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)  
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
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
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 (Artemis 1 / 2020)
• 1 AU maximum distance from Earth

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

- **SMD In-Space Propulsion Technology Project**: 400 m² solar sail demonstrator
  Deployed at Plumrock Station (2000 – 2003)

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

- **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

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

- **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)

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

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

- **In 2021, JWST will deploy 5 layers (772m²) of thin film material traceable to Solar Cruiser (NeXolve)**
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 $R_{\odot}=1.1$, 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 \( C_s = 0.25 \text{ km}^2/\text{s}^2 \)
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?