The Solar Cruiser Mission: Demonstrating Large Solar Sails for Deep Space Missions

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Solar sails use photon “pressure” or force on thin, lightweight, reflective sheets to produce thrust.
Solar Sail Missions Flown (as of October 2019)

**NanoSail-D (2010)**
- **Agency:** NASA
- **Deployment:** Earth Orbit
- **Satellite Type:** 3U CubeSat
- **Dimensions:** 10 m²

**IKAROS (2010)**
- **Agency:** JAXA
- **Deployment:** Interplanetary
- **Satellite Type:** 315 kg Smallsat
- **Dimensions:** 196 m²

**LightSail-1 (2015)**
- **Agency:** The Planetary Society
- **Deployment:** Earth Orbit
- **Satellite Type:** 3U CubeSat
- **Dimensions:** 32 m²

**CanX-7 (2016)**
- **Agency:** Canada
- **Deployment:** Earth Orbit
- **Satellite Type:** 3U CubeSat
- **Dimensions:** <10 m²

**InflateSail (2017)**
- **Agency:** EU/Univ. of Surrey
- **Deployment:** Earth Orbit
- **Satellite Type:** 3U CubeSat
- **Dimensions:** 10 m²
Current and Planned Solar Sail Missions

CU Aerospace (2018)
Univ. Illinois / NASA
Earth Orbit
Full Flight
In Orbit; Not yet deployed
3U CubeSat
20 m²

LightSail-2 (2019)
The Planetary Society
Earth Orbit
Full Flight
In Orbit; Successful
3U CubeSat
32 m²

Near Earth Asteroid Scout (2020)
NASA
Interplanetary
Full Flight
6U CubeSat
86 m²

Solar Cruiser (2024)
NASA
L-1
Full Flight
90 Kg Spacecraft
>1200 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)
- ~86 m² solar sail propulsion system
- Manifested for launch on the Space Launch System (Artemis 1 / 2020)
- 1 AU maximum distance from Earth

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

Target Reconnaissance with medium field imaging
  - Shape, spin, and local environment

Close Proximity Imaging
  - Local scale morphology, terrain properties, landing site survey
Solar Cruiser
Mission Concept
Solar Cruiser may launch as a secondary payload on the NASA IMAP mission in October, 2024. It then cruises past the Sun-Earth L1 point, demonstrating station keeping at an artificial equilibrium point.
Solar Cruiser
Solar Sail Technology Investment Heritage

- **LightSail 1 (The Planetary Society)**
  - 32 m² sail (NanoSail heritage design)
  - Successful flight in 2015

- **LightSail 2 (The Planetary Society)**
  - 32 m² sail
  - Successful flight in 2019

- **MSFC NanoSail-D**
  - 10 m² sail (made using parts left over from 400 m² demonstrator)
  - Successful flight 2010

- **SMD In-Space Propulsion Technology Project**
  - 400 m² solar sail demonstrator

- **HEOMD Near-Earth Asteroid Scout**
  - 86 m², 2-year mission to an asteroid
  - Manifested on Artemis 1 (2020)

- **HEOMD Near-Earth Asteroid Scout Flight Unit Deployment Test**
  - 86 m², 2-year mission to an asteroid
  - Manifested on Artemis 1 (2020)

- **In 2021, JWST will deploy 5 layers (772 m²) of thin film material traceable to Solar Cruiser (NeXolve)**

- **Roccor Composite Boom Technology Phase I & II SBIR (2018 – 2020)**

- **NeXolve Large Sail Fabrication Automation Phase I & II SBIR (2019 – 2021)**

- **Reflective Control Devices (RCDs) NASA STMD Early Career Faculty STRA (2012)**

- **Lightweight Integrate Solar Array (LISA)**
  - thin-film power generation
  - MSFC TIPs, STMD ECI & SSTP (2012-2021)

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Key Feature: The Solar Sail

- Reflectivity Control Devices (RCDs) for sailcraft attitude control
- Composite TRAC booms with excellent strength/weight ratio and thermal stability
- Embedded photovoltaics for additional power
- Passively stable design
- Scalable to future missions like SPI
Key Feature: PELE Coronagraph

PELE instrument (Polarization and Energetics in Line Emission) will provide space-based coronal imaging of both linear polarization states, combined with Doppler velocimetry, for a capability that is readily extensible to future missions.

The PELE coronagraph occults the solar disk down to Rsun=1.1, enabling observations of magnetic structure in CME triggering regions.
Ball Sailcraft Concept

Star trackers (2x), mounted to stationary interior of spool

LGA Patch (1 of 2)

Spool for Solar Sail Deployment

Solar Sail Boom Deployer

AMT

PELE

PELE Aperture

TRAC Booms

Solar Array
## Solar Cruiser Operations Plan

<table>
<thead>
<tr>
<th>Mission Phase</th>
<th>Time Since Launch (days)</th>
<th>Duration (days)</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch and Commissioning</td>
<td>L+0 to L+28</td>
<td>28</td>
<td>Assess spacecraft functionality</td>
</tr>
<tr>
<td>Coronagraph Checkout</td>
<td>L+29 to L+53</td>
<td>24</td>
<td>Test and operate coronagraph</td>
</tr>
<tr>
<td>Sail Deploy and Checkout</td>
<td>L+54 to L+61</td>
<td>7</td>
<td>Deploy and Assess Sail</td>
</tr>
<tr>
<td>Sailcraft Cruise</td>
<td>L+62 to L+221</td>
<td>160</td>
<td>Use sail to fly to sub-L1</td>
</tr>
<tr>
<td>Sub-L1 Halo Orbit</td>
<td>L+222 to L+283</td>
<td>62</td>
<td>Operate coronagraph on the sailcraft</td>
</tr>
<tr>
<td>Leave Ecliptic Plane</td>
<td>L+284 to L+365</td>
<td>92</td>
<td>Demonstrate heliocentric plane change</td>
</tr>
<tr>
<td>Science Enhancement</td>
<td>L+366 to L+730</td>
<td>365</td>
<td>Use coronagraph to obtain science data</td>
</tr>
</tbody>
</table>
Science Enhancement Option

After the Baseline mission, *Solar Cruiser* proposes a 1-year SEO to observe the solar corona from vantage points off the Sun-Earth Line.

The sailcraft will cruise to 5 degrees Earth-trailing, where it will station-keep for 4 months for coronal observations.
WHY SOLAR SAILS?  Solar Storm Warning
WHY SOLAR SAILS? Earth Pole Sitters

- Continual coverage of the polar regions
- Altitudes ranging from 0.75 million km to 3.5 million km, depending on sail performance and inclination chosen
WHY SOLAR SAILS?  High Inclination Solar Science

Part of trajectory below Ecliptic Identified by dashed curve

1. Launch 5-24-18 \( C_3 = 0.25 \text{ km}^2/\text{s}^2 \)
2. Start of Sail Phase 6-3-18
3. Start of Cranking Phase 12-10-20
4. End of Cranking Phase 2-5-25
5. Start of Science Operations 3-2-25
Questions?