Near Earth Asteroid (NEA) Scout

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Topics

• What is a solar sail?
• A brief history of solar sailing
• NASA’s Near Earth Asteroid Scout mission
How does a solar sail work?

Solar sails use photon “pressure” or force on thin, lightweight reflective sheet to produce thrust.
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- 100 kg spacecraft
- 8 triangular sail blades deployed from a central hub after launch by the inflating of structural tubes.
  - Sail blades were each 15 m long
  - Total surface area of 600 square meters
- Launched in 2005 from a Russian Volna Rocket from a Russian Delta III submarine in the Barents Sea:

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Rocket Failed
NASA Ground Tested Solar Sails in the Mid-2000’s

Two 400 square meter sail were autonomously deployed and tested at Plumbrook
Mission Description:

- 10 m² sail
- Made from tested ground demonstrator hardware
Liquid crystal device power was off.

Liquid crystal device power was on.
Fortunately, IKAROS accomplished with Icarus could not…
Sunjammer Solar Sail Demonstration Mission

Based on one of the 400 m² NASA Demonstrators:
- Cold Rigidization Boom Technology
- Aluminized Sun Side
- High Emissivity Eclipse Surface
- Beam Tip Vane Control

STMD Technology Demonstration Mission (TDM)

83 m² ISP L’Garde Solar Sail 2004

318 m² ISP L’Garde Solar Sail 2005

1200 m² L’Garde Sunjammer was to launch in 2015
Sunjammer Solar Sail Demonstration Mission

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Canceled

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2015’s LightSail-A (The Planetary Society)

32 m²
No active ‘sailing’
3U cubesat
• What is a solar sail?
• A brief history of solar sailing
• NASA’s Near Earth Asteroid Scout mission
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 (20cm X 10cm X 30 cm)
• ~86 m² solar sail propulsion system
• Manifested for launch on the Space Launch System (EM-1/2018)
• 1 AU maximum distance from Earth

Leverages: combined experiences of MSFC (PM, SE and Solar Sail) and JPL (flight system bus, instrument and science) with support from GSFC, JSC, & LaRC

Close Proximity Imaging
Local scale morphology, terrain properties, landing site survey
• HEOMD’s Advanced Exploration Systems (AES) selected 3 cubesats for flight on SLS EM1
• Primary selection criteria:
  - Relevance to Space Exploration Strategic Knowledge Gaps (SKGs)
  - Life cycle cost
  - Synergistic use of previously demonstrated technologies
  - Optimal use of available civil servant workforce

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<th>Strategic Knowledge Gaps Addressed</th>
<th>Mission Concept</th>
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<td>BioSentinel</td>
<td>Human health/performance in high-radiation space environments</td>
<td>Study radiation-induced DNA damage of live organisms in cis-lunar space; correlate with measurements on ISS and Earth</td>
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<td><em>ARC/JSC</em></td>
<td>• Fundamental effects on biological systems of ionizing radiation in space environments</td>
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<td>Lunar Flashlight</td>
<td>Lunar resource potential</td>
<td>Locate ice deposits in the Moon’s permanently shadowed craters</td>
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<td><em>JPL/MSFC</em></td>
<td>• Quantity and distribution of water and other volatiles in lunar cold traps</td>
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<tr>
<td>Near Earth Asteroid (NEA)</td>
<td>Human NEA mission target identification</td>
<td>Flyby and characterize one NEA that is candidate for a human mission</td>
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<td><em>Scout MSFC/JPL</em></td>
<td>• NEA size, rotation state (rate/pole position)</td>
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<td>How to work on and interact with NEA surface</td>
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<td>• NEA surface mechanical properties</td>
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Near Earth Asteroid Scout

- Project Manager: Leslie McNutt (MSFC)
- Science PI: Julie Castillo-Rogez (JPL)
- Solar Sail PI: Les Johnson (MSFC)
- Spacecraft System: JPL
- Solar Sail System: MSFC
L1 Science Requirements

- **NEA SCOUT SHALL HAVE THE CAPABILITY TO ADDRESS KEY STRATEGIC KNOWLEDGE GAPS AT A NEAR EARTH ASTEROID**

- **Full Success Criteria:** Fly by a near Earth asteroid and acquire images sufficient to determine the target volume, shape model, asteroid spectral type and meteorite analogs, rotational properties (pole position, rotation period), orbit, debris/dust field in local environment, and regolith characteristics.

- **Minimum Success Criteria:** Fly by a near Earth asteroid and acquire images sufficient to estimate the target volume, the asteroid spectral type, determine rotational properties (pole position, rotation period), and orbit.

- **Rationale:** This requirement addresses the need to fill Strategic Knowledge Gaps related to asteroids as a precursor to subsequent safe and successful human missions. The data obtained will also support the advancement of science interests in asteroids.
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
  - \( \approx 10 \text{m/s} \) dV to target 1st lunar fly-by

- Lunar Fly-by 2+
  - Minimum Ops, Periodic Tracking
  - Rehearsal of science activities

- Cruise
  - Sail deployment
  - Sail characterization
  - Maneuver to 2nd lunar fly-by

- Target (SNR > 5)
  - Ref stars
  - Imaging of the resolved target

- Target Scan Imaging (Image Stacking)

- Target Search and Approach
  - Maximum science success criteria addressed

- Slow target flyby
  - Full success criteria addressed

- Proximity
  - <1 AU Earth dist.
  - >1 kbps DTE (34 m DSN)
  - On-board science processing

- High Resolution Imaging (10 cm/pixel)

- Data Downlink

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

- Earth-Moon Departure
  - Cruise
  - Search/Approach
  - Recon
  - Proximity
  - Downlink

Approximate time line:
- L+4 days: Sail Characterization
- L+42 days: Instrument Calibration
- L+766 days: Target Scan Imaging
- C/A-L+794 days: Imaging of the resolved target
- L+810 days: Target Search and Approach
Near Earth Asteroid Scout Asteroid Flyby

Target Detection and Approach:
50K km, Light source observation
SKGs: Ephemeris determination and composition assessment (color)

NEA Reconnaissance
<100 km distance at encounter
50 cm/px resolution over 80% surface
SKGs: volume, global shape, spin properties, local environment

Close Proximity Science
High-resolution imaging,
10 /px over >30% surface
SKGs: Local morphology
Regolith properties

JPL IntelliCam
(Updated OCO-3 Context Camera)
Baseline Target: 1991 VG

- Diameter ~ 5-12 meters
- Albedo is unknown
- Position is known within 2700 km (1-σ) but optical observation opportunity in July ‘17 will decrease uncertainty to a few 100s km
- Rotation period between a few minutes and less than 1 hour
- Unlikely to have a companion
- Unlikely to retain an exosphere or dust cloud
  - Solar radiation pressure sweeps dust on timescales of hours or day
NEA Scout Flight System Configuration

- Tri-fold solar array (notional)
- High gain antenna
- Low gain antennas
- CSD Connector
- Separation switches
- Payload context camera
- Solar sail
- AMT (placeholder)
- ACS tray
- Battery packs
- Avionics stack
- RCS system

Integrated flight system, stowed sail; Credit: JPL
Solar Sail Subsystem Overview

- Spacecraft Wire Channel
- Single Sail Spool
- Boom Deployers
- Deployment Motor
- TRAC Booms

Solar Sail Subsystem without sail, Credit: NASA
Test Deployment with Linear Springs

Early prototype, Credit: NASA
NEA Scout Approximate Scale

Deployed Solar Sail

6U Stowed Flight System

Folded, spooled and packaged in here

School Bus

Human