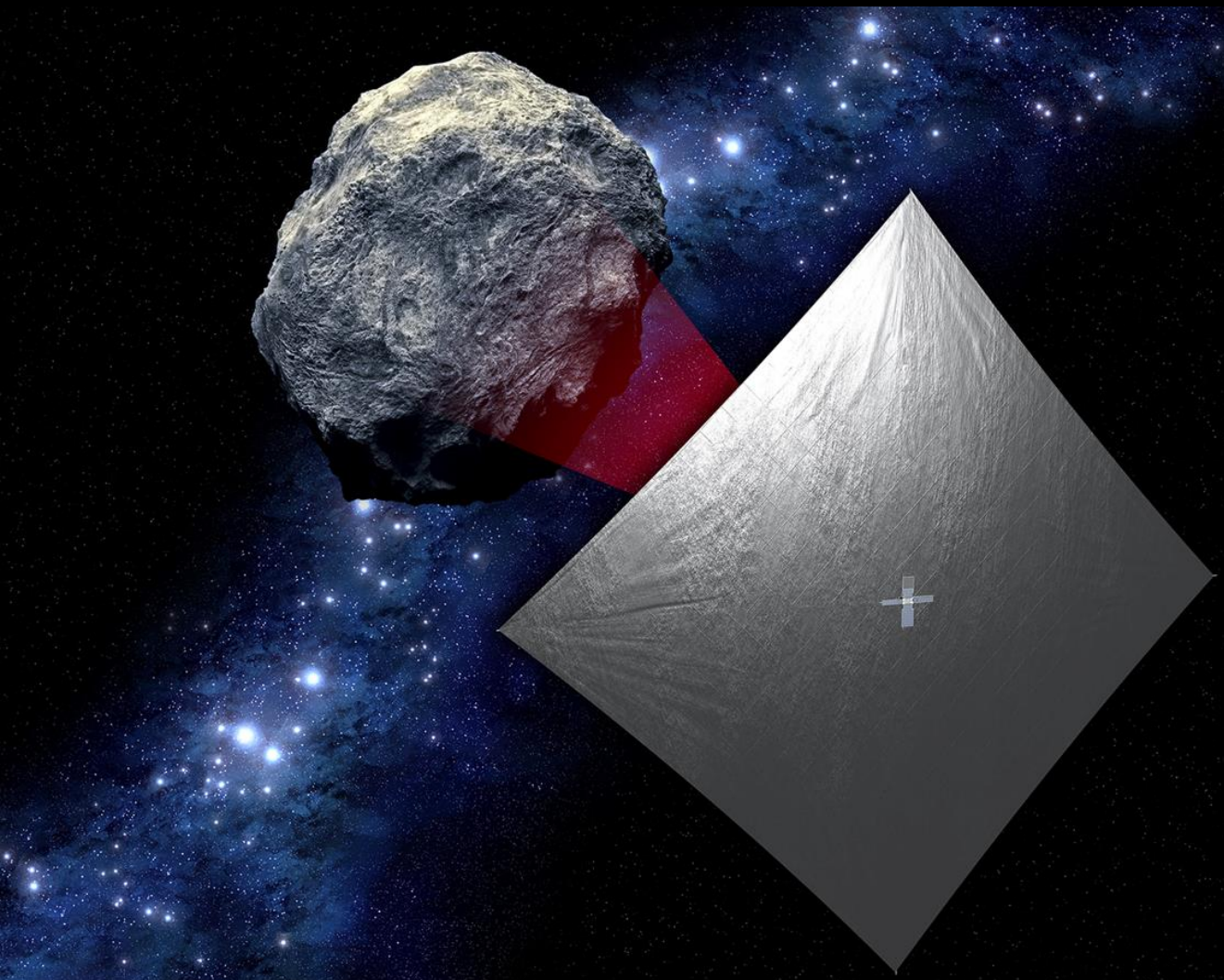
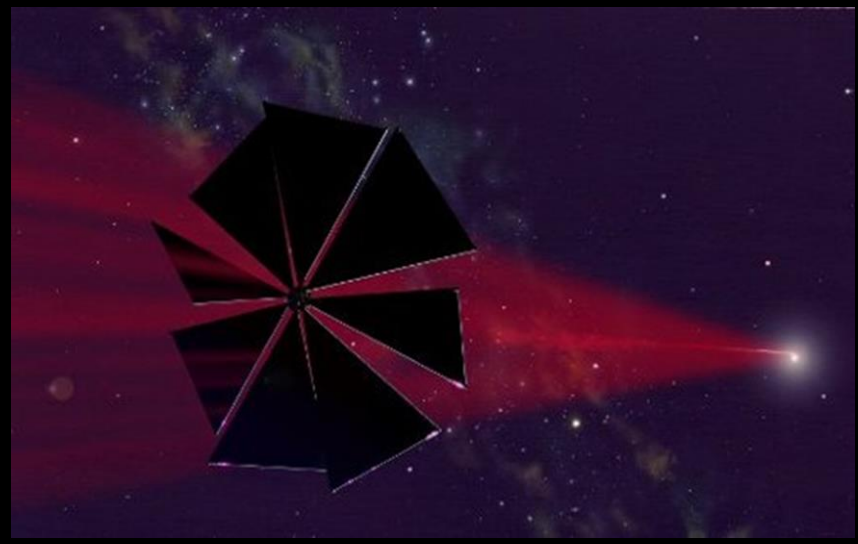
# Sailing in Space
# From Science Fiction to Science Fact



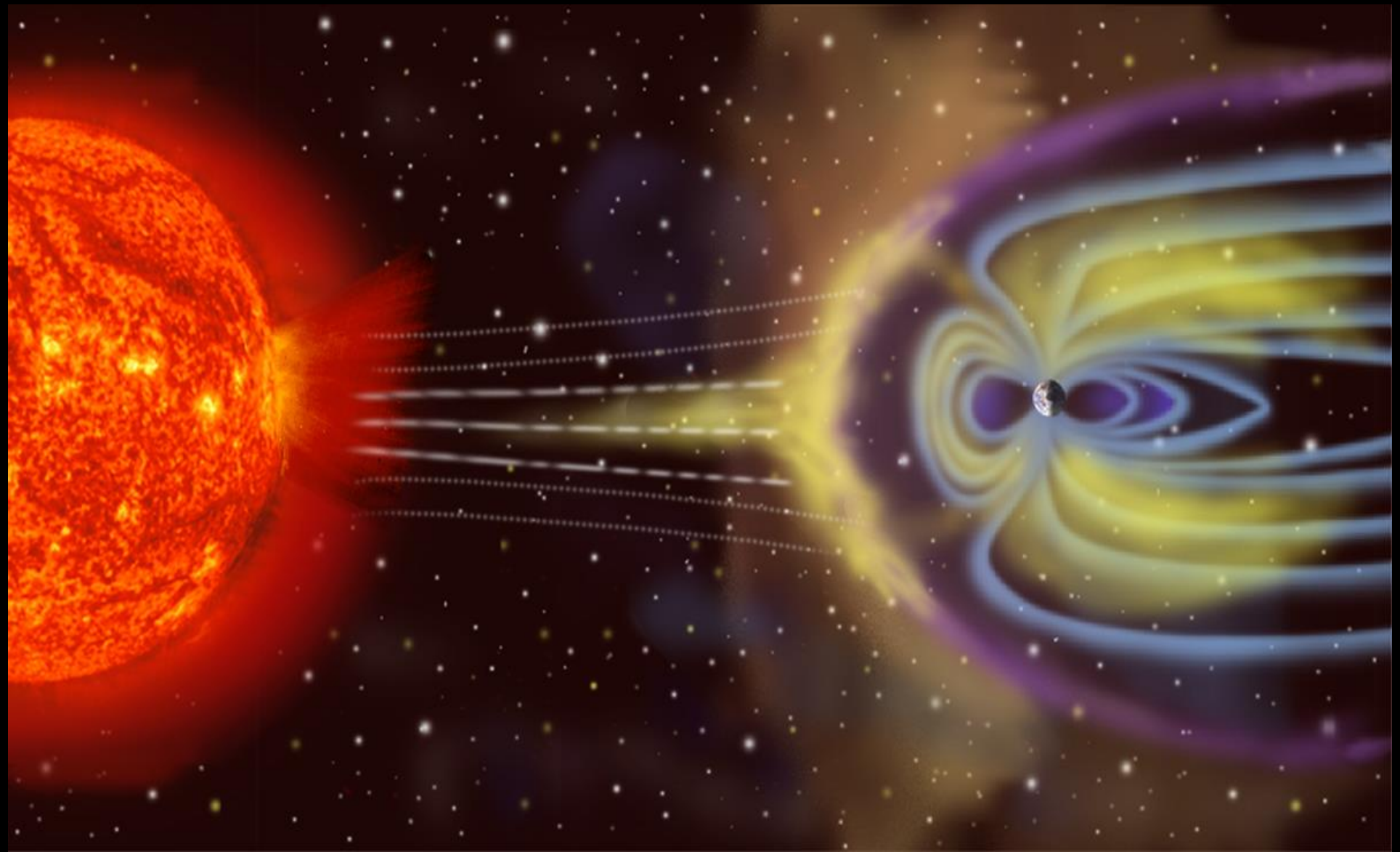


Les Johnson
NASA
George C. Marshall Space Flight Center

# We tend to think of space as being

*big and empty…*

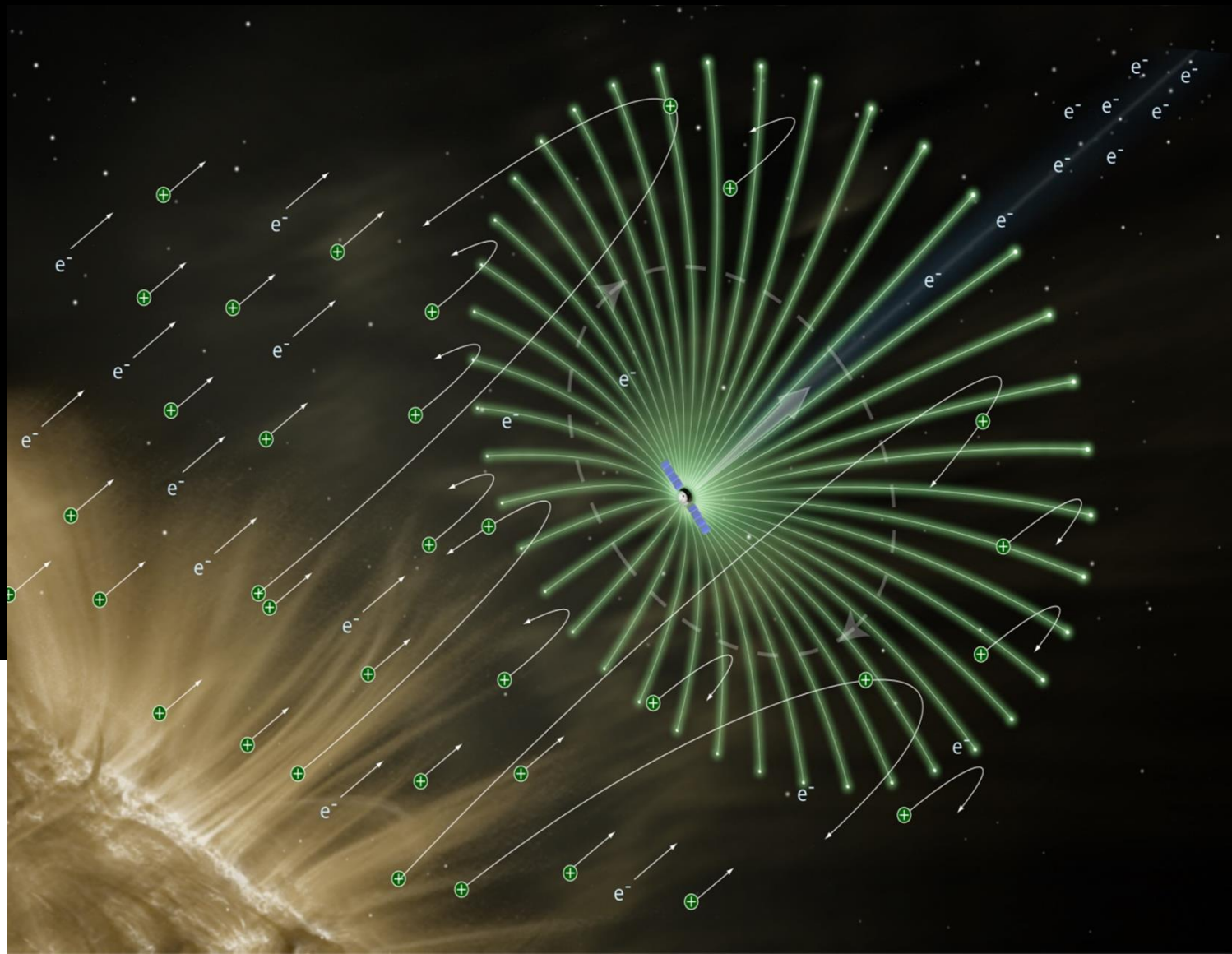
# Space Is NOT Empty.  Can we use the environments of space to our advantage?



# Spacecraft Can Use the Momentum of Sunlight and the Solar Wind

# Electric Sail Propulsion

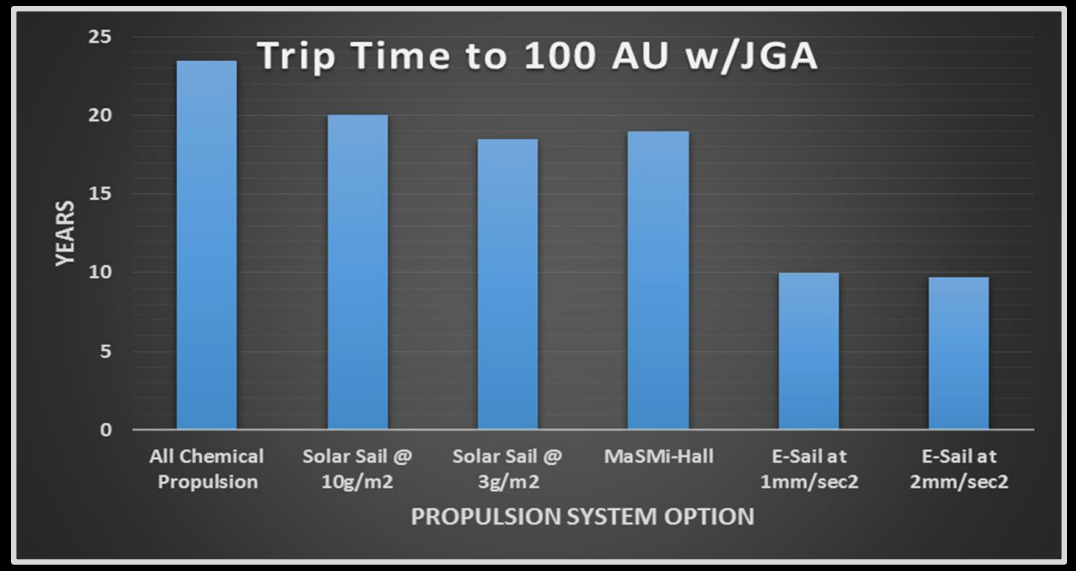
Electric sail utilizes charged tethers to *repel solar wind protons* to gain momentum

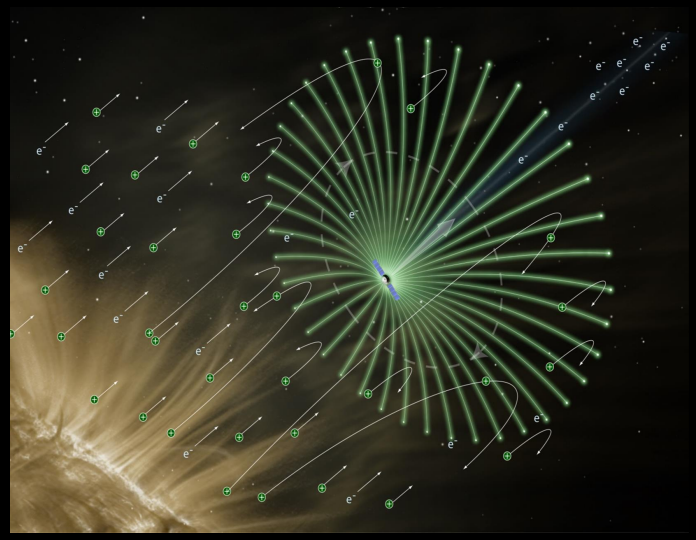



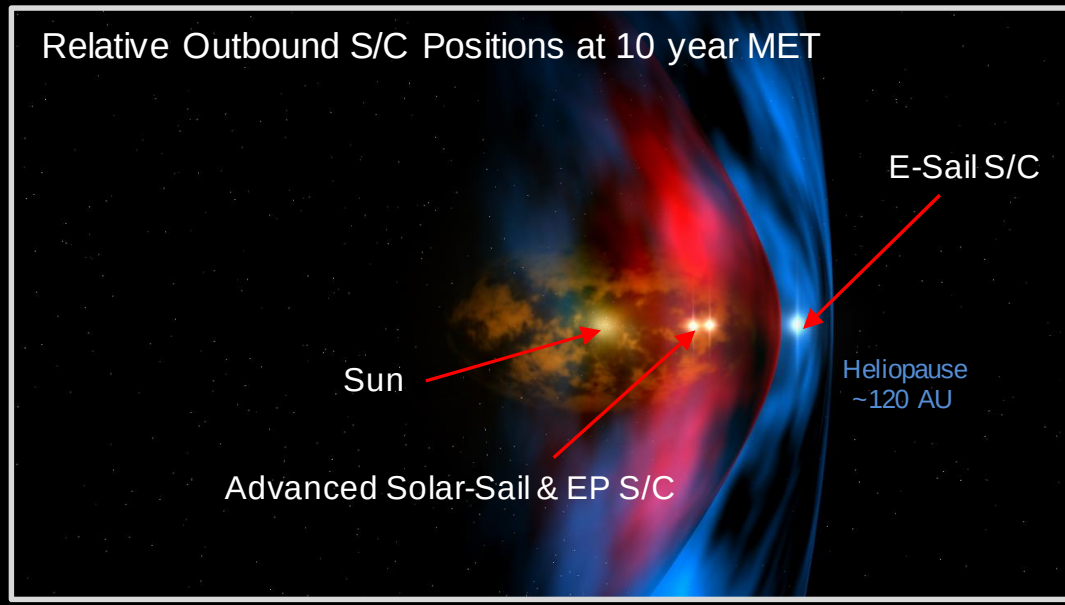
# The Heliopause Electrostatic Rapid Transit System (HERTS)

Bruce M. Wiegmann NASA NAIC Fellow

The HERTS NIAC project investigated the feasibility of a spacecraft concept, propelled by an “Electrostatic Sail” to travel to the edge of the Solar System (~120 AU from the sun) in less than 15 years.

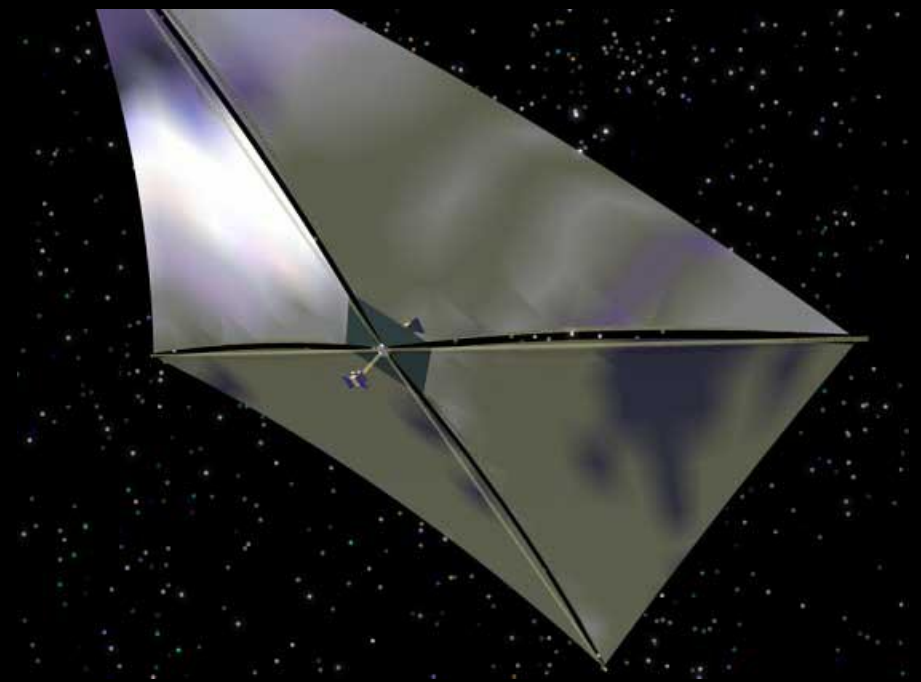


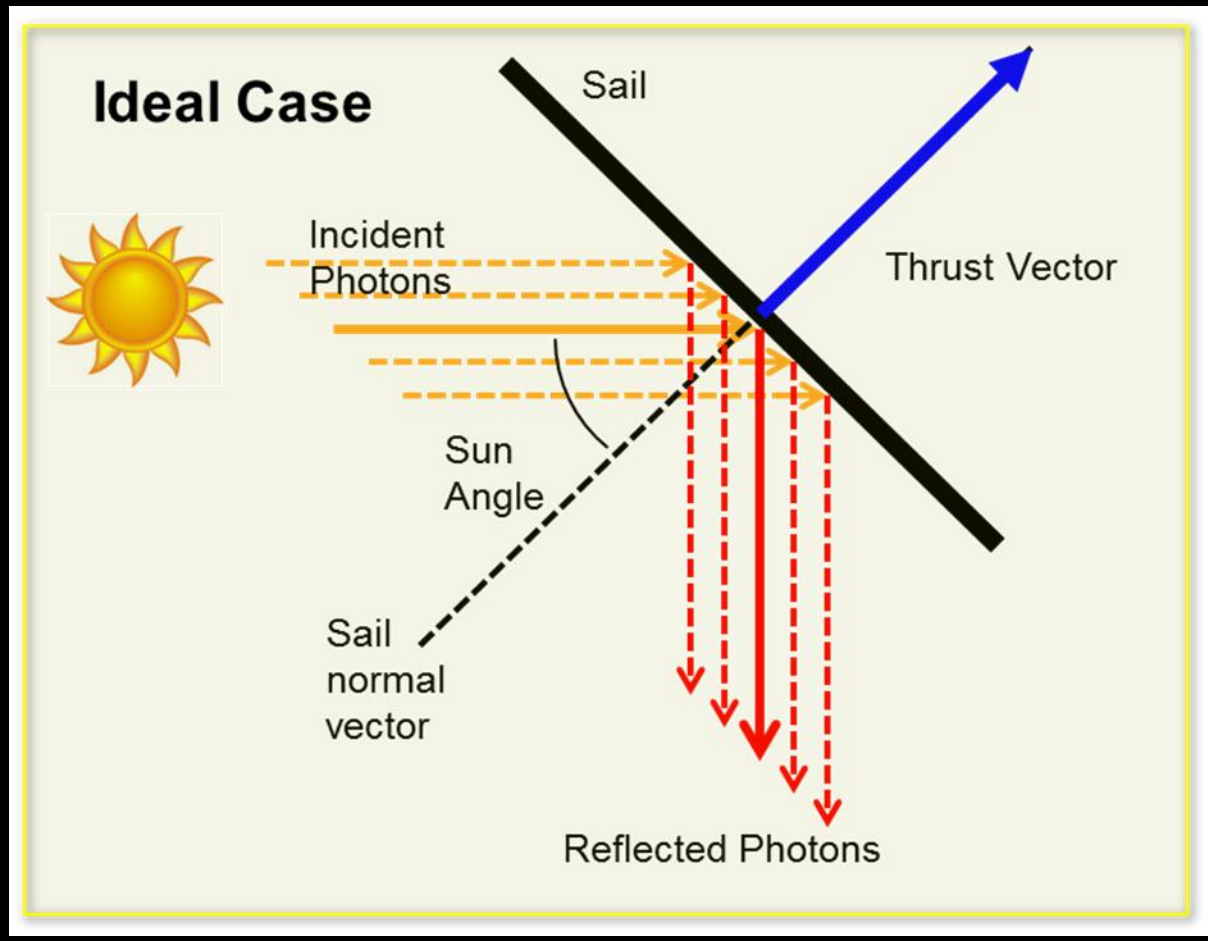





# Solar Sails Use Sunlight (not the Solar Wind!)

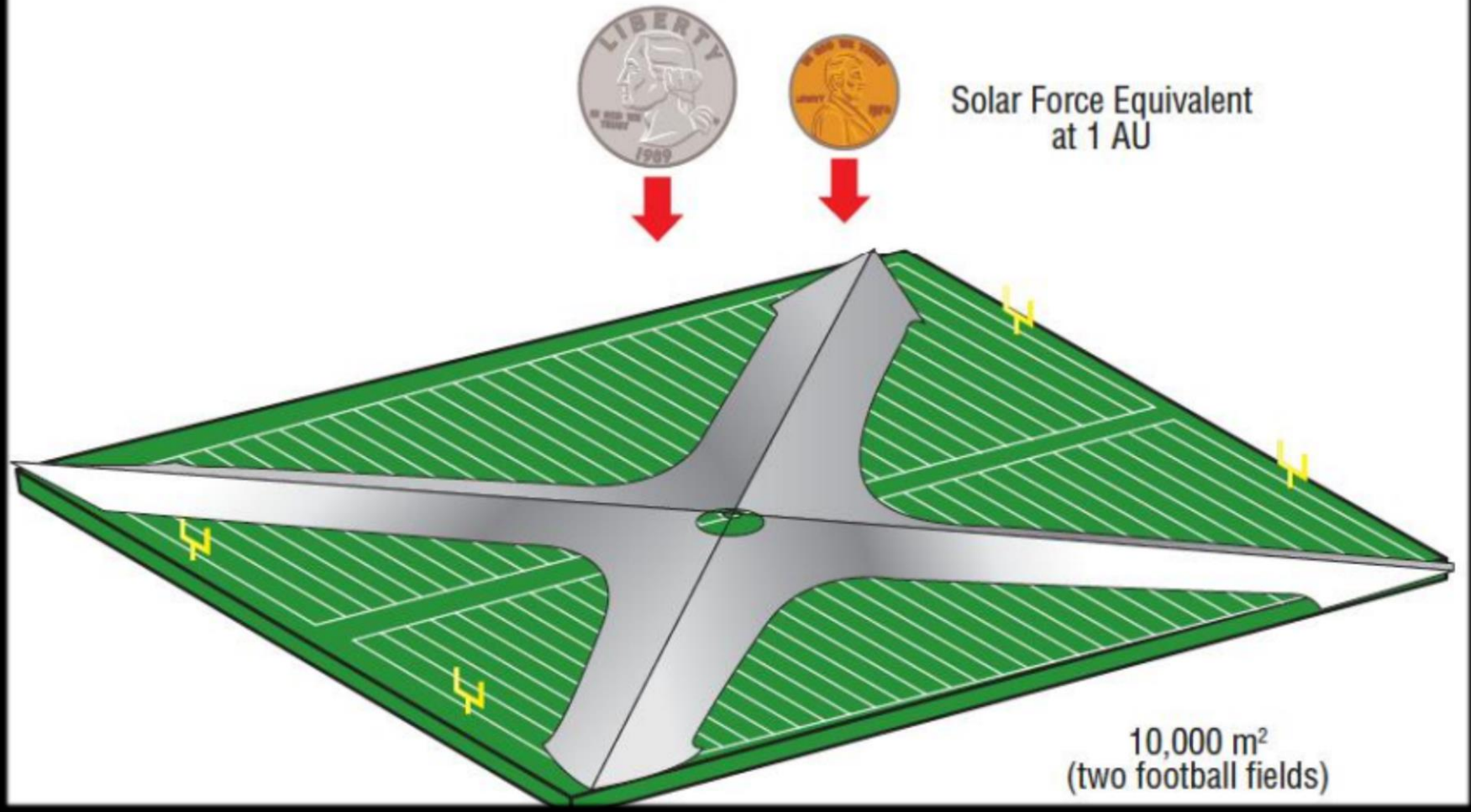
Solar sails use photon "pressure" or force on thin, lightweight, reflective sheets to produce thrust.





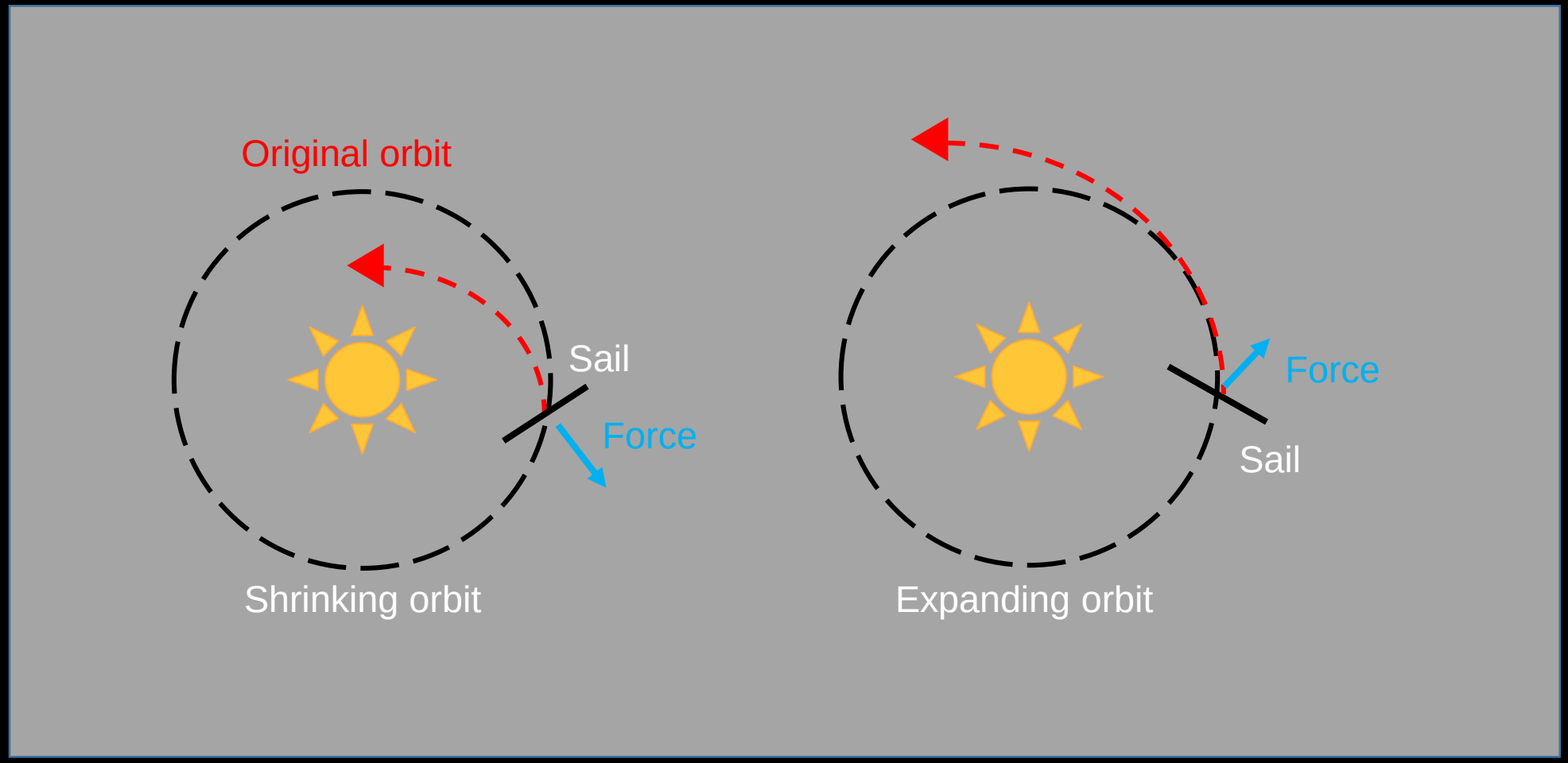
# Solar Sails Experience **VERY** Small Forces

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



# Solar Sail Trajectory Control

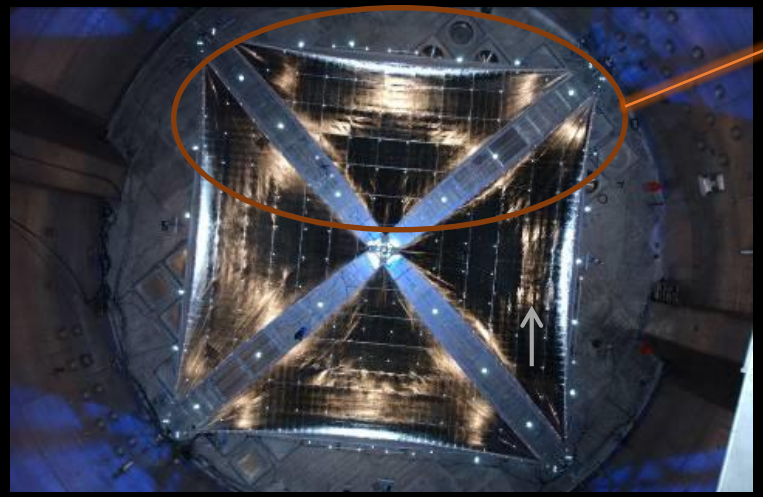
- Solar Radiation Pressure allows inward or outward Spiral

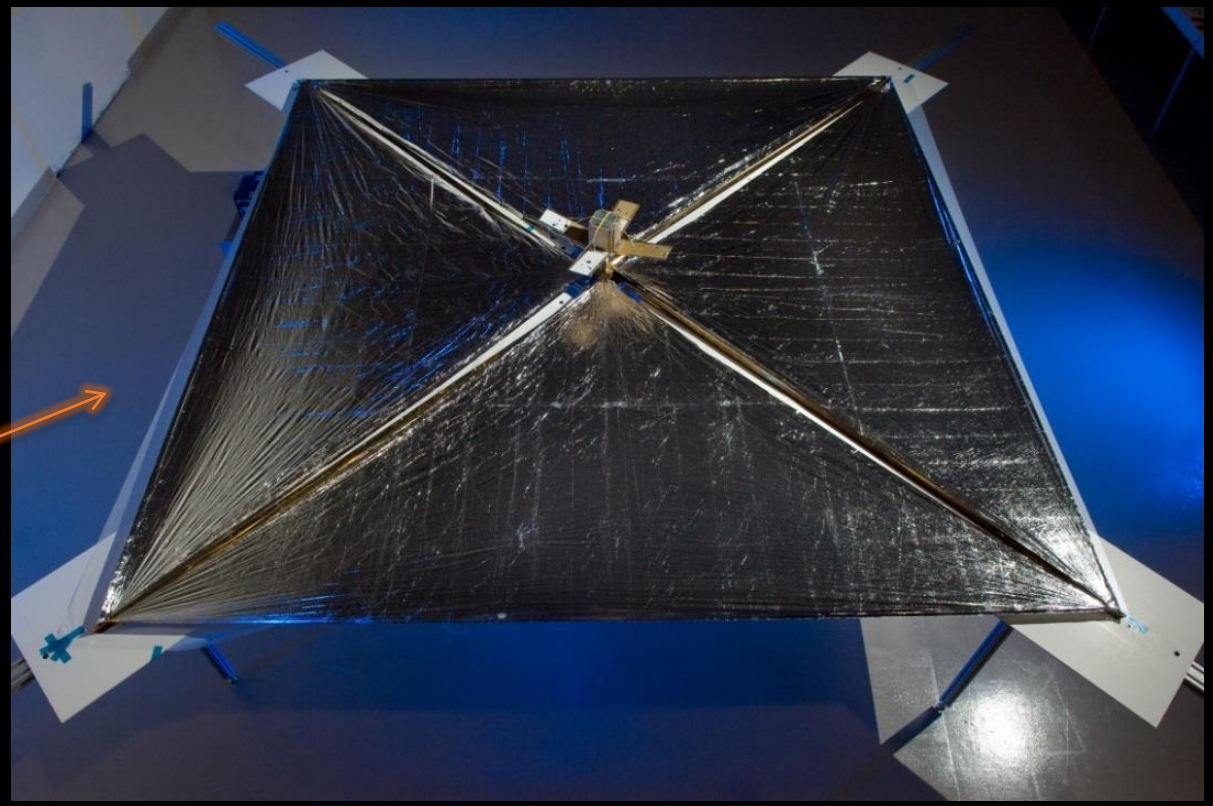


# NanoSail-D Demonstration Solar Sail

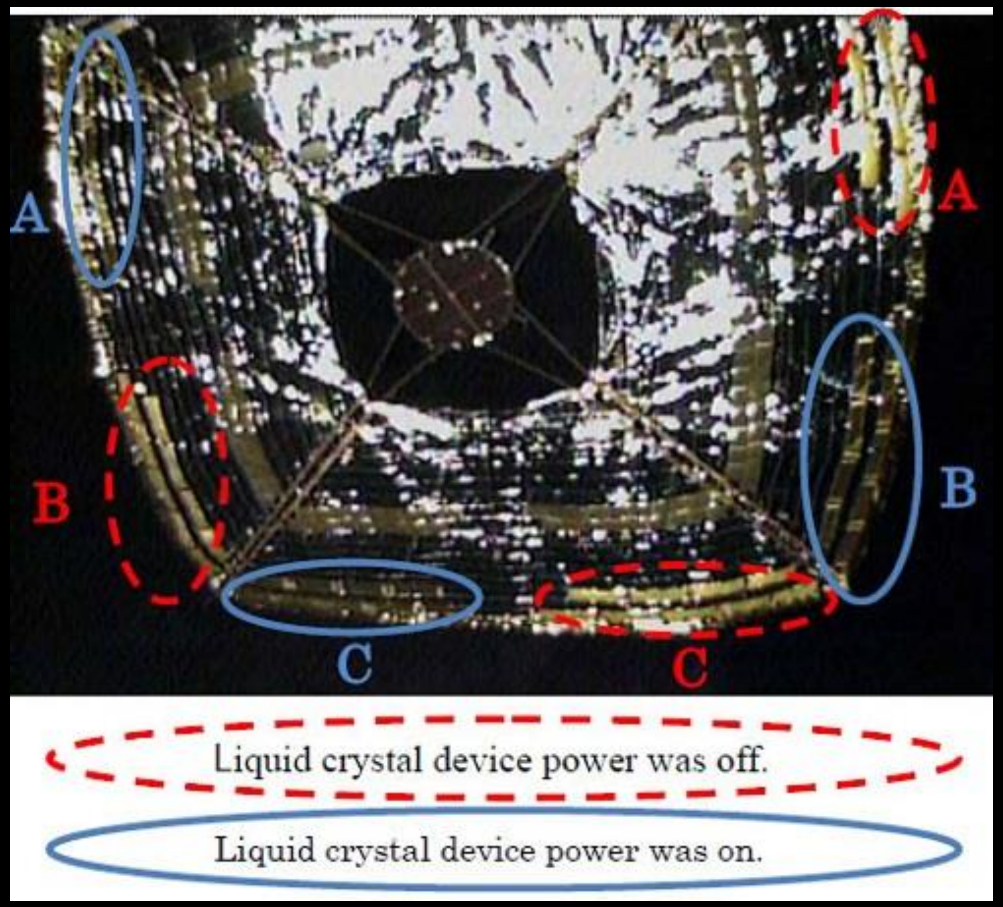
**Mission Description**:

- 10 $m^2$ sail
- Made from tested ground demonstrator hardware

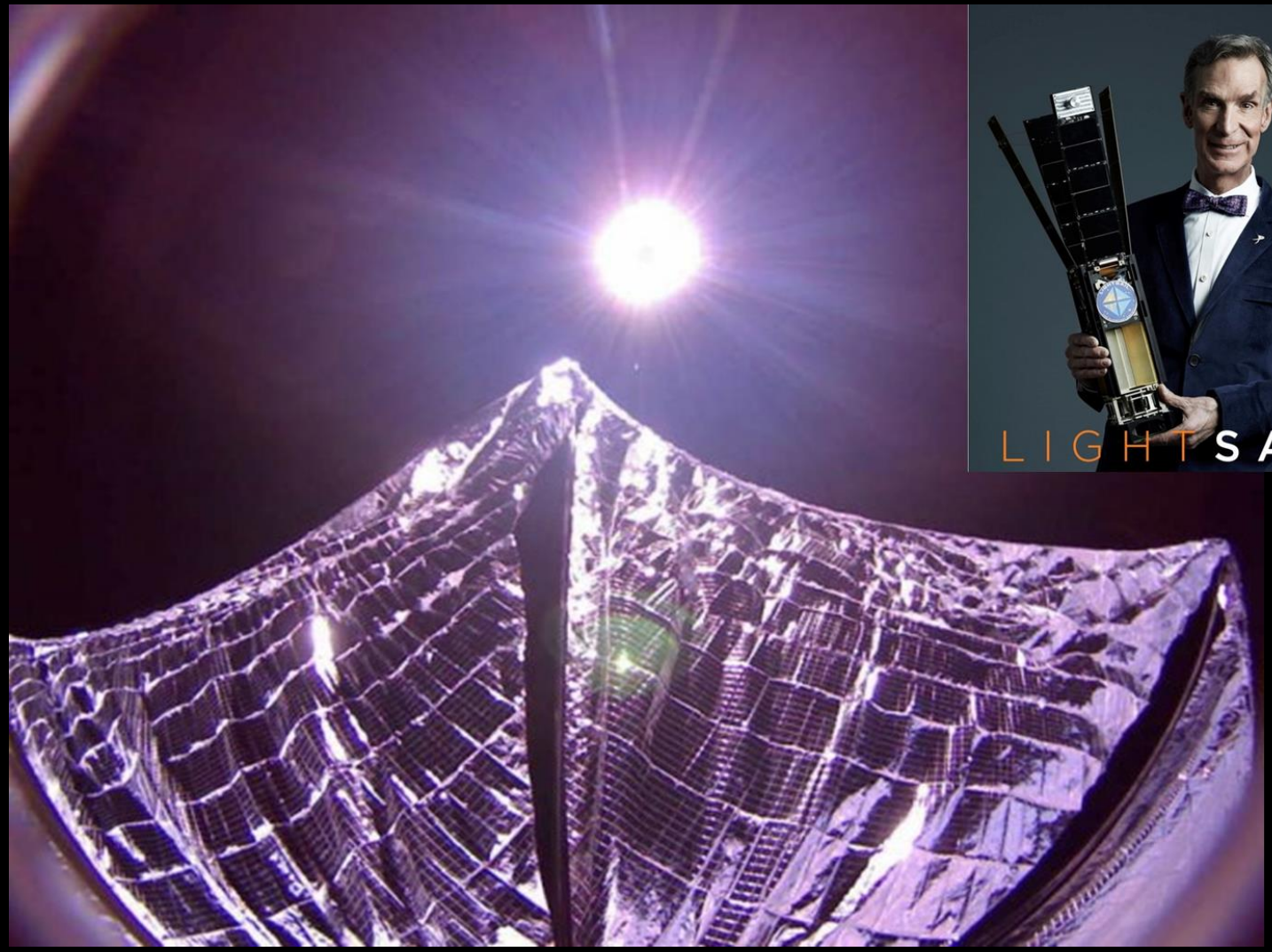




# Interplanetary Kite-craft Accelerated by Radiation of the Sun (IKAROS)




# Lightsail
## (The Planetary Society)






- **32 $m^2$**
- **No active ‘sailing’**
- **3U CubeSat**

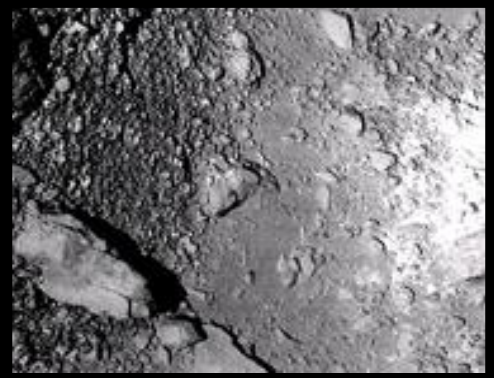
**Flew successfully in 2015 & 2019**

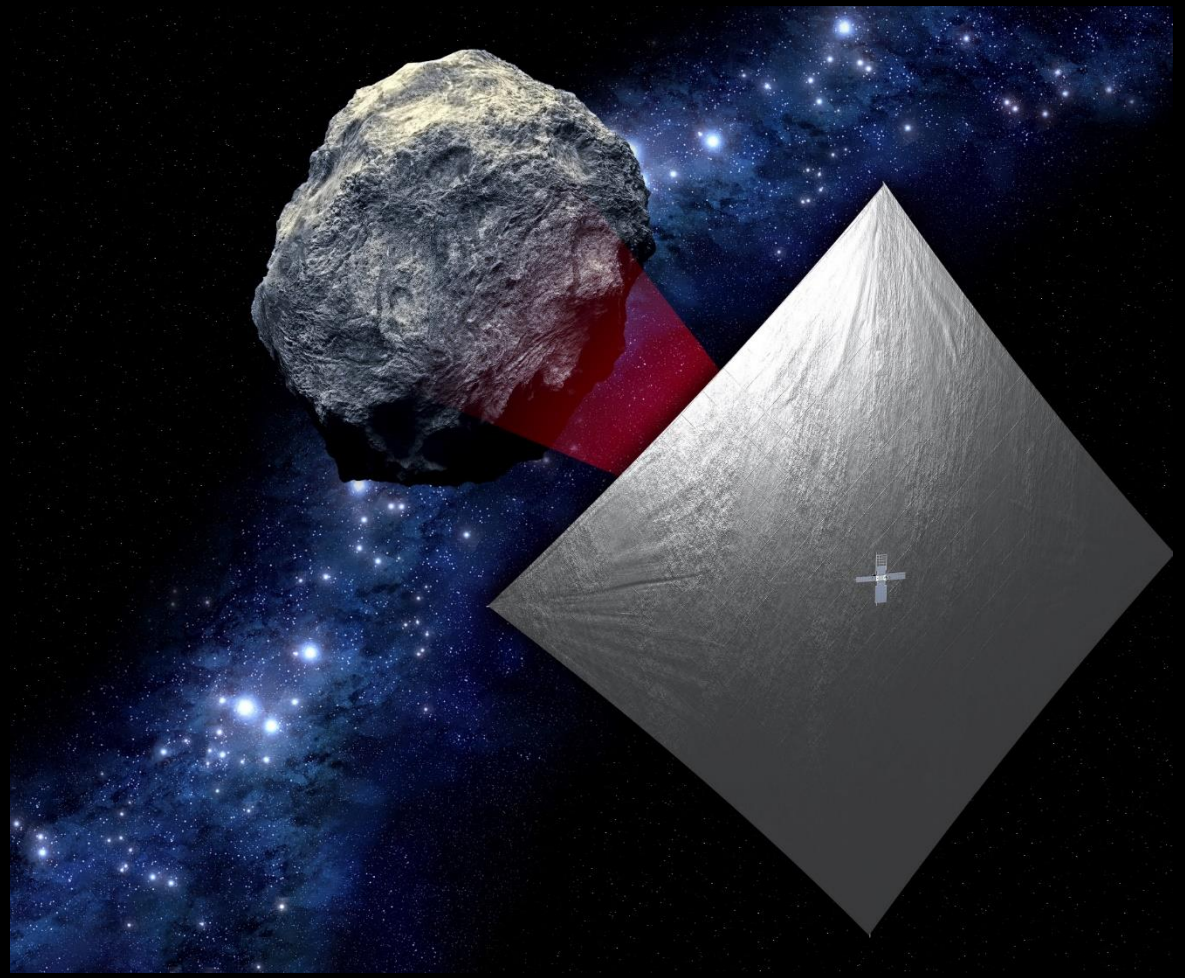
# Near Earth Asteroid Scout

**GOALS**

- Characterize a Near Earth Asteroid for possible future human visits

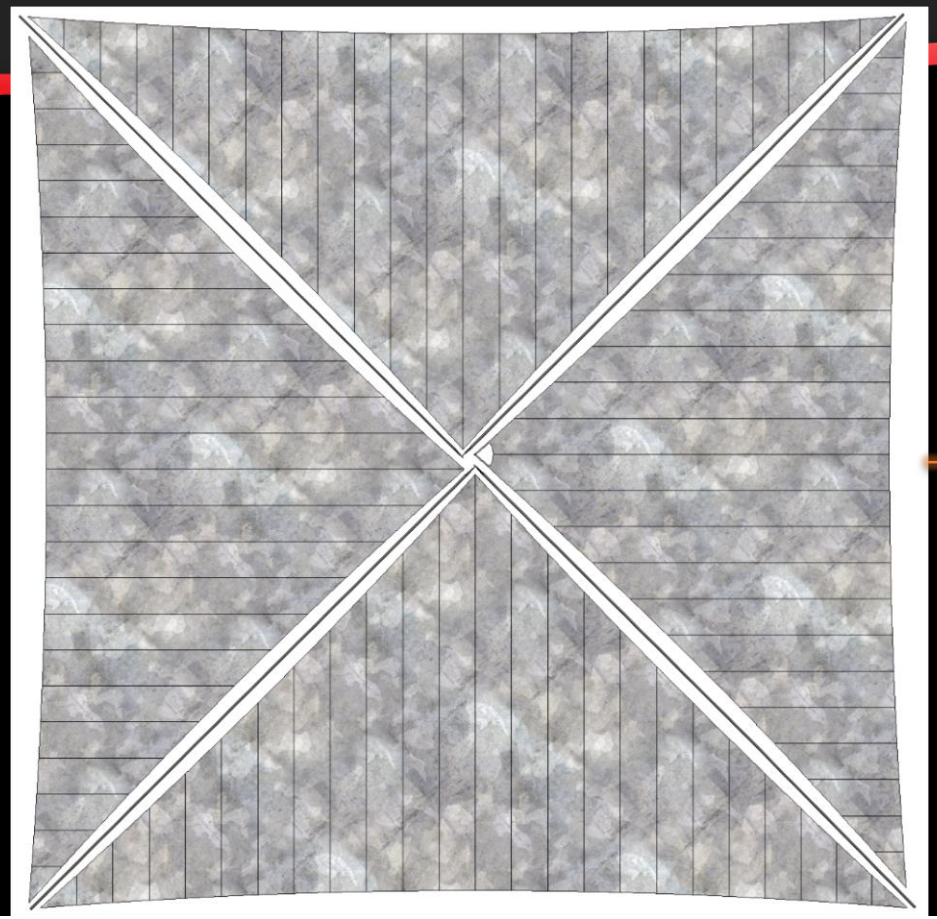
**Measurements:** *NEA volume, spectral type, spin and orbital properties, address key physical and regolith mechanical SKGs*





# ~9 x ~9m Solar Sail (NEA Scout)

**Deployed Solar Sail**



**School Bus**

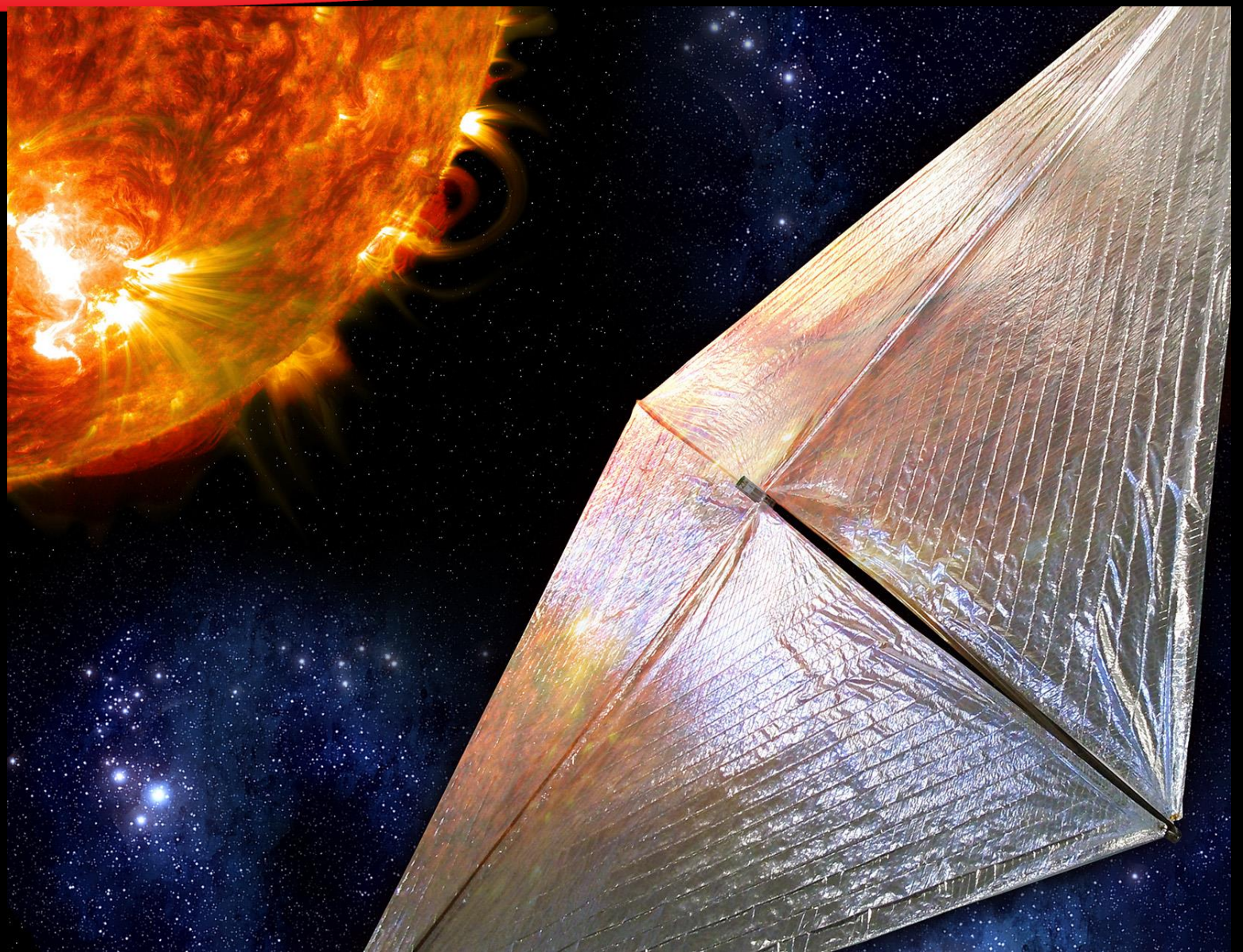

**6U Stowed Flight System**

Folded, spooled and packaged in here

# Full Scale Solar Sail Testing

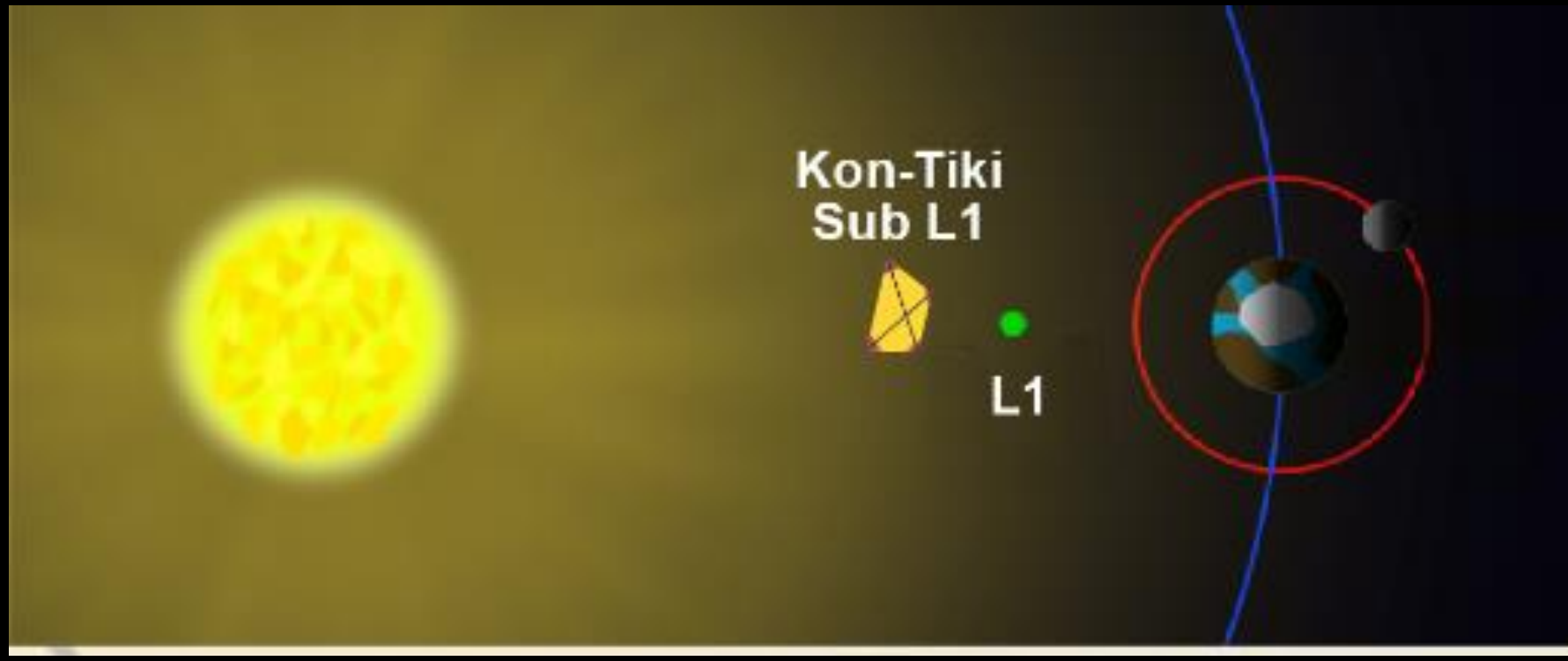
# Solar Cruiser

- 90 kg spacecraft
- 1666 m2 solar sail
- Sub-L1 station keeping

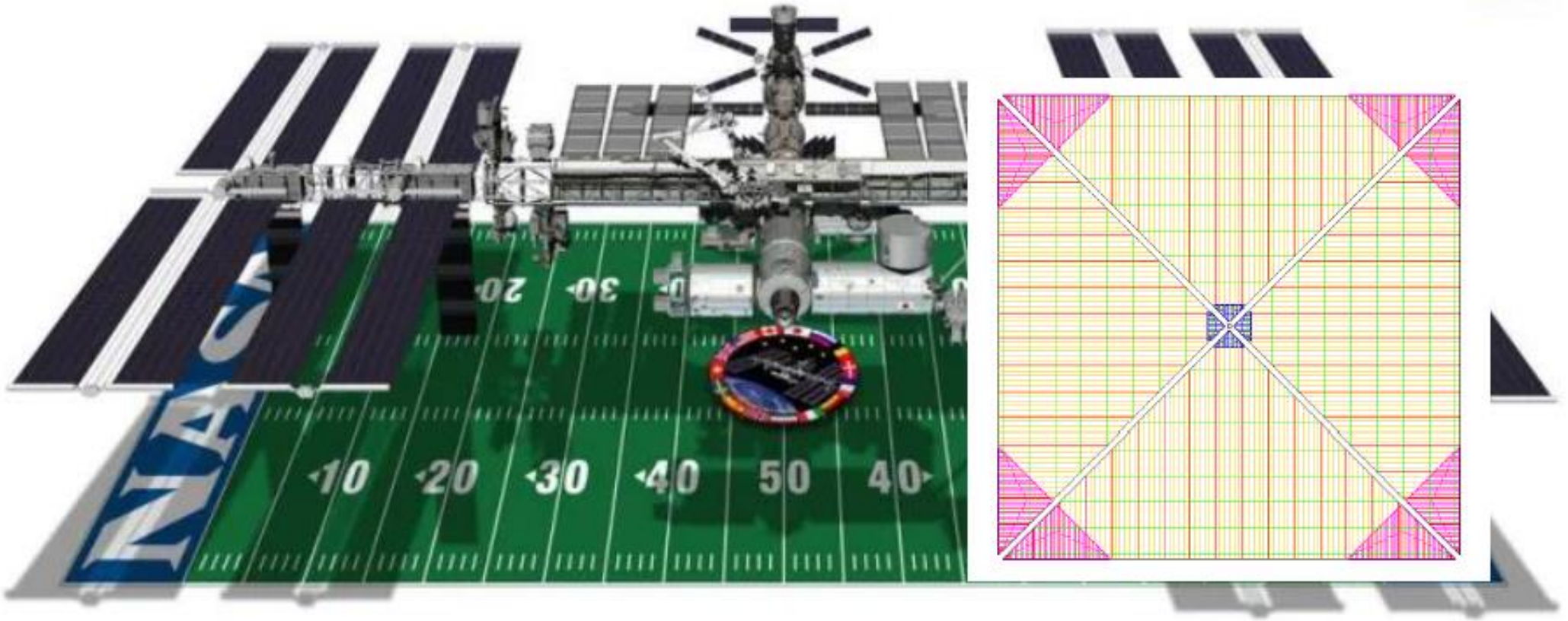


# Solar Cruiser Mission Profile

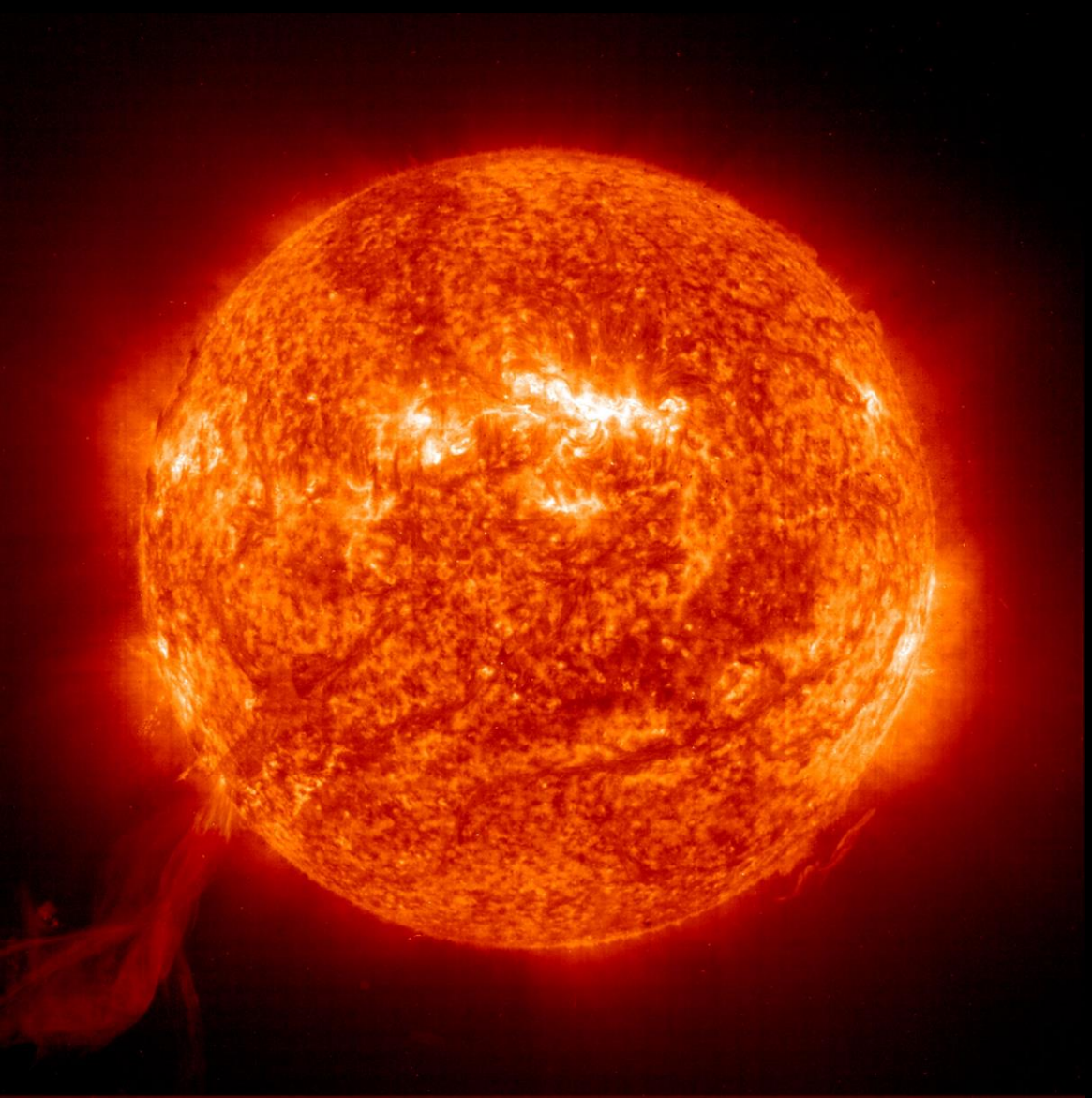
Solar Cruiser launches as a secondary payload on the NASA IMAP mission in October, 2024. It then cruises past the Sun-Earth L 1 point, demonstrating station keeping at an artificial equilibrium point.



# Solar Cruiser: 1/3 the size of a football field

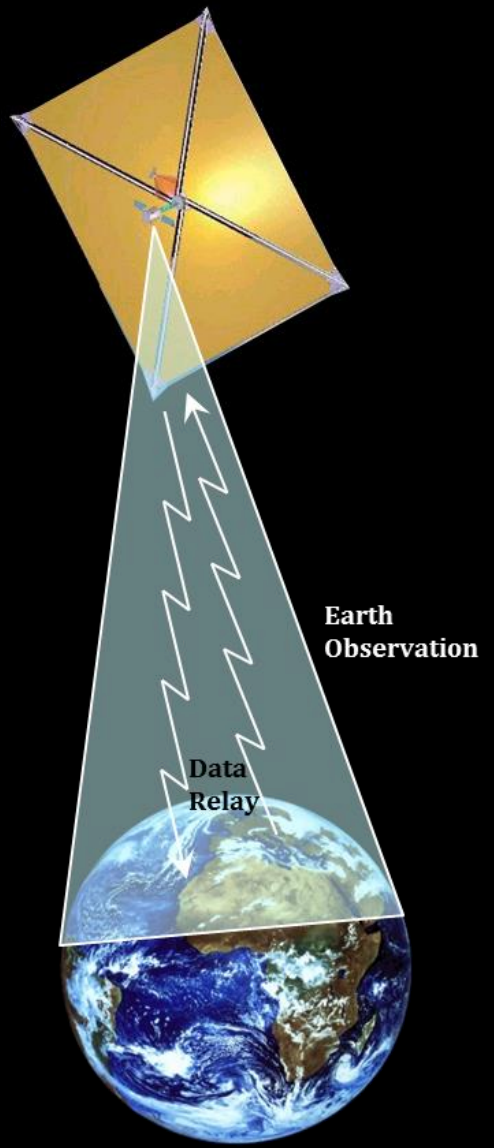


# Possible Future Mission
# Imaging the Solar Poles



- Leaving the ecliptic plane to image the Sun's poles is extremely propulsion intensive
- Solar sails can be used to "crank" a spacecraft's inclination from the ecliptic plane to a solar polar orbit

# Possible Future Mission
# Continuous Polar Observations




- Sailcraft over the polar regions of the Earth
- Sail tilted so the light pressure from the sunlight reflecting from it is exactly equal and opposite to the gravity pull of the Earth.

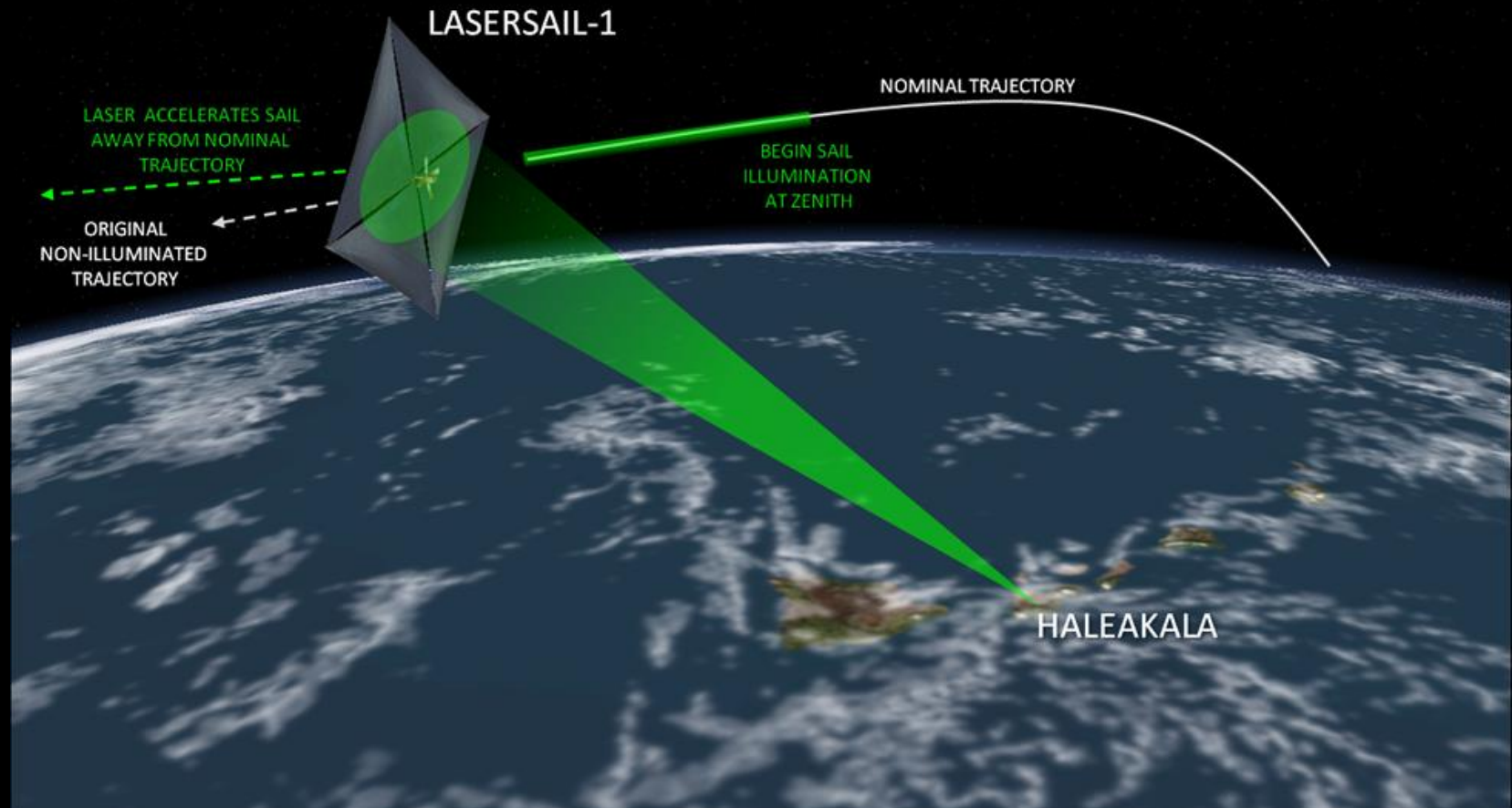
# Possible Future Mission
# Interstellar Medium Exploration

Deploy a large (>10,000 $m^2$) solar sail near the sun to enable travel 4X - 5X faster than Voyager

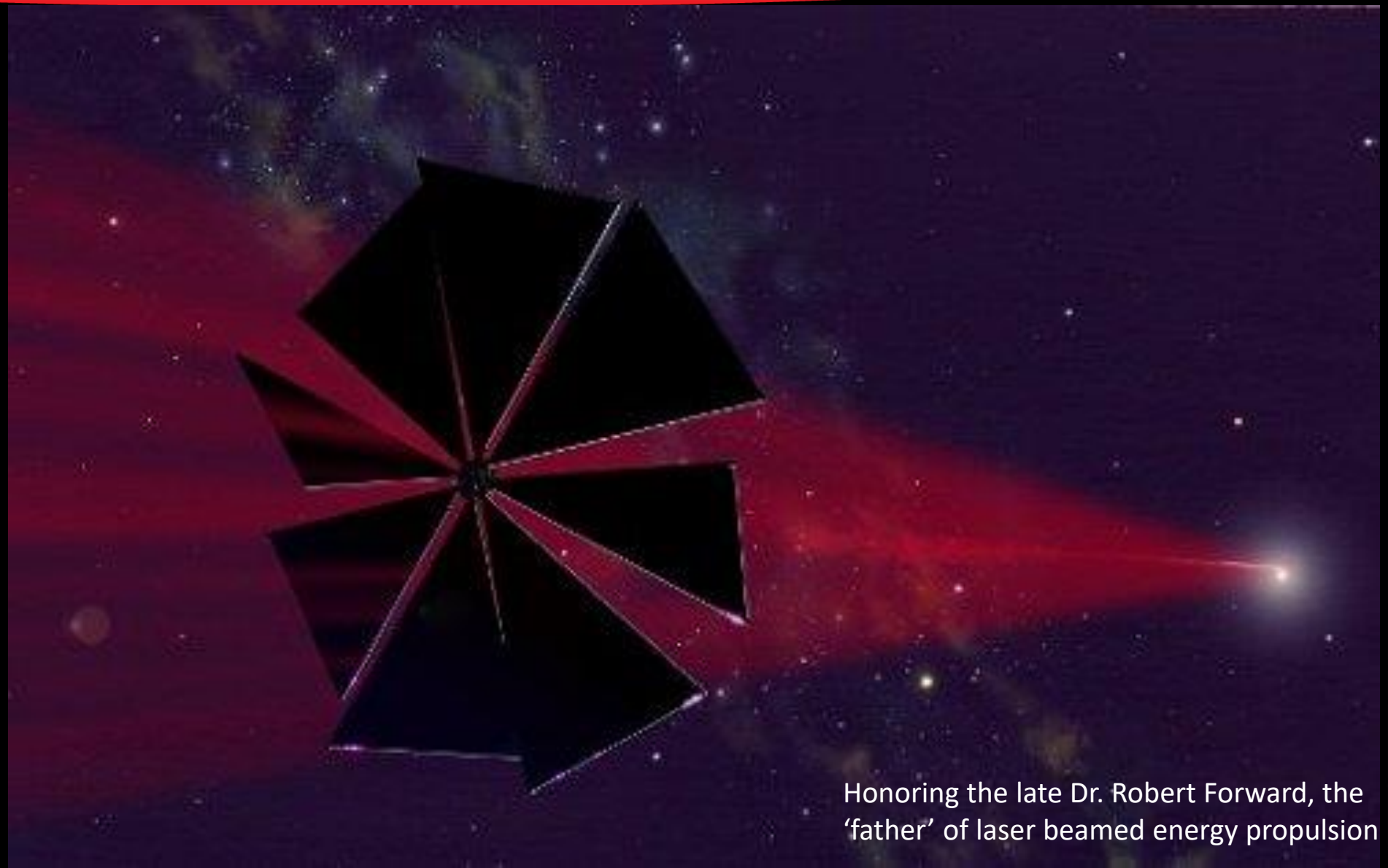

Goal: Reach 250 Astronomical Units within 20 years of launch

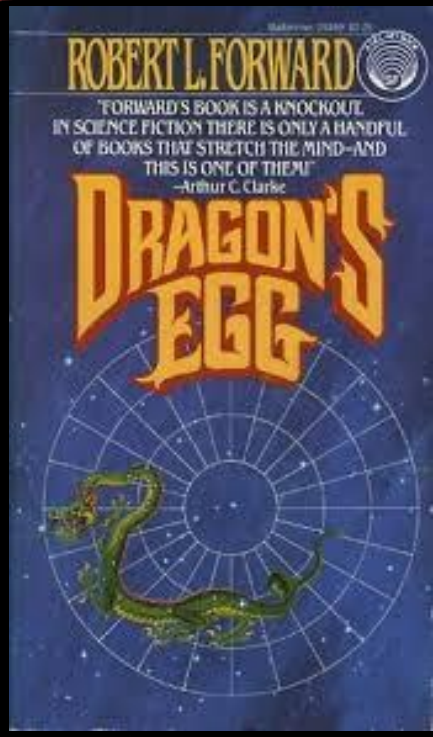
# Laser Sailing: The Next **Big** Step

Ground to space laser illumination of a solar sail to impart measurable thrust



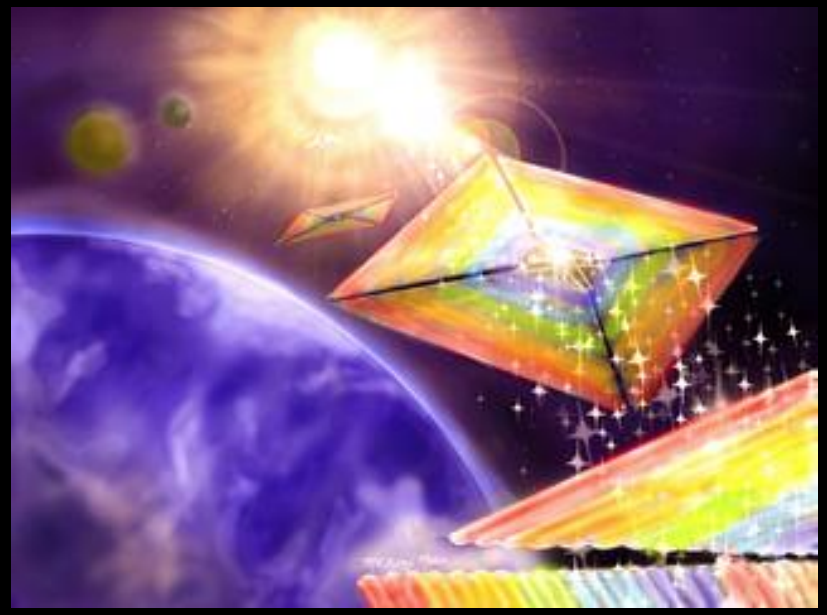
# Solar Sails: A Step Toward the Stars






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

# Future Sailing



**Diffractive Lightsails**
**Grover Swartzlander**
Rochester Institute of Technology