# THIS IS WHAT A MASCOT CAN DO FOR YOU – AT APOPHIS.

C. Lange[1]*, T.-M. Ho, J. T. Grundmann[1#], S. Chand[1], [1]DLR German Aerospace Center, Institute of Space Systems, Robert-Hooke-Strasse 7, 28359 Bremen, Germany, *Caroline.Lange@dlr.de, #jan.grundmann@dlr.de.

**Introduction:** In a similarly brief event some 10½ years before Apophis' fly-by on Friday, April 13th, 2029, the Mobile Asteroid Surface Scout, MASCOT, successfully completed its 17-hours mission on the ~km-sized C-type potentially hazardous asteroid (162173) Ryugu. Investigating the surface and its thermal properties, looking for a magnetic field, and imaging the stark landscapes of this dark rubble pile, it contributed valuable close-up information before the surface sampling by its mothership, HAYABUSA2.

**MASCOT** DLR in collaboration with the French space agency, CNES, has developed the Mobile Asteroid Surface Scout, MASCOT, a small asteroid lander which packs four full-scale science instruments and relocation capability into a shoebox-sized 10 kg spacecraft. [1] It carries the near-IR soil microscope, MicrOmega (MMEGA), [2] a high dynamic range black-and-white camera with night-time multicolour LED illumination (MasCAM), [3] a 6-channel thermal IR radiometer (MARA), [4] and a fluxgate magnetometer (MasMAG). [5]

*MicrOmega* is a near-infrared imaging spectrometer/microscope for the study of mineralogy and composition at grain scale. It acquires 3D (x,y,λ) microscopic image-cubes of an area approximately (3 mm)² in size with a spatial sampling of (25 µm)² in (128² pixel)² images. For each pixel, the spectrum is acquired in contiguous spectral channels covering the range 0.99 to 3.55 µm with spectral sampling better than 40 cm$^{-1}$ and a signal-to-noise ratio of 100, over the entire spectral range.

*MasCAM* uses a clear filter 1 Mpixel Si-CMOS sensor with high dynamic range imaging capability covering a (60°)² field of view, pointed slightly down to image an area in front of the lander. Multiple observations during the day are used for detailled studies of the reflection and scattering properties of the surface. During daytime, images are black-and-white. At night, colour images are taken using 4-channel IR-RGB LED illumination.

*MARA* is a 6-band multispectral thermal infrared radiometer, covering wavelengths from 5 to 100 µm. In addition to a clear filter, the remaining channels are narrow-band filtered and can be adapted to a thermal infrared instrument aboard the orbiter.

*MasMAG* is a vector compensated three-axis fluxgate magnetometer consisting of a digital electronics board and a sensor head. It has a long heritage from previous space missions. Due to the extreme conditions the design covered in these missions, the sensors can be mounted outside of the temperature controlled compartment.

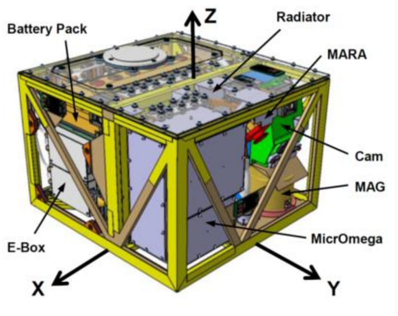

*Fig.1 – The MASCOT Landing Module*

The MASCOT Flight Model (FM) was delivered to JAXA mid-June 2014 and was launched aboard the HAYABUSA2 space probe on December 3rd, 2014, to asteroid (162173) Ryugu. MASCOT is an organically integrated high-density constraints-driven design. [6,7]

**MASCOT2 for AIM in AIDA:** Closest to a follow-on came MASCOT2, developed for the AIM spacecraft which until 2016 was the partner mission of DART in the joint NASA-ESA AIDA mission to perform and study a kinetic impact on 'Didymoon', the moonlet of binary NEA (65803) Didymos.[8] MASCOT2 was a nanolander design to support the surface element of the bistatic low-frequency radar on AIM, LFR. The MASCOT2 design was based on extensive re-use of MASCOT technologies but with tailored capability upgrades in the details of many subsystems. Changes were based as much on the different mission as on the lessons from MASCOT, by then already learned or at least anticipated due to the progress in MASCOT on-asteroid mission planning and the growing knowledge in the highly dynamic field of small solar system body science.

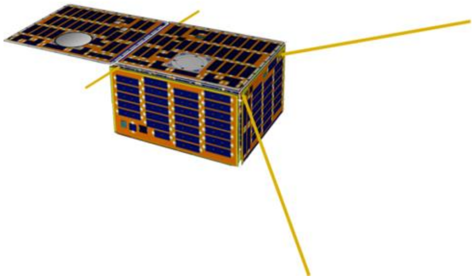

*Fig. 2 - The MASCOT2 nanolander for AIM*

Following the cancellation of MASCOT2 with AIM and the evaluation of nanolander requests and responses to other studies and proposals, the MASCOT team is currently pursuing maximum as-is re-use incarnations for future MASCOT nanolanders for near-term missions as well as designs more optimized in detail, similar in that respect to MASCOT2. Entirely new developments of the MASCOT concept are being studied, as well. [9]

**Small Spacecraft Synergies:** In particular for small interplanetary main spacecraft designed to fit the ‘mini’ and ‘micro’ rideshare payload slots on launch vehicles, resource-sharing concepts have been developed based on technologies qualified in the Gossamer-1 solar sail deployment demonstrator project, itself a small ‘micro’ spacecraft composed of 5 independent ‘nano’ spacecraft. [10,11]

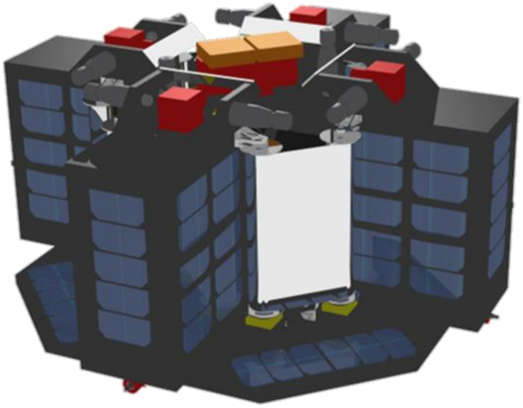

*Fig.3 – Un pour tous, tous pour un – the shared resources multi-sub-spacecraft design of Gossamer-1*

These concepts enable mutual support of the MASCOT nanolander and the small spacecraft carrying it during the cruise phase and until lander separation, for example power redistribution, shared batteries, more data handling and communication capabilities, and additional instruments and viewing angles.

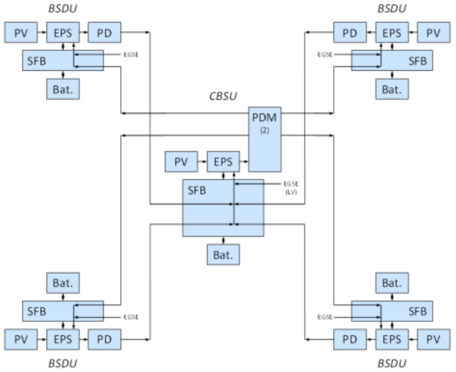

*Fig. 4 - The Gossamer-1 Charging Network sharing all power resourcesof 5 nanospacecraft*

Another feature of the Gossamer-1 system is a wireless communication network between all participating spacecraft. The communication system of Hayabusa2 also shared this feature for optional parallel operation of the three MINERVA-II landers and MASCOT. A more recent addition to the MASCOT portfolio are propulsion systems that enable self-transfer of the lander from a more distant carrier spacecraft. Together, these enable the operation of one lander by another spacecraft that did not carry it to its destination. [12,13]

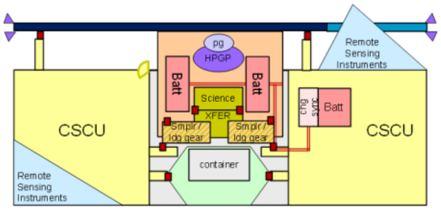

*Fig.5 – Notional accommodation of a sample-return lander integrated organically with its carrier.*

**Conclusion:** From the portfolio of MASCOT follow-on studies, optimized designs of MASCOT@Apophis can be derived to address the needs of the many science missions proposed to rendezvous with Apophis. More than one MASCOT landing can be achieved by the end of the decade.

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**References:** [1] T.-M. Ho et al., (2016) Sp.Sci.Rev., DOI 10.1007/s11214-016-0251-6. [2] J.-P. Bibring et al., (2017) Sp.Sci.Rev. 208, 401-412. [3] R. Jaumann et al., Sp.Sci.Rev. (2016), DOI 10.1007/s11214-016-0263-2. [4] M. Grott et al., Sp.Sci.Rev. (2016), DOI 10.1007/s11214-016-0272-1. [5] David Herčík et al., (2016) Sp.Sci.Rev., DOI 10.1007/s11214-016-0236-5. [6] Grimm et al., (2020) CEAS Space Journal, doi 10.1007/s12567-020-00302-y. [7] Grimm et al., (2019) Progress in Aerospace Sciences 104 (2019) 20–39. [8] C. Lange et al., (2018) Acta Astron., doi: 10.1016/j.actaastro.2018.05.013. [9] C. Lange et al., (2018) Adv. in Sp. Res., https://doi.org/10.1016/j.asr.2018.05.013. [10] P. Seefeldt (2017), Adv. in Sp. Res. doi:10.1016/j.asr.2017.06.006. [11] P. Seefeldt et al., Adv. in Sp. Res., doi:10.1016/j.asr.2016.09.022. [12] S. Chand (2020) MASCOT Follow-on Mission Concept Study with Enhanced GNC and Propulsion Capability of the Nano-lander for Small Solar System Bodies (SSSB) Missions. [13] J.T. Grundmann et al., Acta Astr., doi.org/10.1016/j.actaastro.2018.03.019.