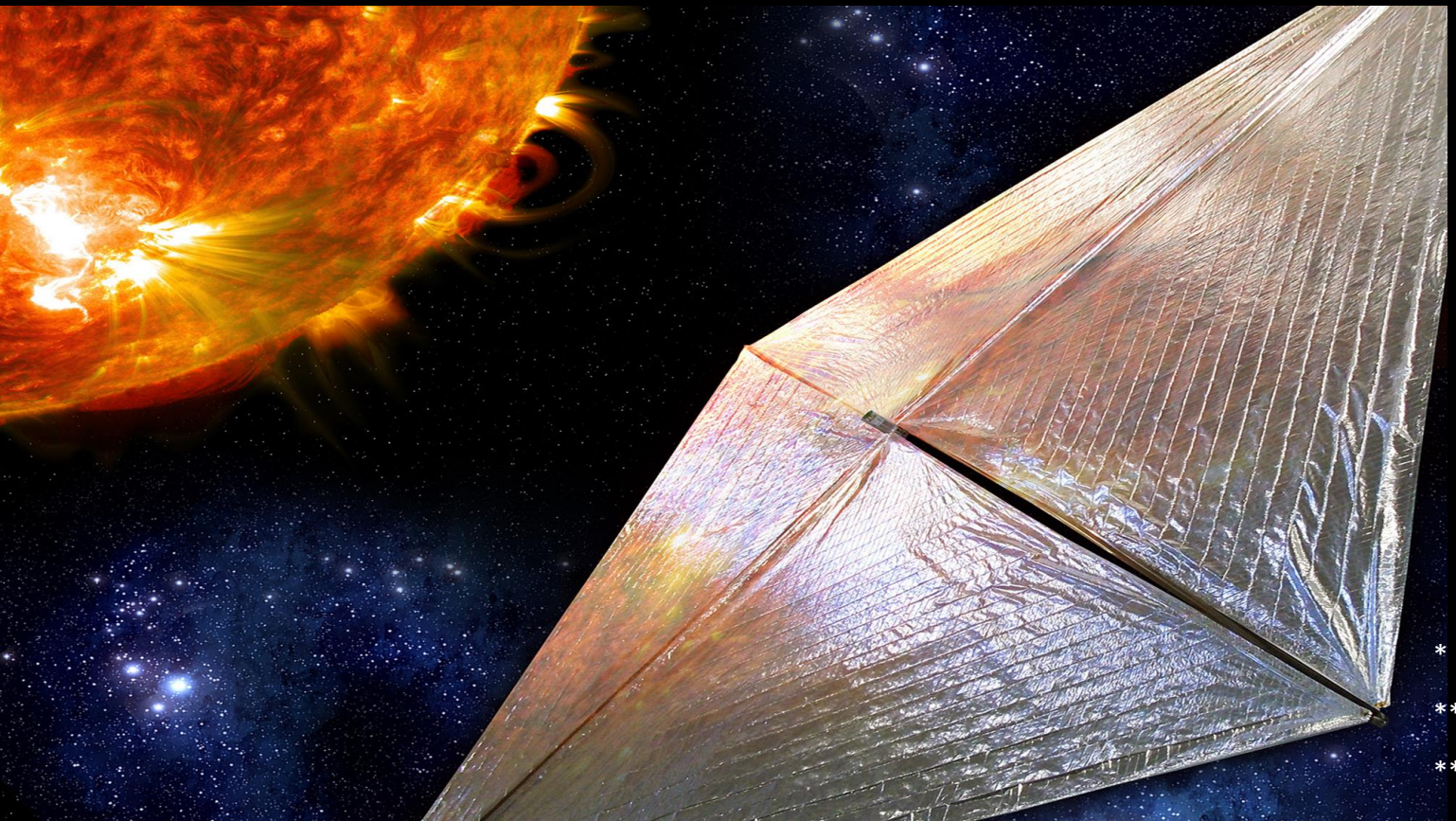
The Solar Cruiser Mission: Demonstrating Large Solar Sails for Deep Space Missions



Les Johnson*, Frank M. Curran**, Richard W. Dissly***, and Andrew F. Heaton*

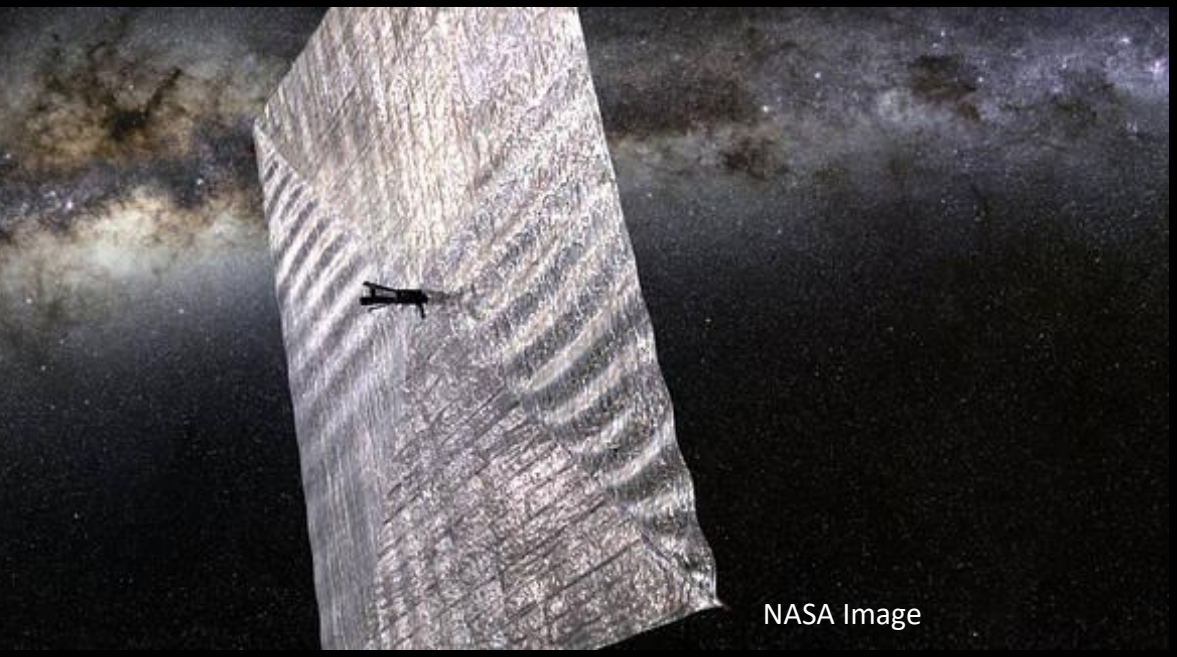
* NASA Marshall Space Flight Center

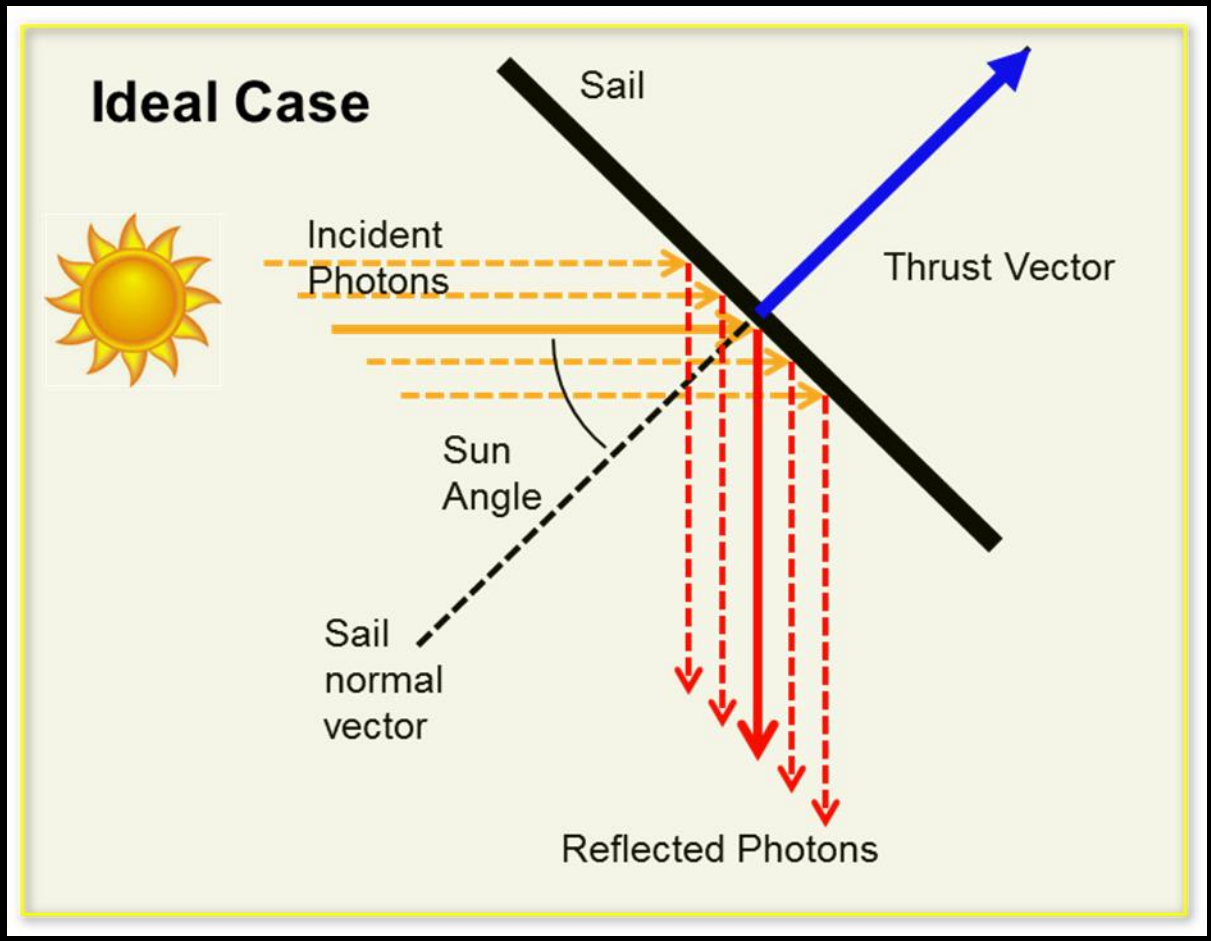
** MZBlue Aerospace

*** Ball Aerospace

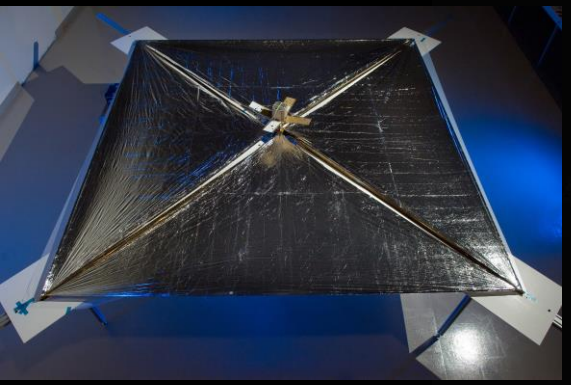
Solar Sails Derive Propulsion By Reflecting Photons

Solar sails use photon “pressure” or force on thin, lightweight, reflective sheets to produce thrust.


NASA Image



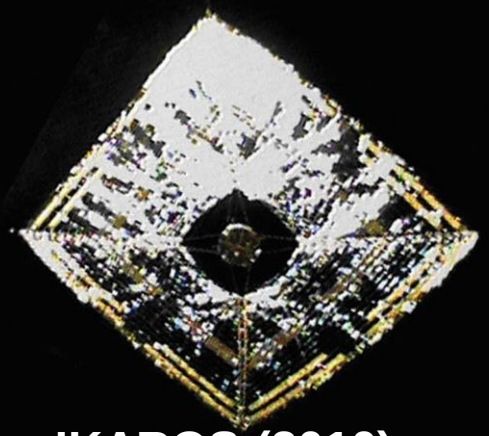
Solar Sail Missions Flown (as of October 2019)



NanoSail-D (2010)
NASA

Earth Orbit
Deployment Only

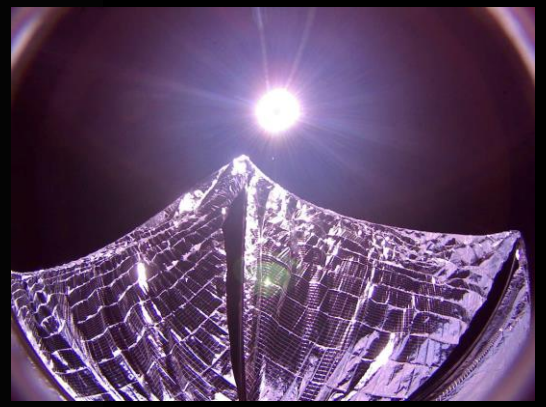
3U CubeSat
10 m^2



IKAROS (2010)
JAXA

Interplanetary
Full Flight

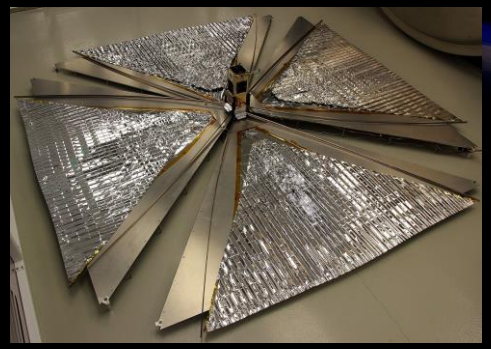
315 kg Smallsat
196 m^2



LightSail-1 (2015)
The Planetary Society

Earth Orbit
Deployment Only

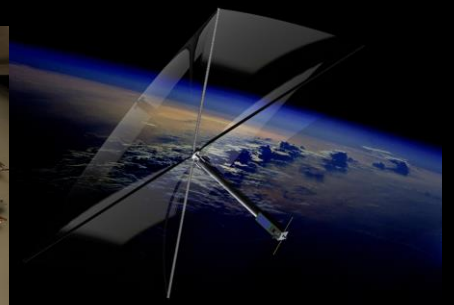
3U CubeSat
32 m^2



CanX-7 (2016)
Canada

Earth Orbit
Deployment Only

3U CubeSat
<10 m^2

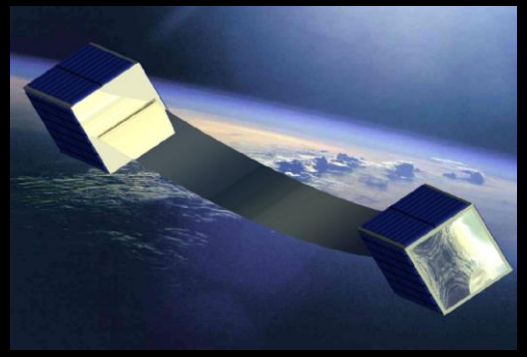


InflateSail (2017)
EU/Univ. of Surrey

Earth Orbit
Deployment Only

3U CubeSat
10 m^2

Current and Planned Solar Sail Missions



CU Aerospace (2018)
Univ. Illinois / NASA

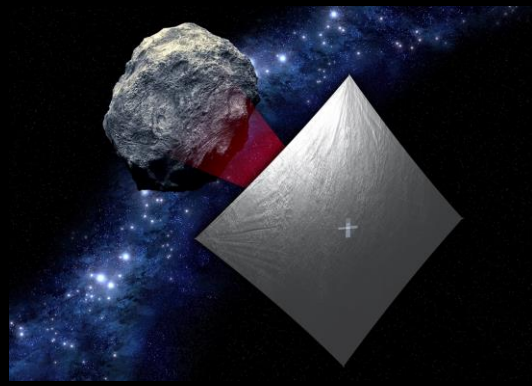
Earth Orbit
Full Flight
In Orbit; Not yet deployed

3U CubeSat
20 m^2

LightSail-2 (2019)
The Planetary Society

Earth Orbit
Full Flight
In Orbit; Successful

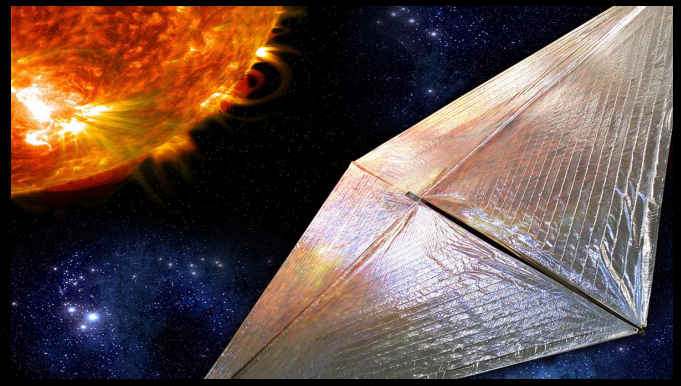
3U CubeSat
32 m^2



Near Earth Asteroid Scout (2020) NASA

Interplanetary
Full Flight

6U CubeSat
86 m^2



Solar Cruiser (2024)
NASA

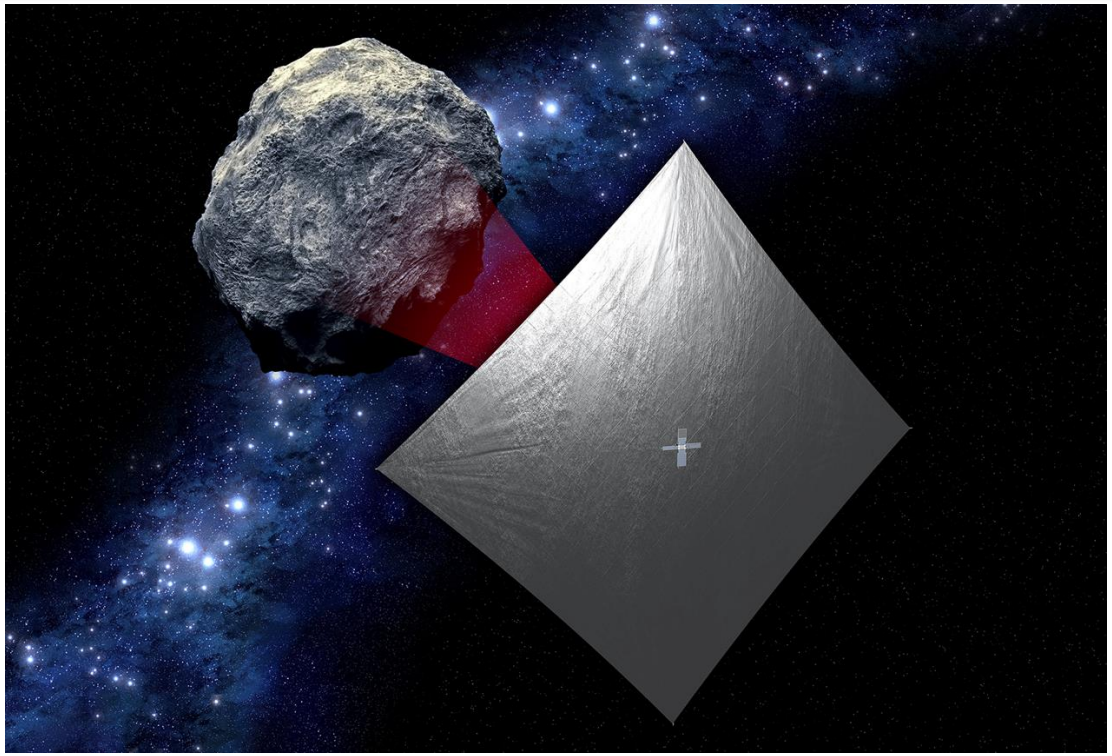
L-1
Full Flight

90 Kg Spacecraft
>1200 m^2

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

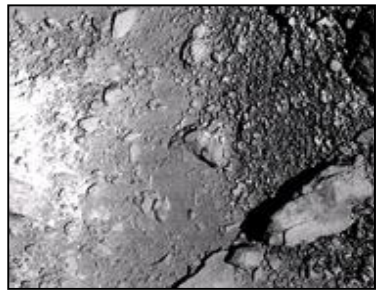


Key Spacecraft & Mission Parameters

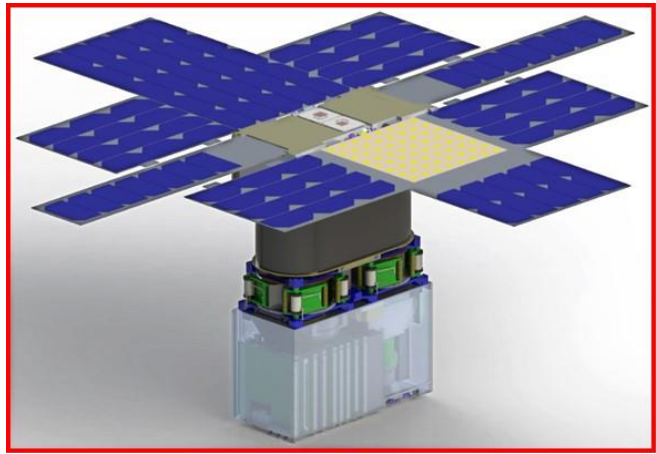
- 6U cubesat (20cm X 10cm X 30 cm)
- ~86 m^2 solar sail propulsion system
- Manifested for launch on the Space Launch System (Artemis 1 / 2020)
- 1 AU maximum distance from Earth

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

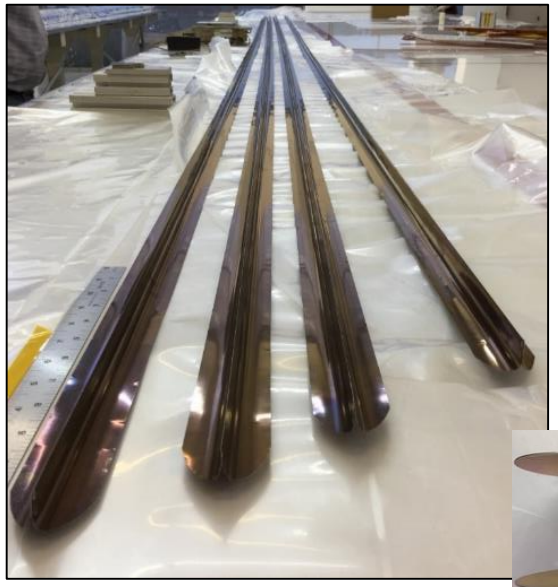
Target Reconnaissance with medium field imaging
Shape, spin, and local environment

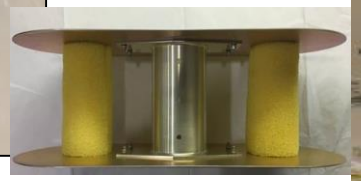


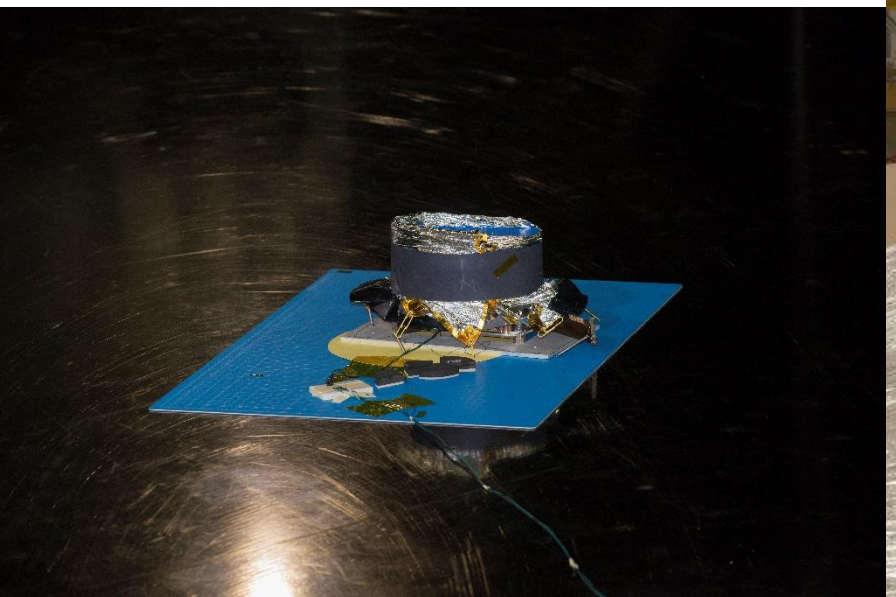
Close Proximity Imaging
Local scale morphology, terrain properties, landing site survey



NEA Scout Full Scale EDU Sail Deployment





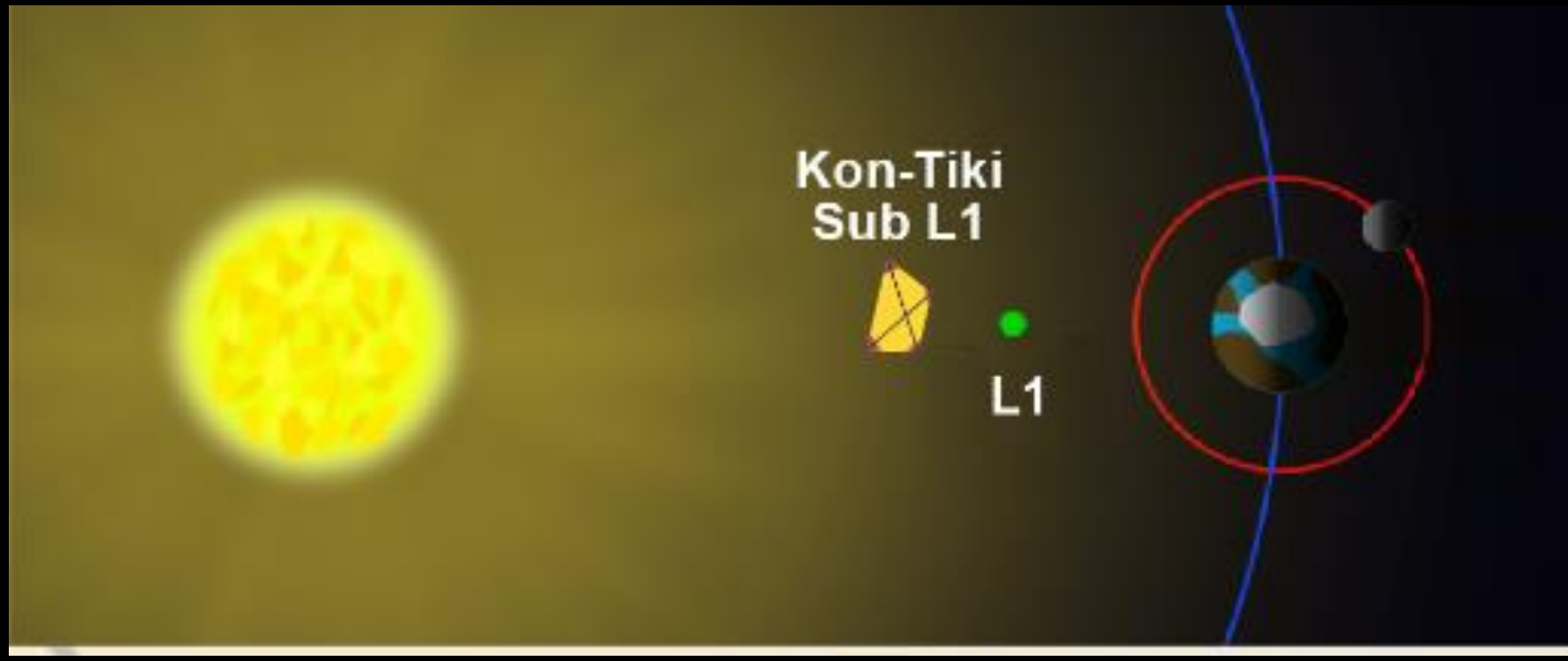


Solar Cruiser

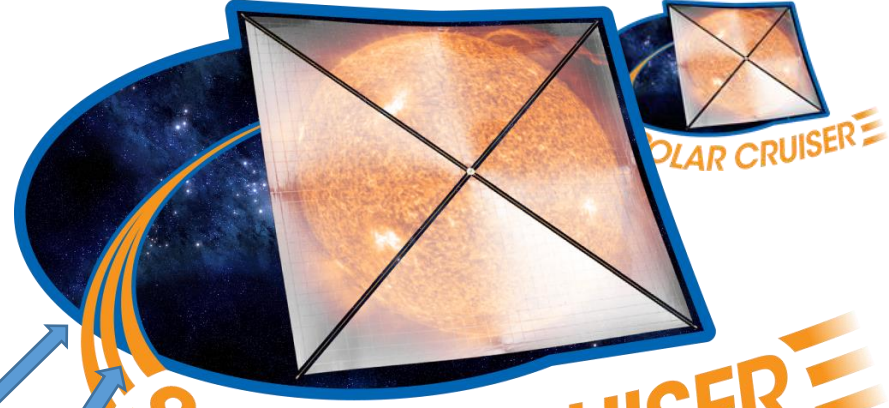
Mission Concept

Mission Profile

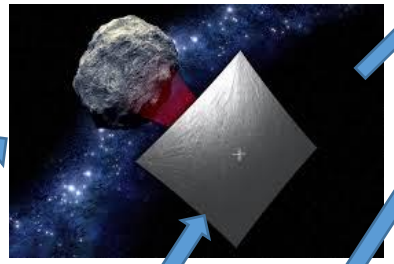
Solar Cruiser may launch as a secondary payload on the NASA IMAP mission in October, 2024. It then cruises past the Sun-Earth L 1 point, demonstrating station keeping at an artificial equilibrium point.



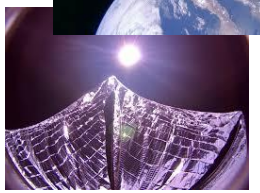
Solar Cruiser
Solar Sail Technology Investment Heritage



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

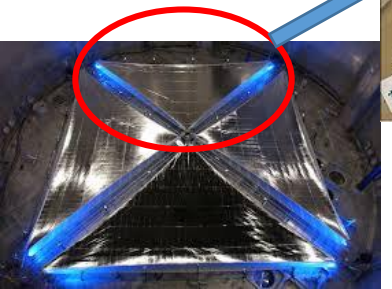


LightSail 2 (The Planetary Society)
32 m^2 sail
Successful flight in 2019

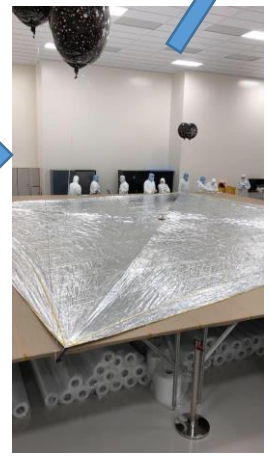


LightSail 1 (The Planetary Society)
32 m^2 sail (NanoSail heritage design)
Successful flight in 2015

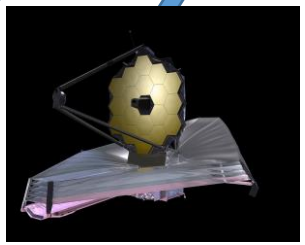
MSFC NanoSail – D
10 m^2 sail (made using parts left over from 400 m^2 demonstrator)
Successful flight 2010



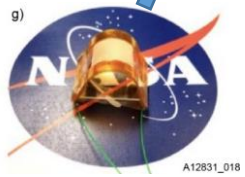
SMD In-Space Propulsion Technology Project
400 m^2 solar sail demonstrator
Deployed at Plumbrook Station (2000 – 2003)



HEOMD Near-Earth Asteroid Scout
86 m^2 solar sail
Flight Unit Deployment Test (2014 - 2018)



In 2021, JWST will deploy 5 layers (772m^2) of thin film material traceable to Solar Cruiser (NeXolve)



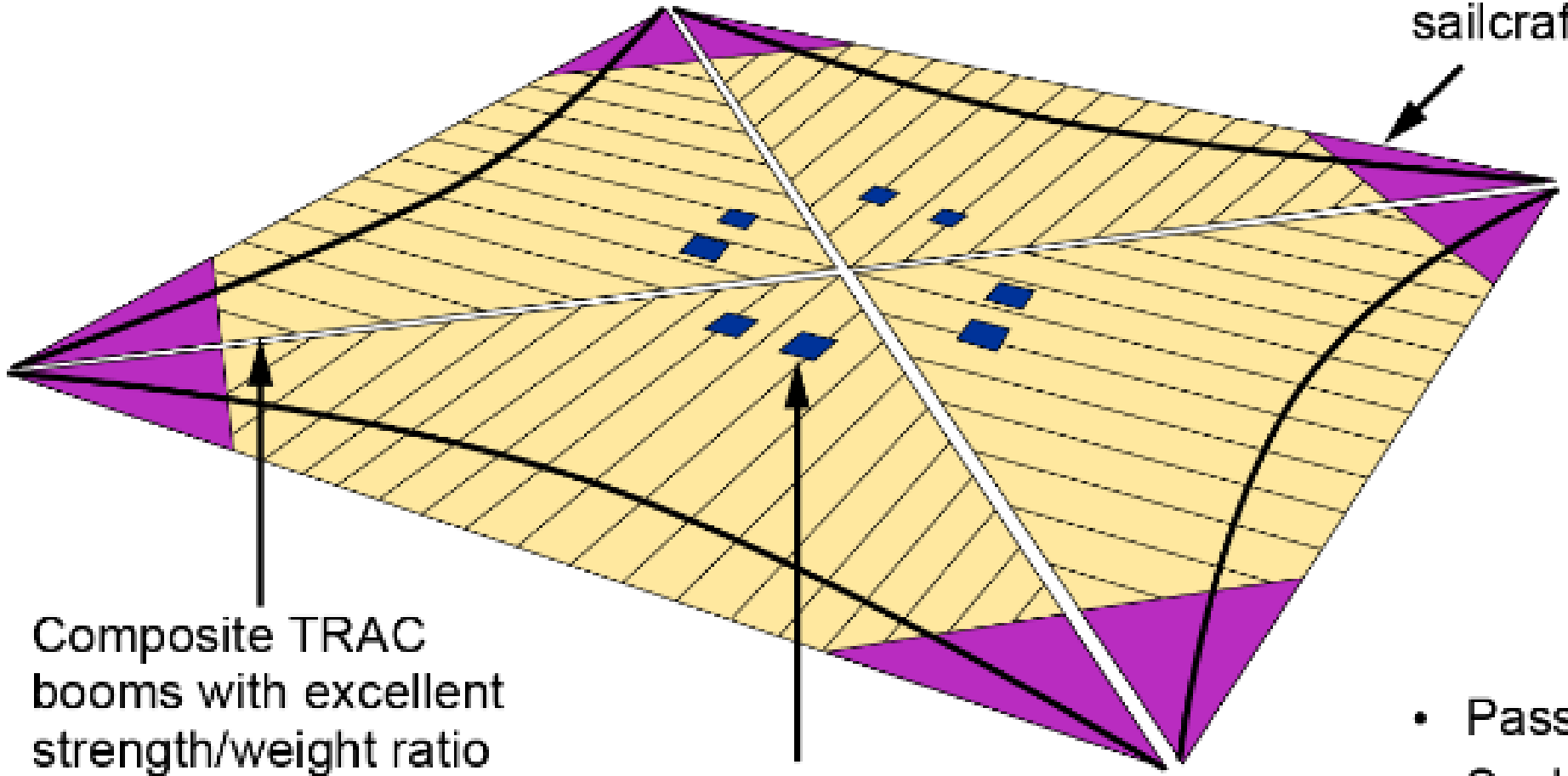
Reflective Control Devices (RCDs) NASA STMD Early Career Faculty STRA (2012)

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)

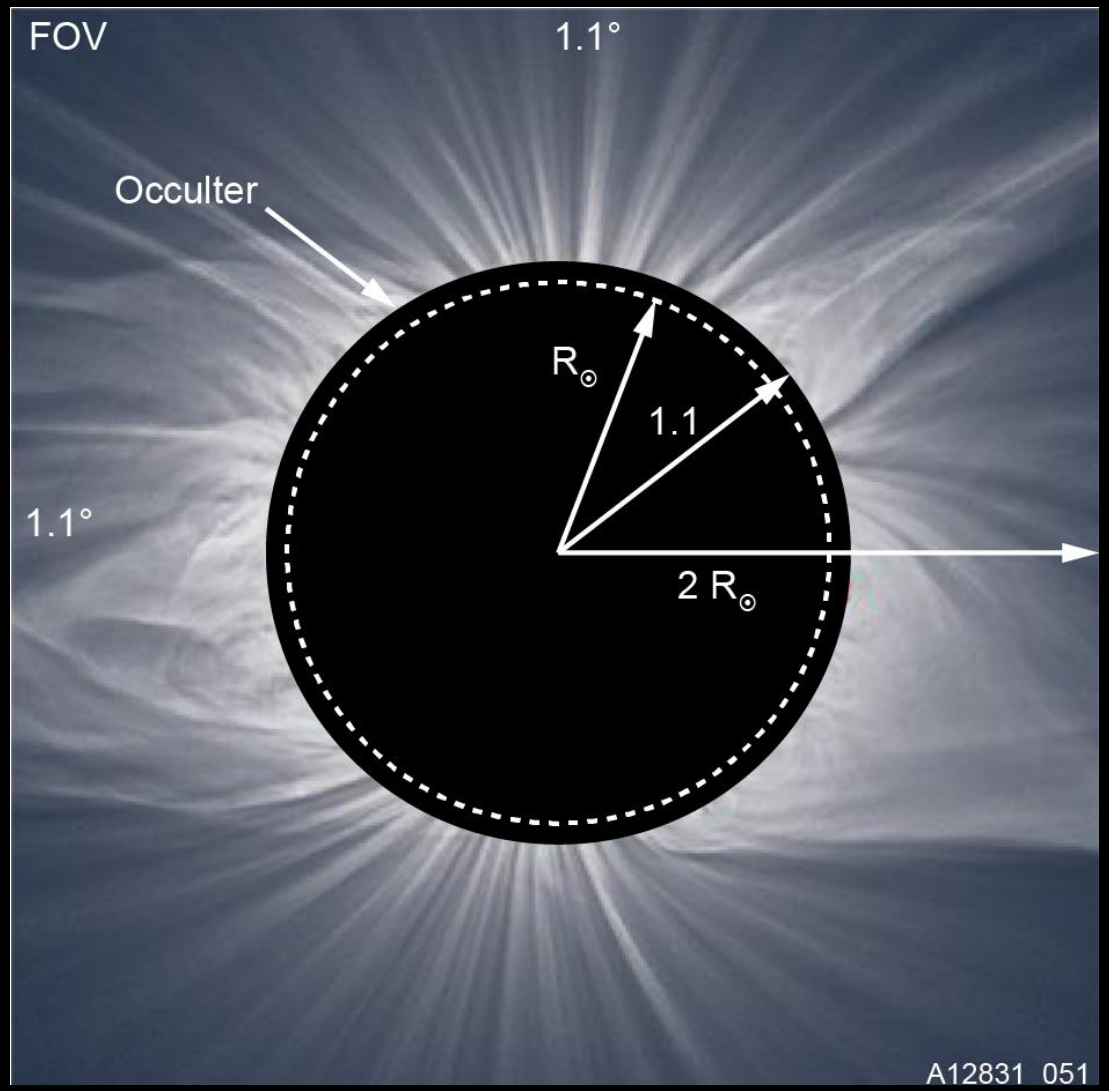
NeXolve Large Sail Fabrication Automation Phase I &II SBIR (2019 – 2021)

Key Feature: The Solar Sail



- Passively stable design
- Scalable to future missions like *SPI*

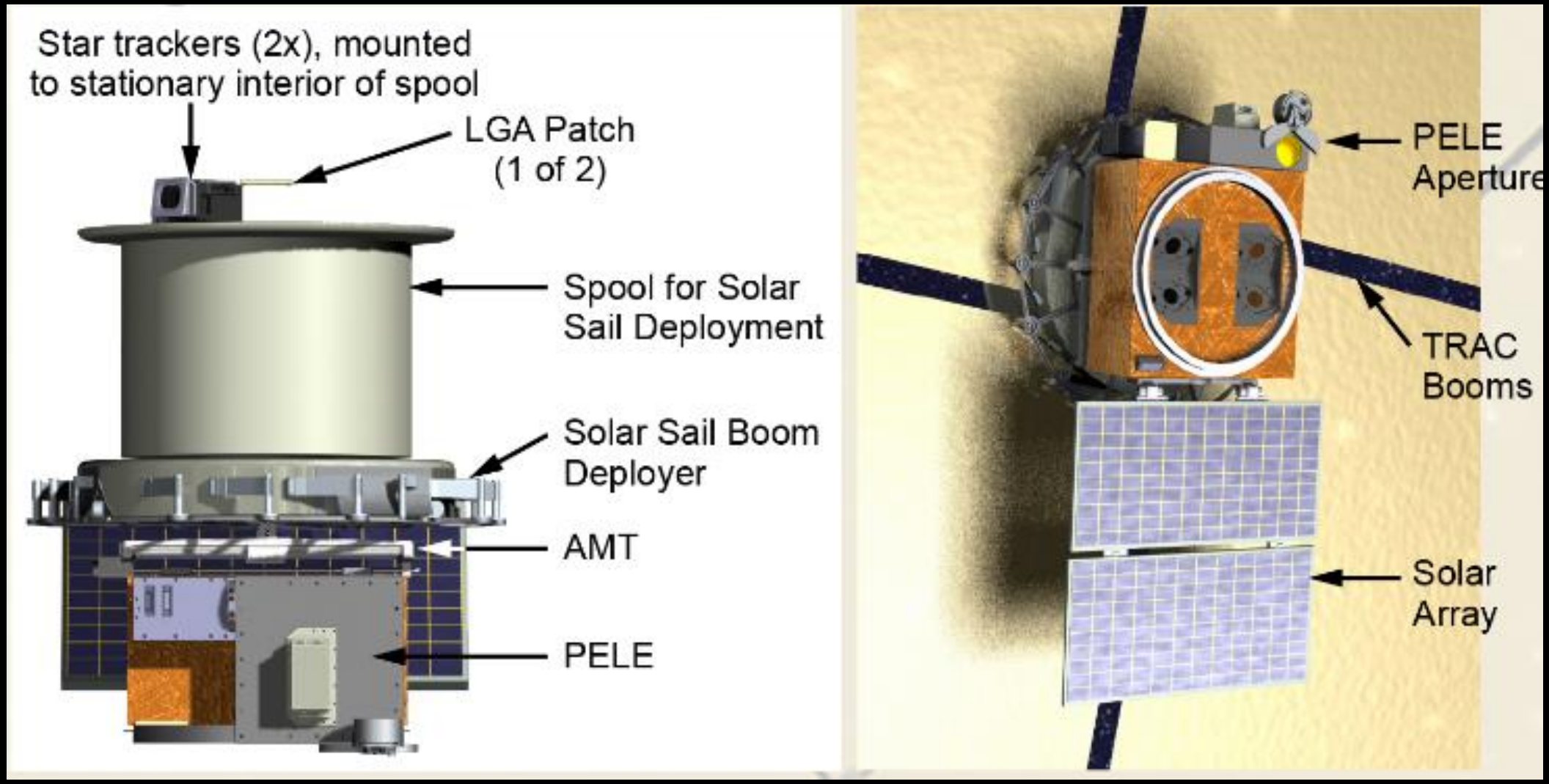
Key Feature: PELE Coronagraph



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



Solar Cruiser Operations Plan

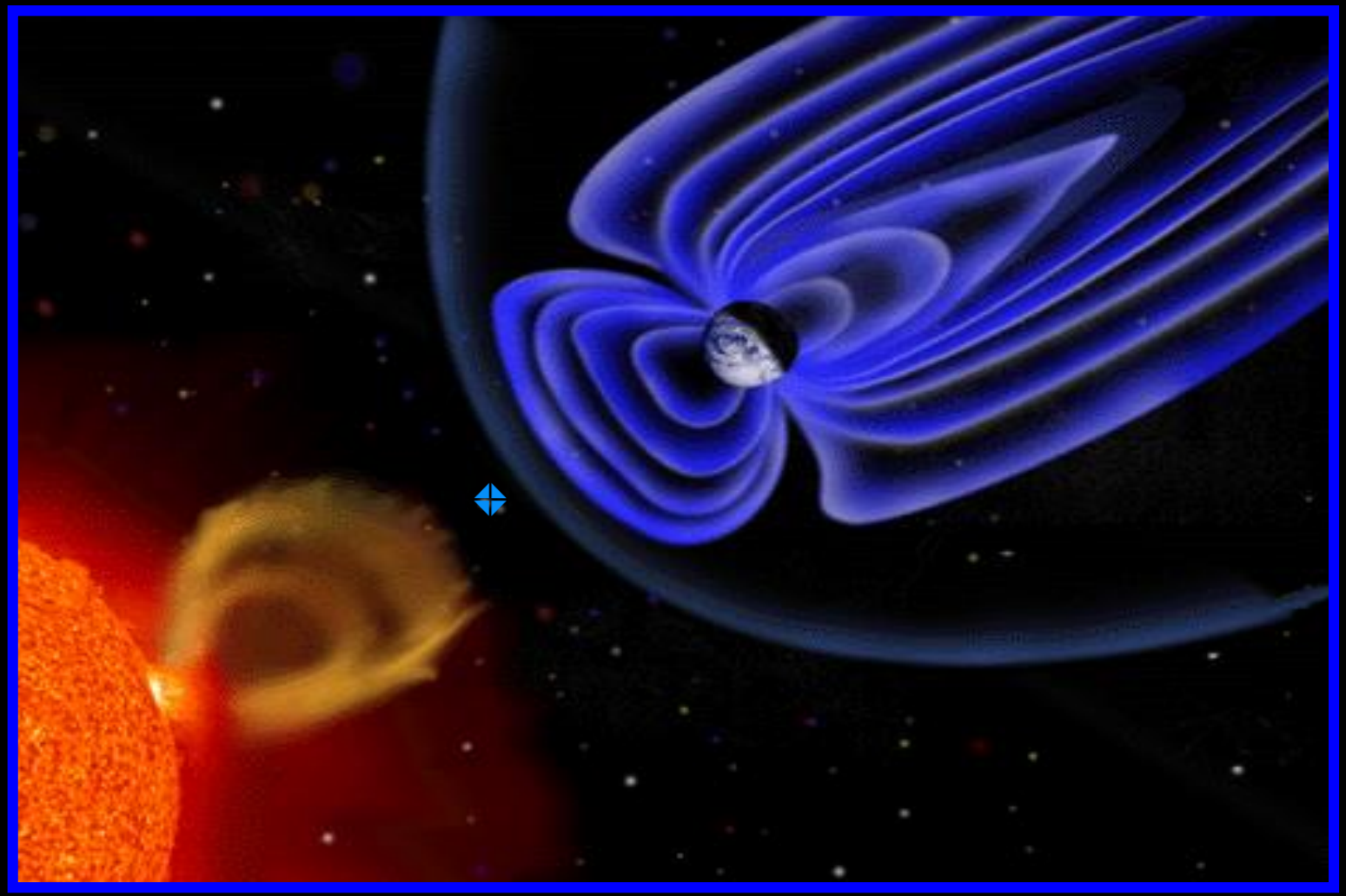
Mission Phase	Time Since Launch (days)	Duration (days)	Activities
Launch and Commissioning	L+0 to L+28	28	Assess spacecraft functionality
Coronagraph Checkout	L+29 to L+53	24	Test and operate coronagraph
Sail Deploy and Checkout	L+54 to L+61	7	Deploy and Assess Sail
Sailcraft Cruise	L+62 to L+221	160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

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

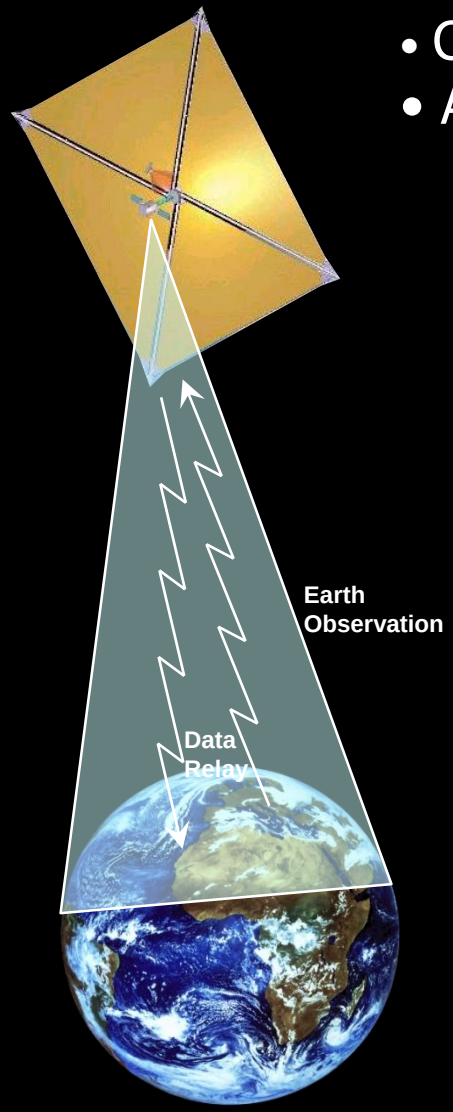
The sailcraft will cruise to 5 degrees Earth-trailing, where it will station-keep for 4 months for coronal observations

WHY SOLAR SAILS? Solar Storm Warning

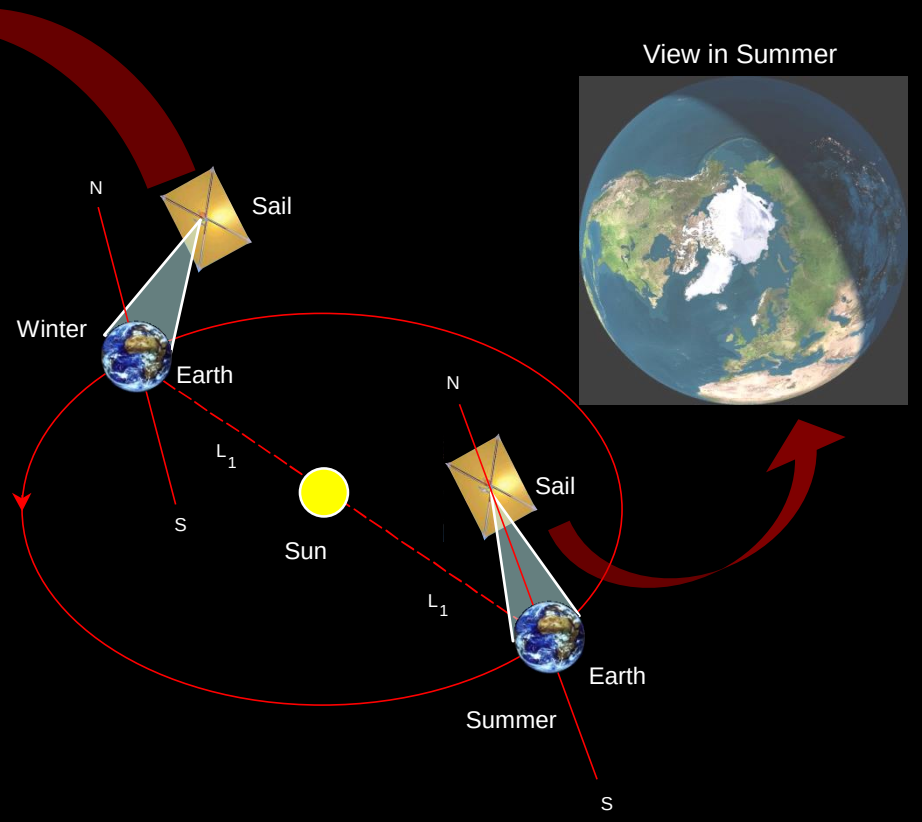


WHY SOLAR SAILS? Earth Pole Sitters

- 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

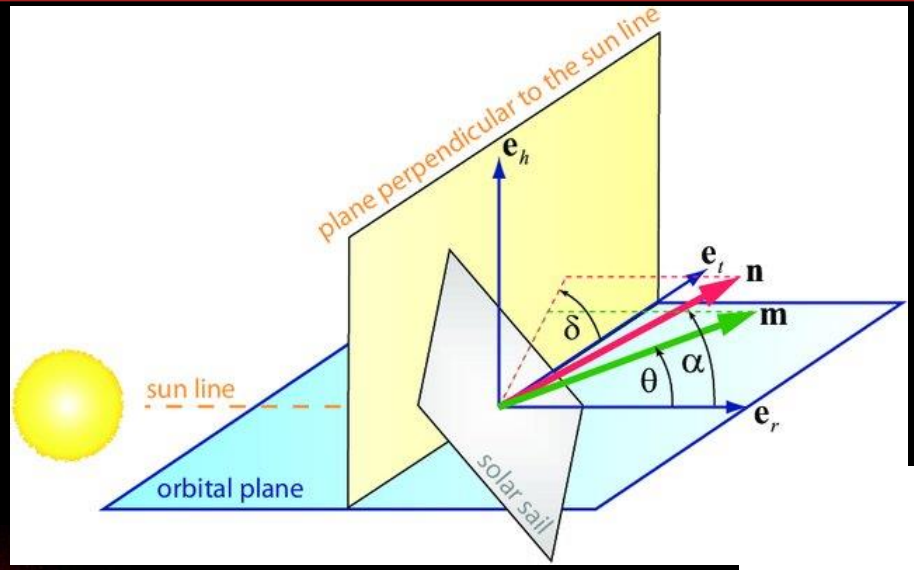


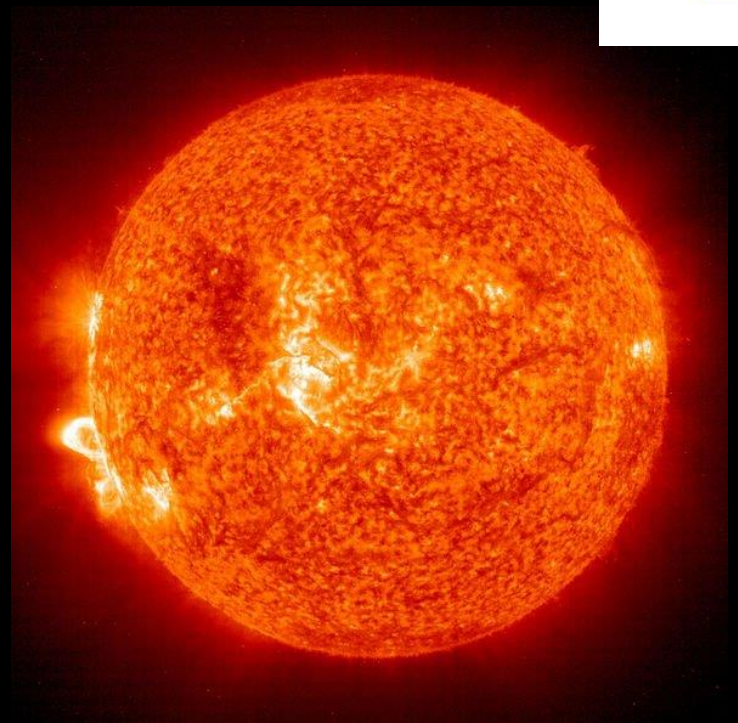
View in Winter

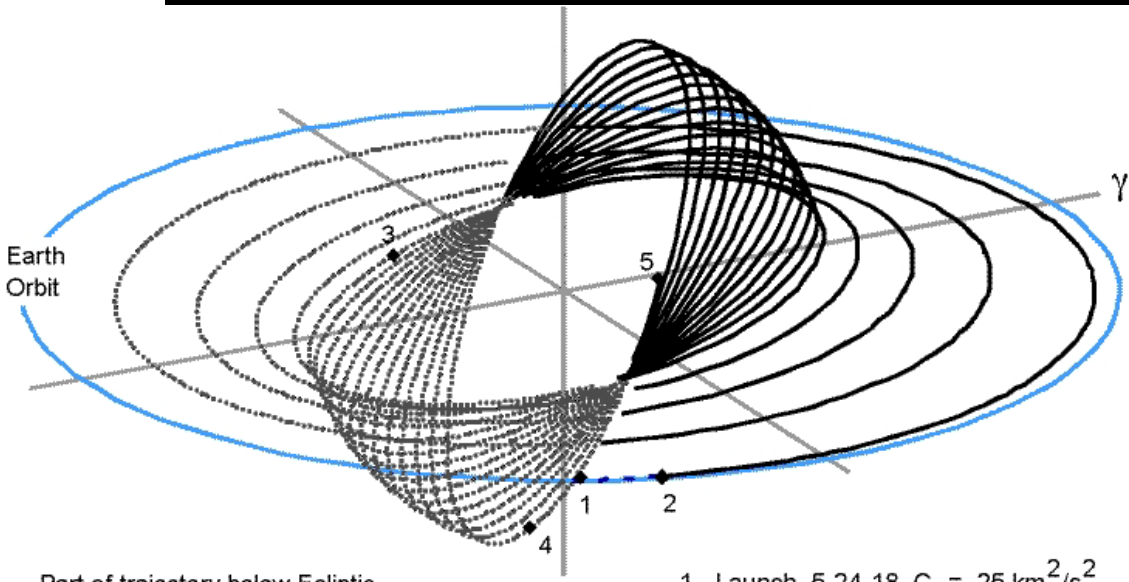


View in Summer

WHY SOLAR SAILS? High Inclination Solar Science

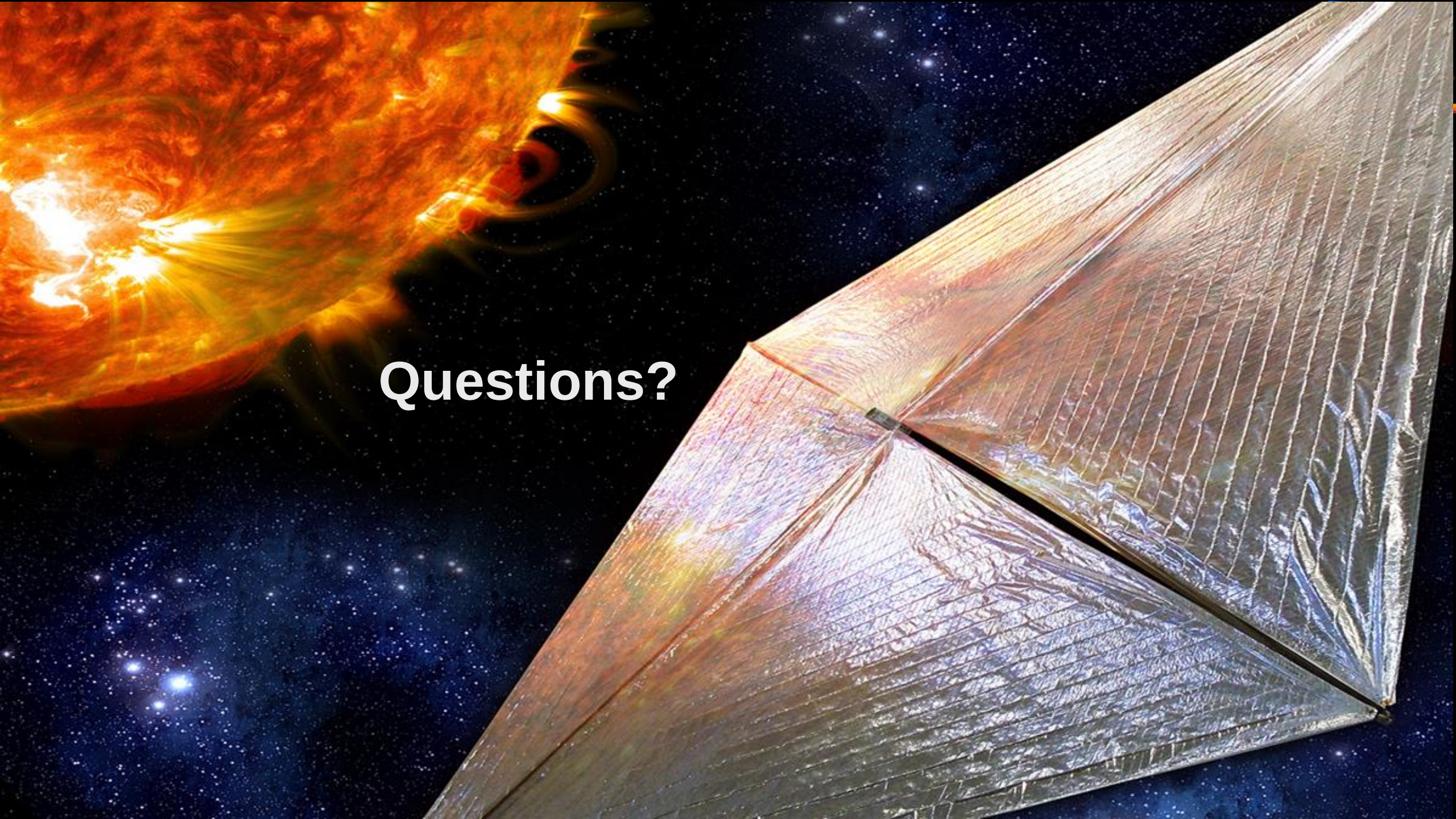






Part of trajectory below Ecliptic
Identified by dashed curve

1. Launch 5-24-18 C_3= .25 km^2/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?