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A POTENTIAL GERMAN CUBESAT CONTRIBUTION TO THE RAMSES MISSION

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Mission Overview

Mission Statement and Objectives

The mission aims to **support the science objectives of the RAMSES mission** by providing valuable insights into the physical characteristics and possible changes in pre- and post- Earth closest approach (ECA) phase of (99942) Apophis. **In addition, it aims to characterize the magnetization of (99942) Apophis and the plasma interactions** as it passes through the Earth's magnetosphere.

Mission Objectives:

1. Support the science objectives of RAMSES mission by observation of the internal composition, shape, and dynamic state of (99942) Apophis and its changes before, during, and after the flyby of Earth in April 2029
2. Investigation of the magnetization of (99942) Apophis and its plasma interaction during the flyby through the Earth's magnetosphere

RAMSES Mission

Credits: [1]

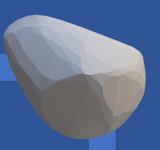
- Adaption of Hera S/C architecture
- Launch Q2 2028
- Planned core payloads:
  - 2 x AFC Cameras
  - 2 X 6U CubeSats

High level RAMSES mission objectives

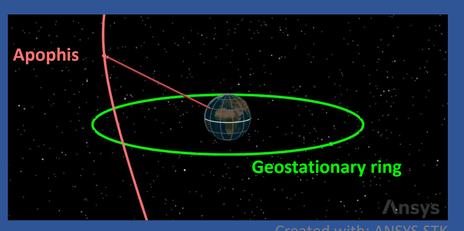
1. Characterize Apophis with high-resolution before (and after) the encounter
2. Monitor Apophis with high temporal resolution during the encounter

Source: [1]

(99942) Apophis



Credits: [3]



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- Sq-type asteroid, avg. diameter: 340±40m
- Earth close encounter: April 13, 2029
- Tidal forces during Earth flyby: expected changes in asteroid dynamic state and small-scale surface displacements → Potential long-term alteration of asteroid spin state and orbit
- Monitoring property changes during Earth flyby helps to improve capabilities to predict further spin and orbital evolution

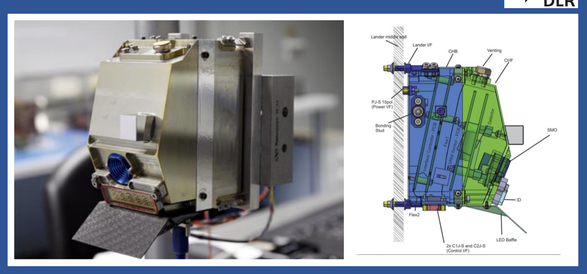
Sources: [2,3]

Scientific Contributions

Optical Observation

Complementary observations from various angles alongside RAMSES observations

Camera System (DLR)



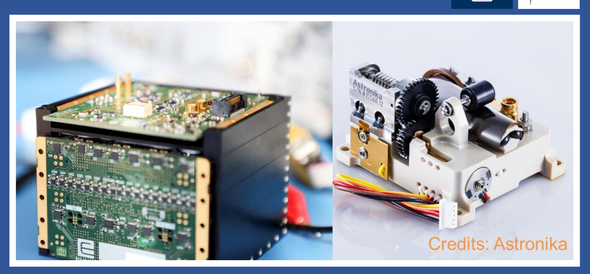
- Camera system based on MASCAM
- 1 U Design, Focal length ~35mm
- Create a global shape model (min. res. 50 cm per pixel)
- Observe surface changes
- Provide optical navigation capabilities

Abstract from Schmitz et al. [Apophis T-5 Workshop]

Radar Measurement

Unique measurements as a direct contribution to the scientific objectives of RAMSES

Low Frequency Radar (IPAG)



Credits: Astronika

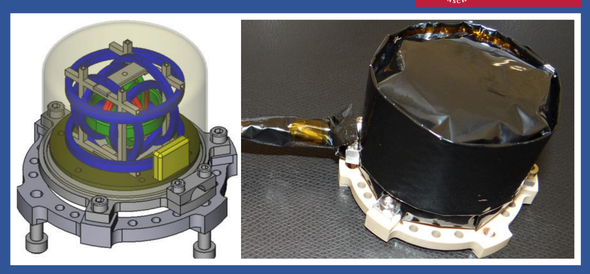
- Based on JuRa Instrument (60 MHz carrier freq. BPSK coded radar)
- 1U electronic box, cross dipole antenna
- Construction of a tomographic asteroid model (spatial resolution approx. 5m)
- Planned monostatic and bistatic operations (CubeSat + RAMSES S/C)

Abstract from Herique et al. [Apophis T-5 Workshop]

Magnetometer Measurement

Distinct measurement beyond RAMSES scientific objectives, also not covered by OSIRIS-APEX

Magnetometer (Technische Universität Braunschweig)



- Set of Magnetometers (1-2) including deploy mechanism
- vector-compensated three-axis fluxgate mag.
- continuously magnetic fields measurements
- Quantify the magnetization of (99942) Apophis and the interactions with the Earth magnetosphere

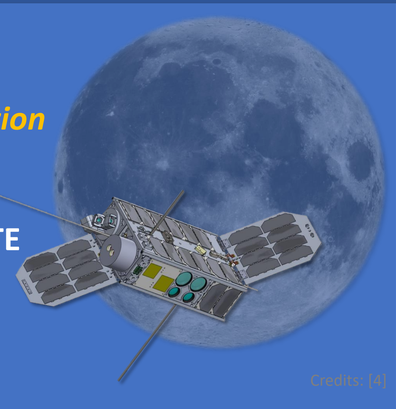
Abstract from Plaschke et al. [Apophis T-5 Workshop]

Mission Architecture

SONATE-2 Bus

Designed with future use in deep space exploration missions in mind

Bus Design	6U+ Cubesat bus based on SONATE
Dimensions	ca. 100 mm x 226 mm x 340 mm
Mass	~13kg

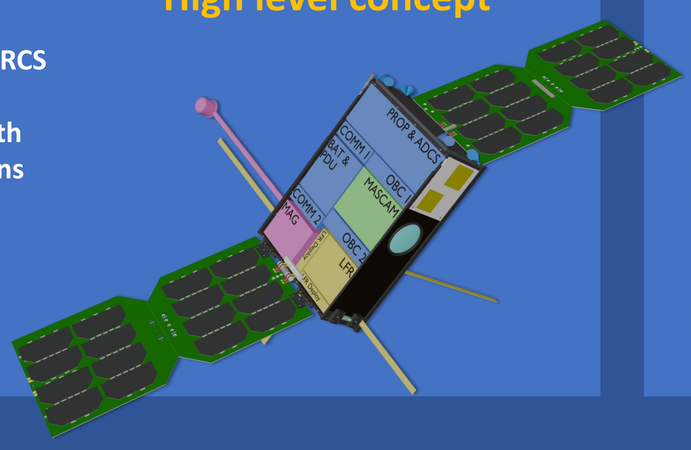


Credits: [4]

Required modifications

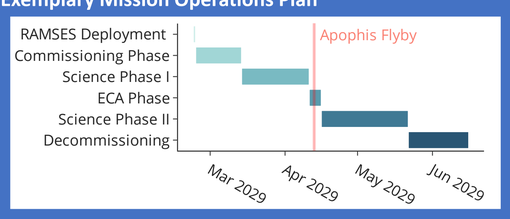
- Adopt propulsion system, integrate RCS thrusters
- Replace communications system with Hera ISL Transceiver, evaluate options for additional radio science measurements
- Perform radiation testing for deep space environment
- Increase solar array size

High level concept



Mission Operation Plan

Exemplary Mission Operations Plan



- Commissioning: initial satellite operations and the calibration of the instruments
- Sciene Phase I&II: see below
- ECA Phase: Imaging of Apophis during ECA
- Decommissioning: touchdown on the asteroids surface

Science Phase I & II

Both science phases are divided into three subphases. The aim of both science phases is to observe (99942) Apophis in detail before and after the ECA, to determine changes caused by the tidal forces.

Subphase	Key science aspects	Instrument priority
Far Range Phase (FRP)	Distance to asteroid surface: > 4km Perform BPSK mode radar measurements for tomographic model Measure interaction with solar wind and Earth magnetosphere	Low Frequency Radar Magnetometer Camera System
Medium Range Phase (MRP)	Distance to asteroid surface: ~1km Imaging of (99942) Apophis to create global shape model	Camera System Magnetometer Low Frequency Radar
Close Range Phase (CRP)	Distance to asteroid surface > 0.4km Quantify the magnetization of (99942) Apophis Imaging of surface details possible Close range radar measurements possible	Magnetometer Camera System Low Frequency Radar

Sources

[1] P. Martino, "RAMSES - ESA Rapid Apophis Mission," Hera Community Meeting, Oct. 2023.
[2] Y. Kim, "Tidal resurfacing model for (99942) Apophis during the 2029 close approach with Earth," MNRAS, vol. 520, no. 3, pp. 3405-3415, 2023.
[3] Apophis Shape Model: Pravec, P., et al. "The tumbling spin state of (99942) Apophis." Icarus, vol. 233, 1 May. 2014, pp. 48-60, doi:10.1016/j.icarus.2014.01.026.
[4] The Moon: NASA/GSFC, No. GSFC_20171208_Archive_e001982, 2017.

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