Apophis rendezvous mission for year 2029 : Draft plan

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Backgrounds: science and planetary defense

- Apophis will approach the Earth **to come within GEO orbit** during the encounter on April 13, 2029, thus expected to offer a unique chance for detailed studies for science and planetary defense.

- The encounter is expected to trigger observable changes in the dynamics, spin-states, and surface arrangements of Apophis due to tidal forces caused by Earth's gravity field, to alter its surface topography with material movement: landslide and mass ejection.

- It will be a unique opportunity to study..
  1) the global properties, 2) the surface arrangements, and 3) their detectable changes expected to happen on the body during the approach.

- The only possible way to quantitatively study such tidally induced effects will be **in-situ measurements** with a dedicated space mission aimed at the encounter.

Backgrounds: policy and technology

- The proposed mission is based on the 3rd revision of the Basic Plan for Promotion of Space Development (2018) of the Korean Government, in terms of planetary science, planetary defense and technology demonstration.

- The proposed mission is also based on the Long-term Research Plan (2022-2030) of Korea Astronomy and Space Science Institute (KASI).

- KASI has research capacities in 1) ground-based observation and data analysis, and 2) dynamical studies on small bodies and IDP, 3) science payload design and building (for small satellites and lunar missions), 4) small satellite development and operations, and 5) precision tracking w/Korea VLBI Network (KVN).

Science traceability matrix: TBR

	Science objectives	Measurement objectives	Instruments	Data products/ results
1	Determine bulk properties: sizes, multiplicities (binarity, satellites), shapes, albedos, surface topography, bulk densities and masses of target NEAs	Map the surfaces of target NEAs at ~0.5 m/pixel under different lighting conditions over several rotations	Navigation Camera, Polarimetric Camera, Multiband Camera, Laser altimeter and (NIR spectrograph)	Global mosaics at 0.5 m/pixel, albedo maps, shape models, rotation models, topographic maps, temporal changes in topography and phase curves
2	Determine dynamic and mechanical properties: rotation and precession periods, rotation/Euler angles, upper limits on tensile strengths and orbit and spin evolution of target NEAs	Map the surfaces of target NEAs at ~0.5 m/pixel over different viewing geometries to mosaic the whole surfaces	Navigation Camera, and Multiband Camera	Global mosaics at 0.5 m/pixel, light curves and physical models; implications for interior structure
3	Determine surface properties: taxonomy, degrees of space weathering, relative regolith size distributions, and detect traces of hydration on target NEAs	Map the surfaces of target NEAs at ~0.5 m/pixel in four visible bands and three polarization angles, and at _ m/pixel with NIR wavelengths over different viewing geometries to mosaic the whole surfaces	Polarimetric Camera, Multiband Camera and (NIR spectrograph)	Global mosaics at 0.5 m/pixel and polarimetric maps
4	Detect mass ejection: characterize source regions, particle size distribution and ejection velocities; Determine their source(s) as function of taxonomy, topography, rotation and orbital positions	Map mass ejection as function of time and location, in four visible bands and three polarization angles	Navigation Camera, Polarimetric Camera, Multiband Camera and Laser altimeter	Gravel size and velocity distributions (temporal variations) and surface activity maps
5	Detect Interplanetary Dust Particles (IDPs): particle size distribution, velocities, their origins and dynamical evolution	Characterize particle size distribution and velocities of dust particles	Dust particle detector	Dust/grain size and velocity distributions (temporal variations),
6	Discover Earth Trojans during the cruise phase	Discover moving objects with the limiting magnitude of V=14.5 over the 2°x2° FOV.	Navigation (mapping) camera	Discovery of at least one Earth Trojan asteroid and size distribution of Earth Trojans
7	Detect the existence of crustal magnetic sources on asteroids and magnetic perturbations generated by solar wind interaction (or space weathering) with small magnetic obstacles (i.e., asteroids)	Vector Magnetic fields in GSE coordinates or specific coordinates; Temporal magnetic field variations to investigate interaction with surface geology and crustal magnetic fields; Upward and downward Particle distributions	Magnetometer and Particle (i.e., solar wind, galactic cosmic ray, solar energetic particle) detector	Crustal magnetic fields map, solar wind interaction map, and space weathering map

Science payloads: TBR

payload	mass	volume	power	reference
navigation camera	< 4 kg	30 x 20 x 10 (cm)	10 W	ONC-T
polarimetric camera	8 kg	70 x 10 x 20 (cm)	10 W	PolCam
laser altimeter	4 kg	22 x 23 x 35 (cm)	17 W	LIDAR

payload	mass	volume	power	reference
Mapping/multiband camera	< 4 kg	30 x 10 x 10 (cm)	10 W	-
dust particle detector	2 kg	100 x 100 x 30 (cm)	< 1 W	Ikaros
magnetometer	3.5 kg	140 x 25 x 15 (cm)	4.6 W	KMAG

System analysis and spacecraft configuration: TBR

Dry mass: *150 kg*
Wet mass: *370 kg*
Maximum thrust: *0.03 N*
Specific impulse: *1500 **

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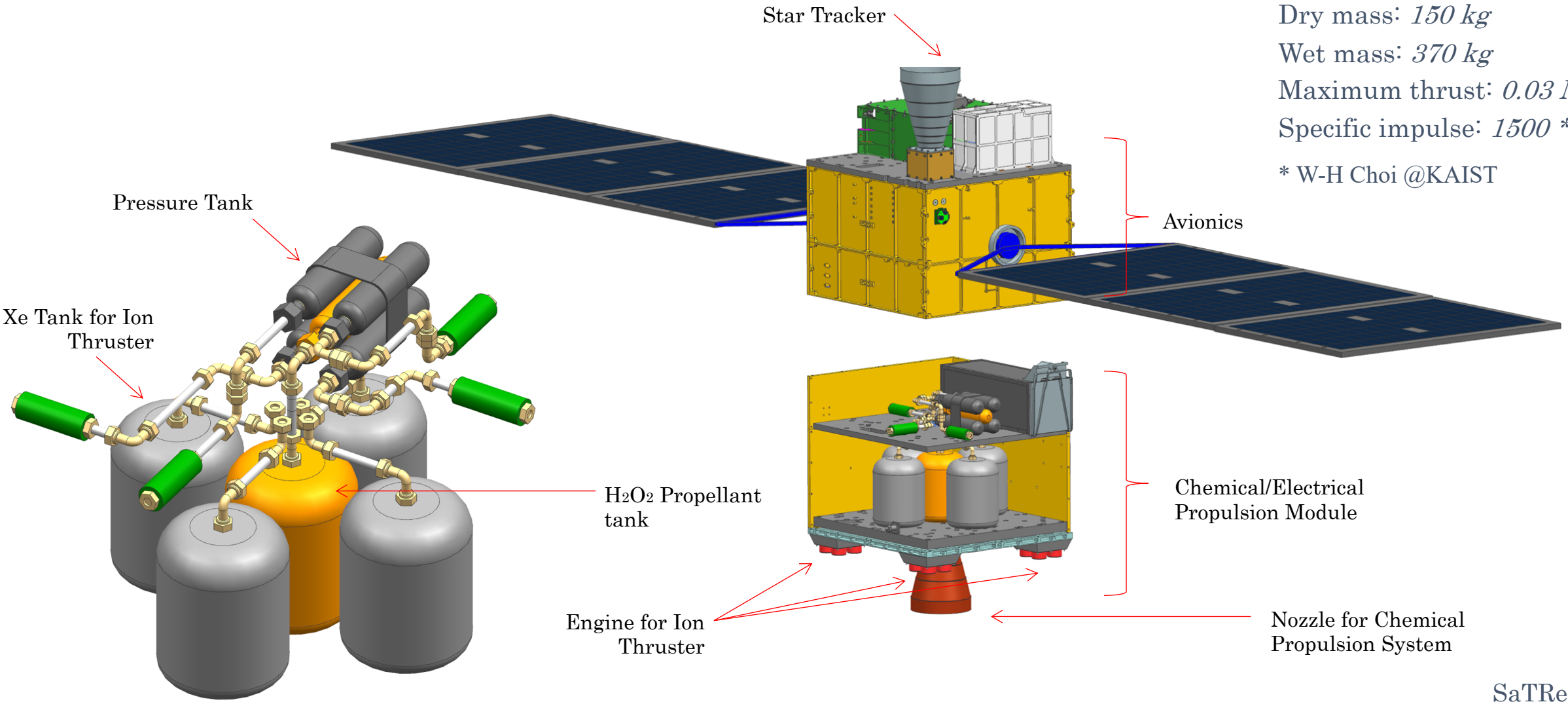
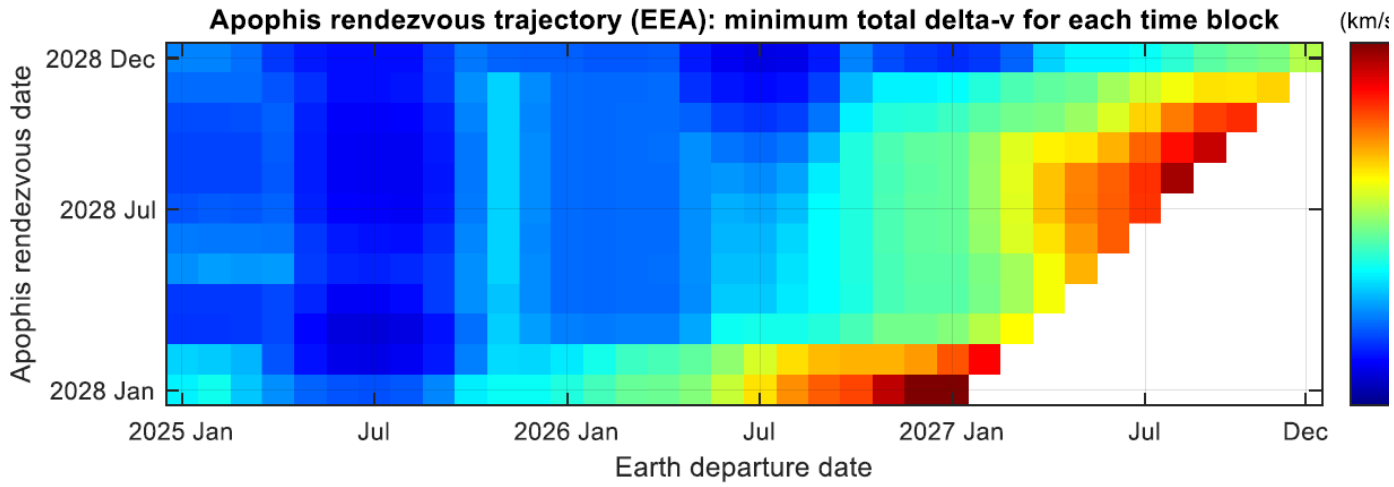
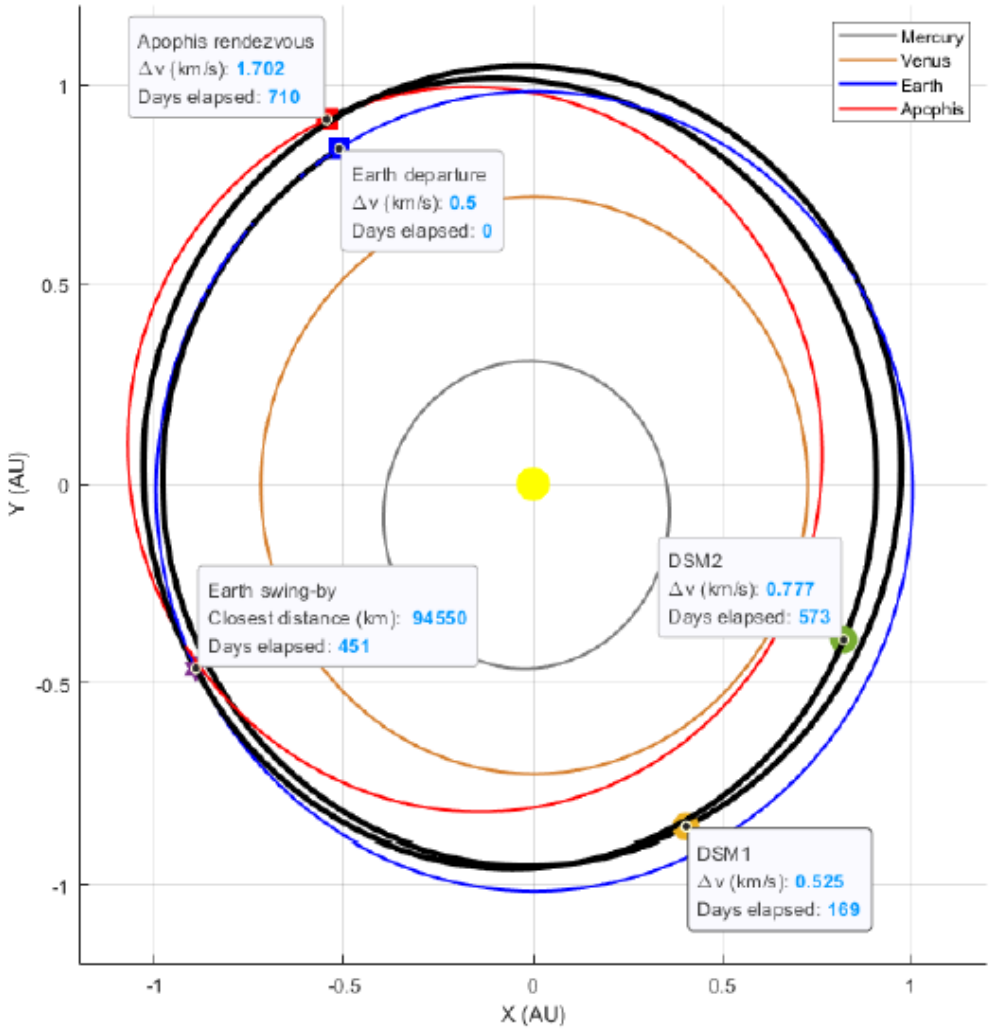


Preliminary mission analysis and trajectory design

순번	출발일	도착일	이동 시간 (일)	방문 순서	총 Δv (v_∞ 가정) (km/s)	총 Δv (LEO 출발 가정) (km/s)
1	2025-01	2028-09	1,318	EEEA	3.269	5.888
2	2025-07	2028-03	965	EEA	3.258	5.875
3	2025-07	2028-09	1,137	EEA	3.335	5.971
4	2026-07	2028-12	902	EEA	3.294	5.931
5	2027-01	2028-12	710	EEA	3.503	6.168





Milestones and collaboration opportunities

- We conducted a preliminary mission analysis for the proposed mission, and found that the **launch windows** in **July 2026** and in **January 2027** are the most energy-efficient opportunities.
- One of our current options for the launcher is to use the KSLV (Korea Space Launch Vehicle) series rocket in development.
- Our tentative plan is **1) to design** (2022-2023), **2) to build, integrate, and test** (2024-2026), **3) to launch** (2026/27), and **to perform 4) science operations** (2026/27-2029) with universities, research institutes, and companies in Korea.
- However, it is opened to overseas institutes for **joint scientific studies and operations.**