

# Apophis Way Forward

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SMPAG

11.10.2023



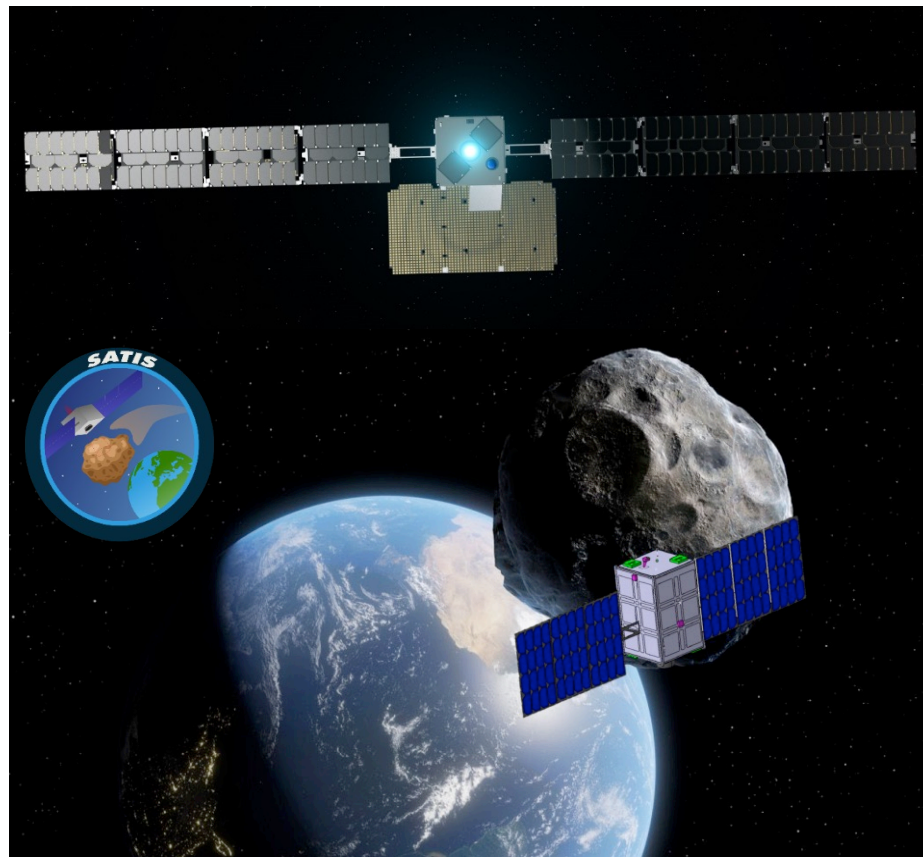


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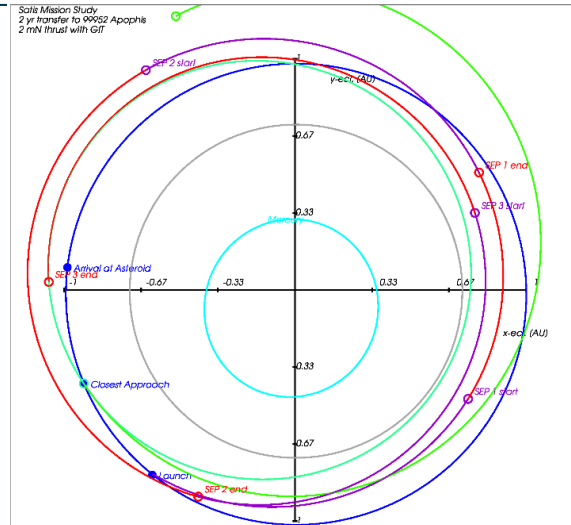
# Satis Apophis Rendezvous Mission Overview (S2P)

- Platform: 12U XL CubeSat
- Payloads:
  - Hyperspectral imager VIS/NIR/SWIR, TIR imager
  - Laser altimeter, radio science experiment
- Mission:
  - Rendezvous with Apophis two months prior to its close encounter with Earth on Friday 13<sup>th</sup> April 2029 at 31,500 km altitude over Atlantic ocean
  - Characterise change in physical properties before/during/after close encounter
- Profile: launch May 2027 to SSO 500 km with 350 kg kick stage, kick stage burn to Earth escape, 2-year transfer with electric propulsion
- Status: Phase A/B approved, two parallel Phase A studies planned to start in Q4 2023 for 7 months (ITT published, closing date 22/09/2023)



# Satis rendezvous scenario

- Launch Apr/May 2027, 2 years transfer, using **GIT with ~2mN thrust, Isp ~3000 s**
- Alternative option of HET with ~5mN thrust might allow for 1 year transfer
- Payload baseline
  - Hyperspectral imager (UV, VIS, NIR)
  - Thermal imager
- Arrival until 15<sup>th</sup> March 2029
- Initial light curve observations, then iteratively closer manoeuvres
- Full **high-resolution** characterisation (morphology and dynamics) pre and post flyby, high speed image acquisition during ECA phase
- Accurate monitoring of **potential surface reconfiguration** and mass shedding during closest approach



esa European Space Operations Centre Mission Analysis Section

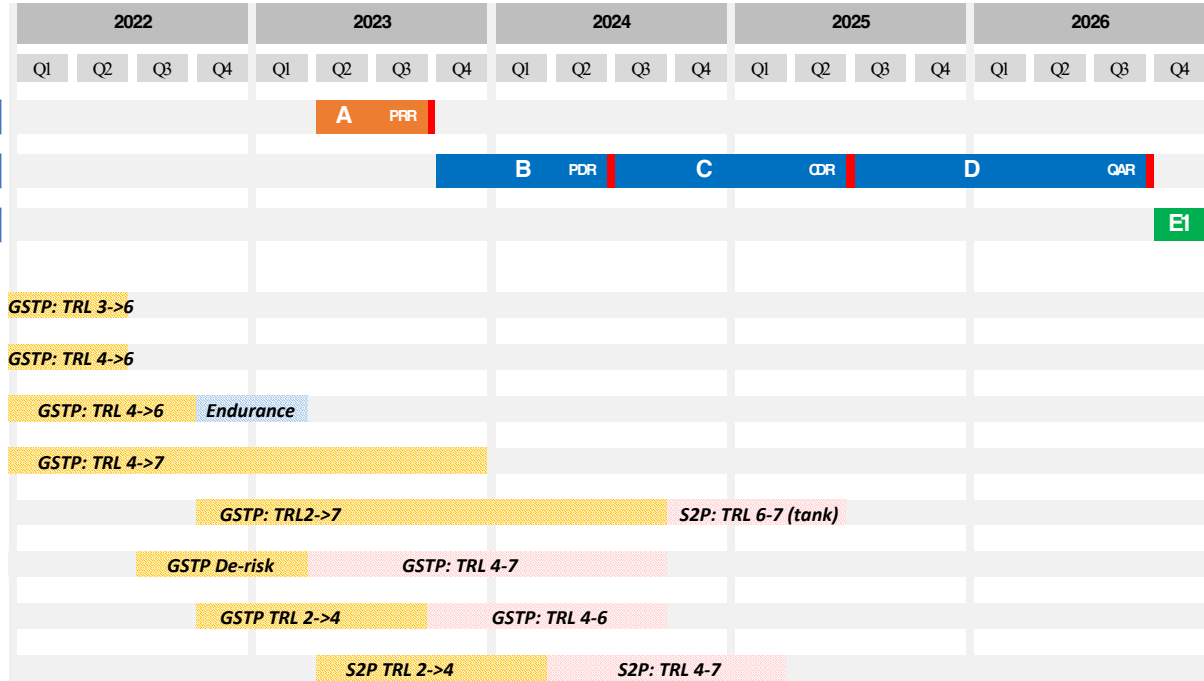
	Value
Launch	2027/5/13 / 4.177 km/s @ 37.1 deg
SEP Arc 1	2028/8/6 – 2027/9/19 / 456 m/s
SEP Arc 2	2028/1/9 – 2028/6/13 / 877 m/s
SEP Arc 3	2028/9/29 – 2029/3/14 / 1206 m/s
Arrival	2029/3/15

# Satis implementation Roadmap (to be updated)



## SATIS RDV SCHEDULE

IOD Missions	Beyond Leo	Phase A Feasibility Study
		Phase B/C/D Design, Development & Verification
		Phase E Launch & Operations



## Mission objectives

1. Characterize Apophis with **high-resolution before** (and after) the encounter:

- Orbit, Spin state and orientation (1%)
- Shape and surface changes (**10 cm**)
- Mass, density and porosity (1%)
- Interior structure, cohesion
- Presence of dust <1mm

2. Monitor Apophis with high temporal resolution (1min) **during** the encounter



## CORE payload suite



- 2 X **AFC** cameras (science/navigation)
  - *Hera AFC flight spare*
  - *Second AFC with complementary FoV (NASA TBC)*

2 X 6U **CubeSats** (Payload suite TBC)

## OPPORTUNITY Payload suite

*depending on resources availabilities*

*maximizing reuse of mature/existing instruments*

Thermal Infrared Imager (JAXA + BE) || Laser Altimeter (PT+LV)  
|| Seismometer (FR) || (Low Frequency) Radar (FR) ||  
Accelerometers (ES) || Radiometers (IT) || Laser  
Retroreflector(IT)

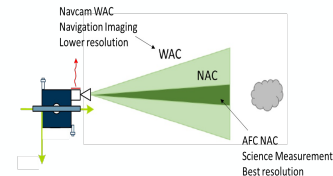
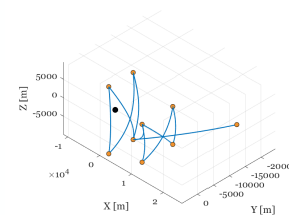
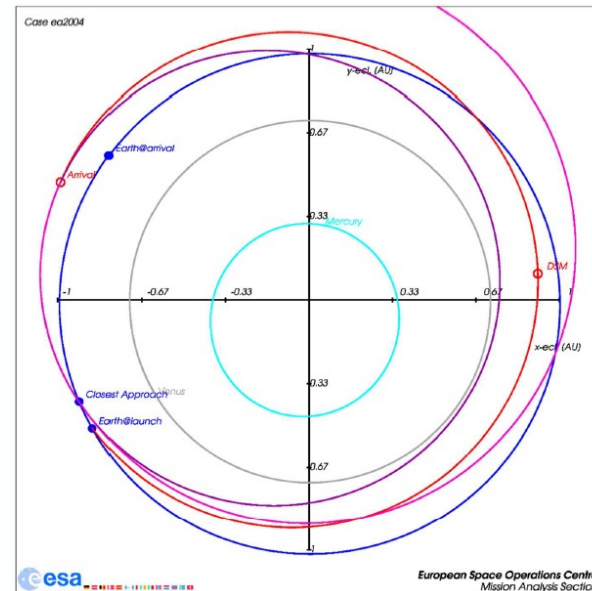
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Expression of interest gathered from Hera WGs

# Mission Profile

## RAMSES Mission Profile

Launch	Launch Vehicle	Ariane 6.2 (CSG)
	Backup Launch Vehicle	Falcon 9 Block 5 reusable (KSC/VSFB)
	Launch Window	20 April 2028 (21 dd)
Transfer	Duration	10 months
	Delta V	< 1590 m/s
	Arrival at Apophis	February 2029
Close Proximity Operations	Insertion Manoeuvres	<20 days
	Pre-encounter Phase (PRE)	1 March – 11 April 2029 Passively safe hyperbolic arcs (20km) Hovering at 20 – 10 – 5 – 1 km
	Close-encounter Phase (CEP)	12-14 April 2029 Hovering at 5 km (Constant Sun phase angle)
	Post-encounter Phase	Hyperbolic + hovering trajectories TBC
	End of nominal Ops	August 2029
	Experimental phase	Extended operations Autonomy experiments Controlled descent Commercial deep-space operations test bench ....



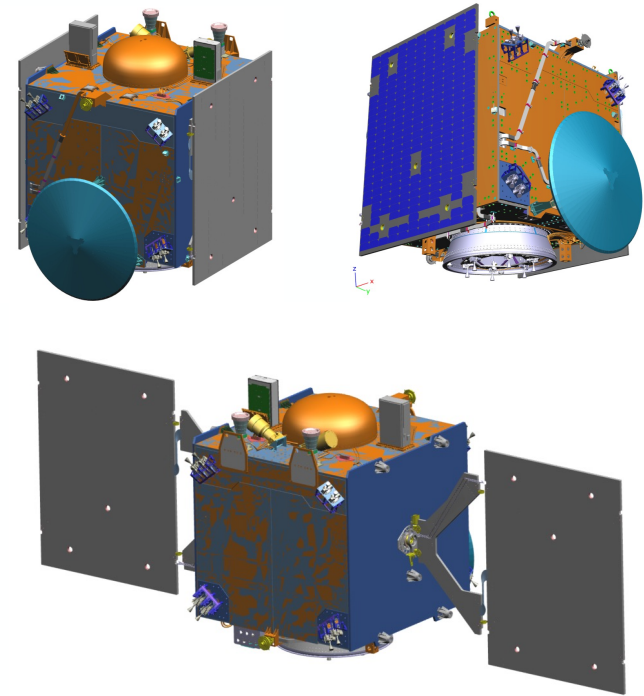
*Reuse of the Hera platform adapted to RAMSES mission profile*

## Mission concept

- Launch in April 2028 (A62/F9), direct transfer (10 months)
- Maximum **re-use** of the **Hera** architecture (> 1000kg class)
- Very limited amount of modification required (larger tanks, adaptation to the payload suite)
- **Single string** architecture for significant **mass, cost and schedule savings** while maintaining high reliability (>0.9) in line with recent mission at NASA (e.g. DART) and JAXA (Hayabusa-2)
- **Large** Opportunity Payload allocation (20-30 kg)
- Very good compliance with observation requirements

## Current status

Ph1 started May 23, **PDR-level maturity in early 2024**



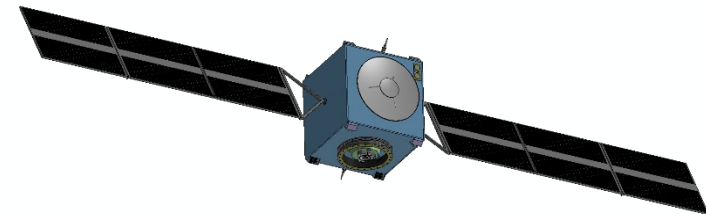
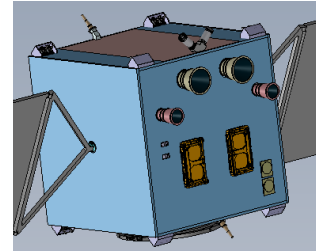
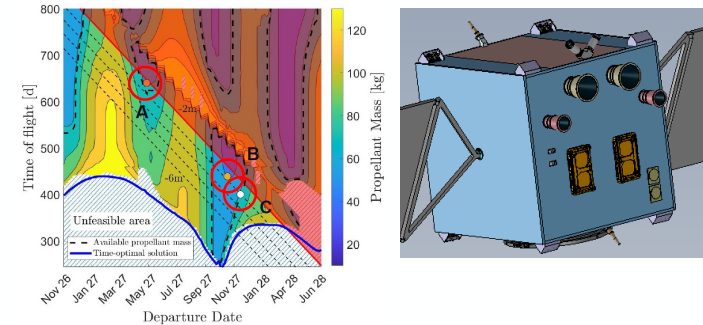


# RAMSES [COTS] concept

*Novel commercial deep space platform to be developed largely based on existing equipment*

## Mission Concept

- Launch in Q4 2027 (A62/F9/PSLV TBC), transfer arc based on electric propulsion
- Major evolution of existing platform (500kg class)
- Large use of COTS and existing equipment with deep space heritage for critical equipment
- Limited opportunity payload allocation (< 10 kg)
- Promising compliance to observation requirements, to be further confirmed along Ph1.



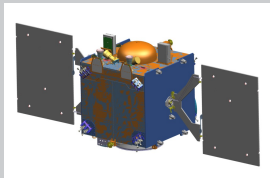
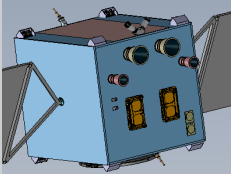
## Current status

Ph1 started Jun 23, **SRR**-level maturity in **early 2024**

# ESA Apophis studies summary

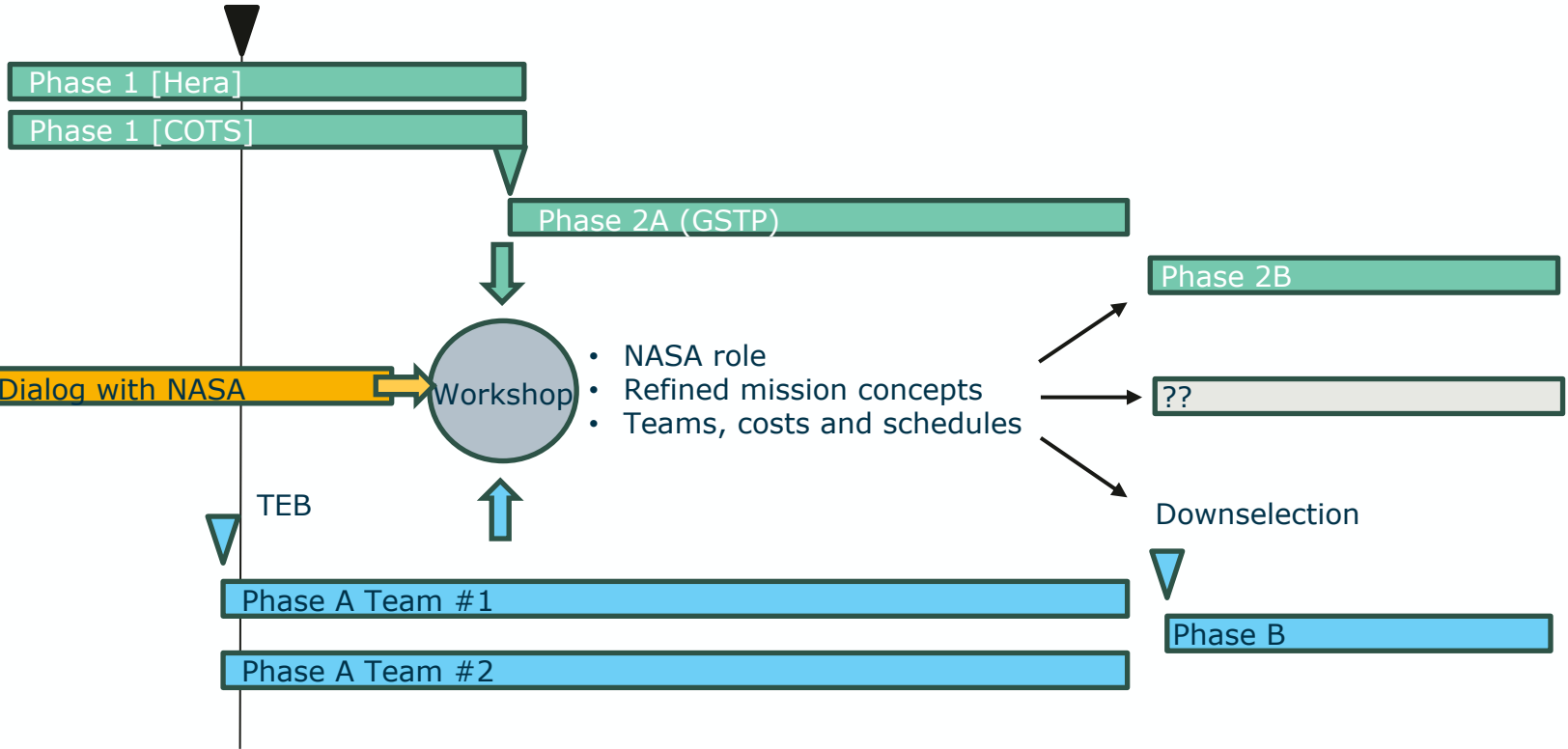
RAMSES is ESA's study for a small mission to rendezvous with Apophis **prior** to Earth encounter in 2029

Complements a range of studies for missions to Apophis within the ESA Planetary Defense programme

	RAMSES	RAMSES II	SATIS
	Adaptation of the Hera platform <i>(Chemical propulsion)</i>	Novel deep space platform based on existing equipment <i>(Electrical propulsion)</i>	12 U CubeSat <i>(Electrical propulsion)</i>
<b>Satellite class</b>	> 1000 kg	500 kg	12 U Cubesat (< 30kg)
<b>Current status</b>	Ongoing, <b>PDR</b> level in Q1 2024 	Ongoing, <b>SRR</b> level in Q1 2024 	Phase A to be KO soon
<b>Launch</b>	Mid 2028	End 2027	Mid 2027
<b>Top risk</b>	Funding continuity	Mostly existing technology, but platform still to be developed	Some enabling technologies still to be developed
<b>Opportunity payloads</b>	2 AFC + 2 6U CubeSats Opportunity: Large (20-30 kg)	2 AFC + 2 6U CubeSats Opportunity: Limited (5 kg)	Hyperspectral + Thermal Imager Opportunity: TBC

# WAY FORWARD

RAMSES



SATIS



Thank You !

