ESA report on SMPAG-related activities

”Mapping of threat scenarios to mission types “

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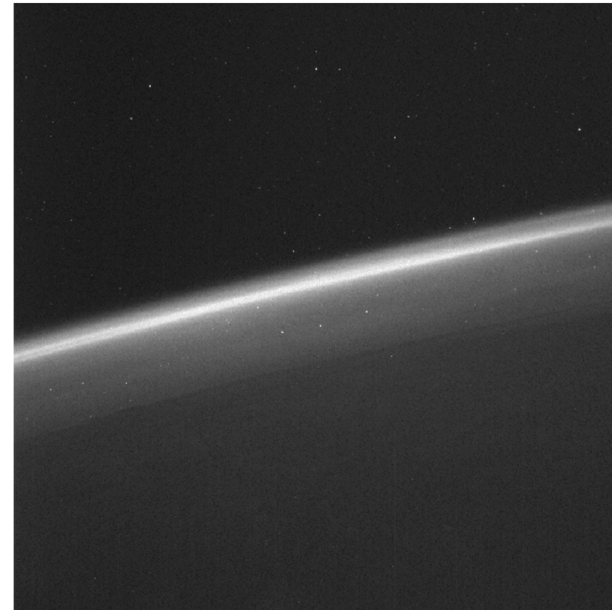
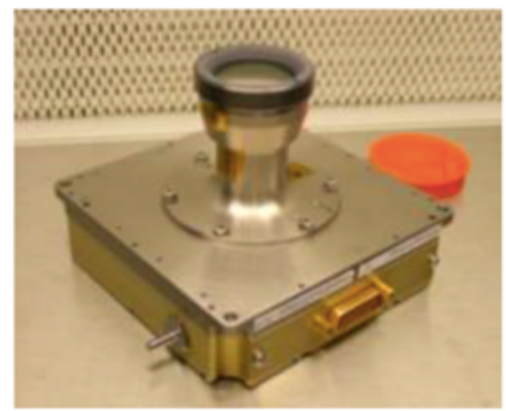
Image credit: ESA

Space-based asteroid observations



Using the Lisa Pathfinder star trackers
to test asteroid observations

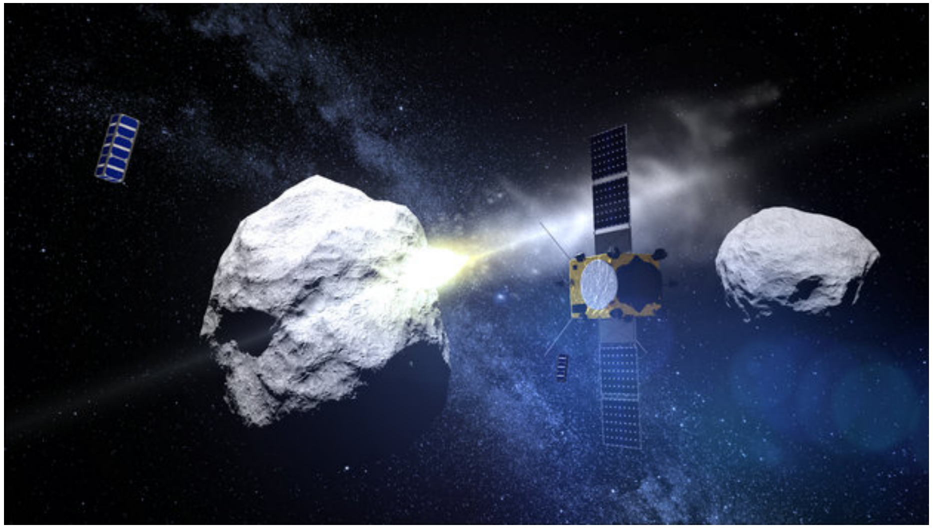


gure 5-3: Terma HE-5AS STR Camera Head Unit

- **ESA leads task: Mapping of threat scenarios to mission types**
  - Task "Reference missions for different NEO threat scenarios" will define missions
  - This task will study detailed links between threat scenarios and mission types
- **Typical questions**
  - Optimum time slots for launch and deflection
  - Latest time for launch and deflection
  - Observation periods allowing to reduce impact uncertainty
  - Opportunities for implementing in-situ observation missions
- **Final goal**
  - Parametric mission designs as function of asteroid orbits and warning time
  - Timeline of events, mission duration, needed delta-v, and more

AIM = Asteroid Impact Mission

- **Part of AIDA (Asteroid Impact Deflection Assessment)**
- **Two parallel studies ongoing**
  - QuinetiQ in Belgium
  - OHB in Germany
  - http://www.esa.int/Our_Activities/Space_Engineering_Technology/Asteroid_Impact_Mission/CubeSat_companions_for_ESA_s_asteroid_mission
- **Science team meeting 1/2 March 2016, ESAC Spain**

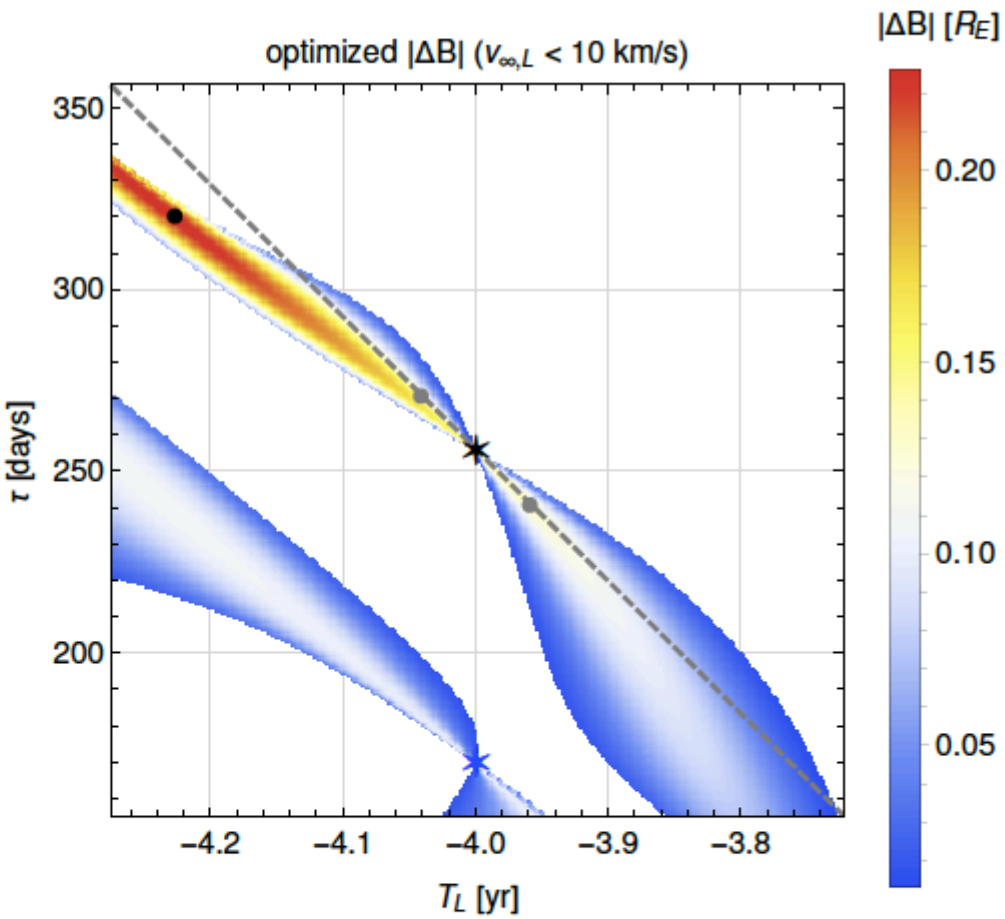


Other current studies

- **A Parametric Assessment of the Full PHA Phase Space, and Deflection Feasibility using Kinetic Impactors**
  - Performed within the mission analysis team at ESA/ESOC
  - Detailed slides and paper available
- **Parking orbits for asteroid characterization and deflection missions**
  - Final report available
- **Fly-by missions at asteroids – how much do they help mitigating a potential impact**
  - Ongoing – developed metric for orbit quality, checking needed instruments for characterisation
  - Link to task “Toolbox”?

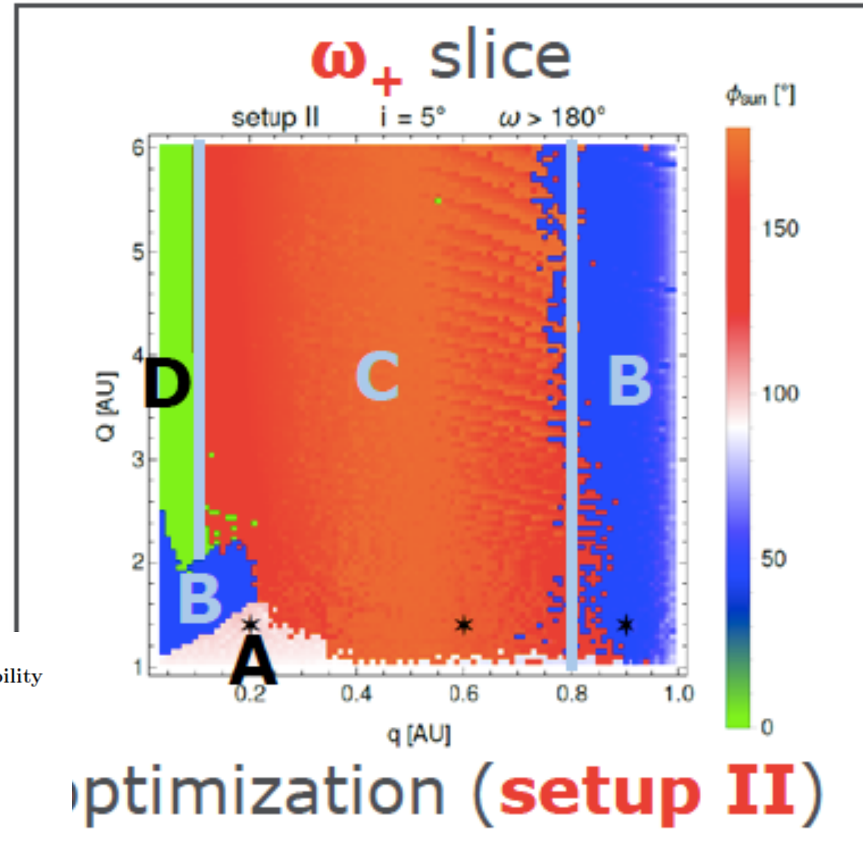
Parametric assessments – results

- **Example =>**
- **Finds different regions in P/a/i phase space:**
  - A: 2π transfer accelerating asteroid
  - B: 2π transfer decelerating asteroid
  - C: π transfer
  - D: no solution



Parametric assessment - results

- **Deflection types in orbital parameter space**
- **For details: See paper**



A Parametric Assessment of the Full PHA Phase Space, and Deflection Feasibility Using Kinetic Impactors

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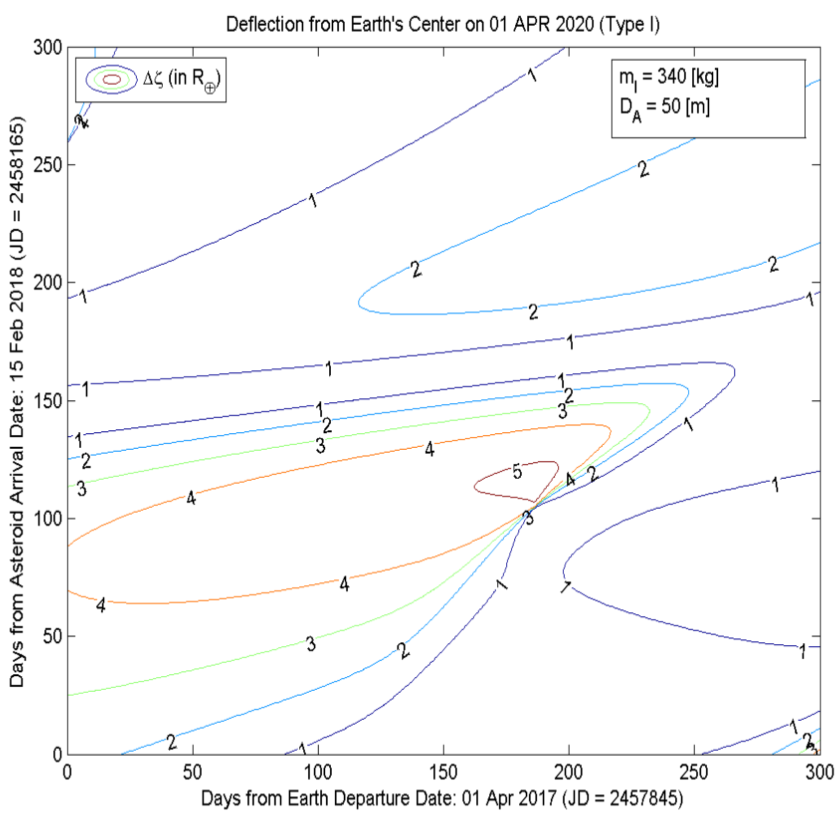
(Dated: October 13, 2015)

We systematically analyze the possibilities to deflect Potentially Hazardous Asteroids (PHAs) by means of a kinetic impactor mission, as a function of the PHAs' orbital states. To that end, we construct hypothetical threat scenarios to impact Earth at a set epoch, and scan the entire possible PHA phase space. For each point, an optimal ballistic deflection transfer is determined, accounting also for launcher performance and other technical limitations. Finally, we analyze the deflection merit as a function of the PHA phase space, identifying and discussing particularly interesting or problematic regions.

Parking orbits

- **Similar to previous work, but focuses on transfers from parking orbits**
- **Can produce pork-chop plots showing not only the delta-v of the transfer but also the deflection**



Deflection Success Criterion

$$\Delta\zeta \geq 2R_{\oplus}$$

Mission Report

t_W = 1 year		D_A [m] 15	50	160	270
m_I [kg]	340	S	F	F	F
	1000	S	S	F	F
	6000	S	S	F	F

t_W = 3 years		D_A [m] 15	50	160	270
m_I [kg]	340	S	S	F	F
	1000	S	S	F	F
	6000	S	S	S	F

t_W = 10 years		D_A [m] 15	50	160	270
m_I [kg]	340	S	S	F	F
	1000	S	S	S	F
	6000	S	S	S	S

See ESA-SSA-NEO-RP-0148/1.0 30 Nov 2015

Orbit accuracy and flybys

- **How much can we improve the orbit accuracy by spacecraft fly-by?**

  Metric for orbit accuracy: Line of Variation only good if uncertainty dominated by one element – here the volume of the uncertainty ellipse is proposed as metric.

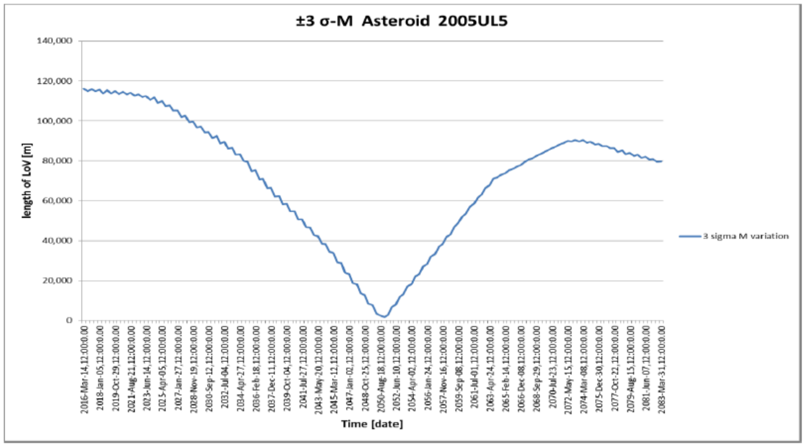


Figure 8 - long time variation M-variation 2005UL5

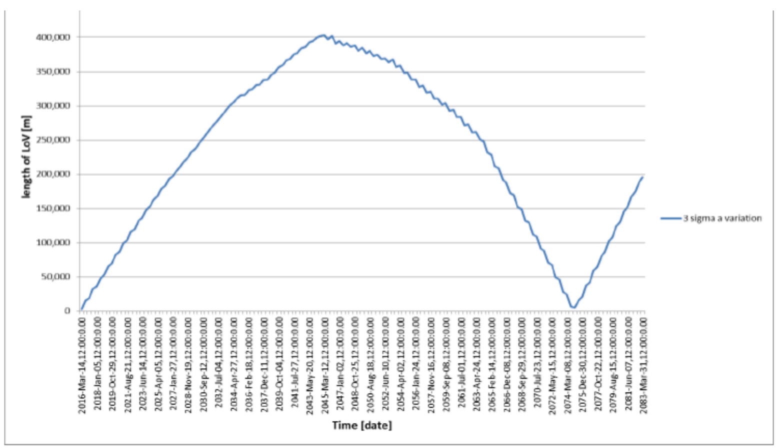
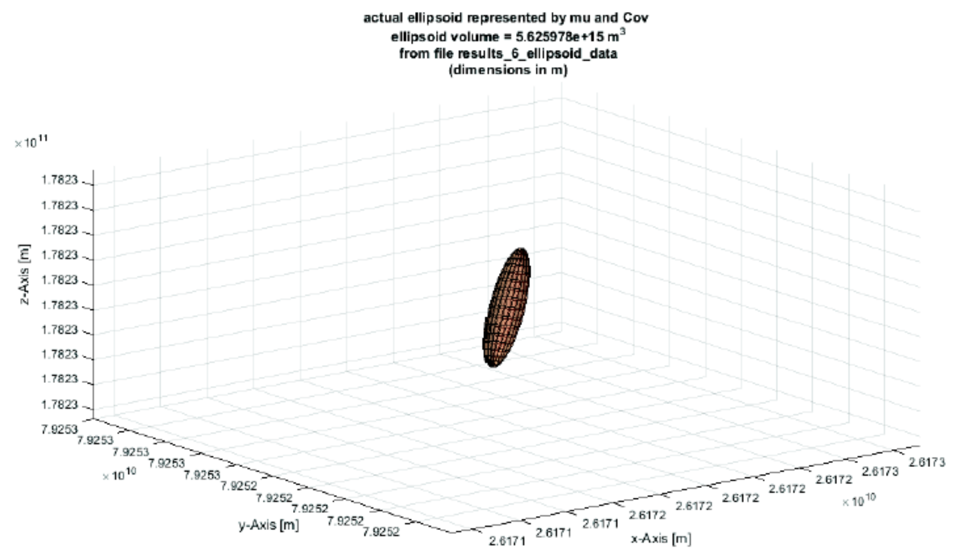


Figure 9 - long time variation a-variation 2005UL5



re 5: **Ellipsoid-Volume Plot** *Asteroid 3200-Phaeton Uncertainty-Ellipsoid at 1-AU*
section on 2019-Aug-13.

Orbit accuracy and flybys

	Mass	Orbit	Gravitational Field and Center of Gravity	Rotation Properties	Size and Shape	Near-surface Properties	Topography an Morphology	Mineralogy	Elemental composition
Radio Science Experiment (+Accelerometer)	■	■	■			■			
Imagers				■	■	■	■		
LiDAR			■		■		■		
Thermal IR Spectrometer		■				■		■	
Vis-NIR Spec.						■		■	
X-/Gamma-ray spectrometer									■
Radar Tomographer			■			■			
Seismic Experiment (+Test Projectile)			■			■			

Table 1: Necessary instrumentation for a space mission to determine various asteroid properties.

Stardust contribution to SMPAG and IAWN

- 5.1 CRITERIA AND THRESHOLDS FOR IMPACT THREAT RESPONSE ACTIONS
  - Support through NEODyS
- 5.2 MITIGATION MISSION TYPES AND TECHNOLOGIES TO BE CONSIDERED
  - Evaluation of a broad range of technologies
  - Assessment of mitigation mission scenarios under uncertainty
- 5.3 MAPPING OF THREAT SCENARIOS TO MISSION TYPES
  - Mission analysis for different scenarios, NEOs and deflection technologies
- 5.4 REFERENCE MISSIONS FOR DIFFERENT NEO THREAT SCENARIOS
  - Assessment of technology requirements for different NEO threat scenarios
- 5.8 CONSEQUENCES, INCLUDING FAILURE, OF NEO MITIGATION SPACE MISSIONS
  - Analysis of atmospheric entry, explosion and airburst
  - Analysis of the consequences of an impact and risk analysis
- 5.9 CRITERIA FOR DEFLECTION TARGETING
  - Definition of targets and criteria for different deflection solutions including uncertainty
- 5.10 STUDY OF THE NUCLEAR DEVICE OPTION
  - Analysis and design of mission scenarios using nuclear devices

Summary

- **We are studying one concrete asteroid characterization mission**
- **We are working on a classification for deflection missions**
- **We have assessed the usefulness of waiting for an object in a parking orbit**
- **We are assessing the potential of improving orbit accuracies by spacecraft flybys**
- **Done via industrial contracts and collaborations with universities – more support could come via Stardust**

- **For discussion:**
  - Metric for the orbit accuracy – comments?

Image credit: ESA