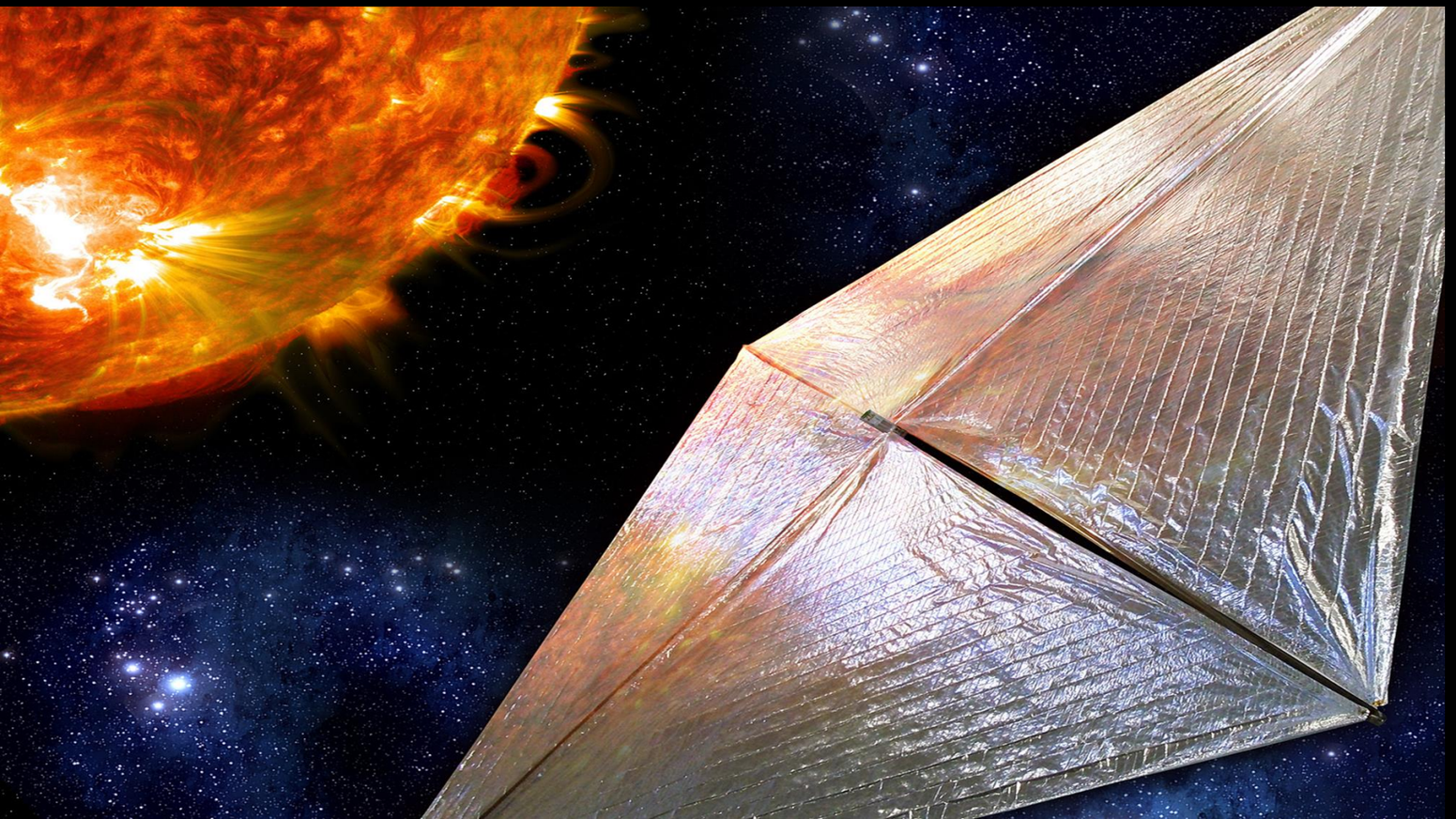
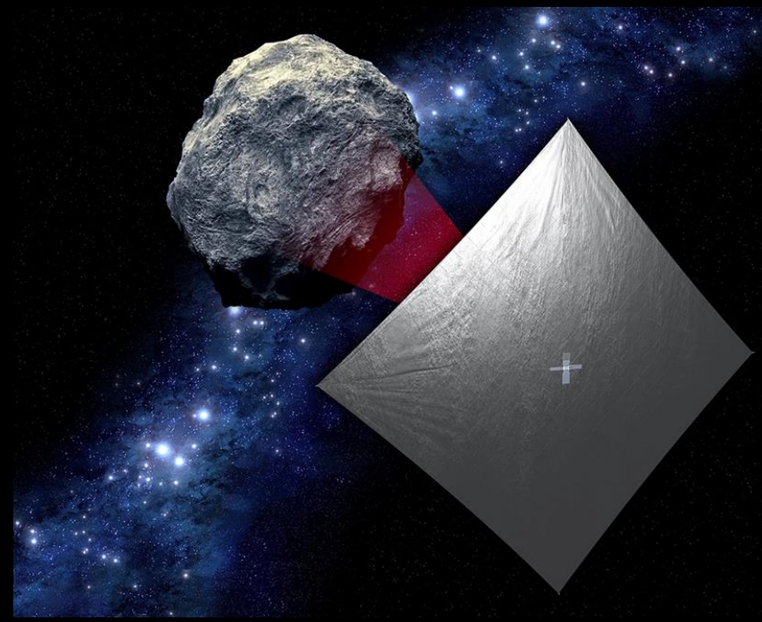
Setting Sail for the Sun
The NEA Scout & Solar Cruiser Missions:



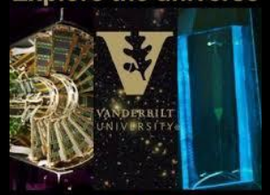


Les Johnson
(NASA MSFC)

A Bit About Me: The Long and Winding Road

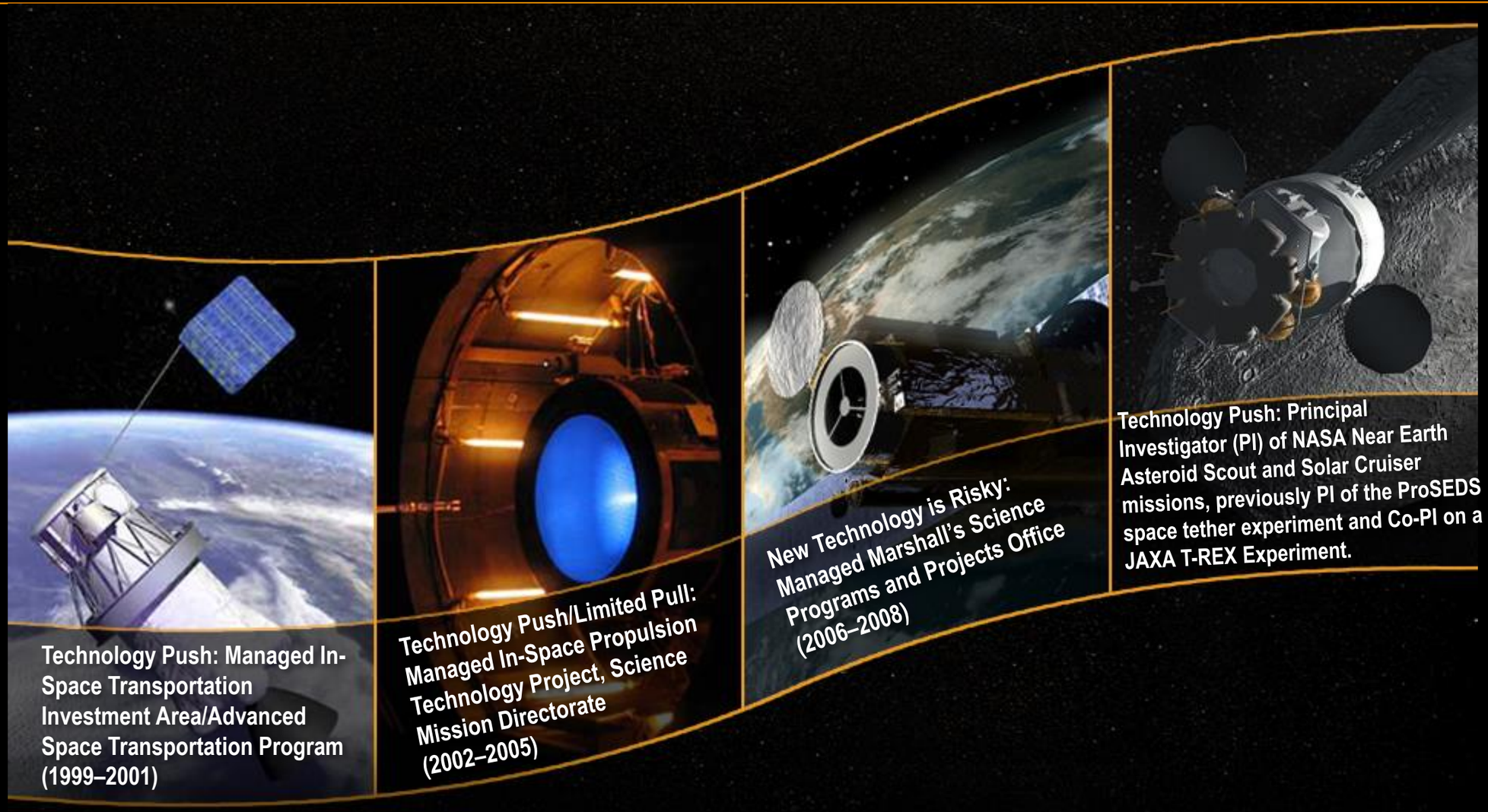
TRANSYLVANIA UNIVERSITY

Explore the universe



Physics & Astronomy

INTERNATIONAL SPACE UNIVERSITY



Technology Push: Managed In-Space Transportation Investment Area/Advanced Space Transportation Program (1999–2001)

Technology Push/Limited Pull: Managed In-Space Propulsion Technology Project, Science Mission Directorate (2002–2005)

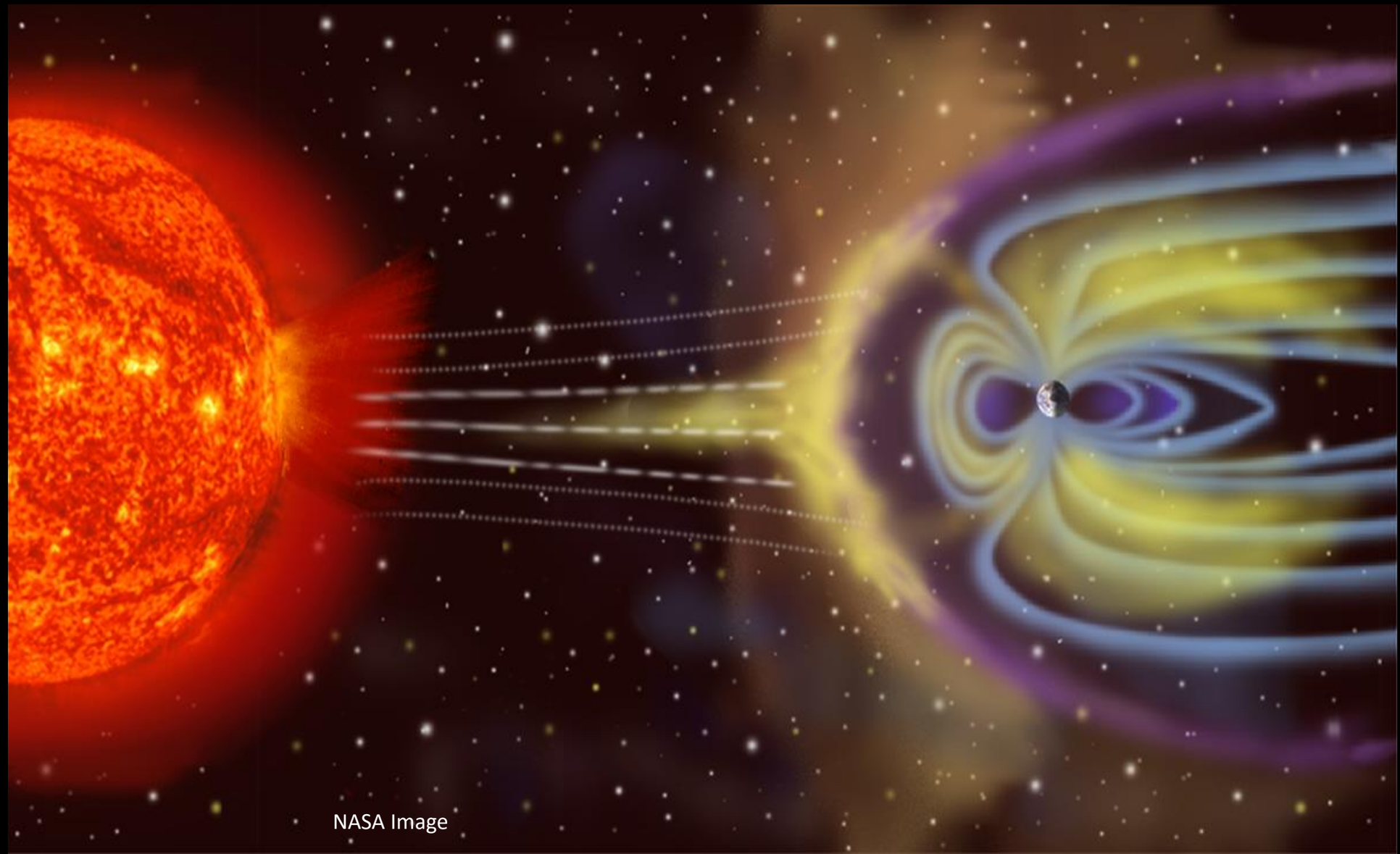
New Technology is Risky: Managed Marshall's Science Programs and Projects Office (2006–2008)

Technology Push: Principal Investigator (PI) of NASA Near Earth Asteroid Scout and Solar Cruiser missions, previously PI of the ProSEDS space tether experiment and Co-PI on a JAXA T-REX Experiment.

We tend to think of space as being

NASA Image

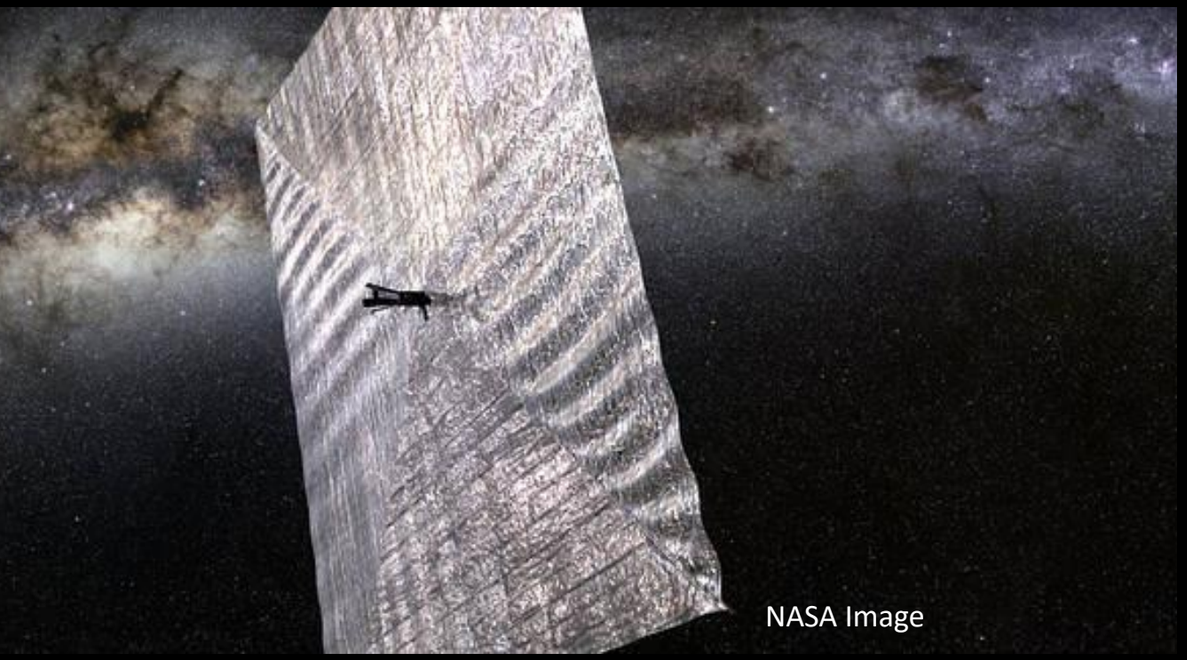
Space Is NOT Empty. We can use the environments of space to our advantage



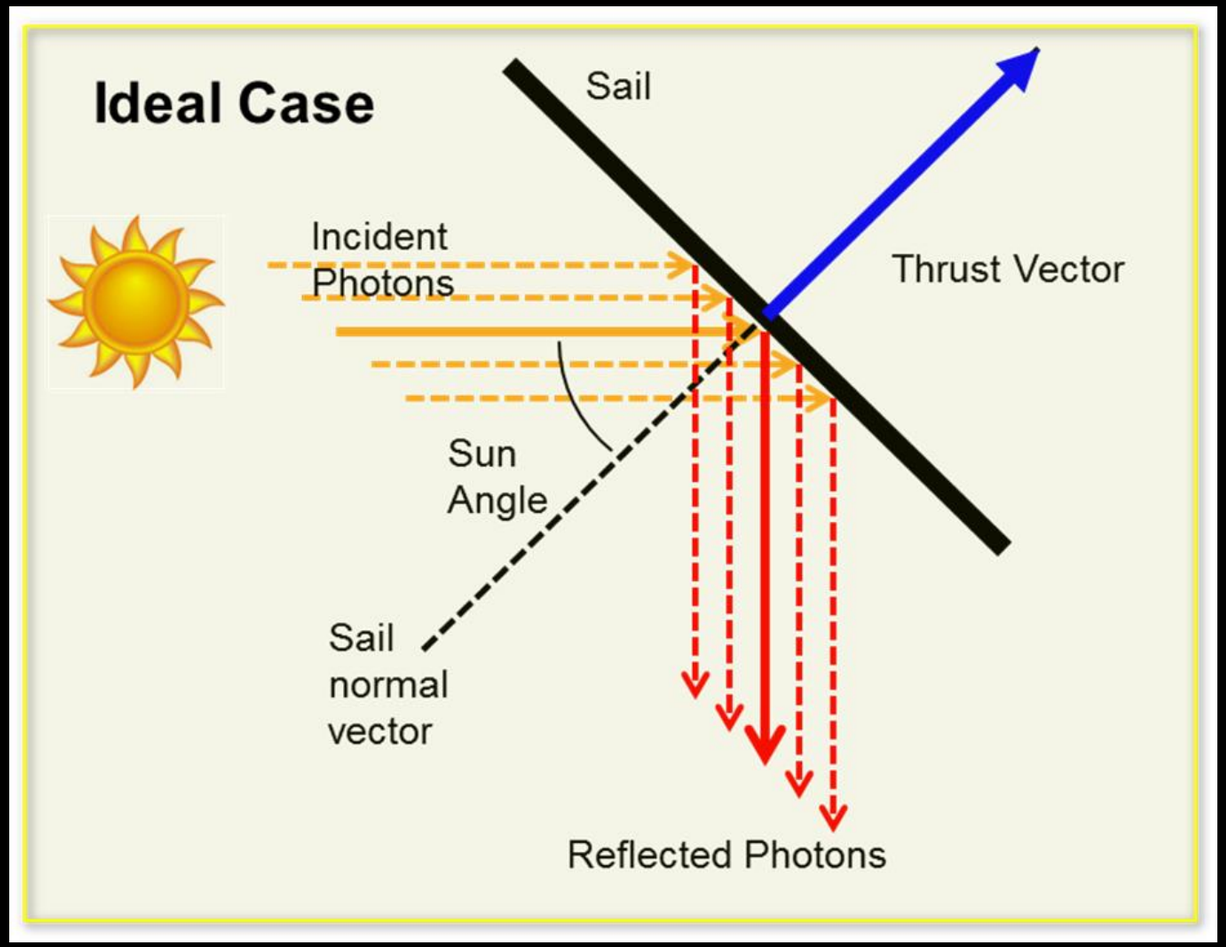
NASA Image

Solar Sails Derive Propulsion By Reflecting Light (Photons)

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

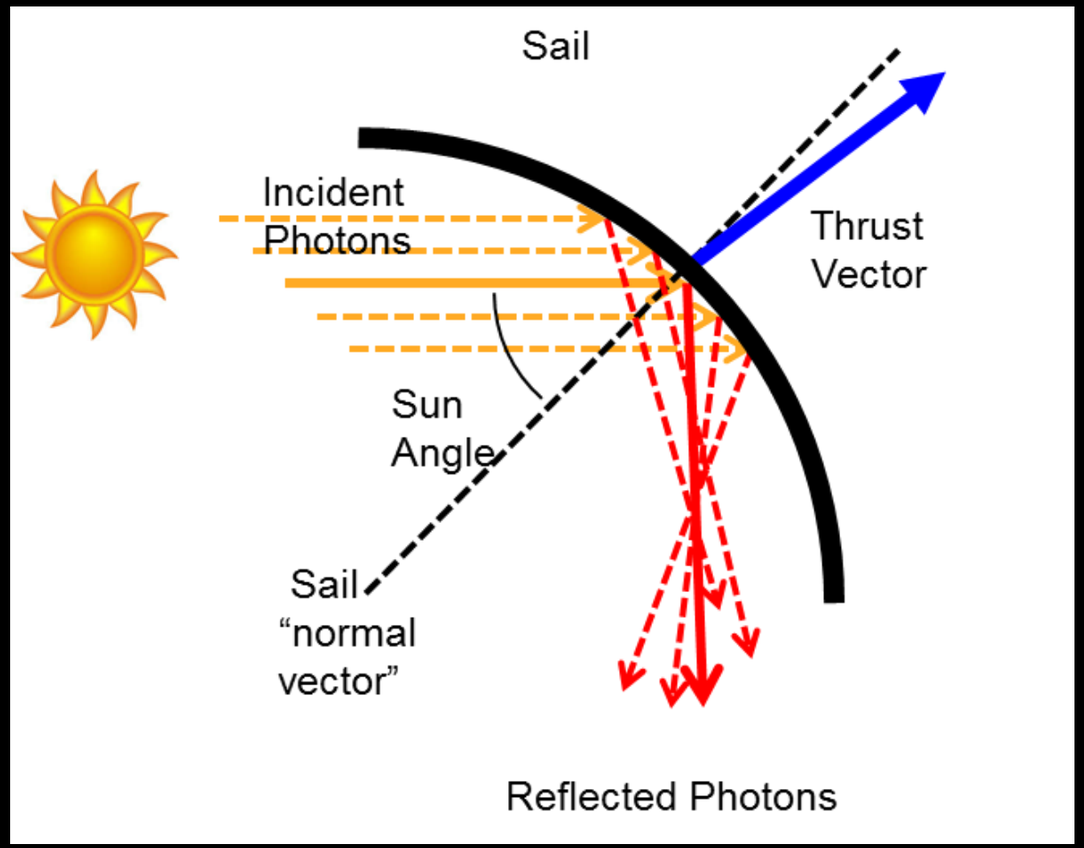


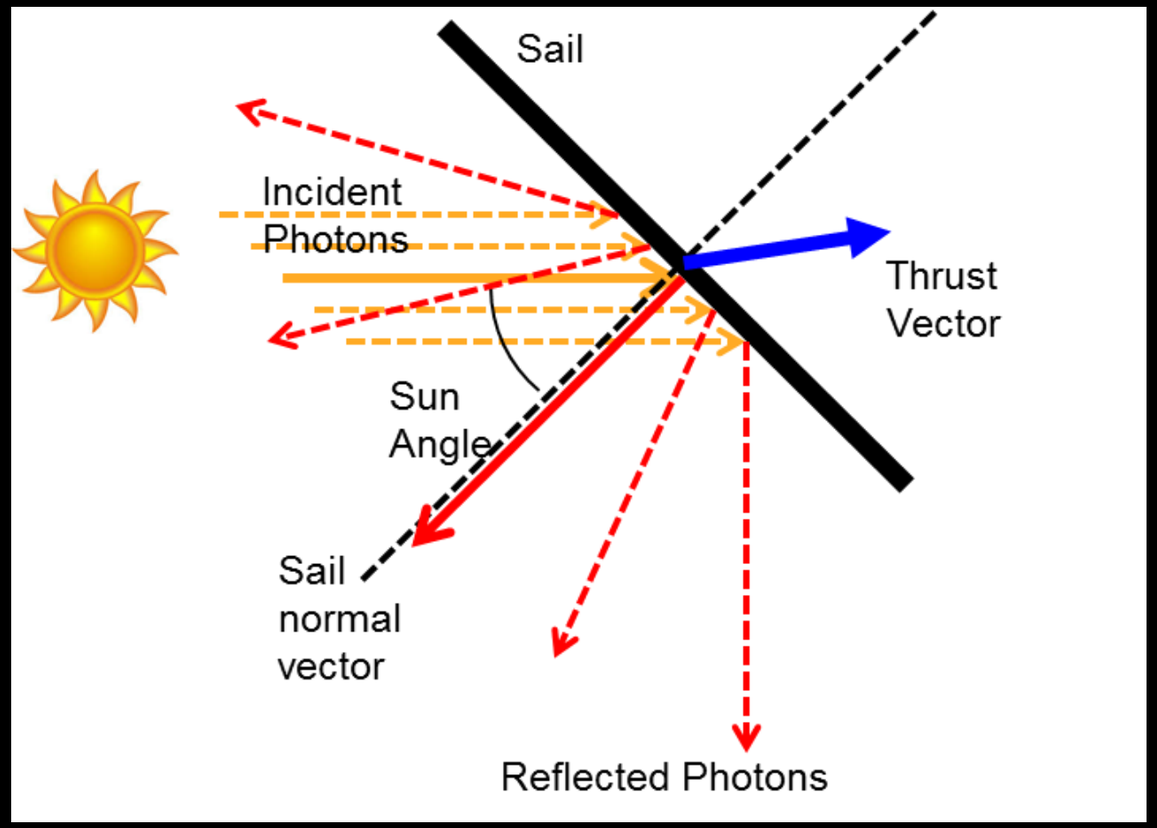
NASA Image



Real Solar Sails Are Not “Ideal”

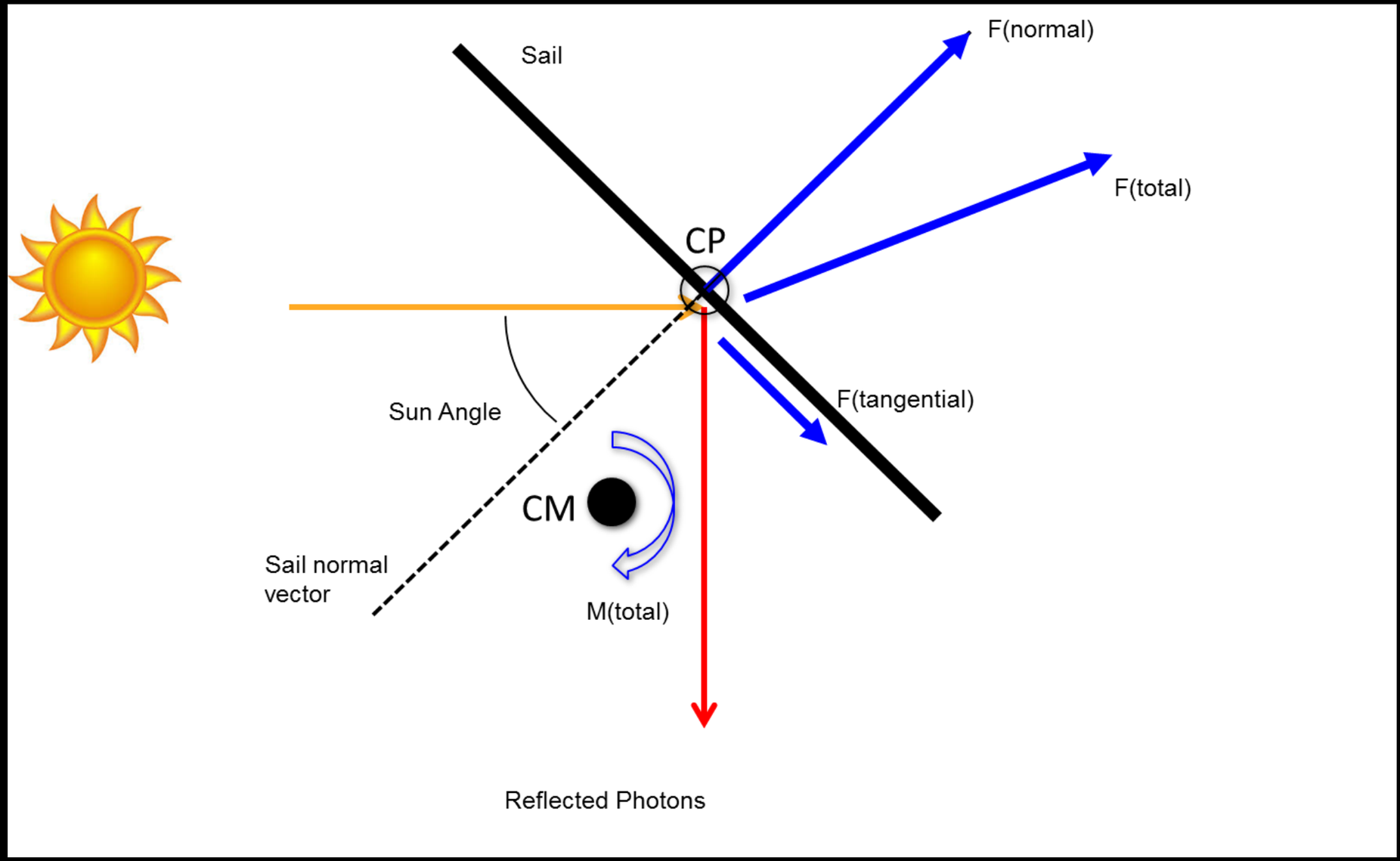
Billowed Quadrant





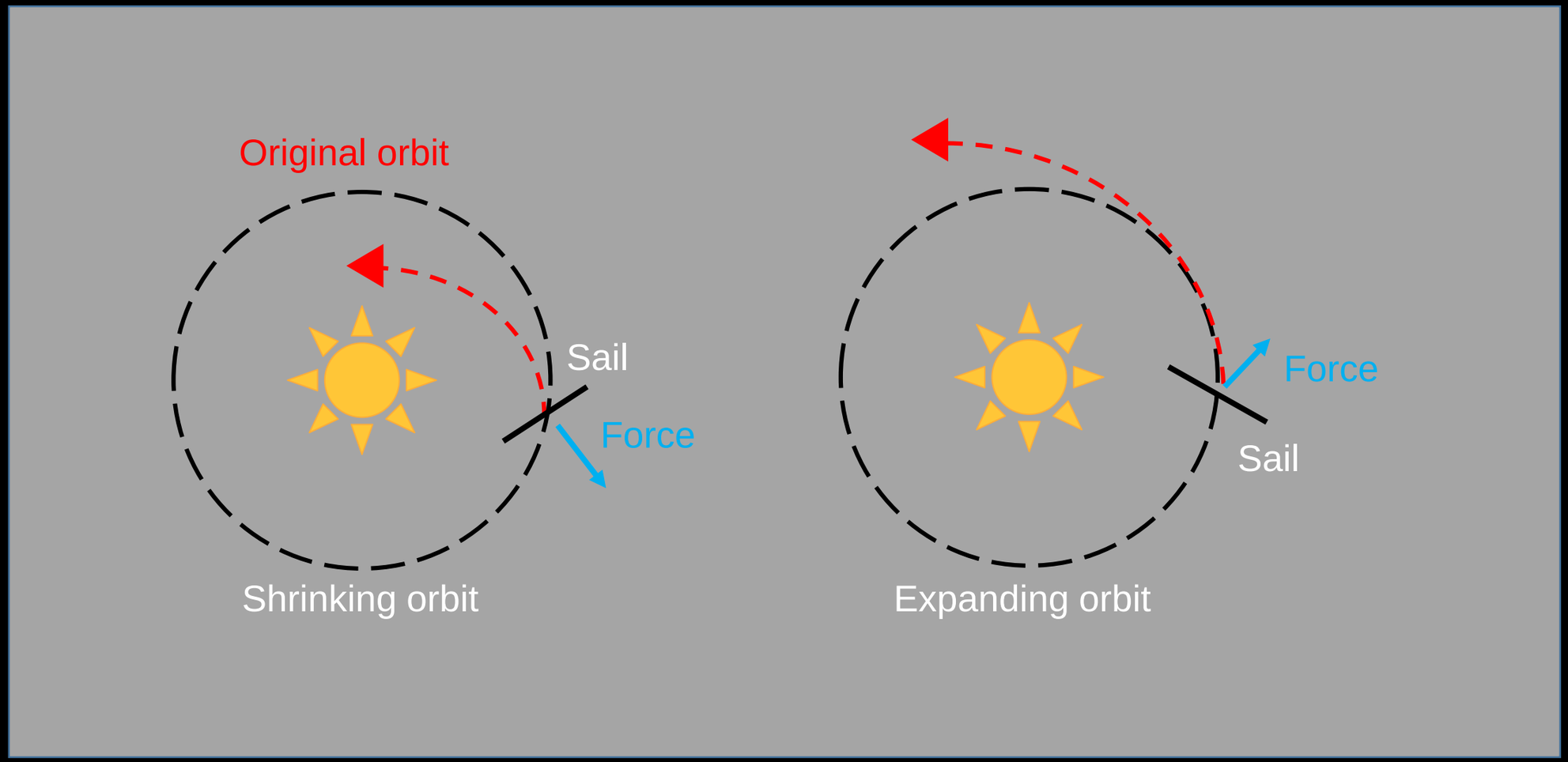
Diffuse Reflection

Thrust Vector Components

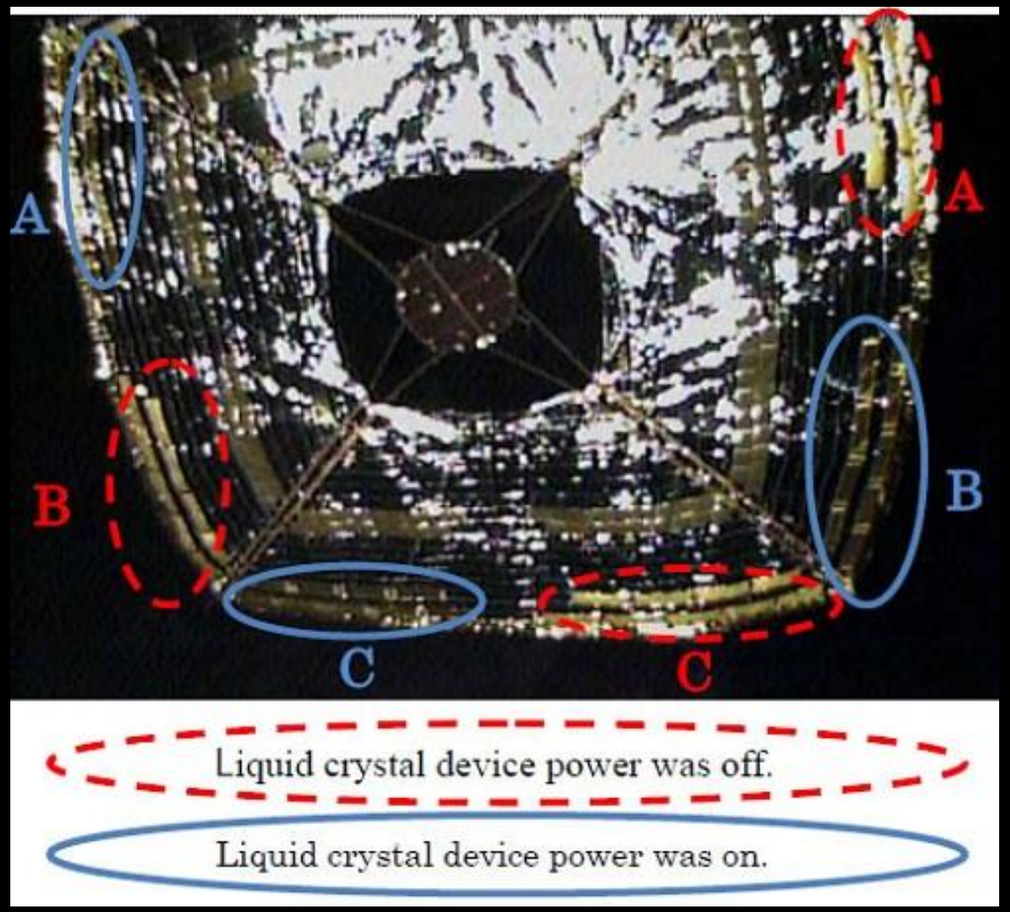


Solar Sail Trajectory Control

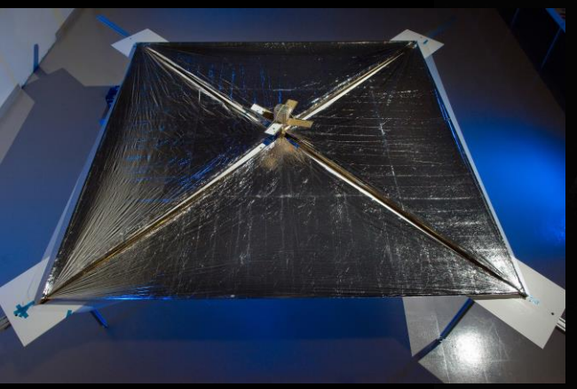
- Solar Radiation Pressure allows inward or outward Spiral



Interplanetary Kite-craft Accelerated by Radiation of the Sun (IKAROS)



Solar Sail Missions Flown (as of October 2019)



NanoSail-D (2010)
NASA

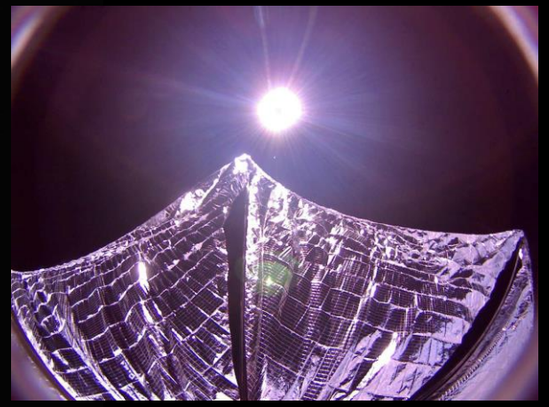
Earth Orbit
Deployment Only

3U CubeSat
10 m^2

IKAROS (2010)
JAXA

Interplanetary
Full Flight

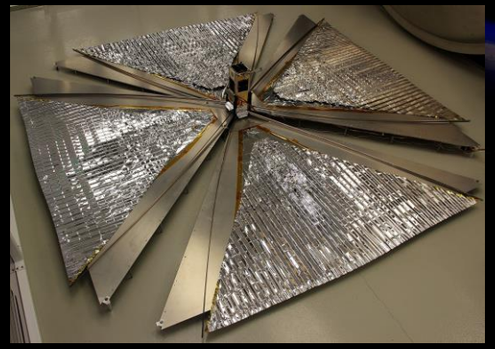
315 kg Smallsat
196 m^2



LightSail-1 (2015)
The Planetary Society

Earth Orbit
Deployment Only

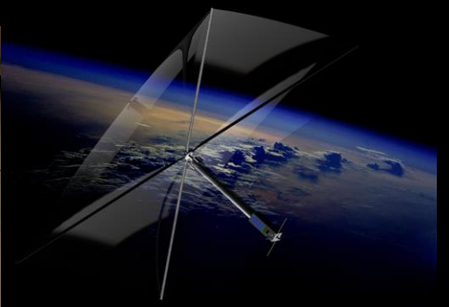
3U CubeSat
32 m^2



CanX-7 (2016)
Canada

Earth Orbit
Deployment Only

3U CubeSat
<10 m^2

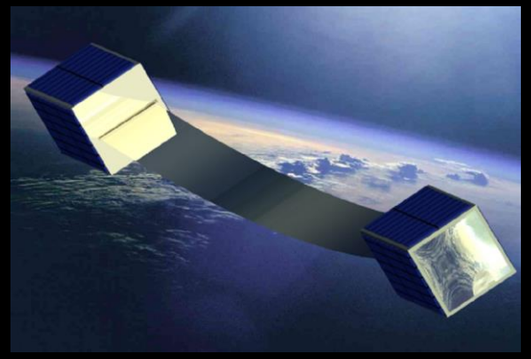


InflateSail (2017)
EU/Univ. of Surrey

Earth Orbit
Deployment Only

3U CubeSat
10 m^2

Current and Planned Solar Sail Missions



CU Aerospace (2019)
Univ. Illinois / NASA

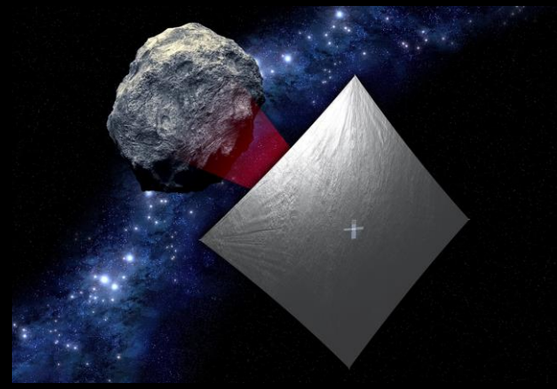
Earth Orbit
Full Flight
In Orbit; Not yet deployed

3U CubeSat
20 m^2

LightSail-2 (2019)
The Planetary Society

Earth Orbit
Full Flight
In Orbit; Successful

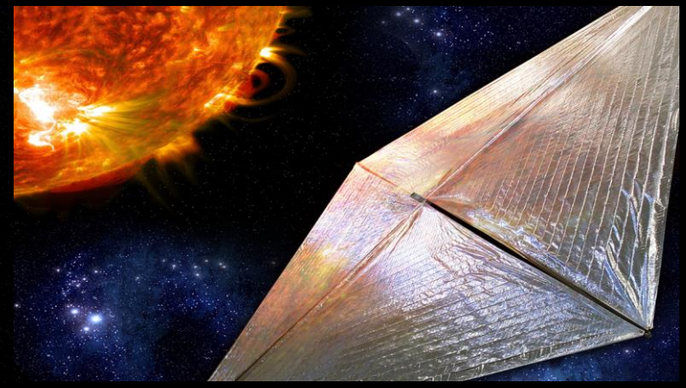
3U CubeSat
32 m^2



Near Earth Asteroid Scout (2020) NASA

Interplanetary
Full Flight

6U CubeSat
86 m^2



Solar Cruiser (2024)
NASA

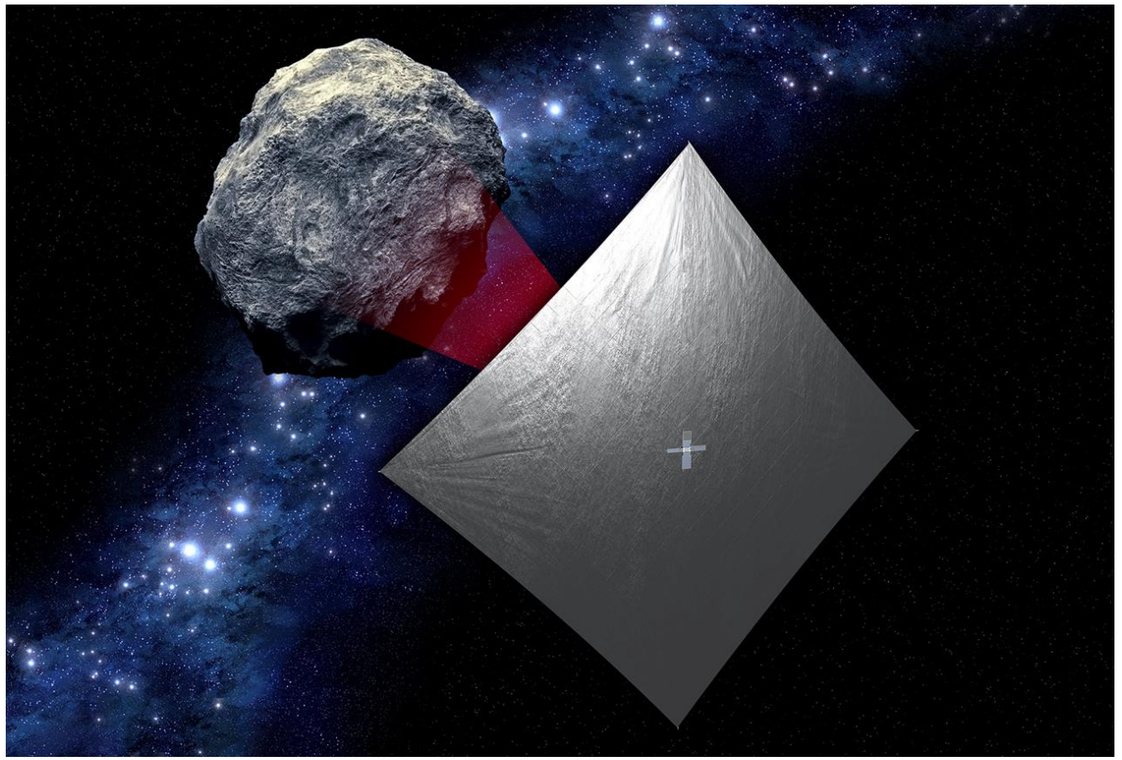
L-1
Full Flight

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

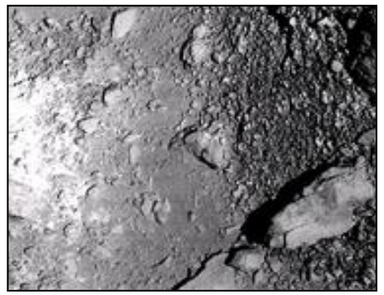


Key Spacecraft & Mission Parameters

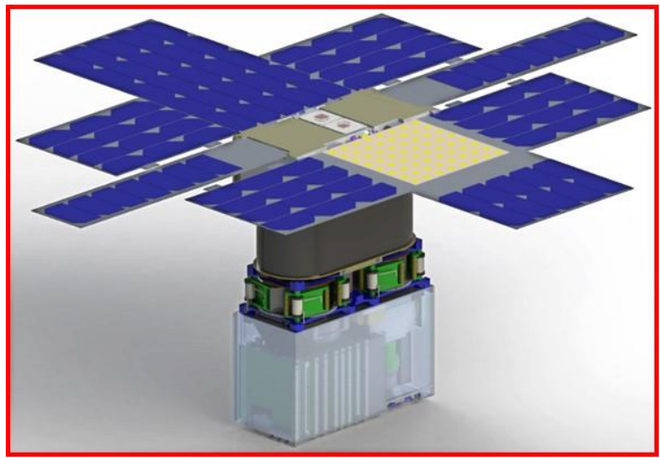
- 6U cubesat (20cm X 10cm X 30 cm)
- ~86 m^2 solar sail propulsion system
- Manifested for launch on the Space Launch System (EM-1/2020)
- 1 AU maximum distance from Earth

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

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

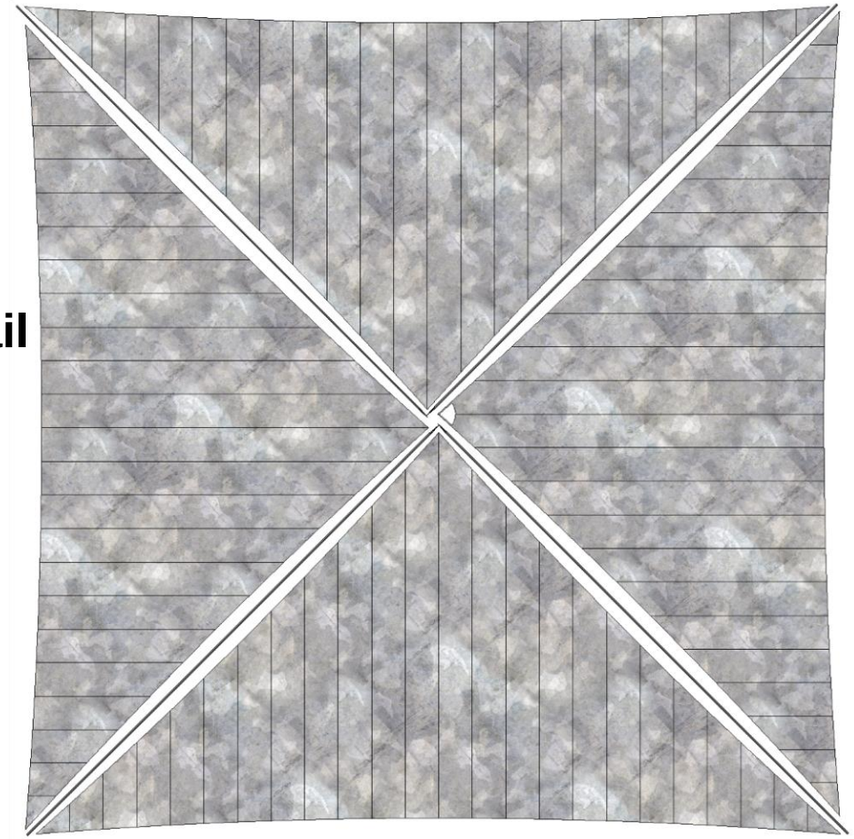


Close Proximity Imaging
Local scale morphology, terrain properties, landing site survey



NEA Scout Approximate Scale

Deployed Solar Sail



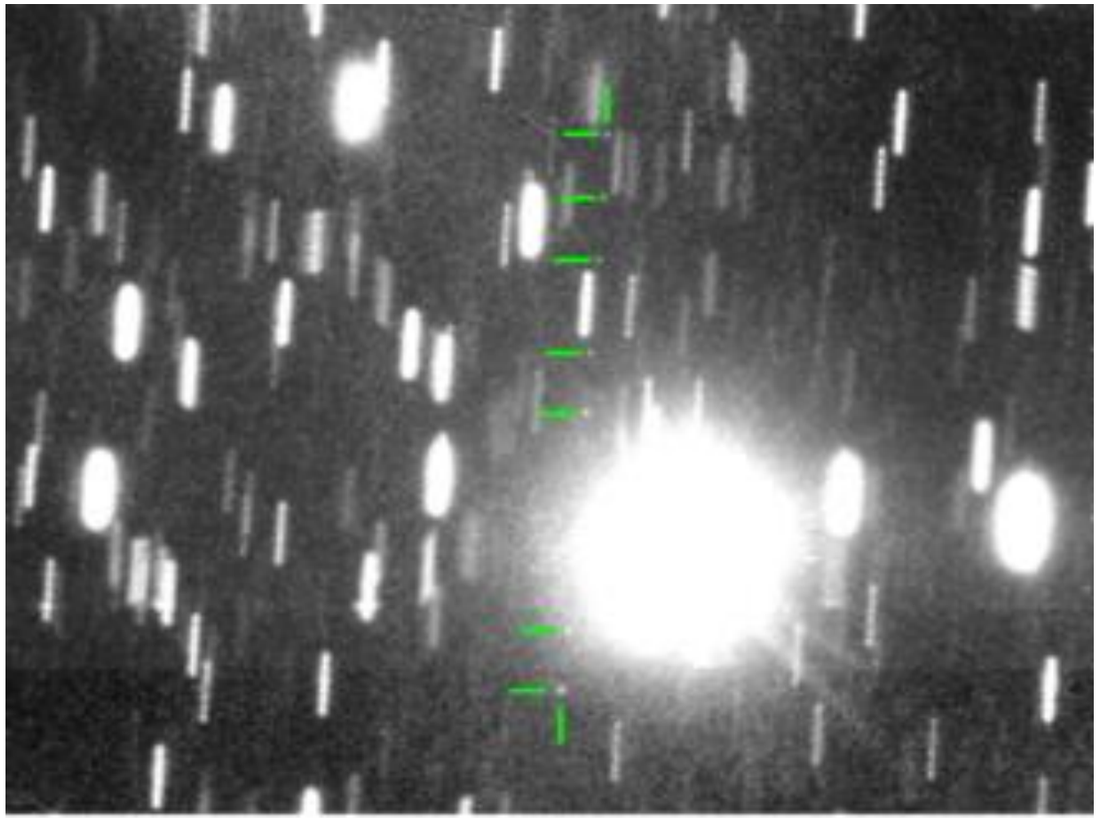
School Bus

Human

6U Stowed Flight System

Folded, spooled and packaged in here

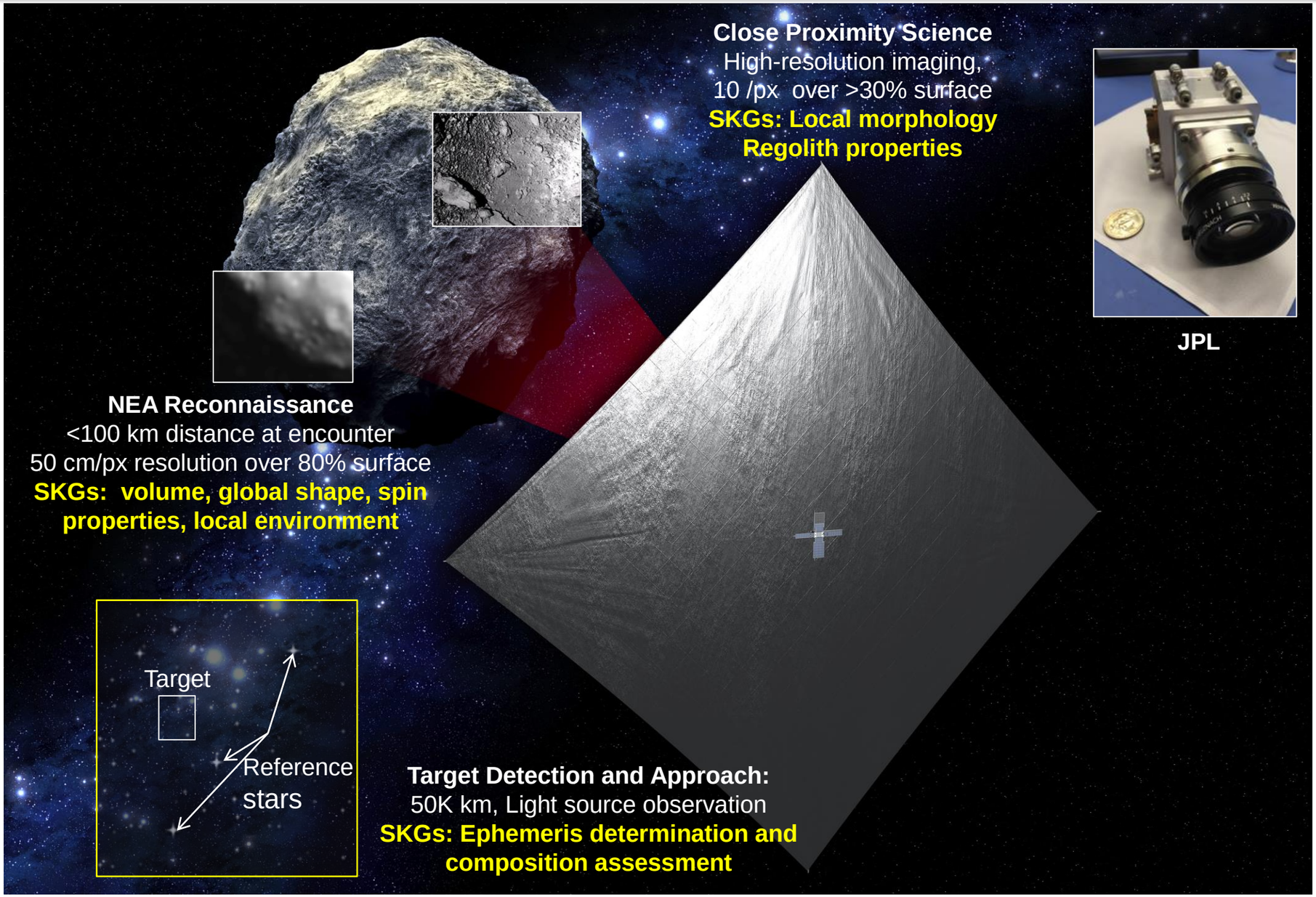
Baseline Target Asteroid: 1991 VG



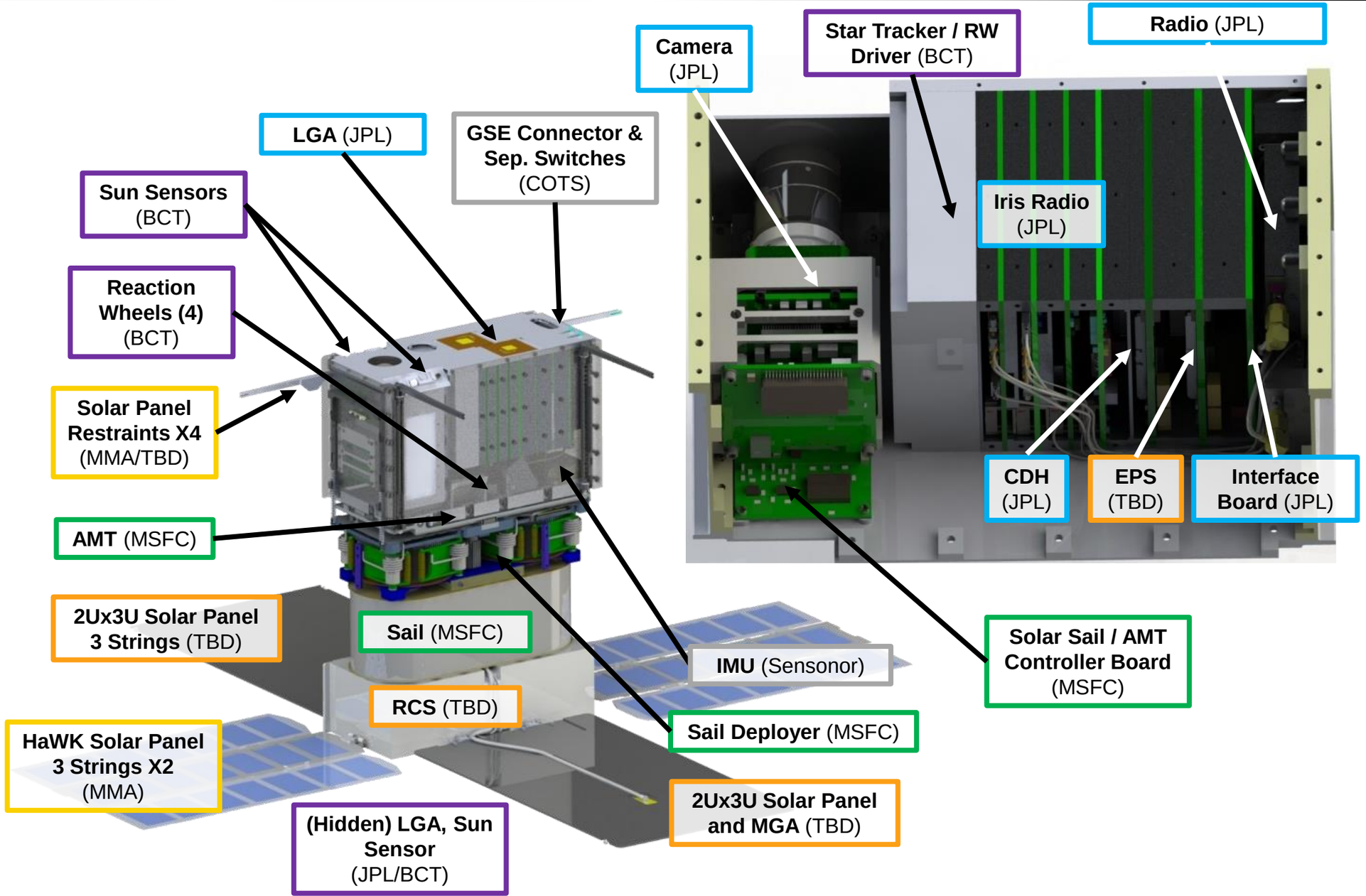
Near-Earth Asteroid 1991VG (marked with green lines) on 2017 May 30. This is a composite of several images obtained with the ESO VLT. The images have been combined in 7 stacks tracking the position of the asteroid, resulting in the object appearing as 7 dots as it moves in front of the background stars. The stars appear trailed due to the motion of the asteroid during each series. Credit Hainaut/Micheli/Koschny

- Diameter ~ 5 -12 meters
- 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

Near Earth Asteroid Scout Mission Overview

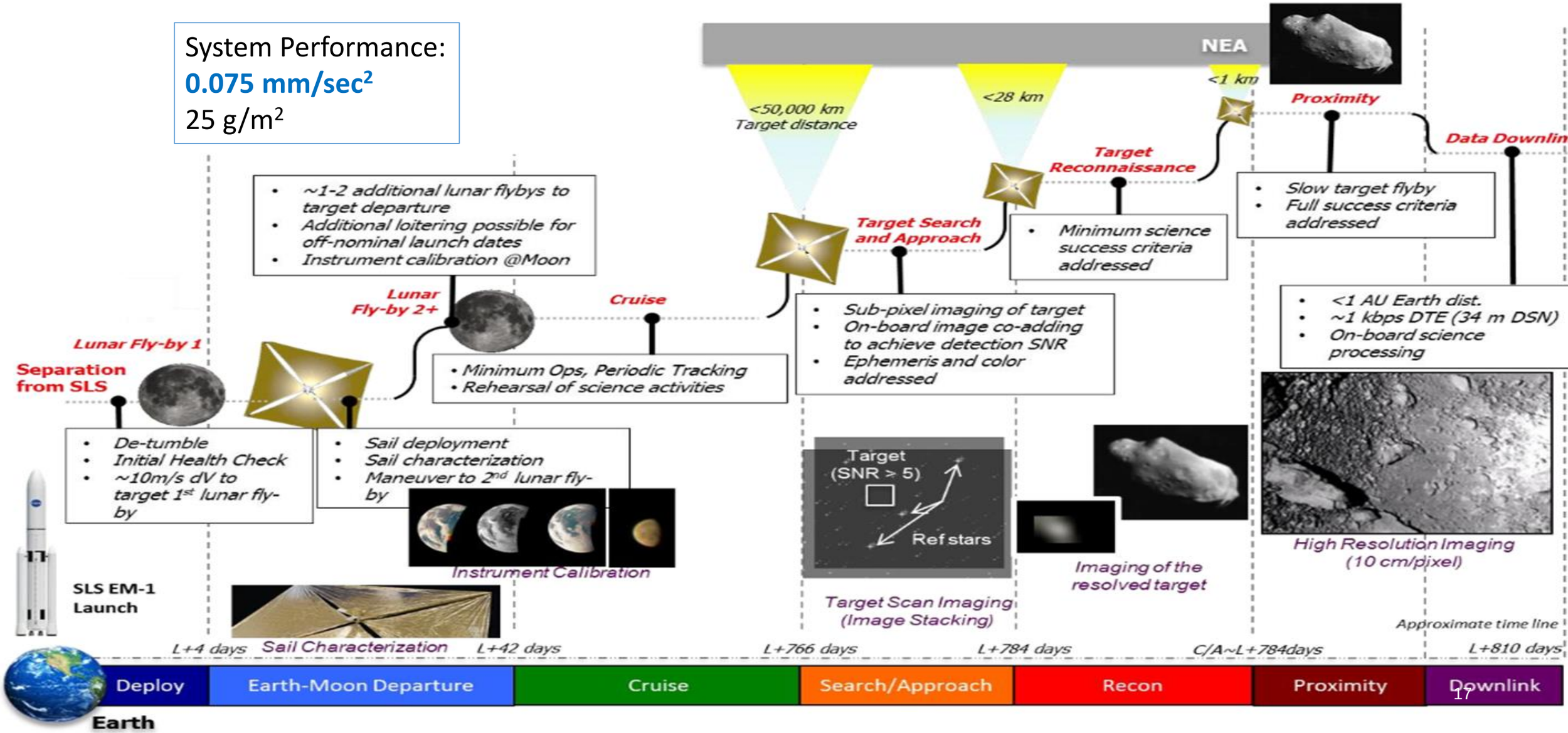


The Flight System



NEA Scout – Mission Overview

System Performance:
0.075 mm/sec²
25 g/m²

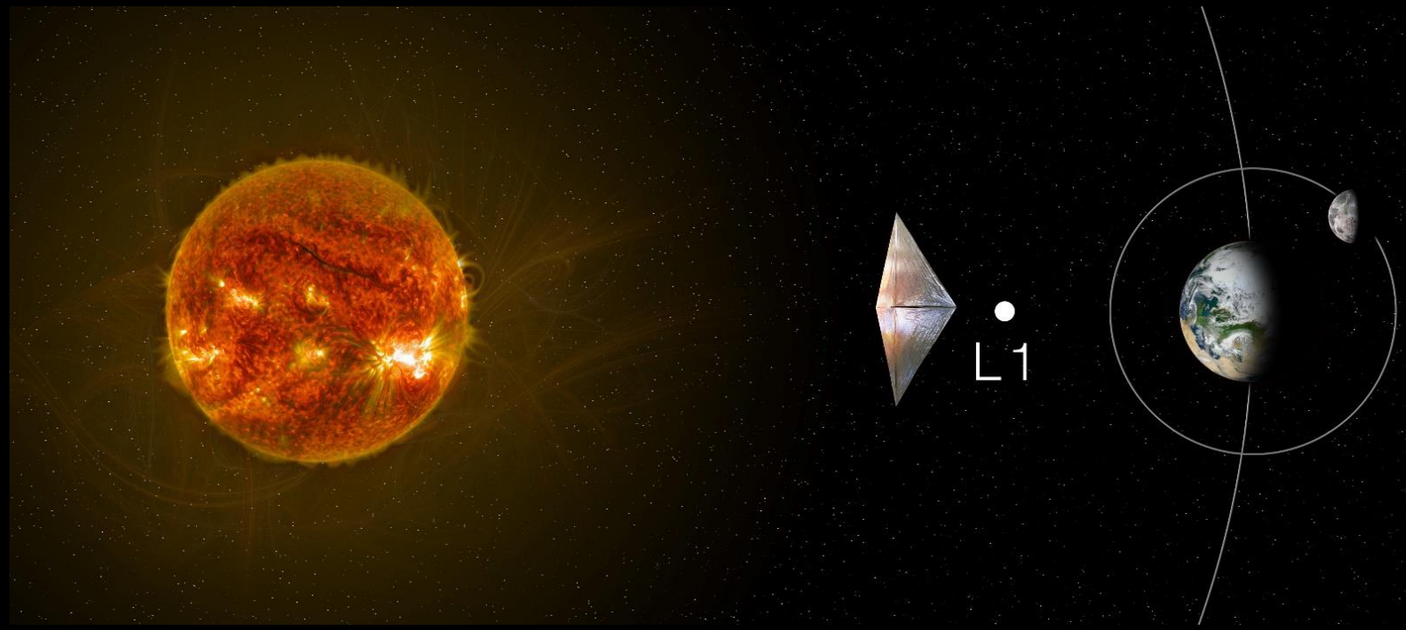


Solar Cruiser

Mission Concept

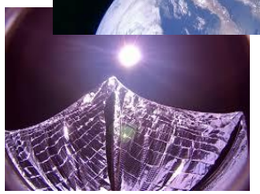
Mission Profile

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.



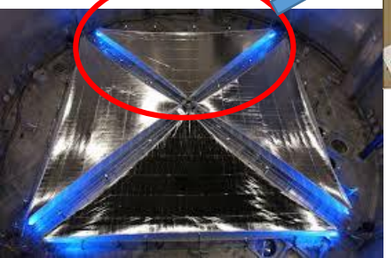
Solar Cruiser
Solar Sail Technology Investment Heritage

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

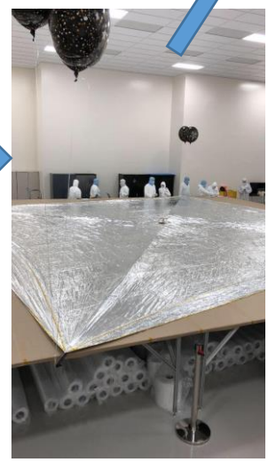


LightSail 1 (The Planetary Society)
32 m^2 sail (NanoSail heritage design)
Successful flight in 2015

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

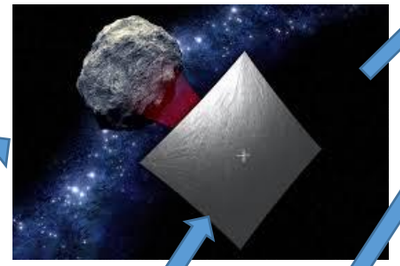


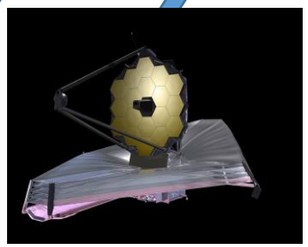
SMD In-Space Propulsion Technology Project
400 m^2 solar sail demonstrator
Deployed at Plumbrook Station (2000 – 2003)



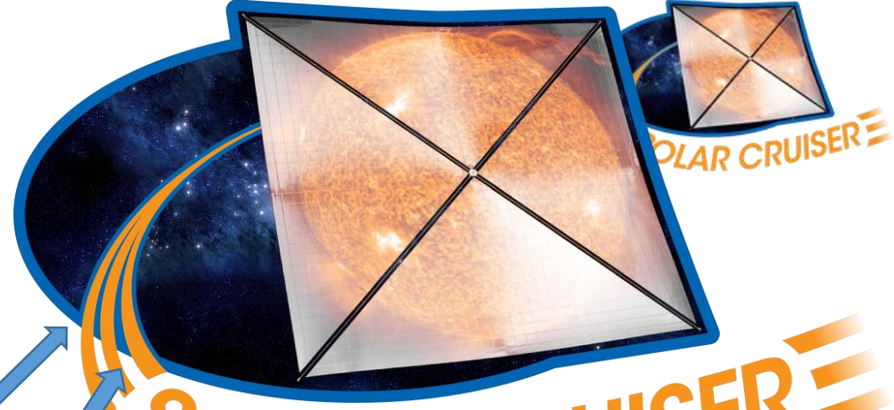
HEOMD Near-Earth Asteroid Scout
86 m^2 solar sail
Flight Unit Deployment Test (2014 - 2018)

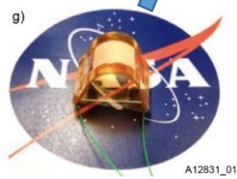
HEOMD Near-Earth Asteroid Scout
86 m^2, 2-year mission to an asteroid
Manifested on Artemis 1 (2020)





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





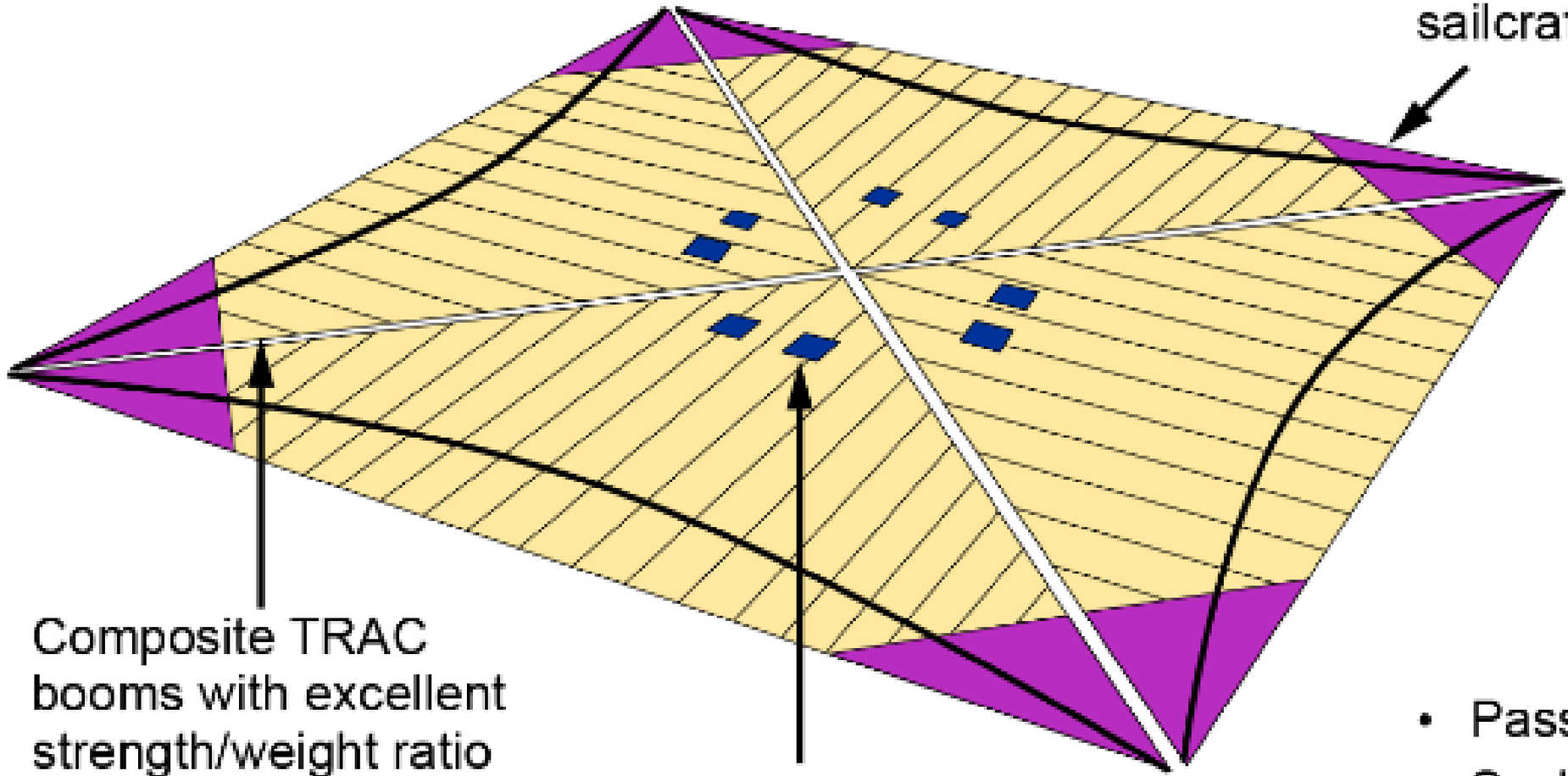
Reflective Control Devices (RCDs) NASA STMD Early Career Faculty STRA (2012)

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)

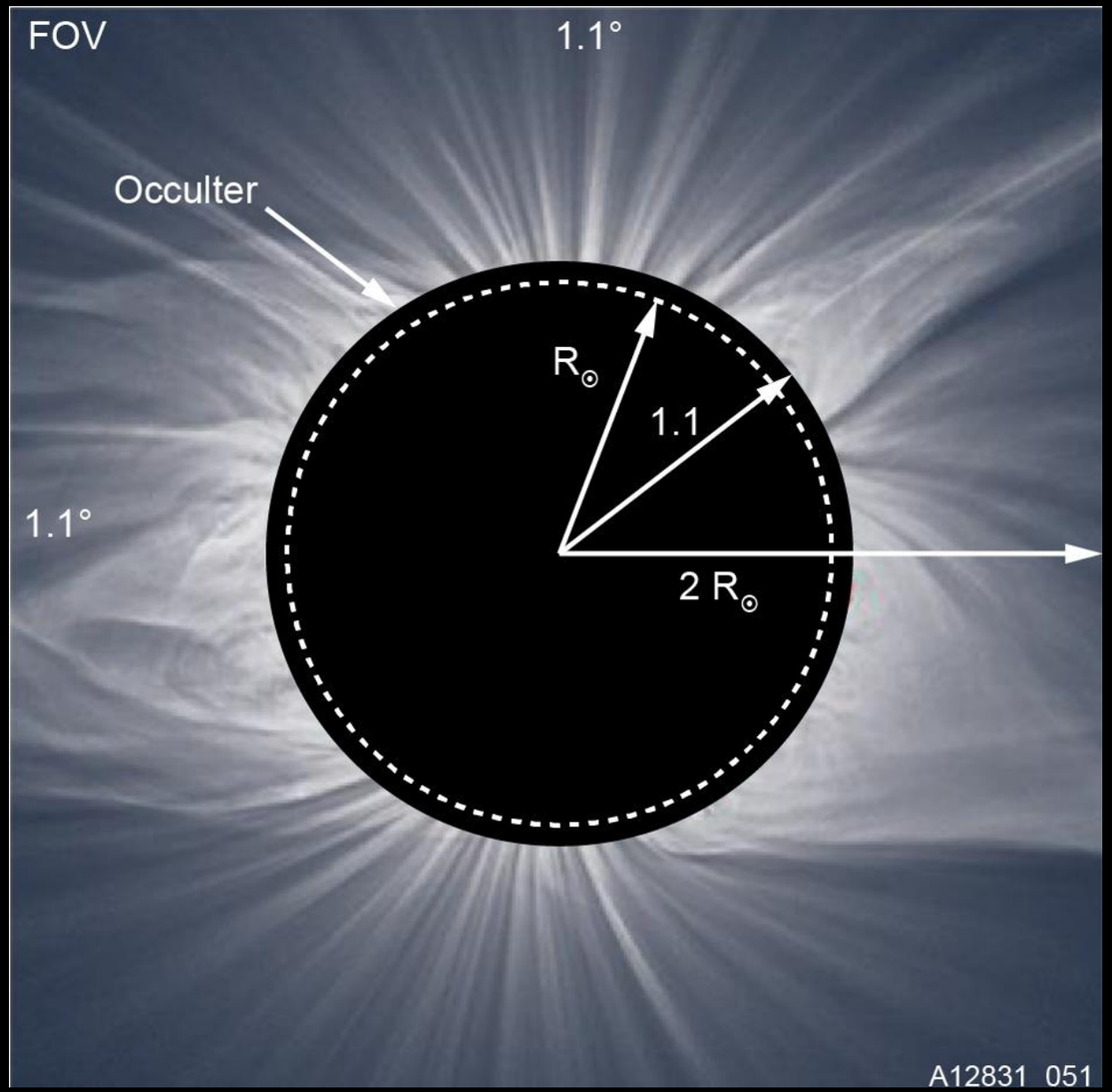
NeXolve Large Sail Fabrication Automation Phase I &II SBIR (2019 – 2021)

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

Solar Cruiser Operations Plan

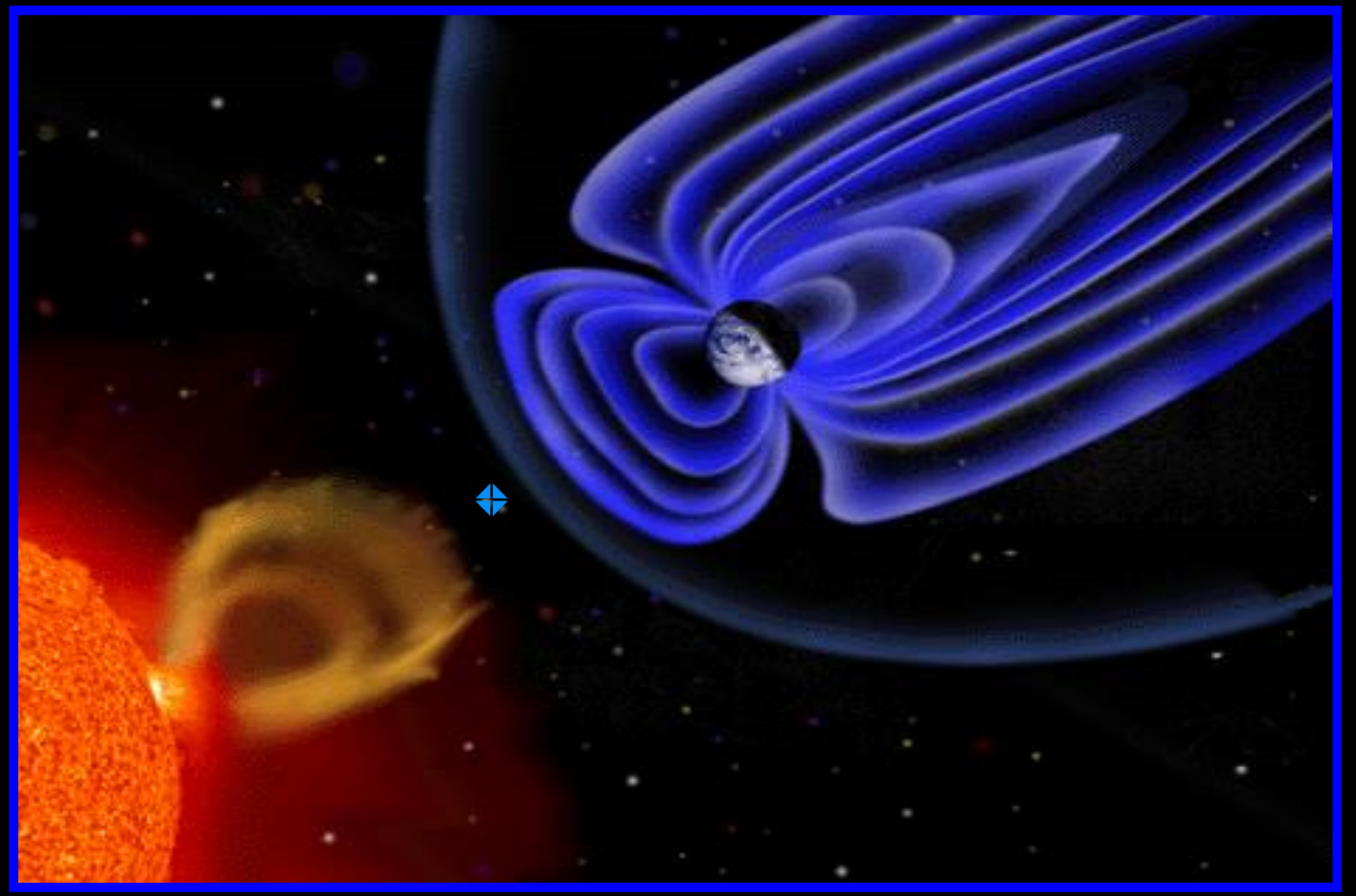
Mission Phase	Time Since Launch (days)	Duration (days)	Activities
Launch and Commissioning	L+0 to L+28	28	Assess spacecraft functionality
Coronagraph Checkout	L+29 to L+53	24	Test and operate coronagraph
Sail Deploy and Checkout	L+54 to L+61	7	Deploy and Assess Sail
Sailcraft Cruise	L+62 to L+221	160	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

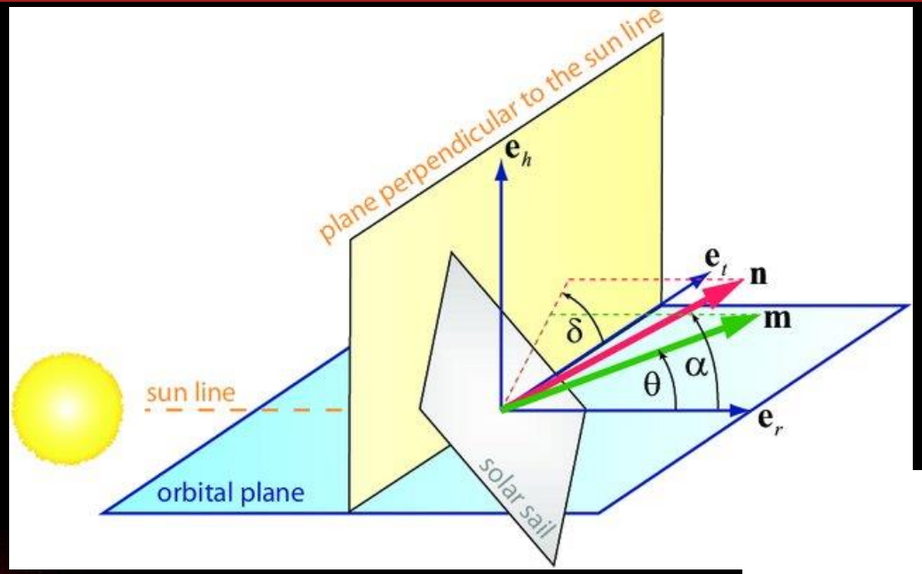
After the Baseline mission, *Solar Cruiser* proposes a 1-year SEO to observe the solar corona from vantage points off the Sun-Earth Line

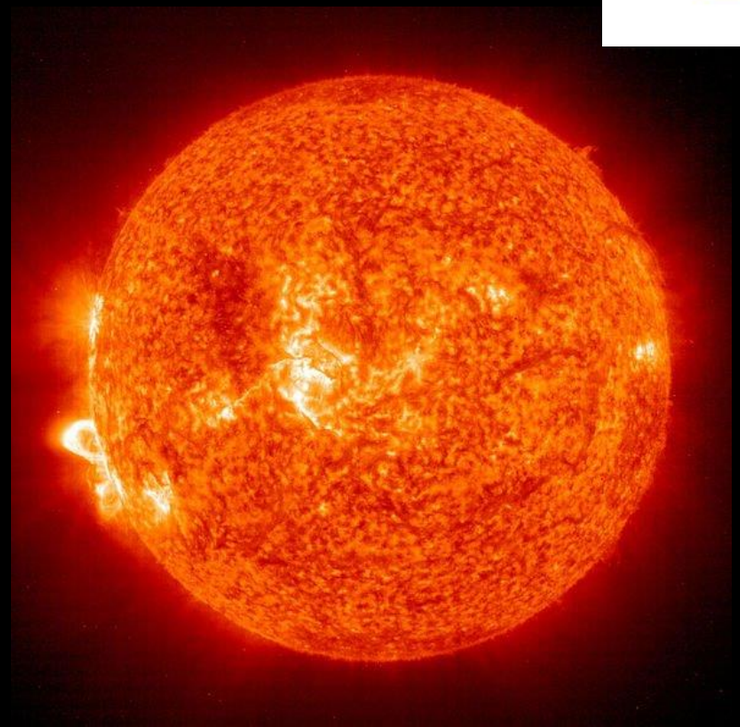
The sailcraft will cruise to 5 degrees Earth-trailing, where it will station-keep for 4 months for coronal observations

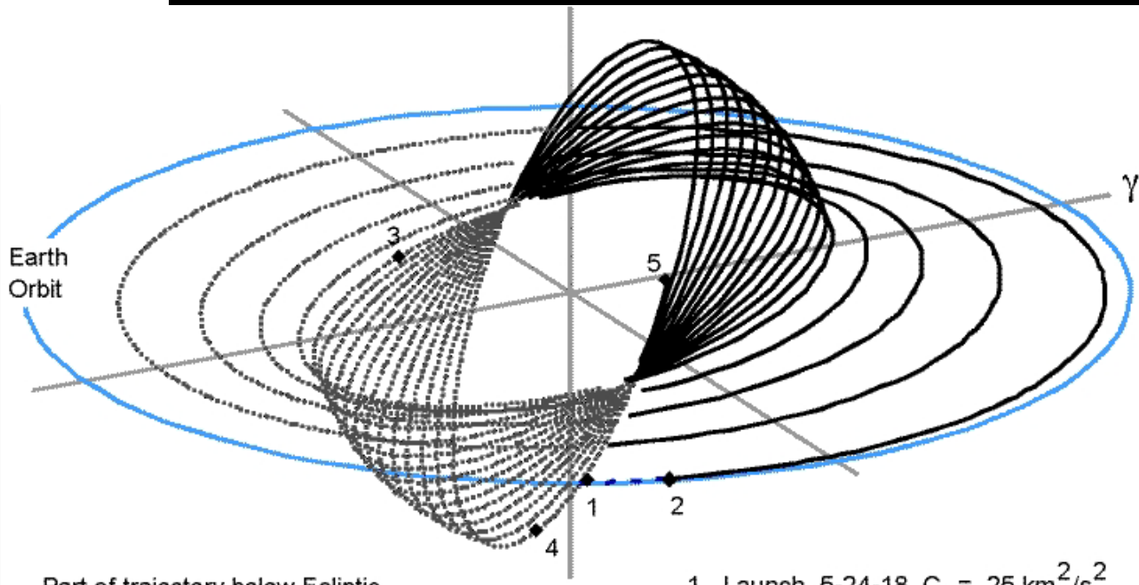
WHY SOLAR SAILS? Solar Storm Warning



WHY SOLAR SAILS? High Inclination Solar Science



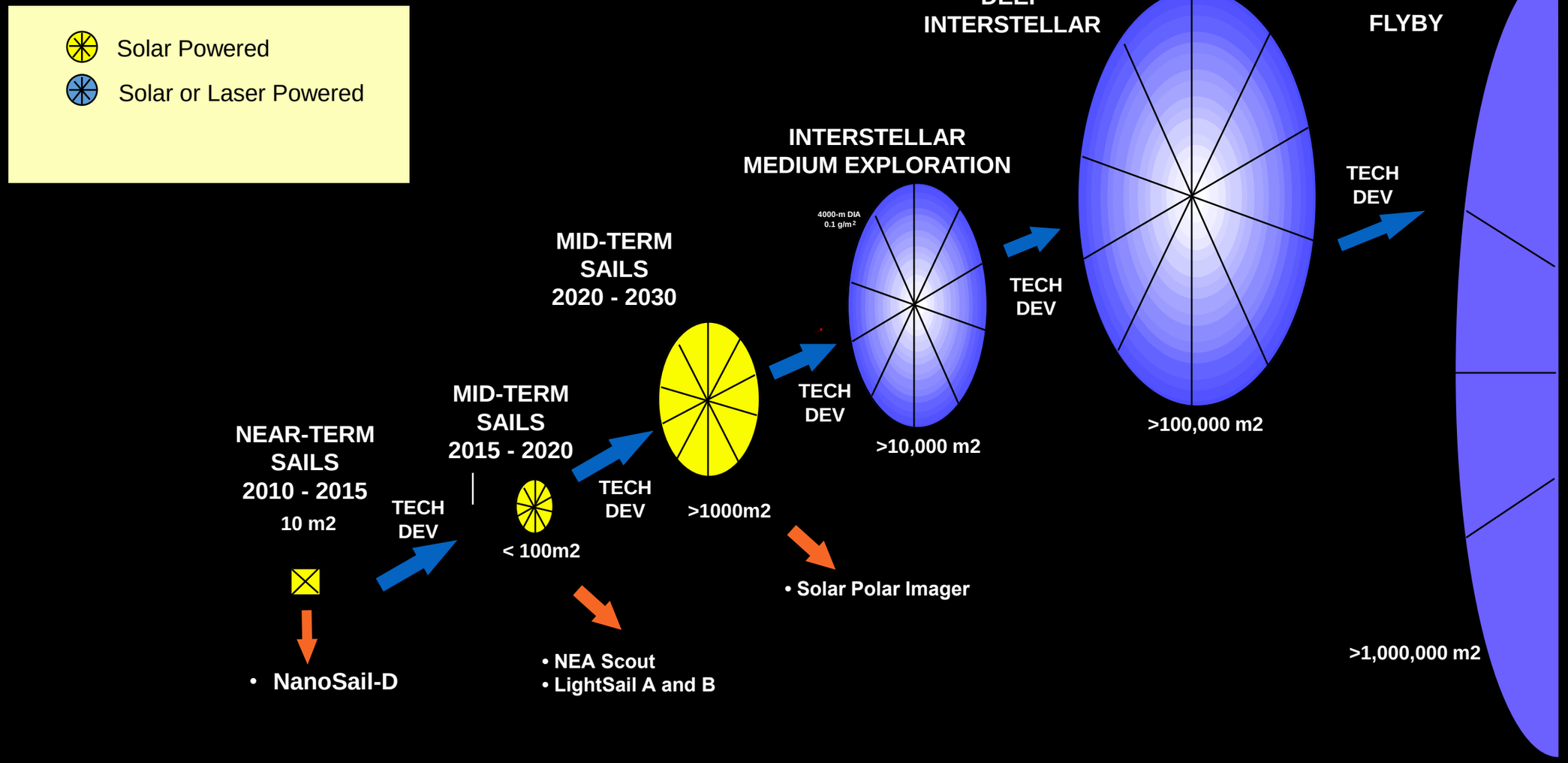


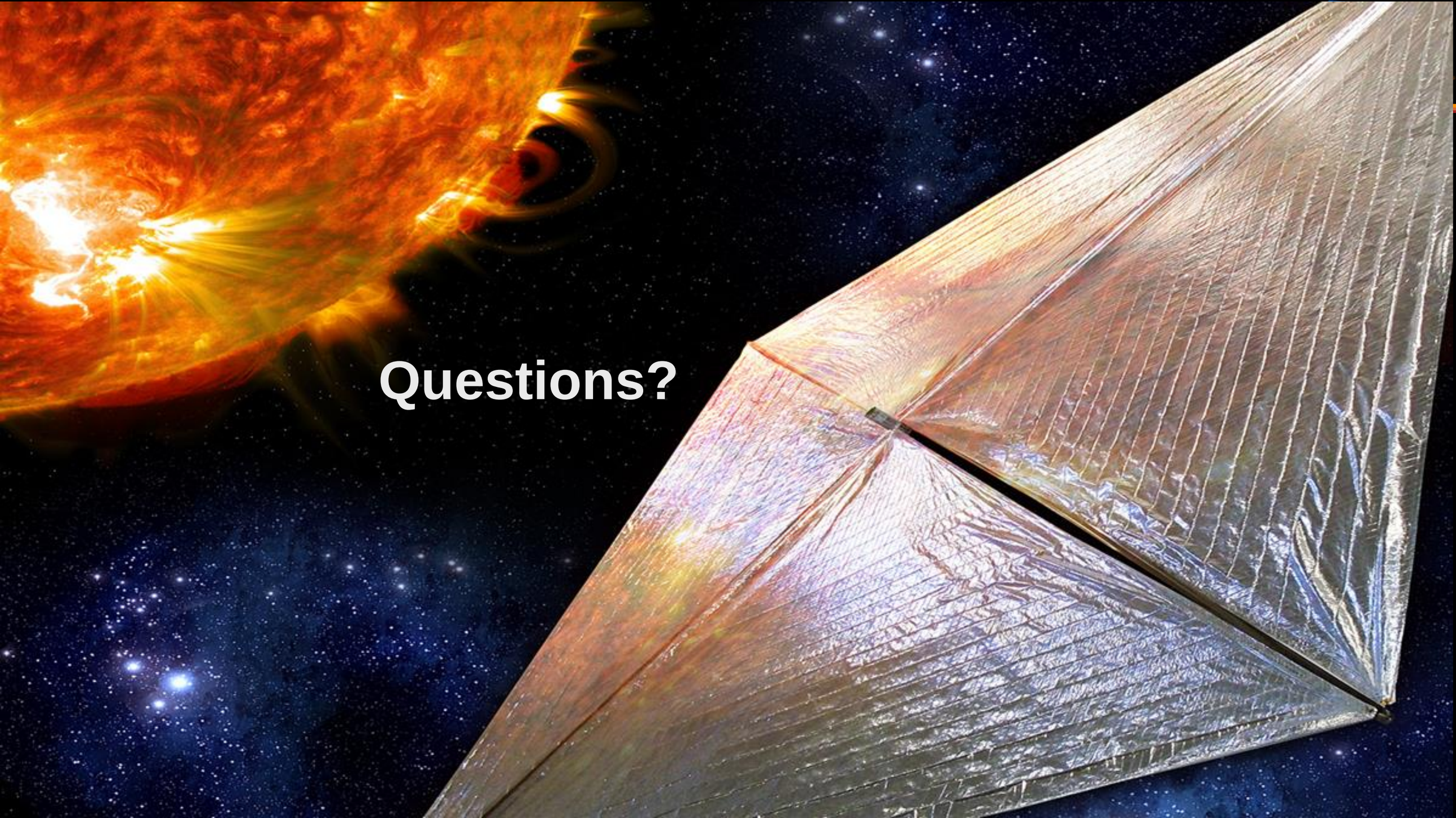


Part of trajectory below Ecliptic
Identified by dashed curve

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

My Real Motive…
Going to the Stars!




Questions?