National Aeronautics and Space Administration

Apophis Recon Concepts

SMPAG Mtg #21

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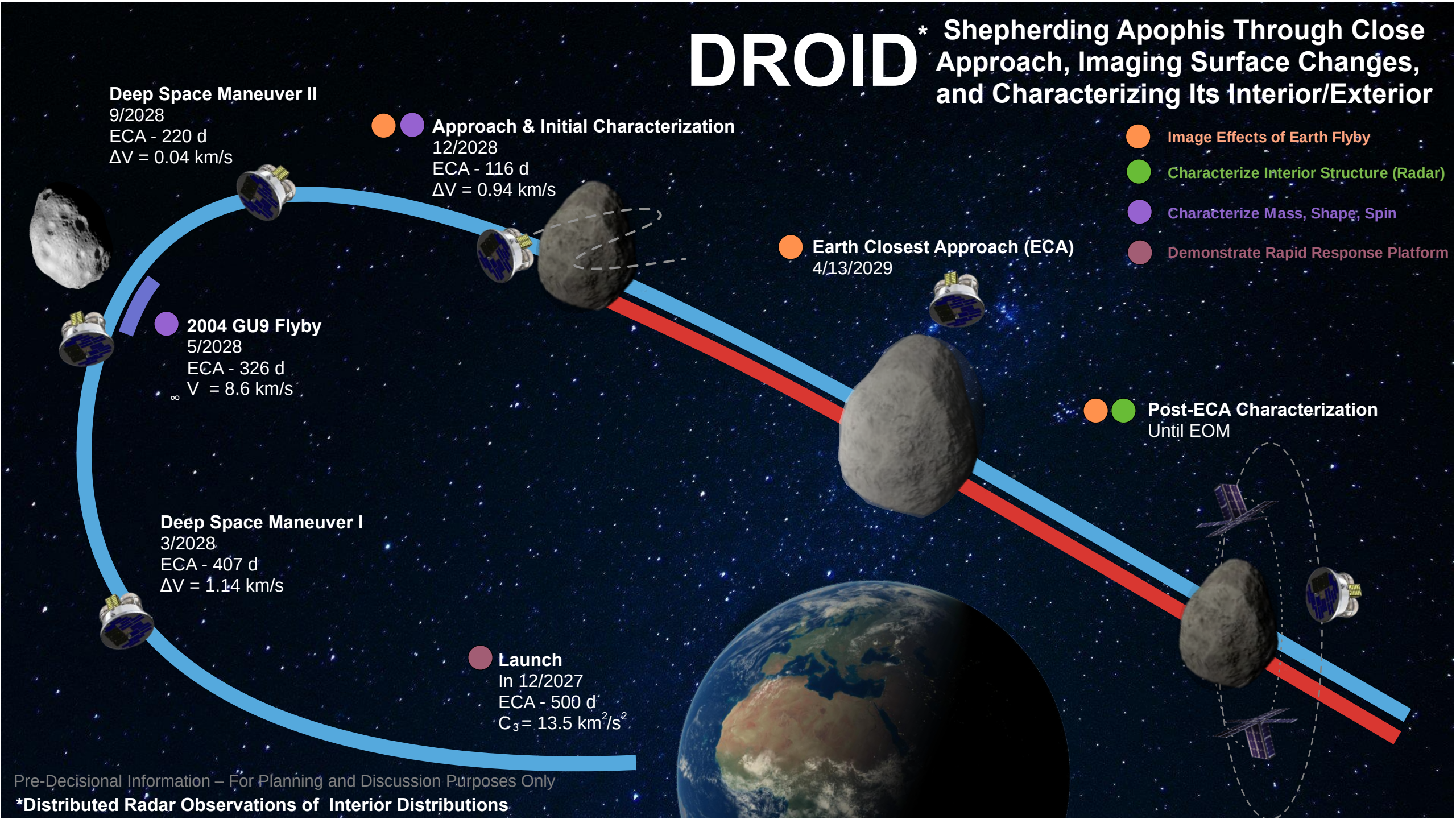
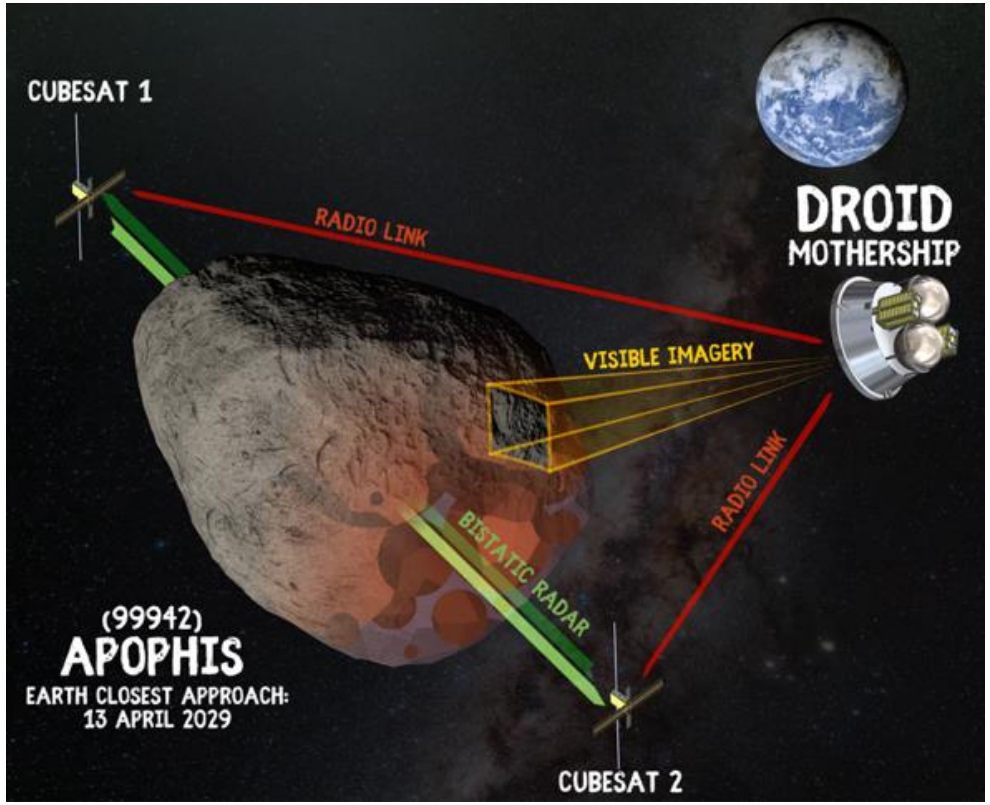
DROID* Shepherding Apophis Through Close Approach, Imaging Surface Changes, and Characterizing Its Interior/Exterior



*Distributed Radar Observations of Interior Distributions

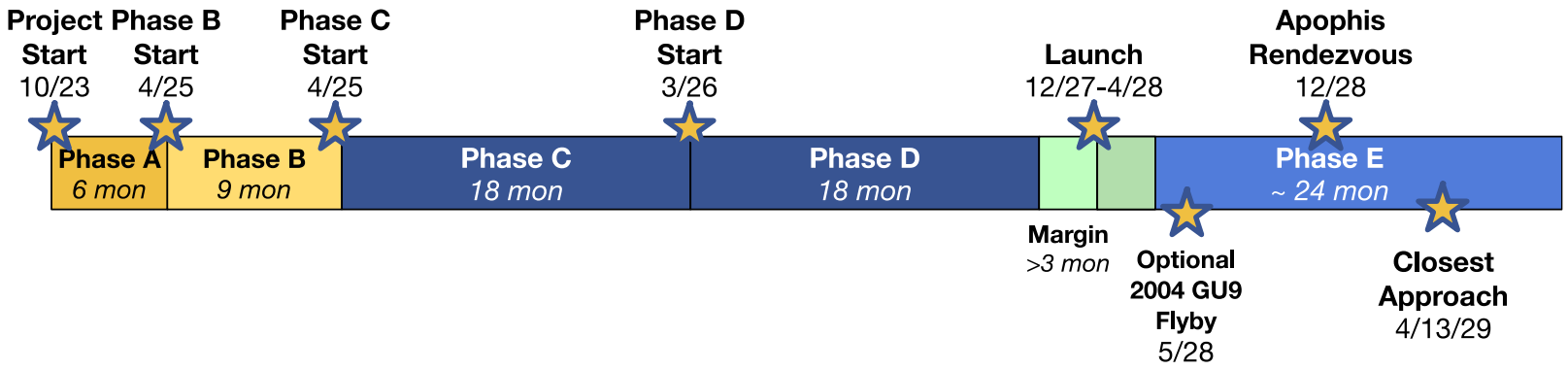
DROID is an International Collaboration

- **CNES:** *CubeSats, Wide Angle Cameras, Inter-Satellite Links*
- **Rocket Lab:** *Mothership, Launch Vehicle*
- **University of Grenoble, Luxembourg:** *Monostatic/Bistatic Radar*
- **JPL:** *Management, Narrow Angle Camera*



CubeSats use their radars to characterize interior structure and dielectric distribution as the Mothership develops a <5 cm/px map.

Preliminary Schedule



FLARE Mission Overview

Launch 6/1/2028
VSFB or KSC
Falcon 9

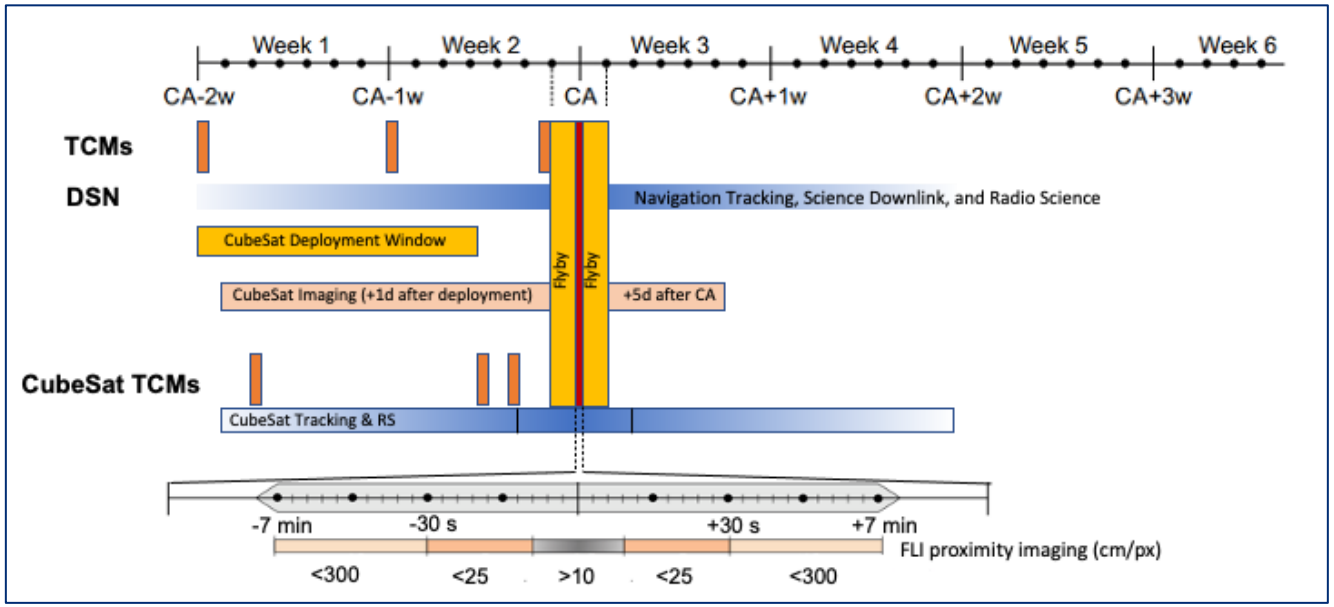
Flyby 1/21/2029
Speed 2 km/s
Closest Approach Distance 40 km

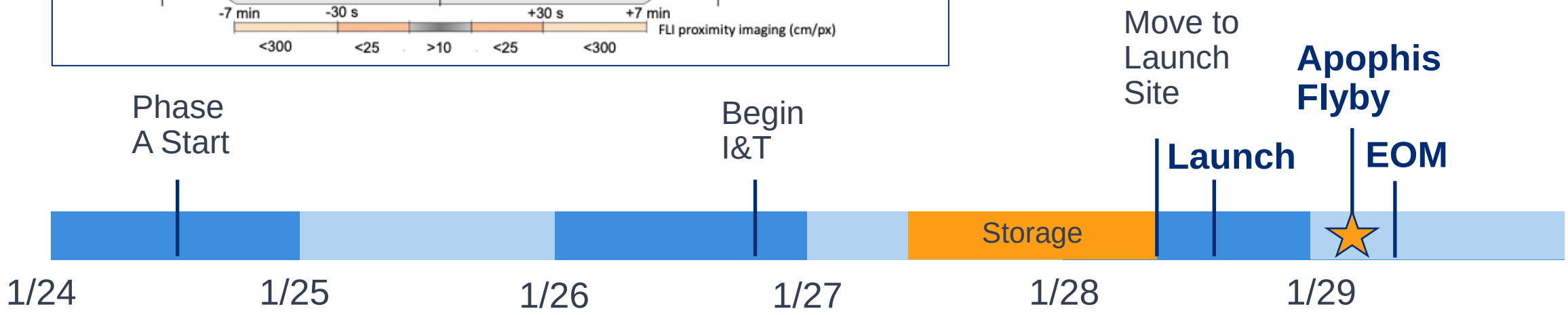
FLARE (Flyby Asteroid REconnaissance) Mission uses a unique opportunity to establish the utility of flyby data by:

1. Characterizing the key physical properties of Apophis that are important for planetary defense, including shape and mass of the asteroid, using two instruments: a Narrow Angle Imager (FLI) and CubeSat Mass experiment (FLAME)
2. Testing rapid response capabilities in a compressed schedule.
3. Validating measurements with higher quality “truth data” from the OSIRIS - APEX rendezvous mission
4. Establishing the surface conditions of Apophis before its close approach

Baseline Conops, Schedule, and Cost

FLARE
FLYBY ASTEROID RECONNAISSANCE MISSION





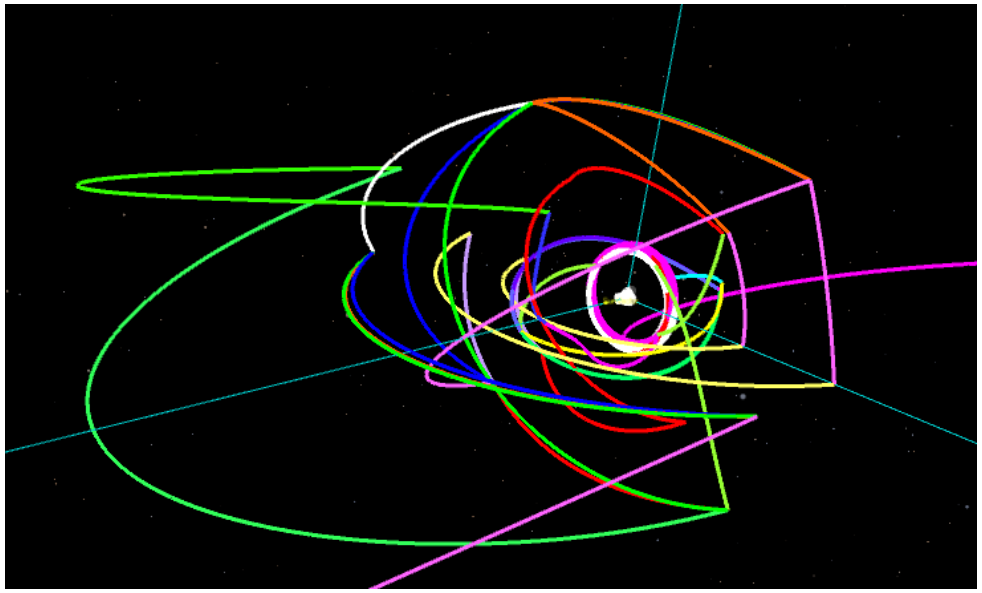
*Schedule Challenges can be implemented to further reduce durations

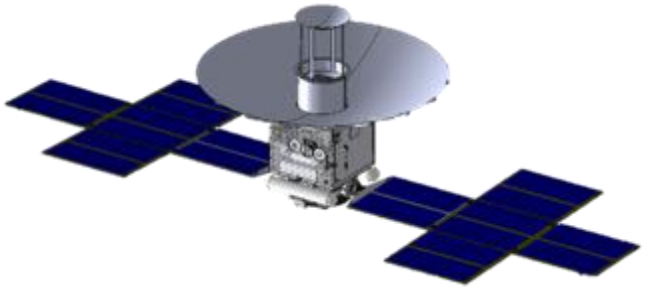
Reconnaissance of Apophis (RA)

NASA/Goddard Space Flight Center (GSFC)

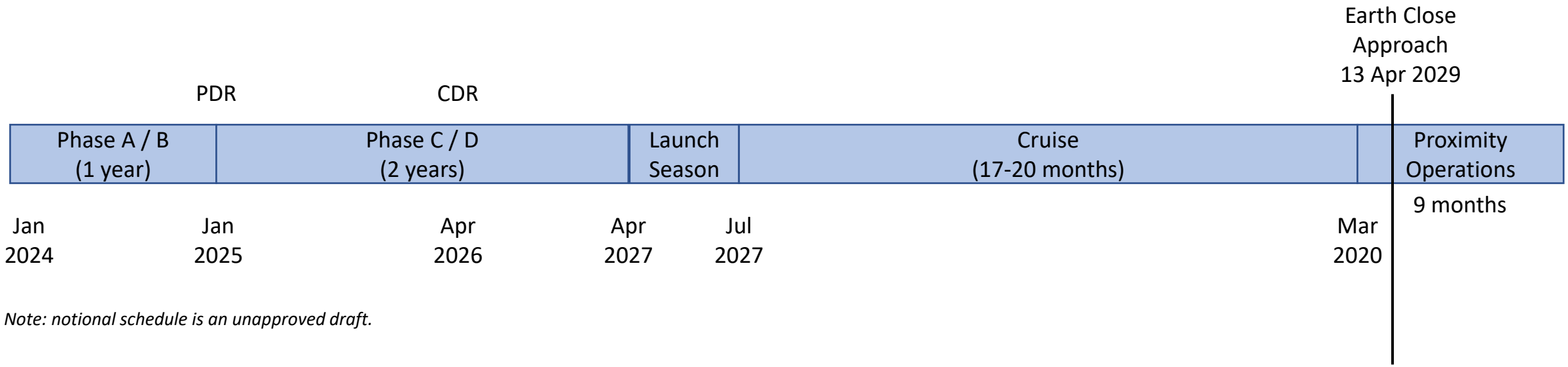
RA is Carefully Designed to Provide Significant Science On a Smallsat Budget

RA is a capable smallsat rendezvous mission able to detect any disturbances to Apophis during the 2029 Earth approach, through both real-time observations and comparison of pre-/post-Earth close approach survey data. The shape models will have a resolution of ≤30 cm, with resolution as fine as 5 cm in select areas. Proximity operations have been designed based on OSIRIS-REx heritage, by personnel with OSIRIS-REx flight operations experience.



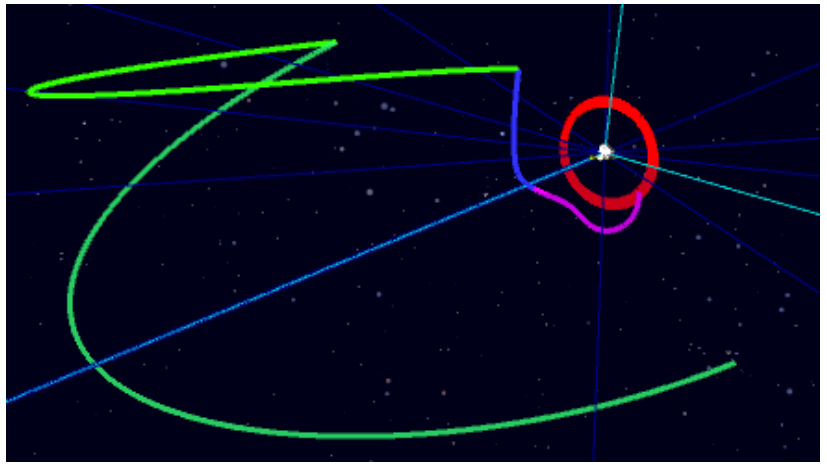


Notional Schedule for RA



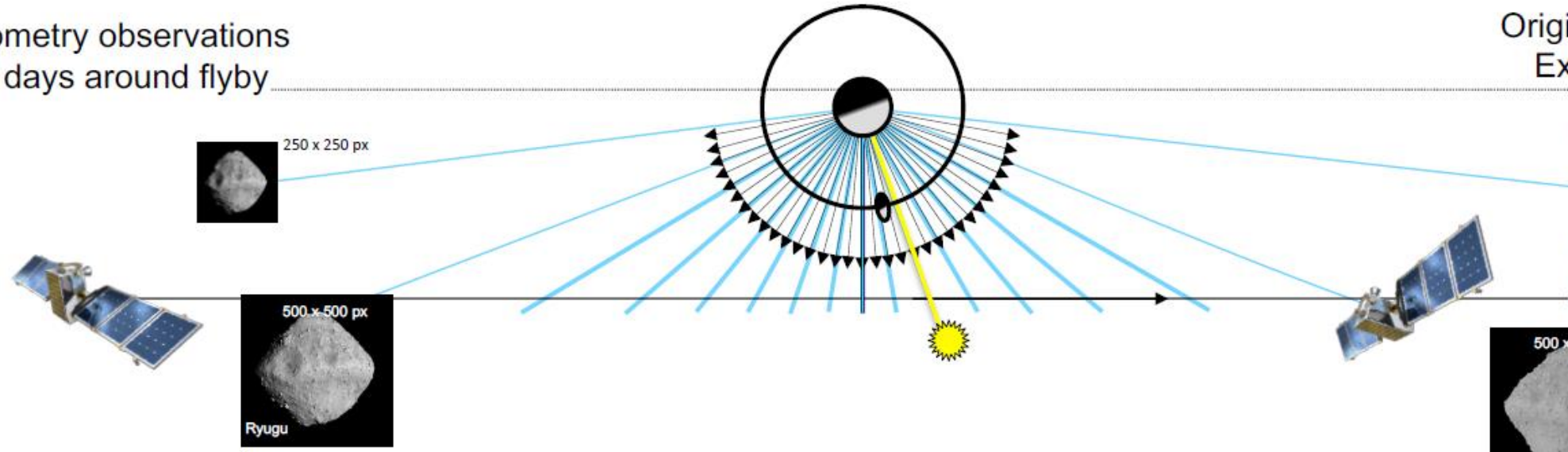
Note: notional schedule is an unapproved draft.

RA can follow Apophis through Earth close approach while both maintaining passive safety and remaining close enough to collect real-time observations.



Janus Apophis observations use the same design as the original *Janus*

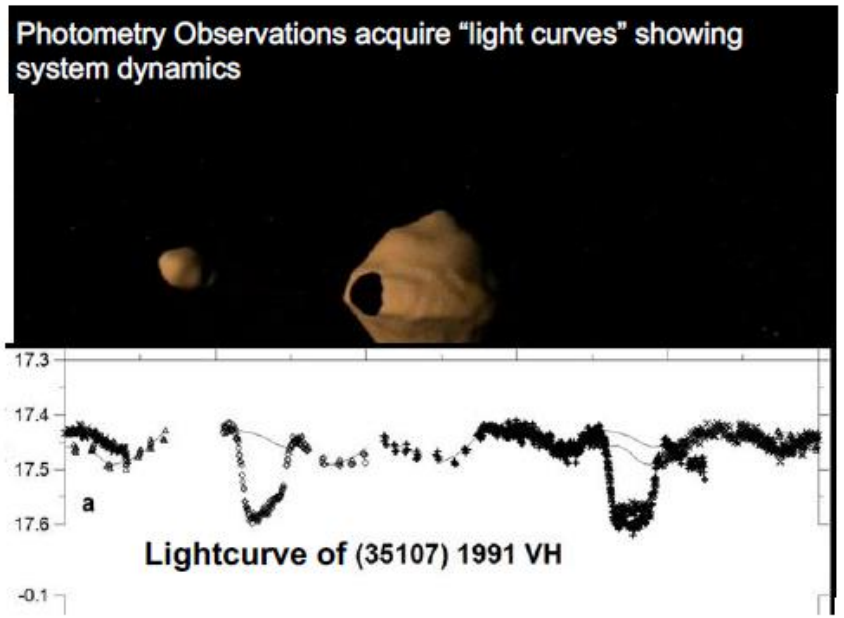
Photometry observations
~±2 days around flyby

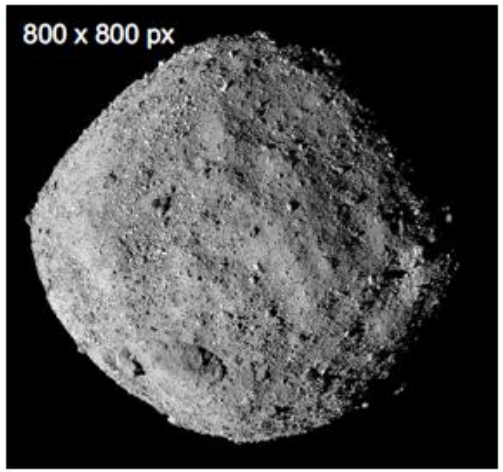


Original *Janus* Examples

Heuristic images showing expected surface resolution and temperature ranges

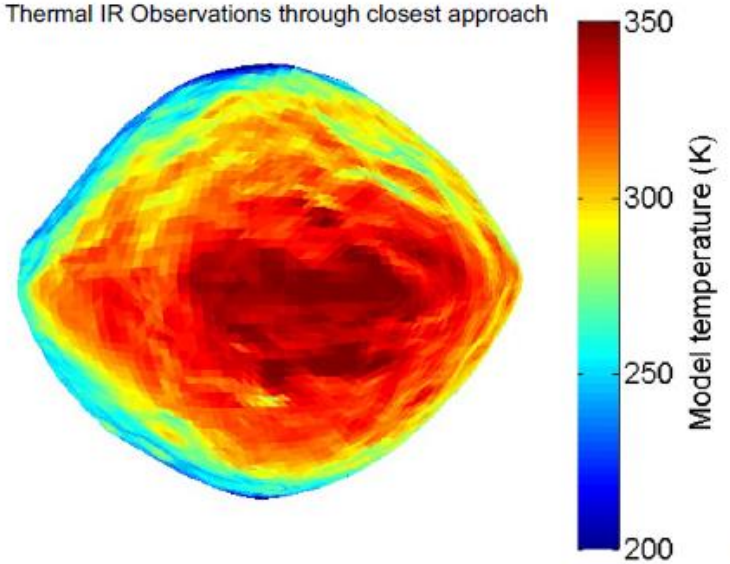
Photometry Observations acquire "light curves" showing system dynamics





Visible imaging will provide surface morphology at a range of phase angles.

Thermal IR Observations through closest approach



Small Bodies Assessment Group (SBAG) Specific Action Team - Apophis Report

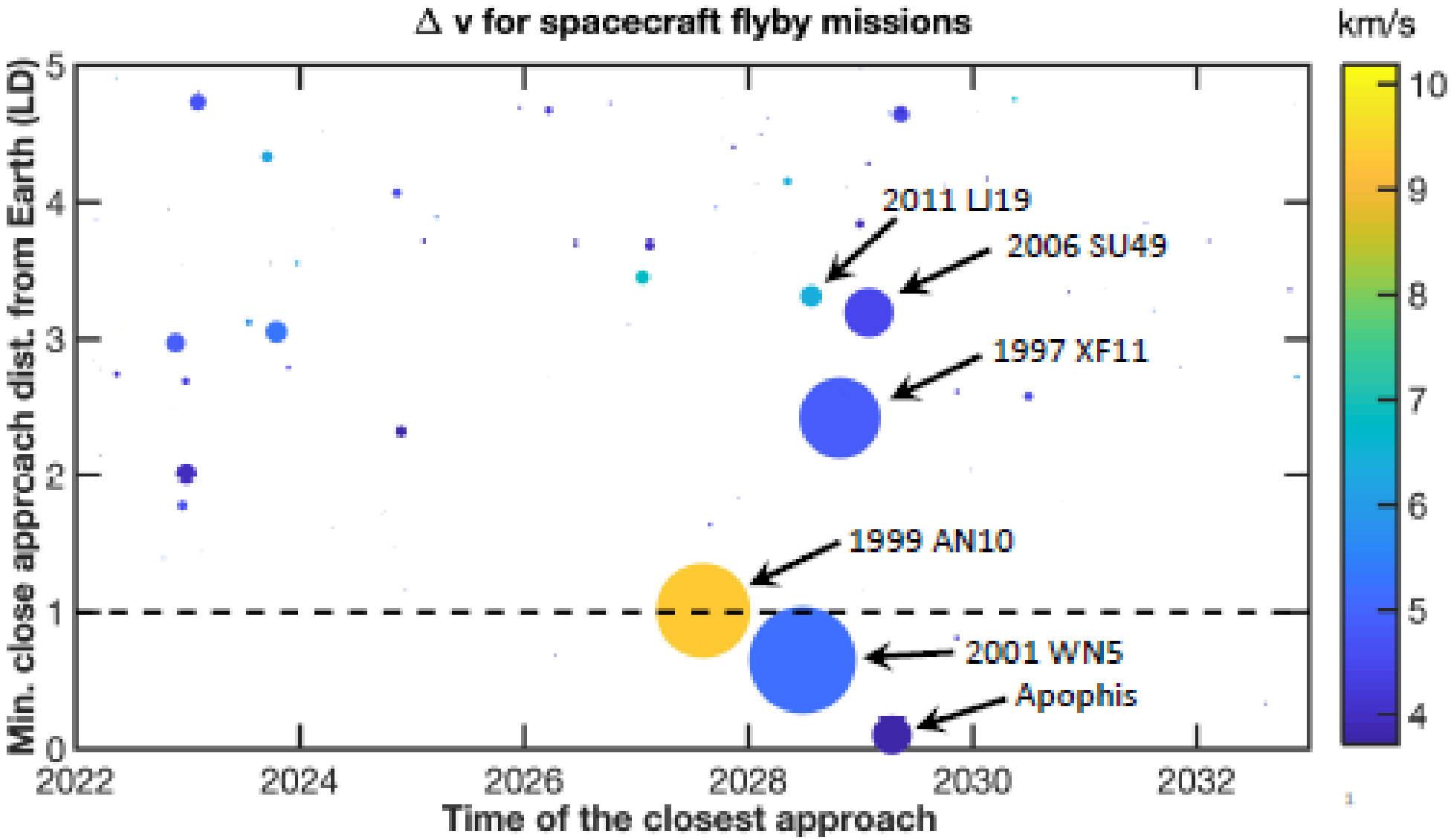
Table 2. Apophis science in 2029 enabled by ground-based and space-based optical facilities

Optical wavelength	Immediate data products	Apophis science	Example Facilities
IR	unresolved images	• effective diameter; • thermal inertia • limited mineralogy	NEO Surveyor
	spectra	• mineralogy and bulk composition; • space weathering; • taxonomy; • inferred microscopic surface density	SpeX@NASA IRTF
mm to sub-mm	unresolved? images	• thermal inertia	ALMA
Visible	lightcurves	• 3D convex shape model; • spin state; • moment of inertia ratios;	
	spectra	• taxonomy; • compositional analogs	ubiquitous
	occultation chords	• size; • limited shape information; • heliocentric orbit improvement	
	adaptive optics	• 10-m resolution images	SPHERE@VLT
	speckle imaging	• 10-m resolution images	QWSSI@LDT
	polarimetry	• regolith properties;• optical albedo;• surface heterogeneity	WIRC+Pol@Palomar 200"

NOTE—NASA IRTF - NASA Infrared Telescope Facility at Mauna Kea, Hawaii
ALMA - The Atacama Large Millimeter/submillimeter Array in the Atacama desert, northern Chile
VLT - ESO's Very Large Telescope in Chile
LDT - Lowell Discovery Telescope, Arizona, USA
Palomar 200' - The Hale telescope at the Palomar Observatory, California, USA

SPHEREx launches in early 2025

https://www.lpi.usra.edu/sbag/documents/Apophis_SAT.pdf


Δ v for spacecraft flyby missions
km/s
Min. close apprcach dist. from Earth (LD)
Time of the closest approach
2011 UI19
2006 SU49
1997 XF11
1999 AN10
2001 WN5
Apophis
0
1
2
3
4
5
2022
2024
2026
2028
2030
2032
4
5
6
7
8
9
10