Rationale of the CNES study

Is there a significant advantage to plan for a space mission where a probe would accompany Apophis during its 2029 pass?

Assumptions:
- first mission to Apophis
- priority to the mitigation preparation objectives
- scientific objectives not excluded but secondary

Main mission objective
Provide informations about Apophis that would be requested for designing a future mitigation mission, if needed:

- Internal structure characterization
- Observation of its possible changes induced by the close approach

Strawman Payload

General features (shape, mass, rotation, gravity)
- Wide Angle and Narrow Angle cameras in VIS and near IR
- Radio science

Surface analysis
- Nac and Wac in VIS and Near IR
- Spectroscopic in VIS and IR large spectrum

Sub-surface analysis
- High Frequency Radar
- Options:
  - Sismometers
  - Artificial craterisation

Sounding
- High Frequency Radar tomography
- Options: sismometers

Long term tracking:
- Radio and/or laser reflector to be assessed

Raders

Low frequency radar for tomography
- Tomography in Reflection
- RF wave propagation (~20 MHz)
- Orbiter only (Marsis-like)
- Deep interior profiles: Interfaces, layers and voids
- Heritage Sharad, Marsis

High frequency radar for regolith characterisation
- 300 MHz-1GHz
- 10 cm resolution @10 m depth
- Can be used in an altimeter mode and contribute to the gravitational field determination
- Used in the range 500 m - 2500 m
- Heritage Wisdom/EXOMARS

Impact risk assessment

Mitigation mission

Reentry model

Mission analysis example

Departure: 22/03/2026
Arrival: 10/02/2027
- 10 cm resolution @ 2.2 km
- 1m @ 10km

Ion Thruster NSTAR
- Ip = 500 W
- T = 511 K

Thrust: 5N
- 01/02/2027 – 08/05/2027
- 11/07/2028

Operational scheme

- Rendez-vous to a waiting position 200 km in the sun direction (mid July 2028)
- Approach to 20 km controled from the ground using NAC (1m@10km)
- VIS and IR science between 20 km and 3 km
- Radio science between 300 m and 3 km
- About 6 months for the programme before April 13
- Spacecraft ahead of Apophis for the flyby
- High accuracy geometry determination of the F/B
- Ground penetrating radar
- Reentry modeling
- Mitigation mission objectives
- Scientific objectives not excluded but secondary
- Priority to the mitigation preparation objectives
- Observation of its possible changes induced by the close approach

Main outcomes
- Compatibility with a SOYOUZ launch from French Guyana Space Center
- Electric propulsion required
- Affordable fuel budget (~50 kg)
- Mitigation objectives can be achieved through VIS and IR cameras and 2 radars
- The mitigation objectives can be satisfied without landing any device
- The 2029 timeframe is a unique opportunity to study Apophis, its internal structure, the possible changes due to the gravitational effects from the Earth and determine the exact geometry of its flyby