New Moon Explorer (NME) Robotic Mission Concept
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Mission/Science Objectives

• Science Objectives
  • Observe Earth’s ‘new moon’, the newly discovered near-Earth companion 2016HO3
  • Obtain spin rate, pole position, shape, structure, mass, density, chemical composition, temperature, thermal inertia, regolith characteristics, and spectral type

• Technology Objectives
  • Continue incremental development of solar sail technology
  • Demonstrate use of thin-film power technologies

• Strategic Objectives
  • Address synergies across multiple NASA and industry needs
New Moon Explorer sits at the intersection of numerous NASA and commercial objectives.
Solar sails use photon “pressure” or force on thin, lightweight, reflective sheets to produce thrust.
Solar Sail Missions Flown (as of September 7, 2018)

- **NanoSail-D (2010)**
  - NASA
  - Earth Orbit
  - Deployment Only
  - 3U CubeSat
  - 10 m²

- **IKAROS (2010)**
  - JAXA
  - Interplanetary
  - Full Flight
  - 315 kg Smallsat
  - 196 m²

- **LightSail-1 (2015)**
  - The Planetary Society
  - Earth Orbit
  - Deployment Only
  - 3U CubeSat
  - 32 m²

- **CanX-7 (2016)**
  - Canada
  - Earth Orbit
  - Deployment Only
  - 3U CubeSat
  - <10 m²

- **InflateSail (2017)**
  - EU/Univ. of Surrey
  - Earth Orbit
  - Deployment Only
  - 3U CubeSat
  - 10 m²
Planned Solar Sail Missions (as of September 7, 2018)

  - Earth Orbit
  - Full Flight
  - 3U CubeSat
  - 20 m²

  - Earth Orbit
  - Full Flight
  - 3U CubeSat
  - 32 m²

- Near Earth Asteroid Scout (2020) / NASA
  - Interplanetary
  - Full Flight
  - 6U CubeSat
  - 86 m²
Notional Roadmap To The Future of Solar Sails

- Solar Powered
- Laser Powered

\[ \mu = \text{Areal Density (Sail Mass/Sail Area)} \]

**Near-Term Sails 2010 - 2018**
- 10 – 100 m²
  - NanoSail-D
  - LightSail
  - Inflatable Sail/Cube Sail

**Mid-Term Sails 2019 - 2025**
- 100 – 1000 m²
  - \( \mu = 10 \text{ g/m}^2 \)

**Interstellar Probe 2025 - 2050**
- 1000 – 10,000 m²
  - \( \mu = 1 - 2.5 \text{ g/m}^2 \)

**Interstellar Medium Exploration**
- 10,000 – 1,000,000 m²
  - \( \mu = 0.1 \text{ g/m}^2 \)

**4.5 LY Interstellar Probe Flyby**
- 1,000,000 – 10,000,000 m²
  - \( \mu = 0.1 \text{ g/m}^2 \)
  - 1000 Astronomical Units
• Solar Radiation Pressure imparts a persistent torque on the spacecraft for the duration of the mission
• Use of expendable propellant to maintain desired Solar Sail attitude and/or desaturate reaction wheels would be mission limiting, particularly in small form factors
• A momentum management system is needed to accompany a solar sail concept
• NEA Scout utilizes Active Mass Translation (right) while IKAROS utilized Liquid Crystal Devices
Thin-Film Power Generation

- Leverages technology development from Lightweight Solar Array and anTenna (LISA-T)
- Thin-film photovoltaics coated with polyimide and solvent bonded on Toughened CP1
- Cells electrically interconnected via micro-welded ribbons and embedded traces
- Placed on independent substrate and deployed (can be integral to Solar Sail)
- Phased array antenna can be similarly embedded resulting in integrated propellantless propulsion, power generation, and telecommunications capability
Thin-Film Power Generation (contd.)

Omni – GN&C simplicity and non-pointed
Planar – pointed, high performance
Target Overview

- 2016HO3 is a Near-Earth companion representing the closest, most stable quasi-satellite to Earth
- Discovered by Pan-STARRS on April 27, 2016
- 40-100 meters in diameter
- Earth MOID 0.0348 AU (13.6 LD)
- Fast rotator with an estimated rotational period of 0.467 hours
Spacecraft Features

• Low-cost 12U form factor
• Solar Sail propelled
  • 200 m² toughened CP1 quadrant configuration
  • 4x 10.5-m Slit-tube composite booms laminate designed using Roccor Solar Sail Tool (SST)
  • Active Mass Translator MMS
• Planar, bi-pedal ‘LISA-T’ for power generation and telecommunications
• Deep space CubeSat avionics as utilized on MarCO (launched 2018) and NEA Scout and IceCube missions (launch 2020)
• Cold gas for momentum desaturations and impulsive events
• Leverages developmental lessons learned from the NEA Scout mission
Deployed Solar Sail Approximate Scale

- New Moon Explorer (200 m²)
- NEA Scout (86 m²)
- NanoSail-D (10 m²)

Folded, spooled and packaged

School Bus

12U Stowed Flight System
Concept of Operations

- **SLS Launch**
  - L+4 days: **Sail Characterization**
  - L+45 days: **Earth-Moon Departure**
  - L+222 days: **Cruise**
  - L+602 days: **Recon & Proximity Ops**
  - L+1082 days: **Downlink**

**Lunar Fly-by 1**
- **Separation from SLS**
- **Lunar Fly-by 2**
- **Minimum Ops, Periodic Tracking**
- **Rehearsal of science activities**

**Earth Fly-by 1**
- **-1 to -2 additional lunar flybys to target departure**
- **Instrument calibration @Moon**

**Earth Fly-by 2**
- **Target Detection**
- **Unresolved and Resolved imagery**
- **High resolution surface imaging (full surface)**
- **Slow, close flyby**

**2016HO3**
- **<0.25 AU**
- **4kbps+ D/L (34m DSN) and/or 2kbps+ (21m MSU DSN affiliate)**

**Data Downlink**

**Target Reconnaissance & Proximity Ops**
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BACKUP
NASA’s Near Earth Asteroid Scout

The Near Earth Asteroid Scout Will:
• Image/characterize a NEA during a slow flyby
• Demonstrate a low cost asteroid reconnaissance capability

Key Spacecraft & Mission Parameters
• 6U cubesat (20 cm X 10 cm X 30 cm)
• ~86 m² solar sail propulsion system
• Manifested for launch on the Space Launch System (EM-1/2019)
• Up to 2.5 year mission duration
• 1 AU maximum distance from Earth

Solar Sail Propulsion System Characteristics
• ~ 7.3 m Trac booms
• 2.5µ aluminized CP-1 substrate
• > 90% reflectivity
NEA Scout Flight System
NEA Scout Hardware Overview
NEA Scout Full Scale Successful Deployment