

Asteroids: next step?

A summary of past and present activities at ESA on the exploration of asteroids and planetary defense

by

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The population of Near-Earth Objects constitutes a significant threat to mankind. The hazard caused by the NEOs is characterized by a small probability of occurrence; however, the consequences of a collision of the Earth with a NEO could be catastrophic for mankind.

Protection against the threat posed by NEO's must go through at least 4 steps, which in part can be carried out in parallel:

Steps 1-2: assessment of the threat, including a characterization of the NEO population;

Steps 3-4: Definition and set up of a protection system.

- The characterisation of the NEO population should comprise at least objects with a diameter larger than 1 km, which could cause a global catastrophe, while keeping in mind that ideally a complete survey should include NEO's with a diameter down to 50-100 meters. Ground-based and space-based facilities are needed to achieve this objective.
- Europe can give immediately major contributions considering existing know-how and facilities, such as European observatories in both hemispheres, and planned space missions such as GAIA. As the purpose of this activity encompasses more than merely scientific objectives, new funds outside of those destined to space research should be made available.



- Step 2: This phase should include more than one mission devoted both to a better understanding of the physical and geophysical characteristics of a NEO and to, at least, another mission to test some space-borne mitigation techniques.

In January 2004, following the presentation of the preliminary studies for 6 space missions for NEO exploration, ESA established an international panel, called NEOMAP (Near-Earth Object Mission Advisory Panel)

Of all six missions reviewed, the Panel recommended that ESA gives highest priority to the Don Quijote concept as the basis for its participation in NEO impact-risk assessment and reduction

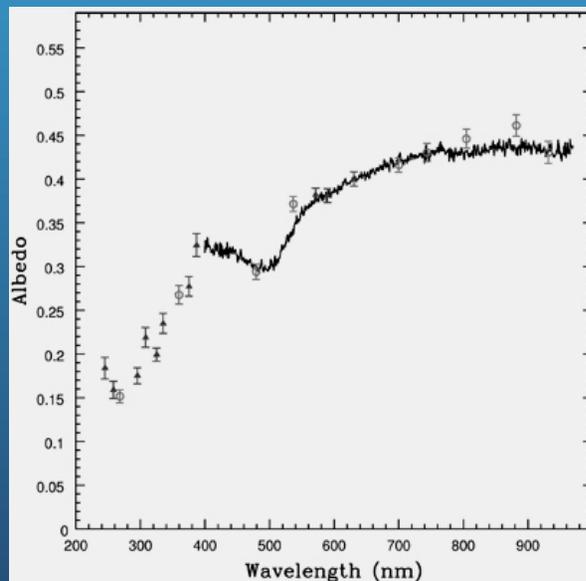
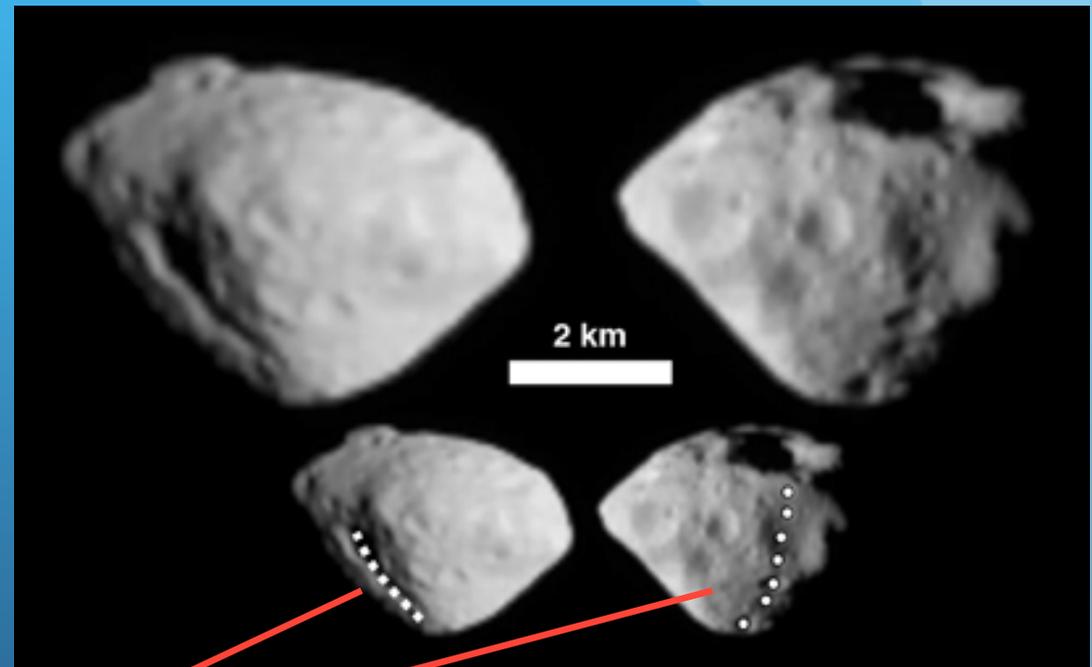
European Main Contributions to Asteroidal Exploration:

- **Cassini/Huygens:** On its way to Saturn, Cassini crossed the Asteroid Belt and took pictures of asteroid 2685 Masursky on 23 January 2000. The images revealed that the side of Masursky imaged by Cassini is roughly 15 to 20 km across.

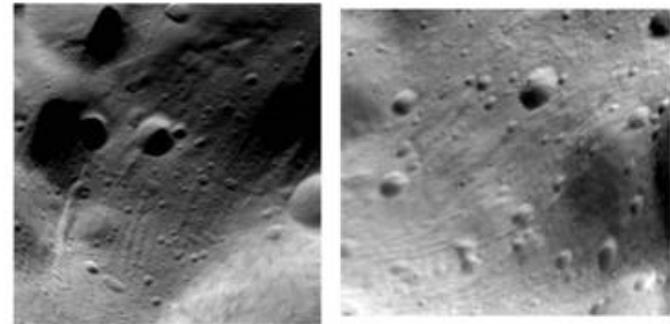
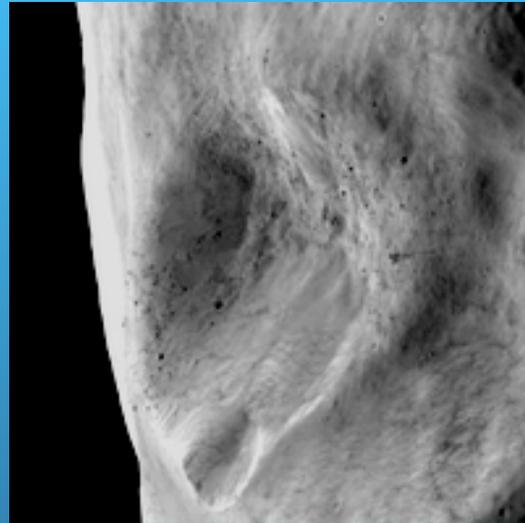
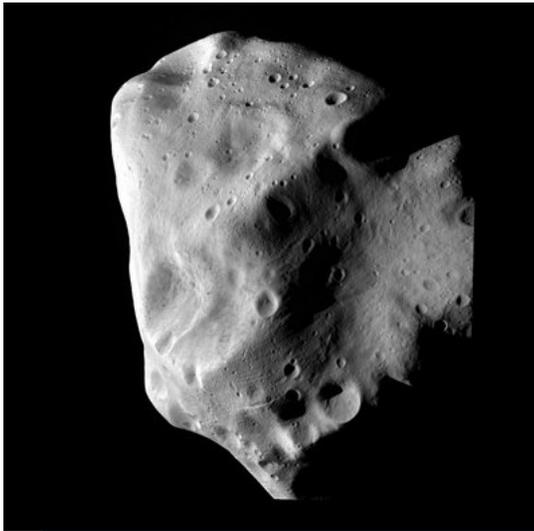


- **Rosetta:** on its way to Churyumov-Gerasimenko, Rosetta has flown by asteroids Steins and Lutetia

E-Type Asteroid (2867) Steins as imaged by OSIRIS on board Rosetta



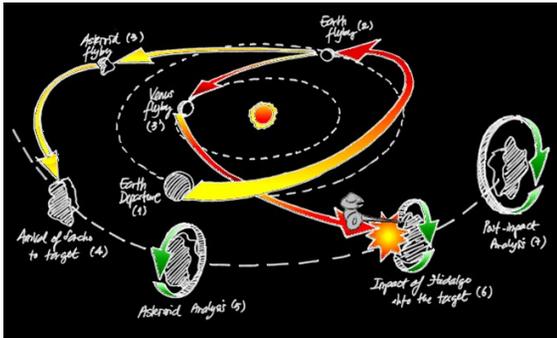
Rosetta at asteroid Lutetia, July 10 2010



Lutetia has been a mystery for many years: In some respects it resembles a 'C-type' asteroid, a primitive body left over from the formation of the Solar System.

In others, it looks like an 'M-type', iron dominated body.

- ***ESA's Don Quijote mission concept consists of two spacecraft which are to be launched in separate interplanetary trajectories:***
- **An Orbiter spacecraft, called Sancho** After arriving to the target asteroid and be inserted into an orbit around it, it will measure with great accuracy its position, shape, mass, and gravity field for several months before and after the impact of the second spacecraft. In addition, the Orbiter will operate as a backup data relay for transferring all the data collected by the Impactor during approach and image the impact from a safe parking position. It will also investigate the surface composition of the asteroid and, after completion of the primary objective, carry out the ASP-DeX.
- **An Impactor spacecraft, named Hidalgo** After following a very different route from that of the Orbiter, the spacecraft will impact an asteroid of approximately 500 m diameter at a relative speed of about 10 km/s. This spacecraft will demonstrate the ability to autonomously hit the target asteroid based on onboard high-resolution camera.



Mission Objectives

The primary objective of the Don Quijote concept is to impact the target Near-Earth Asteroid (NEA) and to be able to determine the deflection resulting from the impact. To achieve this, it will measure with extreme accuracy the asteroid's position in space before and after impact. There is also a secondary objective, involving the so-called Autonomous Surface Package Deployment Engineering eXperiment (ASP-DeX). In this experiment a small device, an Autonomous Surface Package or ASP, would be released from the Orbiter spacecraft while it's on orbit about the asteroid. It would then passively free-fall towards the asteroid surface after its release, and touchdown within a certain distance of a target landmark, most likely the crater resulting from the impact of the Hidalgo spacecraft. In addition, part of the mission secondary goals are to and study the asteroid's surface chemical composition and the characterization of the thermal and mechanical properties of the asteroid surface.

Impactor spacecraft



- The mission of the Impactor spacecraft is a peculiar one: the spacecraft should remain in a dormant state during most of its lifetime until the last days of asteroid approach where the autonomous guidance takes over and targets it toward the asteroid. During the cruise phase only minimum functions are required but before the impact all the sub-systems have to be up and functional with high level of reliability.
- A major system design constraint is also on the spacecraft mass that (contrarily what normally is required) shall be above a certain threshold to achieve the required asteroid orbit deflection and lower than the launch system escape performance. In order to increase the impact mass, the propulsion module is not jettisoned at escape but is kept attached during the whole mission until impact as a ballast.



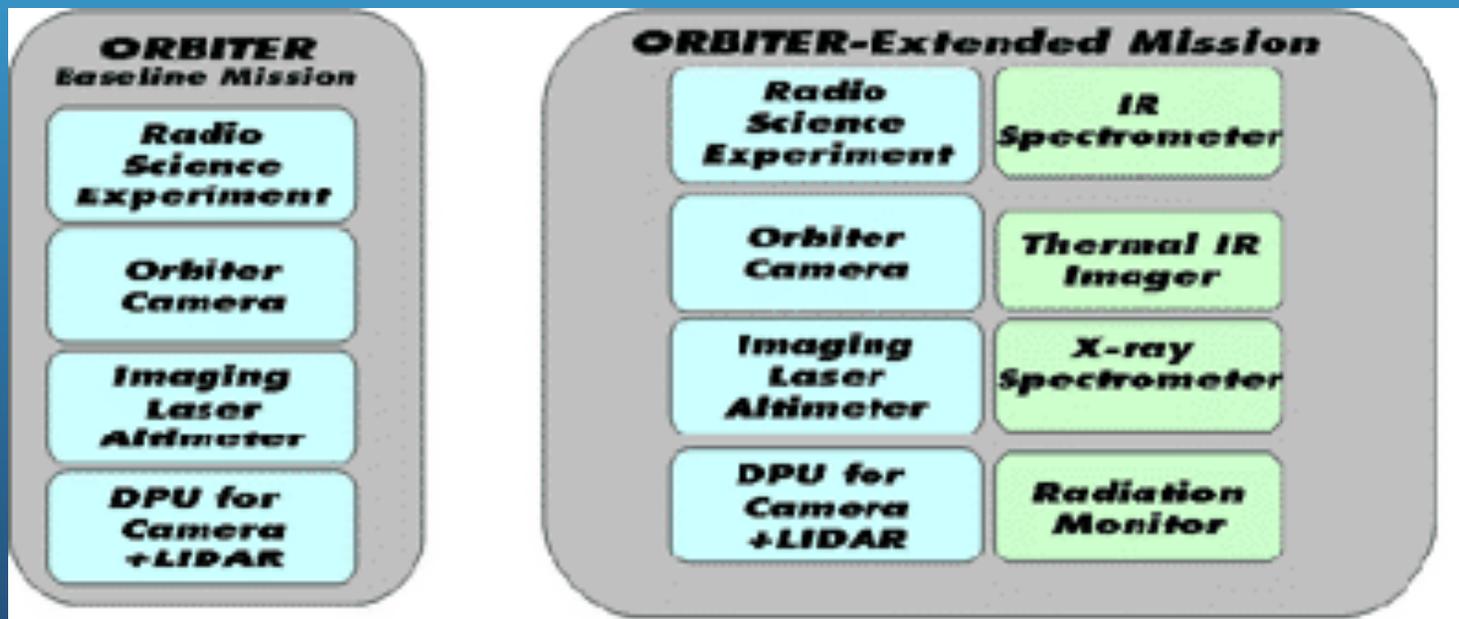
- **Orbiter spacecraft**

For the design of the Orbiter, a re-use of the SMART-1 bus was considered during the internal mission feasibility studies. Though this approach provides a good reference case to assess mission costs and the maturity of the technologies, there are some limitations, mainly given by the availability of a single PPS-1350 engine, a fixed Xenon tank capacity that limits the propellant mass, and finally a given bus structure.

- The mass budget for the Orbiter spacecraft, with the extended payload set (see below), is:
 - Dry mass 395 kg
 - Payload mass 20.6 kg
 - Propellant mass 96 kg



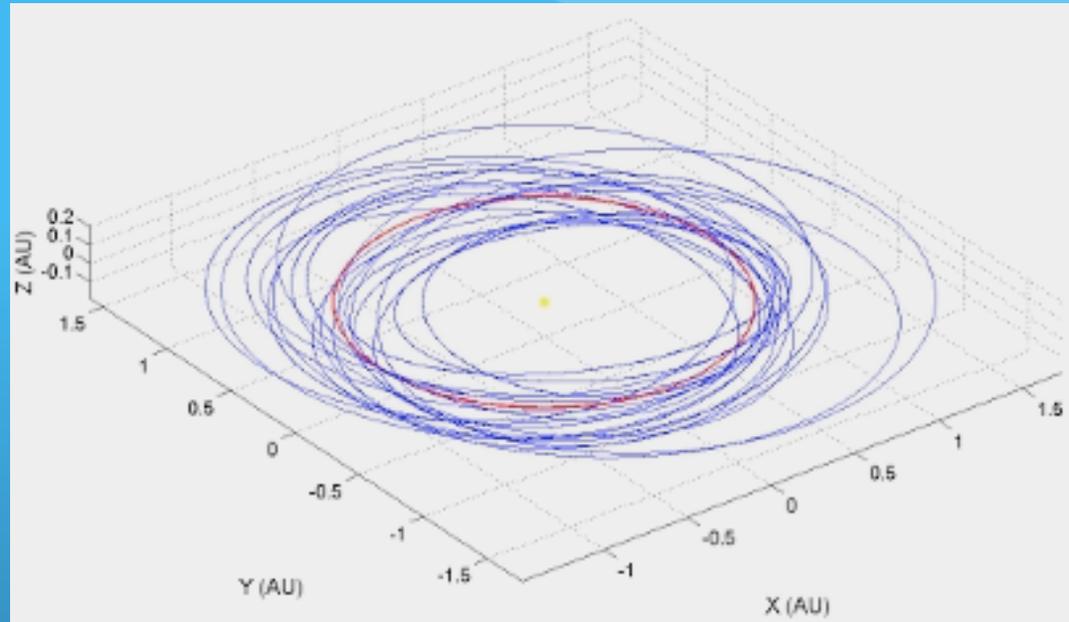
- Orbiter payload
- A basic payload (made up by the navigation camera, the Radio Science Experiment and a LIDAR) addressing the primary objective of the mission would be complemented by a set of scientific instruments dedicated to the secondary mission goal, as shown in the accompanying figure.



- **Step 3:** This phase should deal with the realist test of a mitigation mission, depending on the outcome of step 2.
- **Step 4:** This is real “Spaceguard” phase where both a ground based and space-borne systems are simultaneously operational and capable of a quick response.



- For a first human mission to an asteroid after 2020, one can assume some basic requirements in order to help down selecting a list of interesting asteroids:
- The asteroid should be not too small in order to be able to eventually land and take samples;
- A minimum stay on the asteroid should be guaranteed to allow for a useful scientific return.
- Furthermore, it is reasonable to assume some further human-related constraints, such as:
- The trajectory should allow for a safe way to return rapidly to Earth in case of problems up to half way to the target asteroid.
- The overall mission duration should not be too long in order to keep the journey bearable for astronauts.



Baseline for asteroid selection

Apparent magnitude (corresponding to roughly 200m) $H \leq 22$

Time of flight < 1.5 years

Stay time on the asteroid > 5 days

Relative velocity at Reentry 4.5 km/s

Propulsion **Chemical**, with 1 deep space manoeuvre per leg

Launch V infinity 6 km/s

Conclusions

- The international effort of exploration of small bodies of the Solar System is providing a wealth of interesting data.
- In terms of planetary defense and human exploration, major scientific and technological advancements are needed.
- International (global) collaboration is the way to go to carry out successful manned and robotic missions and to implement a ground-based/space-borne system of planetary defense.