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CARINA: A sample return mission concept to a near-Earth D-type asteroid

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Abstract

To obtain new insights into D-type asteroids and their possible relationship with extinct comets we introduce the mission concept CARINA (Comet Asteroid Relation INvestigation and Analysis). A description of the scientific objectives, the proposed payload, as well as the mission profile will be presented.

1. D-type asteroids

D-type asteroids are characterized by a red spectral gradient and very low albedos. They are believed to be among the most primitive asteroids, containing primordial organics, volatiles and perhaps water, either in the form of ice or hydrated minerals [1]. Most of them are localized beyond the outer edge of the Main Belt, especially in the Jupiter Trojans. Only a small percentage of the near-Earth objects (NEOs) observed so far have been classified as D-types [2, 3].
Among other asteroid classes, D-types remain quite poorly investigated. Questions related to their origin, their distribution and the variation of their physical properties with the heliocentric distance are still under debate [2]. Particularly, a possible relationship between D-types and comets has been questioned for more than three decades [4]. To the best of our knowledge, no space mission has addressed this subject so far. Based on physical and dynamical characteristics, some NEOs have been suggested to be extinct comets [5]. There is also evidence that some of them, especially the D-types, might bear a resemblance to Jupiter family comets [2, 5]. If D-type NEOs could represent extinct comets, they would offer us a unique opportunity to investigate the relationship between two classes of minor bodies in our solar system.

2. CARINA mission concept

CARINA is a sample return mission concept to the D-type NEO asteroid 2002 AT4. The target was suggested as a possible extinct comet [2]. The main goal of CARINA is to obtain new insights on the following scientific questions:
- How did the Solar System evolve and how did planetesimals form?
- What is the origin of life on Earth?
- Is there a relationship between comets and asteroids?

To address those questions, many advanced analytical techniques are needed to examine a sample from 2002 AT4. However, some of the required instruments are still too massive to be brought on board a spacecraft. Therefore, a sample collection will be carried out by means of a touch and go manoeuvre. CARINA will collect samples from the surface and subsurface of the asteroid. They will be returned and analysed in facilities on Earth. Part of this material could be stored for future needs.

3. Spacecraft and Instruments

The CARINA spacecraft (Figure 1) will carry a return capsule and nine scientific instruments on board:
- A mapping camera to collect an image data set of the target asteroid with high enough image resolution to retrieve a shape model at the $1\,\mathrm{m}$ resolution level;
- A sampling camera capable of taking images of the surface with a $20\,\mathrm{cm}$ resolution, to identify possible

landing sites and to produce a detailed surface topography;
- A visible and near infrared spectrometer, covering the wavelength range 0.3 to $4.3\,\mu\mathrm{m}$, will be used to investigate the asteroid surface composition (to relate surface mineralogy with surface topology) and also to detect spectral signatures associated with the presence of water;
- A thermal infrared spectrometer to investigate the surface composition and thermal properties;
- A mass spectrometer designed mainly to establish in *situ* the identity, abundance and isotopic compositions of the volatiles present on the asteroid surface;
- A subsurface radar to investigate the shallow subsurface of the asteroid down to the first tens of meters. The objective is to gather information on the vertical context of the sample;
- A magnetometer to measure any magnetic field present, which is important for understanding asteroid formation;
- A bristle sampler to collect surface samples;
- A harpoon sampler to collect subsurface samples.

Both the bristle and the harpoon samplers are novel instruments that have never flown before.

The crushable Earth return capsule will land by direct impact with no parachutes to increase system reliability.

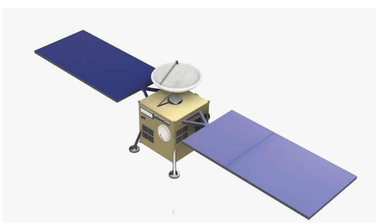

Figure 1: The proposed CARINA spacecraft in deployed configuration. It will be powered by a solar array and propelled by ion thrusters.

4. Mission timelines

The first possible launch window for the CARINA mission would be in the year 2030, after 10 years dedicated to target observations, mission development and testing phases. Assuming this earliest launch opportunity, the spacecraft is expected to reach 2002 AT4 in late 2034 (Figure 2). The mission profile includes a total stay time escorting the asteroid of about 7 months with an operation profile consisting of different phases: arrival, approach, orbiter operations, touch and go sampling campaigns and departure. The return capsule with the 2002 AT4 samples is expected to enter the Earth atmosphere in 2037. After immediate sample retrieval from the capsule at the landing site, we estimate that it will take about one year to catalogue the sample and start the first scientific analysis.

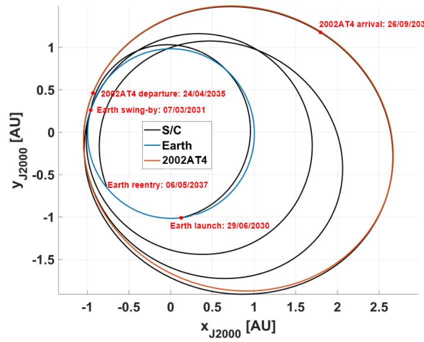

Figure 2: Low-thrust interplanetary trajectory in the J2000 reference frame calculated for the earliest possible launch window in the year 2030.

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