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SNATCHING A PROBE OF A GENUINE NEAR-EARTH ASTEROID: FAST SAMPLE RETURN OPPORTUNITY IN THE FRAME OF RAMSES MISSION SCENARIO

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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 Friday 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 present the results of the 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 for APOSSUM - APOhiS SUrface saMpler

The Sample Return Probe should be launched as part of the RAMSES mission and be compatible with its mission and requirements. Depending on the launch date, we assume that RAMSES will rendezvous with asteroid (99942) Apophis in mid-February 2029. APOSSUM will be detached, land with partly autonomous navigation guidance, actively controlled by thrusters, sample the regolith, depart in mid-March 2029 and be 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 about one month and arrive 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 fly-by, 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]. The trajectory sketch illustrates the described scenario.

Design approach for Concurrent Engineering (CE) study

The development follows a tailored oncurrent engineering approach that considers the compressed timeline until the envisaged launch window of RAMSES. The recently completed CE study is followed by further detailing of the design that will incorporate additional CE studies and workshops (project phases 0/A, B) and Concurrent AIV in the implementation (phases C/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 technology providers and ongoing developments at the CE study partners. The required interfaces (mechanical, electrical, thermal and software) of the custom-designed core system have to be adapted to selected off-the-shelf units. The spacecraft is a complex system and therefore all subsystems involved in flight control and collision avoidance need to be highly dependable. Most subsystems require some development within the project as they are not standard systems addressed by current off-the-shelf products but still can be based on their readily available technologies. The entry capsule and the sampler are entirely mission-specific, but for both subsystems, some flight-proven designs exist [8,9] but would also need to be adapted in the early stages of the project, most likely involving international collaborations.

Brief sketch of storyline for CE study

The envisaged operations are illustrated in the Operations Sketch: After launch, communication during cruise and near (99942) Apophis is via RAMSES (high bandwidth). Direct communication to Earth is possible after separation from RAMSES at Apophis (low bandwidth). RAMSES can remain at a safe distance while APOSSUM approaches and scouts Apophis earlier. The initial mapping/reconnaissance phase, carried out by the spacecraft's navigation and guidance cameras, identifies possible sampling targets. Asteroid approaches begin from a home position (≈5 km altitude) under ground control, similar to Hayabusa2. Tracking of features for final approach begins from ≈1 km down, for a simple mark-and-go "contrast seeker" with horizon tracking. In the final automatic approach, this effectively locks APOSSUM to Apophis' slow rotation at about 5 - 10 cm/s. A toroidal rotary brush is spun up before touchdown for sampling during an inertia- and thruster-supported touch-and-go ground contact. A reversible shutter is closed on bounce-back to prevent samples from drifting out again. A small lift-off burn ensures APOSSUM clears the surface; later it is accelerated to near-escape towards the parking position. A rehearsal and multiple sampling attempts can be performed. Return to Earth is achieved by a large departure burn and successive correction burns into the re-entry corridor, with low-bandwidth communications and ranging with Earth.

APOSSUM System Design

The spacecraft is designed around the selected entry capsule design. All other subsystems are attached and integrated, such as a 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 are specified based on current knowledge about RAMSES. Extensive use should be made of small documentation cameras, based on previous missions' experience. The attitude and orbit control system is based on flight-proven cameras, sensors and propulsion units. An integrated core avionics approach using a mix of scalable on-board computers and communication equipment with off-the-shelf units such as antennae is envisaged, with new designs only where gap-fillers are needed. The outer shell of the structure provides space for thermal control and photovoltaics. The heat shield is protected from micrometeoroids by facing the RAMSES orbiter. The centre of gravity should be as close as possible to the RAMSES orbiter. A mechanical and electrical support subsystem (MESS) and data relay subsystem (DRSS) interface APOSSUM to RAMSES, derived from previously flown separation systems.

References

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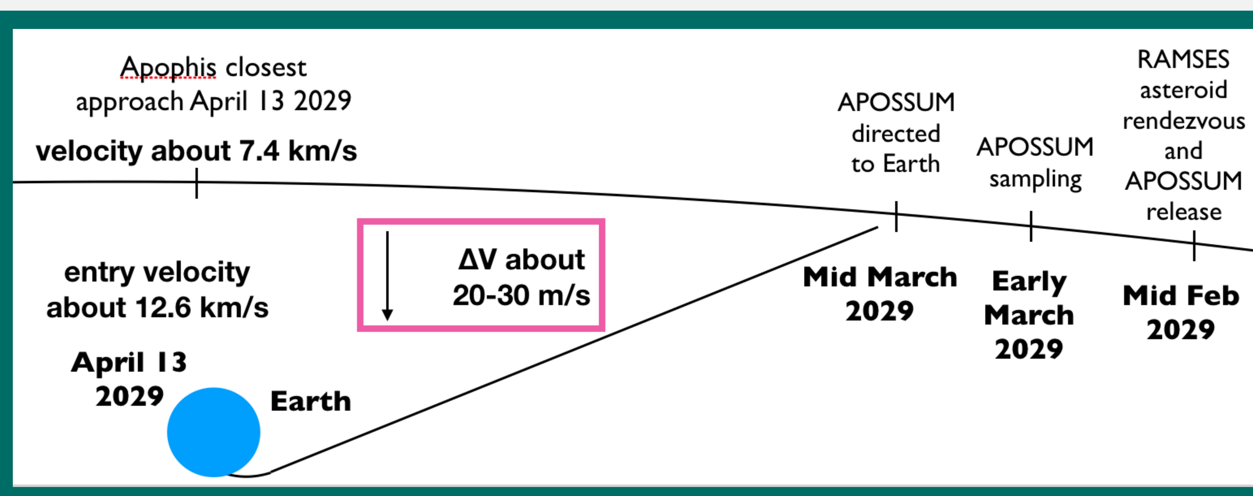
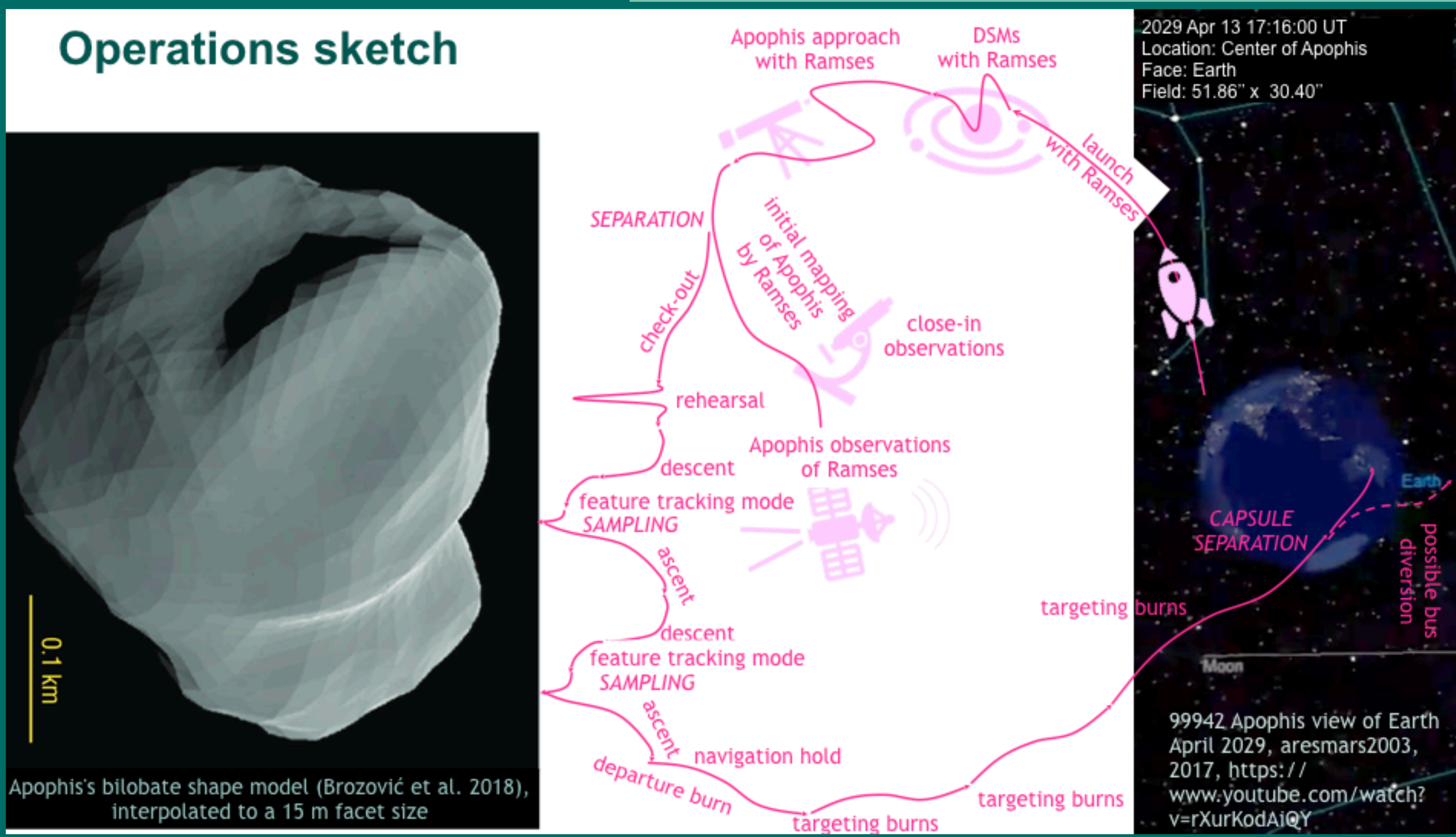
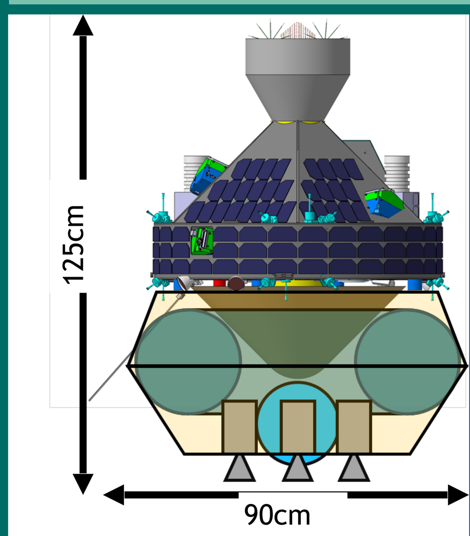
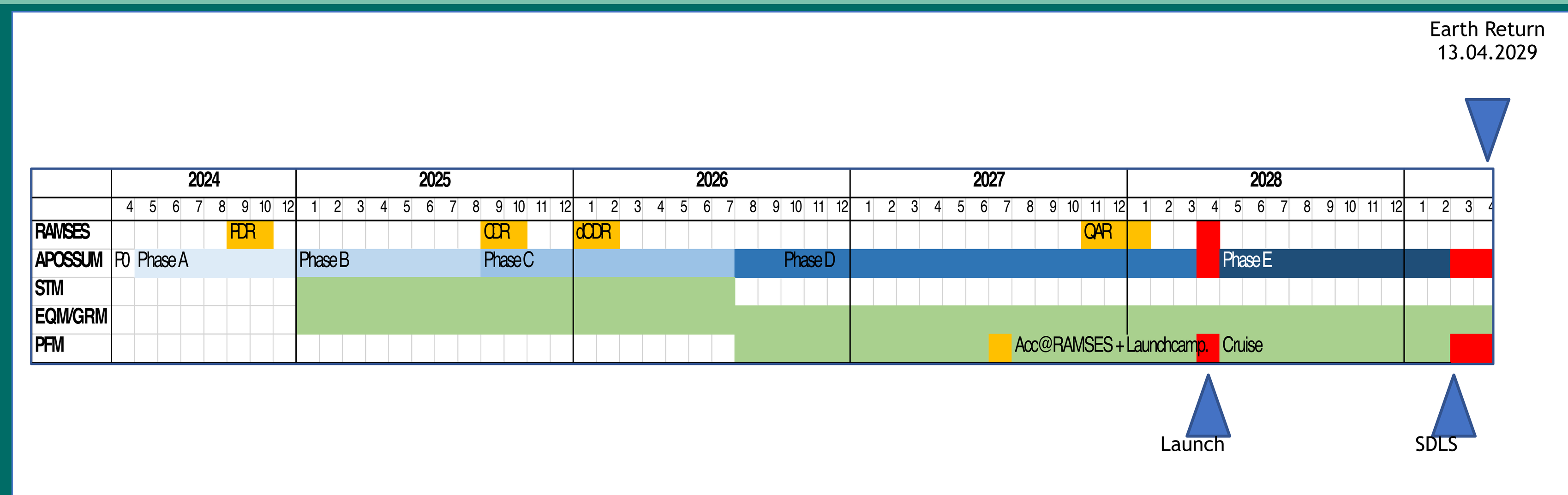


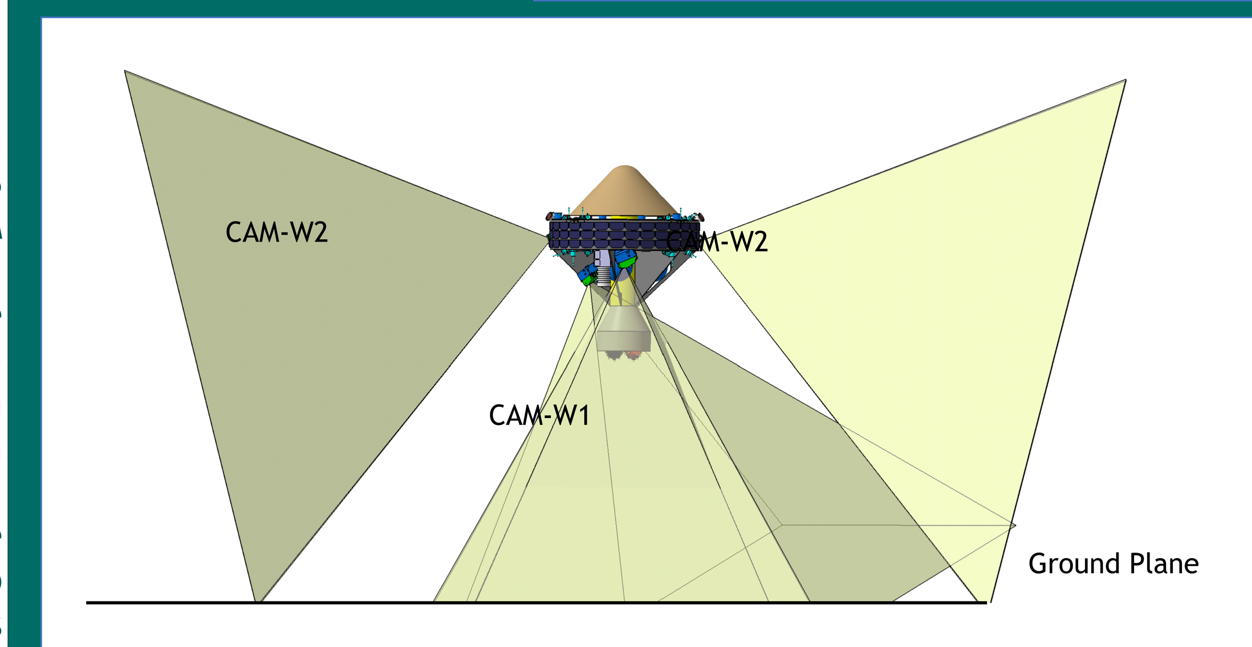
Overview of APOSSUM mission scenario as envisaged for February to April 2029. The sample return and the asteroid swing-by will happen on the same date.

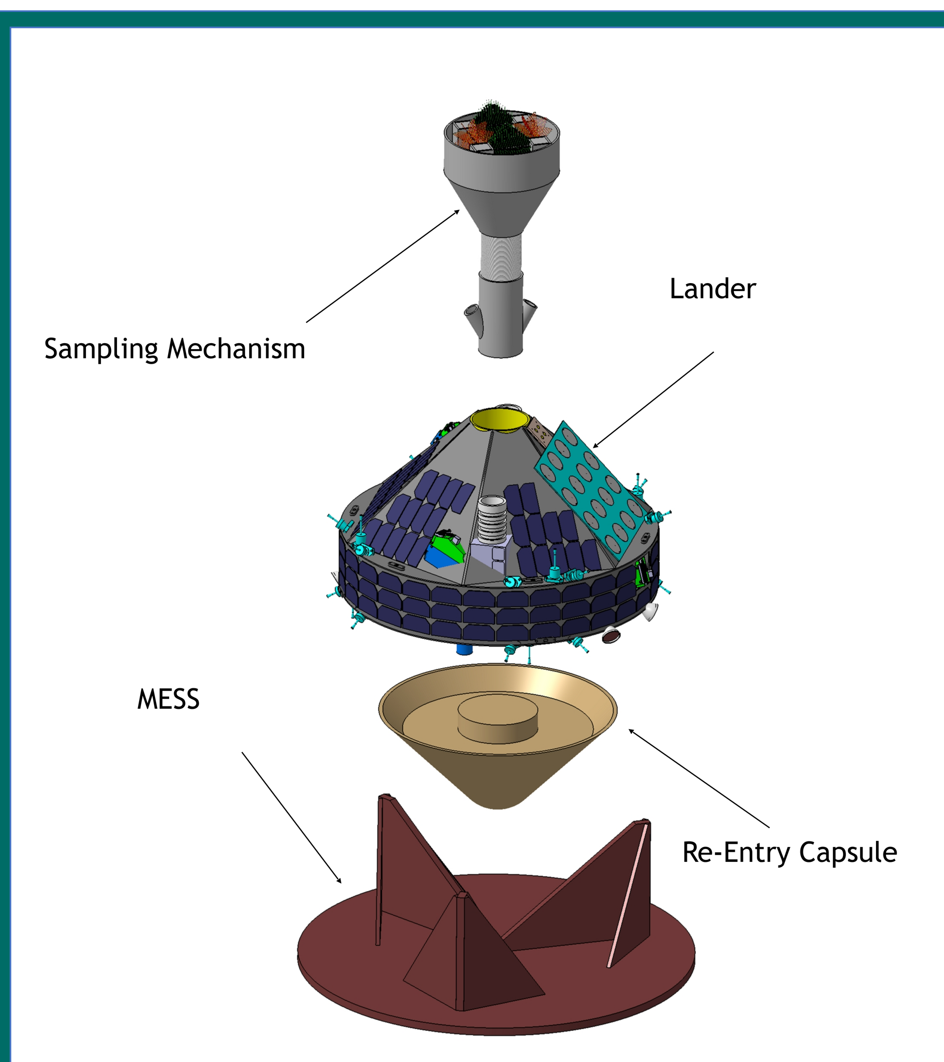


Outline of the concept of operations of sample return mission APOSSUM launched with the RAMSES mission and operating independently.









CONCLUSIONS

- The CE Workshop demonstrated that a Fast Sample Return Mission to Apophis, APOSSUM, is feasible with current technology in a small spacecraft format
- APOSSUM spacecraft design is possible within resources envelopes deduced from the standard margins and launcher of a mid-class planetary rendezvous probe
- Multiple sampling attempts can be enabled by independent operation of APOSSUM after arrival at Apophis, much improved by communication via RAMSES
- To adapt to the fast pace development of RAMSES following steps are required until the End of 2024:
- 2nd CE Workshop End of 2024 for detail design and preparation of a System Requirements Review (SRR)
- Advance design studies for Re-entry Capsule and Sampler are recommended to go ahead ASAP

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