La missione ANIME:
esplorazione degli asteroidi vicini alla Terra

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on behalf of the ANIME team

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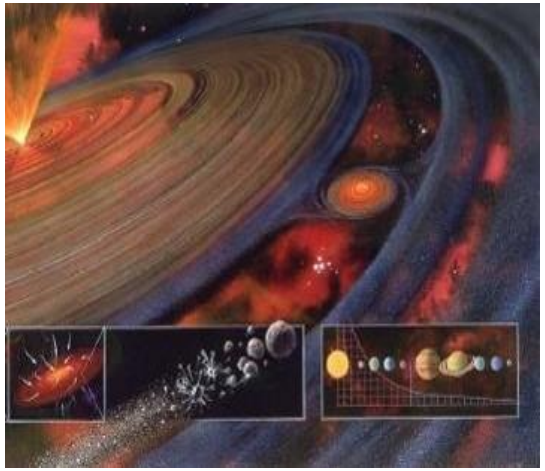
Agenzia Spaziale Italiana

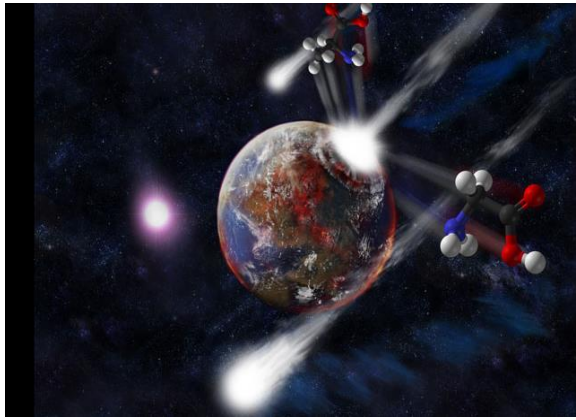
ANIME
Asteroid Nodal Intersection Multiple Encounters

In a nutshell

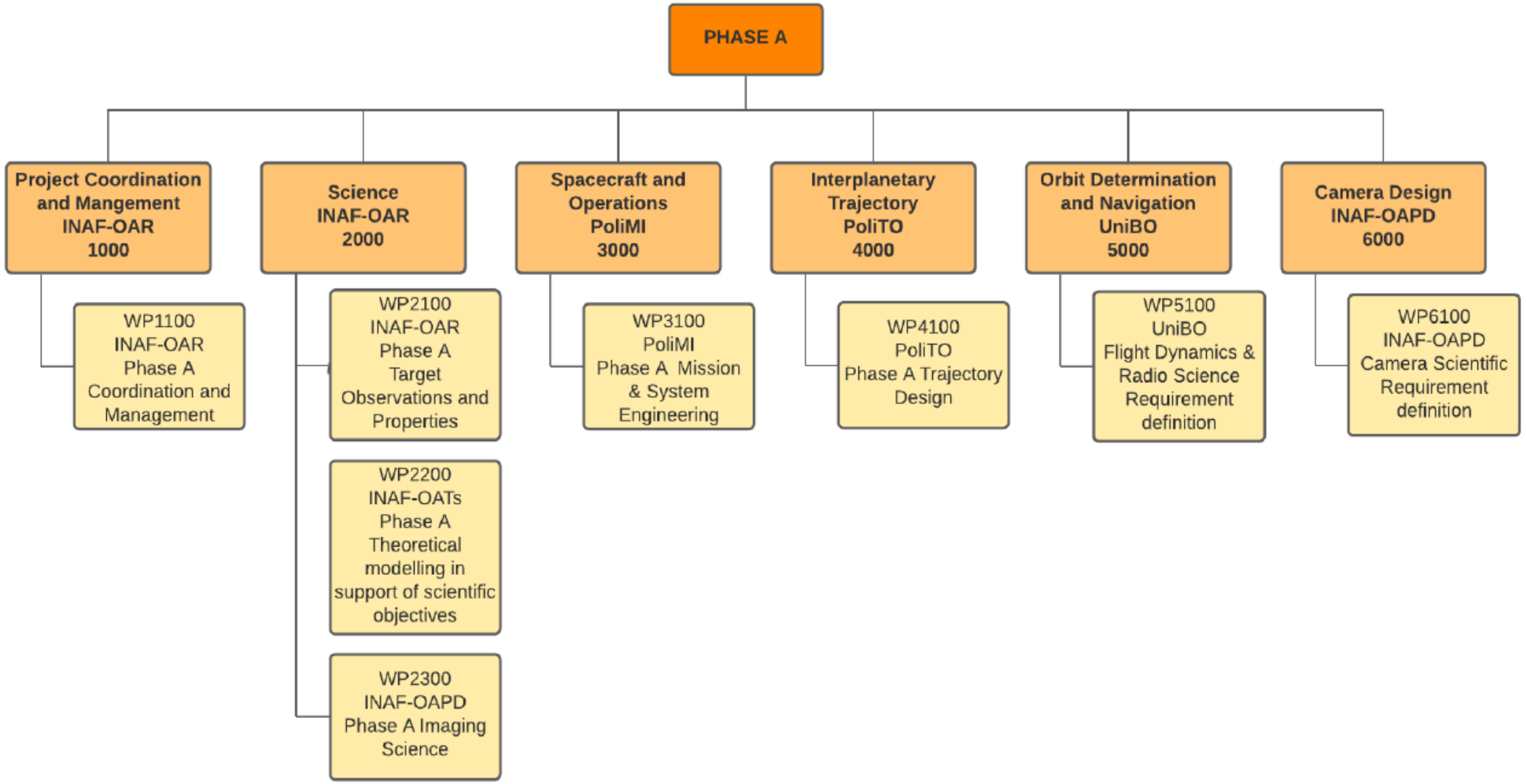
Agenzia Spaziale Italiana

- ✓ ASI ALCOR small satellites program
  - 8-month Phase A KOM: 29 Nov. 2023
- ✓ 12-U CubeSat
  - Payload: 2 COTS cameras (+ transponder)
- ✓ Encounters with multiple near-Earth asteroids (2 fly-bys + 1 rendezvous)
  - Science
  - Planetary defense
  - Future resource utilization and human exploration
  - Technology validation in deep space

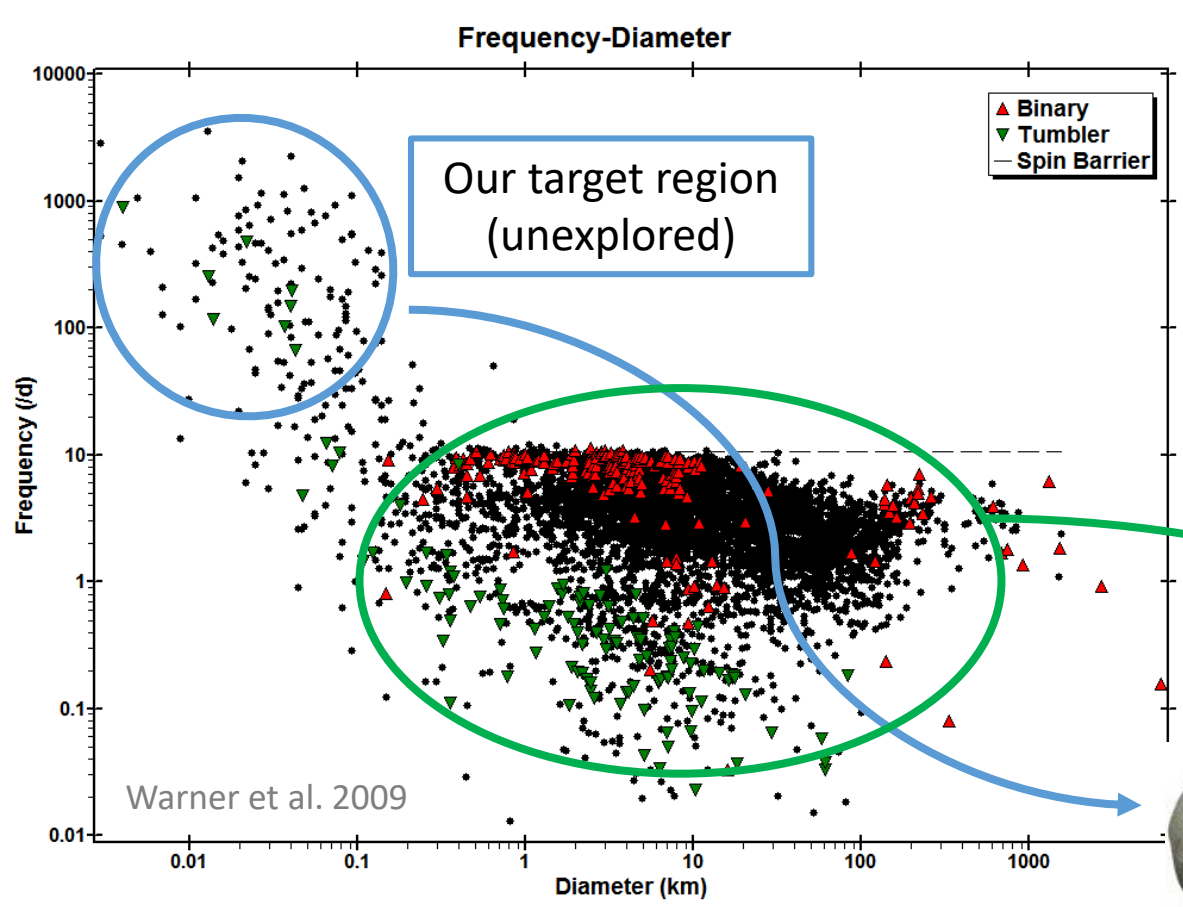


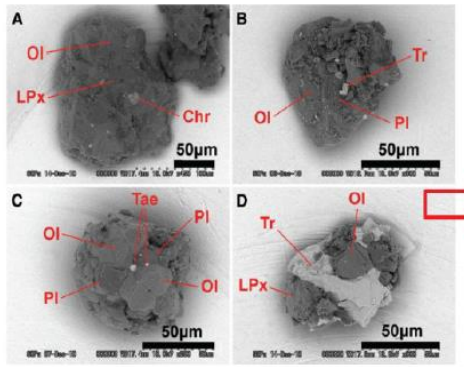


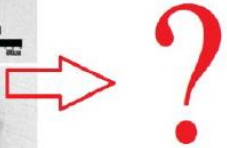
WBS

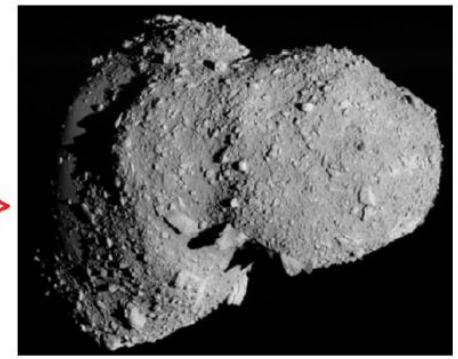

PHASE A
Project Coordination and Mangement INAF-OAR 1000
WP1100 INAF-OAR Phase A Coordination and Management
Science INAF-OAR 2000
WP2100 INAF-OAR Phase A Target Observations and Properties
WP2200 INAF-OATs Phase A Theoretical modelling in support of scientific objectives
WP2300 INAF-OAPD Phase A Imaging Science
Spacecraft and Operations PoliMI 3000
WP3100 PoliMI Phase A Mission & System Engineering
Interplanetary Trajectory PoliTO 4000
WP4100 PoliTO Phase A Trajectory Design
Orbit Determination and Navigation UniBO 5000
WP5100 UniBO Flight Dynamics & Radio Science Requirement definition
Camera Design INAF-OAPD 6000
WP6100 INAF-OAPD Camera Scientific Requirement definition

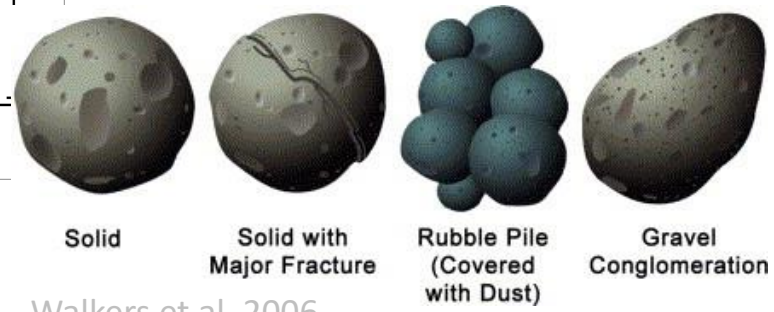
Target asteroids











Walkers et al. 2006

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Asteroid Nodal Intersection Multiple Encounters

Target asteroids

- ✓ *Rendez-vous target: 2000 SG344*
  - Diameter ~ 40 m (H=24.7)
  - ESA/NASA: Risky & Accessible

- ✓ *Fly-by targets:*
  - Potentially Hazardous Asteroids
  - Alternative scenarios

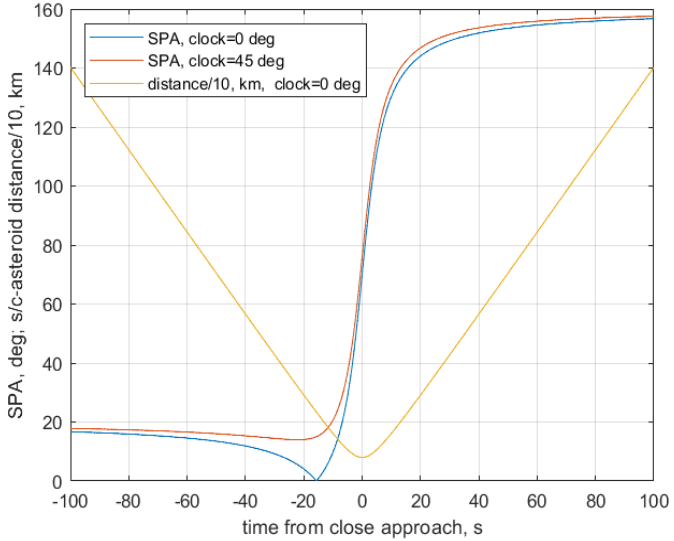
Risk List

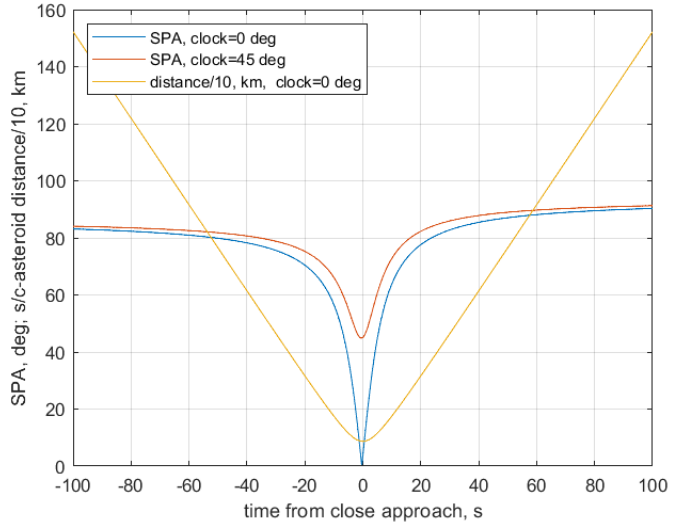
No.	Object designation	Diameter in m	Impact date/time in UTC	IP max	PS max	TS	Years	IP cum	PS cum	Vel. in km/s	In list since in d
1	2023VD3	11 - 24*	2034-11-08 17:09	1/387	-2.65	0	2034-2098	1/387	-2.65	21.01	226
2	1979XB	400 - 900*	2056-12-12 21:38	1/4.27E6	-2.84	0	2056-2113	1/1.36E6	-2.72	27.54	5729
3	2008JL3	23 - 50*	2027-05-01 09:05	1/6711	-2.92	0	2027-2122	1/6211	-2.92	14.01	5729
4	2000SG344	27 - 60*	2071-09-16 00:54	1/1117	-3.19	0	2069-2122	1/354	-2.78	11.27	5729

Object	Orbit ID	H (mag)	Estimated Diameter (m)	OCC	Min. delta-V [delta-V, dur.] (km/s), (d)	Min. Duration [delta-V, dur.] (km/s), (d)	Viable Trajectories
(2000 SG344)	17	24.7	20 - 89	3	**3.563**, 346	5.952, **114**	3302685
(2023 YO1)	13	25.9	12 - 52	2	**4.120**, 354	5.940, **178**	2557209
(2001 FR85)	13	24.8	19 - 85	3	**4.610**, 354	5.991, **162**	1681641

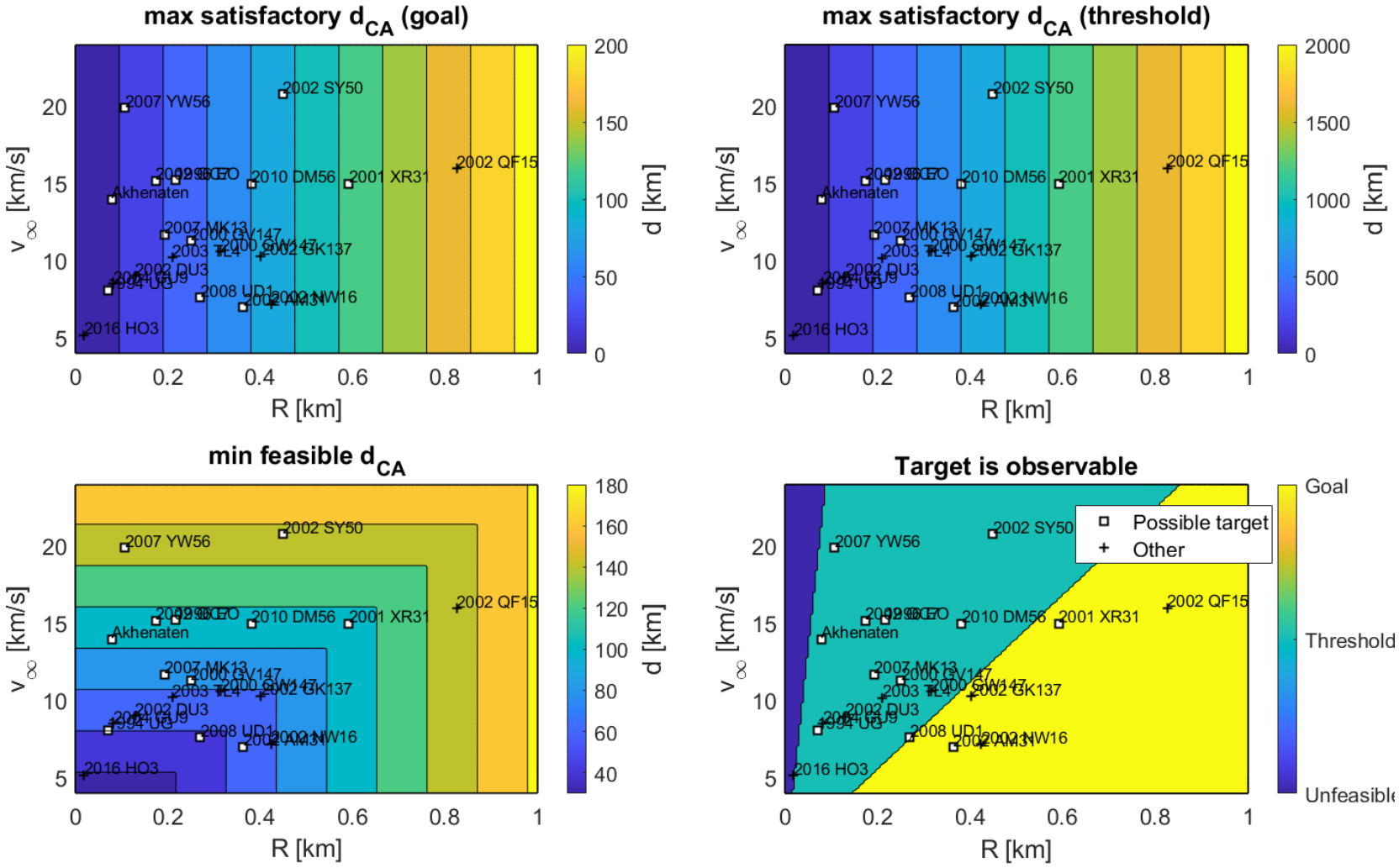
Interplanetary trajectory

- ✓ Selection of flyby targets in light of observation requirements
- ✓ Launch windows in 2030 – 2033
- ✓ Range of escape conditions considered
- ✓ Fly-by approach analysis
  - Reaction wheels performance → minimum altitude at CA
  - Clock angle influences phase angle at close approach





Interplanetary trajectory – Fly By Targets Observability



1. A max **satisfactory distance** is identified from Sci. Requirements
   - *Threshold*: 1/100 D
   - *Goal*: 1/1000 D
2. A min **feasible distance** is retrieved assuming:
   - Max spin rate: 10 °/s
   - Max spin acc.: 0.67 °/s^2
   - Entire target in FoV
3. If feasible distance < satisfactory distance, the target is deemed **feasible for correct observation**

Interplanetary trajectory – Fly By B-Plane Targeting

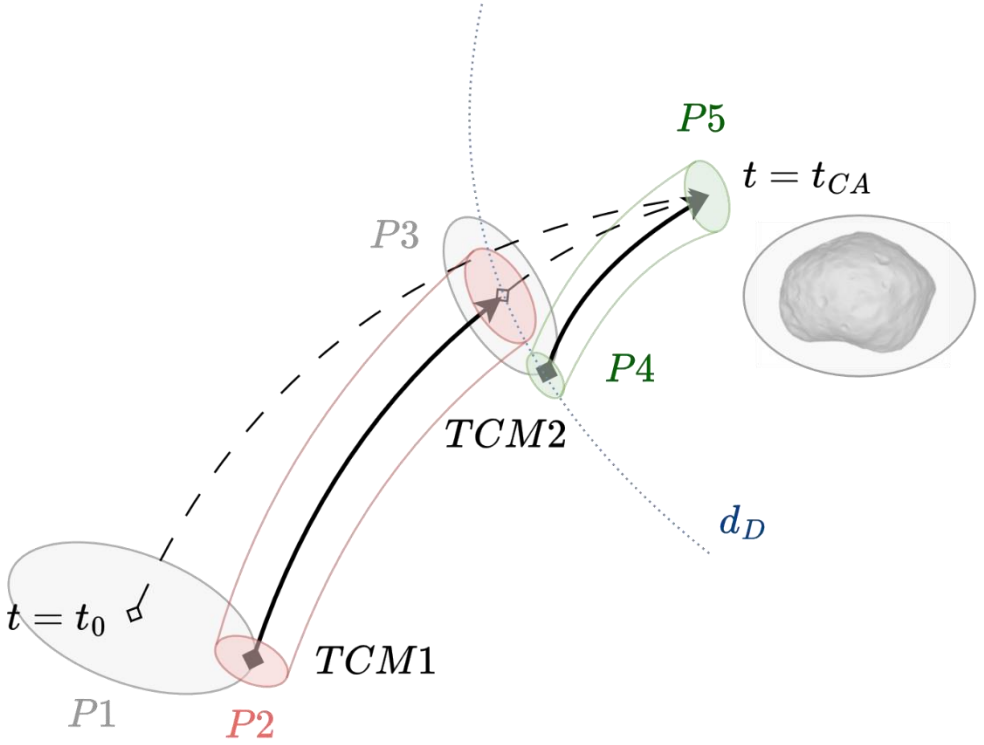
Approach

- After asteroid detection, a guidance strategy must be computed, to correct B-plane entry errors

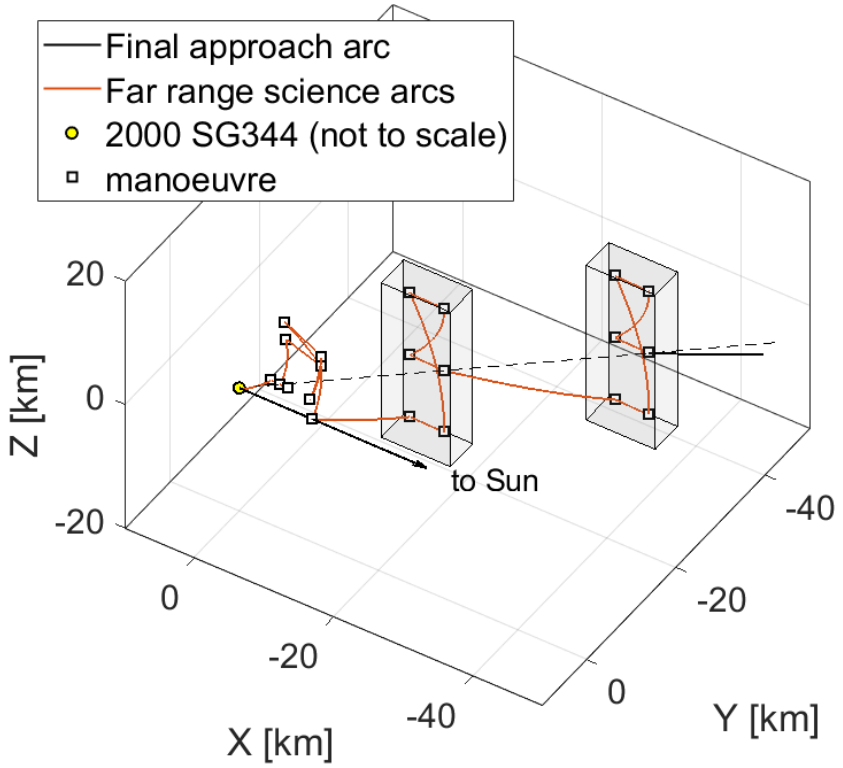
- A **chemical propulsion unit is needed** to grant the necessary control authority in the small time available

Solution

- **Algorithm selected**: Two-TCM stategy



Rendezvous Trajectory Analysis – Far Range



Far Range Trajectory, Hill's Frame.

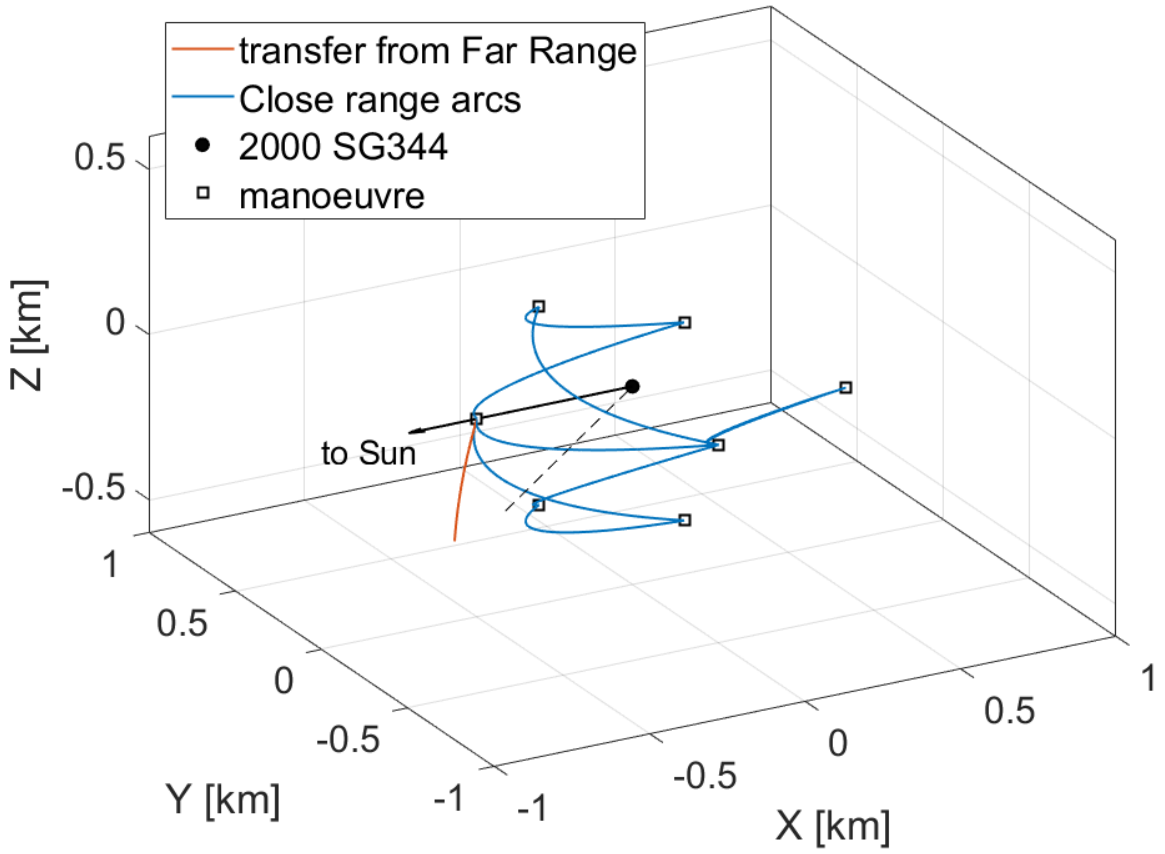
Requirements and Constraints

- Imaging at different resolution in pan and RGB
- Imaging at different intervals of SPA
- Out of plane imaging
- Camera performance, NEMOCAM focal distance

Strategy

- Bi-impulse arcs and unpowered SRP exploiting arcs at 50 km and 25km distance
- Hyperbolic arcs at 10.5 km, to reach also higher SPA
- Holding distance at 5km, to have a more robust transfer towards the close range.

Rendezvous Trajectory Analysis – Close Range



Close Range Trajectory, Hill's Frame

Requirements and Constraints

- Imaging at high resolution
- Imaging at different intervals of SPA
- Out of plane imaging
- Unpowered arcs at distance <1km (radioscience)
- Unpowered arcs at $v < 2v_{esc}$
- NEMOCAM Out of Focus
- Camera performance, Pharos focal distance (400m)

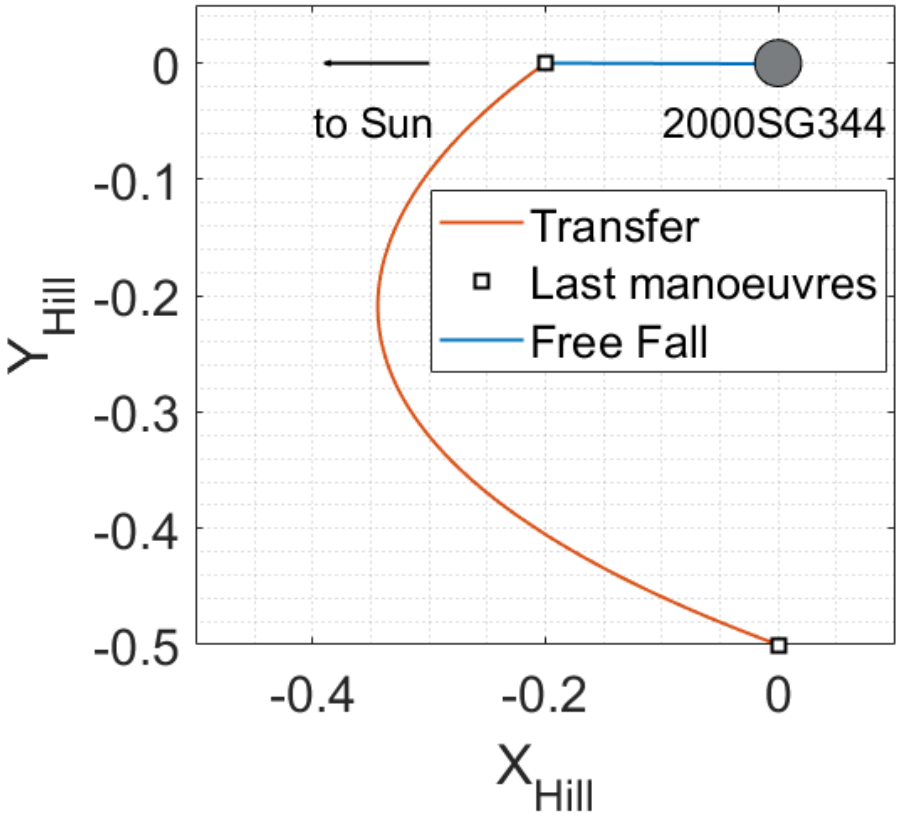
Strategy

- Hyperbolic arcs at 500m distance

Rendezvous Trajectory Analysis – Disposal

- After CR operations, **transfer arc** towards 200m distance, 0° SPA, in plane
- **Free fall** driven by SRP and asteroid's gravity
- Transfer of 1 day
- Free fall of 7.76 h (nominal)

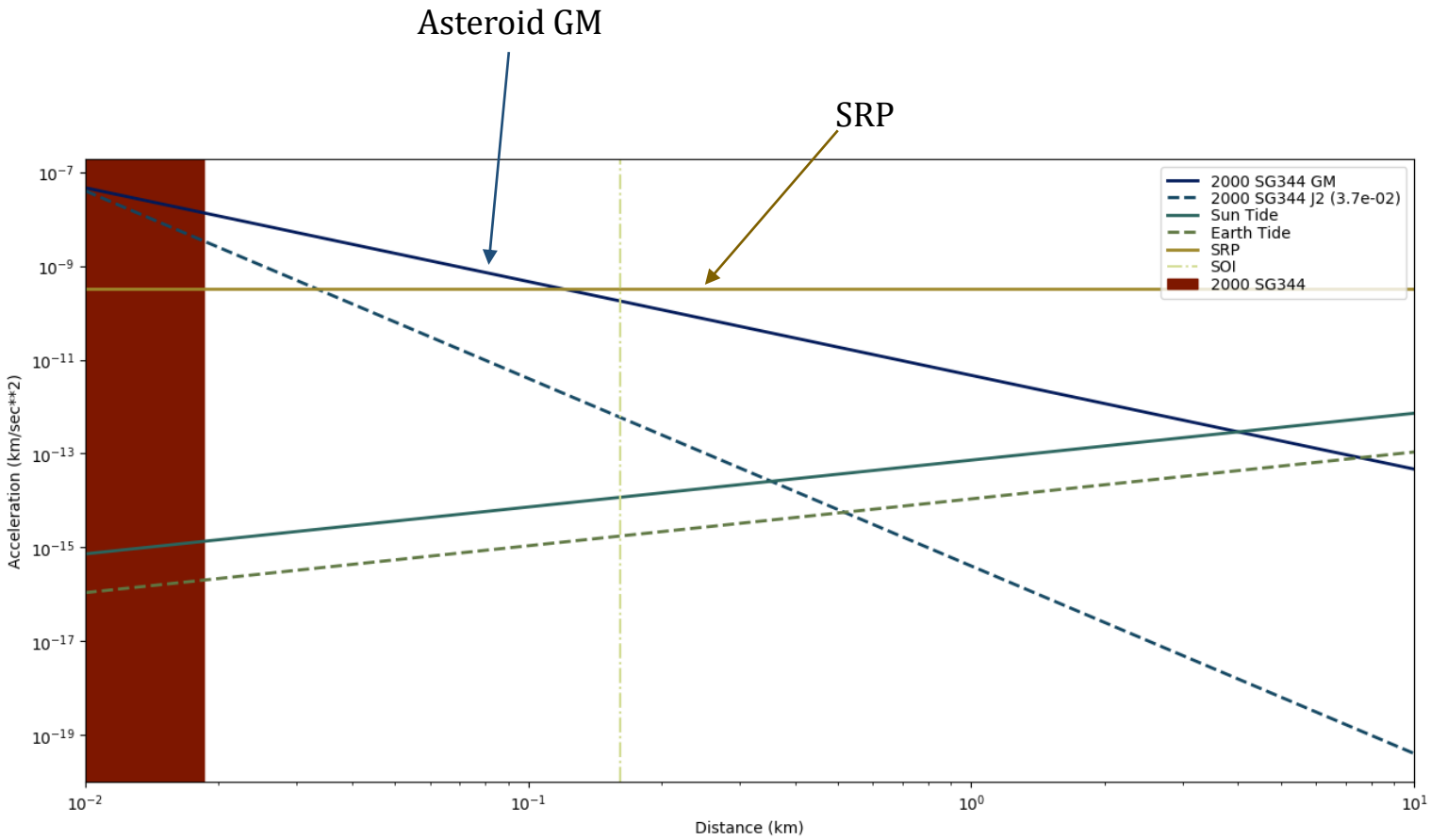
The free fall could represent a **possible opportunity for radioscience**



Proposed disposal trajectory, Hill's Frame.

Radio science experiment

- ✓ To measure the asteroid's gravity to constraint its interior structure (total mass and mass distribution)
- ✓ To characterize the heliocentric orbit and non-gravitational accelerations (Yarkovsky)
- ✓ SRP particularly influent at small bodies environments → for 2000 SG344 it is the dominant acceleration above ~ 150 m altitude



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Scientific return

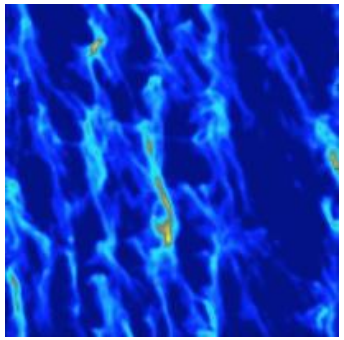
	FoV (across track)	Spatial Resolution (@ 100 km)	Focus
NEMOCAM	2.22°	0.95 m	> 10 km
PHAROS	5.0°	7.8 m	> 400 m

- ✓ *Both fly-bys*
  - V_{rel} ~10 km/s @ ~50 km distance
  - Decimetre-scale images

Geological units, crater SFD, boulder SFD, etc.

- ✓ *Rendezvous with 2000 SG344*
  - 2-month nominal campaign
  - Cm-scale images
  - Radio science
  - Constraints to orbit/Yarkovsky/YORP
    - ➢ Refinement of Earth impact solutions

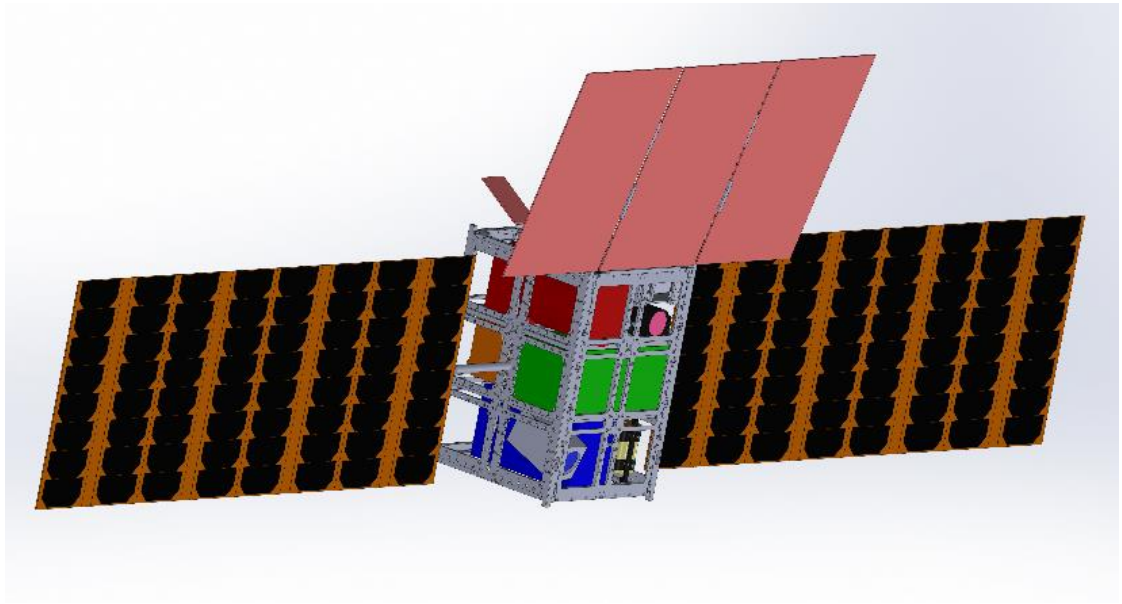
Input for streaming instability
+ N-body numerical simulations

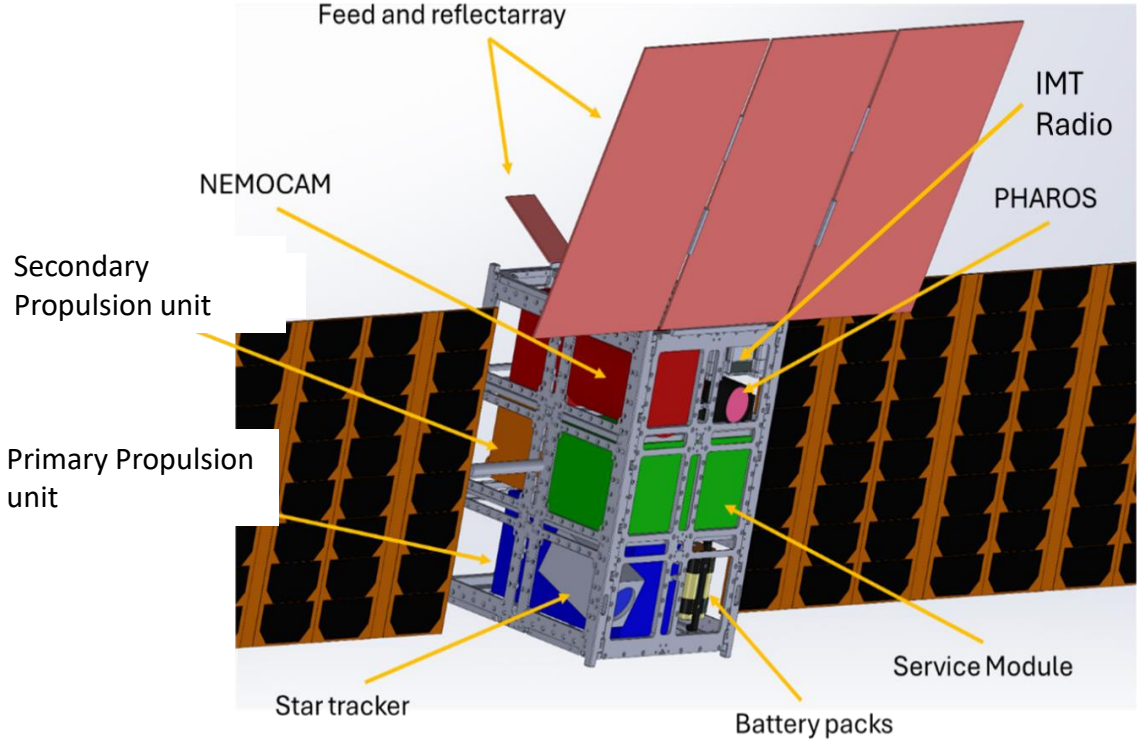


Platform Configuration

Configuration

- Configuration defined, **Standard 12U structure** with minor customization.
- Protrusions: folded solar wings, secondary propulsion nozzles.





GRAZIE DELL'ATTENZIONE!

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