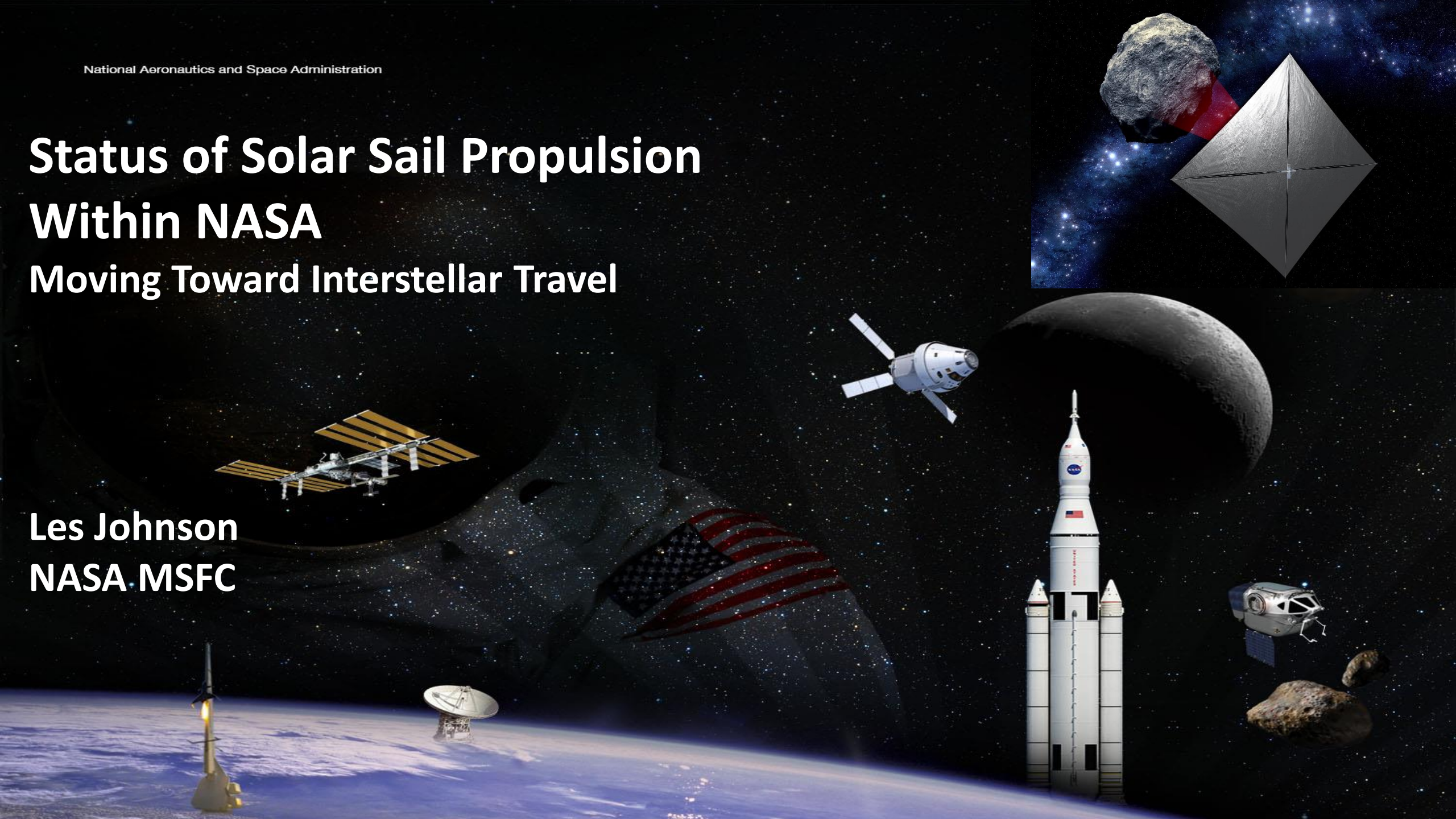
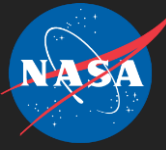


Status of Solar Sail Propulsion Within NASA

Moving Toward Interstellar Travel

Les Johnson
NASA MSFC





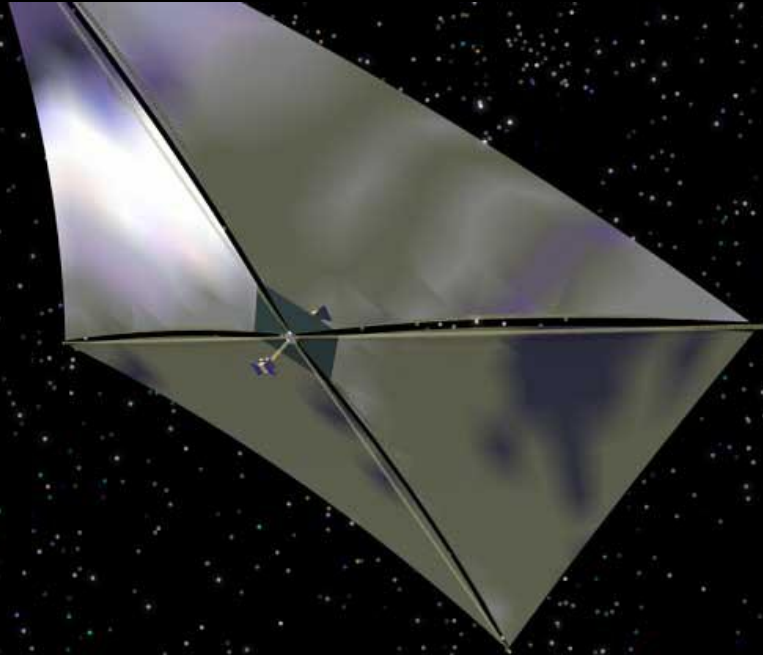
NASA and Solar Sails



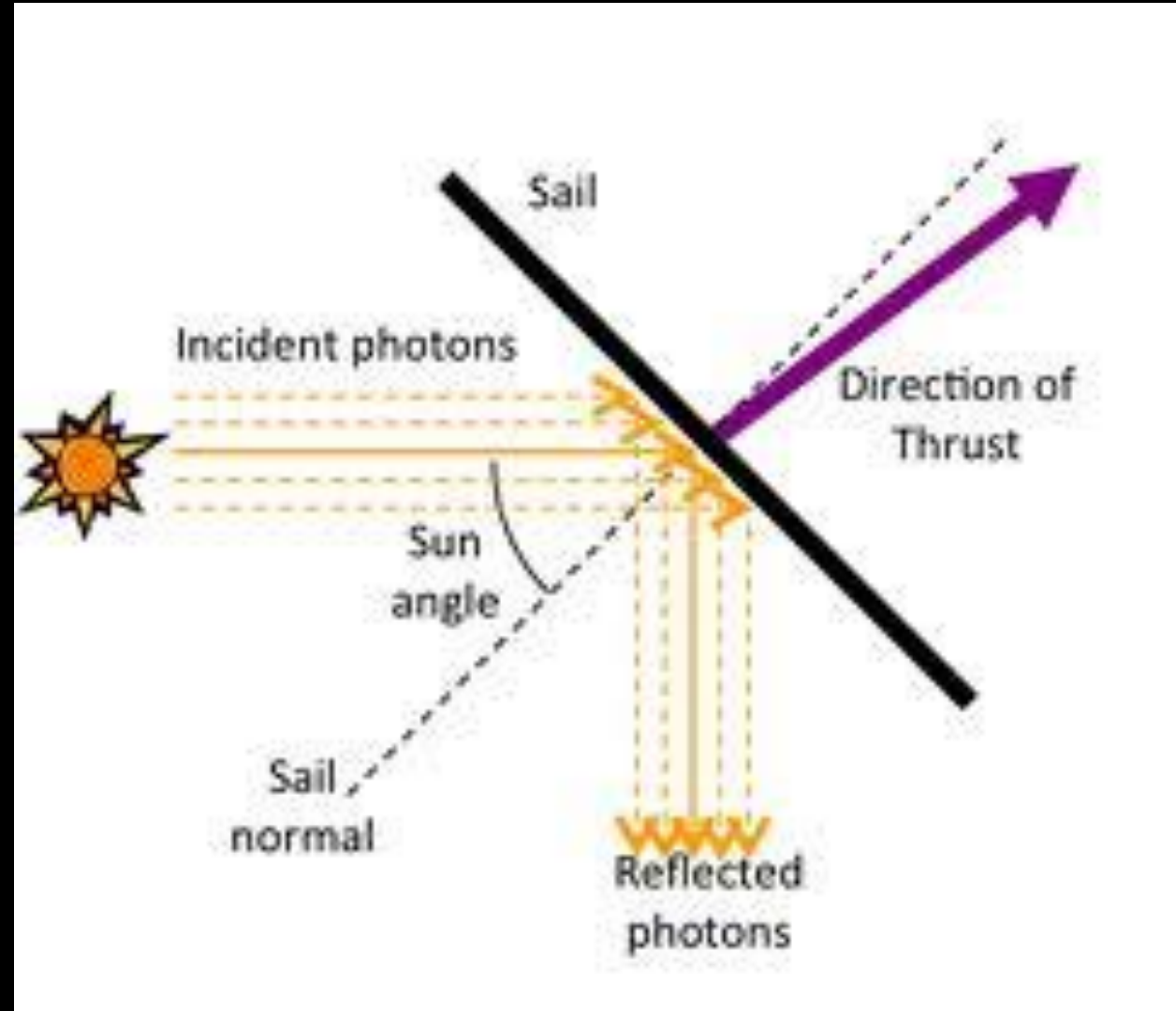
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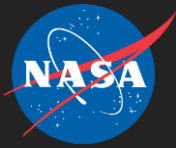


How Does a Solar Sail Work?



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

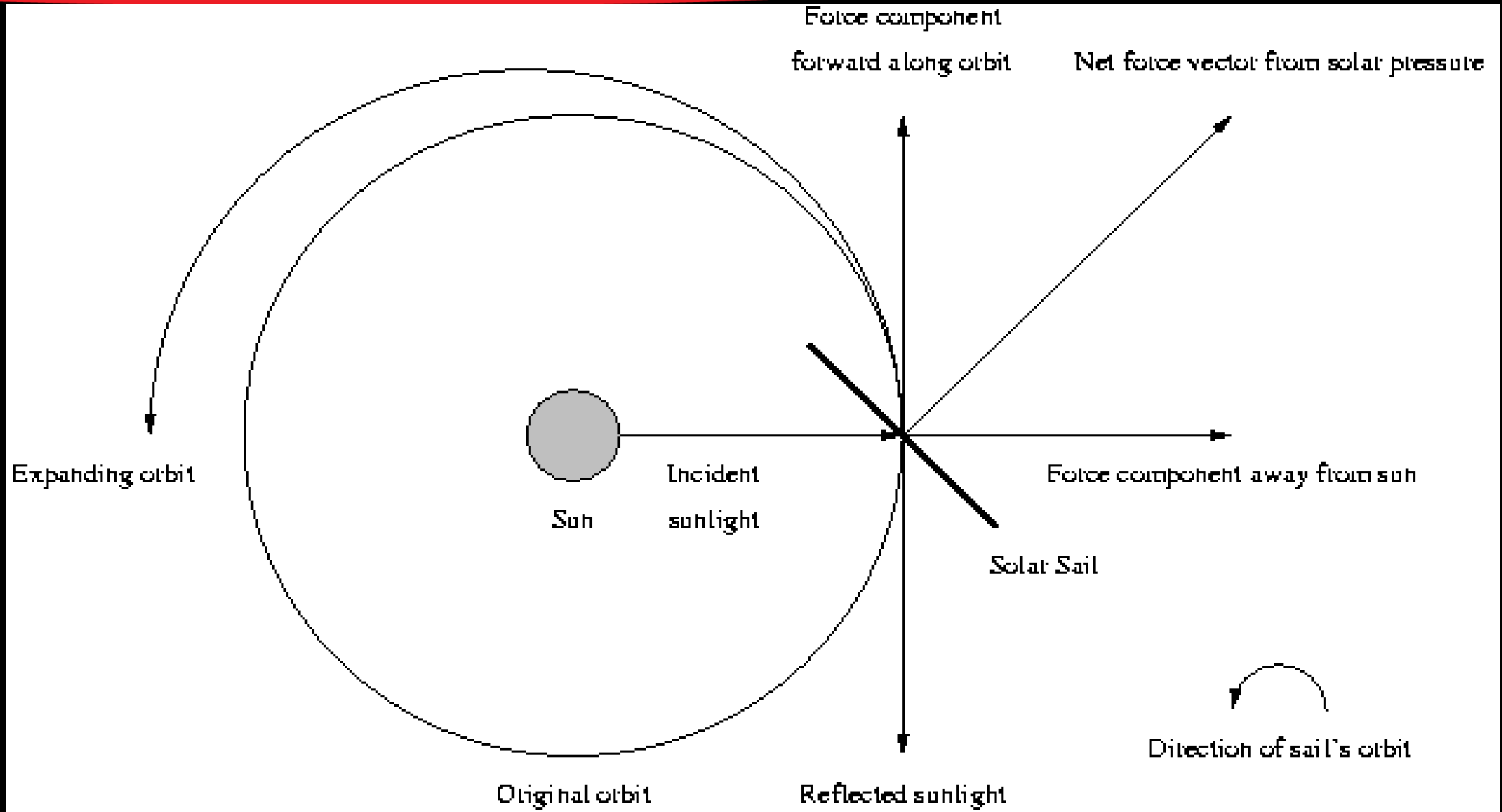




Solar Sails Can Spiral Inward or Outward From The Sun



Image courtesy of Colorado Center for Astrodynamics Research

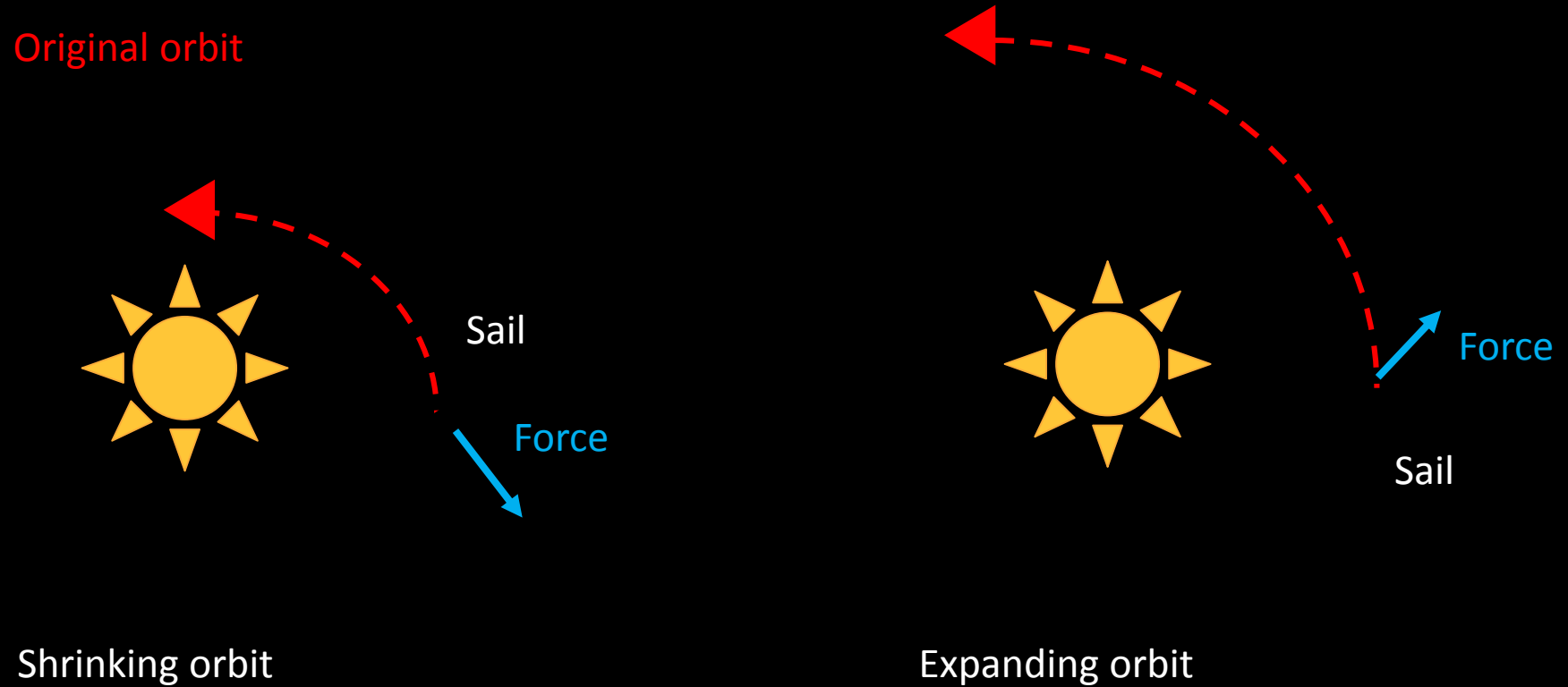




Solar Sail Trajectory Control

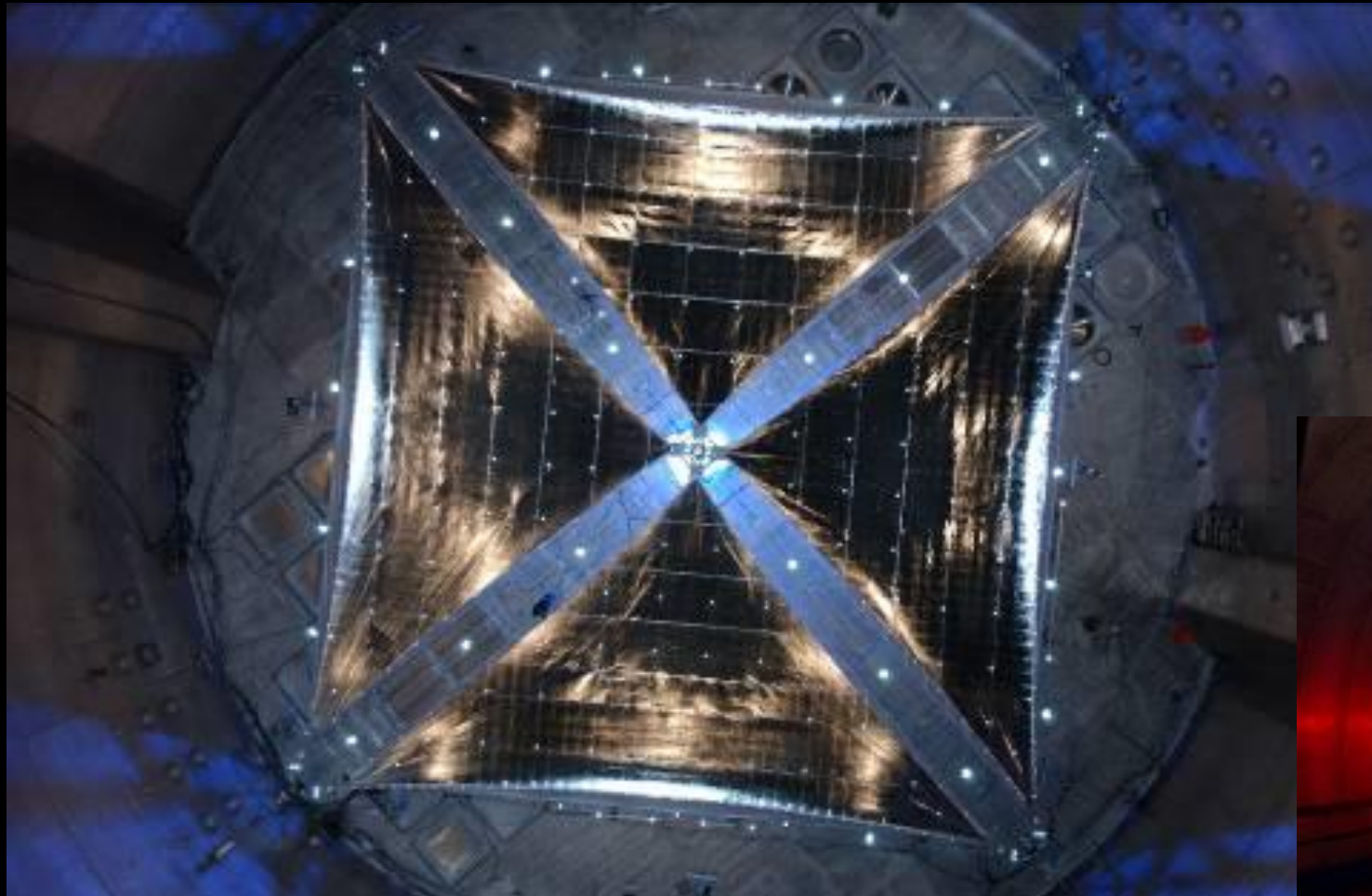


Solar Radiation Pressure: Inward and outward Spiral





NASA Ground Tested Solar Sails

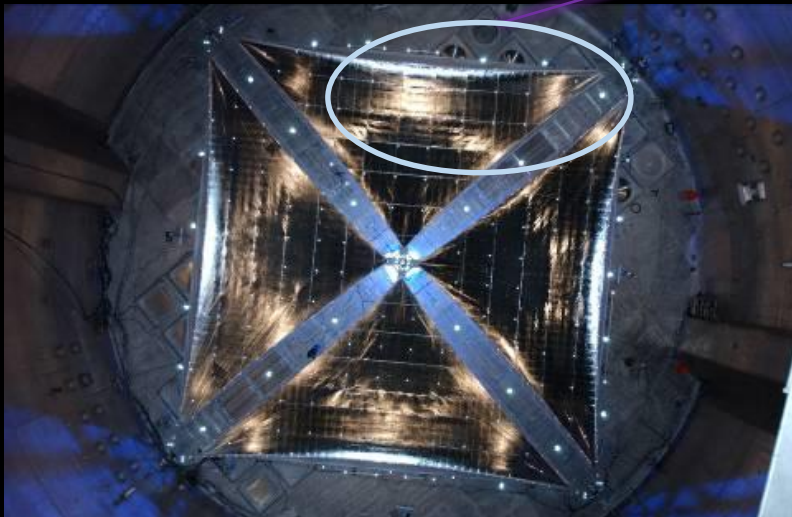




NanoSail-D Demonstration Solar Sail



- 10 m² sail
- Made from tested ground demonstrator hardware



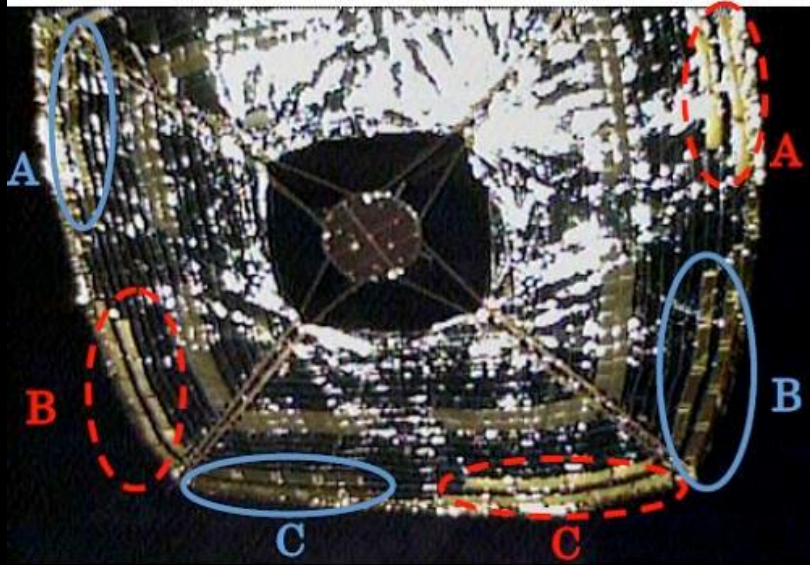


NanoSail-D in Flight





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



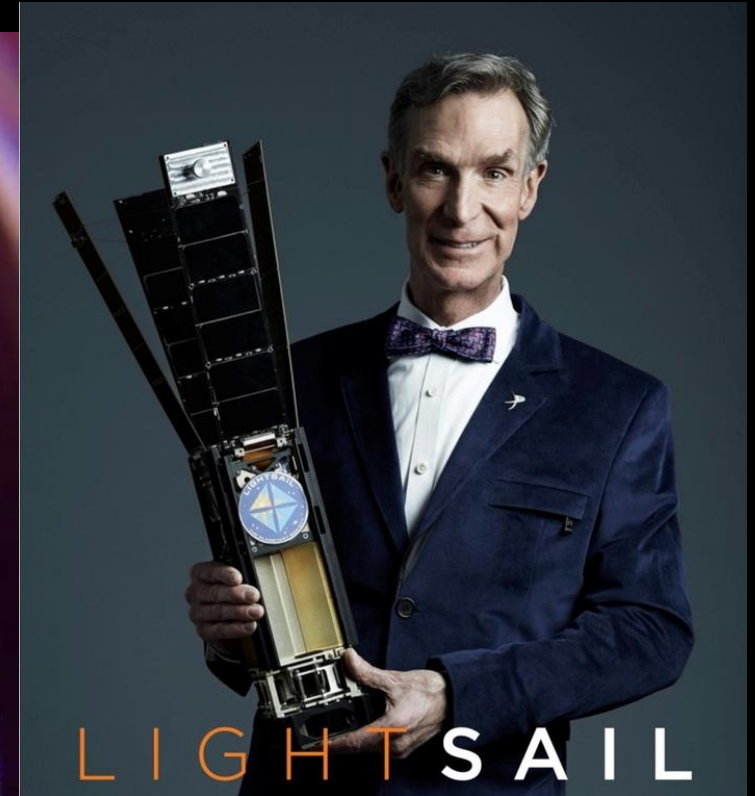
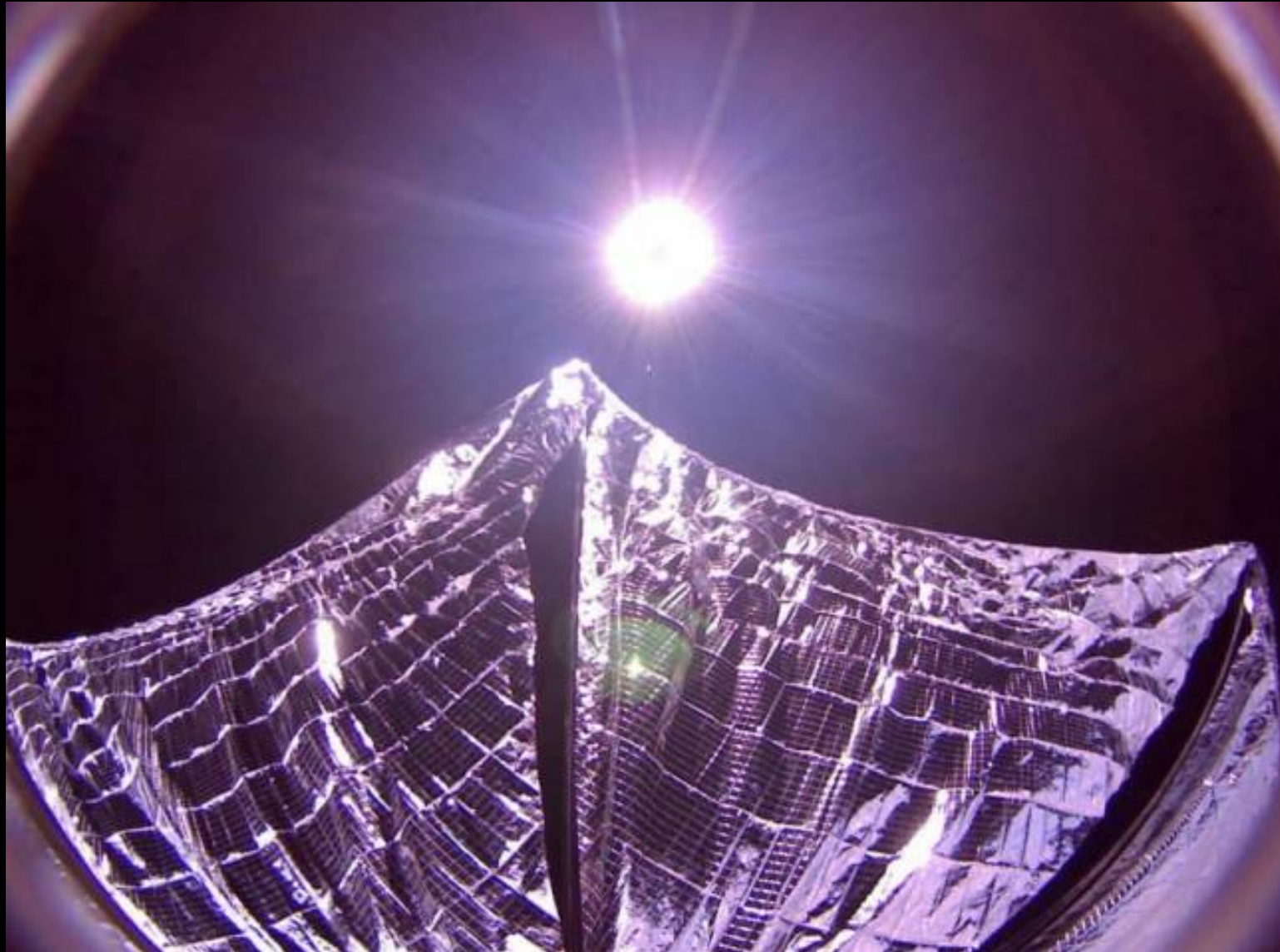
Liquid crystal device power was off.

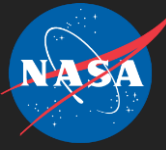
Liquid crystal device power was on.





The Planetary Society's LightSail-A





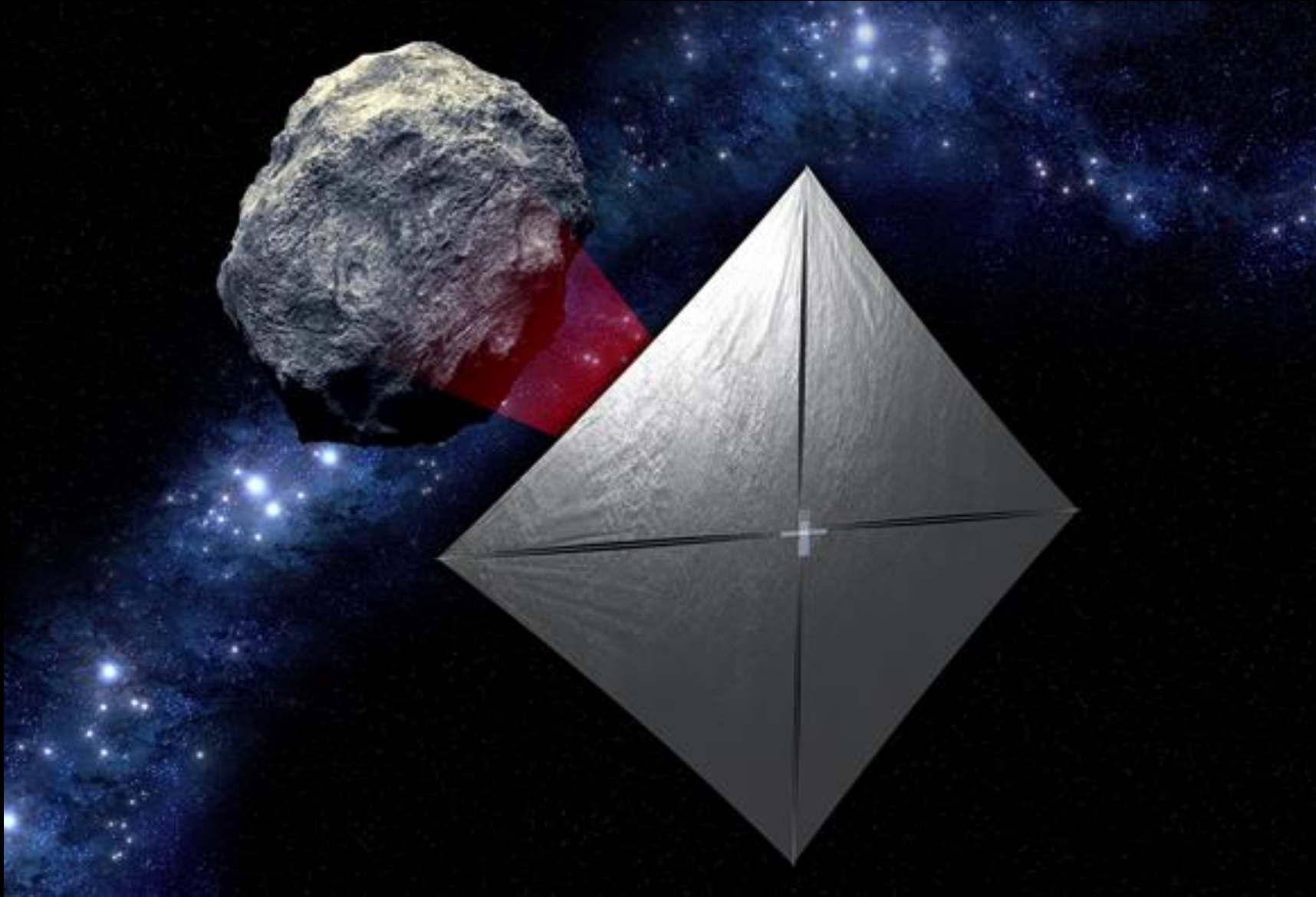
NASA and Solar Sails



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Near Earth Asteroid (NEA) Scout





Near Earth Asteroid Scout Overview



The Near Earth Asteroid Scout Will

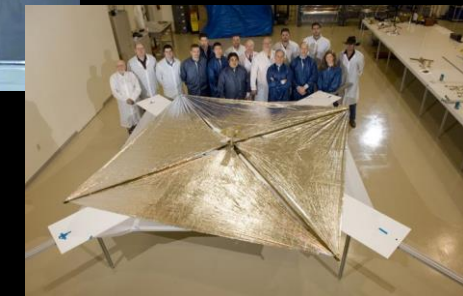
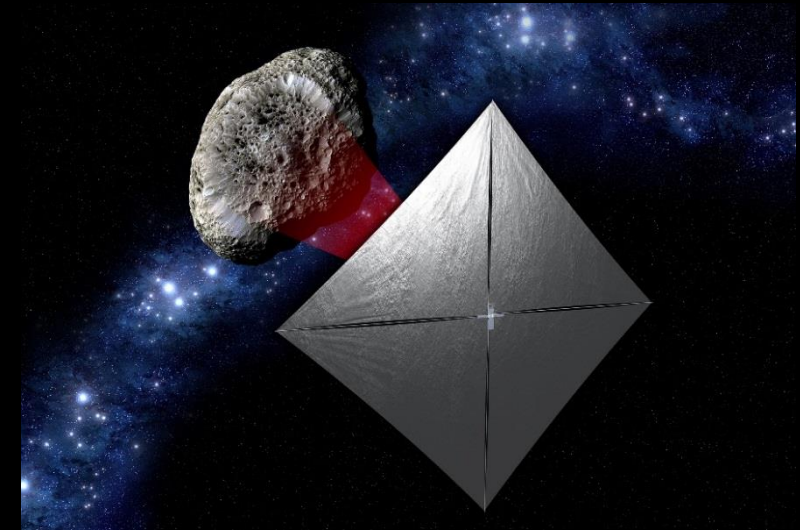
- Image/characterize an asteroid
- Demonstrate a low cost asteroid reconnaissance capability

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-1/2018)
- Up to 2.5 year mission duration
- 1 AU (93,000,000 mile) maximum distance from Earth

Solar Sail Propulsion System Characteristics

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





NEA Scout Overview



Why NEA Scout?

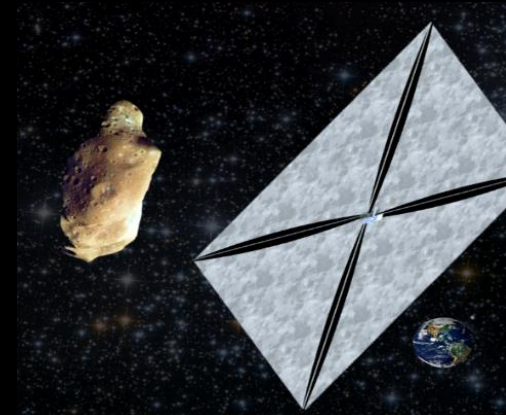
- Detect and track a Near Earth Asteroid (NEA) target
- Characterize the physical properties of the unresolved NEA target
- Flyby and characterize the physical properties of the resolved NEA target

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

- $\geq 80\%$ surface coverage imaging at ≤ 50 cm/px
- Spectral range: 400-900 nm (incl. 4 color channels)
- $\geq 30\%$ surface coverage imaging at ≤ 10 cm/px

Key Technical Constraints:

- 30 month maximum mission duration
- Target must be within ~ 1 AU distance from Earth due to telecom limitations
- Slow flyby with target-relative navigation on close approach





What do we Know About 1991 VG?

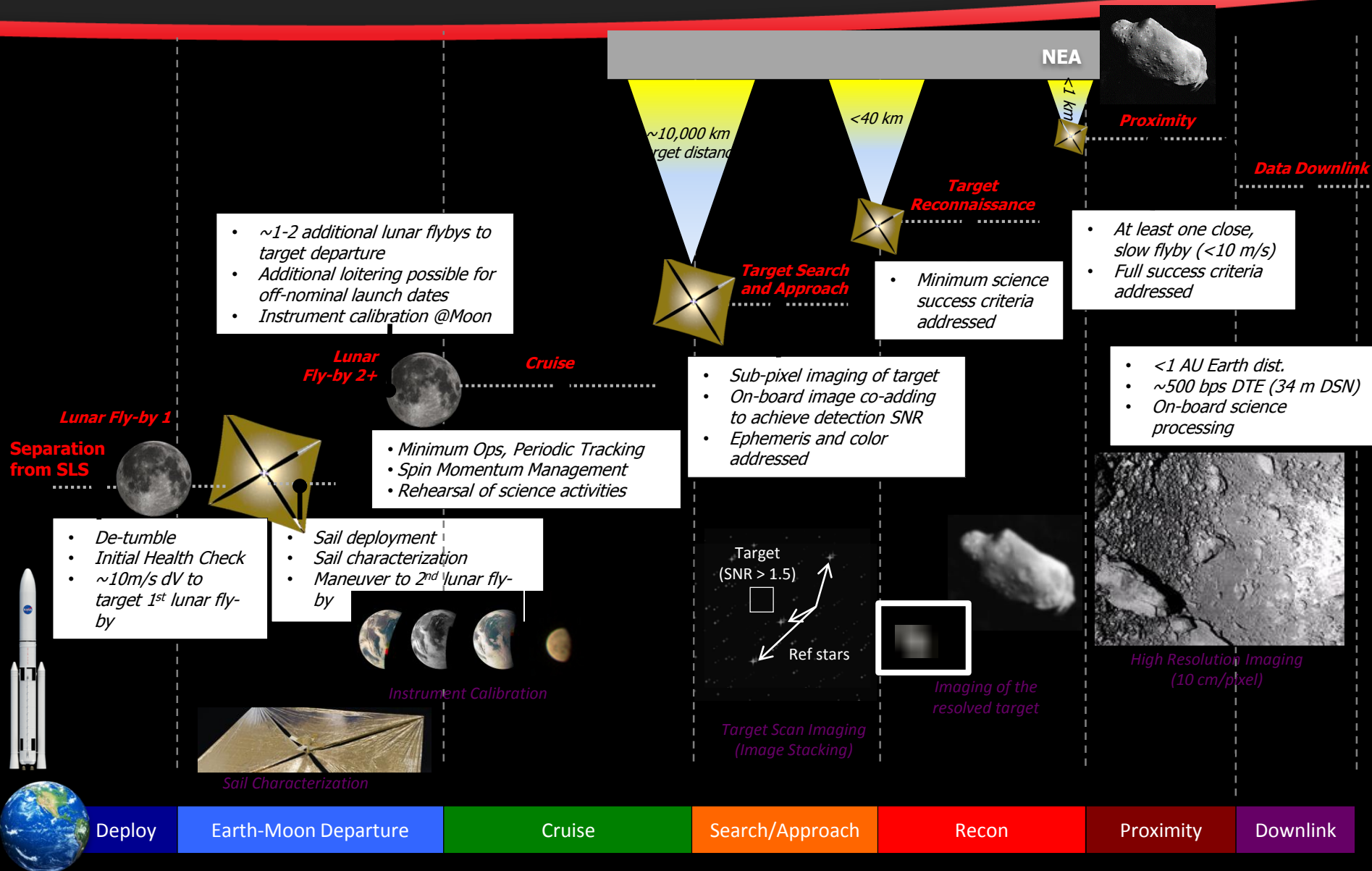


- Not much
- $H = 28.4 \pm 0.7$
- Diameter ~ 4-17 meters
- Albedo is unknown
- Rotation period between a few minutes and less than 1 hr.
- Unlikely to have a companion
- Likely did not retain an exosphere or dust cloud
 - Solar radiation pressure sweeps dust on timescales of hours or days





NEA Scout Operations Overview

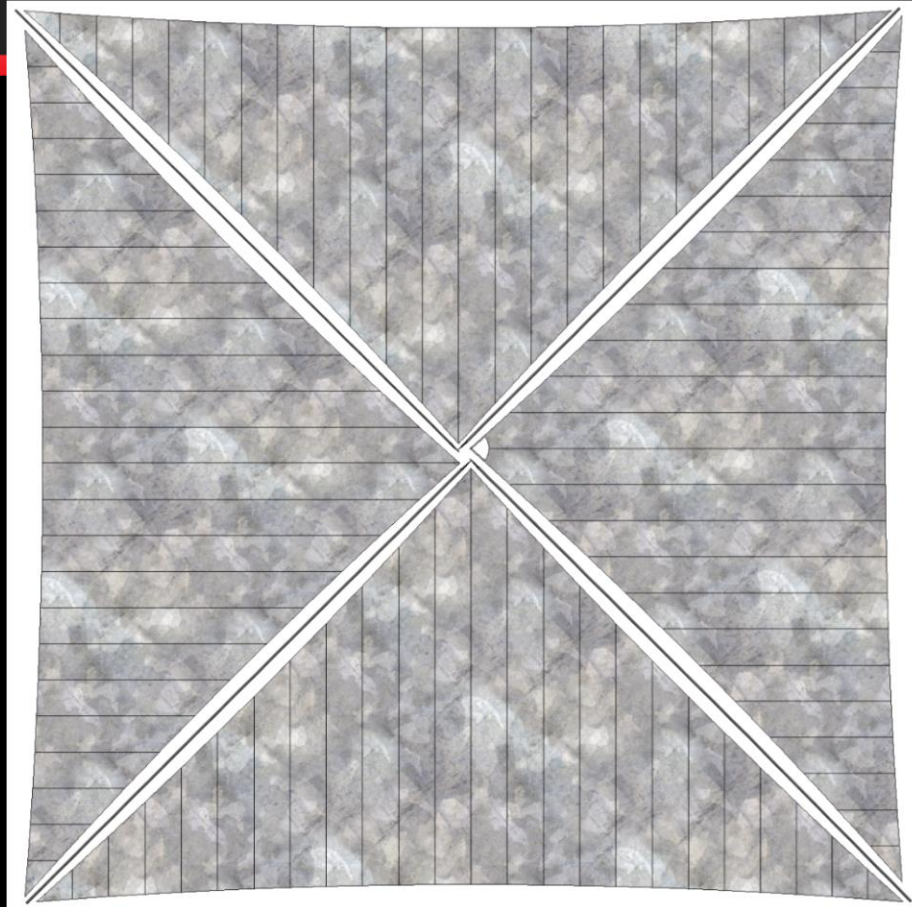




NEA Scout Approximate Scale



Deployed Solar Sail



6U Stowed Flight System



Folded, spooled and packaged in here



University of Surrey's InflateSail



InflateSail is an inflatable, rigidizable sail for flight in Low Earth Orbit:

- 3U CubeSat with deployed sail area of 10 m²
- Sail supported by bistable booms
- Inflation is driven by Cool Gas Generators (CGG): low system mass, long lifespan

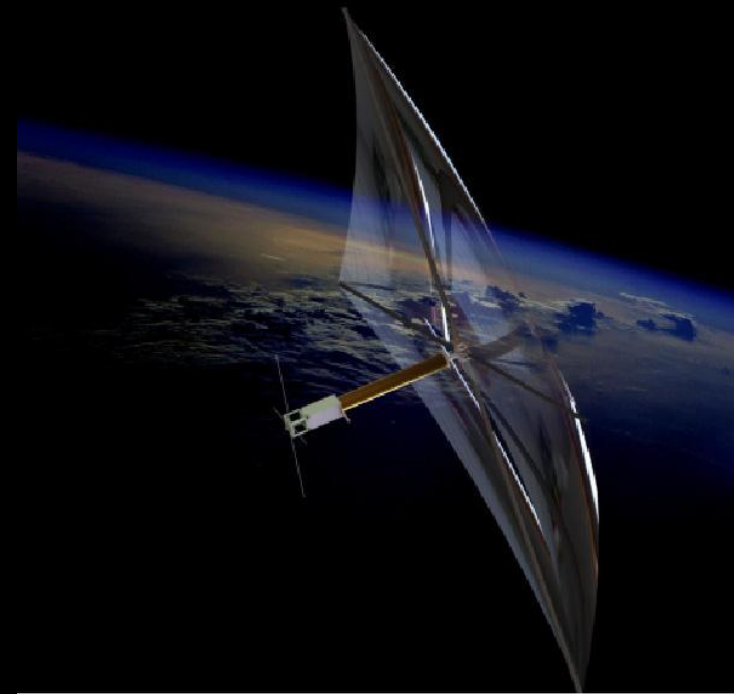


Fig. 1: InflateSail design concept



Fig. 2: 80 mg CGG George C. Marshall Space Flight Center

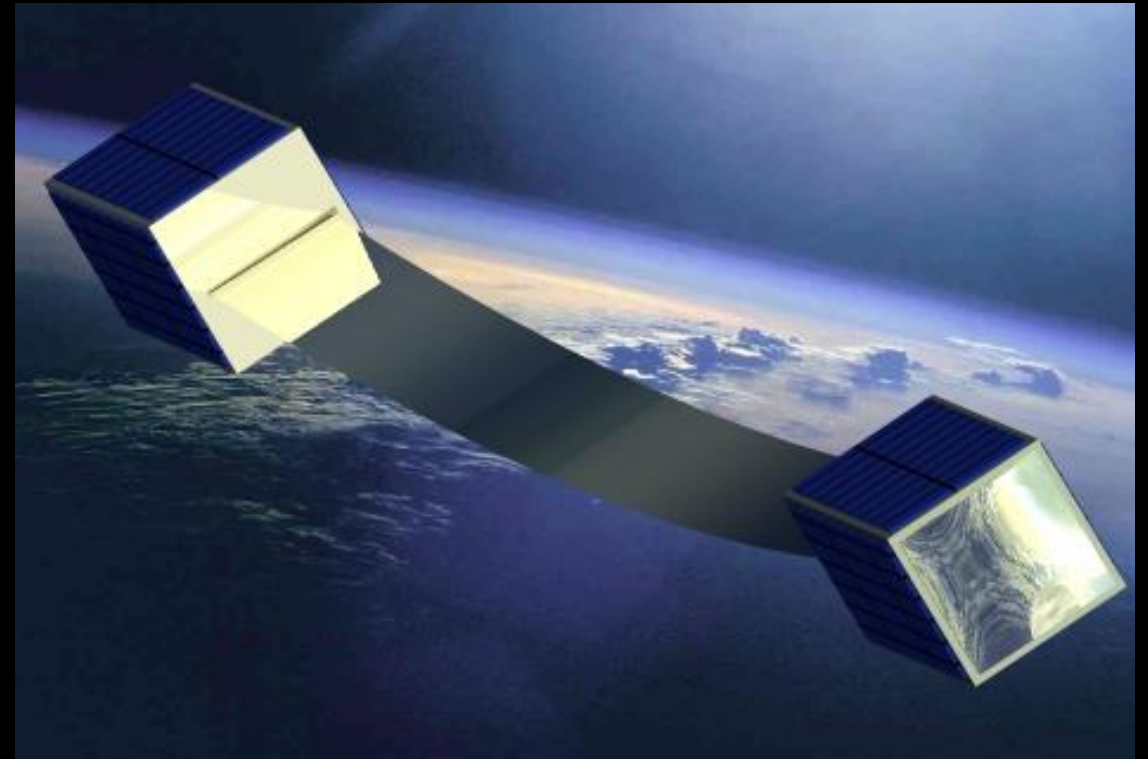




CubeSail CubeSat Solar Sail Propulsion Demonstration



- The University of Illinois at Urbana-Champaign (UIUC), working with NASA MSFC, NSF and CU Aerospace, built the flight hardware for a CubeSat-based 20 m² solar sail orbit raising demonstration mission
- Selected for flight under the NASA CubeSat Launch Initiative





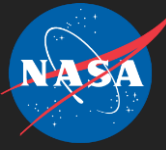
Interstellar Probe: A Possible NASA Mission in the 2020's



Deploy a large (>10,000 m²) solar sail near the sun to enable travel 5X faster than Voyager



Goal: Reach 250 Astronomical Units within 20 years of launch



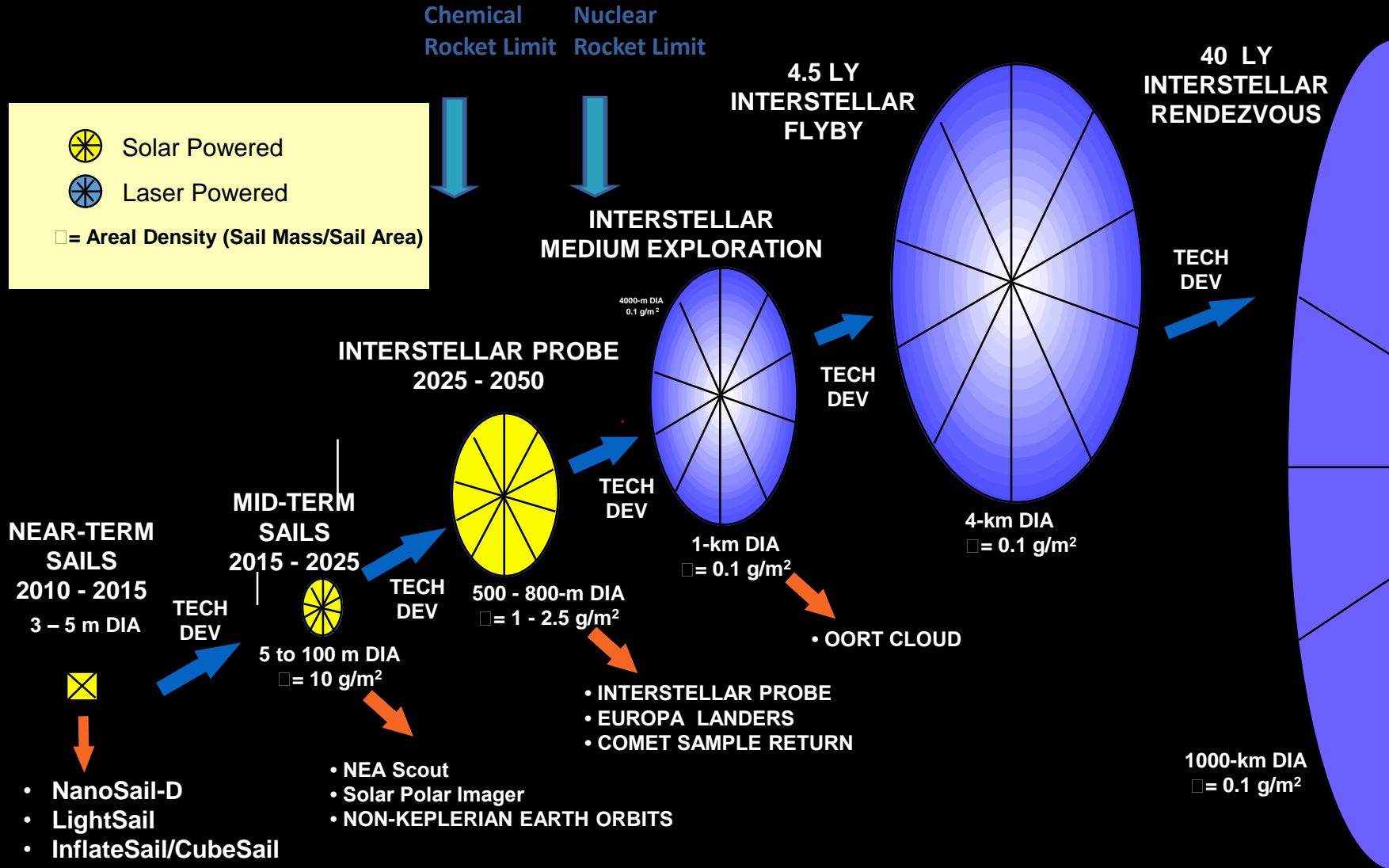
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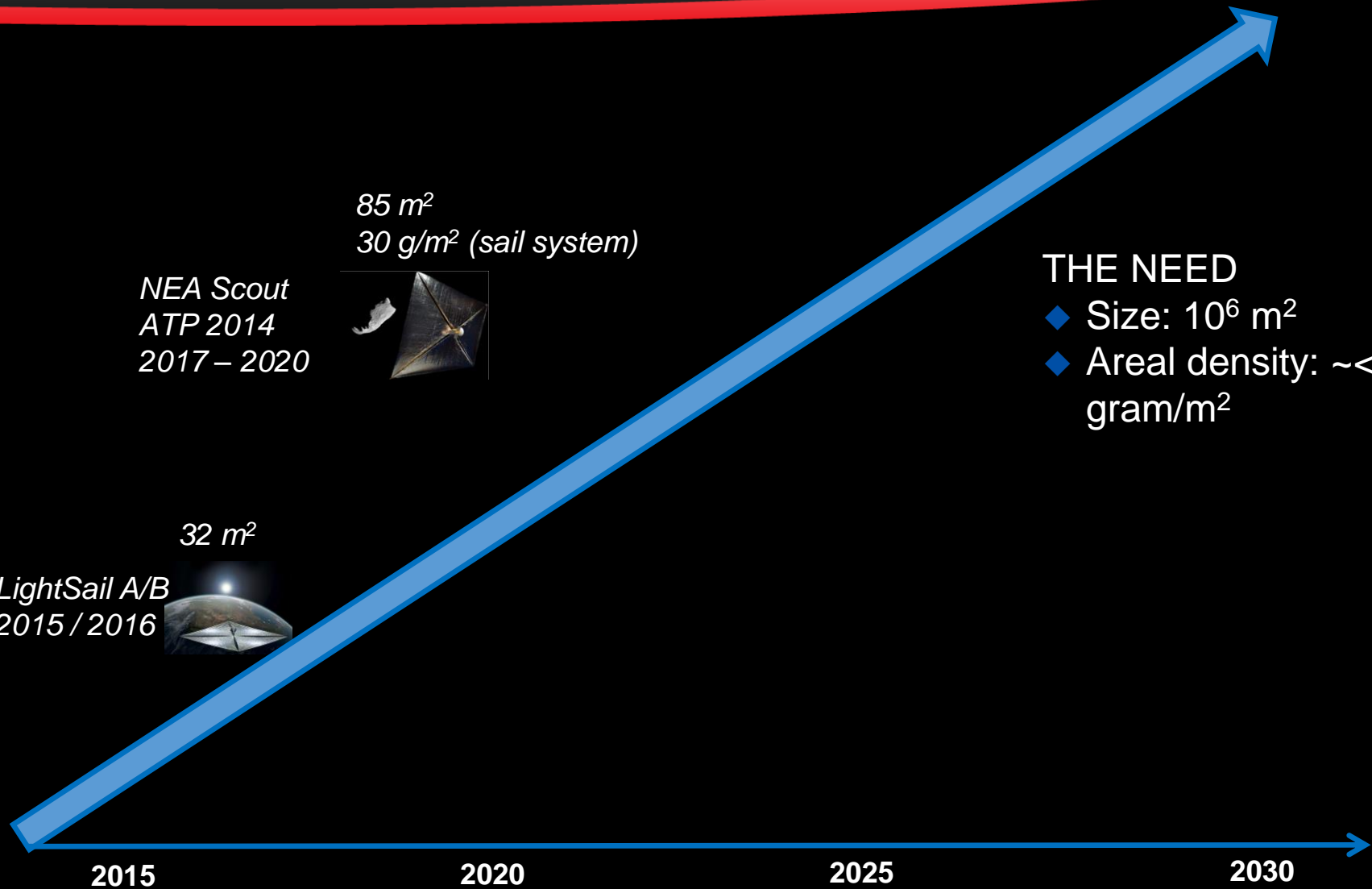


The Real Reason to Develop Solar Sails



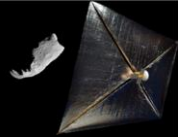


The Plan (as yet unfunded)



NEA Scout
ATP 2014
2017 – 2020

85 m²
30 g/m² (sail system)



32 m²

LightSail A/B
2015 / 2016

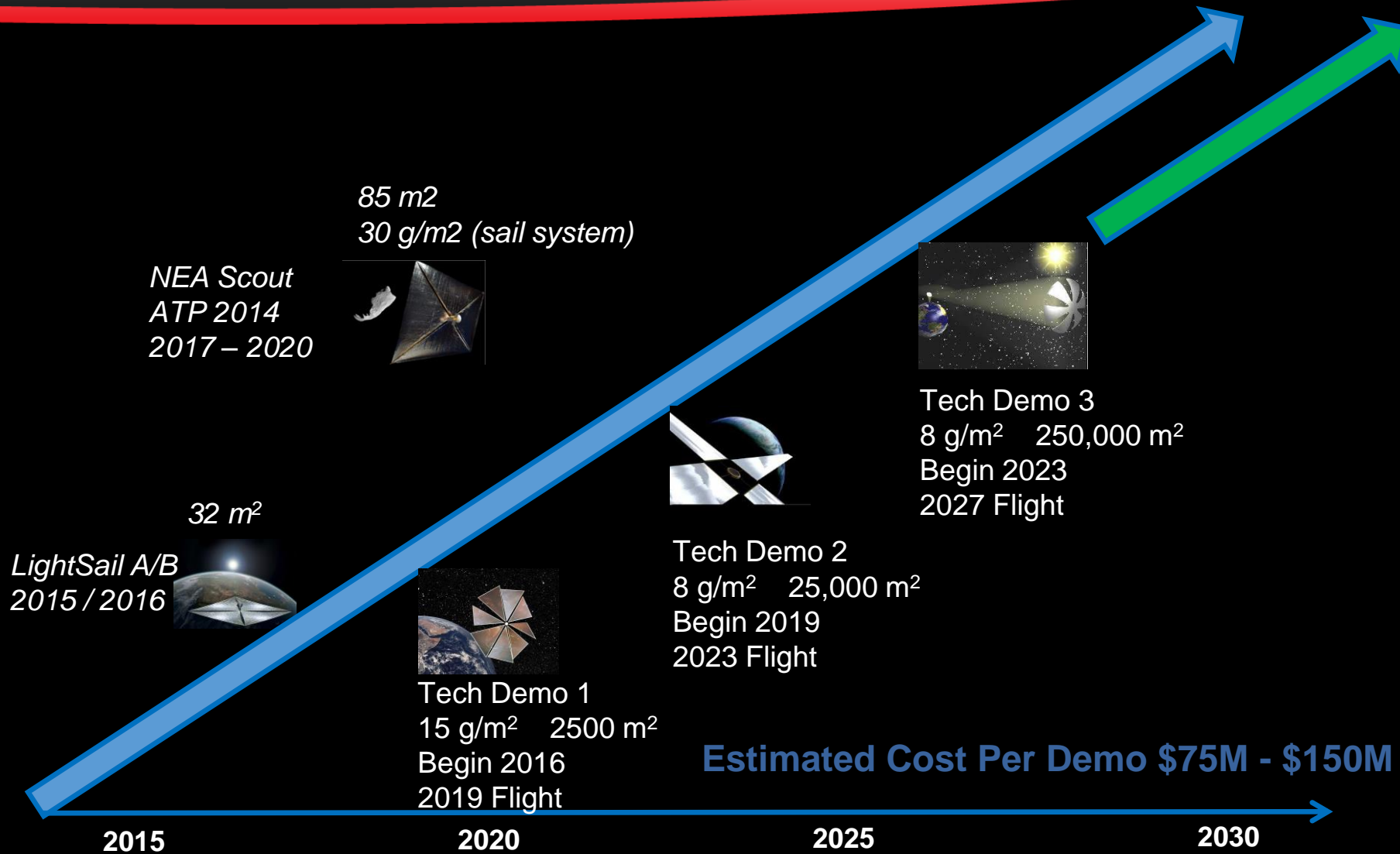


THE NEED

- ◆ Size: 10⁶ m²
- ◆ Areal density: ~< 3 gram/m²

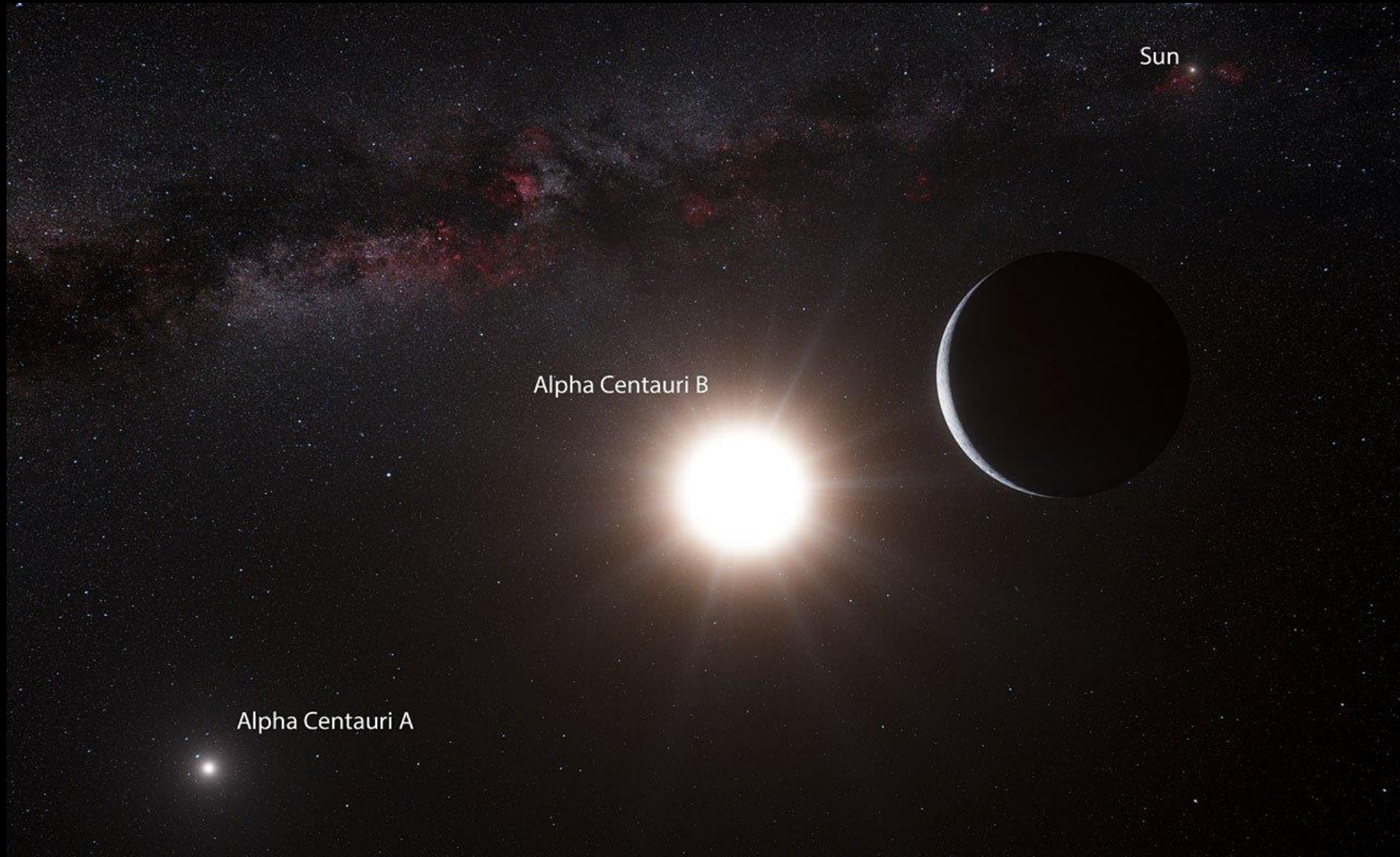


Aggressive Sail Development To Enable Interstellar Exploration





Looking Back Toward Home



Sun

Alpha Centauri B

Alpha Centauri A