Solar Sail Propulsion Technology for Planetary Missions

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Solar Sail Propulsion

- Produce thrust with sunlight pressure or on thin, lightweight, reflective sheets
- Will never run out of fuel, allowing space missions to new locations
- Low mass & volume, high ΔV propulsion

Large area, lightweight sail
2.5 microns thick
(thinner than a human hair)
Solar Sail Missions Flown

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 & 2 (2015/2019)
The Planetary Society
Earth Orbit Deployment / Flight
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
Near Earth Asteroid Scout
Launched: Status *Unknown*

Goals
- First long duration (> 2 years) interplanetary science mission using solar sail propulsion

Key Spacecraft & Mission Parameters
- 6U cubesat (8” X 4” X 12”)
- 86 m² (925 ft²) solar sail propulsion system
- Launched November 16 with Artemis 1
- Unable to make radio contact (as of this time)
Near Earth Asteroid Scout
Launched: Status *Unknown*

Still attempting to make radio contact
Advanced Composite Solar Sail System (ACS3)

Objectives:
- Demonstrate successful deployment of the composite boom as well as sail packing and deployment systems in low-Earth orbit
- Evaluate the efficacy of the shape and design of the solar sail
- Characterize the thrust functionality of the sail as the spacecraft gradually changes orbit
- Appx. 81 m²

Images Courtesy of NASA’s Langley Research Center
Solar Cruiser Technology Demonstration Mission (as currently defined)

**Mission Technology Goals**
Demonstrate solar sail propulsion technology to enable near- and mid-term science missions up to and including high solar inclination orbits, sub-L1 halo orbits, non-Keplerian solar and other planetary orbits
- Mercury, Venus and other inner solar system missions
- Mission destinations of interest to the nation in cis-lunar space
- Increased Space Weather warning times (Sub L1 station keeping)
- Sustained in-situ measurements within the Earth’s magnetotail
- High inclination solar orbital observations

**The Team**
- NASA MSFC: Project Management, ADCS Software, MDNav, Mission Operations
- Ball Aerospace: Sailcraft Bus & Sailcraft I&T
- Redwire: Solar Sail System

**Status**
- Completed Phase B and successful technical PDR
- Not confirmed for 2025 launch (by NASA SMD) due to schedule
- Offered rideshare to L1 by NOAA in 2028
- Secured $10M to mature sail technology to TRL-6 in FY23
- Secured additional funding from NOAA to fabricate the flight sail

**Technical Details**

**Solar Sail**
- Deployed Area: ~17,800 ft² (1653 m²)
- Fabric: 2.5 micron thick Colorless Polyimide-1
- Composite Boom Lengths (X4): 97 ft (29.5 m) each

**Destination**
- Non-Keplerian sub-L1 halo orbit

**Launch**
- Secondary payload on ESPA Grande on Falcon 9 with IMAP mission

**Payload**
- 2.5 kg context camera
- Can accommodate 5 – 10 kg without significant changes
Solar Cruiser Flight and Technology Systems

- +Z LGA/Sun Sensor
- Bus-Mounted TS Electronics
- IFM Thrusters (4x)
- Separation System (MLB)
- -Z LGA
- Total System Mass: 111 kg Designed for ESPA Grande
- Solar Sail Technology System: Booms, Sail Deployment Deployment Mechanism, and Quadrants
- Technology System Active Mass Translator
- Sailcraft Bus
- Context Camera
- SSADCS Software

Designed for ESPA Grande
Prototype Quadrant Deployed and Tested

- Full-scale quadrant Prototype deployment testing complete

Prototype Sail Quadrant (SQ) Manufacturing

SQ Deployment
Test Design layout in MSFC Activities Center

Prototype single quadrant hardware:
- 1 full-scale SQ
- 2 full-scale TRAC booms
- 1 full-scale Sail Deployment Mechanism
Prototype Solar Sail Quadrant Deployed and Tested (~4700 ft\(^2\) / 440 m\(^2\))
For more information, contact

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NEA Scout Spacecraft (Exploded View)

NEA Scout Spacecraft (Exploded View)

Near Earth Asteroid Scout (NEA Scout): The USA’s First Solar Sail Propelled Interplanetary Science CubeSat
NEA Scout Science

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

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

Target Detection and Approach:
<40K km, Light source observation
SKGs: Ephemeris determination
NASA Has Two Decades of Solar Sail Development Experience Increasing Solar Sail Capabilities

Advanced Composite Solar Sail System [LaRC] (80 m² – 2022/23)

Near-Earth Asteroid Scout [MSFC] (86 m² or 925 ft² - 2022)

NanoSail-D [MSFC] (10 m² – 2010)

Lightweight Integrated Solar Array & anTenna [MSFC] (2023)

Solar Sail Ground Demonstrators [MSFC] (400 m² - 2004)

Solar Cruiser [MSFC] (1653 m² - ~17,800 ft²) Larger than an Olympic swimming pool