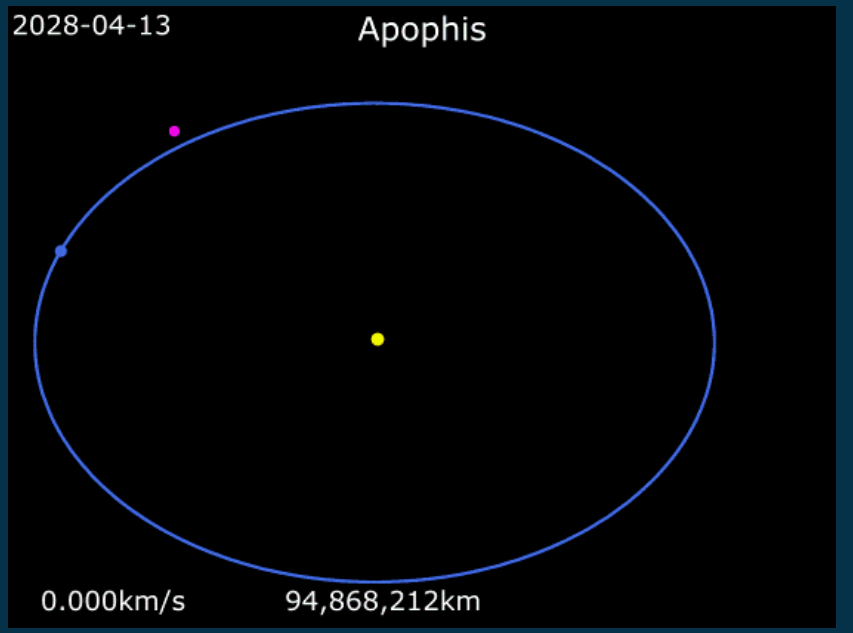
Apophis Reconnaissance Mission

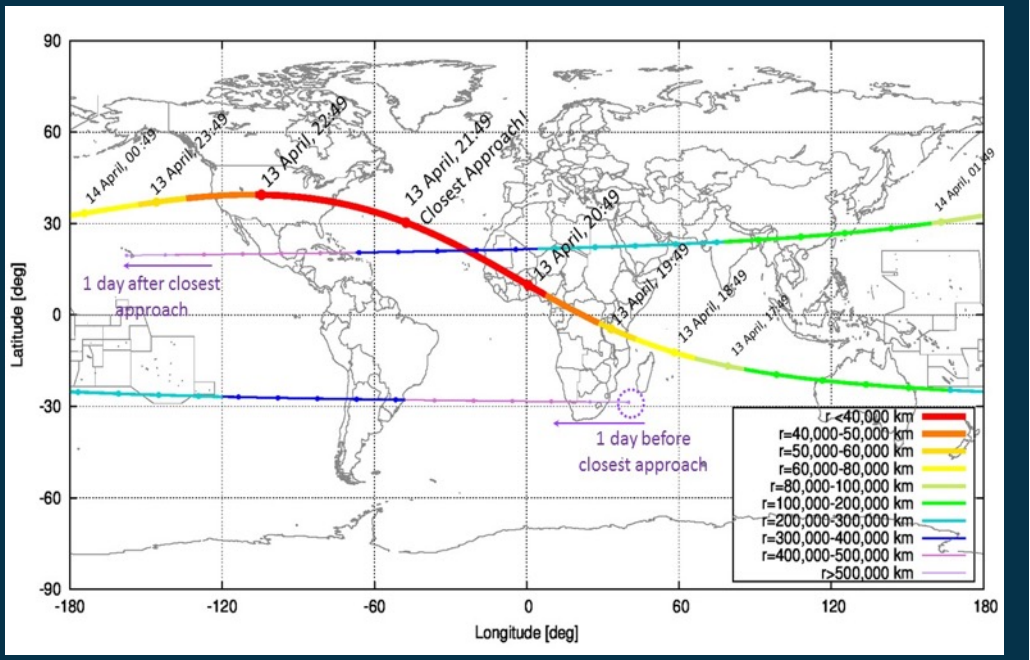
S2P Period 2 small mission of opportunity

Asteroid Apophis: unique opportunity for planetary defense

Flyby date:
Friday, 13 April 2029
21:49 UTC

Distance:
5 x Earth radius
(within GEO ring)





Apophis very close Earth flyby in 2029 presents an unprecedented planetary defense and science opportunity because of the Earth's physical interactions on the body of Apophis itself. It is expected that Earth's gravity will modify the asteroid physical properties, in addition to the dynamical ones. This natural event will allow scientists to access a "natural laboratory" to verify models on cohesion and strength of asteroids that are key to any planetary defense mission. The greatest uncertainty factor derives from the lack of knowledge on its internal structure. This mission could allow transforming our understanding of the internal structure of potentially dangerous asteroids.

Planetary defense community & Apophis

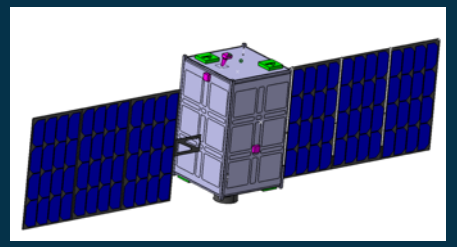
- Several mission concepts have been studies by ESA, NASA, CNES since 2004.
- Workshops have been held for an international mission to Apophis (incl. “Apophis T-7 Years: Knowledge Opportunities for the Science of Planetary Defense”)
- NASA's Small Bodies Assessment Group (SBAG) issued a finding in January 2019 encouraging NASA and the small bodies community to determine the science and planetary defense goals for the 2029 Earth flyby of (99942) Apophis, and to evaluate the opportunities
- A resolution passed by the 2019 International Academy of Astronautics Planetary Defense Conference acknowledged that the occurrence of such a large asteroid flyby is a once-per-thousand-years natural event that will provide a unique opportunity for advancing small body knowledge for both science and planetary defense.
- Mention of a mission to Apophis in the 2022 Planetary Decadal Survey: Apophis opportunity is recognized as a key science opportunity of high priority.

► **Community’s high-priority in the Planetary Defence roadmap: a fast asteroid reconnaissance mission, Apophis represents a unique opportunity.**

Mission concepts

Three avenues are being explored for the Apophis mission of opportunity:

1. Micro-satellite based on the M-ARGO ► CDF ”SATIS” study (12U XL CubeSat)
2. Mini-satellite based on Hera re-use ► preliminary feasibility assessment
3. New mini-satellite platform



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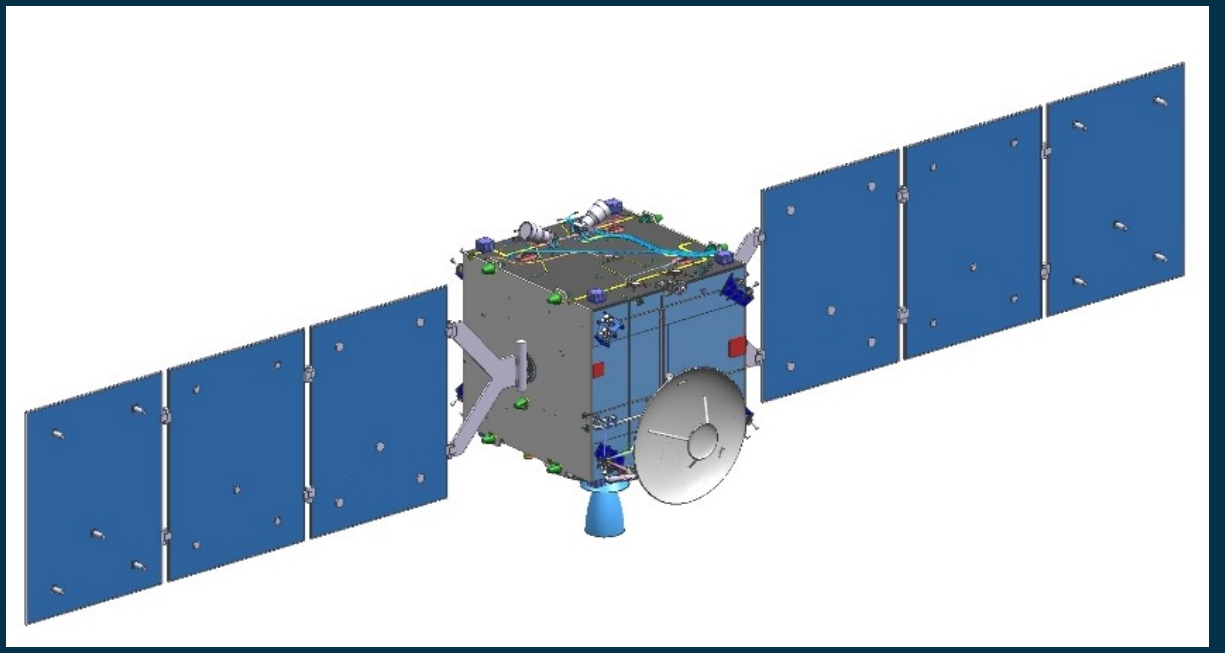

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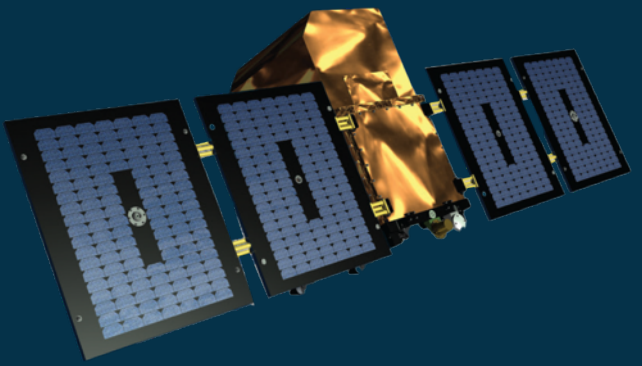

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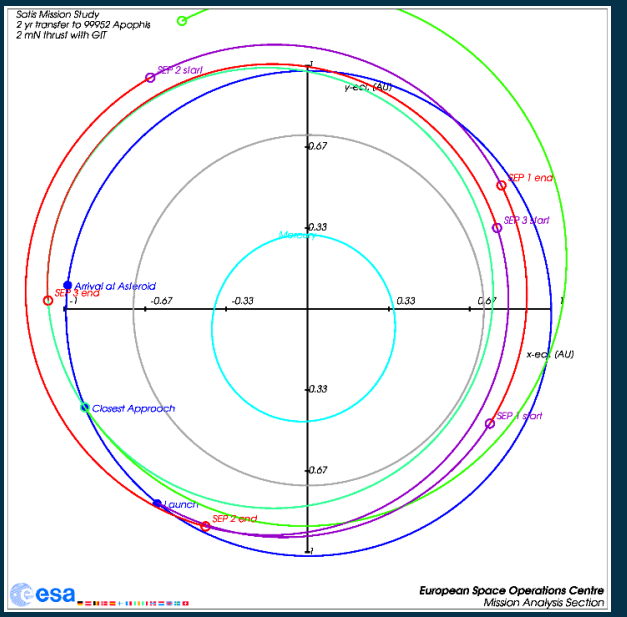
Satis CDF study summary 1

- 4 Sessions in June 2022. Outcome is available for distribution.
- 2 Mission scenarios have been analysed:
  - Earth-bound high eccentricity orbit with fast flyby (~2.8 km/s) observation (based on LUMIO design)
  - Heliocentric orbit with rendezvous two months in advance of close approach to earth. (Based on the M-ARGO design)
- Fast flyby could be launched until January 2029
- Rendezvous launch window ends on 13th May 2027
- Different GNC configuration, but same baseline instrumentation
- Both options similar in cost, but much more data from rendezvous

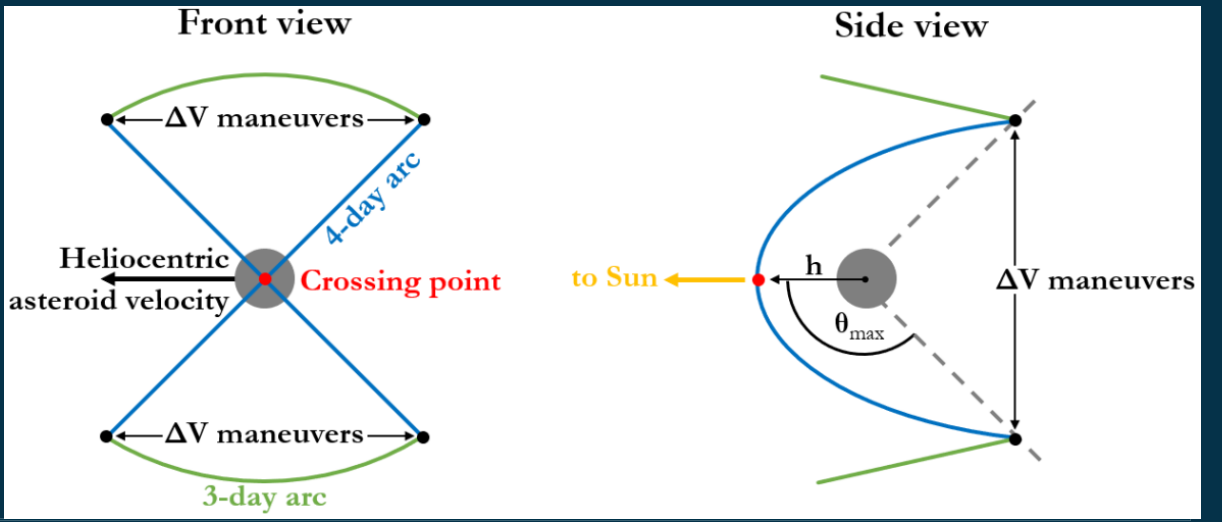
➔ Rendezvous option chosen as baseline scenario

Satis scenario

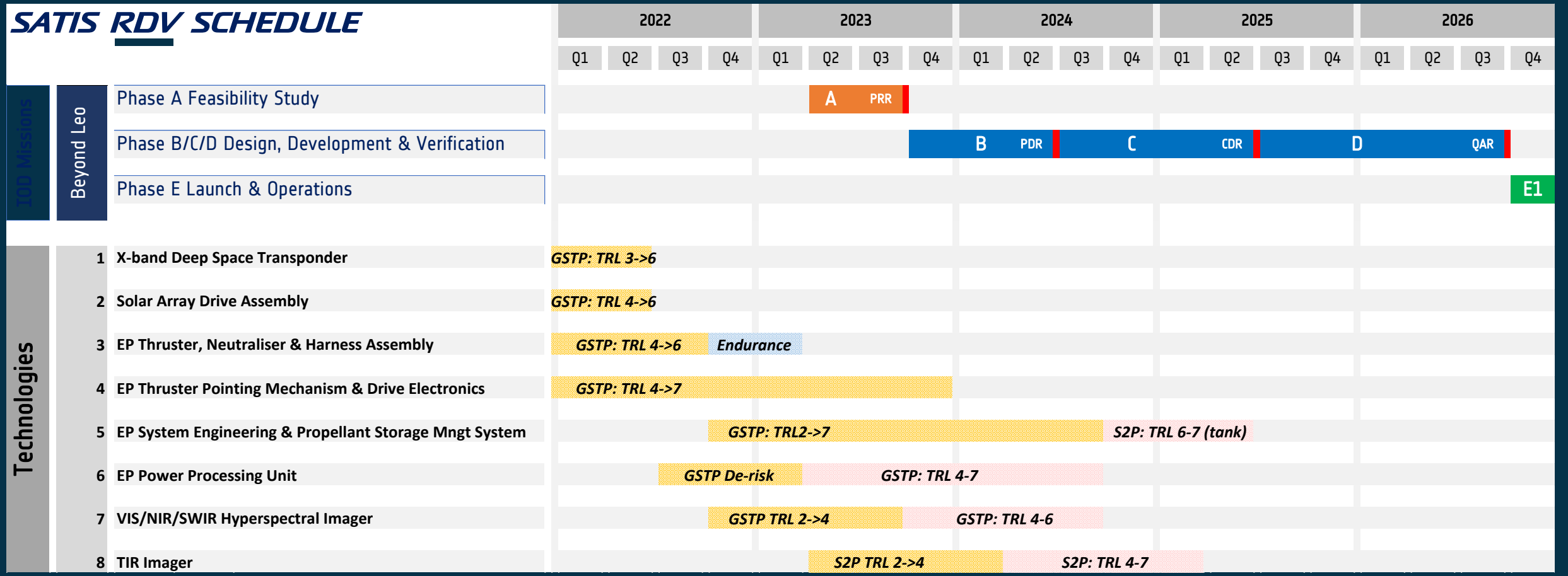
- 12U-XL Cubesat, adapted from M-ARGO concept
- Launch Apr/May 2027, 2 years transfer, using **GIT with ~2mN thrust, Isp ~3000 s**
- Payload baseline (TBC)
  - Hyperspectral imager
  - Thermal imager, capable of acquiring hydrations lines
- Arrival until 15th March 2029
- Initial light curve observations, then iteratively closer manoeuvres
- Full characterisation pre and post flyby
- Monitoring of potential surface reconfiguration and mass shedding during closest approach



	Value
Launch	2027/5/13 / 4.177 km/s @ 37.1 deg
SEP Arc 1	2028/8/6 – 2027/9/19 / 456 m/s
SEP Arc 2	2028/1/9 – 2028/6/13 / 877 m/s
SEP Arc 3	2028/9/29 – 2029/3/14 / 1206 m/s
Arrival	2029/3/15



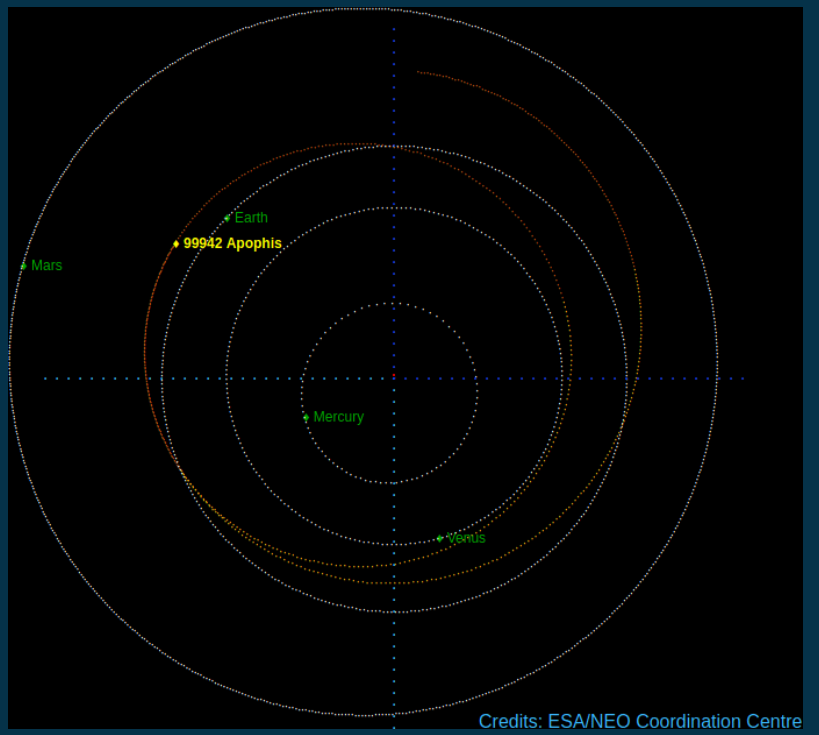
Implementation roadmap (Satis/12U-XL Cubesat)

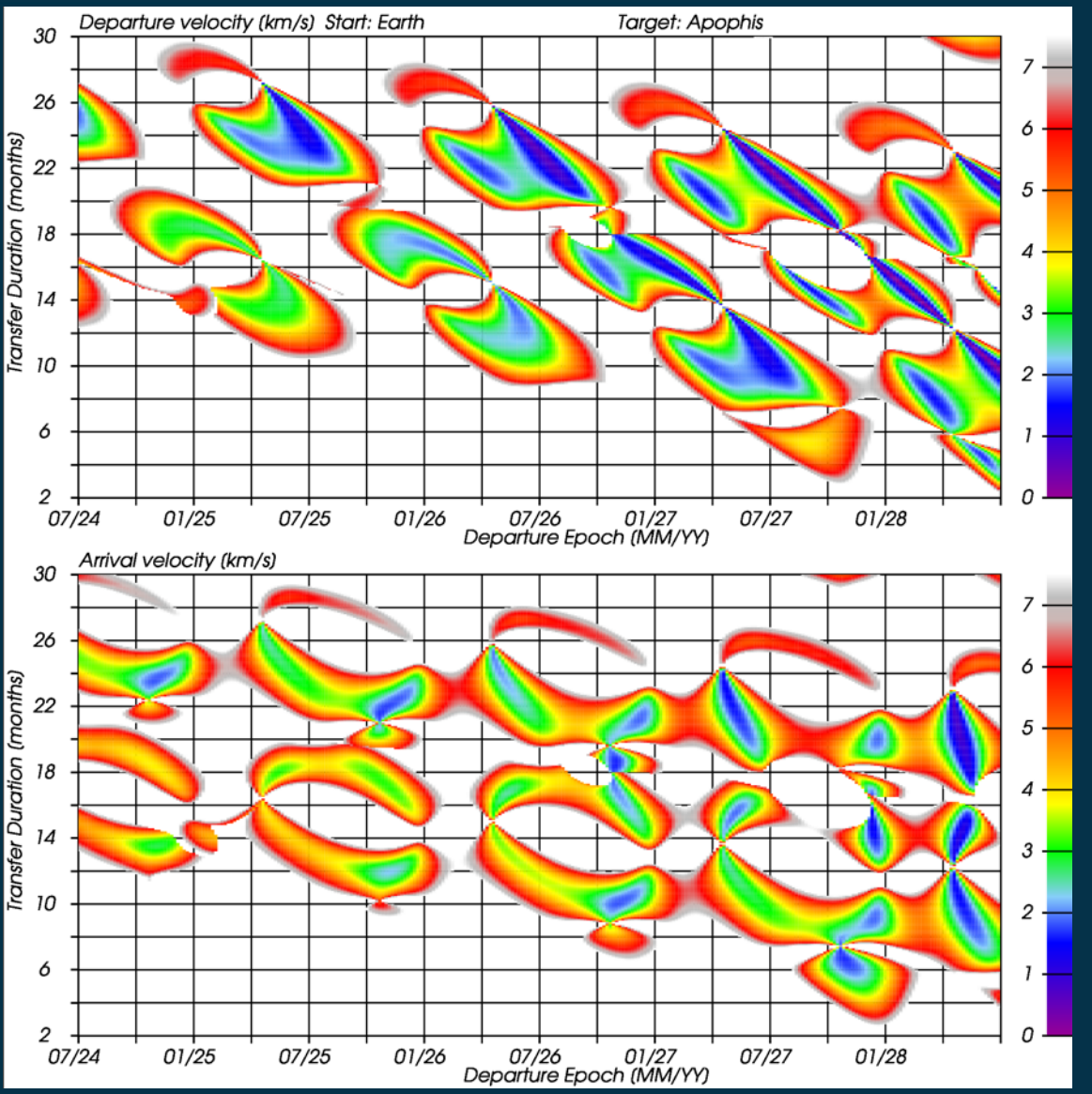


Hera re-use and minisat scenario

Earth-Asteroid transfer:

- Launch: LPO on 2028/4/23 / LPC on 2028/5/6
- Arrival February 2029
- Transfer 10 months
- delta-V = 1534 m/s





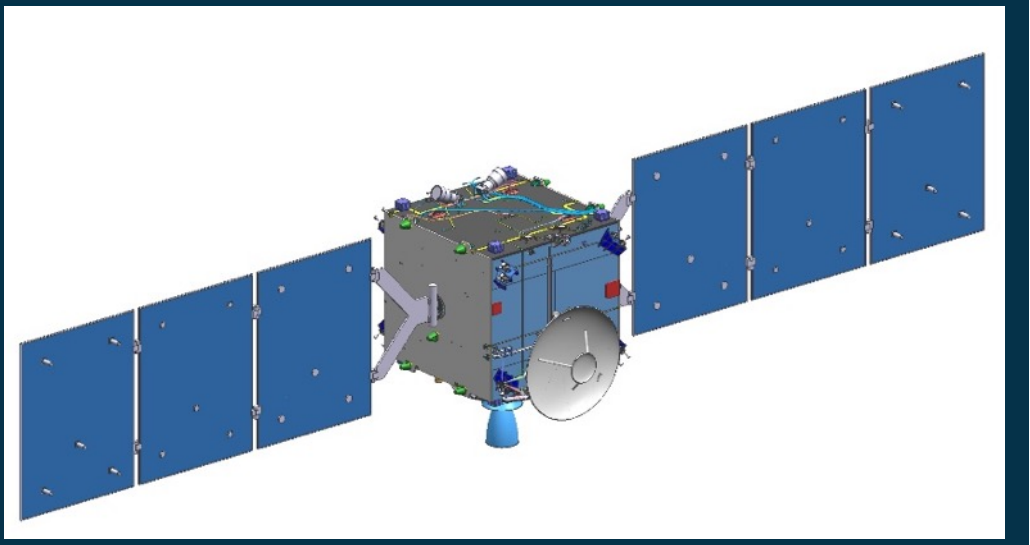
Hera re-use and minisat scenario

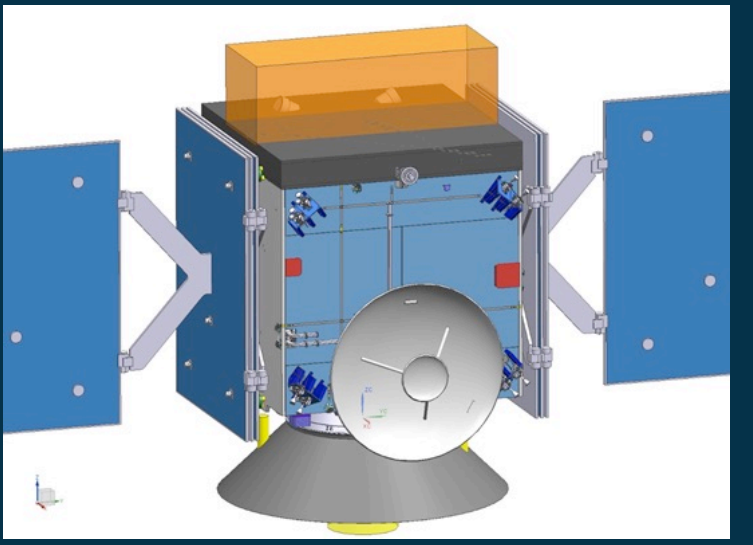
Payload envelope characteristics

- External volume envelope : 1550 x 600 x 500 mm (LxWxH)
- Mass envelope: 40 kg in mass budget (up to 50 kg for top panel)
- Nadir-pointing of top deck

Potential payload trade-offs:

- Mandatory: optical cameras for navigation and science
- Options:
  - 2 CubeSats + 1 payload (6kg-class)
  - 3 CubeSats (incl. potential contribution from NASA)
- CubeSat payload options:
  - Low-frequency radar
  - Multi-spectral imager
  - Gravimeter
  - Dust detector
  - Infrared imager
  - …





Conclusions

- The Apophis mission represents a unique opportunity for planetary defense to demonstrate rapid inspection spacraft and interior structure of potentially hazardous object
- A space mission to Apophis will be supported in 2029 by a worldwide ground-based observation campaign
- Several options for a fast and low-cost mission
- International contributions (i.e. by NASA) are expected due to the high-interest from the community
- Opportunity to re-use technologies and payloads as well as to demonstrate the next step in deep-space exploration with self-standing cubsat technology
- Strong potential for public engagement and research opportunities

Thank you

Richard Moissl, Ian Carnelli