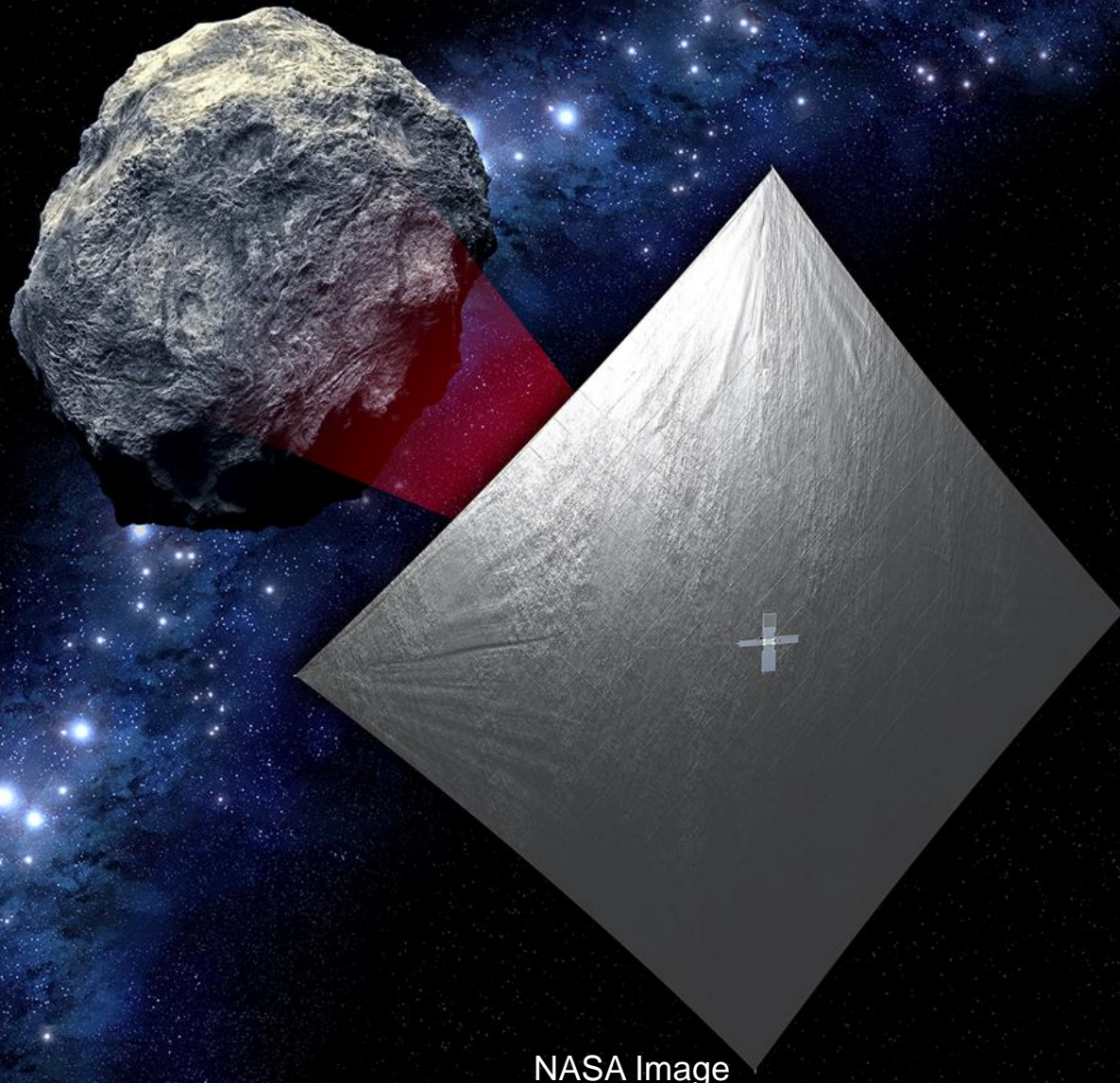




Solar Sail Propulsion for Small Spacecraft



NASA Image

Les Johnson, Tiffany Lockett,
and Alex Few

NASA

George C. Marshall Space Flight Center

les.johnson@nasa.gov



We tend to think of space as being

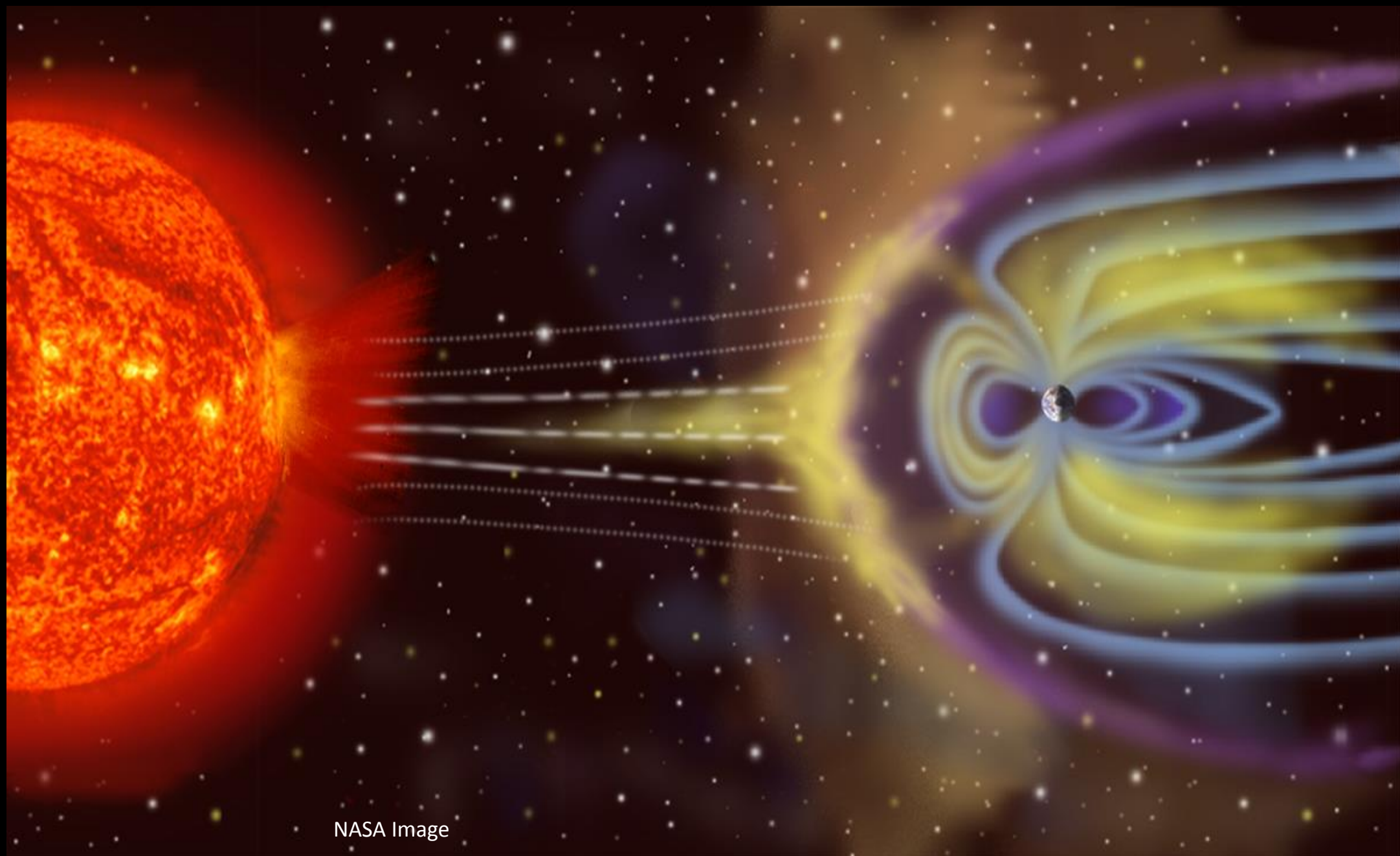
big and empty...



NASA Image



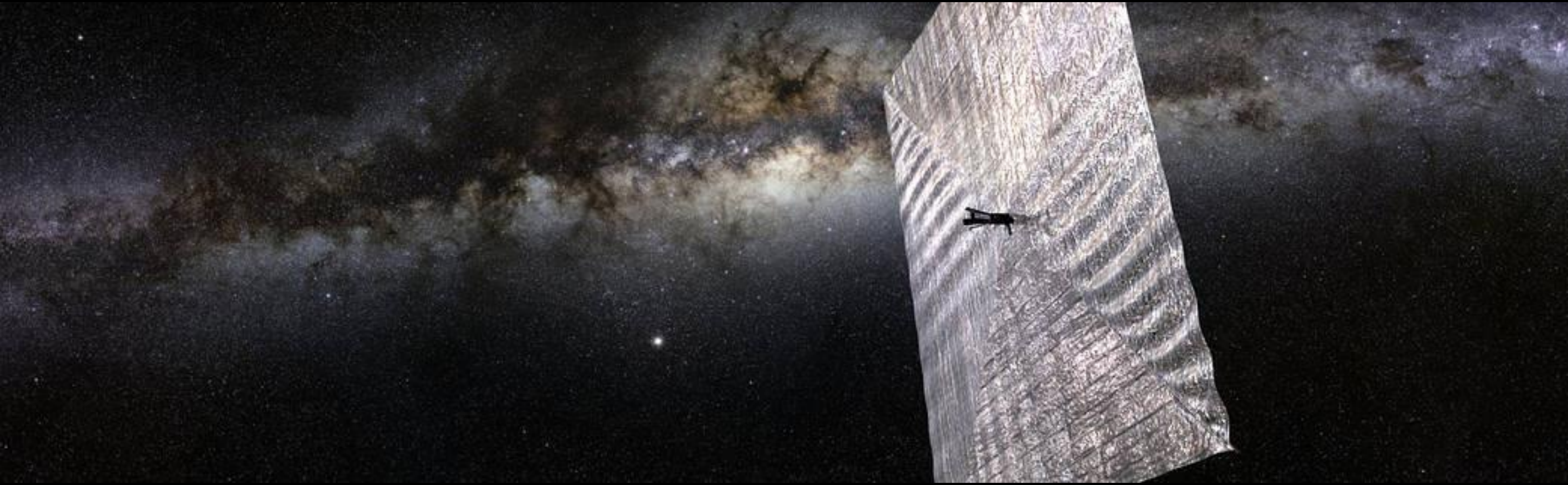
Space Is NOT Empty. We can use the environments of space to our advantage



NASA Image



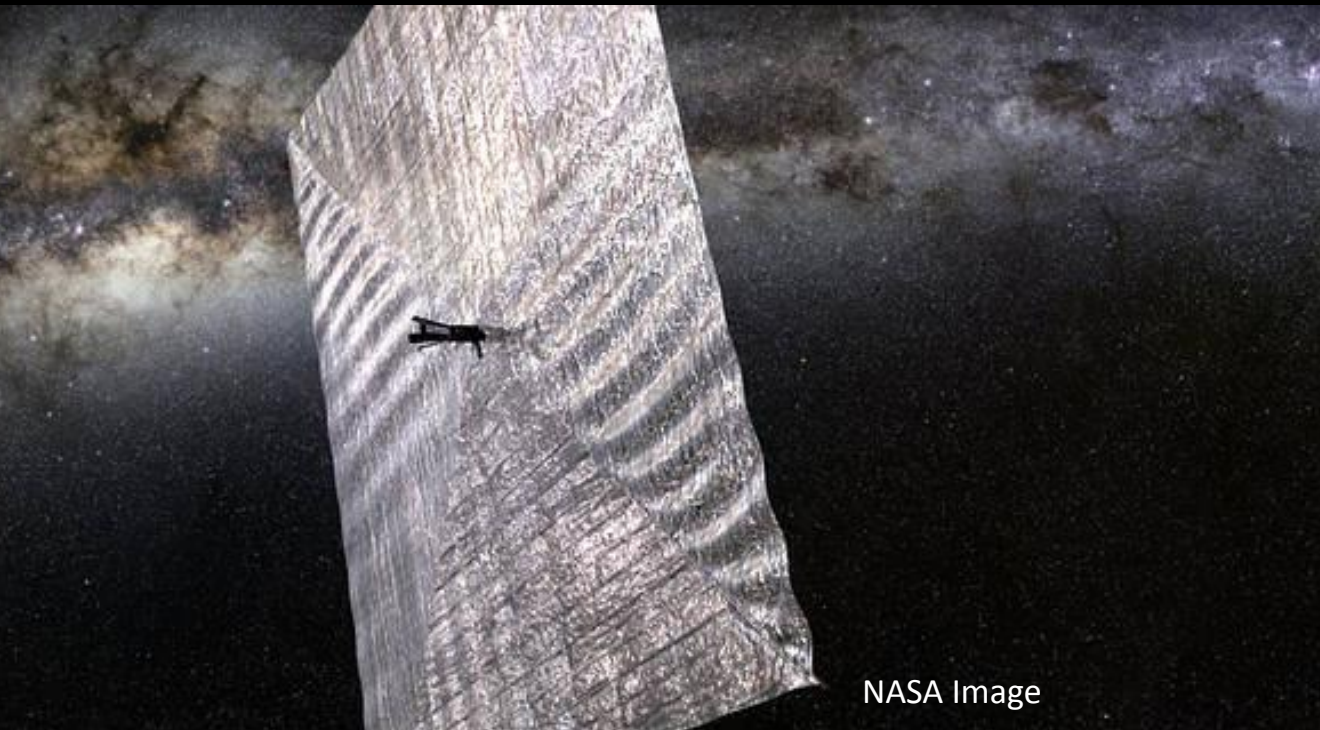
Spacecraft Can Use the Momentum of Sunlight



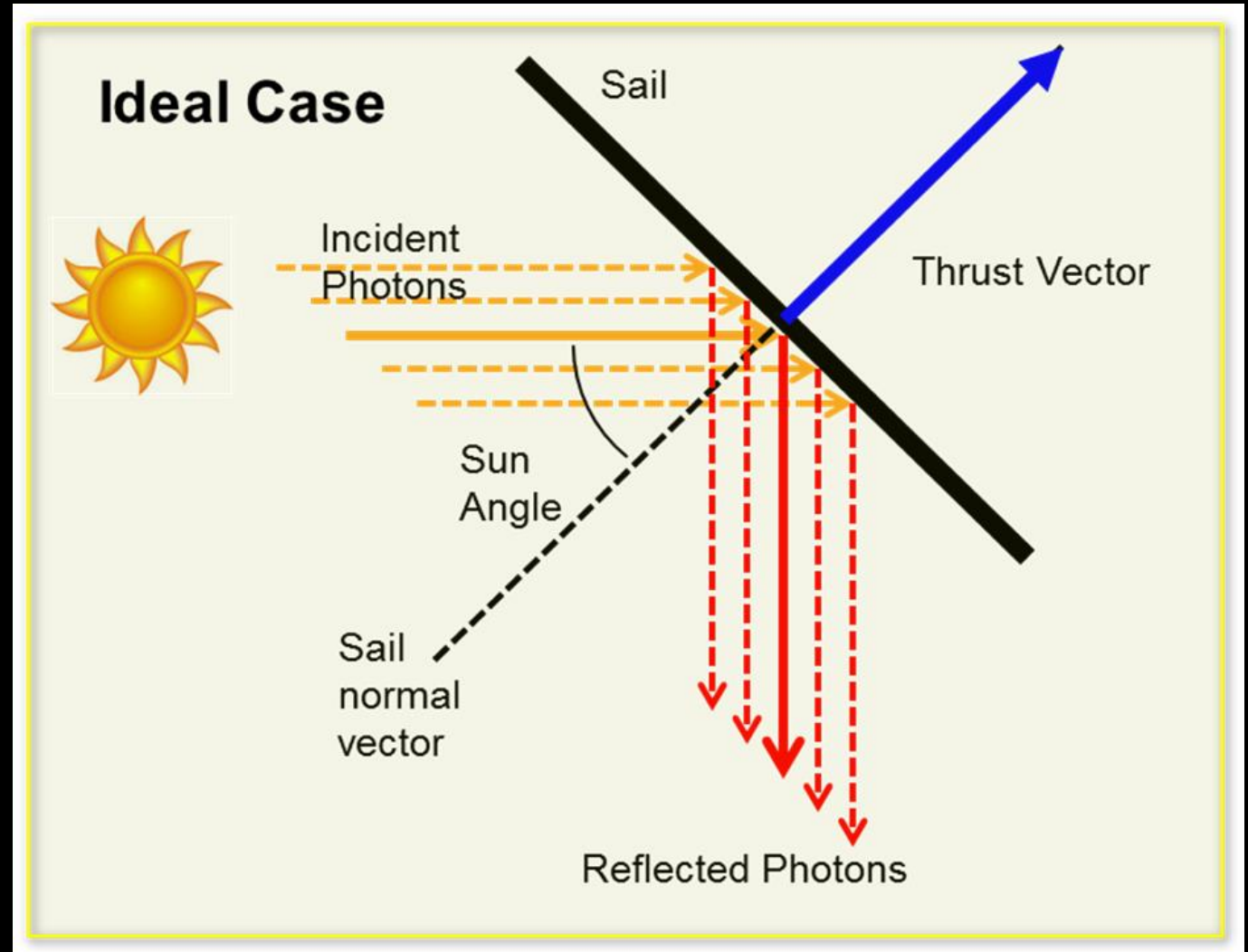


Solar Sails Derive Propulsion By Reflecting Photons

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



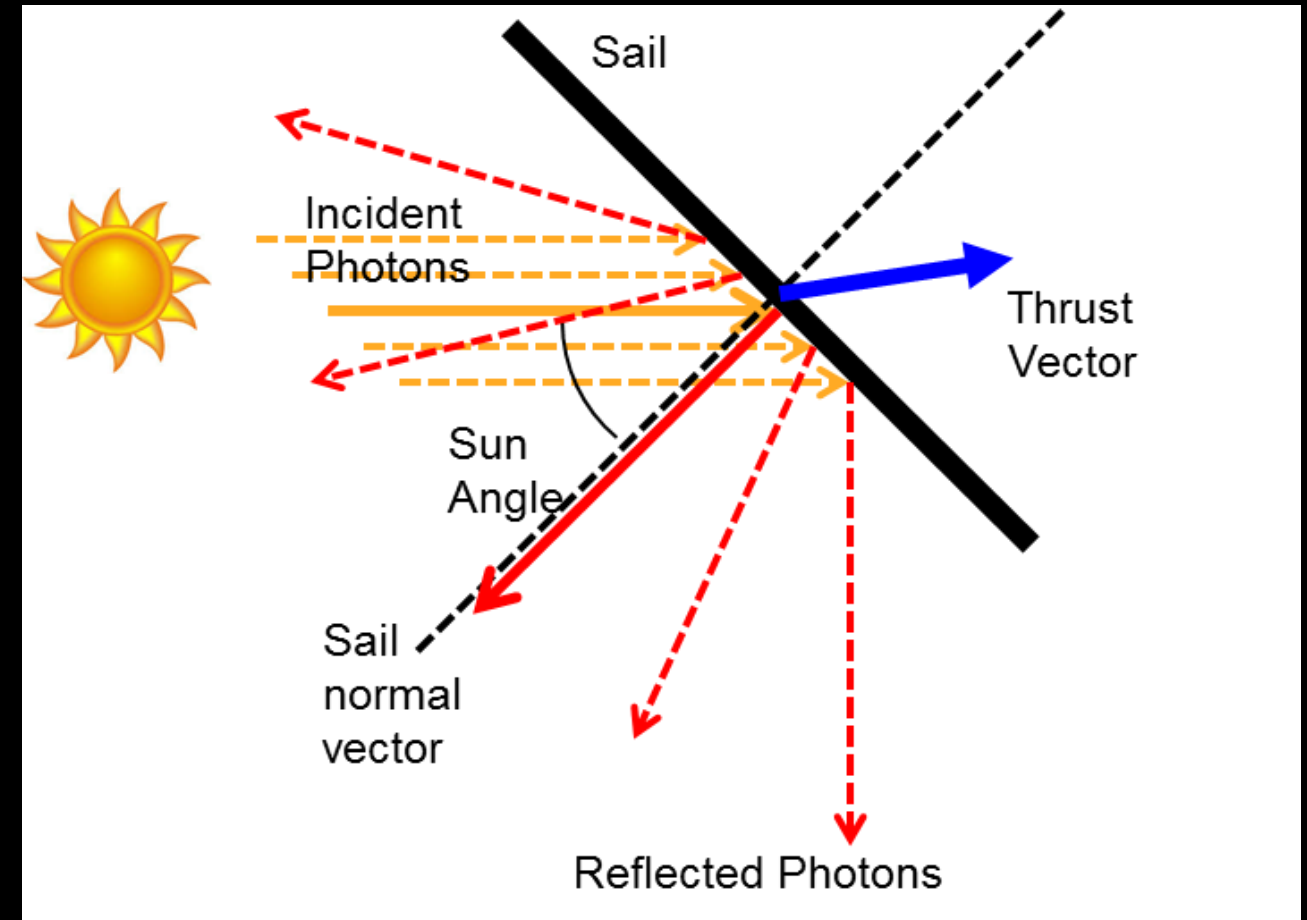
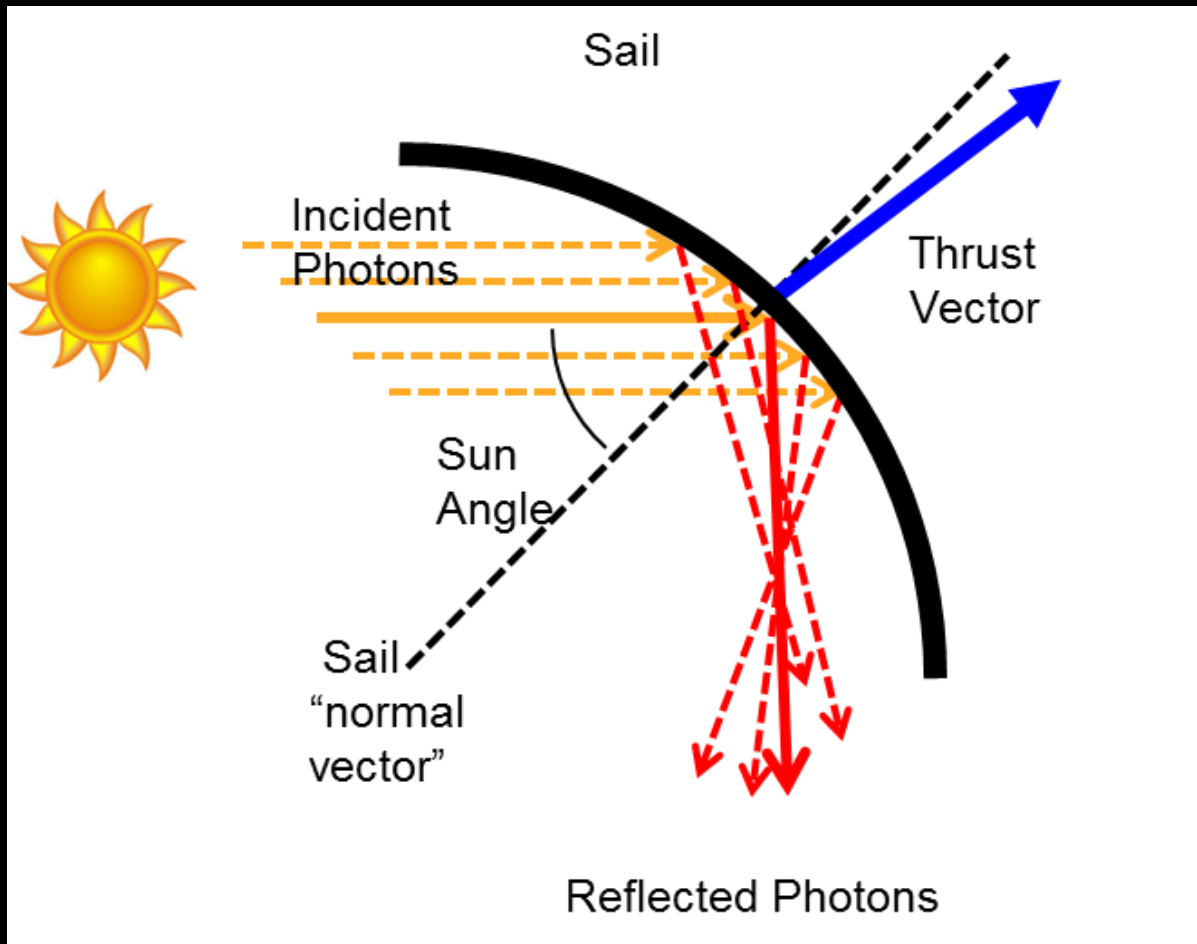
NASA Image





Real Solar Sails Are Not "Ideal"

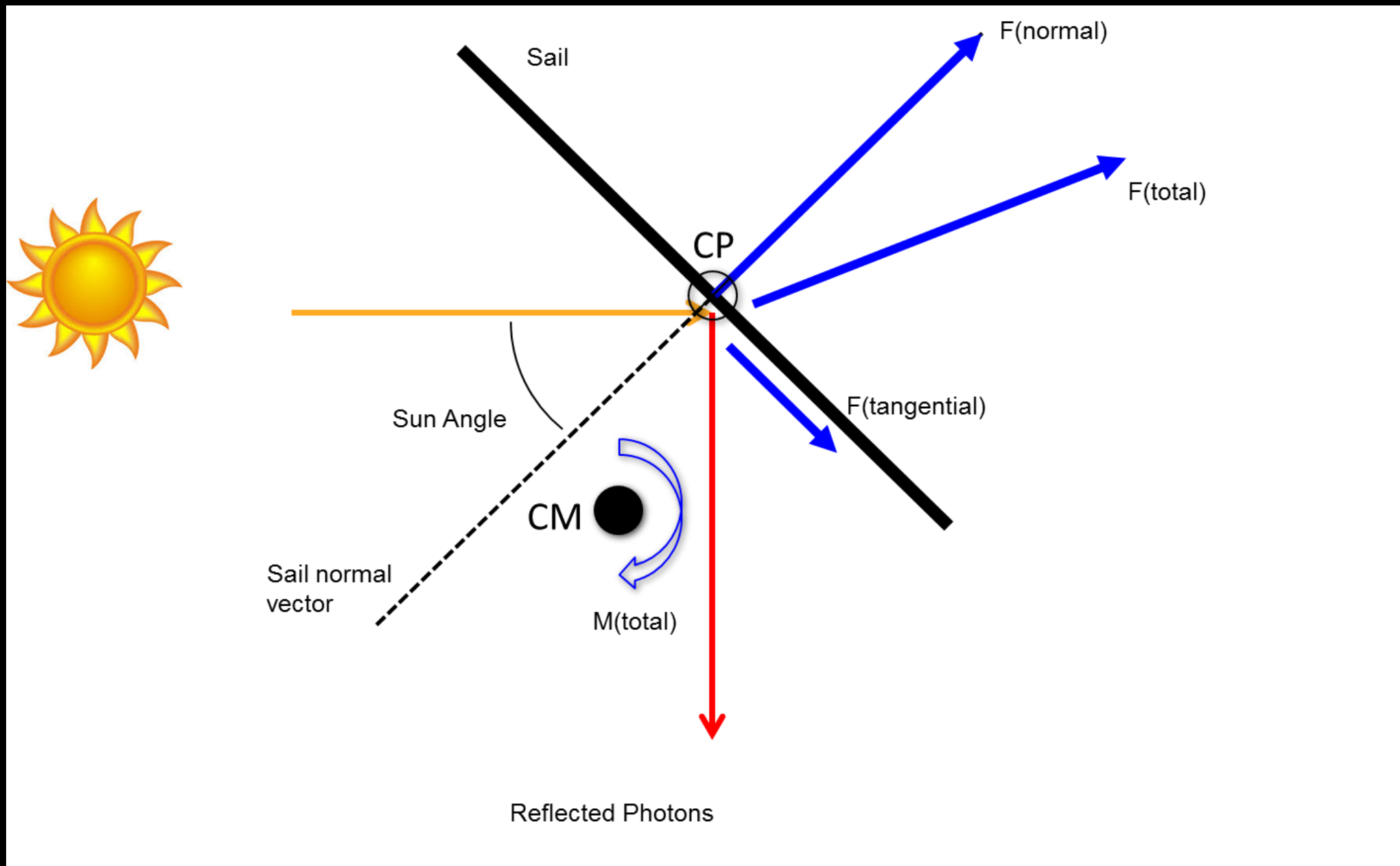
Billowed Quadrant



Diffuse Reflection



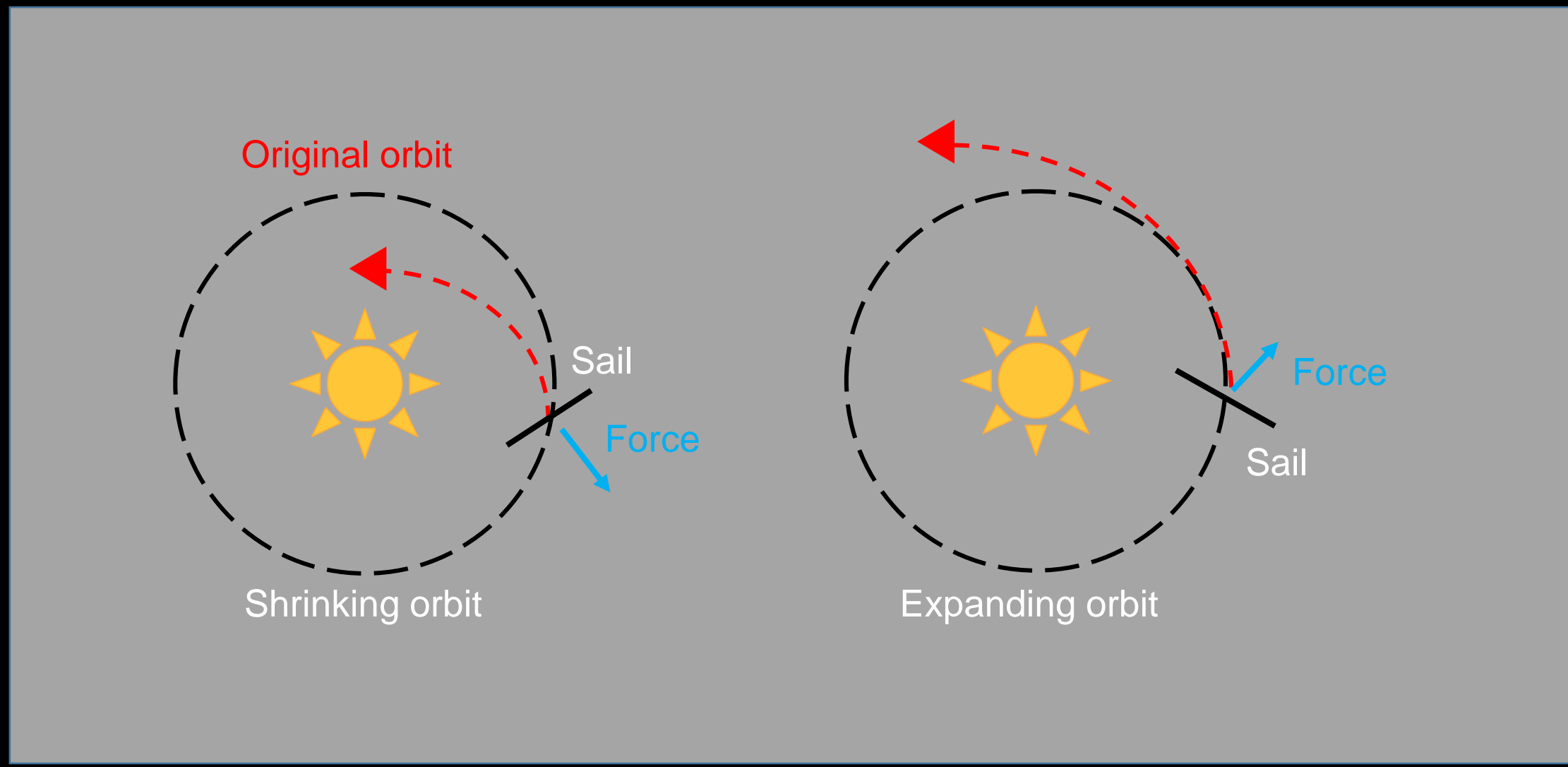
Thrust Vector Components





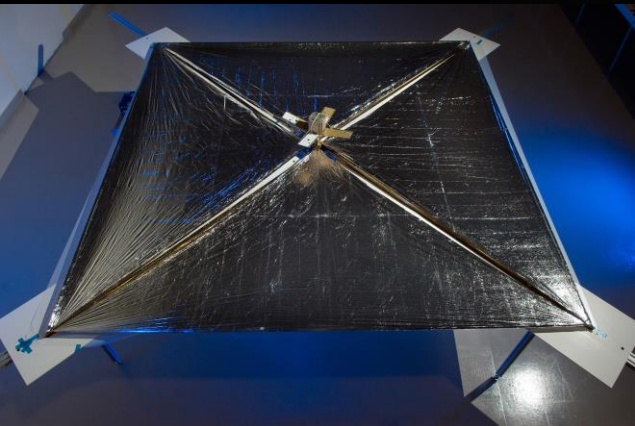
Solar Sail Trajectory Control

- Solar Radiation Pressure allows inward or outward Spiral





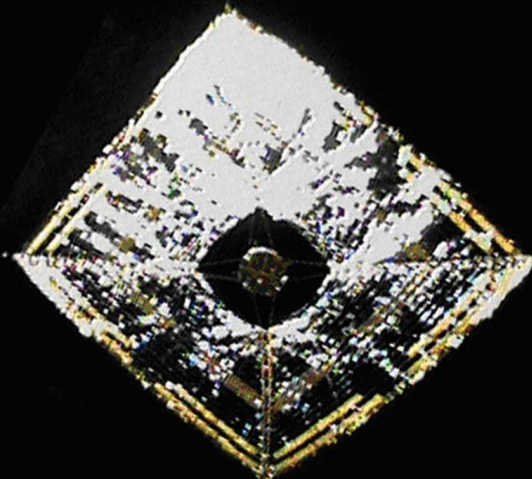
Solar Sail Missions Flown (as of May 2018)



NanoSail-D (2010)
NASA

Earth Orbit
Deployment Only

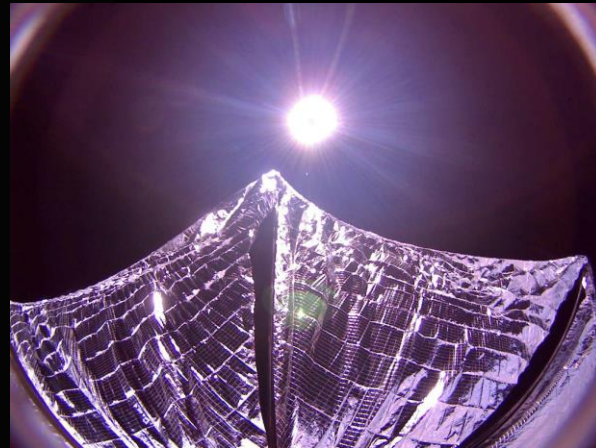
3U CubeSat
10 m²



IKAROS (2010)
JAXA

Interplanetary
Full Flight

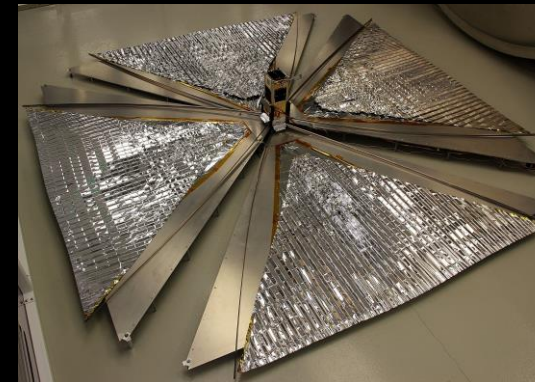
315 kg Smallsat
196 m²



LightSail-1 (2015)
The Planetary Society

Earth Orbit
Deployment Only

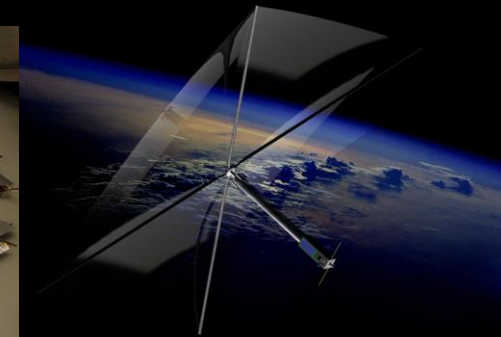
3U CubeSat
32 m²



CanX-7 (2016)
Canada

Earth Orbit
Deployment Only

3U CubeSat
<10 m²



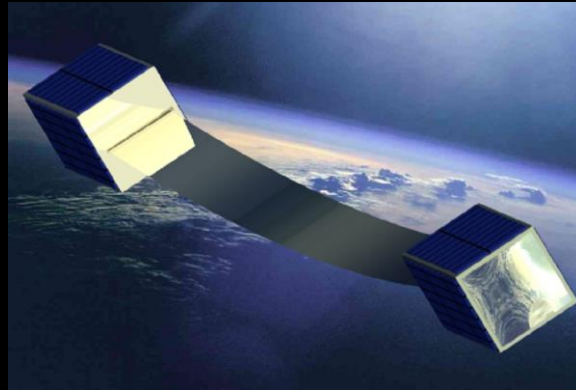
InflateSail (2017)
EU/Univ. of Surrey

Earth Orbit
Deployment Only

3U CubeSat
10 m²



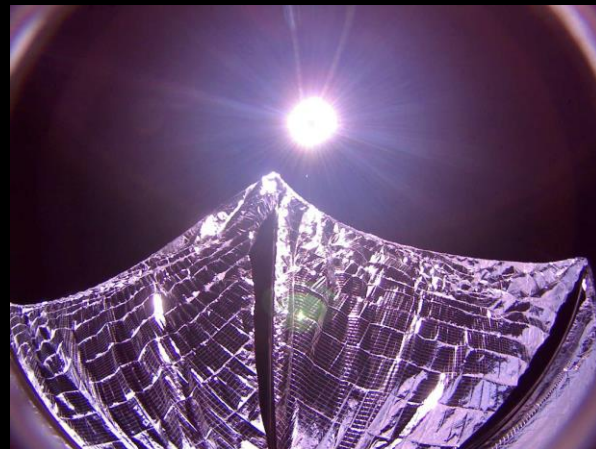
Planned Solar Sail Missions (as of April 11, 2018)



CU Aerospace (2018)
Univ. Illinois / NASA

Earth Orbit
Full Flight

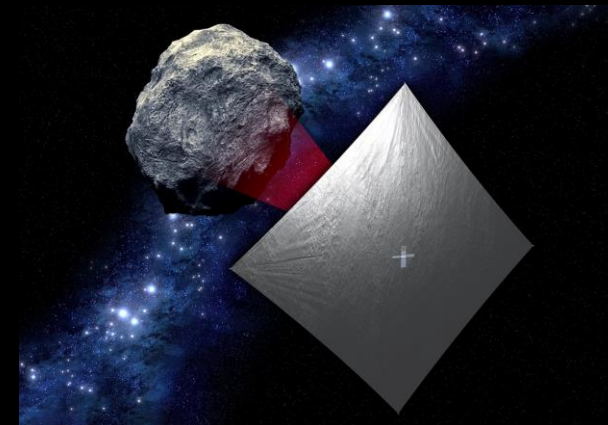
3U CubeSat
20 m²



LightSail-2 (2018)
The Planetary Society

Earth Orbit
Full Flight

3U CubeSat
32 m²



Near Earth Asteroid Scout (2019) NASA

Interplanetary
Full Flight

6U CubeSat
86 m²



NASA's Near Earth Asteroid Scout

The Near Earth Asteroid Scout Will:

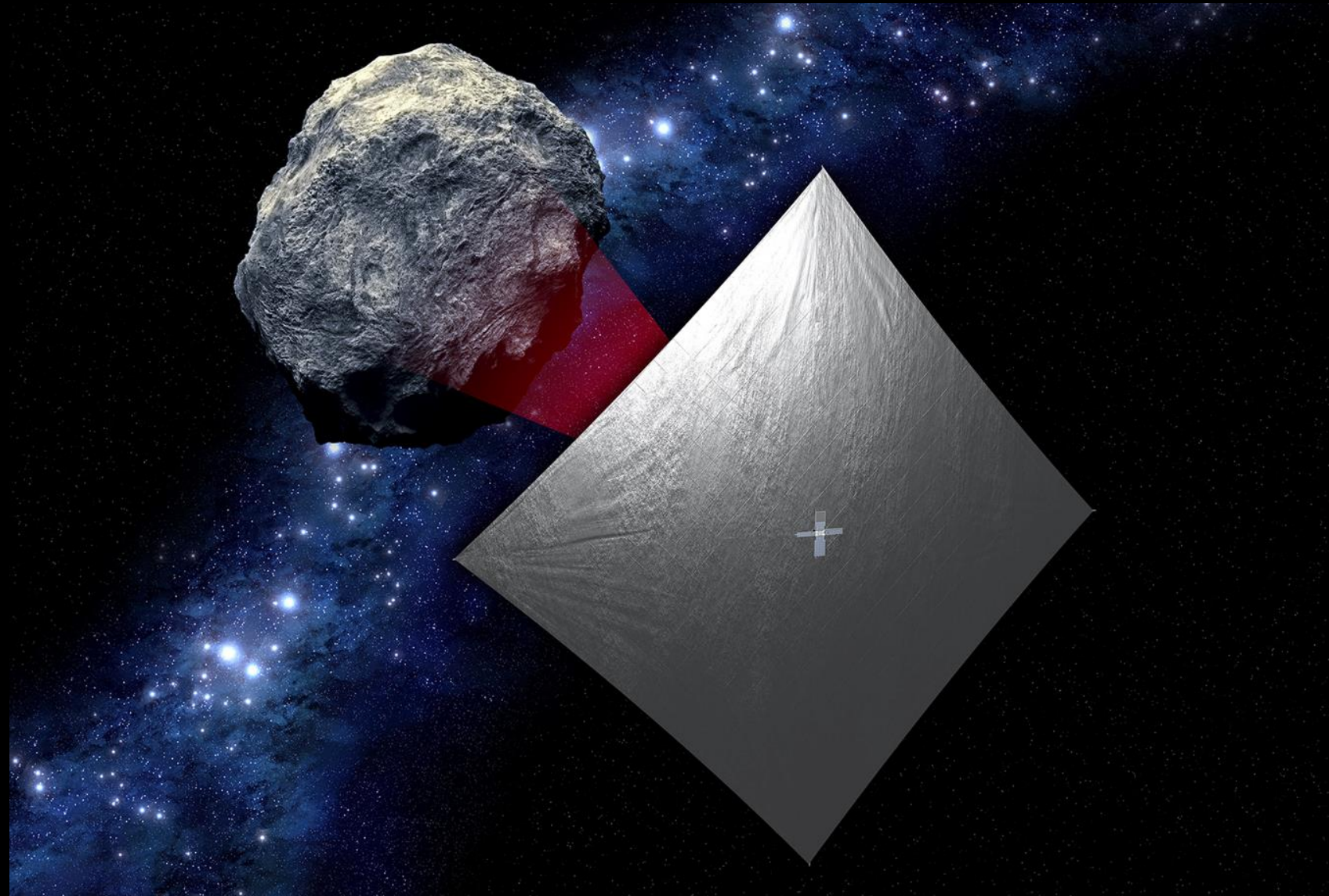
- Image/characterize a NEA during a slow flyby
- Demonstrate a low cost asteroid reconnaissance capability

Key Spacecraft & Mission Parameters

- 6U cubesat (20 cm X 10 cm X 30 cm)
- ~86 m² solar sail propulsion system
- Manifested for launch on the Space Launch System (EM-1/2019)
- Up to 2.5 year mission duration
- 1 AU maximum distance from Earth

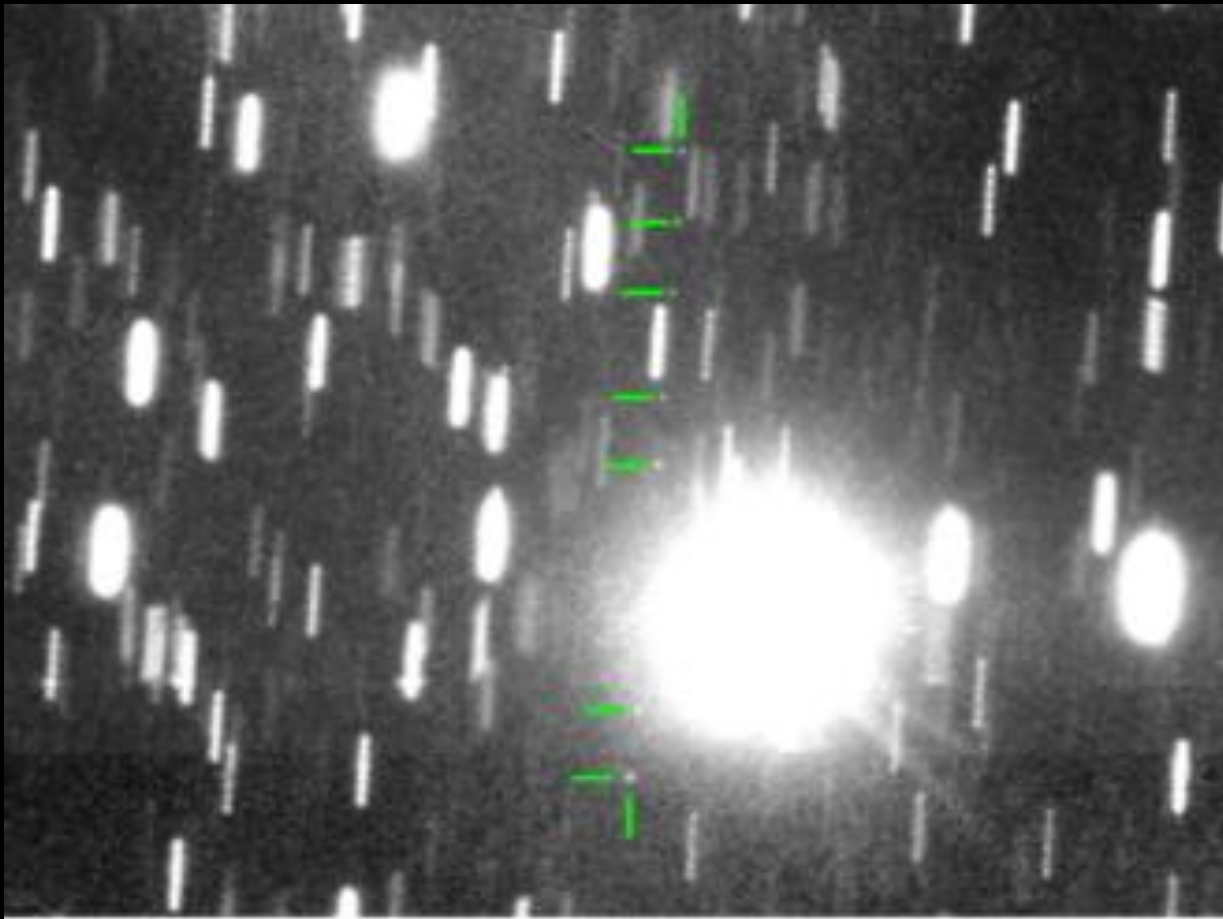
Solar Sail Propulsion System Characteristics

- ~ 7.3 m Trac booms
- 2.5 μ aluminized CP-1 substrate
- > 90% reflectivity





Baseline Target Asteroid: 1991 VG



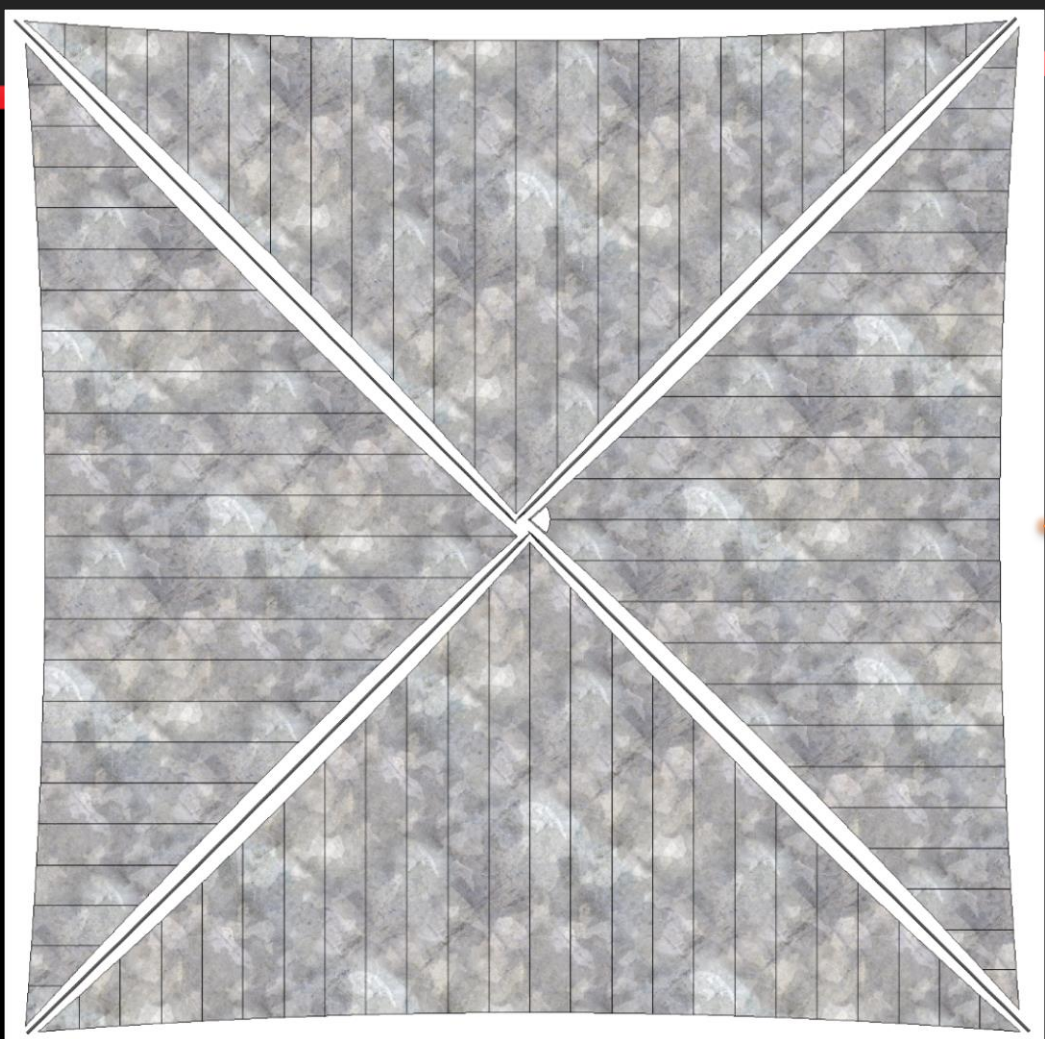
- Diameter ~ 5 -12 meters
- Rotation period between a few minutes and less than 1 hour
- Unlikely to have a companion
- Unlikely to retain an exosphere or dust cloud
 - Solar radiation pressure sweeps dust on timescales of hours or day

Near-Earth Asteroid 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



NEA Scout Approximate Scale

Deployed Solar Sail



School Bus



6U Stowed Flight System



Folded, spooled and packaged in here

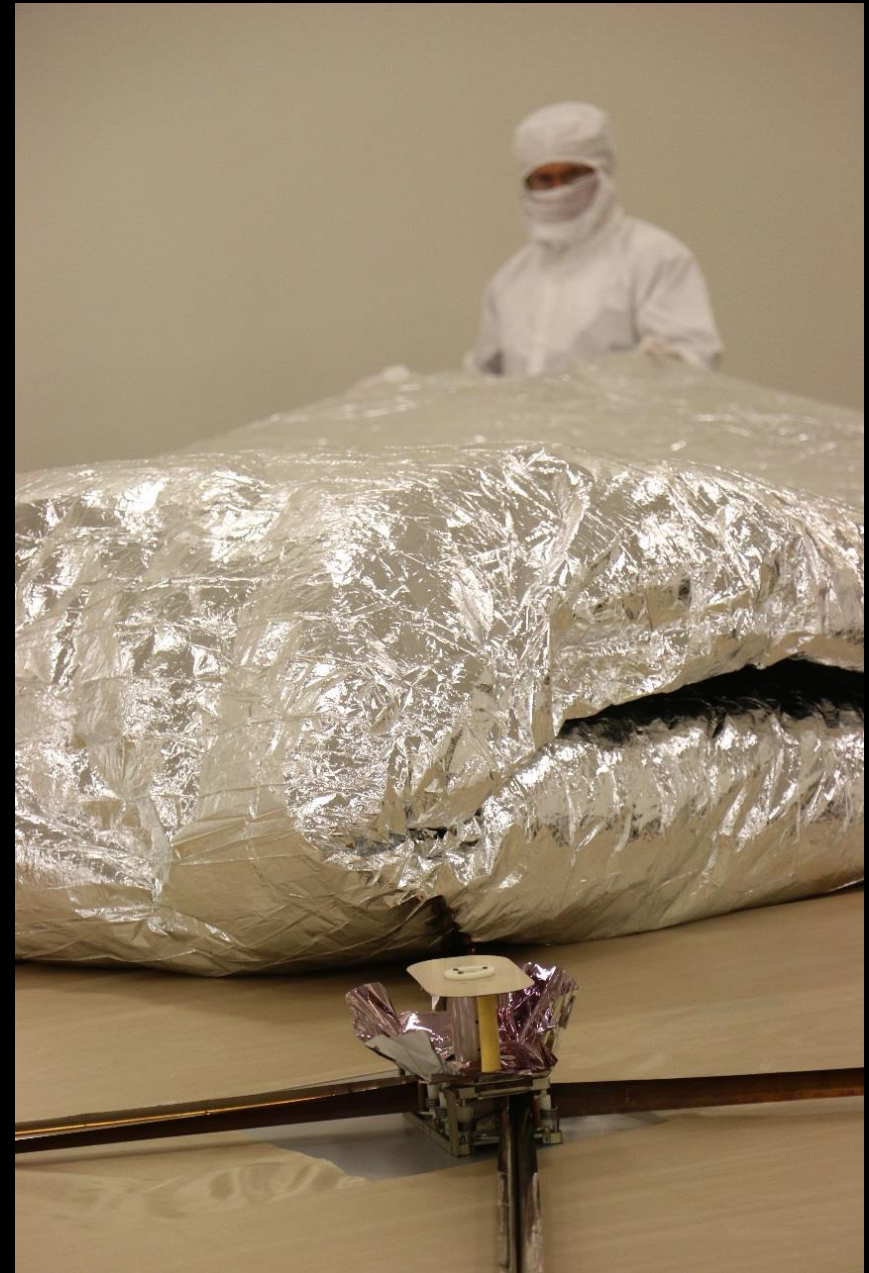


NASA's Near Earth Asteroid Scout Full Scale Successful Deployment



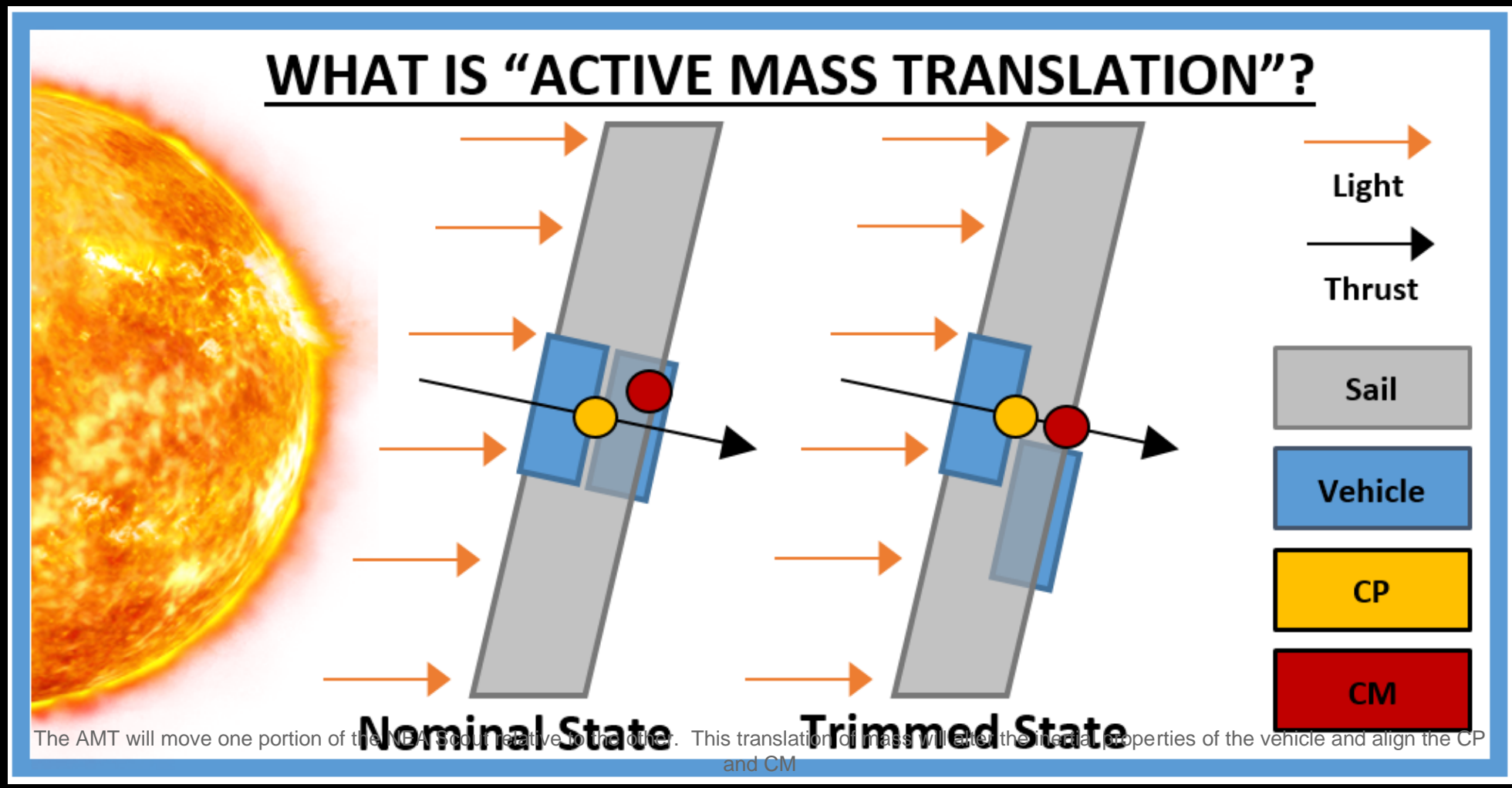


NASA's Near Earth Asteroid Scout Hardware





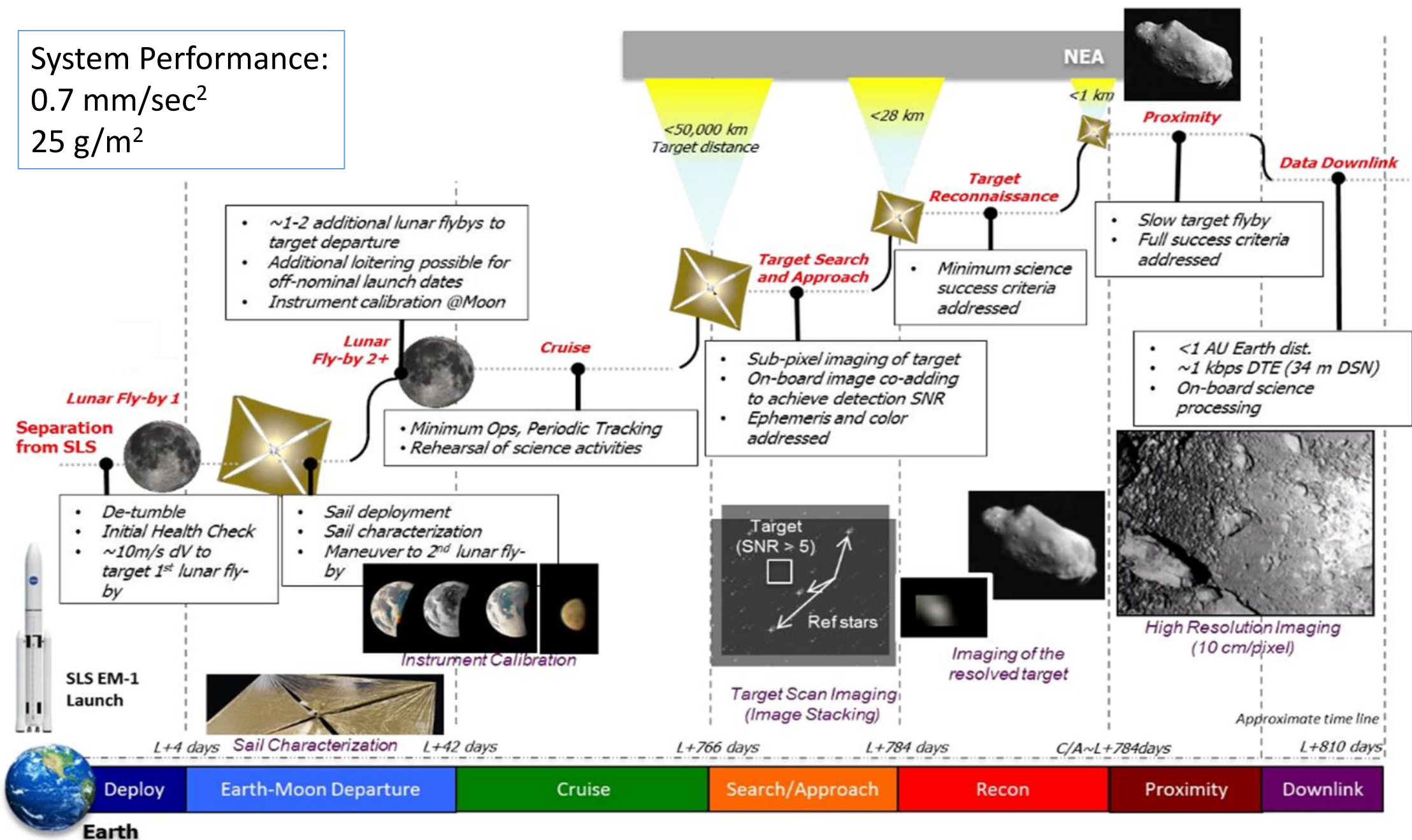
The Need for CM/CP Adjustment





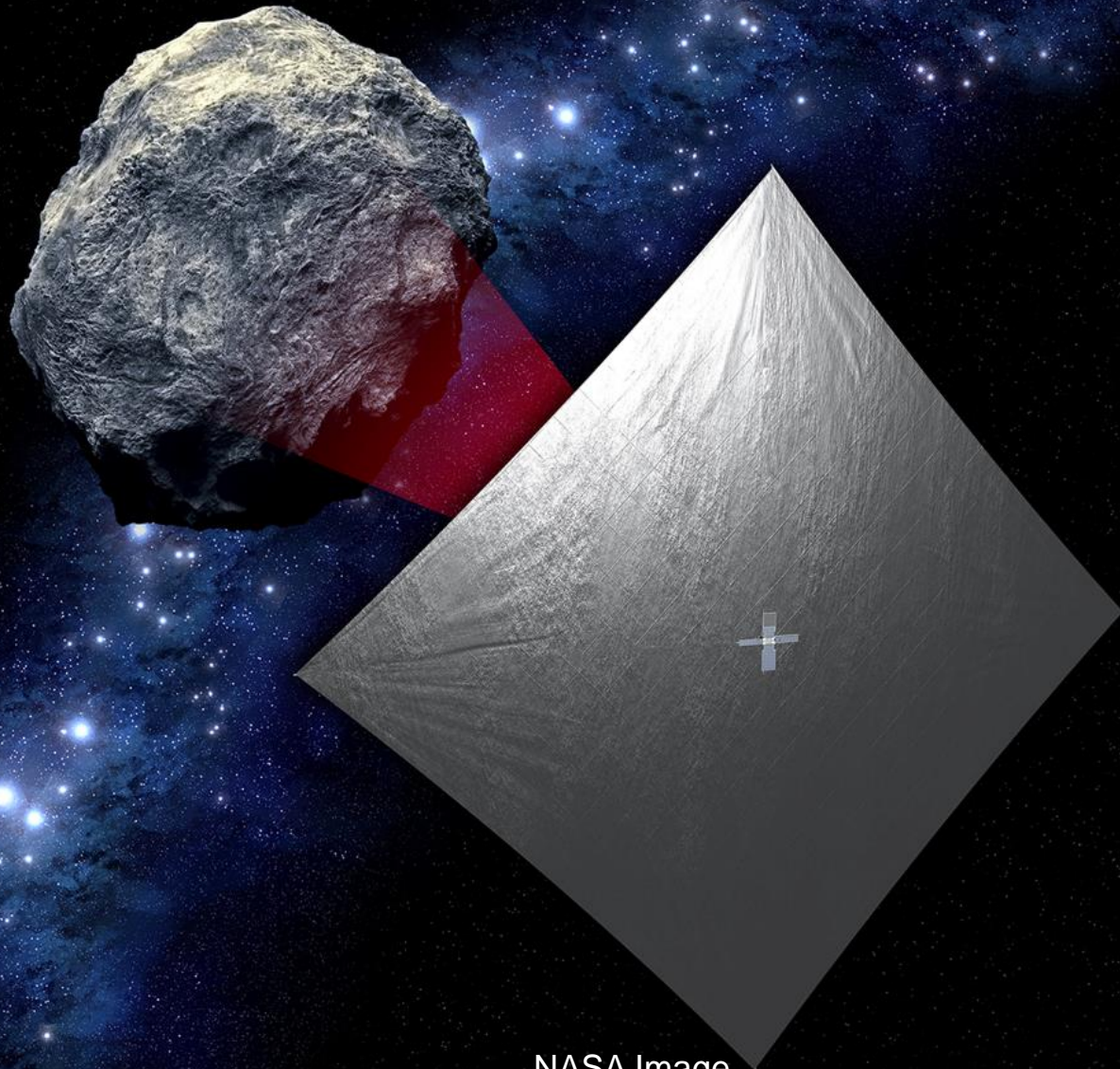
NEA Scout – Mission Overview

System Performance:
 0.7 mm/sec²
 25 g/m²





Solar Sail Propulsion for Small Spacecraft



Questions?