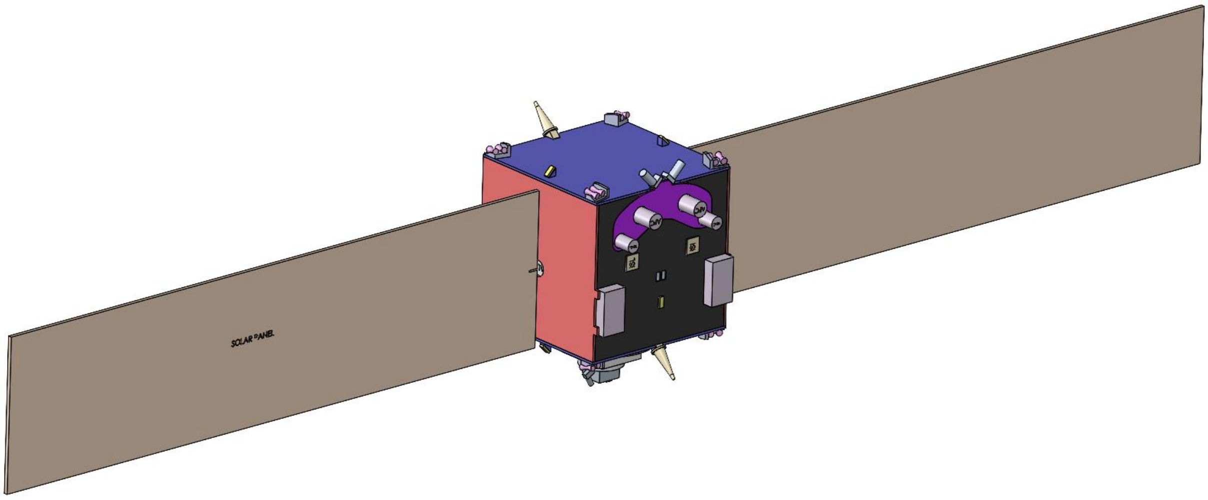
➔ PREPARATION



Pre-Phase A/Phase A System Study of an Apophis Mission

Executive summary

Pre-Phase A/Phase A System Study

Affiliation(s): Tyvak International (Prime), Politecnico di Milano (Sub 1), GMV (Sub 2), OHB-Italy (Sub 3).

Activity summary:

One of the next priorities in ESA's Space Safety Programme related to Planetary Defense is the implementation of class of fast rendezvous satellites to characterize potentially dangerous asteroids. The scientific community and the Agency regularly monitor Near Earth Asteroids. The main objective of the ongoing study is to conceive a small satellite baseline design with high delta-V capability enabling an asteroid scout mission to a wide range of targets. The novelty of the architecture is the main propulsion system of the spacecraft being electric. The rationale is to lower the overall vehicle mass for a given mission, thus enabling the use of lighter and cheaper launch vehicles, or conversely to enable a greater flexibility for target selection, and less rigid launch windows, for a given launch opportunity.
The starting point of the study was the list of known NEAs with high interest for Planetary Defense and reasonable rendez-vous possibility in the next 8 years. A short list was further elaborated by the consortium, defining the list of targets for the Zodiac Pioneer mission.

➔ THE EUROPEAN SPACE AGENCY

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Mission analysis effort includes the definition of the interplanetary trajectories required to reach these objects. A priori, a large number of small bodies could be potential targets for the Zodiac Pioneer mission. To shortlist the candidate objects, a fast and reliable trajectory optimization method based on convex optimization is used to rapidly compute the porkchops associated with hundreds of asteroids. To this scope, simple two-body dynamics and constant thruster parameters are used. After this first screening, the list of targets for the Zodiac Pioneer mission is defined. The porkchop plots are computed with more accurate thruster models (e.g., considering variable thrust and specific impulse as function of the distance from the Sun), and operational constraints are considered. The possibility of using different launchers to favor cheaper missions is explored by adding the infinite velocity provided by the launcher in terms of magnitude, right ascension, and declination as optimization variable. In the refined analysis, to assure the optimality of the solutions found, the trajectories computed by the convex optimization-based algorithm are reoptimized using an indirect method-based strategy.

Close proximity operations are analyzed in support of the definition of the systems design. Different orbital strategies for the proximity operations are presented and discussed and each option is discussed in terms of its suitability to achieve the defined scientific objectives and mission requirements and its impact on the system design. The critical system(s) to make each option feasible is identified with a discussion on the current design status for Zodiac Pioneer. A focused discussion on the high autonomy GNC sub-system designed for Zodiac following GMV's heritage is provided – this key technology allows autonomous attitude pointing and ΔV manoeuvres which provides a significant increase on the scientific return by allowing closer distances to obtain higher resolution measurements with increased coverage of the target body.

The outcome of these efforts is taken as inputs for the definition of the system requirements and selection of the platform subsystems and system architecture definition. Tyvak International avionics is considered as the baseline for the platform, while the rest of the systems are being screened and pre-selected with priority to the European Market.

The design status baselines a 500 kg satellite, with a 1.5 kW class solar array, 45-90 mN gimballed main thruster, and X-Band links with Earth via two omni LGAs and a 75 cm class HGA dish. Monopropellant RCS enables momentum management and agility near the target.

This feasibility study represents a breakthrough in the Planetary Defense and small body exploration roadmap, which could lead to new and novel mission scenarios in the characterization of potentially hazardous objects. Furthermore, at the current state of the art, absence in Europe of a small satellite based on Electric Propulsion System for deep space missions gives this study a paramount innovation value.