SNATCHING A PROBE OF A GENUINE NEAR-EARTH ASTEROID: FAST SAMPLE RETURN OPPORTUNITY IN THE FRAME OF RAMSES MISSION SCENARIO. Martin Hilchenbach[1], Oliver Stenzel[1], Christian Renggli[1], Andreas Nathues[1], Norbert Krupp[1], Henning Fischer[1], Thorsten Kleine[1], Jens Biele[2], Stephan Ulamec[2], Jan Thimo Grundmann[3], Tra-Mi Ho[3], [1]Max Planck Institute for Solar System Research, Justus-von-Liebig-Weg 3, 37077 Göttingen, Germany,hilchenbach@mps.mpg.de, [2]Deutsches Zentrum für Luft- und Raumfahrt (DLR), Raumflugbetrieb und Astronautentraining, Microgravity User Support Center (MUSC), Linder Höhe 1, 51147 Cologne, Germany, [3]Institute of Space Systems (DLR), Robert-Hooke-Straße 7, 28359 Bremen

Introduction: A mission to (99942) Apophis would provide a unique opportunity to collect and return a regolith sample from a Near-Earth asteroid (NEA) as it passes very close to Earth [1,2]. ESA is currently investigating the possibility of an orbiter, as part of the RAMSES mission study, to fly close to (99942) Apophis before it makes its closest approach to Earth on 13 April 2029, with the aim of observing the tidal and magnetospheric effects on the NEA during this close flyby [3]. Later, the asteroid will be well observed by the OSIRIS-APEX (or OSIRIS-REx Extended Mission to Asteroid Apophis) mission [4].

At present, none of these missions or mission studies are investigating the possibility of sample return with a very short duration sample return leg, requiring only a tiny additional momentum to return to Earth. We will present the results of a forthcoming concurrent engineering (CE) study on the feasibility of a sample return capsule based on "now-term technology" available from the space industry and the necessary mandatory mechanical, electrical and software interfaces based on the experience gained from previous small asteroid projects [5].

Overview of envisaged mission scenario baseline: The Sample Return Probe should be launched as part of the RAMSES mission and meet all the RAMSES mission requirements. Depending on the launch date, we assume that RAMSES will rendezvous with asteroid (99942) Apophis in mid-February 2029, the spacecraft will be detached, land with autonomous navigation guidance, actively controlled by thrusters, sample the regolith, and be launched in mid-March 2029 and guided towards Earth at a speed of a few tens of metres per second relative to the asteroid. This is orders of magnitude less than the speed required by previous sample-return missions because of the very close Earth flyby of (99942) Apophis on 13 April 2029. The spacecraft will cover the distance to Earth in one month as the asteroid passes at a safe distance. The spacecraft's entry velocity is about 12.6 km/s, compared to the asteroid's 7.4 km/s due to Earth's gravitational field. By entering the atmosphere in phase with the Earth's rotation, the entry velocity can be slightly reduced [6,7]. Figure 1 illustrates the described scenario.

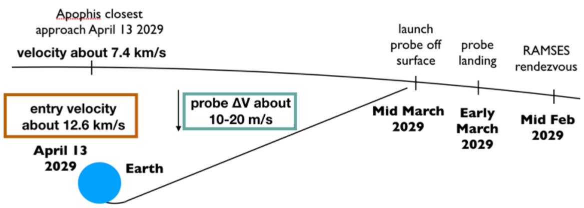

Fig. 1: Overview of sample return mission scenario as envisaged for Feb to Apr 2029 and the sample return and the asteroid swing-by will happen on the same date.

Design approach for CE study: Design approach for the CE study: The development will follow the classical approach with a primary CE study followed by project phases 0, A, B1 and B2, C and D [5]. The selected subsystems must be available as "now-term technology", similar to "off-the-shelf", and are expected to be available from the commercial cubesat technology providers. The required interfaces (mechanical, electrical, thermal and software) have to be adapted to the selected subsystems. The spacecraft is a complex system and therefore all subsystems require a high level of reliability. Two subsystems are most likely to be developed within the project as they are not standard systems addressed by current cubesat technologies: The entry capsule and the sampler. For both subsystem, designs, some flight proven, exist [8,9] and will need to be adapted in the early stages of the project, most likely in international collaborations.

Brief sketch of storyline for CE study: The envisaged operations are illustrated in Fig. 2: After launch, communication during cruise and near (99942) Apophis via RAMSES (high bandwidth). Direct communication to Earth only after separation (low bandwidth) from RAMSES, RAMSES can then remain at a safe distance. The initial mapping/reconnaissance phase, carried out by the spacecraft's navigation and guidance system, identifies possible sampling targets. Asteroid approach from a home position (about 20 km altitude) with ground control, similar to Hayabusa2. Tracking of features for final approach from a few kilometres down, simple mark-and-go "contrast seeker" with horizon tracker planned, effectively locking the probe to Apophis' rotational creep at about 5 - 10 cm/s. Toroidal rotary brush firing before touchdown, thruster push-down firing period on ground contact, full thrust ahead for about 10 sec, then shutter closed on bounce-back to prevent samples from drifting out again. Lift-off burn to near v-escape to allow time to recover parking position. Possible prior rehearsal and multiple sampling. Return to Earth with successive approach burns to the re-entry corridor based on automatic navigation and guidance systems and low-band communications with Earth.

Design envelope for CE study: The spacecraft will be designed around the selected entry capsule design. All other subsystems will be attached and integrated, such as a potential toroidal rotary brush sampling mechanism with particle ballistic labyrinth capture and shutter, or the data relay subsystem for near-RAMSES communications and data/electrical interfaces. The main structural envelopes for the capsule and interfaces will also need to be specified, and extensive use should be made of small documentation cameras based on previous experience. The attitude and orbit control system could be based on a 4 to 8 commercial cubesat module and guidance, navigation and control on a 2 to 3 cubesat module. For avionics, a mix of scalable on-board computers for space avionics and off-the-shelf cubesat modules is envisaged, with new designs only where gap-fillers are needed. Outer shell should provide space for thermal control and photovoltaics. The heat shield should be protected and facing the RAMSES orbiter, the centre of gravity should be close to the RAMSES orbiter, and the mechanical and electrical support subsystem as an interface to the RAMSES orbiter should be derived from previously flown separation systems.

The regolith sampling success criteria might be:

Minimum: ≈ 1000 grains of ≈10 µm size, i.e. the same science as Hayabusa1

Full success: ≈ 5 g with pea-sized grains, i.e. same science as Hayabusa2

Capsule capacity: ≈ 1 kg & 1 dm³ up to several cm of pebble-sized particles

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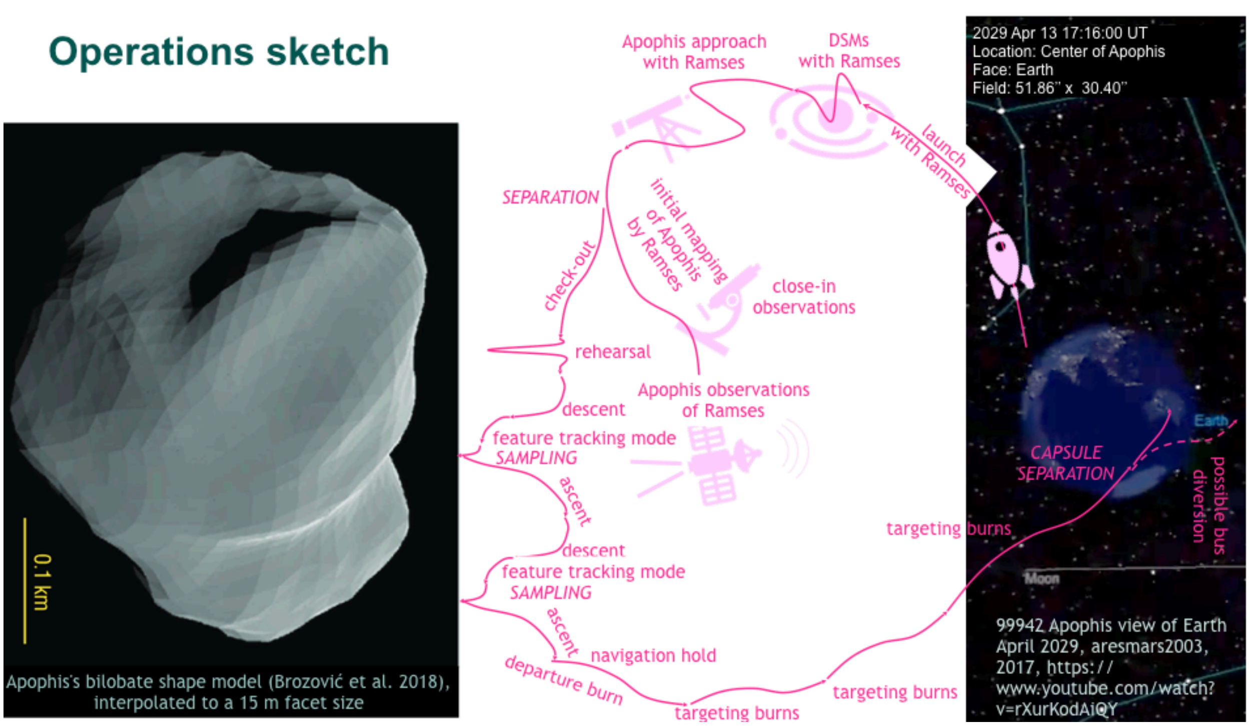

Fig. 2: Outline of the planned operations of the sample return mission