A CubeSat-based Minimal Interstellar Mission

Introduction

**CubeSats for interplanetary missions**

- Mars Cube One, Lunar Flashlight, and NEA Scout.

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**Is a CubeSat-based Solar System escape mission feasible?**

**Potential targets**

- Kupier belt objects (> 30 AU)
- Interstellar objects (11° Oumuamua)
- Planet Nine (200 – 1200 AU)
- Other stars (> 268,000 AU)

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**Why a CubeSat?**

- Availability of off-the-shelf technologies for deep space missions in the future
- Low mass: launch as secondary payload, low launch cost, multiple spacecraft

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**Science Objectives**

1. Determine properties of the interstellar medium
2. Determine properties of the heliopause
3. In-situ observations of minor bodies (interstellar asteroids / comets, Kupier belt objects) and planets (Planet Nine)
4. In-situ analysis of ejecta of minor bodies (interstellar asteroids / comets, Kupier belt objects)

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**Key Technologies**

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**Propulsion**

- Advanced solar sail
- Electric sail

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**Power**

- Technology: Solar system hyperbolic escape (AU/a) vs trip duration [years]
- Specific power Potential
  - RTG: 2.3–2.6 W/kg Specific power marginal
  - Alphavoltaics: 0.33 W/kg Specific power too low
  - Betavoltaics: Too heavy; too short half-life of Tritium / Promethium-147
  - CubeSat Nuclear D-cell battery (Thermophotovoltaics): 12-16 W/kg Acceptable specific power
  - Microbial battery: Insufficient stability

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**Thermophotovoltaics** seems to be the most promising technology for deep space CubeSat missions

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**Communication**

- Transponder: (JPL Iris deep space transponder: 0.5 W, 1.2 kg, 26 W)
- Optical communication: (further miniaturization of existing technologies required, e.g. JPL 1U optical com system)

Performance of existing CubeSat optical communication technologies requires improvement (pointing accuracy, single-photon detectors)

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**Sample Mission Concepts**

**Obertmann maneuver 1: Jupiter-Solar Obertmann maneuver**

- Mission phases:
  1. Earth escape trajectory to Jupiter
  2. Flyby at Jupiter
  3. Solar approach trajectory
  4. Boost at Perihelion
  5. Solar system escape trajectory

**Obertmann maneuver 2: Starshot prototype laser infrastructure**

- Mission phases:
  1. Geostationary or highly elliptic orbit
  2. Laser boost
  3. Solar approach trajectory
  4. Boost at perihelion
  5. Solar system escape trajectory

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**Conclusions**

- CubeSat solar system escape missions are likely feasible in the next 10-20 years
- Key technologies are currently under development for interplanetary CubeSat missions
- Key technologies require further performance increase: optical communication, advanced laser sails, power generation, miniaturized science instruments (impactor), CubeSat-sized heat shield for solar Obertmann maneuver

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**References**