Near Earth Asteroid Scout – NASA’s First Interplanetary Solar Sail Mission

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Solar Sail Missions Flown and Planned

- **NanoSail-D (2010)**
  - NASA/MSFC/ARC
  - 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

- **CU Aerospace (2018)**
  - Univ. Illinois / NASA
  - Earth Orbit Full Flight
  - 3U CubeSat 20 m²

- **LightSail-2 (2018)**
  - The Planetary Society
  - Earth Orbit Full Flight
  - 3U CubeSat 32 m²

- **Near Earth Asteroid Scout (2019)**
  - NASA
  - Interplanetary Full Flight
  - 6U CubeSat 86 m²
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 (20cm X 10cm X 30 cm)
- \(\approx 86 \, \text{m}^2\) solar sail propulsion system
- Manifested for launch on the first Space Launch System mission (EM-1)
- 1 AU maximum distance from Earth

Leverages: combined experiences of MSFC and JPL with support from GSFC, JSC, & LaRC
NEA Scout Approximate Scale

Deployed Solar Sail

School Bus

Human

6U Stowed Flight System

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Concept of Operations Overview

- **SLS EM-1 Launch**
  - L + 4 days: Sail Characterization
  - L + 42 days: Instrument Calibration

- **Lunar Fly-by 1**
  - De-tumble
  - Initial Health Check
  - ~10 m/s ΔV to target 1st lunar flyby

- **Lunar Fly-by 2+**
  - Sail deployment
  - Sail characterization
  - Maneuver to 2nd lunar flyby

- **Cruise**
  - Minimum Ops, Periodic Tracking
  - Rehearsal of science activities

- **Target Search and Approach**
  - ~1-2 additional lunar flybys to target departure
  - Additional targeting possible for off-nominal launch dates
  - Instrument calibration @Moon
  - Minimum science success criteria addressed
  - Sub-pixel imaging of target
  - On-board image co-adding to achieve detection SNR
  - Ephemeris and color addressed

- **Target Scan Imaging (Image Stacking)**
  - Target (SNR > 5)
  - Ref stars
  - Imaging of the resolved target

- **Data Downlink**
  - Slow target flyby
  - Full success criteria addressed
  - <1 AU Earth dist.
  - ~1 kbps DTE (34 m DSN)
  - On-board science processing

- **Proximity**
  - High Resolution Imaging (10 cm/pixel)

- **NEA**
  - <50,000 km Target distance
  - <28 km Target Distance
  - <1 km Proximity

- **Approximate timeline**
  - L + 766 days
  - L + 784 days
  - C/A ~ L + 784 days
  - L + 810 days

- **Earth-Moon Departure**
  - Earth
  - Cruise
  - Search/Approach
  - Recon
  - Proximity
  - Downlink
## Flight System Overview

<table>
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<tr>
<th>Payload</th>
<th>• Context Camera</th>
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| Mechanical & Structure | • “6U” CubeSat form factor  
• <14 kg total launch mass  
• Modular flight system concept |
| Propulsion | • ~86 m² aluminized CP-1 solar sail (based on NanoSail-D2) |
| Avionics | • Radiation tolerant architecture |
| Electrical Power System | • Trifold deployable solar arrays with GaAs cells (~51.2 W EOL at 1 AU solar distance)  
• 6.2 Ah Battery  
• 10 -12.3 V unregulated, 5 V/3.5 V regulated |
| Telecom | • JPL Iris 2.0 X-Band Transponder; 4 W RF output power supports doppler, ranging, and D-DOR  
• 2 pairs of INSPIRE-heritage LGAs (RX/TX)  
• 8x8 element microstrip array MGA (TX); ~1 kbps to 34m DSN at 0.8 AU |
| Attitude Control System | • 15 mN-m·s (x3) & 100 mN-m·s RWAs  
• Active mass translation system  
• VACCO R-236fa (refrigerant gas) ‘warm gas’ RCS system  
• Nano StarTracker, Coarse Sun Sensors & MEMS IMU for attitude determination |

**A fully functional planetary spacecraft in a shoebox**
Active Mass Translation (AMT) Overview

Problems and Challenges

- NEA Scout’s center of mass (CM) and center of pressure (CP) are not collinear with the estimated thrust vector. This creates a *disturbance torque*. Furthermore, the CP is fore of the CM, creating a naturally unstable vehicle and necessitating an active control mechanism.

- Little mass and volume available. This challenge is compounded by the vehicle’s total mass (14 kg) and volume (6 Liters) requirement. The AMT was originally given 250 grams and a volume of 226 x 105 x 17 mm (400 cc). This *volume* and *mass* will include: an X-Y translation stage, thermal controls, limit switches, and a wire harness. The *wire harness* must pass through the AMT and survive exposure to *deep space environments*. 

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KEY

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<th>Thrust</th>
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<td>CM</td>
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<td>Disturbance Torque</td>
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On Schedule to Deliver Spacecraft
MSFC Small Spacecraft Experience

DART (2005)  
MSFC/Orbital Sciences  
Earth Orbit  
AR&D Demonstrator

Iodine Satellite (iSAT)  
NASA/MSFC  
Iodine propulsion system demonstrator  
6U CubeSat

Orbital Express (2007)  
DARPA/Boeing/Ball/MSFC  
Earth Orbit  
AR&D & Refueling Demonstrator

FASTSAT-HSV-01 (2010)  
MSFC/Dynetics/USAF  
Earth Orbit  
Rapid Development  
7 science instruments

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

Near Earth Asteroid Scout (2019)  
NASA  
Interplanetary  
Full Flight  
6U CubeSat

Lunar Flashlight (2019)  
NASA/MSFC/JPL  
Lunar science mission  
6U CubeSat
NASA MSFC Flight Robotics Lab

Provides a full scale, integrated simulation capability to support the design, development, test, integration, validation, and operation of orbital space vehicles.

The Flight Robotics Laboratory (FRL) is built on developed technologies: air bearing vehicles, a servo drive overhead robotic simulator, precision target motion controllers, gimbals, and a mobile solar simulator with 6 lights totaling 42 KVA.

The facility is centered around a 44 foot by 86 foot precision air bearing floor - the largest of its kind.

The FRL has air-bearing vehicles ranging in size from 200 lbs to 4000 lbs, each with its own compressed air supply. An 8-Degree-of-Freedom (DOF) overhead gantry (the Dynamic Overhead Target Simulator or DOTS) provides an 800 pound payload capability for simulating relative motion with respect to a fixed target in the facility with a motion envelope of 30’ x 160’ x 20’. A computer system provides inverse kinematics and allows the gantry to act as a target or as the 6 DOF rendezvous vehicle. The target reaction dynamics can be simulated through force/torque feedback from sensors mounted at the payload interface.

Collaboration areas could include sensor testing, system testing, multi-vehicle algorithm simulation and testing, orbital debris tracking, automated capture and manipulation, and wireless video and control.

Past DoD collaborations include DARPA’s Orbital Express mission, MARCbot reconfiguration and testing, DART mission to MUBLCom satellite, and sensor tests utilizing Army ranges and facilities.
Questions?
Backup Information
The Need for CM/CP Adjustment

WHAT IS “ACTIVE MASS TRANSLATION”?  

The AMT will move one portion of the NEA Scout relative to the other. This translation of mass will alter the inertial properties of the vehicle and align the CP and CM.
AMT Overview

Current Design State

**CAPABILITIES**
- Translation: 160 X 68 mm (X & Y respectively)
- Speed: 0.3 and 0.1 mm/s (X & Y respectively)
- Precision: 0.01 mm
- Volume: 220 x 99 x 14 mm (300 cc)
- Mass: < 350 grams (including control board)

* Stepper Motors are housed inside of the aluminum block and are not readily visible
FASTSAT-HSV01
Seven Instruments on One Platform

NASA and USNA Miniature Imager for Neutral Ionosphere Atoms and Magnetospheric Electrons (MINI-ME)
• Improve space weather forecasting for operational use

AFRL Light Detection System (LDS)
• Evaluate atmospheric propagating characteristics on coherent light generated from known ground stations

NASA + ARMY SMDC + AFRL + VCSI Nano Sail Demonstration (NSD)
• Demonstrate deployment of a compact 10-m² solar sail ejected as a CubeSat

NASA MSFC Memory Test Experiment (MTE)
• Flight Demonstration of Ferroelectric Memory technology

NASA and USNA Thermospheric Temperature Imager (TTI)
• Increase accuracy of orbital predictions for low-Earth orbiting assets

NASA & USNA Plasma Impedance Spectrum Analyzer (PISA)
• Permit better predictive models of space weather effects on communications and GPS signals

AFRL + NASA + AF Miniature Star Tracker (MST)
• Demonstrate small and low-power star tracker