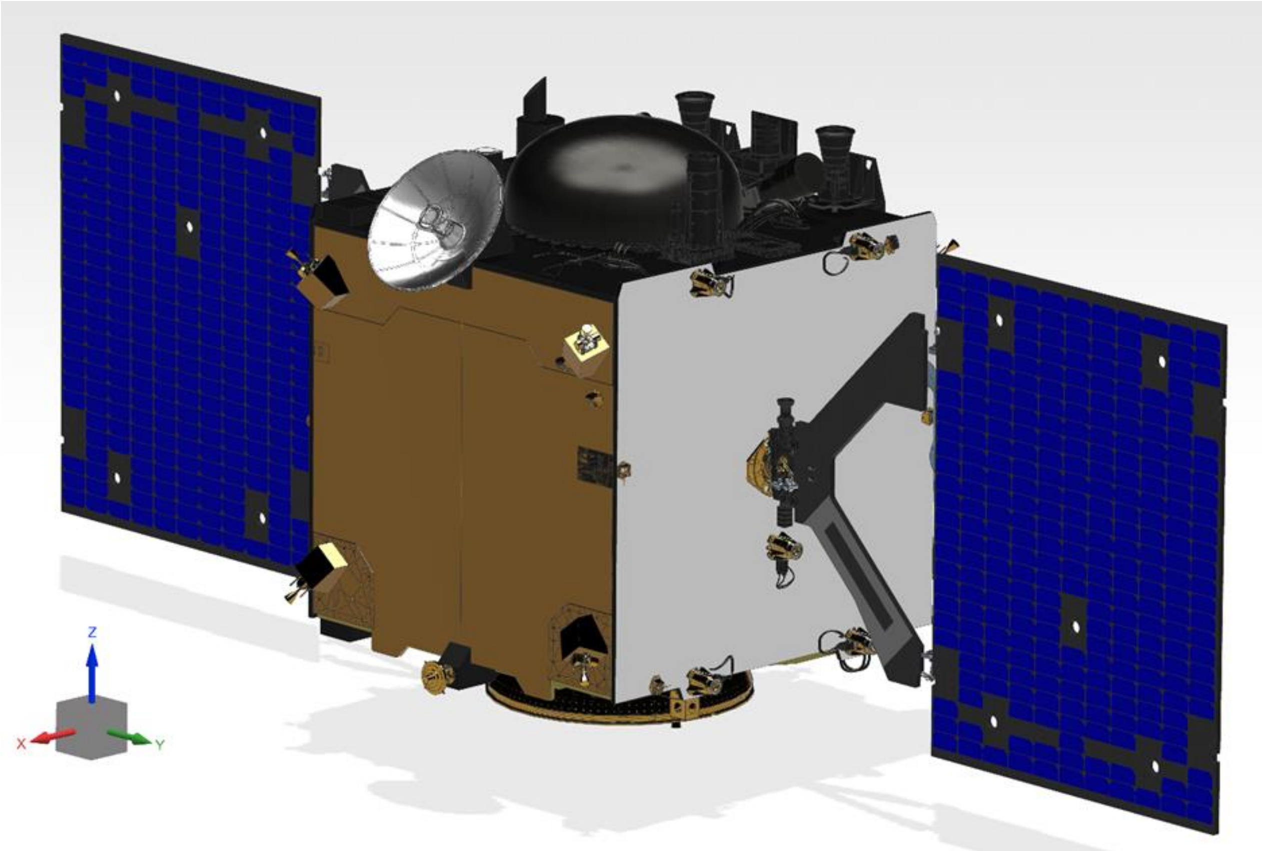
➔ PREPARATION



Rapid Apophis Mission for Security and Safety (RAMSES)

Executive summary
Pre-phase A/Phase A

Affiliation(s): OHB System, GMV

Activity summary:
This executive summary covers the RAMSES Phase 1 carried by OHB System. It covers the science objectives of the mission, design philosophy adopted, and payloads carried on board.

Publishing Date: 26.04.24
Contract Number: 4000141550/23/NL/GLC/my
Implemented as ESA Standard Procurement

The Rapid Apophis Mission for Security and Safety (RAMSES) primary mission objective is to characterize and monitor the dynamic behaviour of the asteroid 99942 Apophis before, during, and after its close Earth fly-by in 2029. The RAMSES spacecraft shall provide capabilities that enable to:

1. Determine the orbit of Apophis
2. Determine the spin state and orientation of Apophis
3. Determine the shape and surface change of Apophis due to the tidal forces during Earth close encounter
4. Determine the interior structure of Apophis
5. Identify the presence of sub-millimetre dust particles

The primary mission objective is to characterize those properties of 99942 Apophis, which are critical for planetary defence, prior to the encounter. The unique mission opportunity in Ramses is in the pre-encounter characterization and close-encounter monitoring. The mission therefore offers a unique opportunity for the planetary defence community. However, as a by-product, Ramses also offers the opportunity for asteroid science, as many potential science measurements of interest are covered by those measurements required for planetary defence.
The spacecraft is based on an extensive reuse of the HERA[1] spacecraft design, notably with similar:

- Spacecraft system concept:
  - A core structure built around a central tube primary structure,
  - Body-mounted instruments on the top spacecraft deck,
  - Fixed antennas,
  - Two solar arrays with a one-degree-of-freedom mechanism.
- Spacecraft structure and propulsion subsystem.
- Avionics and platform equipment units
- Software baseline
- Concept of operation for proximity operations, with pre-scheduled observations, on-board storage and alternating asteroid- and Earth-pointing attitude for ground communication and forwarding of the science and navigation data.

However, one driving difference from the HERA mission is the larger delta-v needed for Asteroid capture. This drives the use of larger tanks and imposes stringent mass constraints. A key difference from the HERA design is therefore that the RAMSES spacecraft is almost entirely single-string (without redundancy) to reduce mass. A single-string architecture for interplanetary spacecraft is commonly adopted by other Agencies for highly mass-constrained, low-cost and/or short duration missions, with successful examples including NASA’s Mars Science Laboratory, DART or the upcoming DaVinci spacecraft and entry probe. Lessons learned from these missions are adopted to best extent possible.

The spacecraft will embark the following payload units:

- Scientific instruments:
  - Narrow Angle Camera (NAC) Asteroid Framing Camera (AFC)

[1] HERA is an ESA mission to be launched in the second half of 2024 to the binary asteroid Didymos to characterize the impact of the 2022 NASA DART probe.

    - MapCam
    - Thermal Infrared Imager (TIRI)
- Sensors with dual use purposed for GNC:
    - Wide Angle Camera (WAC) Navigation camera (Navcam)
    - Planetary Altimeter (PALT)
- In addition, the spacecraft will also host two 6U CubeSats with their support equipment. These are CFIs and will take complimentary measures of Apophis at a close distance.

Spacecraft launch is baselined on Ariane 6.2 in April 2028 for an arrival at Apophis in February 2029. No backup launch window is planned for Apophis, but a backup target has been selected based on a list of candidates identified by ESA: asteroid 2011 CG2.

Conclusion of Phase 1 allowed to reach PDR maturity with a complete mission definition including:

- Mission timeline, from launch to disposal
- Mission analysis, including transfer and rendezvous with Apophis
- Concept of operation definition, with several observation phases defined pre, post and during close encounter of the asteroid with Earth
- Trajectories definition during those observation phases (arcs and hovering)

Moreover, the design was defined and developed on system and subsystem levels with:

- System budgets (mass, power, data volume, delta-v, propellant and pointing)
- Spacecraft modes and GNC modes
- Complete electrical and avionics architecture
- Complete subsystem design (GNC, DHS, EPS, STR, TCS, CPS, COMS)
- Configuration of the spacecraft and accommodation of all units on board
- Payload performance analysis
- Thermal, trajectory, attitude, MMOD, Eigenfrequencies, load, reliability and link analysis.

Technical feasibility of the mission has thus been established. Because of the lack of a backup launch for the nominal mission, programmatics are one of the most critical constraints though. To accelerate the development process, re-use of HERA is planned in particular with regards to existing hardware, qualification status, specifications, procedures and industrial setup.