compression algorithm to maximize data return within stringent mission down-link limits.

Table 1. MSC CAM Instrument Characteristics

Key Characteristics

- Highly compact CMOS imaging system
- Mounted inside MASCOT lander, upper left corner. Boresight calibrated with MASCOT MARA (radiometer)
- Boresight direction (optical axis): azimuth: 0° (±180°), elevation: -(22 ± 0.5)°
- Illumination Unit (4 x 36 LEDs) for colour imaging
- 77 x 96 x 114 mm (without alignment cube, LED baffle)
- Mass: 0.403 kg
- Typical power consumption: 1.5W panchromatic, 6.5 W multiband nighttime imaging
- Onboard calibration target (shared with MASCOT MARA)

Optics

- Double gauss lens system
- Fixed focal length
- Design according to Scheimpflug principle, Scheimpflug angle: 7.395°
- 14.8 mm focal length, f/16 system
- FOV (square): 54.8° x 54.8°
- Depth of Field: 150 mm to ∞
- Pixel footprint @ 15cm: 0.15 mm
- Optical Performance: Diffraction-limited, PSF <30 µm
- <1% f tanθ geometric distortion

Illumination Unit

- 4x36 LEDs in 4 colours, centered at: 470 nm (Blue), 530 nm (Green), 640 nm (Red), 805 nm (NIR)

Image Sensor

- 1024 x 1024 CMOS imaging sensor (ON Semiconductor)
- 15 micron square pixels
- Quantum efficiency x fill factor: 30% (between 450 nm and 750 nm)
- Spectral range: 400 nm - 1000 nm
- Full well (to 5% line): 135 Ke-
- Average dark signal @ 22 ± 3°C: 1173.9 e-/s

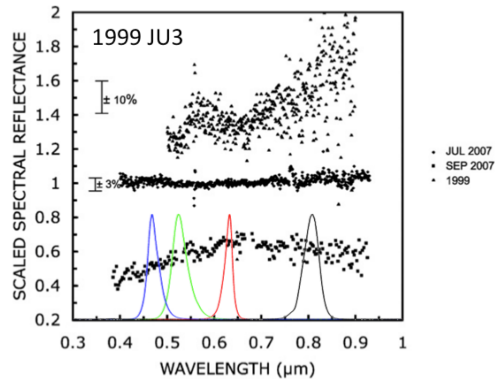

Figure 3. Normalized spectral reflectance of the MASCOT-CAM FM LEDs, drawn over the observations of asteroid 1999JU3 [1].

A piece of the Murchison meteorite has been used for spectral cross-calibration between MSC CAM, MSC MicrOmega (hyperspectral microscope) and Hayabusa-2's ONC-T camera.

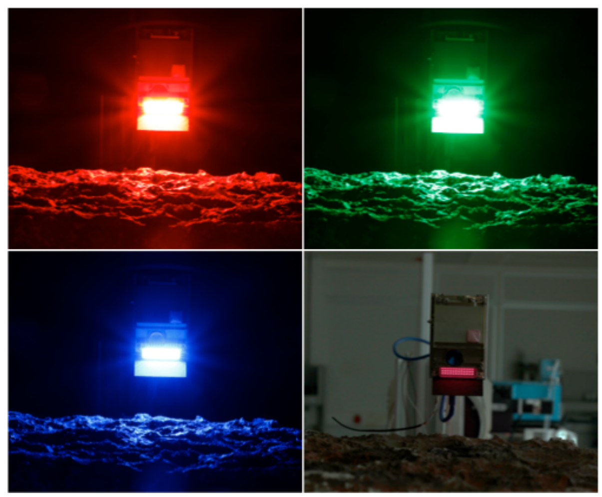

Figure 4. MASCOT/CAM spectral characterization during radiometric calibration of the flight model.

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.