



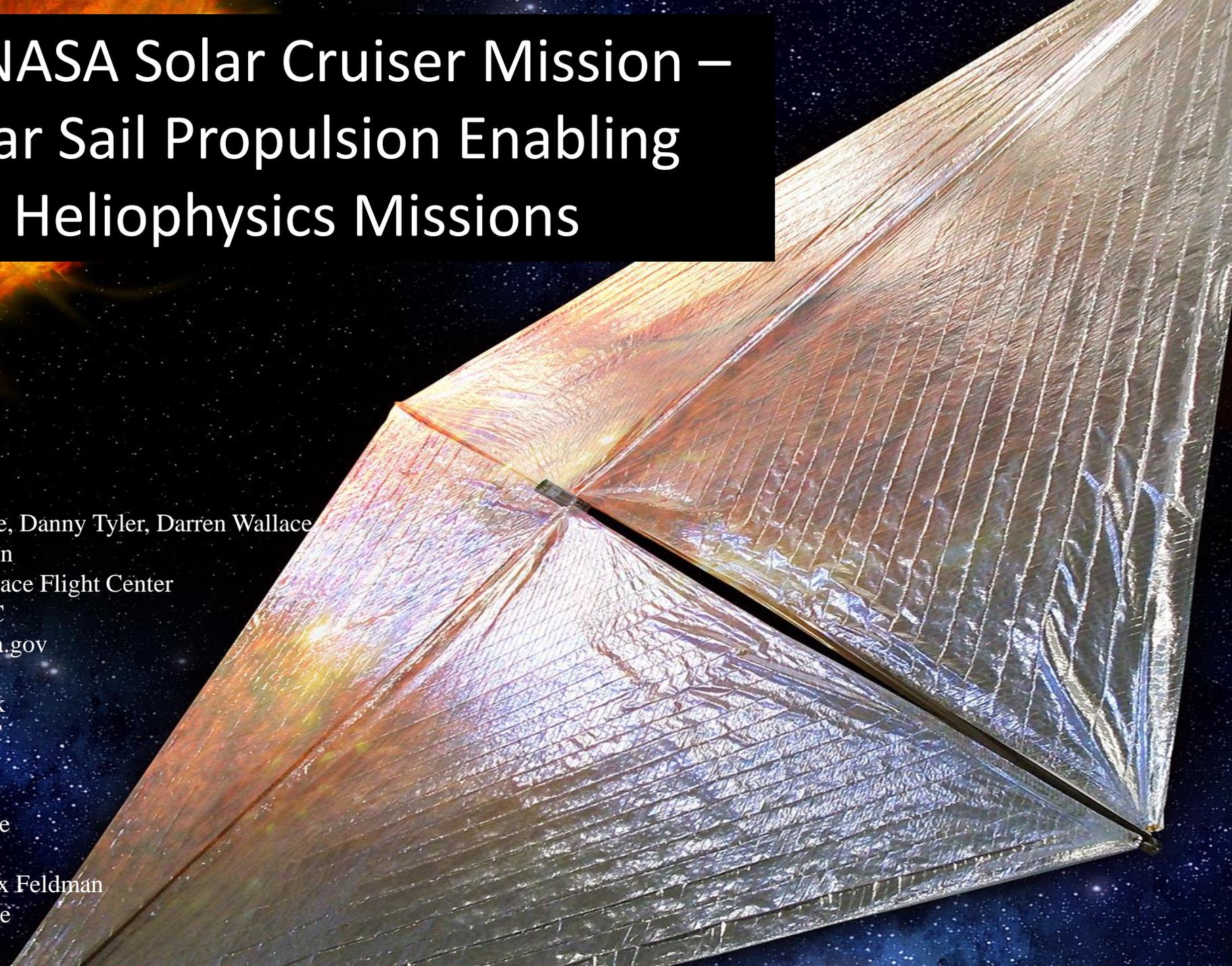
# The NASA Solar Cruiser Mission – Solar Sail Propulsion Enabling Heliophysics Missions

Les Johnson, Jason Everett, David McKenzie, Danny Tyler, Darren Wallace  
and Jeff Wilson  
NASA George C. Marshall Space Flight Center  
NASA MSFC  
[les.johnson@nasa.gov](mailto:les.johnson@nasa.gov)

Jeff Newmark  
NASA GSFC

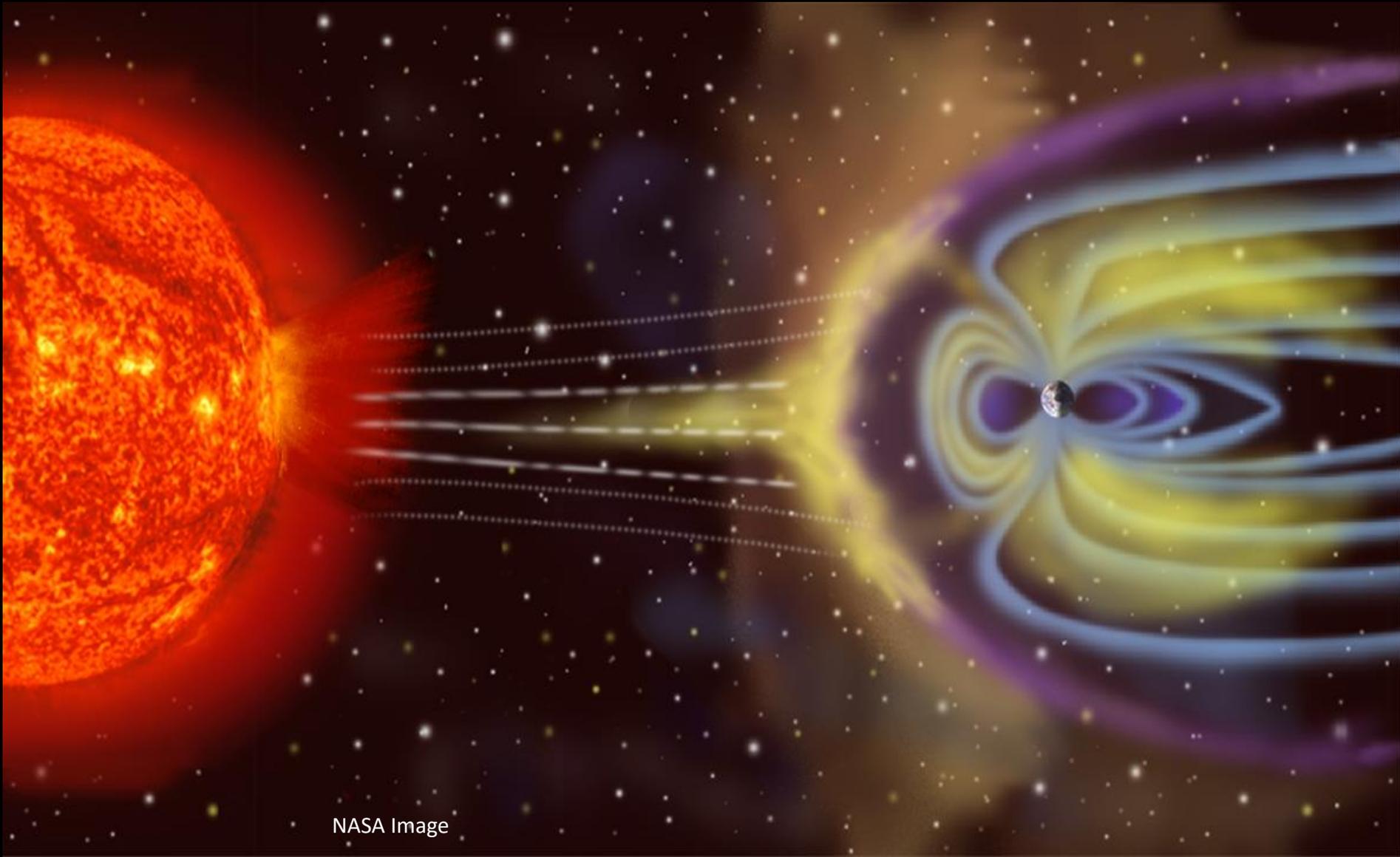
Dana Turse  
Redwire Space

Matthew Cannella, Max Feldman  
Ball Aerospace





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



NASA Image



# Just As Sailing Ships Can Use the Momentum of the Wind

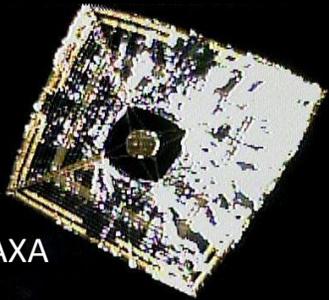
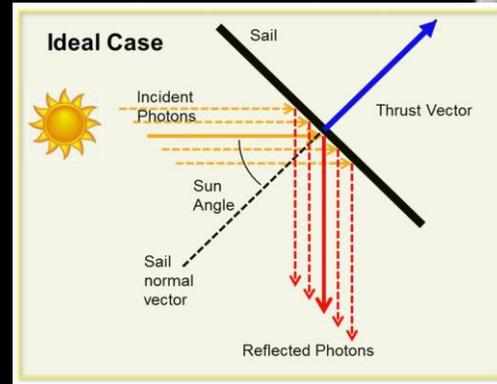


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# Solar Sails: Sailing On Sunlight

- Producing thrust with sunlight “pressure” or force on thin, lightweight, reflective sheets
- Will never run out of fuel, allowing space missions to new locations



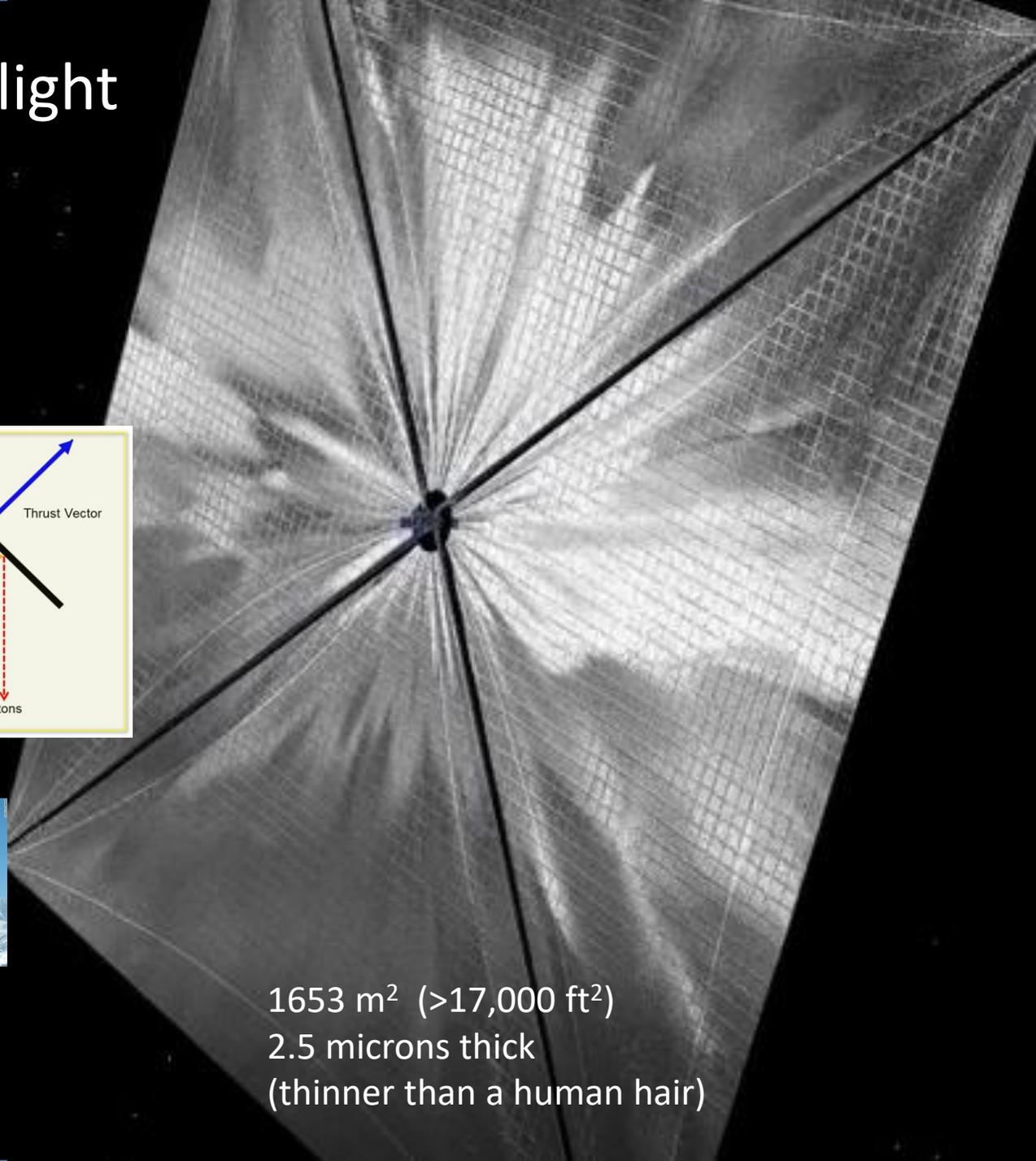
JAXA



The Planetary Society



1653 m<sup>2</sup> (>17,000 ft<sup>2</sup>)  
2.5 microns thick  
(thinner than a human hair)

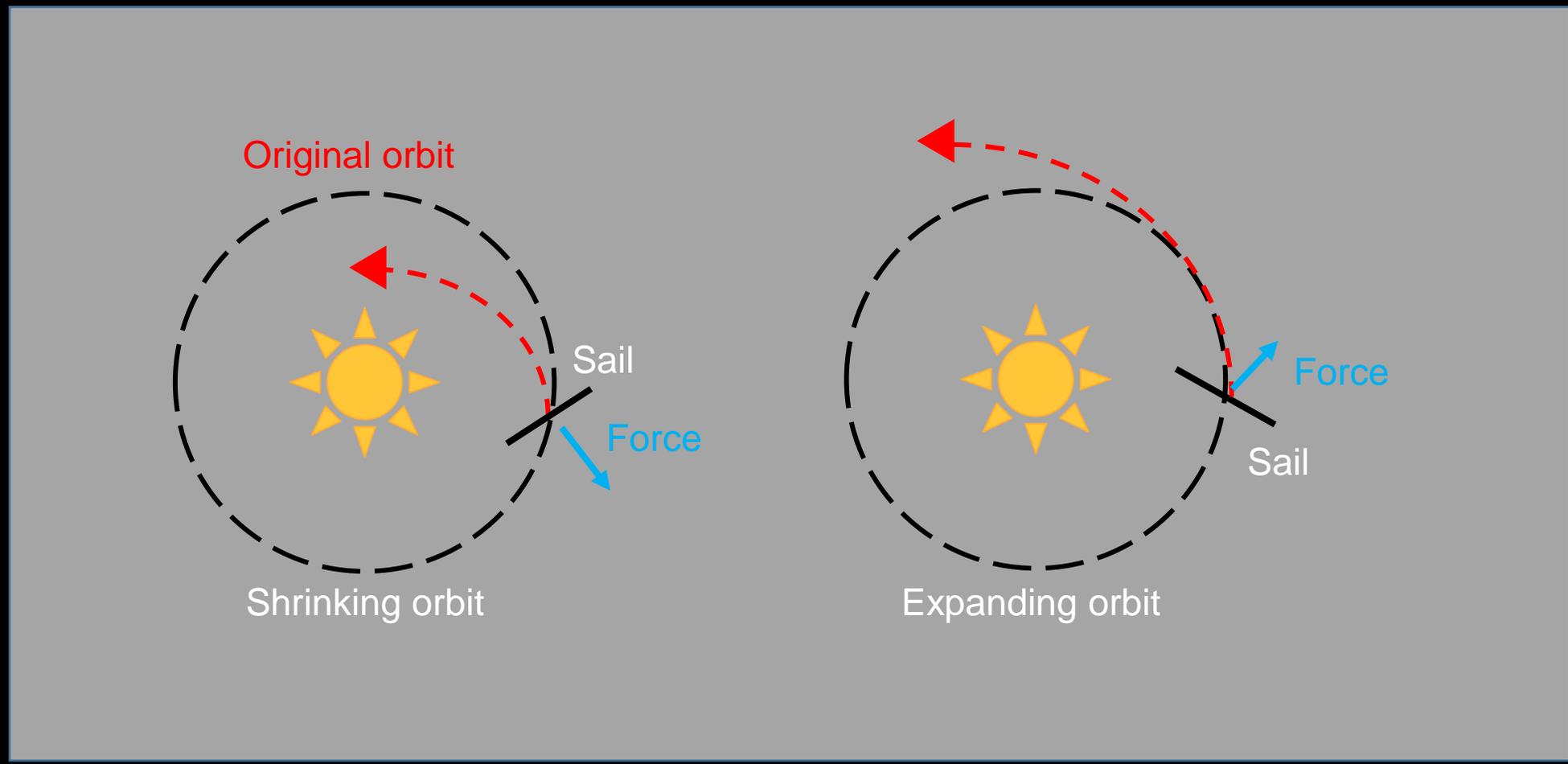




# Solar Sail Trajectory Control

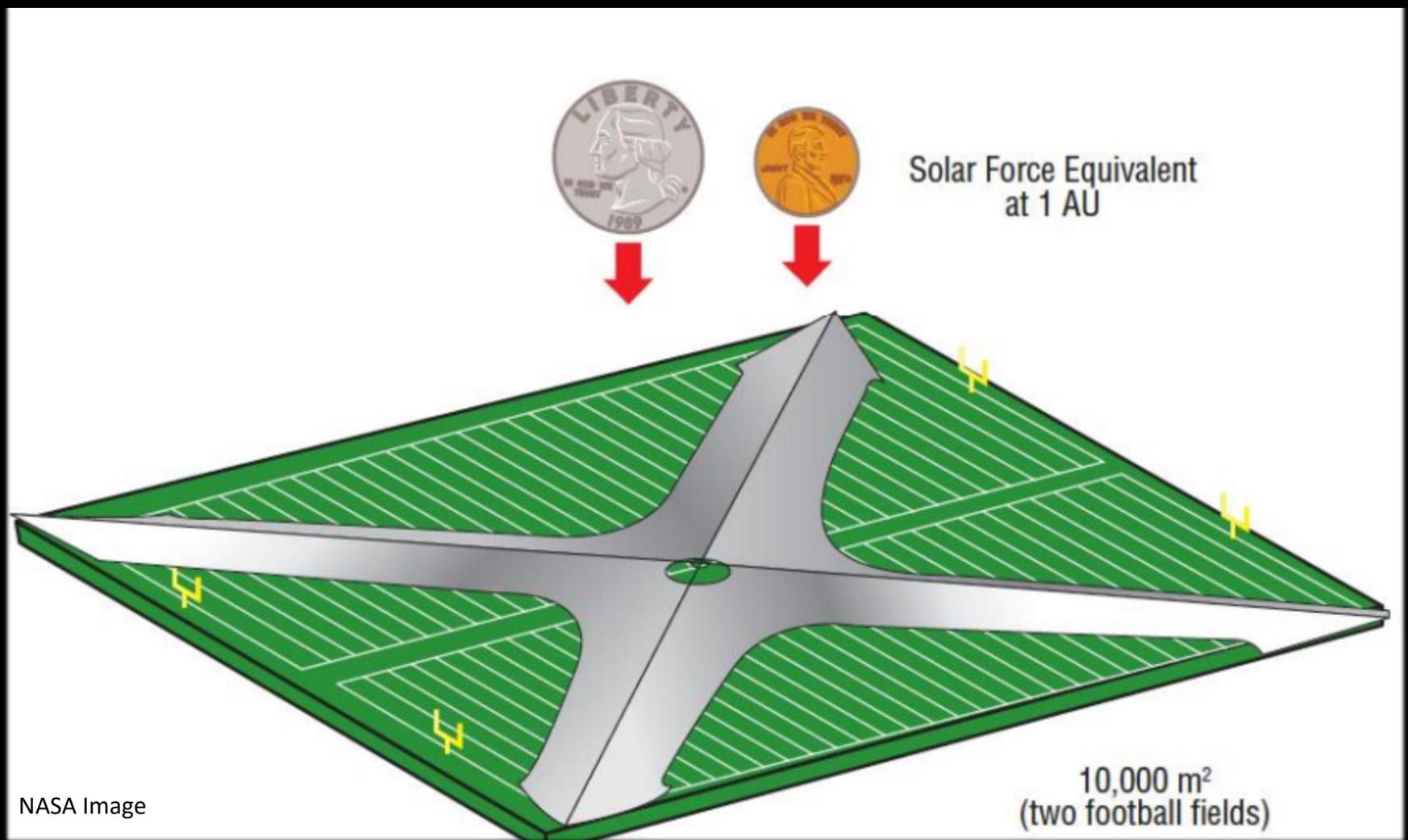


Sunlight Pressure allows inward or outward spiral toward or away from the sun





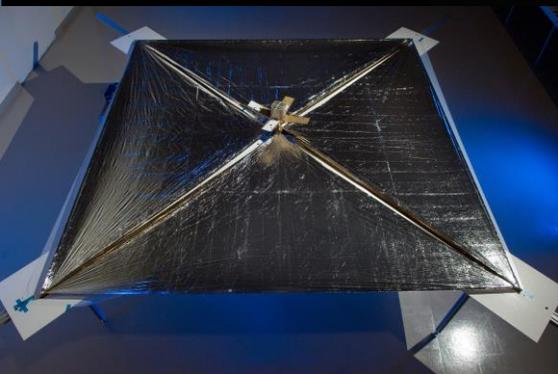
# Solar Sails Experience VERY Small Forces and Reduce or Eliminate the Need for Propellant



NASA Image



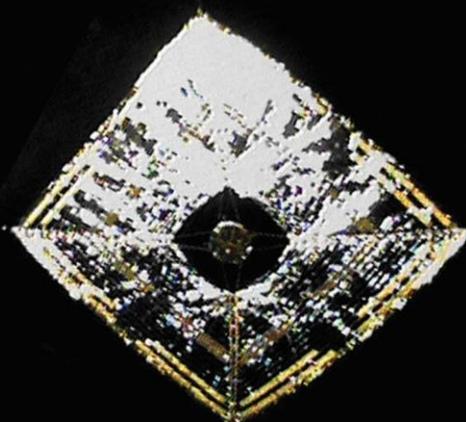
# Solar Sail Missions Flown



**NanoSail-D (2010)**  
**NASA**

**Earth Orbit**  
**Deployment Only**

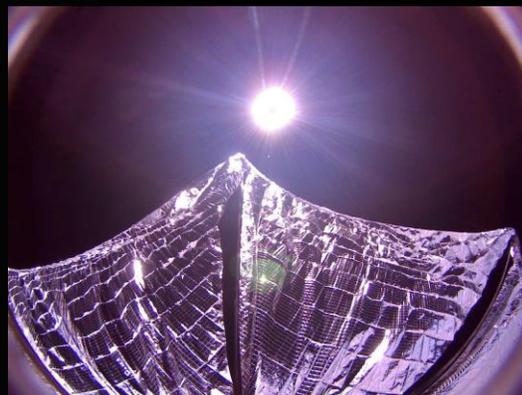
**3U CubeSat**  
**10 m<sup>2</sup>**



**IKAROS (2010)**  
**JAXA**

**Interplanetary**  
**Full Flight**

**315 kg Smallsat**  
**196 m<sup>2</sup>**



**LightSail-1 & 2**  
**(2015/2019)**  
**The Planetary Society**

**Earth Orbit**  
**Deployment / Flight**

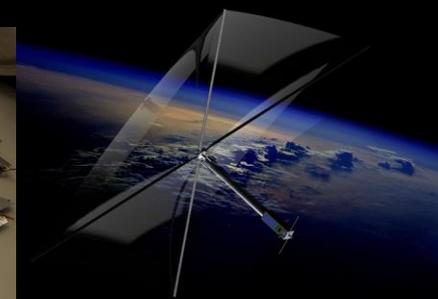
**3U CubeSat**  
**32 m<sup>2</sup>**



**CanX-7 (2016)**  
**Canada**

**Earth Orbit**  
**Deployment Only**

**3U CubeSat**  
**<10 m<sup>2</sup>**



**InflateSail (2017)**  
**EU/Univ. of Surrey**

**Earth Orbit**  
**Deployment Only**

**3U CubeSat**  
**10 m<sup>2</sup>**



# Near Earth Asteroid Scout

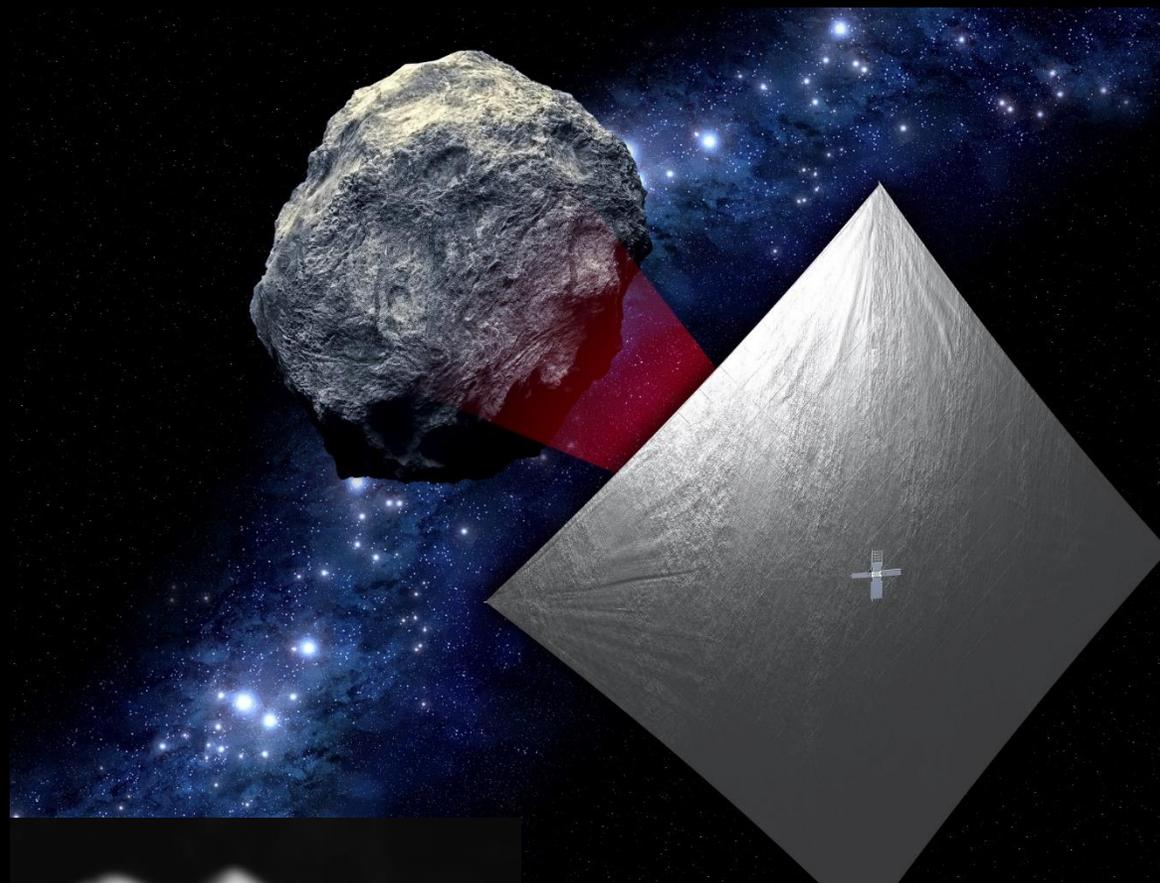


## GOALS

- First interplanetary mission using solar sail propulsion
- Characterize a Near Earth Asteroid for possible future human visits

## Key Spacecraft & Mission Parameters

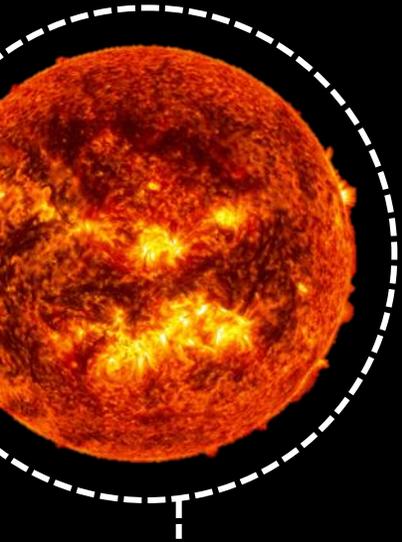
- 6U cubesat (8" X 4" X 12")
- 86 m<sup>2</sup> solar sail propulsion system
- Manifested for launch on the Space Launch System (Artemis 1)
- 1 AU maximum distance from Earth



# NEA Scout is one of 10 Secondary Payloads on Artemis 1



SMALLSATS TO BE DEPLOYED FROM THE ORION STAGE ADAPTER



## SUN

- CuSP (Southwest Research Institute)

## MOON

- Lunar Flashlight (NASA)
- Lunar IceCube (Morehead State University)
- LunaH-Map (Arizona State University)
- OMOTENASHI (JAXA)
- LunIR (Lockheed Martin)
- EQUULEUS (JAXA)

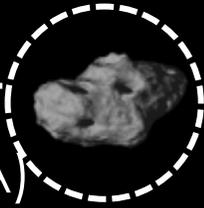


## EARTH-MOON

- ArgoMoon (ESA/ASI)

## ASTEROID

- NEA Scout (NASA)



## ...AND MORE

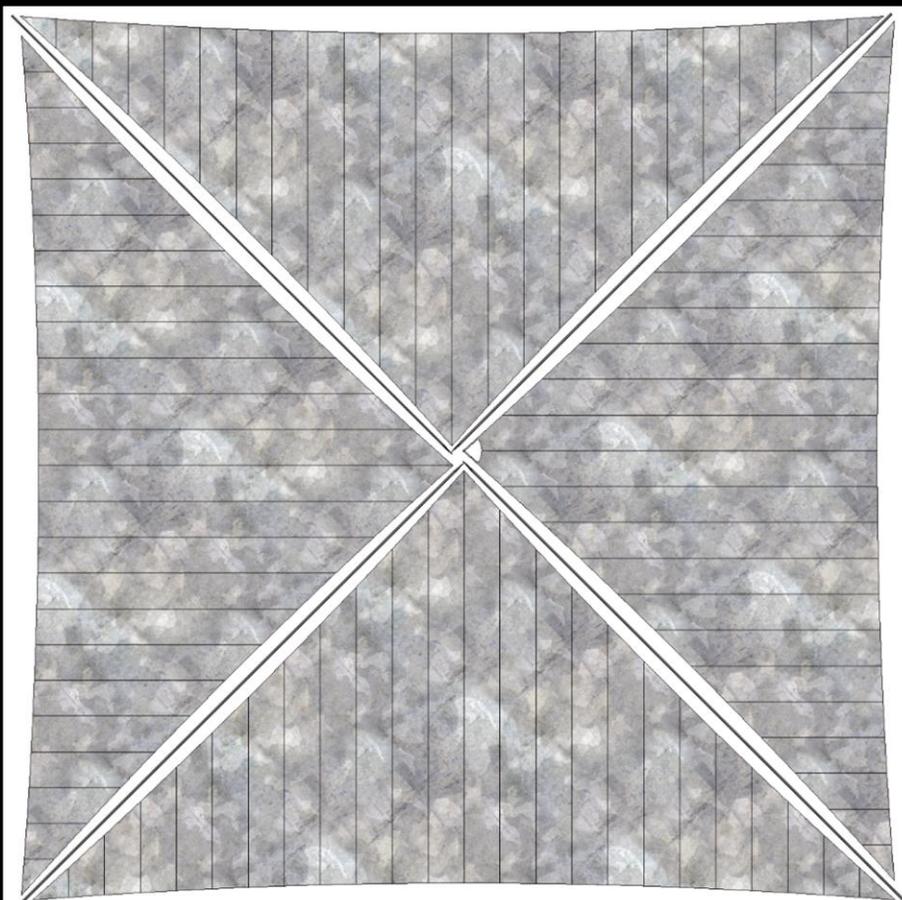
- Biosentinel (NASA)
- Cislunar Explorers (Cornell University)
- CU-E<sup>3</sup> (University of Colorado Boulder)
- Team Miles (Miles Space)



# 86 m<sup>2</sup> Solar Sail (NEA Scout)



Deployed Solar Sail



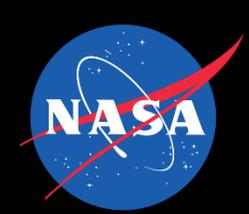
School Bus



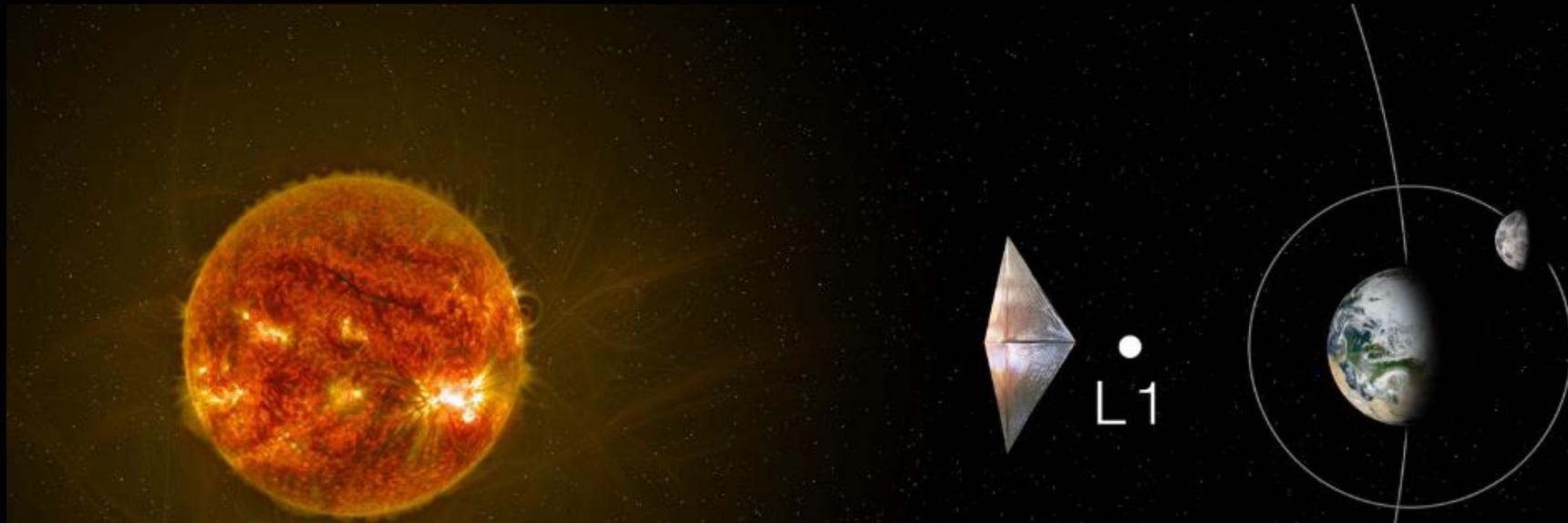
Spacecraft



Folded, spooled and packaged in here



# Solar Cruiser Mission Overview



Solar Cruiser was to launch as a secondary payload on the NASA IMAP mission in 2025. Using a solar sail, it would have cruised toward the sun and demonstrate the ability of a solar sail to remain stationary along a line from the Sun to the Earth for long periods of time.

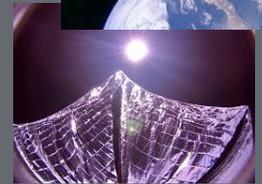
Due to a technical problem with the spacecraft and insufficient schedule margin to accommodate required changes, the mission was not confirmed for flight.



# Sail Developments Leading to Solar Cruiser



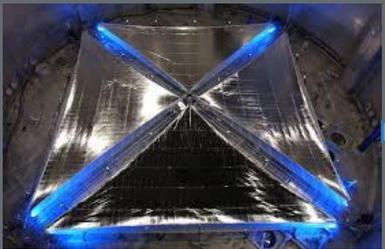
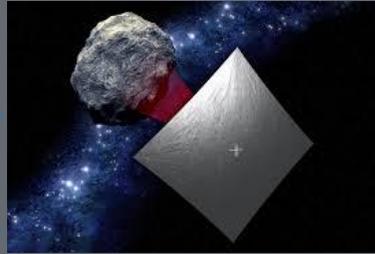
## Solar Cruiser Team Members Have Been Involved In Each Of These Maturation Efforts



LightSail 1 & 2  
(The Planetary Society)



NASA Near-Earth Asteroid Scout



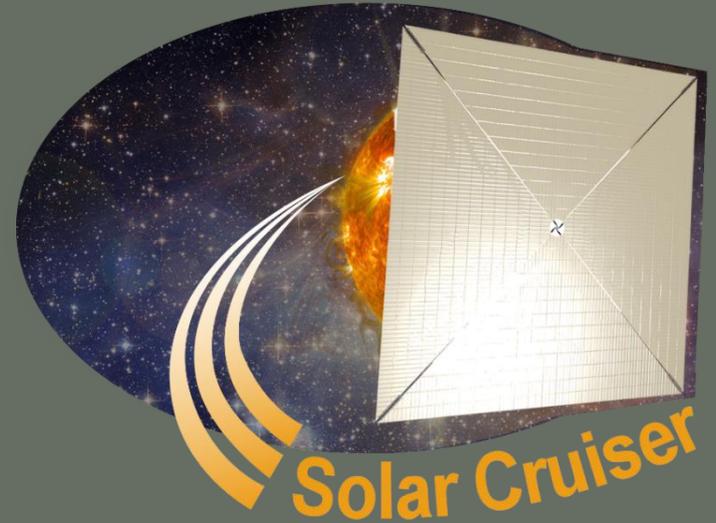
NASA 400 m<sup>2</sup>  
Ground Tests



NASA MSFC  
NanoSail - D



NASA Near-Earth Asteroid Scout



Solar Cruiser



Integration of Small Spacecraft



Solar Sail System Design

Sail Software



ROCCOR

Composite Booms  
Sail Deployer



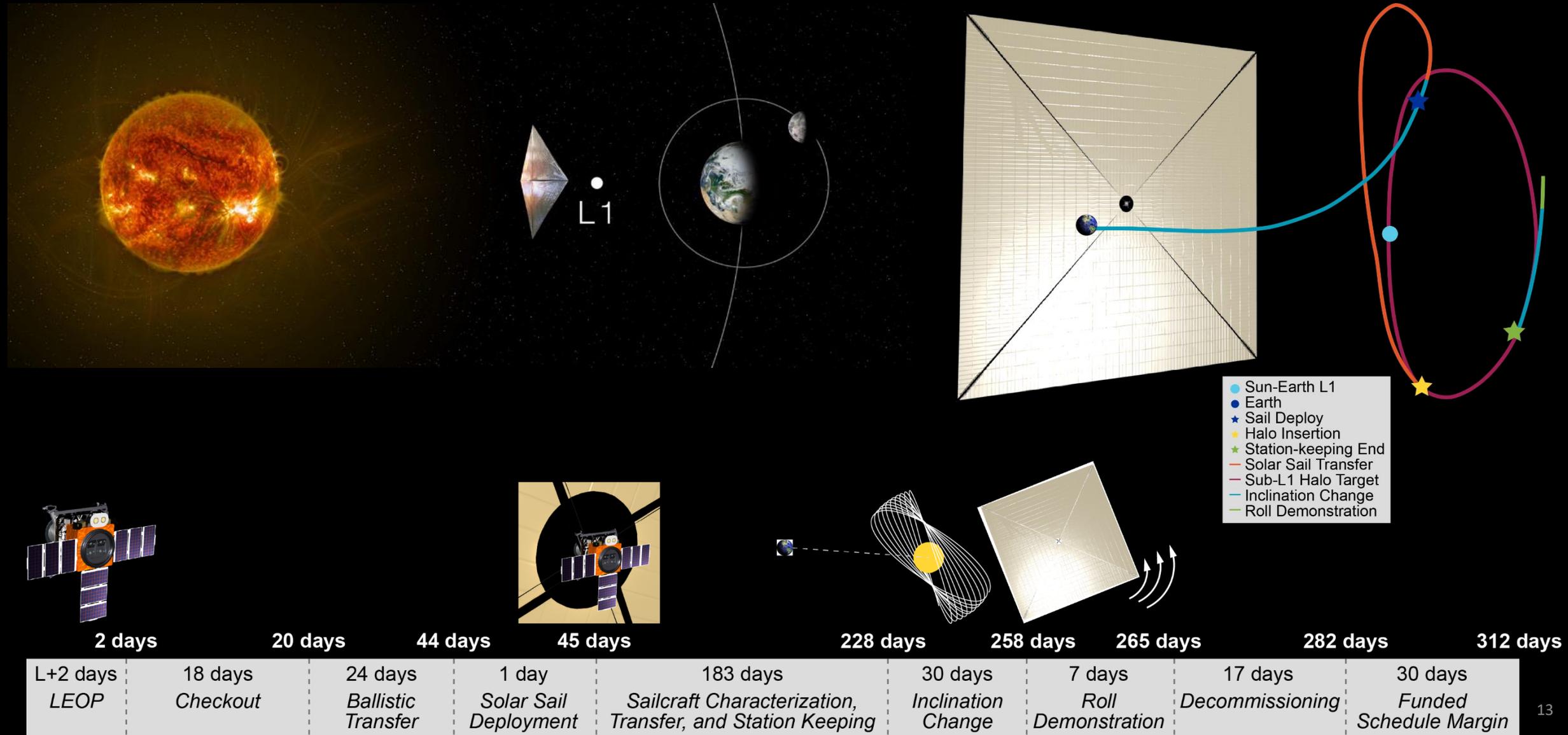
Sail Membrane Fabrication



Sail Context Camera



# Solar Cruiser Will Demonstrate Solar Sail Propulsion Enabling Novel Orbits and Destinations



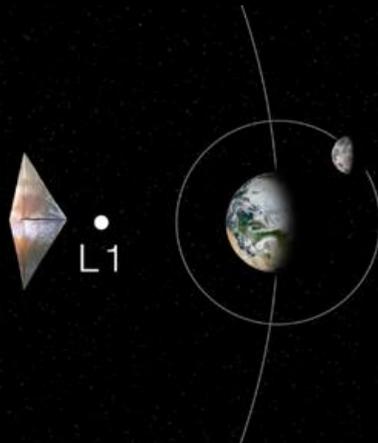
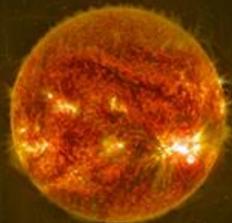


# Solar Cruiser *Immediately Enables Solar Science and Solar Storm Monitoring*



## Space Weather Applications:

- Increase the warning times by up to 50% for solar storms, benefiting Earth power utilities and spacecraft operators.
- Directly benefits human exploration beyond Earth orbit



### Severe Sun Storm Threatens Utilities

By MATTHEW L. WALD

*New York Times (1857-Current file); Jun 6, 1991; ProQuest Historical Newspapers The New York Times (1851 - 2001) pg. A16*

## Severe Sun Storm Threatens Utilities

By MATTHEW L. WALD

A severe disturbance of the Earth's magnetic field, caused by temporary changes in solar activity, began on Tuesday night, threatening electric

ment Services Center, in Boulder, Colo.

Electric utilities in the northern United States and in Canada are concerned because the solar activity changes the shape of the earth's mag-

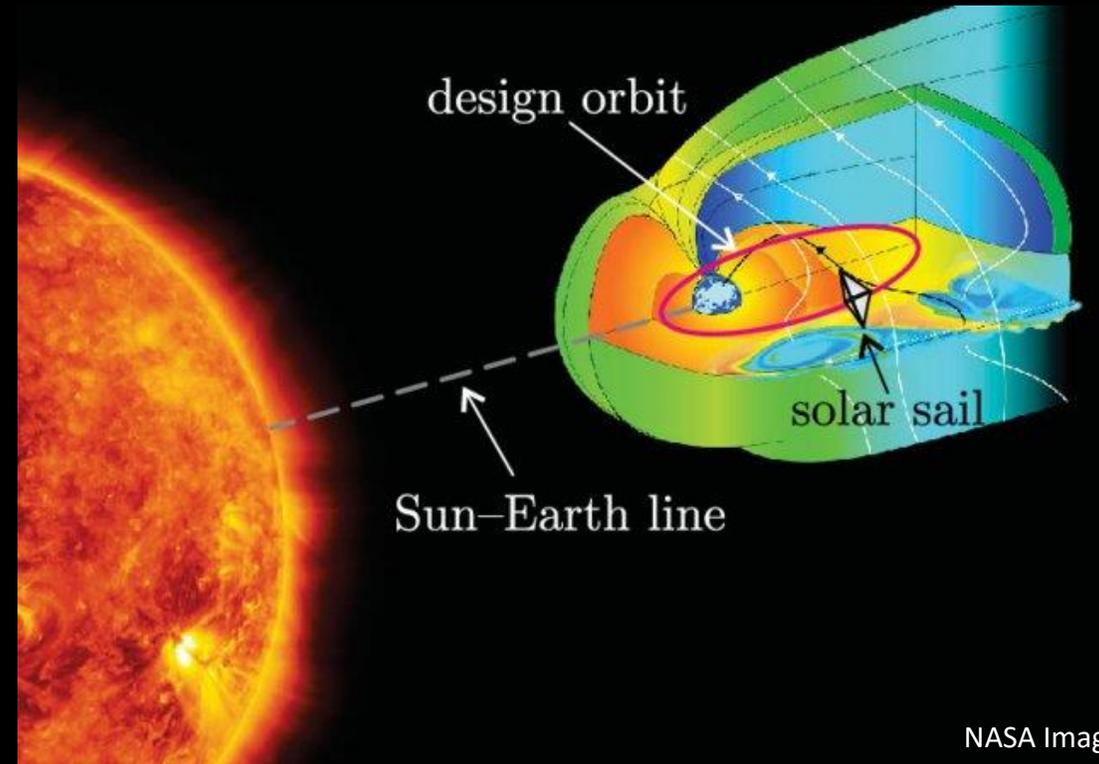
blackouts could result. Presumably, after a warning from the probe, utilities would try to reduce demand and send less power over long distances, relying more on local generators.



# *Immediately Enables* Sustained Sampling of the Earth's Magnetotail



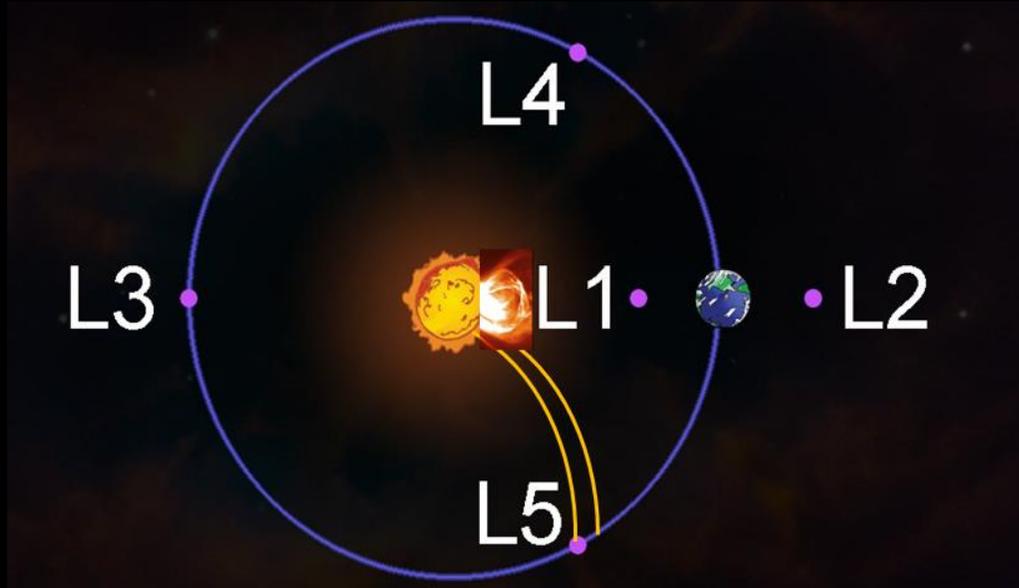
- Using multiple sailcraft, the entire geomagnetic tail could be populated by particle and field instruments that can remain there for long periods of time



NASA Image



# *Immediately Enables* Sustained Solar Observations Off the Sun-to-Earth Line



- Long term station keeping and flexible repositioning to be responsive to changing solar conditions

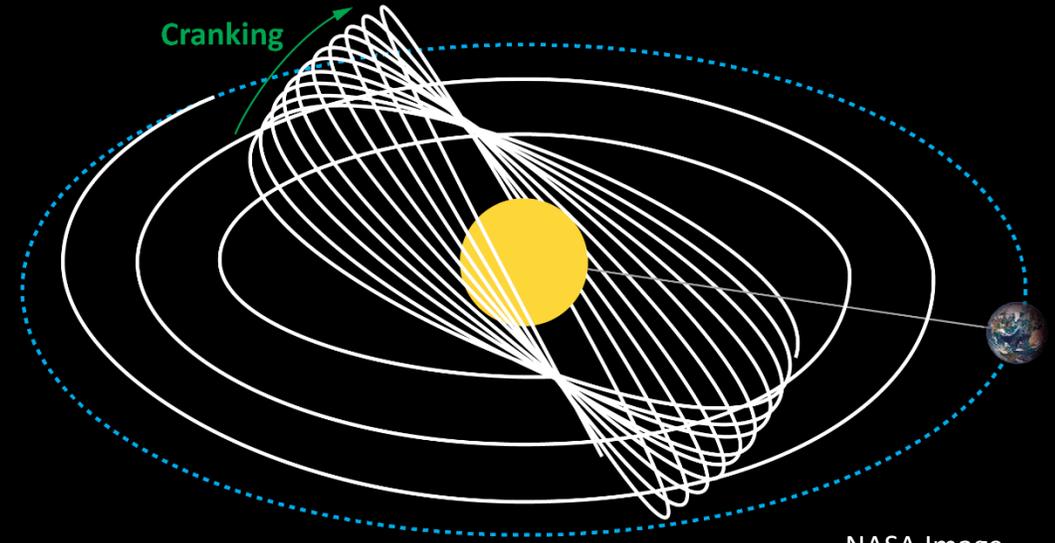
Observations enabled include imaging coronal mass ejections (CMEs) between the sun and Earth and in-situ measurements of solar wind streams in the vicinity of L5 before they rotate into Earth



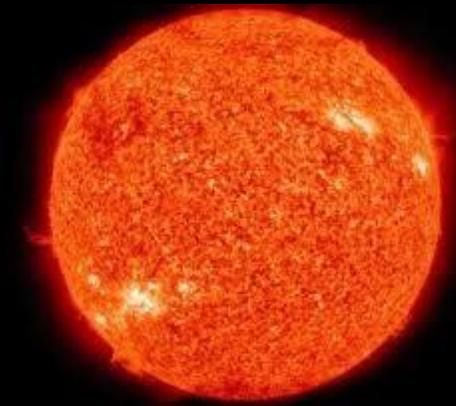
# *Immediately Enables* SmallSat Missions for Studying High Solar Latitudes



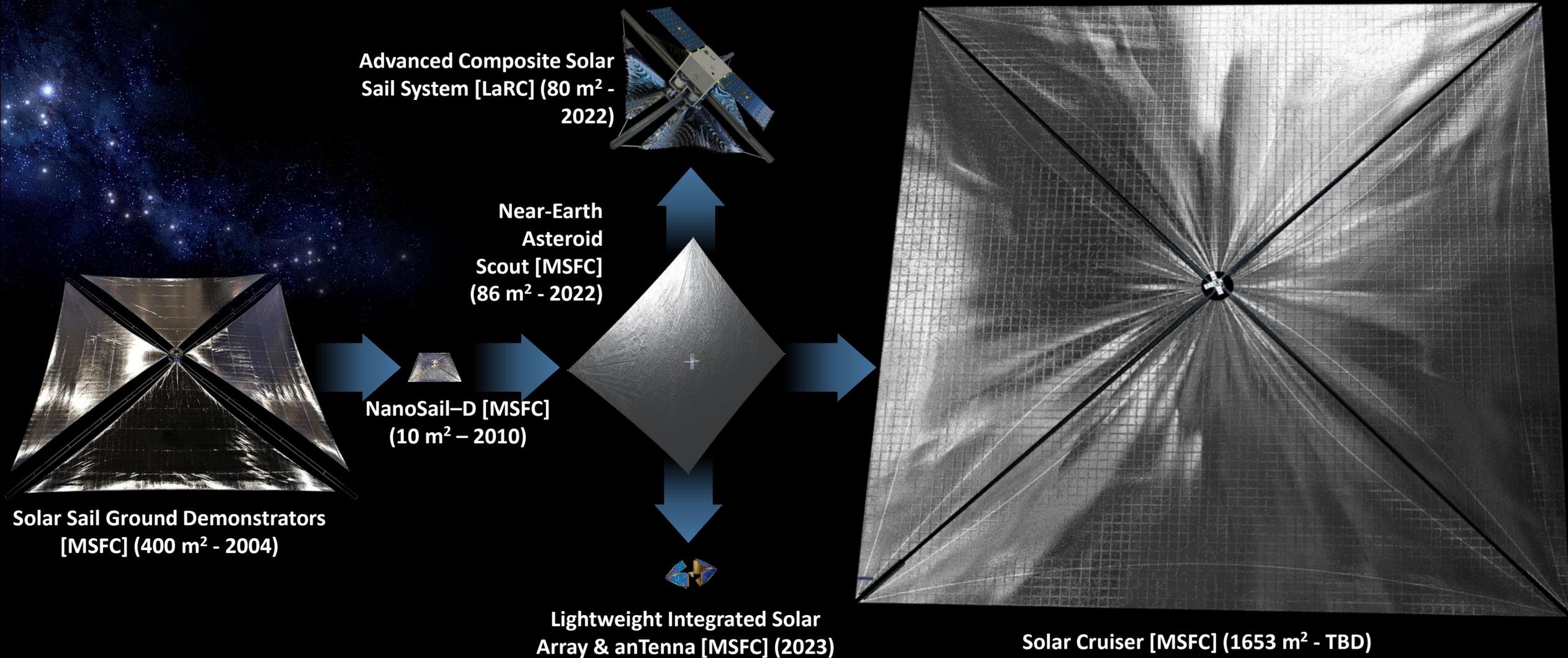
- A Solar Cruiser-class sailcraft (*without scaling*) can image the Sun at high latitudes – something not easily accomplished using rockets

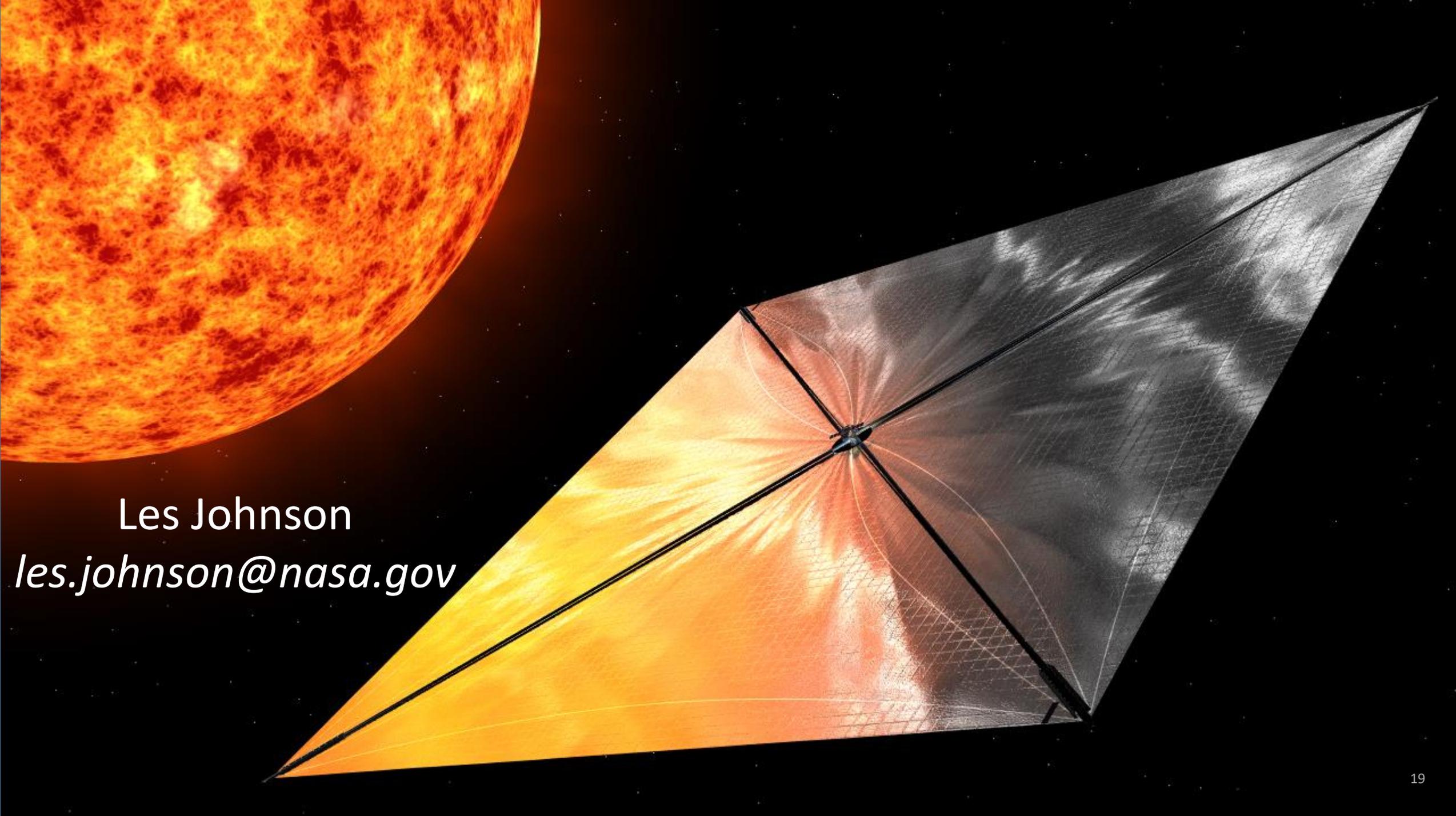


NASA Image



# Two Decades of NASA Solar Sail Development Increasing Solar Sail Capabilities





Les Johnson  
*les.johnson@nasa.gov*