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MASCOT2, a Lander to Characterize the Target of an Asteroid Kinetic Impactor Deflection Test (AIM) Mission

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Abstract

In the course of the AIDA/AIM mission studies [1,2] a lander, MASCOT2, has been studied to be deployed on the moon of the binary Near-Earth Asteroid system, (65803) Didymos.
The AIDA technology demonstration mission, composed of a kinetic impactor, DART, and an observing spacecraft, AIM, has been designed to deliver vital data to determine the momentum transfer efficiency of the kinetic impact and key physical properties of the target asteroid. This will enable derivation of the impact response of the object as a function of its physical properties, a crucial quantitative point besides the qualitative proof that the asteroid has been deflected at all.
A landed asset on the target asteroid greatly supports analyzing its dynamical state, mass, geophysical properties, surface and subsurface structure. The lander's main instrument is a bistatic, low frequency radar (LFR) [3a,b] to sound the interior structure of the asteroid. It is supported by a camera (MasCAM) [4], a radiometer (MARA)[5], an accelerometer (DACC [9]), and, optionally regarding the science case, also a magnetometer (MasMAG)[6].

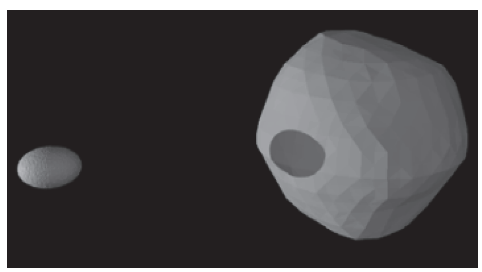

Figure 1 Sketch of the Didymos binary system. Diameter of primary: (shape from radar) 775m±10%, diameter of secondary (shape assumed) 163m±10%, bulk density 2146 kg/m³, system semimajor axis 1180 m, orbital period and assumed rotation period of secondary 11.92h, rotation period of primary 2.26h.

1. Design

MASCOT2 is a small (~13kg) long-lived lander, based on the design of MASCOT, which is part of the Hayabusa2 mission [7,8].

The lander will be deployed from the mother spacecraft in close vicinity to and soft-land on ”Didymoon”. After several bounces and likely re-location and self-righting by an internal mobility mechanism, it will operate for several months on the asteroid surface and provide detailed information about the asteroid’s interior, its landing site and key physical properties (Mechanical, thermal, structural) of the surface material.

Deployables
MASCOT2 will carry deployable LFR antennae (one for descent, one pair for on-surface ops) and a deployable photovoltaic top panel to enhance power generation once it has arrived at the optimal site for LFR operations. The deployment mechanisms have been studied in detail.

1.1 Payload

Besides the unit of LFR aboard the lander, a camera will provide high-resolution images of the landing area and of the regolith in particular, and accelerometers will interpret the bouncing dynamics. During the DART impact, MASCOT2 will possibly be able to detect the seismic shock with its accelerometers. Exact timing could give valuable information on the internal structure (from the velocity of p-waves). A radiometer will determine the thermal inertia at the landing site and, with MasCAM, track seasonal changes in the thermo-optical environment. MAG will investigate the interplanetary medium interacting with the binary system while on site on the moonlet as it orbits the primary, and the moonlet’s immediate environment during the descent, landing, and relocation hopping phases.

1.2 Operational concept

- CAM pictures and MARA measurements at each resting position
- MARA measurement at least during one whole Didymoon day
- Seven LFR measurements to scan the interior of the body
- The MASCOT2 bus will run continuously but also supports duty-cycled operation based on photovoltaic power available at the respective sites.
- Payloads can be used as heat dissipation source for thermal management
- System operation, payload operation and COM is possible during charging of battery
- System operation, payload operation and COM is possible during day or night
- System power consumption is averaged
- Data uplink MASCOT to AIM: 32 kbit/s similar to MASCOT
- Data Margin used: 20%

MASCOT2 will also serve as a technology demonstrator for asteroid landing and extended operations, powered by a solar generator mounted on deployable panels.

Table 1 – operational phases. The duration of the phases is as follows: Orientation , up to 24h; DCP-2, DCP-3: each 60 moon days; impact, 30 moon days. 1 Moon day is ~11.9h.

Phase	LFR	CAM	MARA	DACC
SDL	4 hours	5 pictures	On	On
Orientation		14 pictures	On	
Relocation	1 hour	5 pictures	On	On
DCP-2	7 scans	14 pictures	On	
Impact	Beacon		On	
DCP-3	7 scans	14 pictures	On	

2. Deployment on Didymoon

Contrary to Keplerian deployment on a single body with a defined escape velocity, the deployment proposed here leads to a dynamical trapping of the lander on the surface despite impact velocities near classical V_{esc} if only very little damping is present. Surface regolith properties cannot be reliably estimated prior to launch. Moreover, the presence of rocks at the surface, that present a hard surface, is likely. Thus, the damping should be considered as the damping of MASCOT2 on a very hard surface (such as concrete). This will give a coefficient of restitution of ≤ 0.6 from the MASCOT2 structure alone.

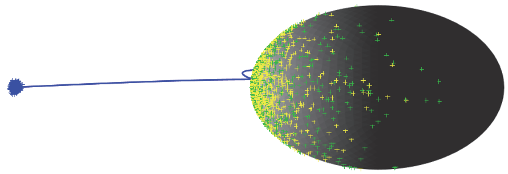

Figure 2 Typical deployment through L2. COR = 0.60 (constant); Spring delta-v: possible range 3 to 15 cm/s, nominal 5 cm/s, speed accuracy +/-30% at 3sigma, angular accuracy +/-15° at 3sigma. Spacecraft: state vector known, at time of release, to +/-25 m and +/-5 mm/s , both 3sigma. Altitude of release fixed at 200m. Success rate is 100% of trajectory impacted. 99.9% of trajectories are eventually settled (i.e. 1 trajectory out of the 1000 bounced back). Yellow symbols: 1st touchdown. Green symbols: final rest positions

It was found that robust deployment (meaning at 3sigma success probability) of MASCOT2 on Didymoon is possible even from an altitude of 200m (~150m over L2), provided these conditions are fulfilled, in order of importance:
1) the velocity dispersion (sum of spacecraft velocity dispersion and the one by the separation device) is low enough (order of < 1 cm/s at 3sigma)
2) the combined coefficient of restitution (surface and structural, worst case only structural) is low enough (< about 0.6), and
3) the positional dispersion at the point of release is low enough (order of dozens of m)
Then the resting ellipse dispersion on the surface is also small enough to virtually guarantee sufficient elevation of the Sun such that MASCOT2 can determine its attitude and can relocate (autonomously or commanded) to the desired operational site in about 2 hops.
A sizable libration (geometric libration for orbital eccentricity 0.16) is no hindrance to successful deployment.

3. Summary and Conclusions

MASCOT2 as a long-lived, hopping lander for the AIDA/AIM mission will significantly enhance our understanding of the beta factor for kinetic deflectors. This is accomplished by a bistatic radar determination of the interior structure of the target and, from its other experiments, an understanding of the surface mechanical and thermal properties. Detailed design studies have proven the Lander's feasibility; there is also a strong heritage from MASCOT flying on the Hayabusa2 mission (Ho et al., 2016). AIM funding has not been fully confirmed by ESA Member States during the ESA ministerial council meeting in 2016, yet the concept of MASCOT2 stays valid and we support flying MASCOT2 on a full AIM mission even if 2 years later than planned.

References

[1] Cheng, A. F., J. Atchison, et al. (2015). "Asteroid impact and deflection assessment mission." Acta Astronautica **115**: 262-269.

[2] Michel, P., A. Cheng, et al. (2016). "Science case for the Asteroid Impact Mission (AIM): A component of the Asteroid Impact & Deflection Assessment (AIDA) mission." Advances in Space Research(57): 2529-2547.

[3a] Herique, A. and V. Ciarletti (2016). A Direct Observation of the Asteroid's Structure from Deep Interior to Regolith: Two Radars on the AIM Mission. 47th Lunar and Planetary Science Conference.

[3b] Herique, A., et al., , 2017, Direct Observations of Asteroid Interior and Regolith Structure: Science Measurement Requirements, ASR submitted to ASR.

[4] R. Jaumann, N. Schmitz, A. Koncz, et al. (2016), The Camera of the MASCOT Asteroid Lander on Board Hayabusa2; Space Science Reviews, DOI 10.1007/s11214-016-0263-2

[5] M. Grott, J. Knollenberg, et al. (2016), The MASCOT Radiometer MARA for the Hayabusa 2 Mission, Space Science Reviews, DOI 10.1007/s11214-016-0272-1

[6] David Herčík, Hans-Ulrich Auster, et al. (2016), The MASCOT Magnetometer; Space Science Reviews, DOI 10.1007/s11214-016-0236-5

[7] Ulamec, S. and J. Biele (2015). Relevance of PHILAE and MASCOT In-Situ Investigations for Planetary Defense. IAA Planetary Defense Conference. Frascati, Italy.

[8] Ho, T.-M., et al. (2016). "MASCOT—The Mobile Asteroid Surface Scout Onboard the Hayabusa2 Mission." Space Science Reviews: 1-36.

[9] Biele, J., The small body bouncing lander (MASCOT-2) accelerometer experiment (DACC), Technical note DLR-RB-MUSC-TN-1036 Iss. 0.9.0.5 , J.Biele, 23.7.2016