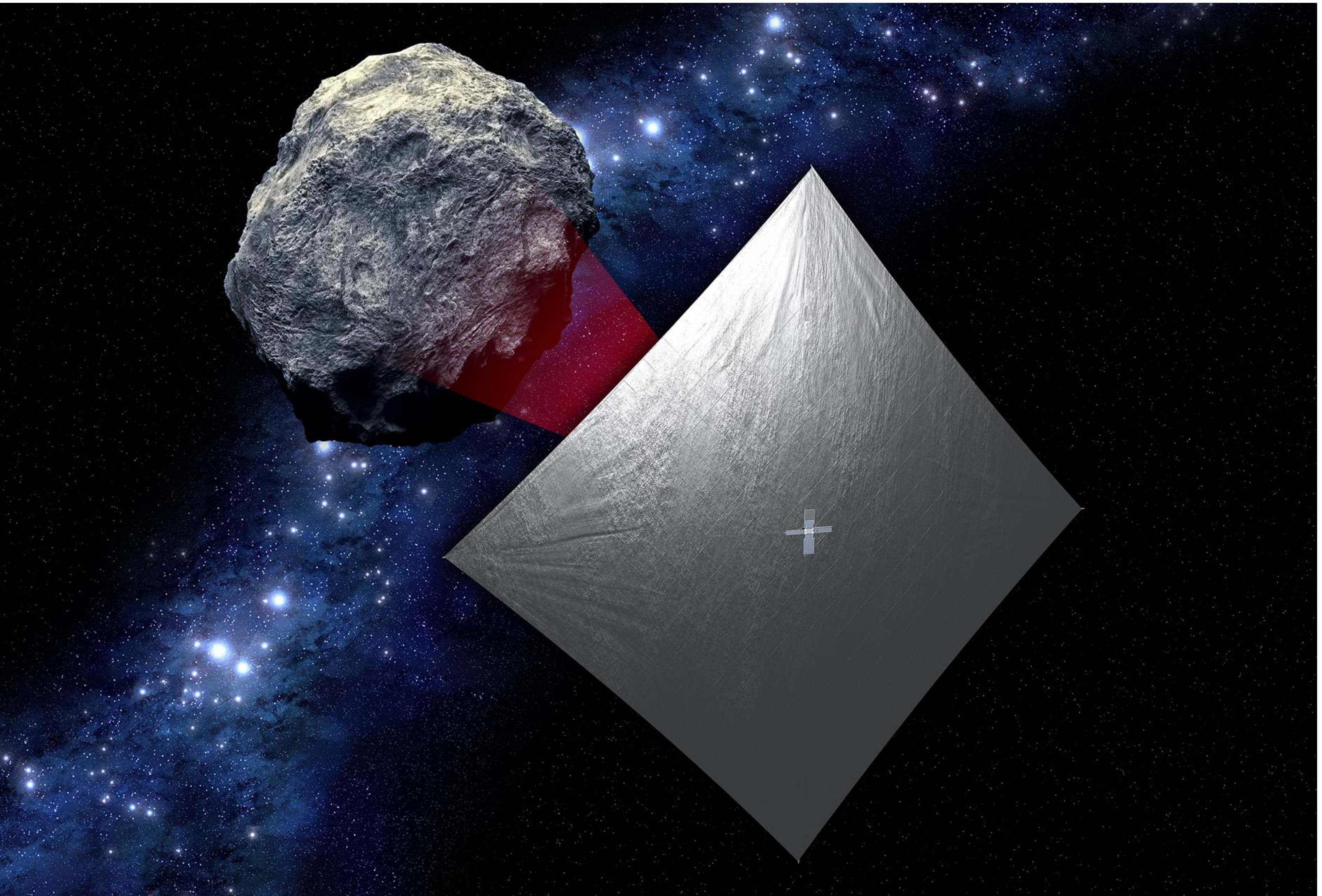
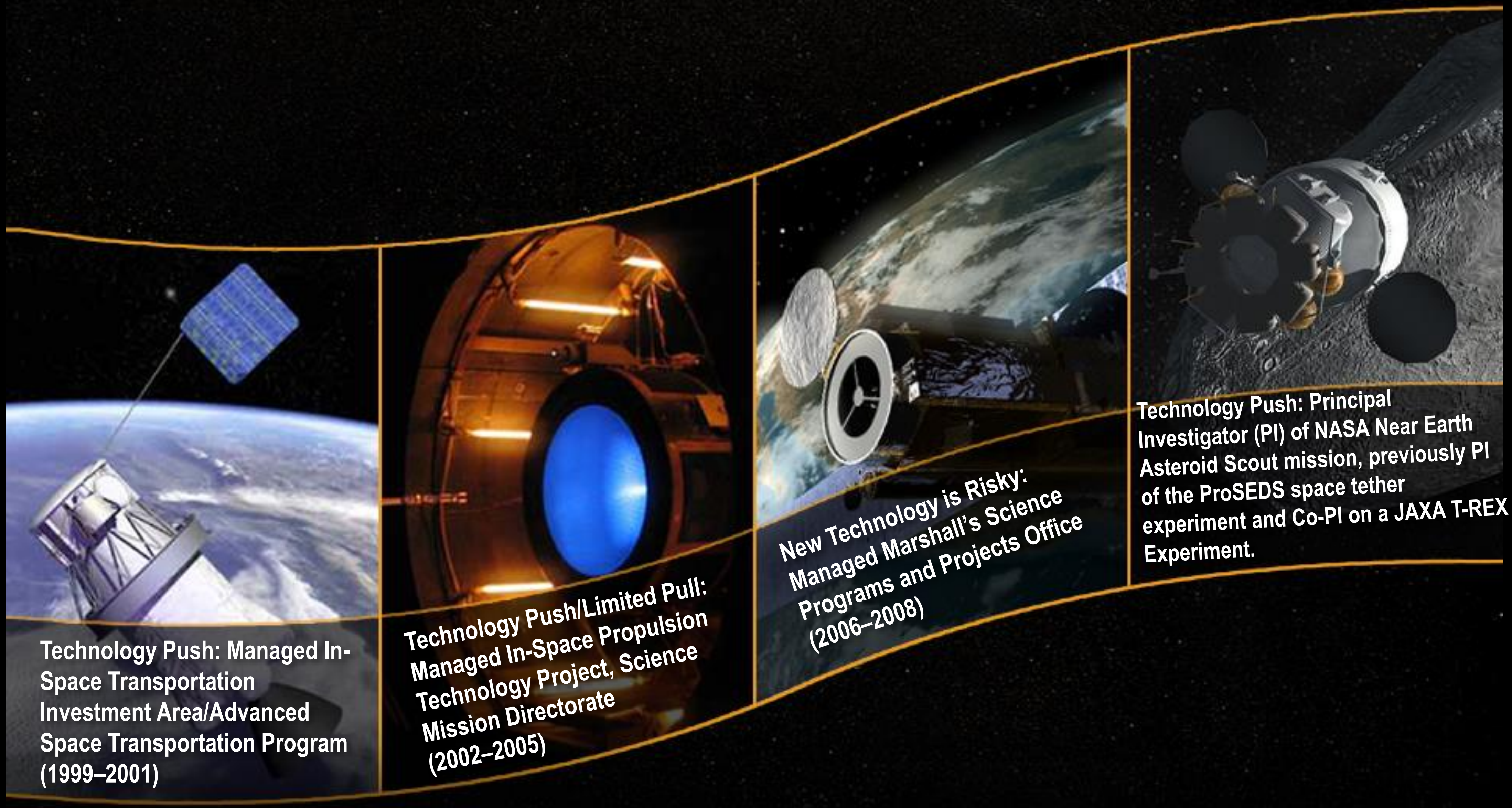
Solar Sail Propulsion



July 26, 2018

Les Johnson
Science and Technology Office

A Bit About Me: The Long and Winding Road

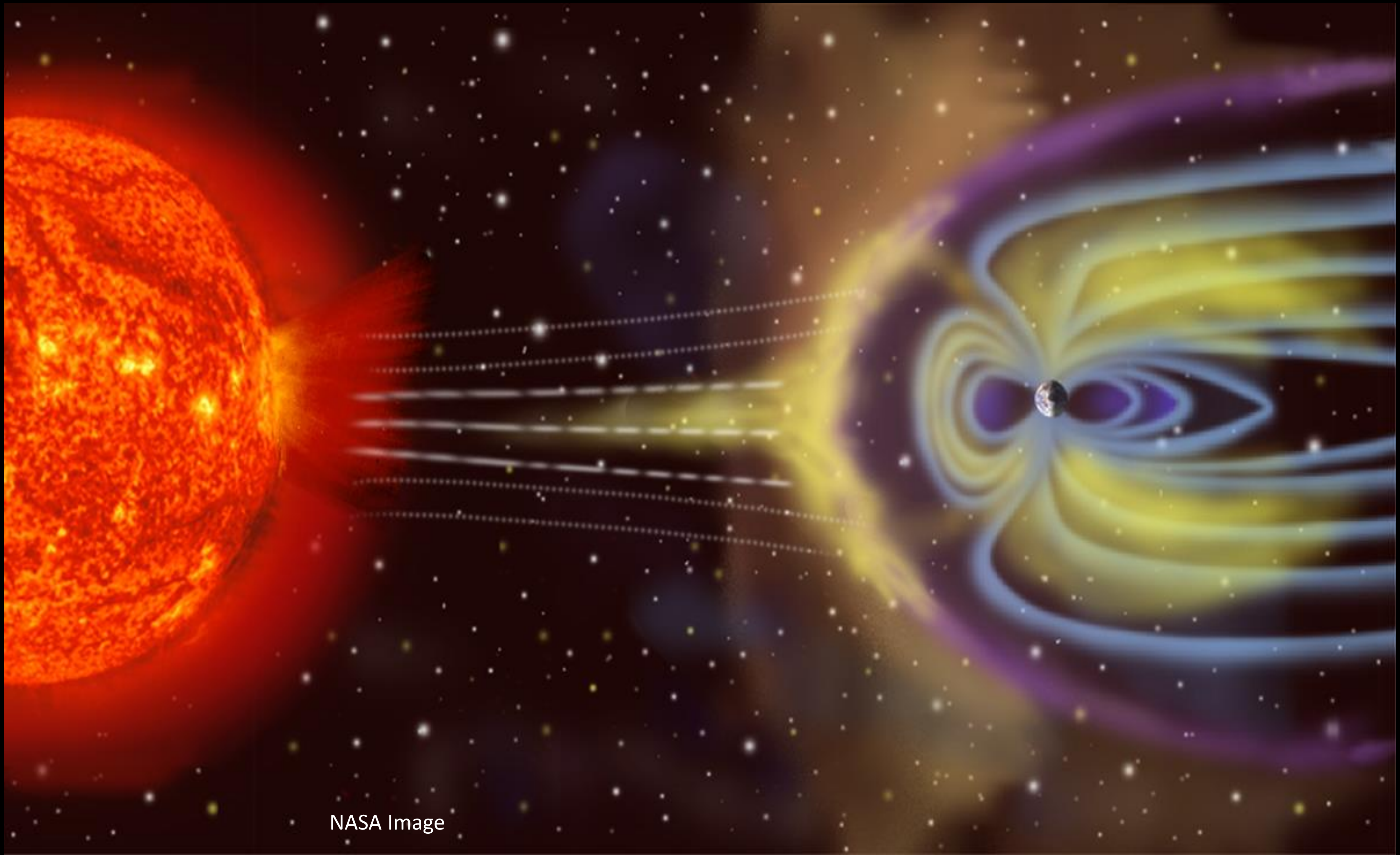


Within NASA, your acceptance of new technologies depends upon where you sit.

We tend to think of space as being

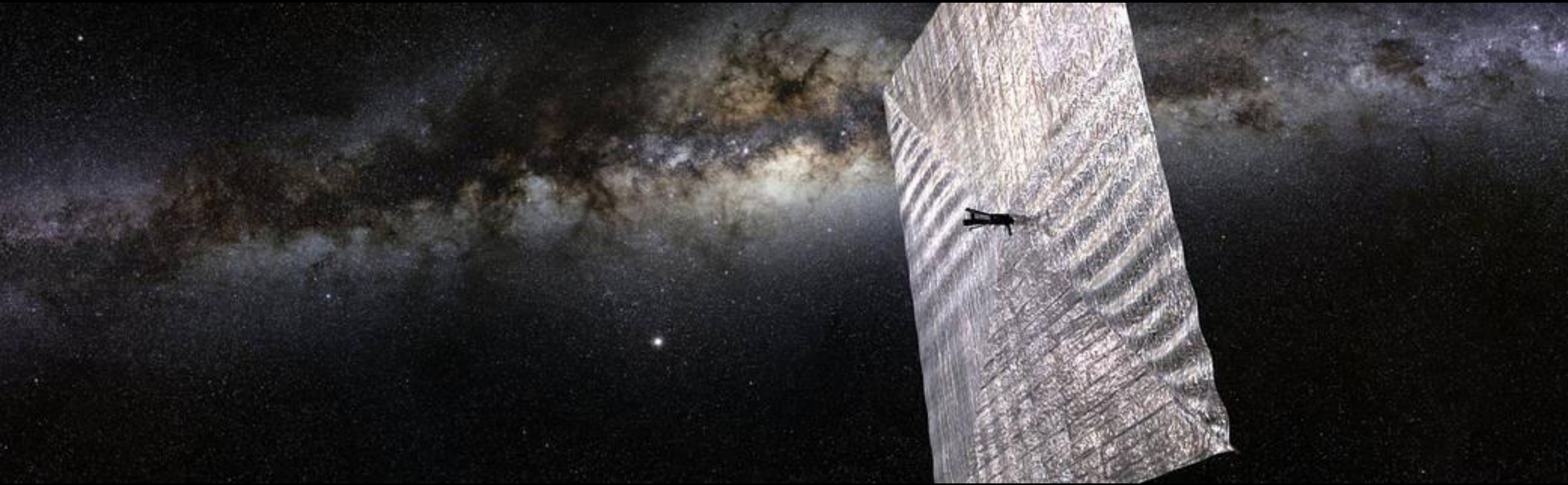
NASA Image

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



Just As Sailing Ships Can Use the Momentum of the Wind

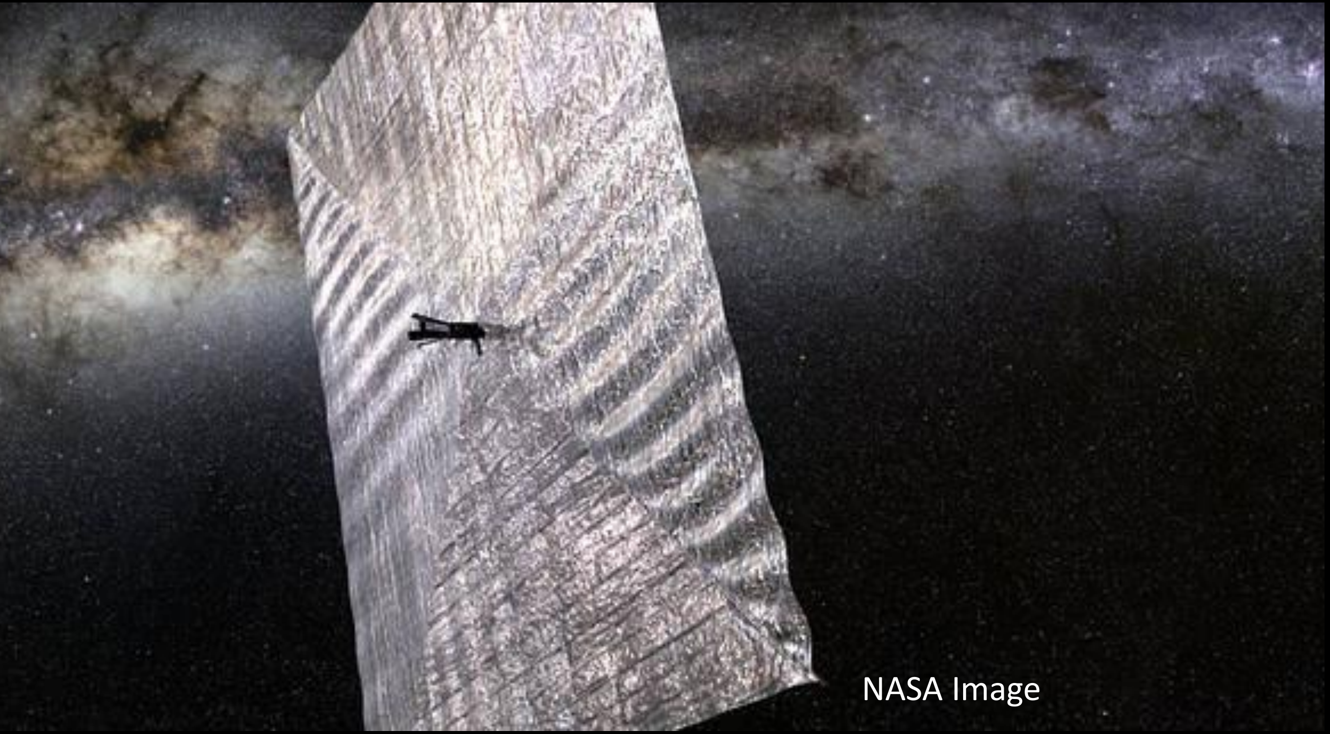
Spacecraft Can Use the Momentum of Sunlight



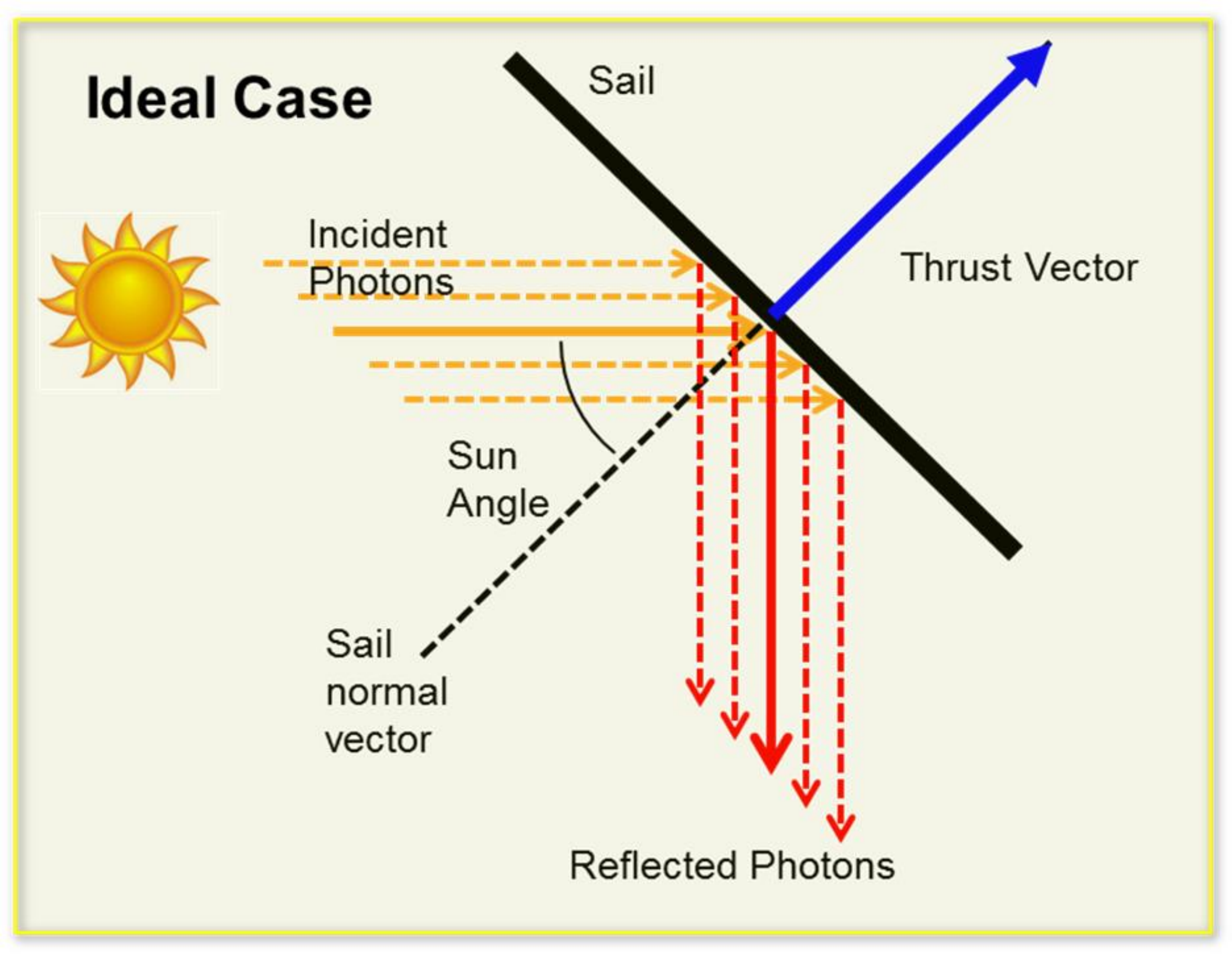
NASA Image

Solar Sails Derive Propulsion By Reflecting Photons

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

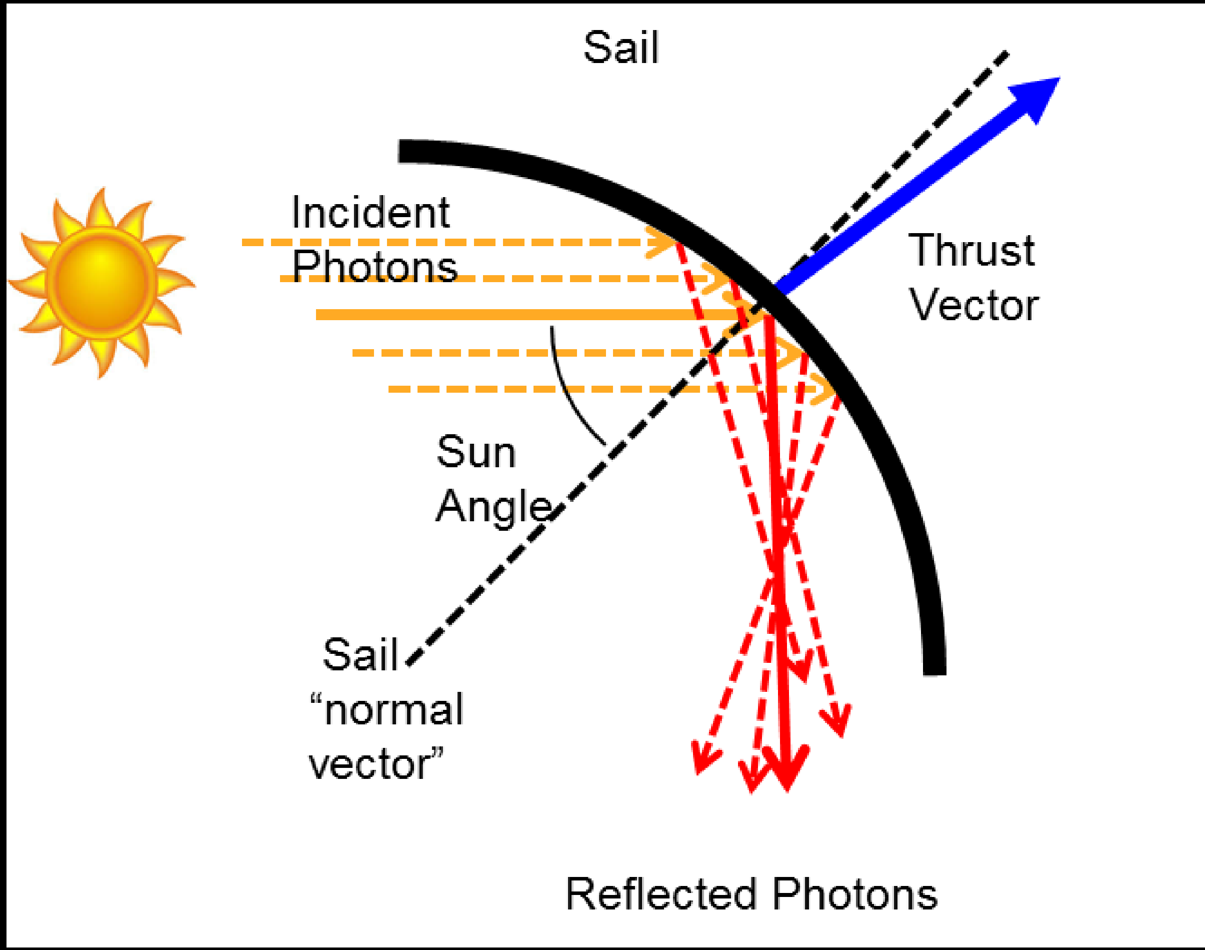


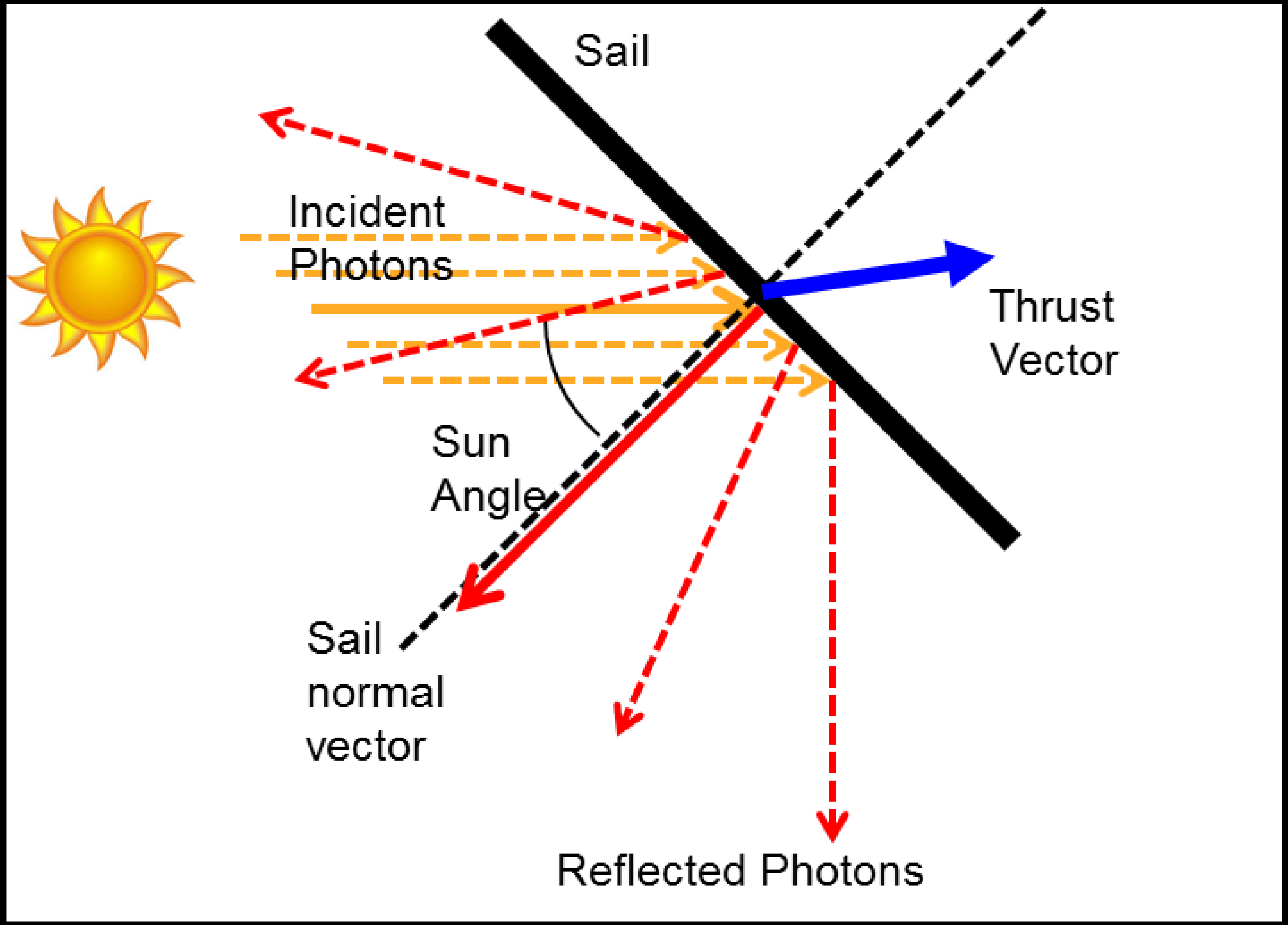
NASA Image



Real Solar Sails Are Not "Ideal"

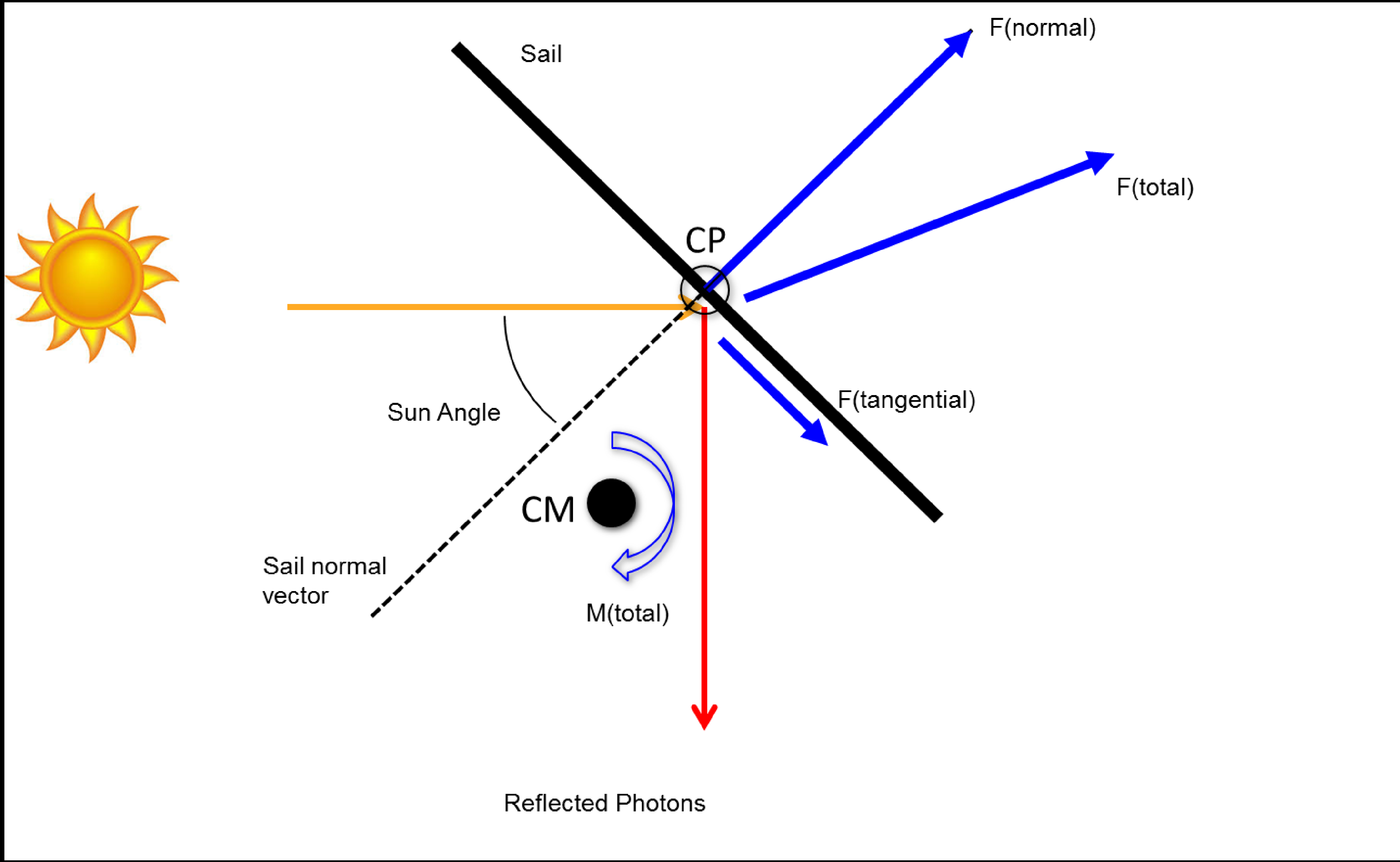
Billowed Quadrant





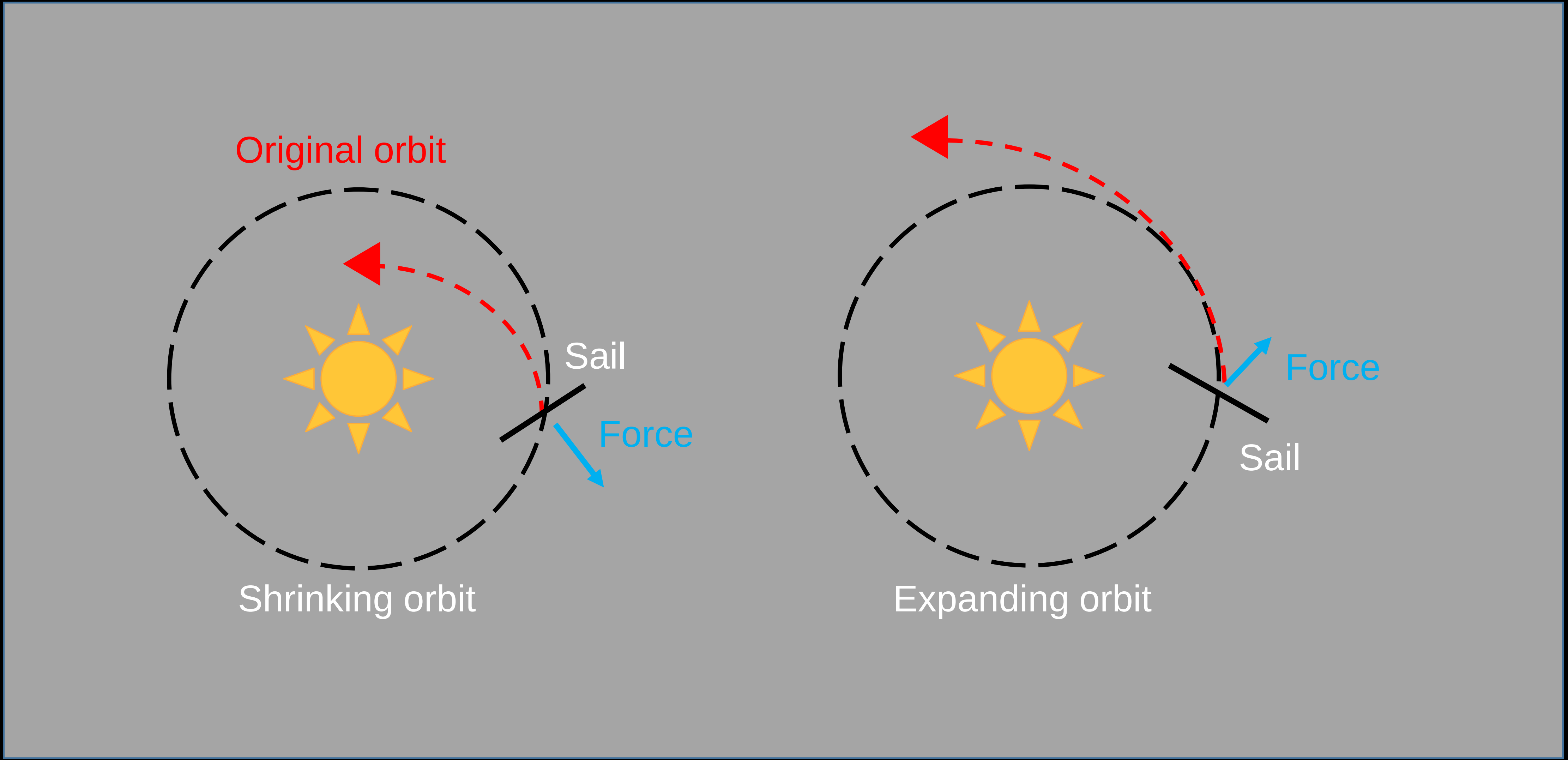
Diffuse Reflection

Thrust Vector Components



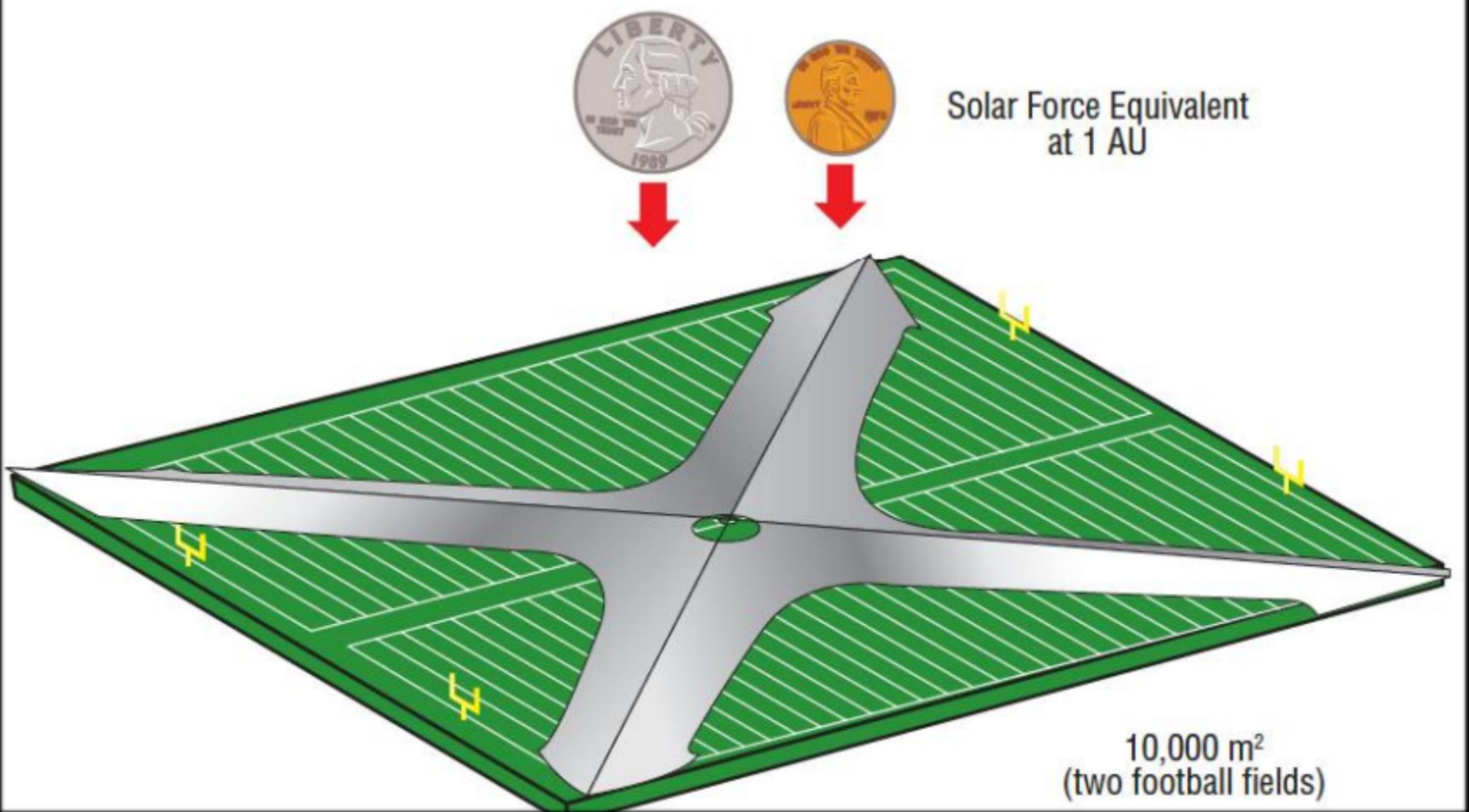
Solar Sail Trajectory Control

- Solar Radiation Pressure allows inward or outward Spiral



Solar Sails Experience **VERY** Small Forces

- **Force on a 100 m x 100 m square sail:**

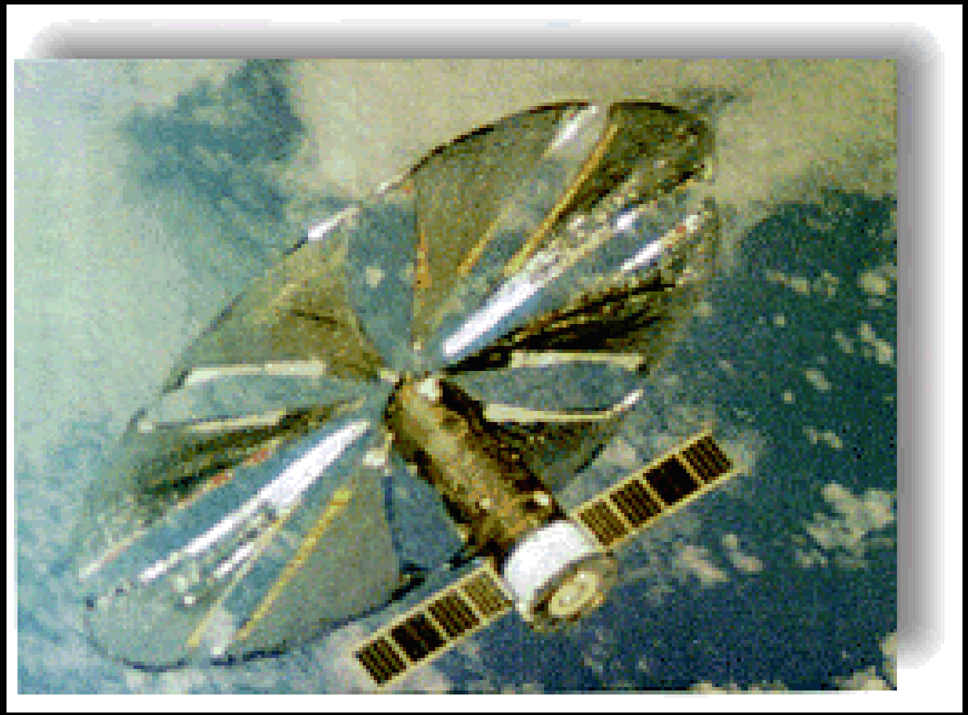


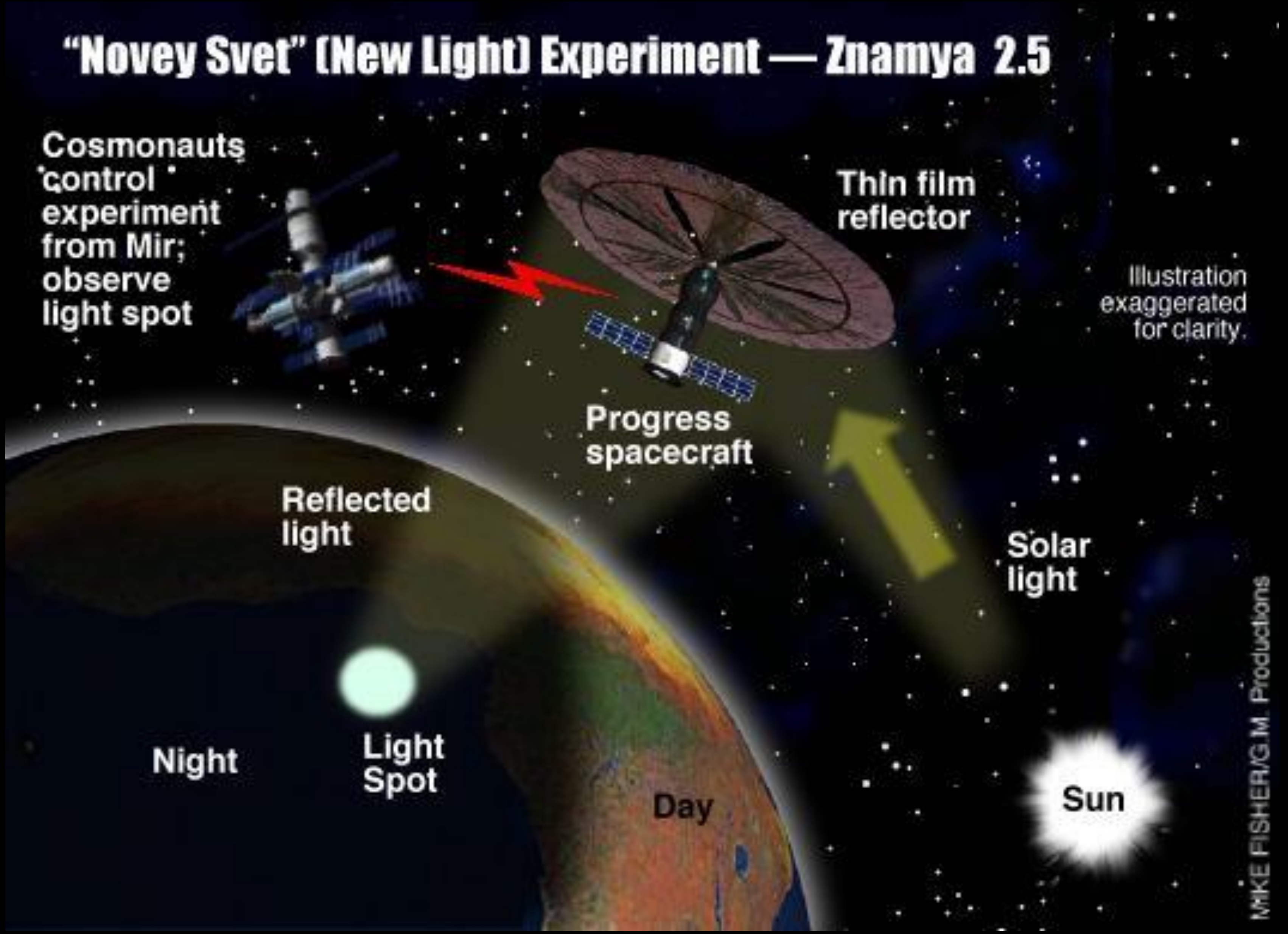
Echo II 1964
Solar thrust effect on spacecraft orbit

When folded, the satellite was packed into the 41-inch diameter canister shown in the foreground.

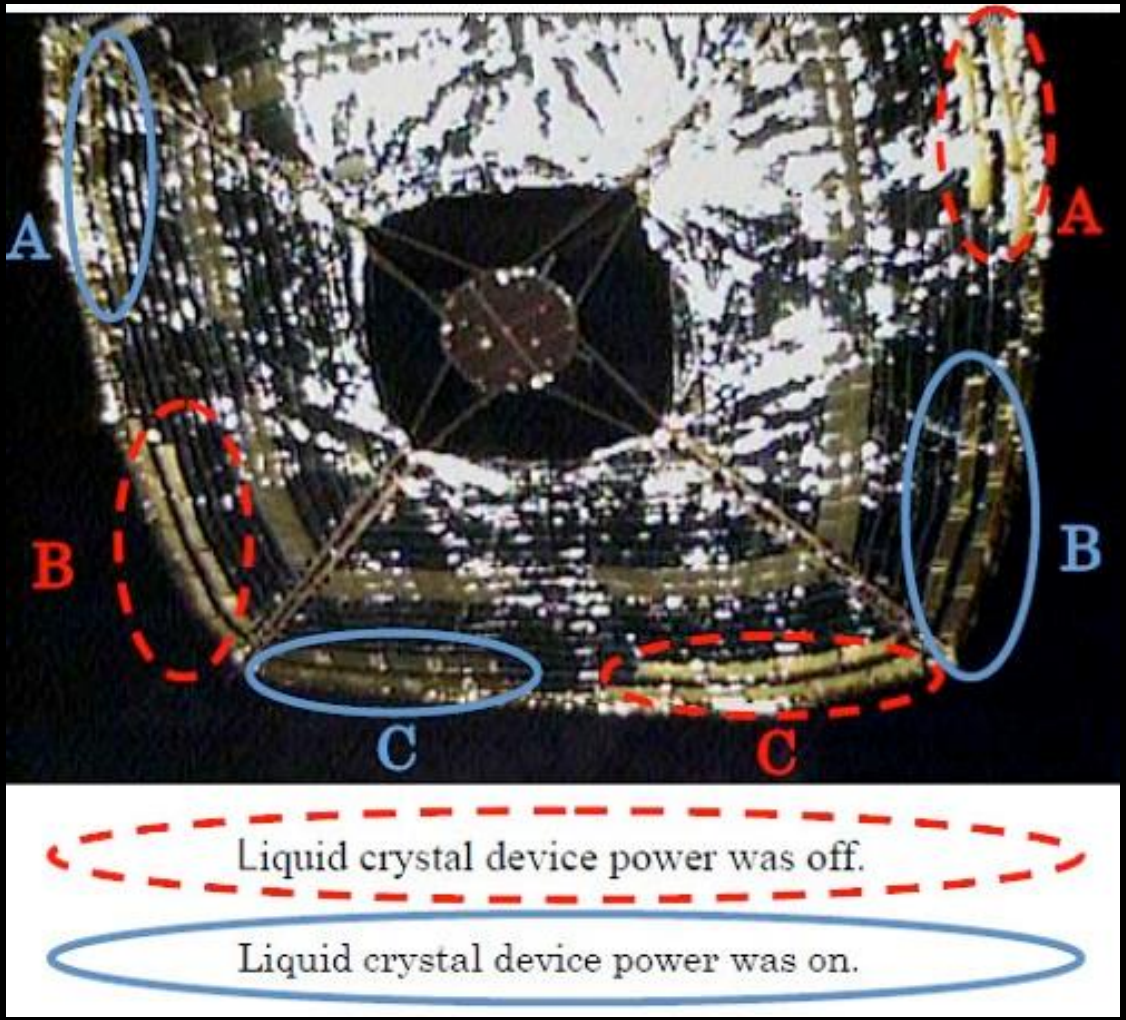
- 135-foot rigidized inflatable balloon satellite
- laminated Mylar plastic and aluminum
- placed in near-polar Orbit
- passive communications experiment by NASA on January 25, 1964

Znamya (Space Mirror)

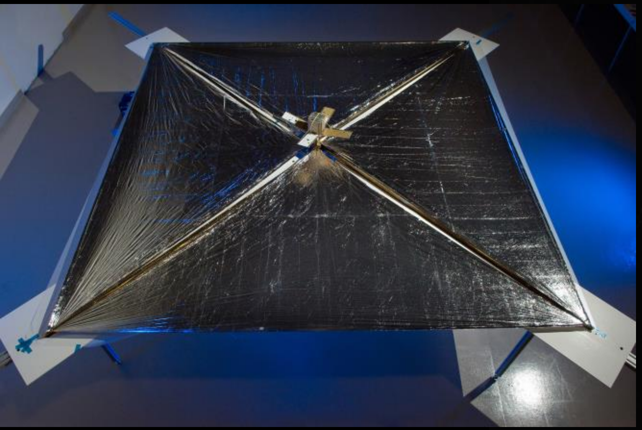




Interplanetary Kite-craft Accelerated by Radiation of the Sun (IKAROS)



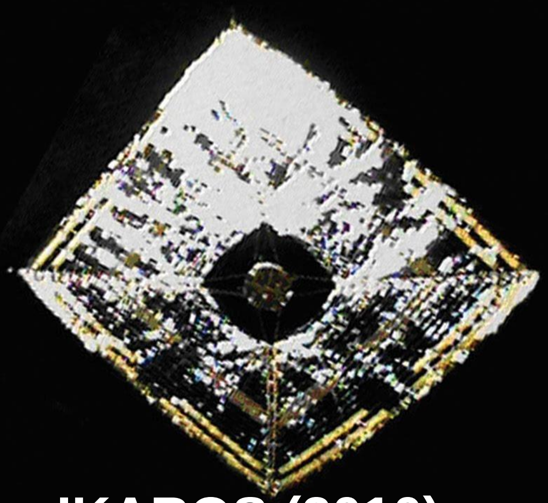
Space Sail Missions Flown (as of July 11, 2018)



NanoSail-D (2010)
NASA

Earth Orbit
Deployment Only

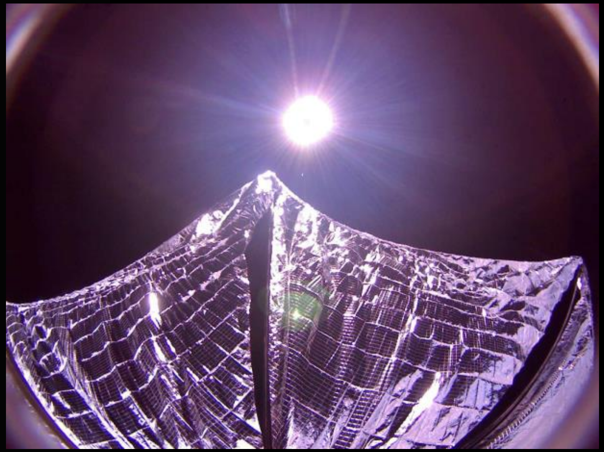
3U CubeSat
10 m²



IKAROS (2010)
JAXA

Interplanetary
Full Flight

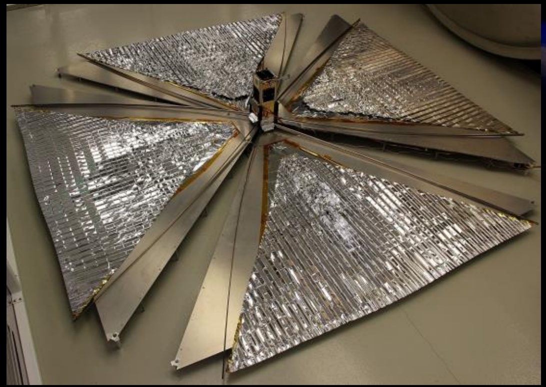
315 kg Smallsat
196 m²



LightSail-1 (2015)
The Planetary Society

Earth Orbit
Deployment Only

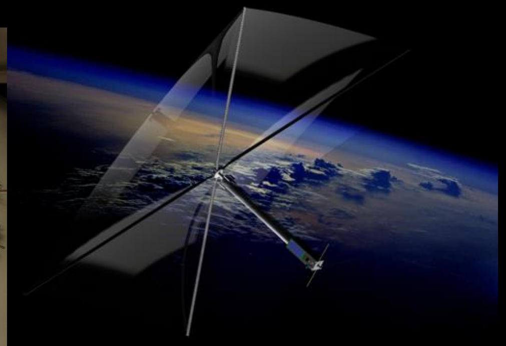
3U CubeSat
32 m²



CanX-7 (2016)
Canada

Earth Orbit
Deployment Only

3U CubeSat
<10 m²

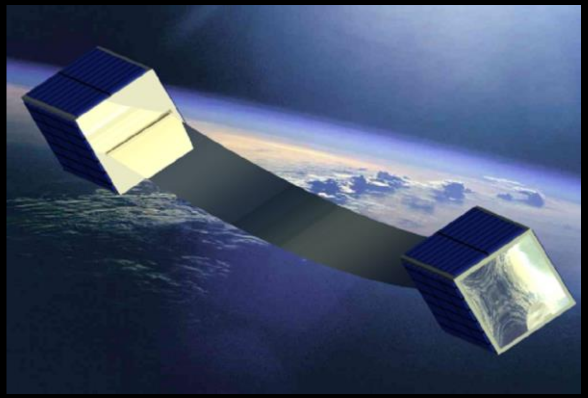


InflateSail (2017)
EU/Univ. of Surrey

Earth Orbit
Deployment Only

3U CubeSat
10 m²

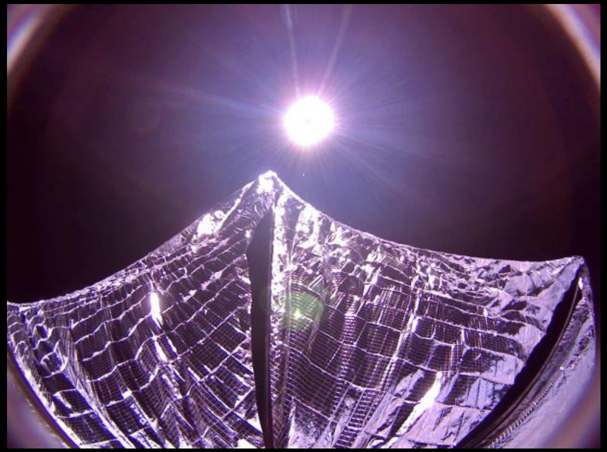
Planned Solar Sail Missions (as of July 11, 2018)



CU Aerospace (2018)
Univ. Illinois / NASA

Earth Orbit
Full Flight

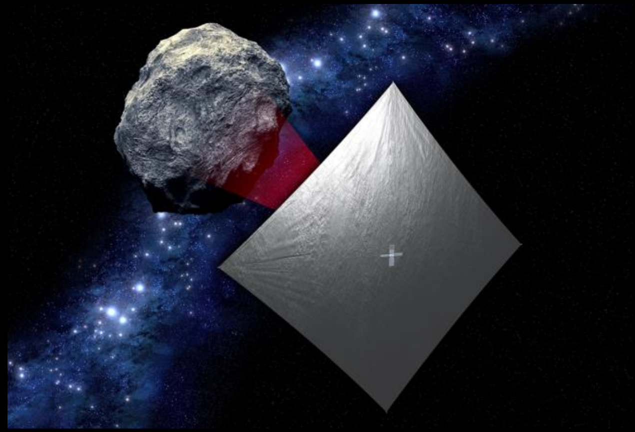
3U CubeSat
20 m^2



LightSail-2 (2018)
The Planetary Society

Earth Orbit
Full Flight

3U CubeSat
32 m^2



Near Earth Asteroid
Scout (2020) NASA

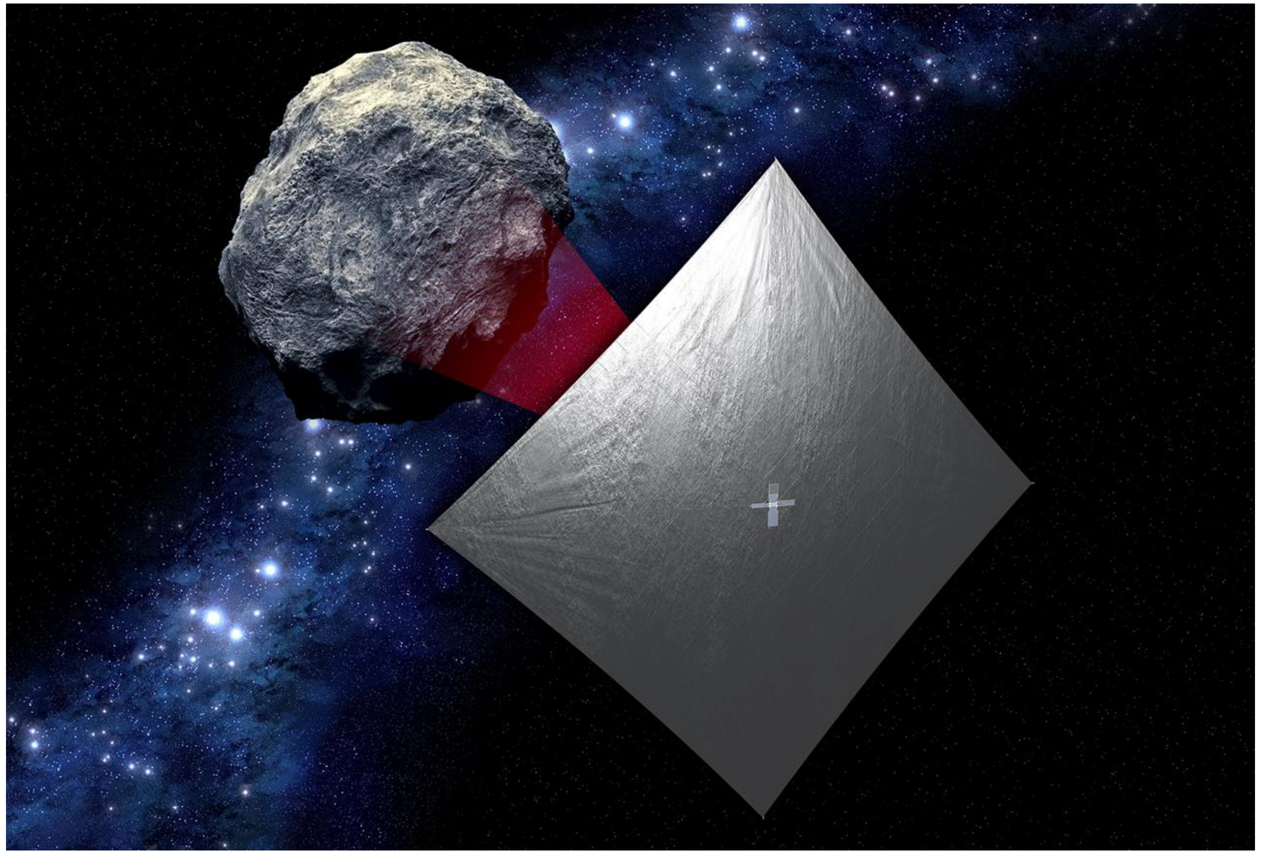
Interplanetary
Full Flight

6U CubeSat
86 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

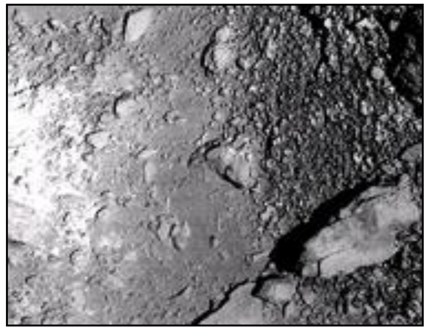


Key Spacecraft & Mission Parameters

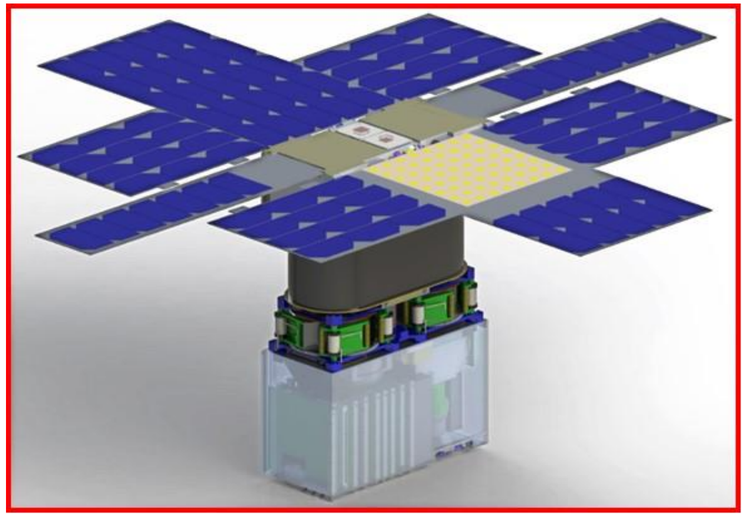
- 6U cubesat (20cm X 10cm X 30 cm)
- ~86 m^2 solar sail propulsion system
- Manifested for launch on the Space Launch System (EM-1/2020)
- 1 AU maximum distance from Earth

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

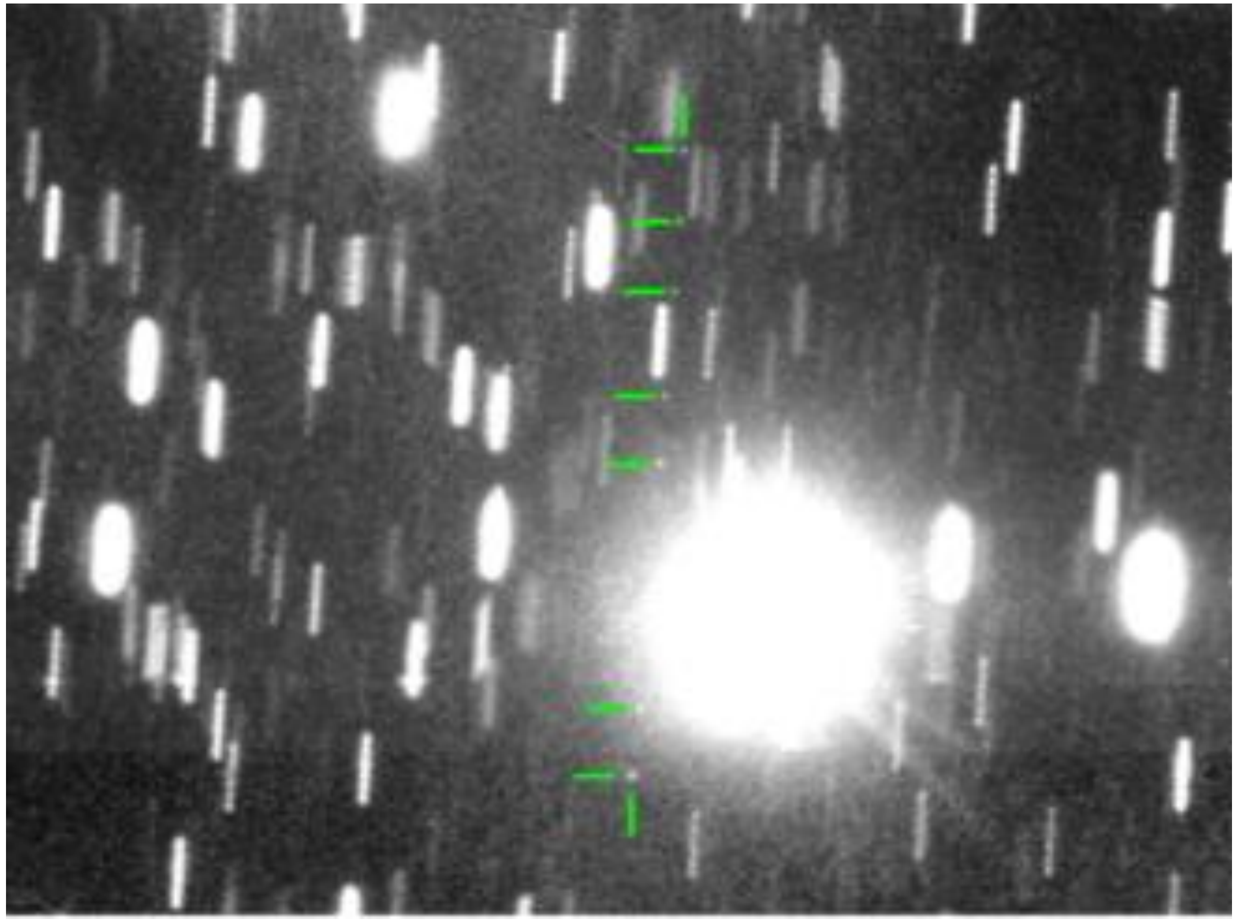
Target Reconnaissance with medium field imaging
Shape, spin, and local environment



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



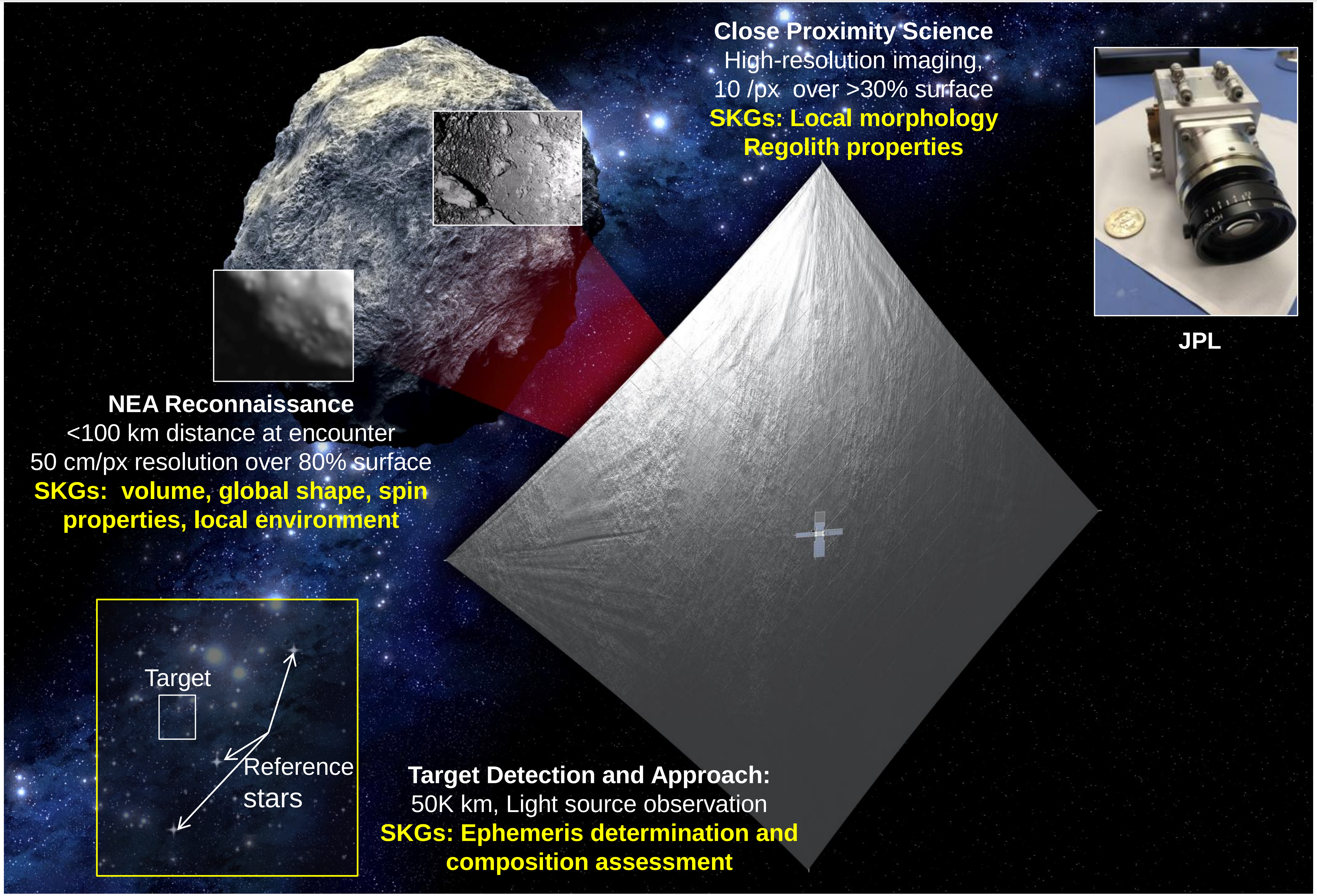
Baseline Target Asteroid: 1991 VG



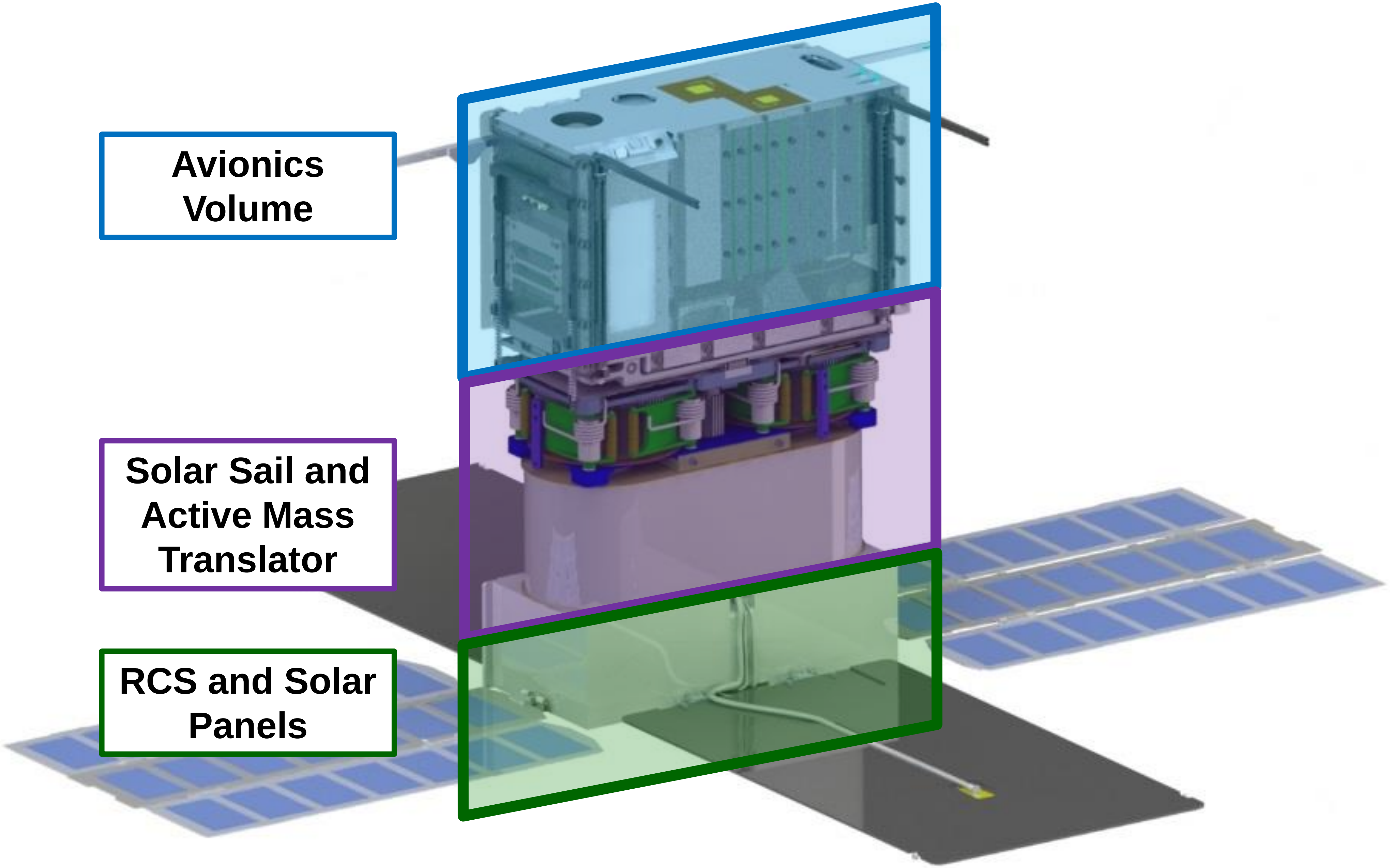
Near-Earth Asteroid 1991VG (marked with green lines) on 2017 May 30. This is a composite of several images obtained with the ESO VLT. The images have been combined in 7 stacks tracking the position of the asteroid, resulting in the object appearing as 7 dots as it moves in front of the background stars. 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

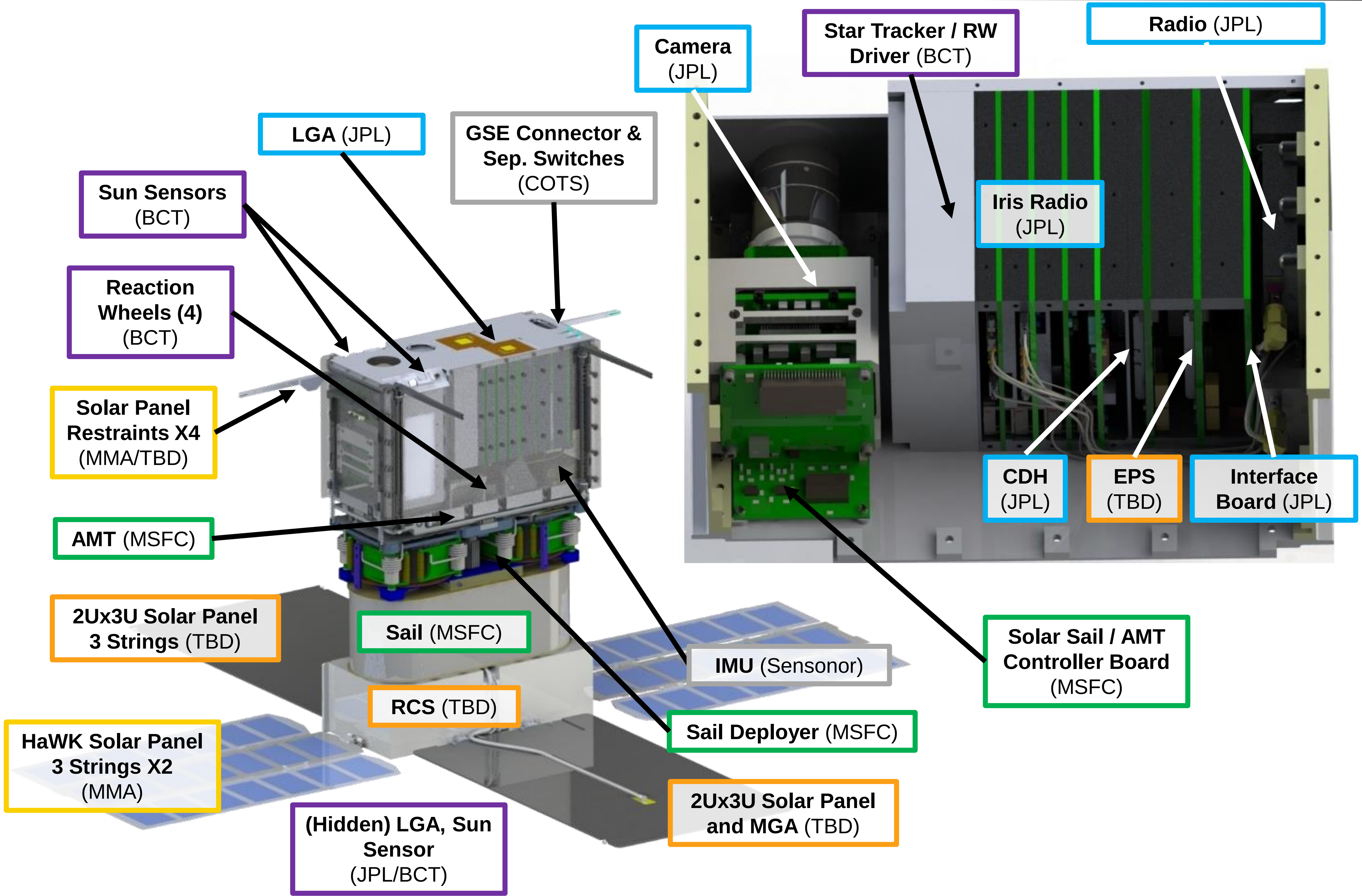
Near Earth Asteroid Scout Mission Overview



NEA Scout Flight System has 3 Main Sections

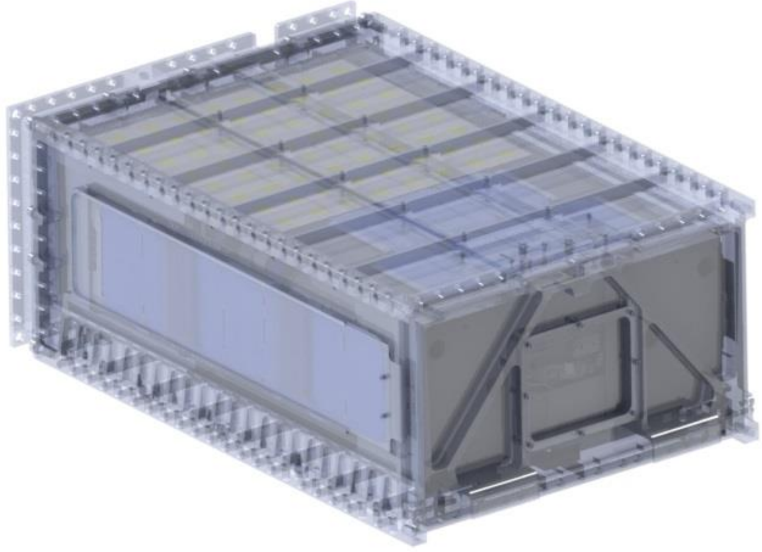


The Flight System

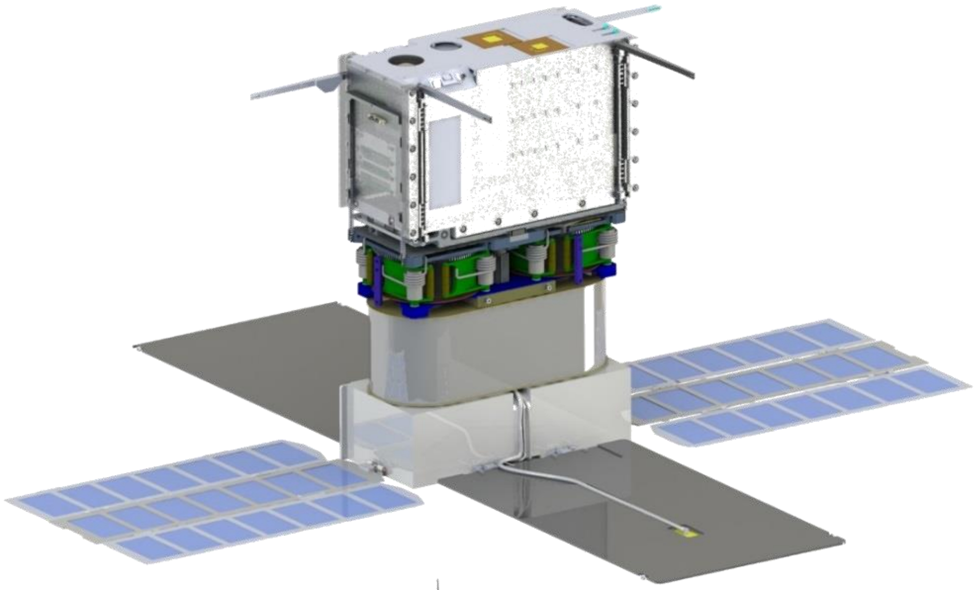


NEAS Configurations

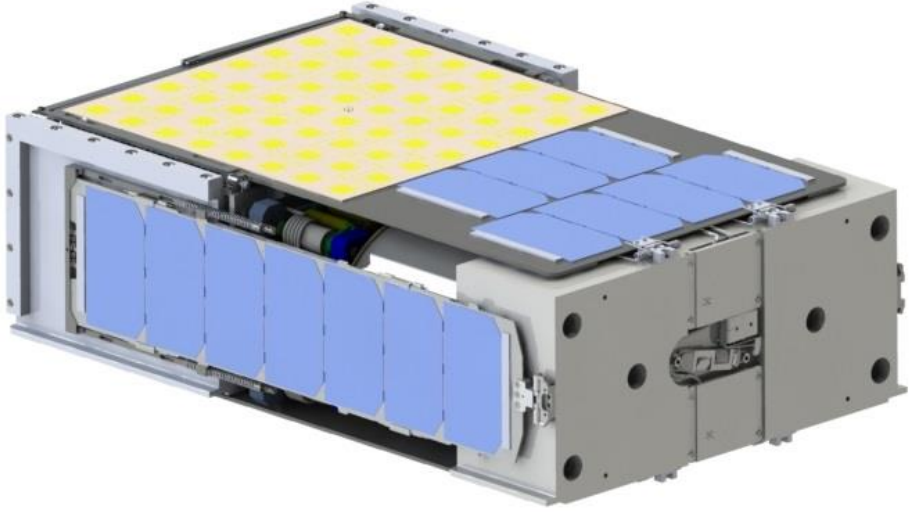
Stowed in Dispenser

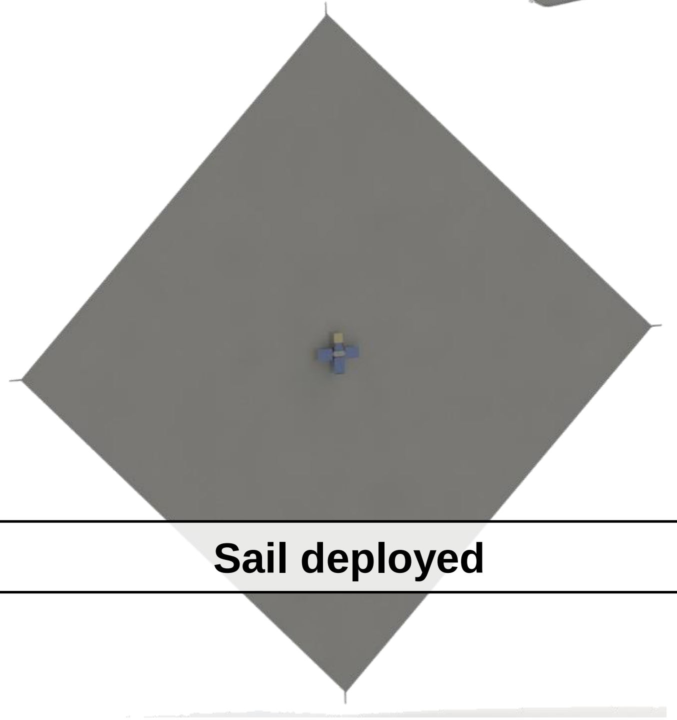


Configuration before sail deployment



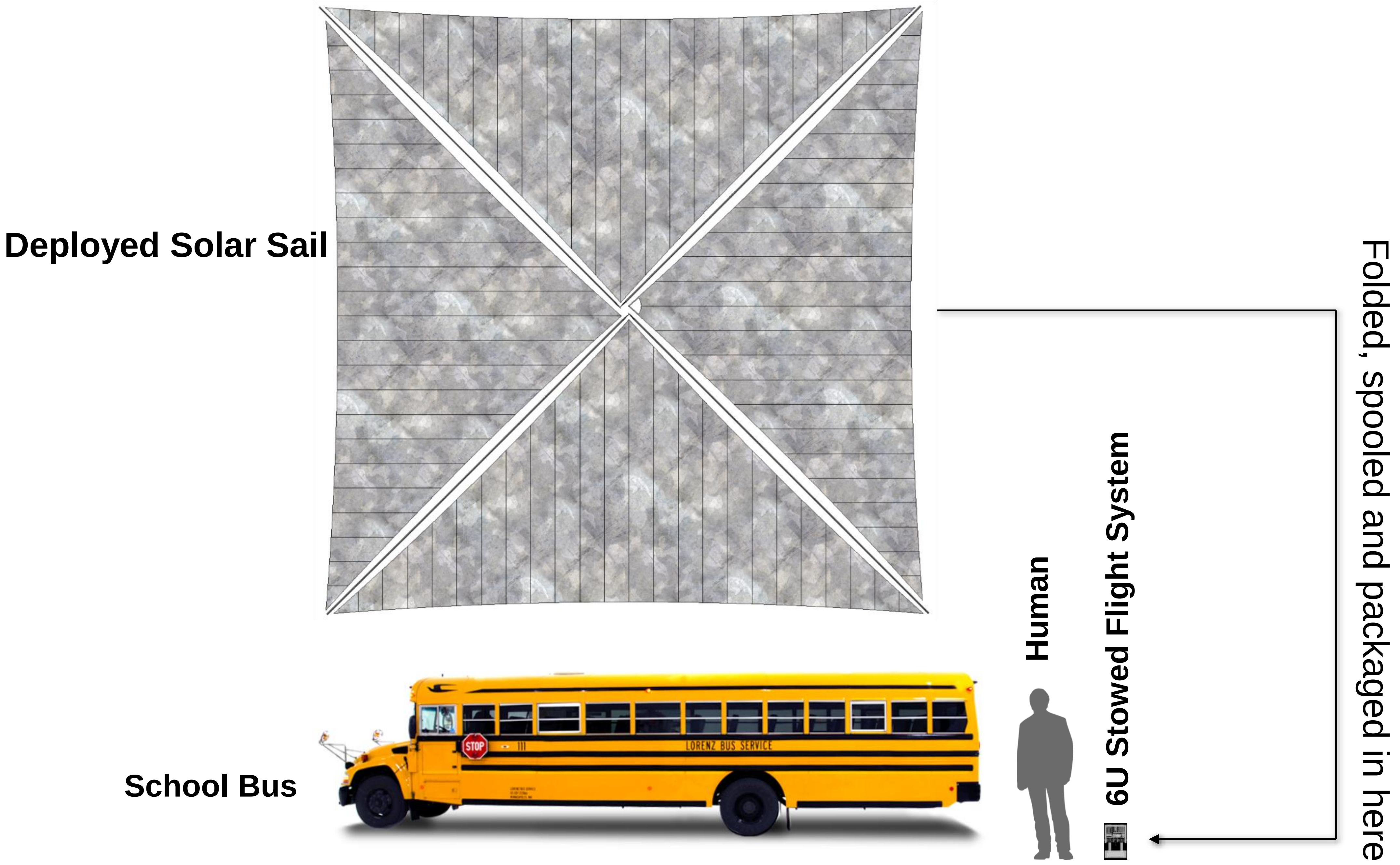
Ejection, before panel deployments





Sail deployed

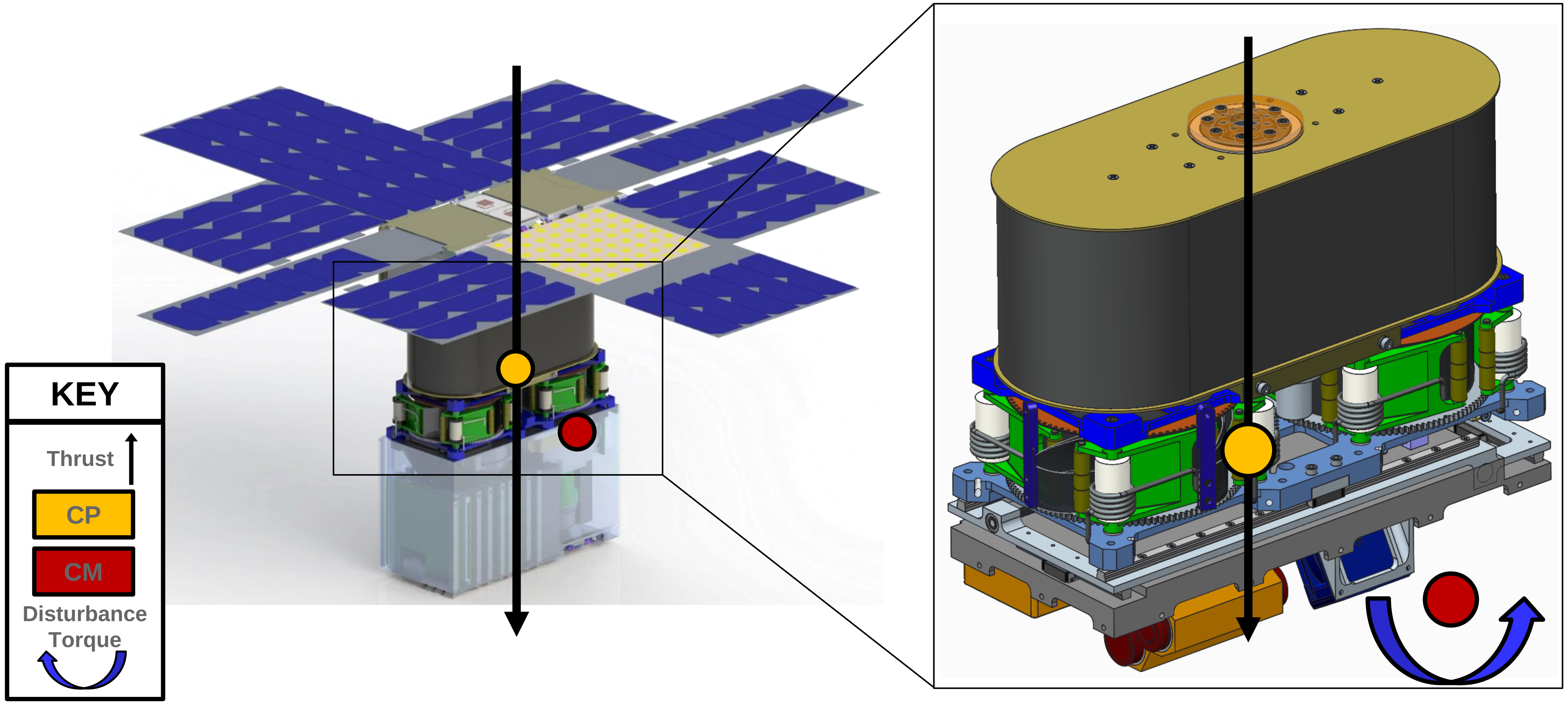
NEA Scout Approximate Scale



Active Mass Translation (AMT) Overview

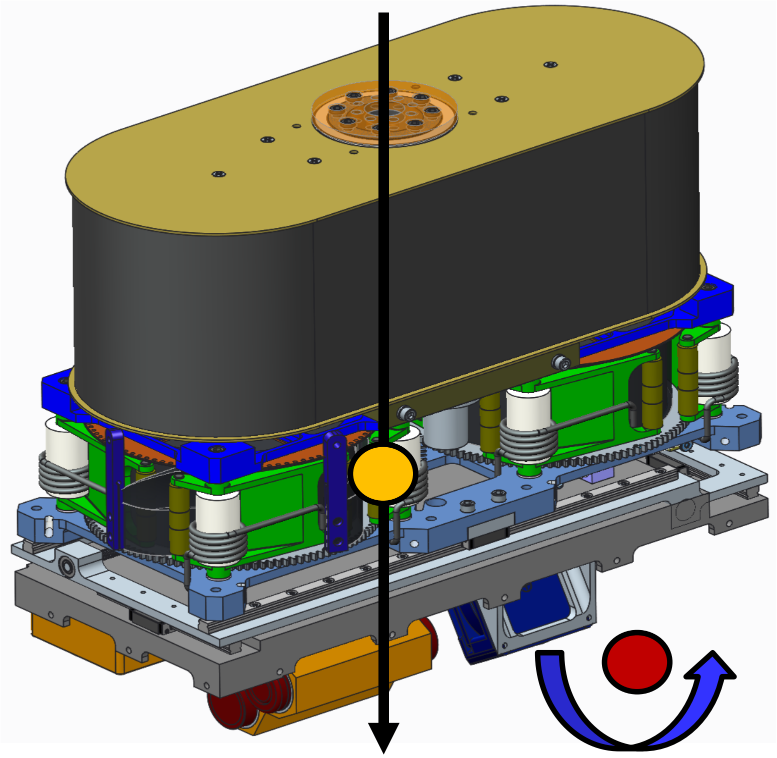
Problems and Challenges

- NEA Scout's center of mass (CM) and center of pressure (CP) are not collinear with the estimated thrust vector. This creates a ***disturbance torque***. Furthermore, the CP is fore of the CM, creating a naturally unstable vehicle and necessitating an active control mechanism.
- Little mass and volume available. This challenge is compounded by the vehicle's total mass (14 kg) and volume (6 Liters) requirement. The AMT was originally given 250 grams and a volume of 226 x 105 x 17 mm (400 cc). This ***volume*** and ***mass*** will include: an X-Y translation stage, thermal controls, limit switches, and a wire harness. The ***wire harness*** must pass through the AMT and survive exposure to ***deep space environments***.

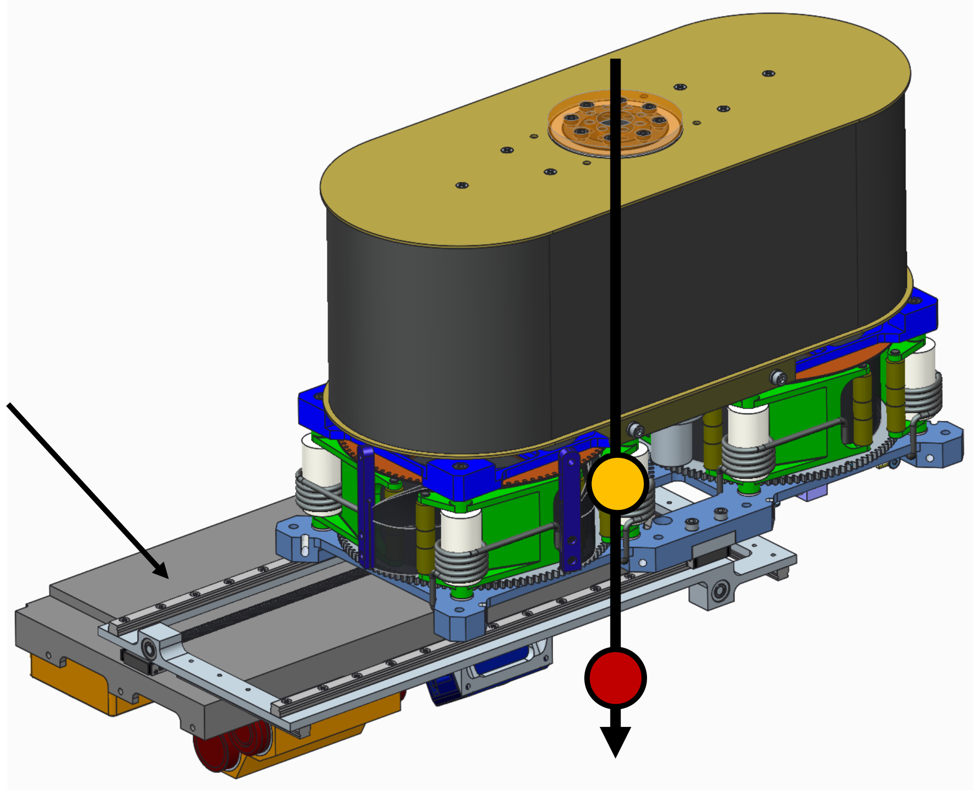


AMT Overview

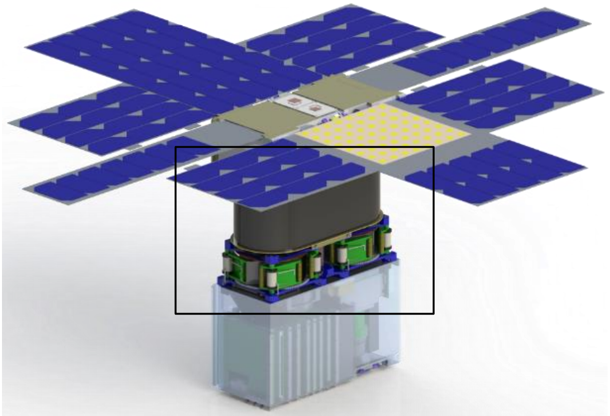
Nominal State



Trimmed State



AMT



KEY

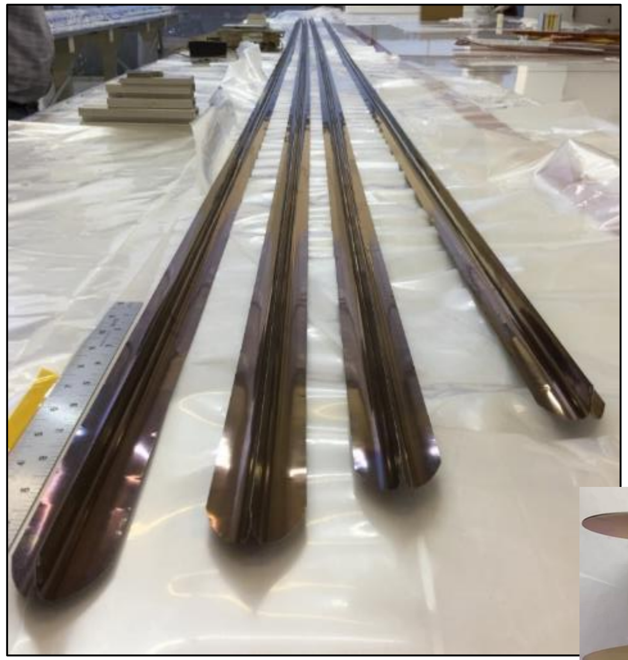
Thrust

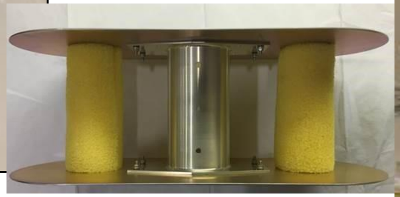
CP

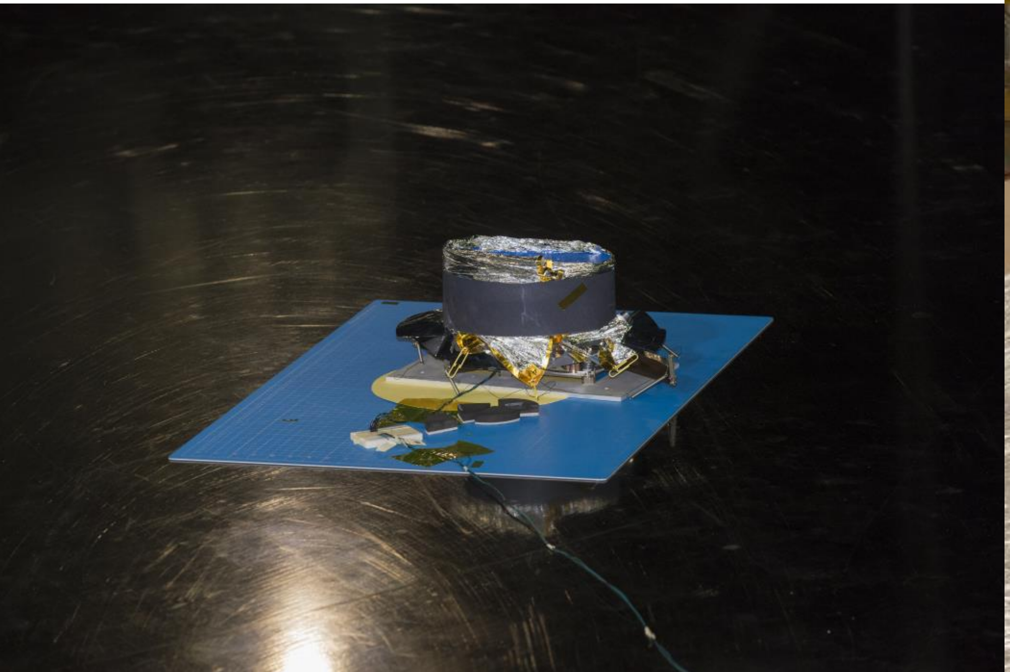
CM

Disturbance Torque

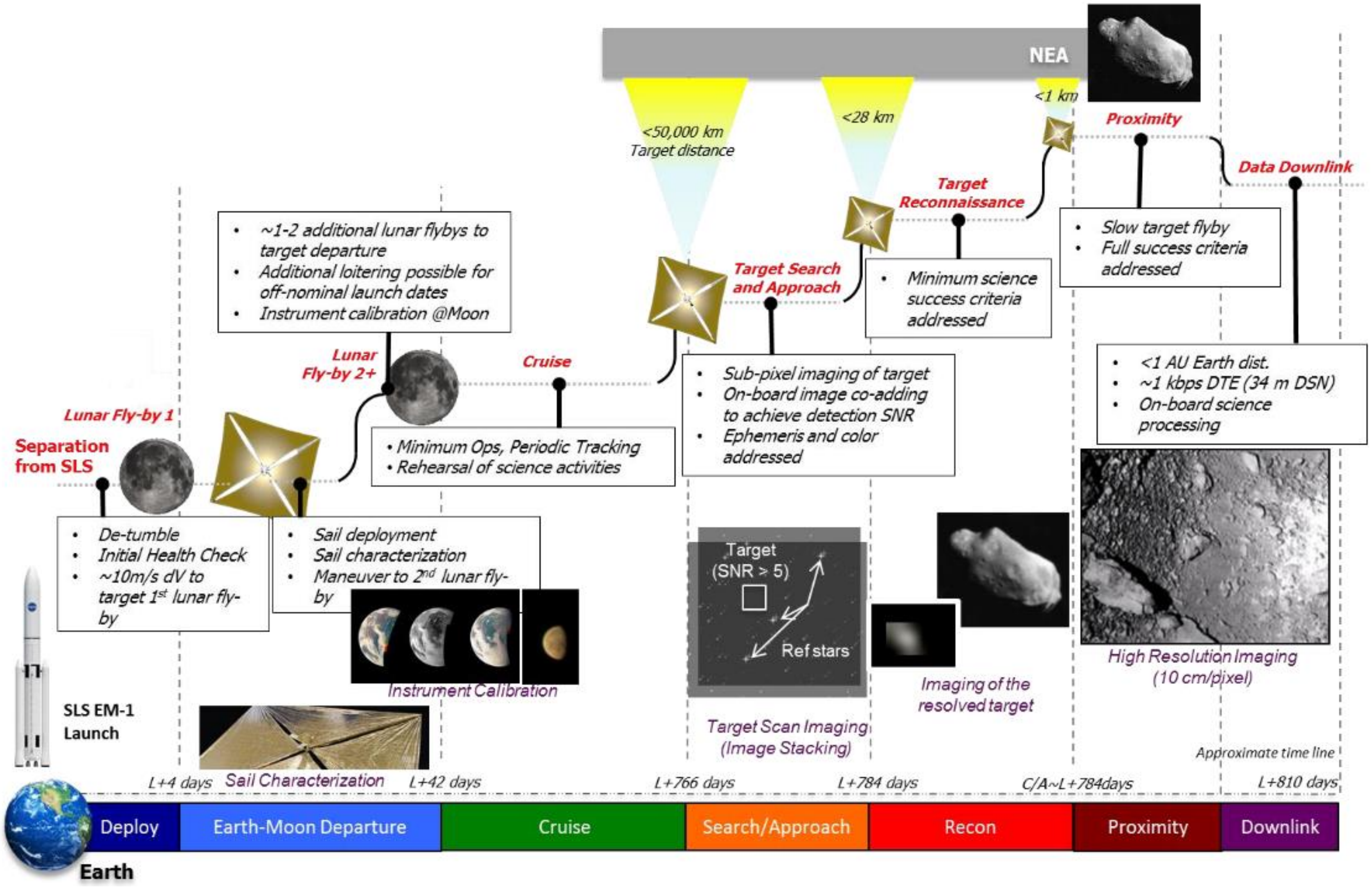
On Schedule to Deliver Spacecraft





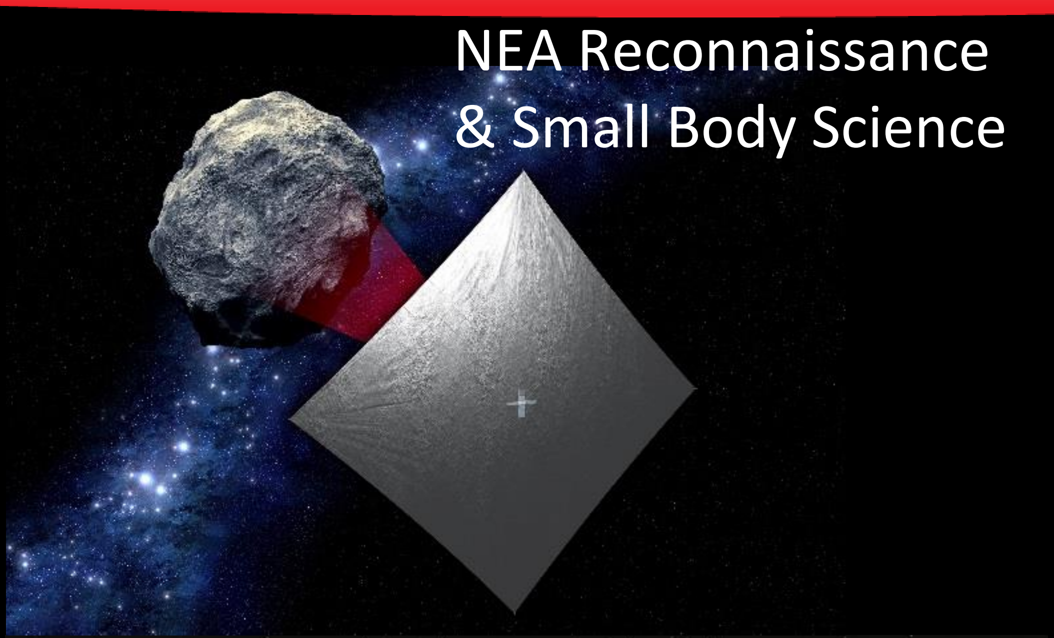


Concept of Operations Overview

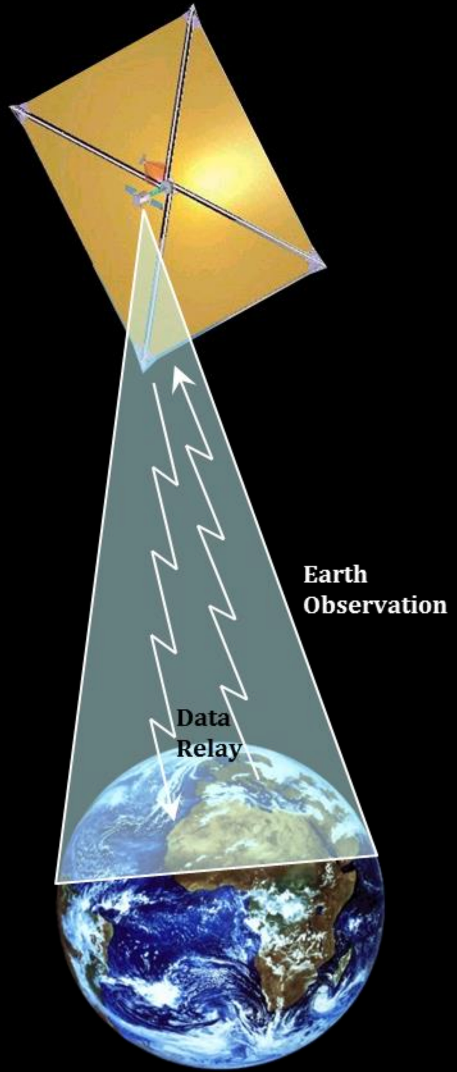


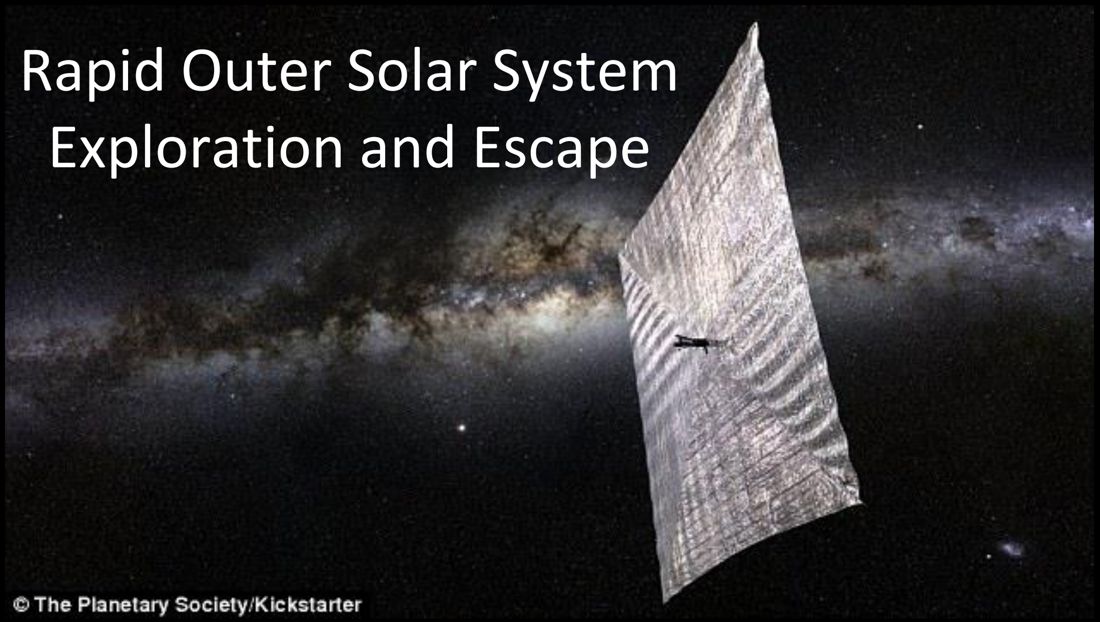
Potential Future Solar Sail Applications

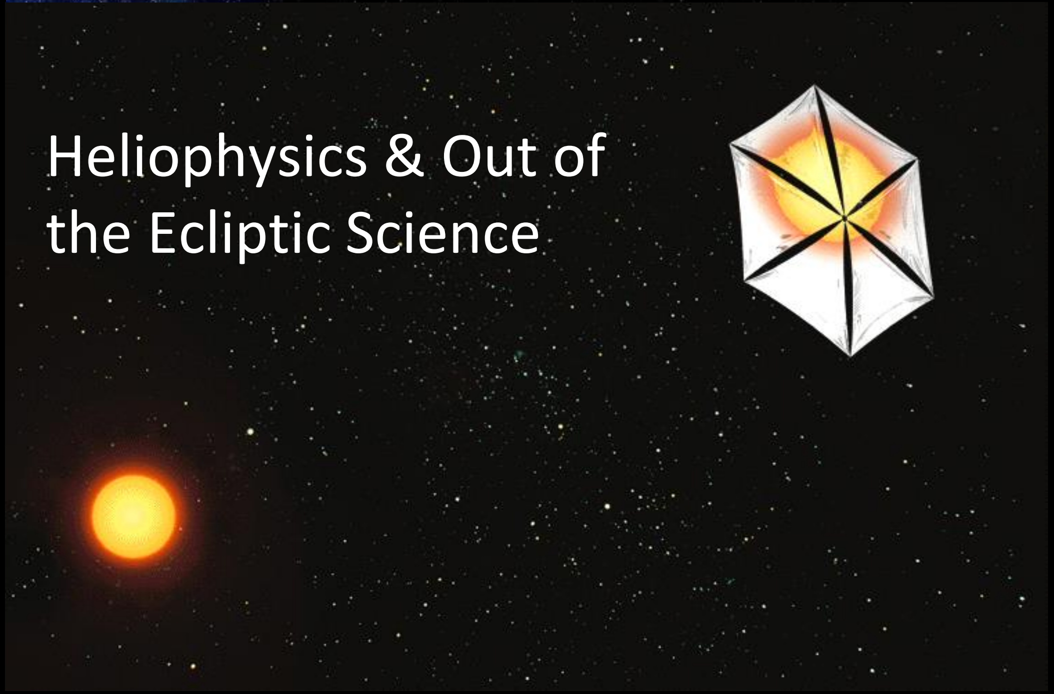
(A Partial List!)



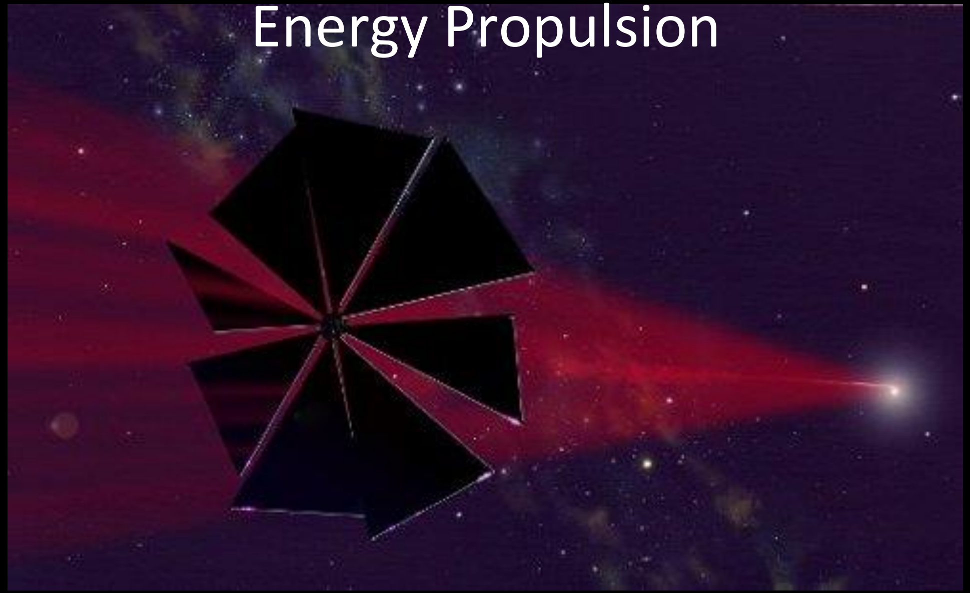
Earth Pole Sitting



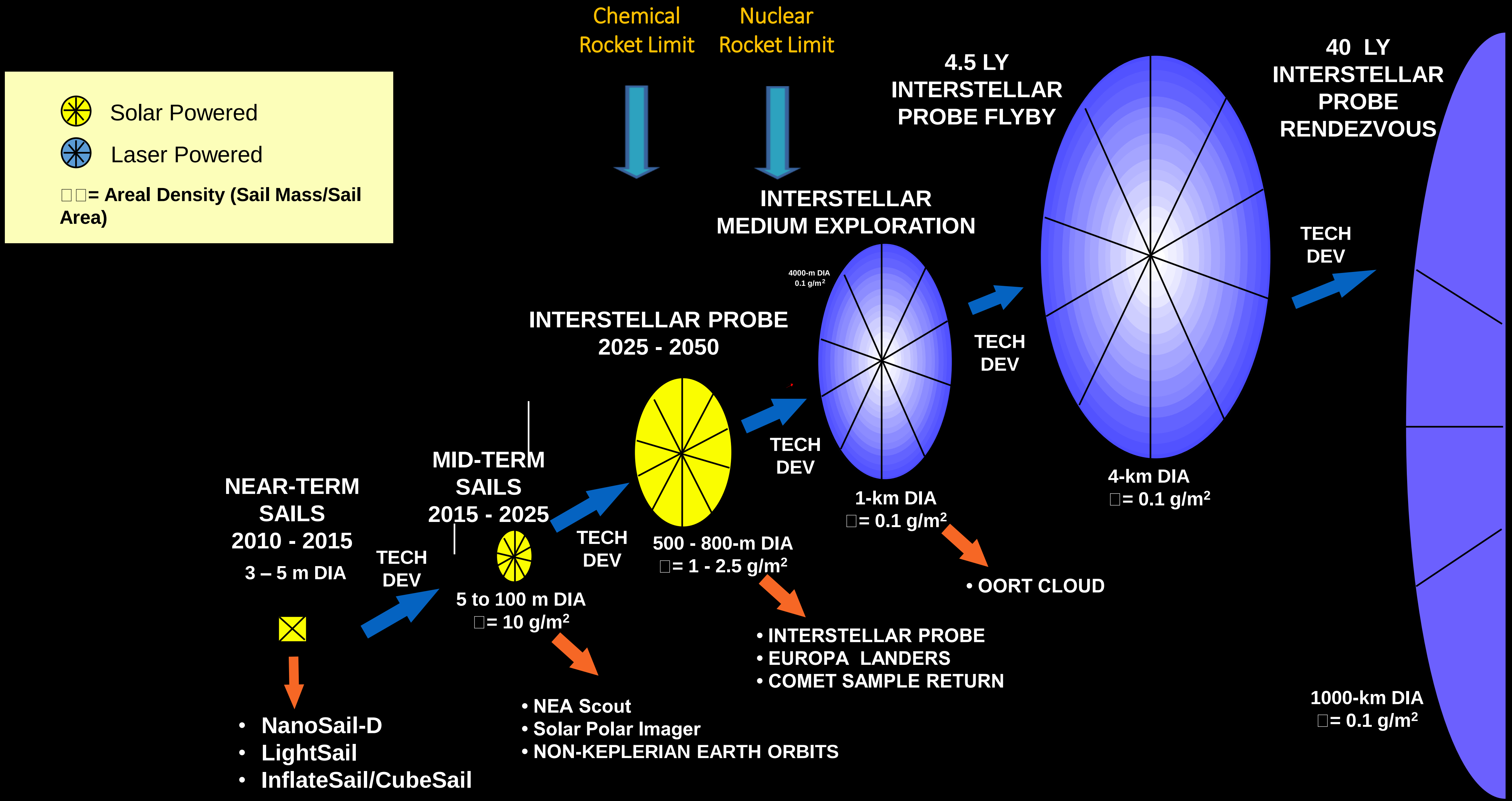




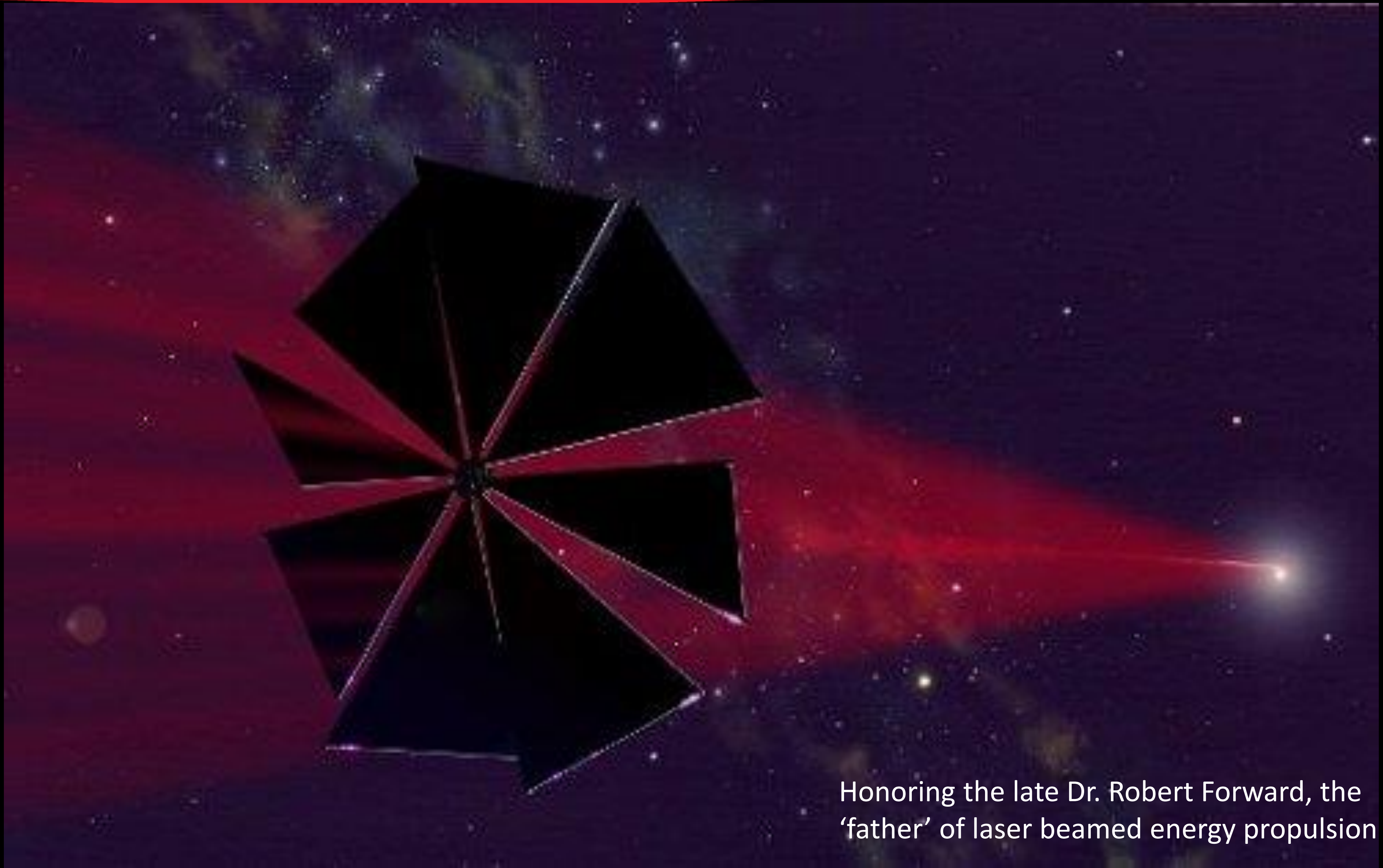
Toward Higher Performance Beamed



My Real Motive…



Solar Sails: A Step Toward the Stars



Honoring the late Dr. Robert Forward, the ‘father’ of laser beamed energy propulsion

Questions?