Paper ID: 27815
student

SPACE EXPLORATION SYMPOSIUM (A3)
Interactive Presentations (IP)

Author: Mr. Sung Wook Paek
Massachusetts Institute of Technology (MIT), United States

Ms. Patricia Egger
Switzerland
Dr. Olivier de Weck
Massachusetts Institute of Technology (MIT), United States

# MODELING AND OPTIMIZATION OF MULTI-STAGE ASTEROID DEFLECTION CAMPAIGNS UNDER EPISTEMIC UNCERTAINTIES.

**Abstract**

A wide variety of methods are proposed today to prevent an impact from an asteroid or comet, but their scope is limited to a single spaceflight or sortie. This paper develops a system-level framework for an asteroid deflection campaign consisting of closely related mission phases or stages. This multi-stage framework identifies an optimal combination of spatiotemporally distributed stages and technologies required for each stage. The temporal and spatial distribution of stages contributes to different aspects of a successful asteroid deflection campaign.

Temporally dividing an asteroid deflection campaign into precursor, deflection, and tuning stages can reduce the epistemic uncertainties in the target asteroid's physical properties and displacement from its original trajectory. A precursor stage provides in-situ information, which is used to tailor the design of a deflector in the subsequent deflection stage. If a kinetic energy impactor is used as a deflector, a precursor stage can narrow down uncertainties in the mass and the momentum multiplication factor of an asteroid. Thus, the prior knowledge reduces the uncertainties in the changes of the asteroid's velocity and trajectory. Should additional actions be required on top of this "coarse" displacement, tuning stages can be added as necessary for "fine" displacement using smaller impactors, gravity tractors, or other slow-push methods. These chronological stages allow for accurately adjusting displacement to enhance the likelihood of success of the overall deflection campaign.

Each stage in an asteroid deflection campaign may occur on the ground, in cislunar space, or in deep space. First-hand characterization of potentially hazardous objects (PHO) employs ground-based telescopes or space-based telescopes in low-Earth orbits or Lagrange points. Materials for impactors can be obtained in space by mining on the lunar surface or repurposing defunct geostationary satellites. Pre-deploying the impactor materials or spacecraft fuel improves the responsiveness of a deflection campaign and increases the upper limit in deflection distance or asteroid size.

The paper describes mathematical formulation of a multi-stage deflection campaign as a network optimization problem. The cost is the sum of launch masses for all stages, and the performance is the likelihood that an asteroid will be deflected into a "safe harbor" containing no keyholes that can cause resonant encounters with Earth. In addition to trade-offs between the cost and the performance, future work is discussed in the context of space logistics for human exploration to Mars and other celestial bodies.