CONCEPT OF OPERATIONS FOR A RENDEZVOUS RECONNAISSANCE MISSION TO AN IDENTIFIED ASTEROID THREAT: THE FIRST STEP TOWARDS DEFLECTION

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INTRODUCTION

Reconnaissance missions are a crucial next step when a NEO threat has been confirmed to be significant. Stakeholders need accurate information to plan for multiple COA's (Course of Action) and a flyby or a rendezvous mission if time permits allows for determining precise orbital characteristics and physical specifications to plan for either a deflection or a impact minimization strategy

OBJECTIVE

To plan a rendezvous reconnaissance mission to 2025 PDC (classified as a PHA) that would identify the physical, environmental and orbital characteristics before a deflector spacecraft is sent or a planned controlled impact takes place. A preliminary overview of the mission design process and the concept of operations (ConOps) for such a scenario is presented here.

KEY DETAILS FOR MISSION PLANNING

Given the background as follows, mission planning is executed in several stages

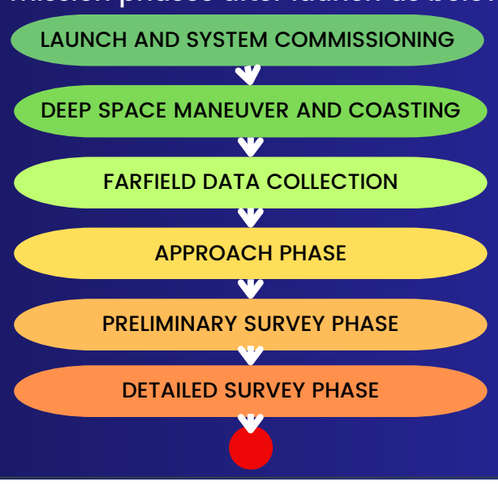
- Possible impact date: Apr 24, 2041 (~16 years)
- S-type PHA of size between 145 to 155 m
- Modestly eccentric orbit with perihelion = 1.0 au, aphelion = 2.29 au and T = 774 days. Inclination wrt Earth = 11 deg

MISSION DESIGN METHODOLOGY

- Science mission objectives → Clear, measurable mission requirements
- Goals for asteroid property characterization and measurement → Payload selection and operation
- Types of measurements and timelines → Mission phases and ConOps
- Reference for measurements, quality and coverage → Transfer Trajectory and Orbit Design
- Mission requirement specifications → System requirements and constraints
- System requirements → Spacecraft bus design with subsystem development
- Close approach or low delta-v transfer window → Launch Analysis and LV selection
- Mission handling → Ground Segment and Mission Operations

CONOPS FRAMEWORK

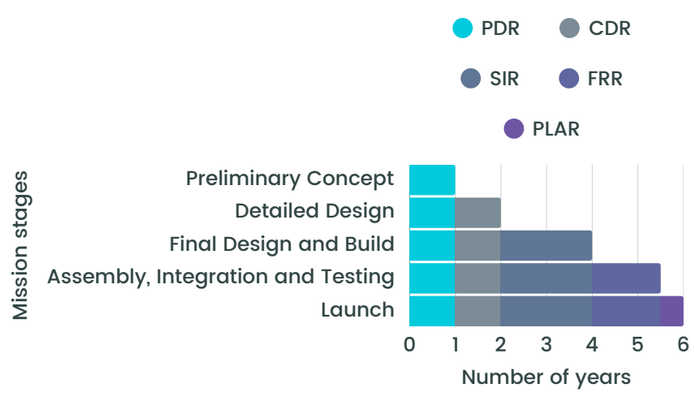
The generalized concept of operations framework is presented along with the mission phases after launch as below

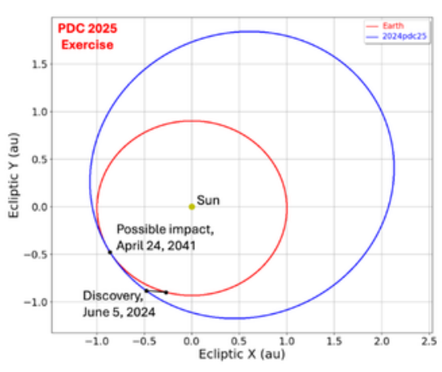


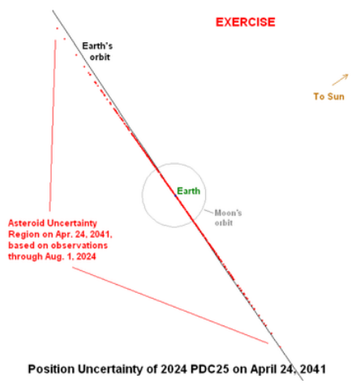
After LEOP, the spacecraft performs a DSM burn or follows a low thrust trajectory transfer to rendezvous with 2025PDC based on mission analysis. While coasting, farfield observations are collected and transmitted to Earth, in order to enable better trajectory and orbit determination. When the spacecraft is approaching the threshold for initial near field, appropriate payloads are turned ON for their duty cycles. A series of orbit lowering burns takes place to transition to the preliminary survey phase and the spacecraft settles to a stable or a quasi-stable orbit depending on the gravitational field and additional data is collected. At the pre-final stage (before decommissioning), i.e., Detailed Survey Phase, precise orbit determination along with topographic mapping (for deflection sites) and updated physical property measurements occur and **if possible, a deflection attempt at the end-of-life**

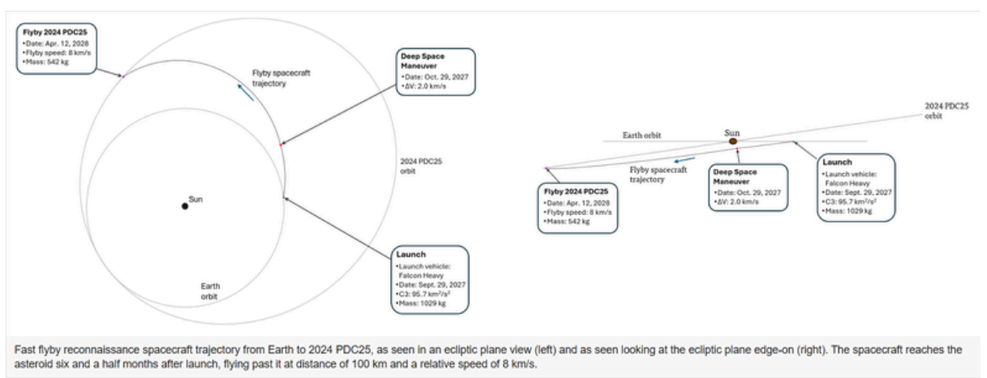
MISSION ANALYSIS

As seen on the right, ~ 6 years are required for executing a carefully planned reconnaissance rendezvous mission with dedicated launch and subsystem development. This could be traded off by introducing COTS components, using rideshare and developing a series of spacecrafts (incremental mission and iterative design).
Given that the warning was issued in June 2024 and a 100% impact was confirmed in September 2025, building on the momentum from the fast flyby mission recommended by SMPAG, the rendezvous/potential deflection mission is launched in 2030, after undergoing parallel development with the flyby mission and learning from its outcomes.





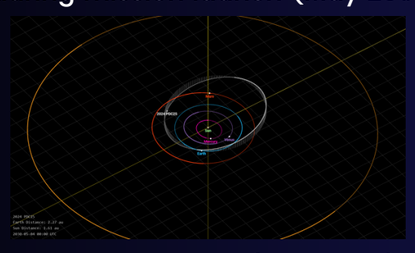




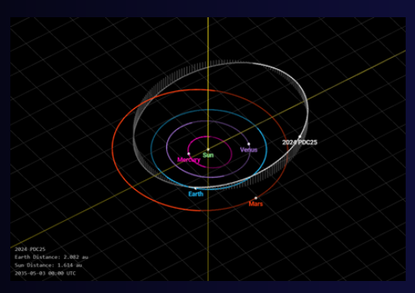
Fast flyby reconnaissance spacecraft trajectory from Earth to 2024 PDC25, as seen in an ecliptic plane view (left) and as seen looking at the ecliptic plane edge-on (right). The spacecraft reaches the asteroid six and a half months after launch, flying past it at distance of 100 km and a relative speed of 8 km/s.

ORBIT VISUALIZATION

Orbit during mission launch (May 2030)



Orbit during mission end (May 2035)



CONCLUSION

After the warning was issued and the impact was confirmed in September 2025, quick actions were crucial - leading to timely flyby mission
It is important to follow up and using iterative and parallel development, a rendezvous mission was launched with a secondary mission objective of colliding at its EOL and deflecting the asteroid to avoid a severe impact and instead divert it to lesser populated areas.
A framework for general mission design and ConOps is presented which can be adapted to specific usecases, depending on the need.

RELATED LITERATURE

1. CNEOS and PDC websites
2. SMAD (Space Mission Analysis and Design) by Wertz
3. "DART: Latest results from the Dimorphos impact and a look forward to future planetary defense initiatives" - Nancy Chabot, et. al