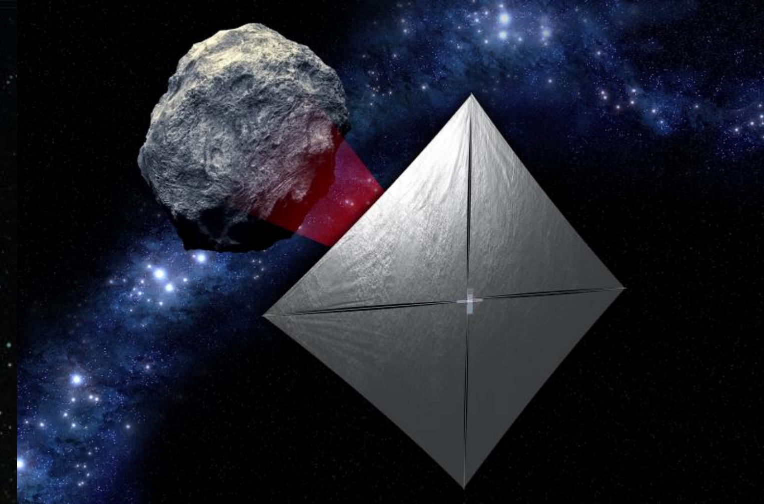
National Aeronautics and Space Administration

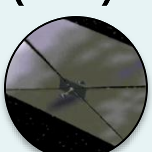


Near Earth Asteroid Scout

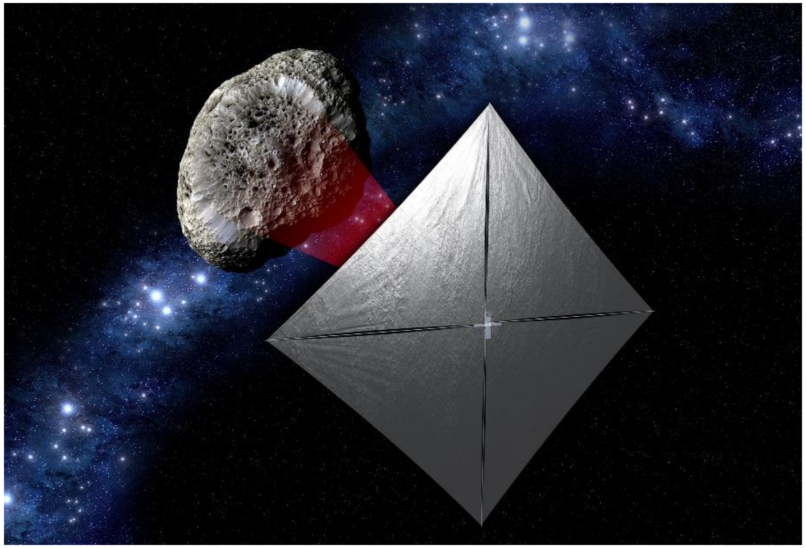
Les Johnson
NASA MSFC

SLS EM-1 Secondary Payloads

- **HEOMD's Advanced Exploration Systems (AES) selected 3 cubesats for flight on SLS EM1**
- **Primary selection criteria:**
  - Relevance to Space Exploration Strategic Knowledge Gaps (SKGs)
  - Life cycle cost
  - Synergistic use of previously demonstrated technologies
  - Optimal use of available civil servant workforce
- **Completed Mission Concept Review, System Requirements Review, and a Non-Advocate Review of the Science Plan**
- **Leslie McNutt (FP) is the NASA Project Manager**

Payload *NASA Centers*	**Strategic Knowledge Gaps Addressed**	**Mission Concept**
BioSentinel ***ARC**/JSC* 	**Human health/performance in high-radiation space environments** • Fundamental effects on biological systems of ionizing radiation in space environments	Study radiation-induced DNA damage of live organisms in cis-lunar space; correlate with measurements on ISS and Earth
Lunar Flashlight ***JPL**/MSFC* 	**Lunar resource potential** • Quantity and distribution of water and other volatiles in lunar cold traps	Locate ice deposits in the Moon's permanently shadowed craters
Near Earth Asteroid (NEA) Scout ***MSFC**/JPL* 	**Human NEA mission target identification** • NEA size, rotation state (rate/pole position) **How to work on and interact with NEA surface** • NEA surface mechanical properties	Flyby/rendezvous and characterize one NEA that is candidate for a human mission

Near Earth Asteroid Scout Overview



The Near Earth Asteroid Scout Will

- Image/characterize a NEA during a slow flyby in order to address key Strategic Knowledge Gaps (SKGs) for HEO
- Demonstrate a low cost asteroid reconnaissance capability

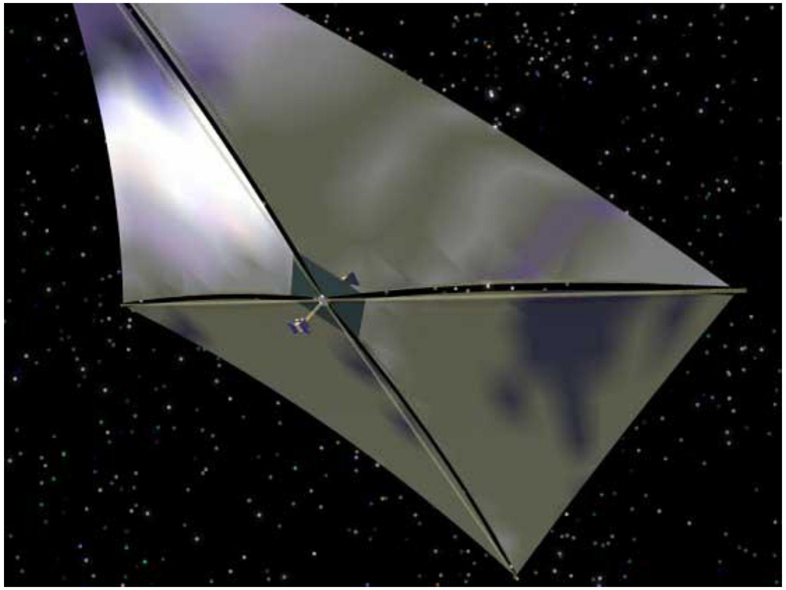
Key Spacecraft & Mission Parameters

- 6U cubesat (20 cm X 10 cm X 30 cm)
- ~85 m^2 solar sail propulsion system
- Manifested for launch on the Space Launch System (EM-1/2017)
- Up to 2.5 year mission duration
- 1 AU maximum distance from Earth

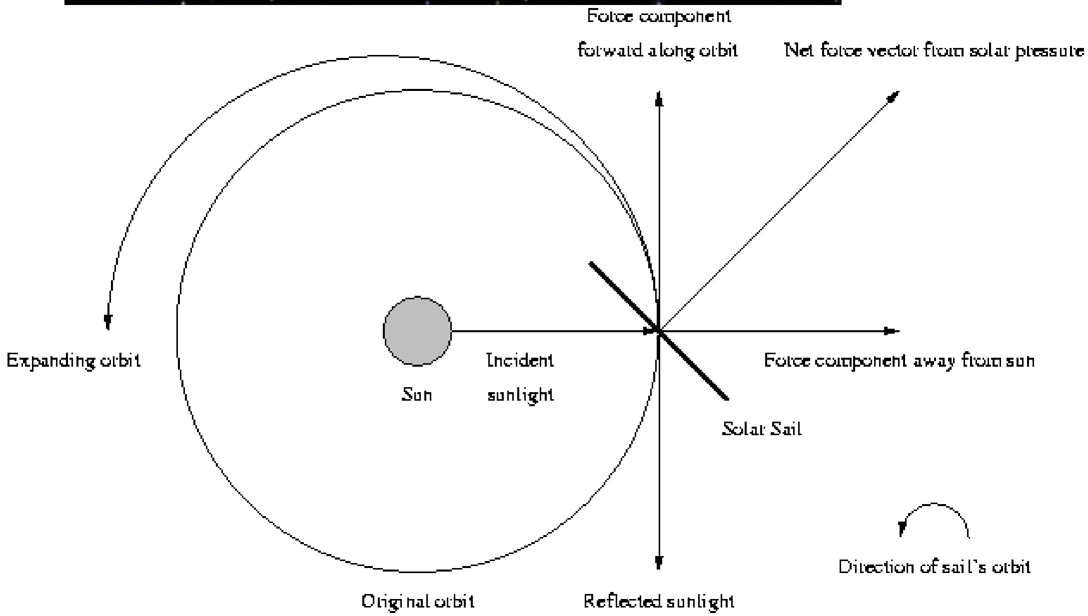
Solar Sail Propulsion System Characteristics

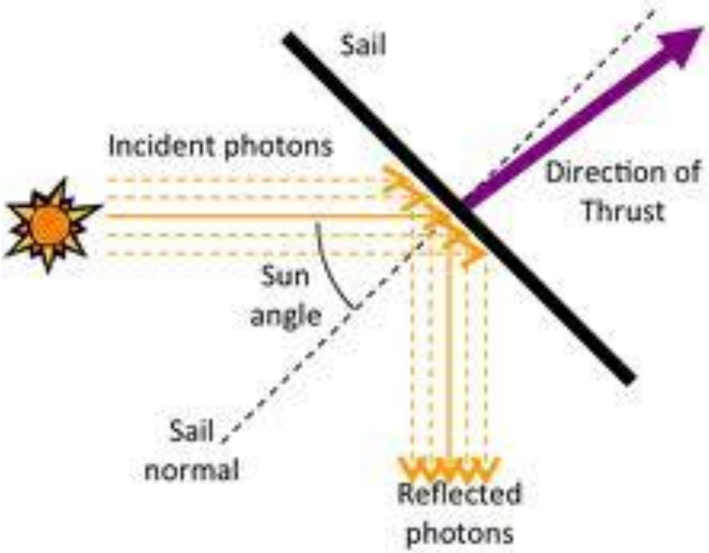
- ~ 7.3 m Trac booms
- 2.5μ aluminized CP-1 substrate
- > 90% reflectivity

How does a solar sail work?



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



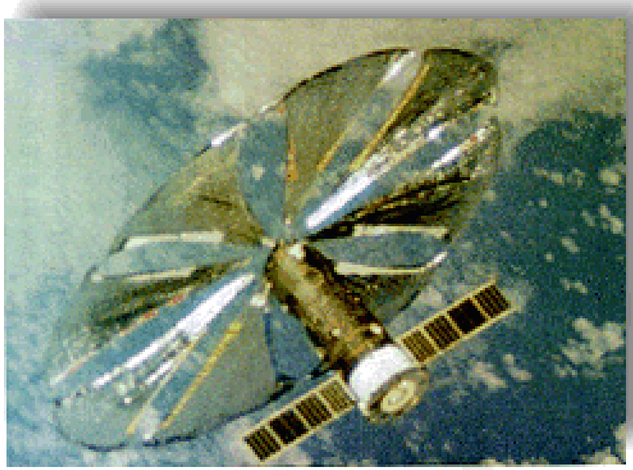


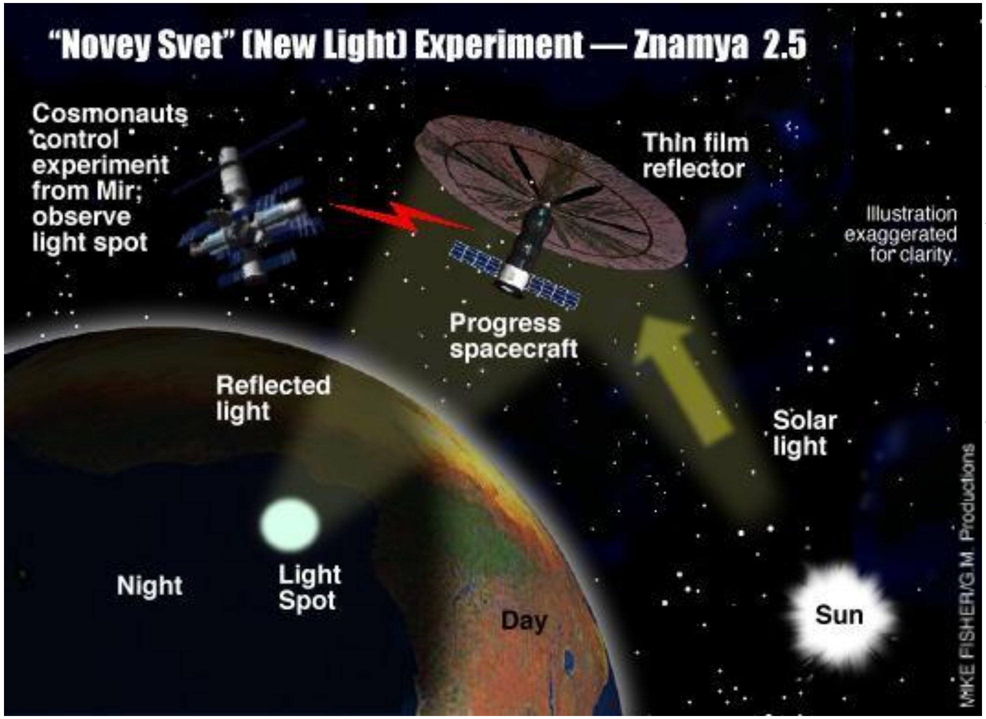
Echo II 1964
Solar thrust affect on spacecraft orbit

- **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**

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

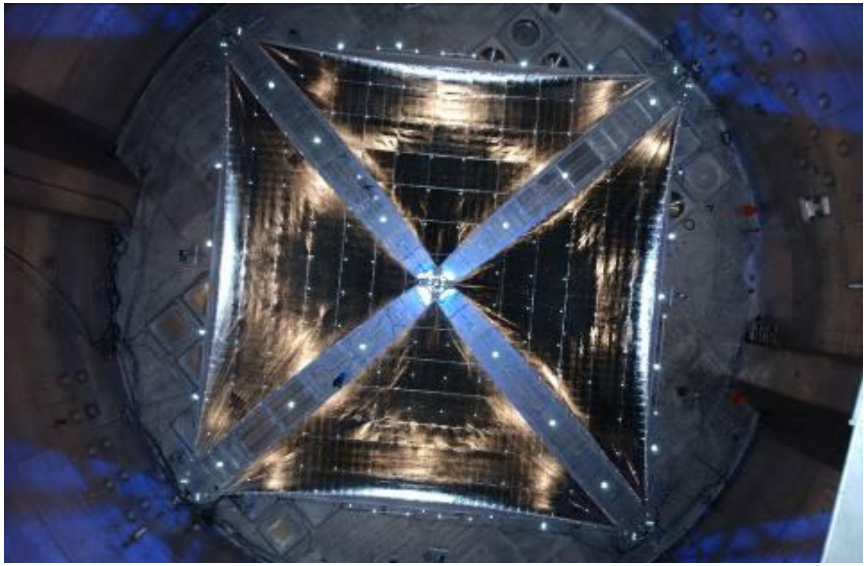
Znamya (Space Mirror)





- Russian experiment that flew on Progress after undocking from Mir Space Station in 1993.
- Purpose was to reflect sunlight onto the ground from space.
- 20-m diameter sail successfully deployed
- 5-km spot illuminated Europe from France to Russia moving at 8 km/sec.
- Follow-on mission flew, but was damaged during deployment.

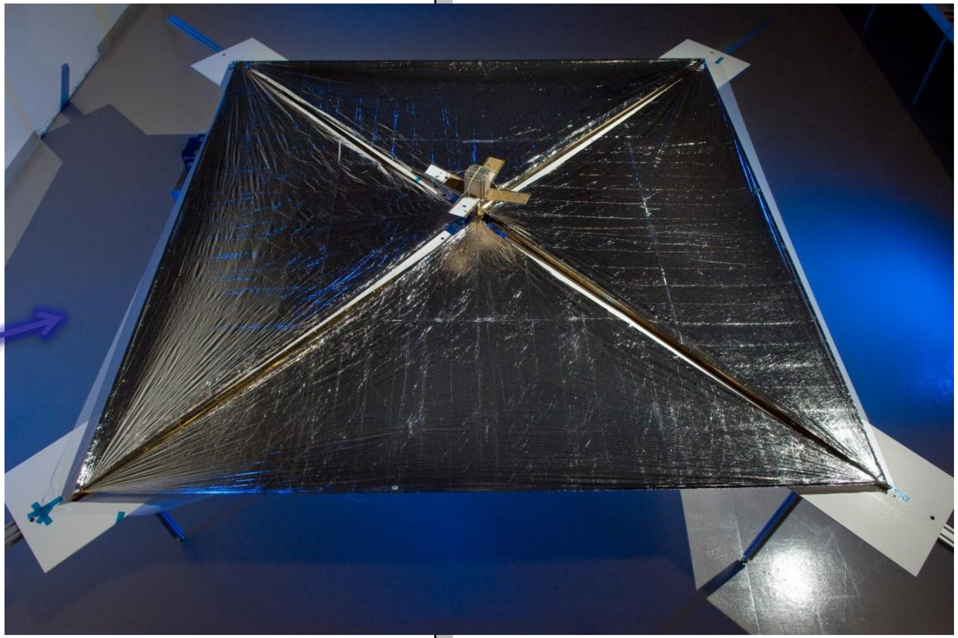
NASA Ground Tested Solar Sails

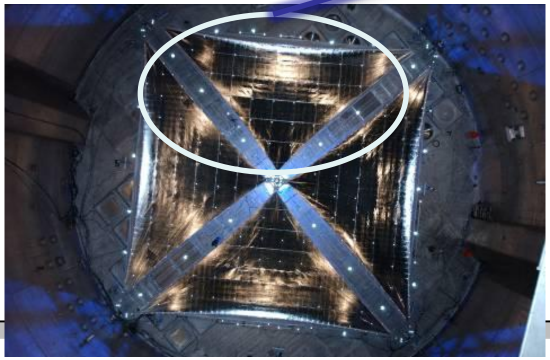


- Two solar sail technologies were designed, fabricated, and tested under thermal vacuum conditions in 2005:
  - 10 m system ground demonstrators (developed and tested in 2004/2005)
  - 20 m system ground demonstrators (designed, fabricated, and tested)
- Developed and tested high-fidelity computational models, tools, and diagnostics
- Multiple efforts completed: materials evaluation, optical properties, long-term environmental effects, charging issues, and assessment of smart adaptive structures

NanoSail-D Demonstration Solar Sail

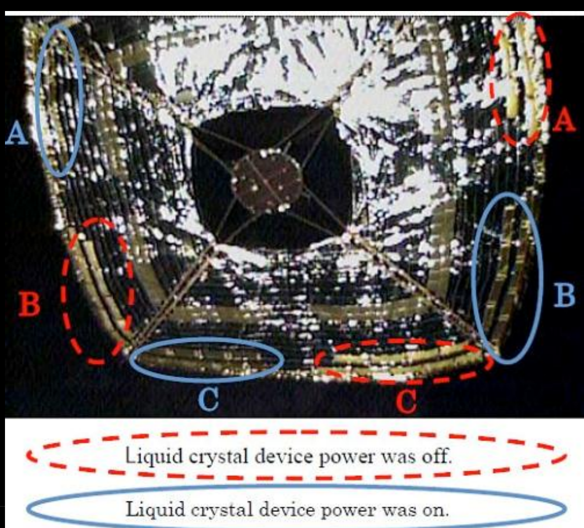
- Mission Description:
  - 10 m^2 sail
  - Made from tested ground demonstrator hardware



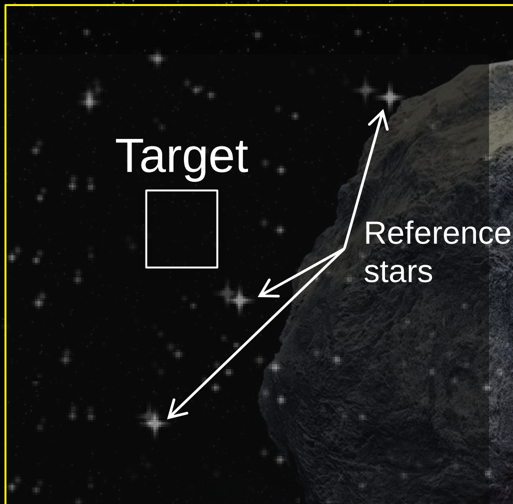


NanoSail-D in Flight

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



NEA Scout Science Objectives



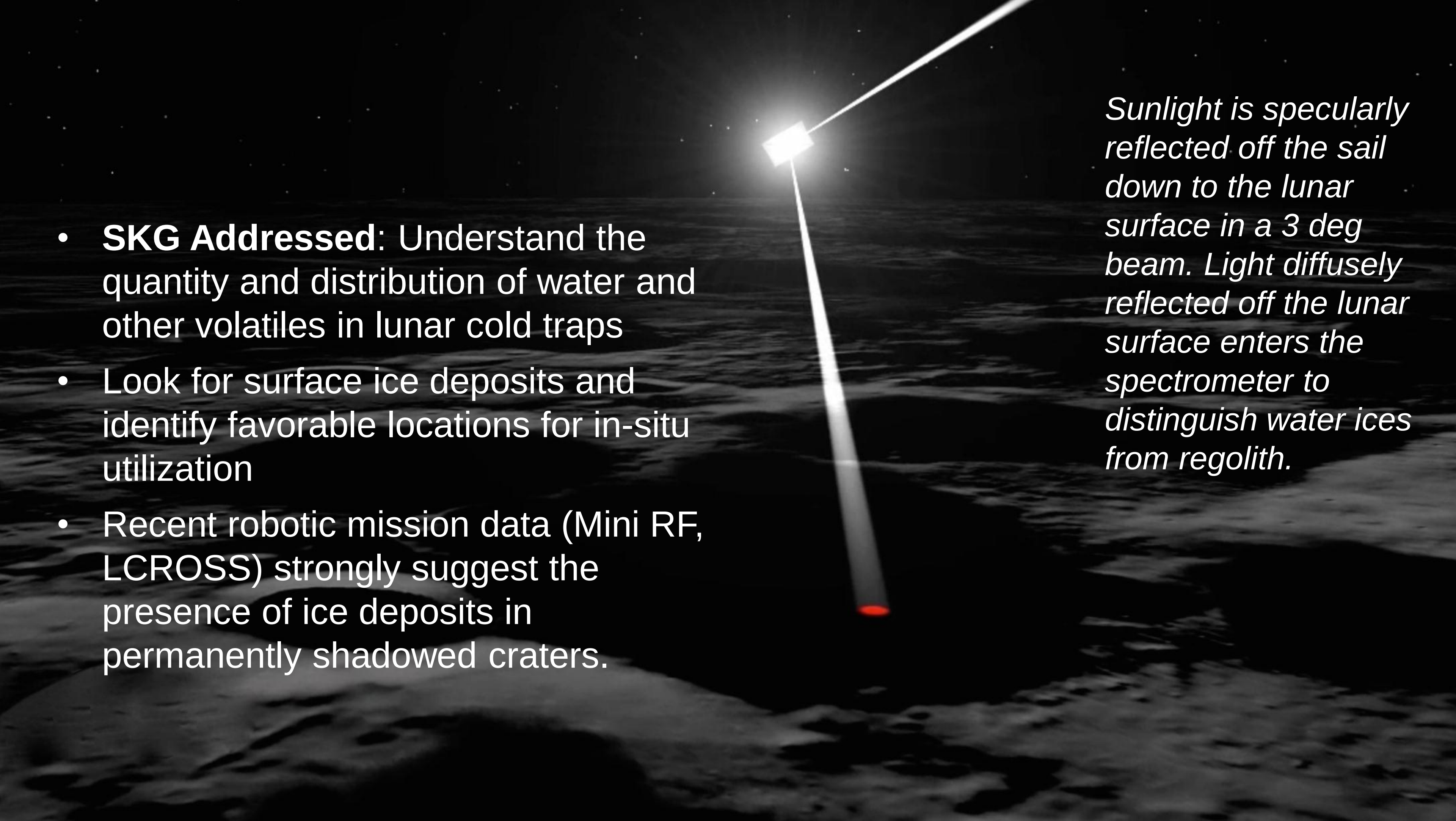
Target Detection and Approach
Light source observation
SKGs: Ephemeris determination and composition assessment

Target Reconnaissance
50 cm/px resolution over 80% surface
SKGs: volume, global shape, spin rate and pole position determination

Malin ECAM M-50 NFOV
(OSIRIS-Rex derived)

Close Proximity Imaging
High-resolution imaging,
10 cm/px GSD over >30% surface
SKGs: Medium-scale morphology, regolith properties, and local environment characterization

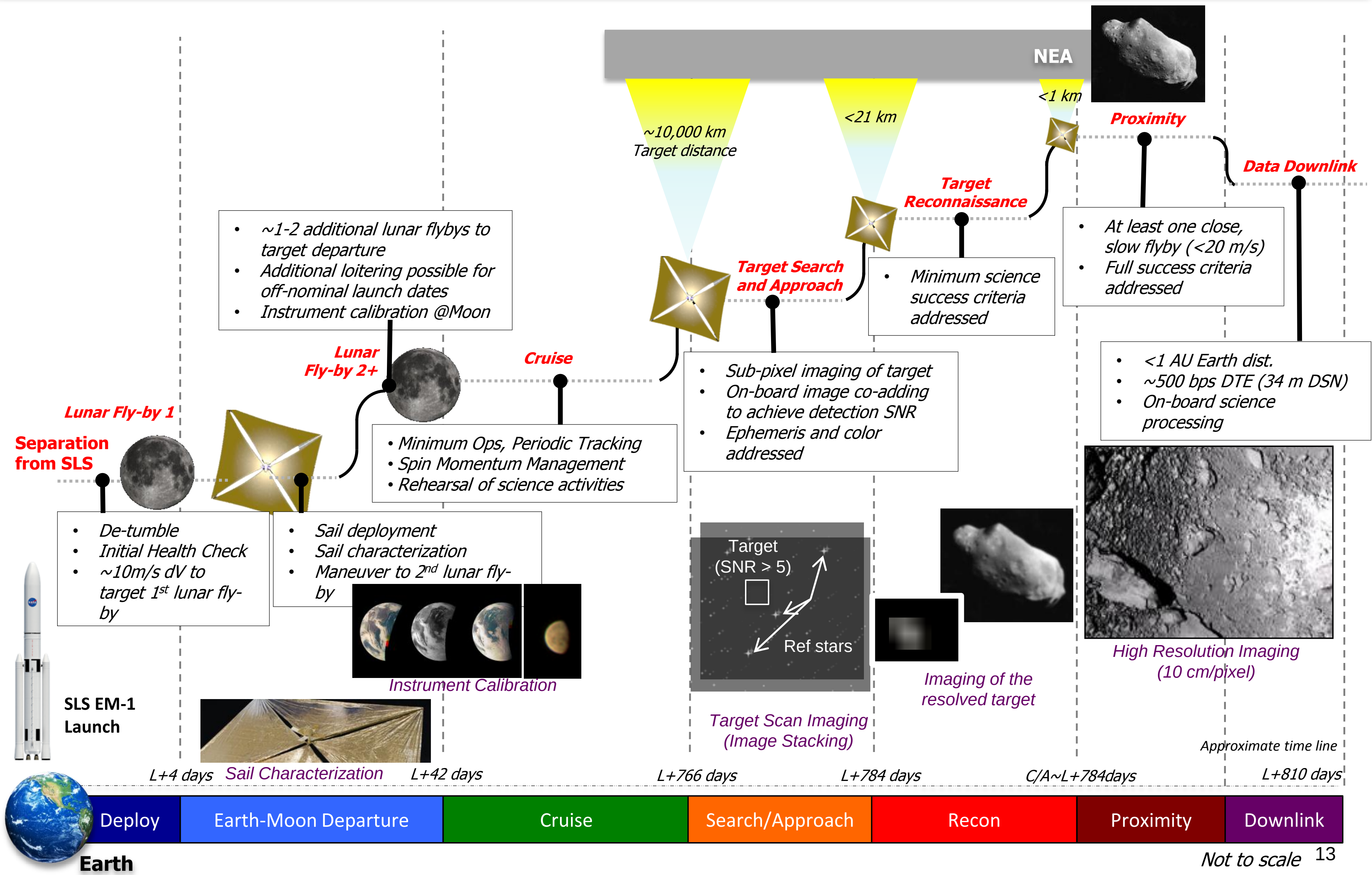
Lunar Flashlight Science Objectives (Same Spacecraft, Same Solar Sail, Difference Instrument)



- **SKG Addressed**: Understand the quantity and distribution of water and other volatiles in lunar cold traps
- Look for surface ice deposits and identify favorable locations for in-situ utilization
- Recent robotic mission data (Mini RF, LCROSS) strongly suggest the presence of ice deposits in permanently shadowed craters.

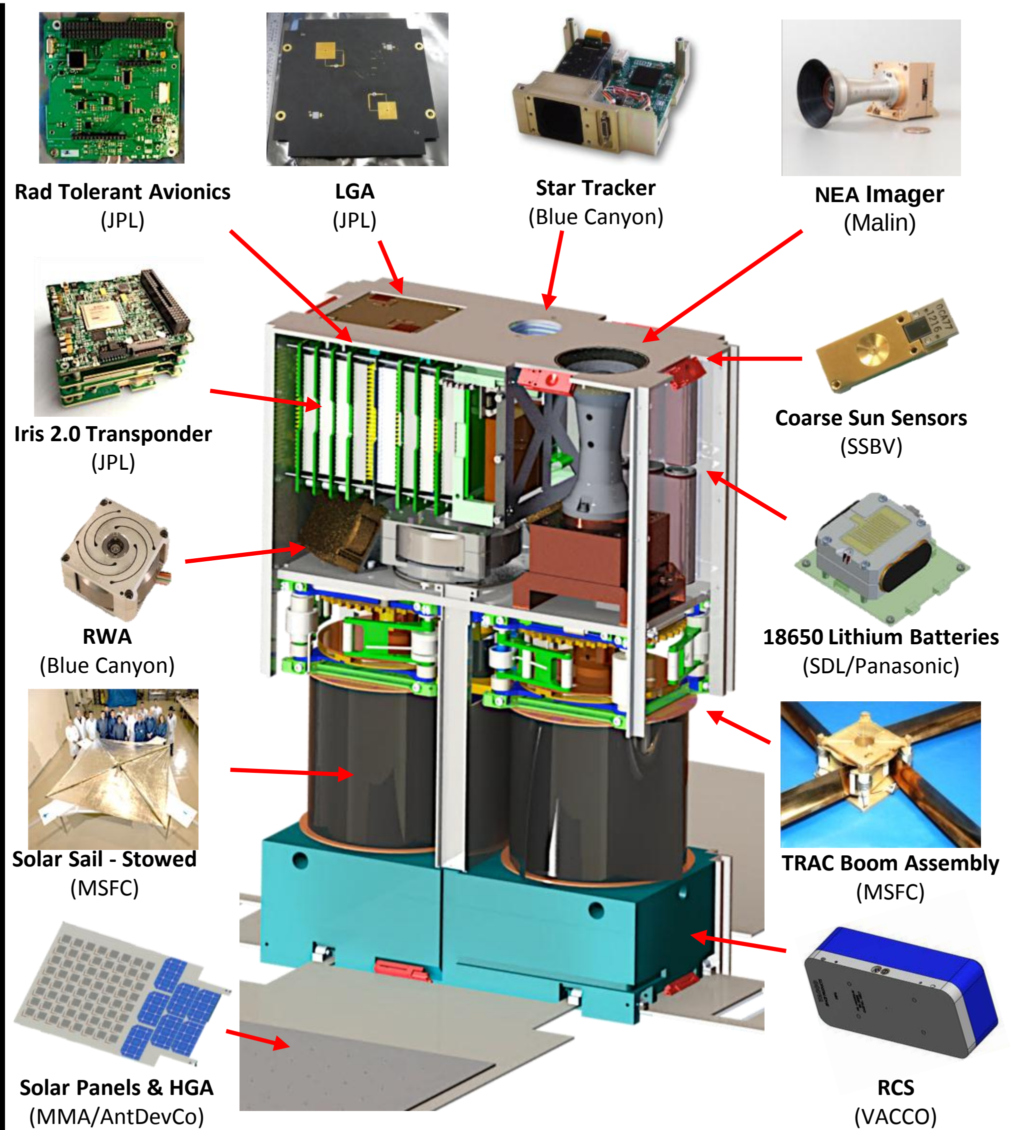
Sunlight is specularly reflected off the sail down to the lunar surface in a 3 deg beam. Light diffusely reflected off the lunar surface enters the spectrometer to distinguish water ices from regolith.

NEA Scout Concept of Operations

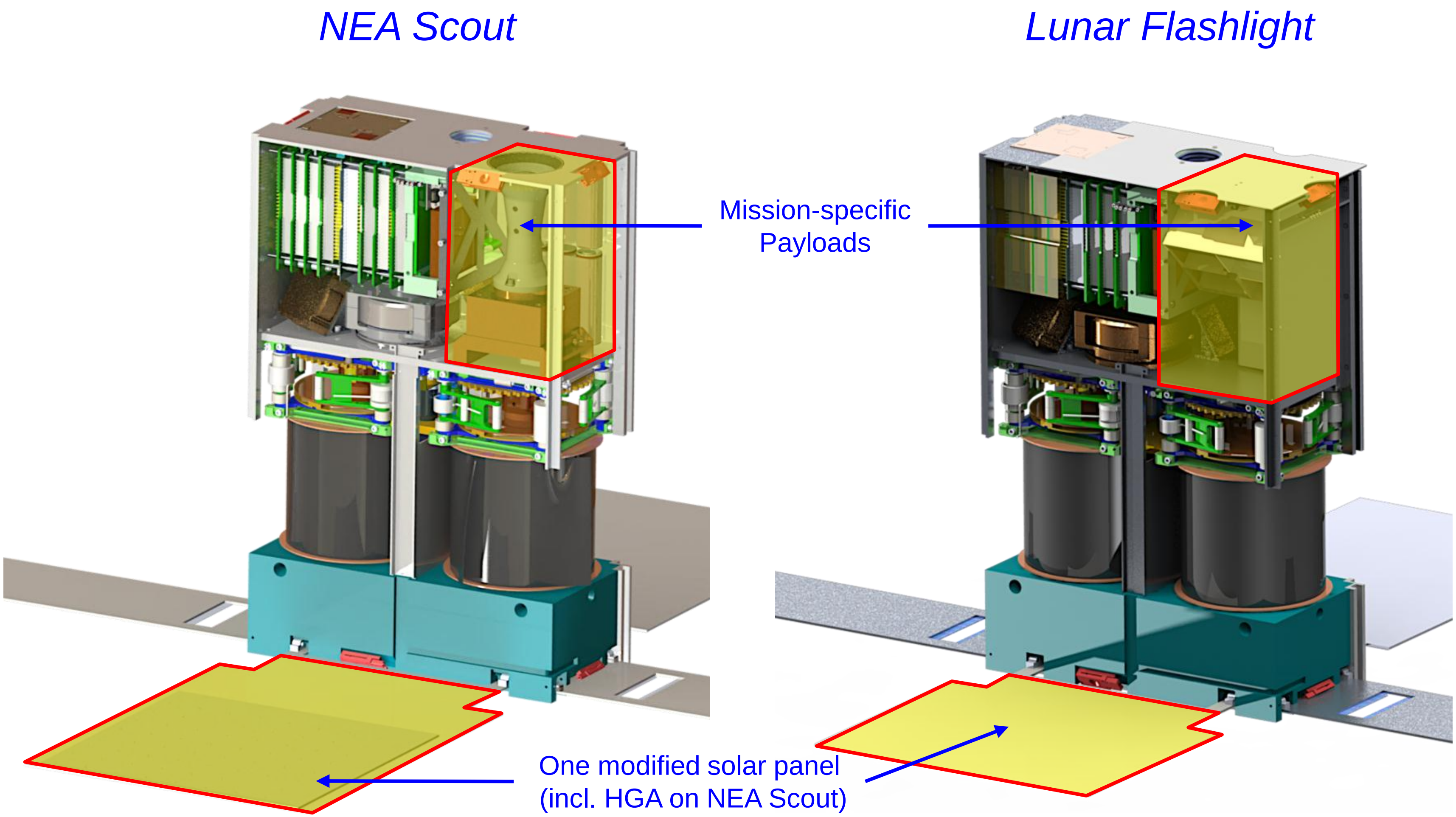


Flight System Overview

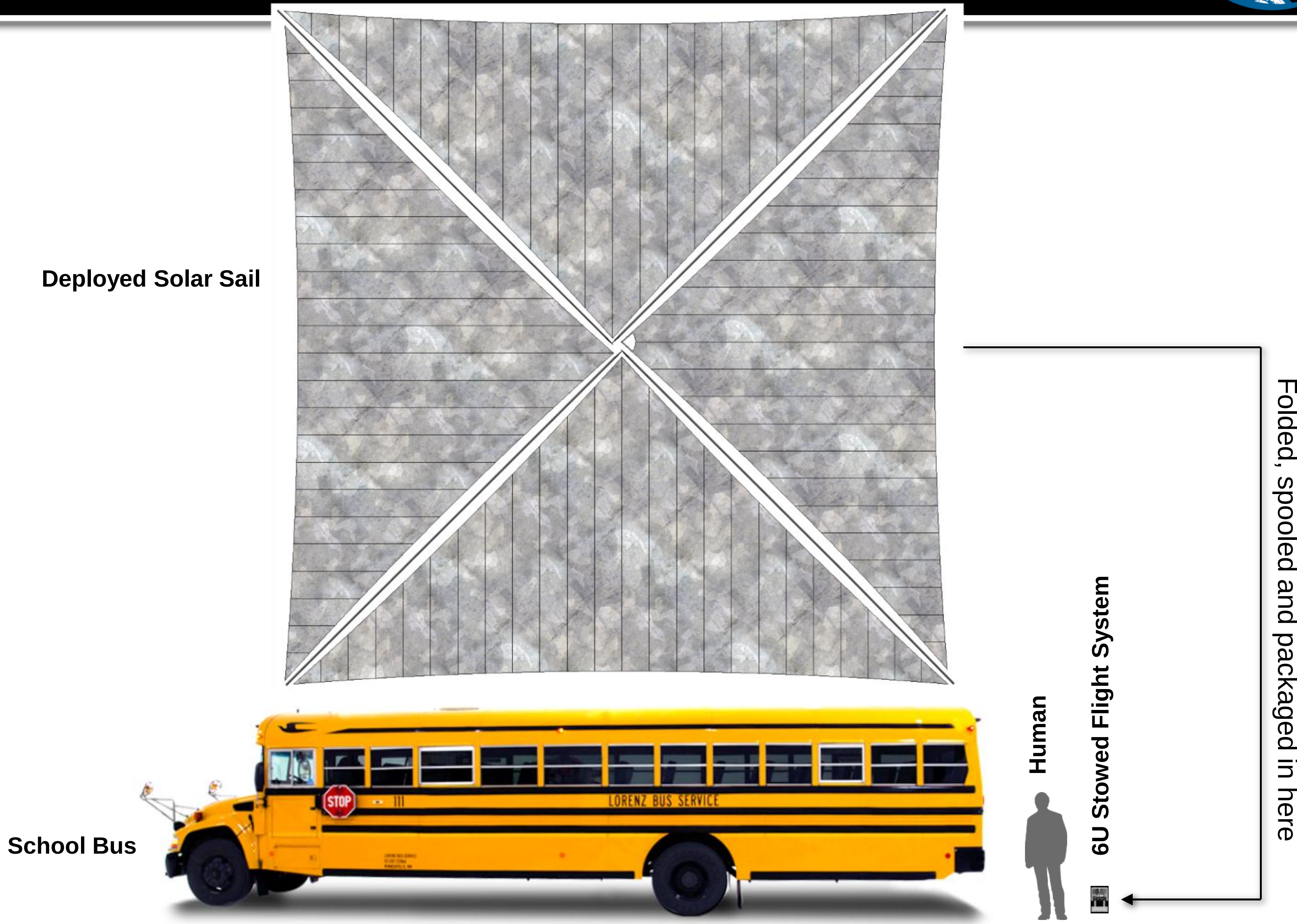
Mission Concept	• Characterize a Near Earth Asteroid with an optical instrument during a close, slow flyby
Payload	• Malin Space Science Systems ECAM-M50 imager w/NFOV optics • Static color filters (400-900 nm)
Mechanical & Structure	• "6U" CubeSat form factor (~10x20x30 cm) • <12 kg total launch mass • Modular flight system concept
Propulsion	• ~85 m^2 aluminized CP-1 solar sail (based on NanoSail-D2)
Avionics	• Radiation tolerant LEON3-FT architecture
Electrical Power System	• Simple deployable solar arrays with UTJ GaAs cells (~35 W at 1 AU solar distance) • 6.8 Ah Battery (3s2p 18650 Lithium Cells) • 10.5-12.3 V unregulated, 5 V/3.5 V regulated
Telecom	• JPL Iris 2.0 X-Band Transponder; 2 W RF SSPAs; supports doppler, ranging, and D-DOR • 2 pairs of INSPIRE-heritage LGAs (RX/TX) • 8x8 element microstrip array HGA (TX) • ~500 bps to 34m DSN at 0.8 AU
Attitude Control System	• 15 mNm-s (x3) & 100 mNm-s RWAs • Zero-momentum slow spin during cruise • VACCO R134a (refrigerant gas) RCS system • Nano StarTracker, Coarse Sun Sensors & MEMS IMU for attitude determination



NEA Scout – Lunar Flashlight Commonality

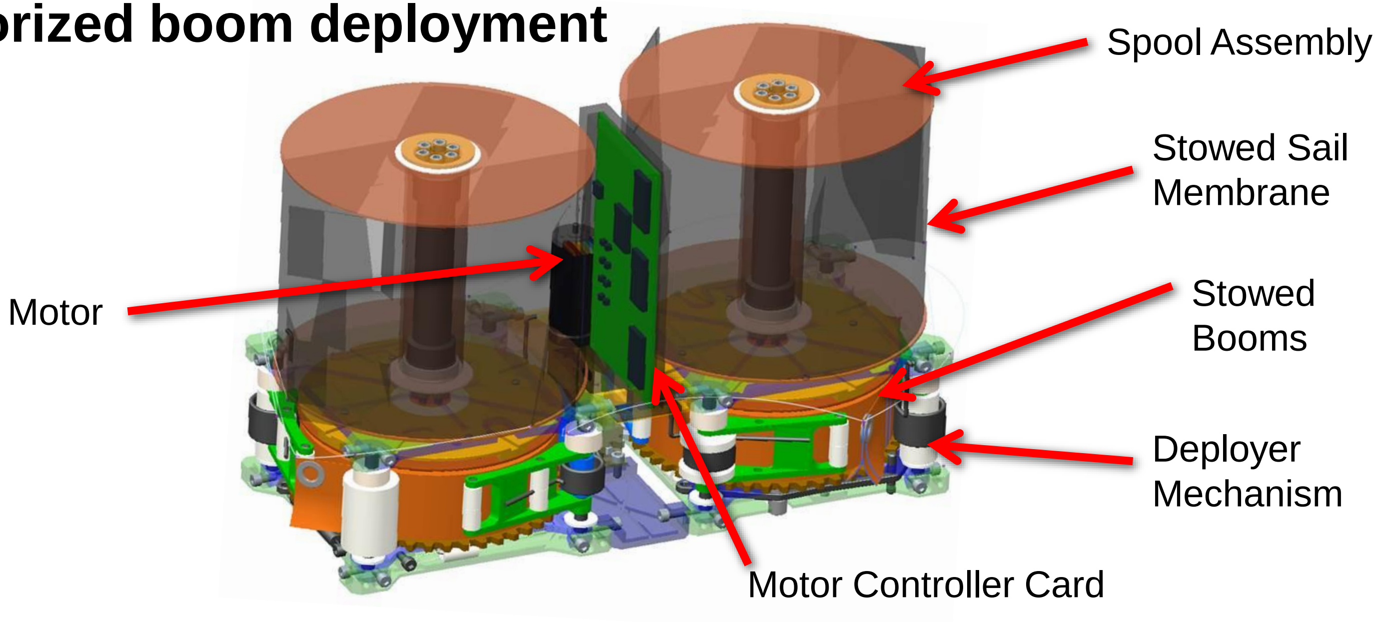


NEA Scout Approximate Scale

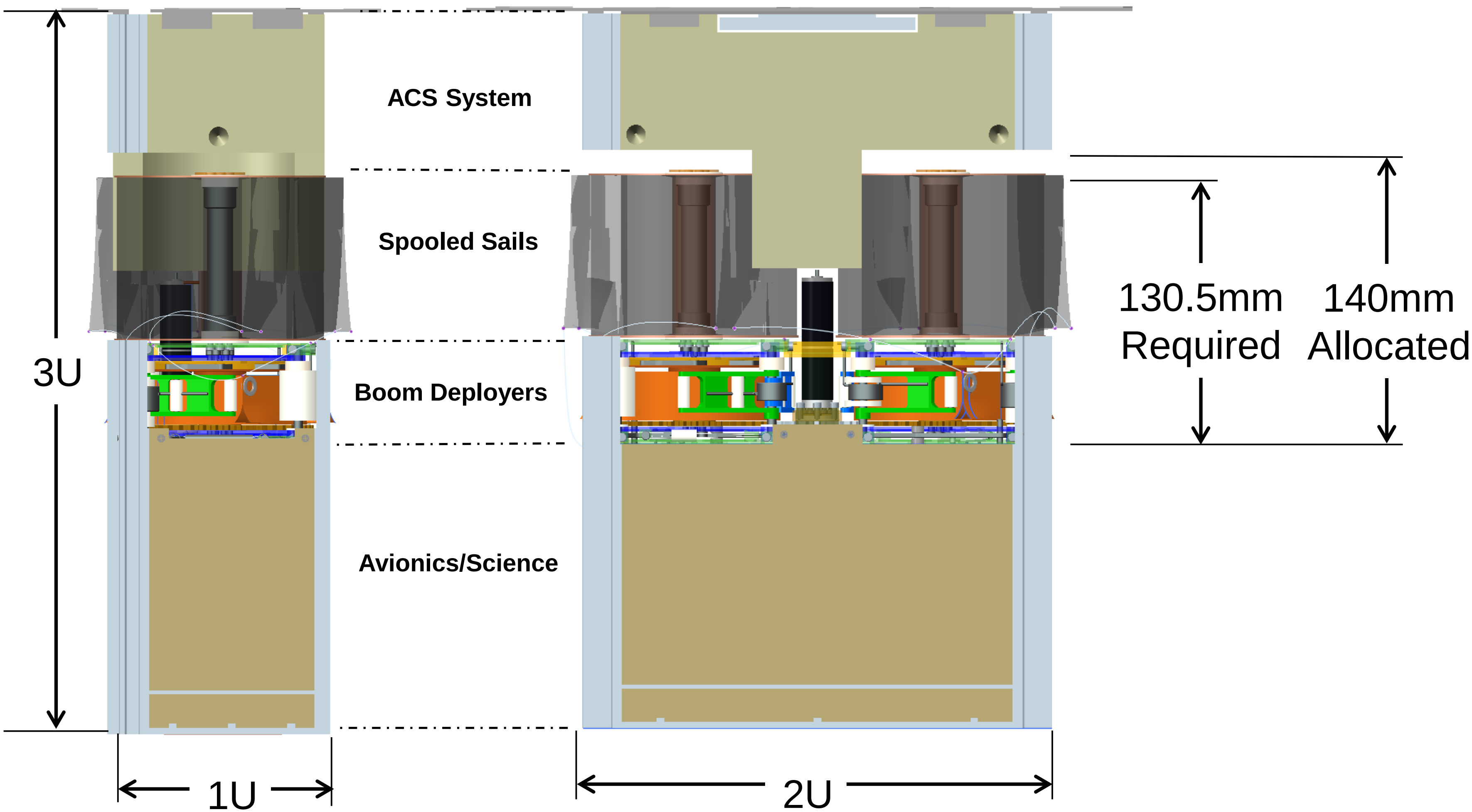


Solar Sail Mechanical Description

- 4 quadrant sail
- 85 m2 reflective area
- 2.5 micron CP1 substrate
- Z folded and spooled for storage
  - 2 separate spools with 2 sail quadrants folded onto each
- 4 7-meter stainless steel TRAC booms coiled on a mechanical deployer
  - 2 separate deployers and each deployer releases 2TRAC booms
  - Motorized boom deployment



Solar Sail Volume Envelope

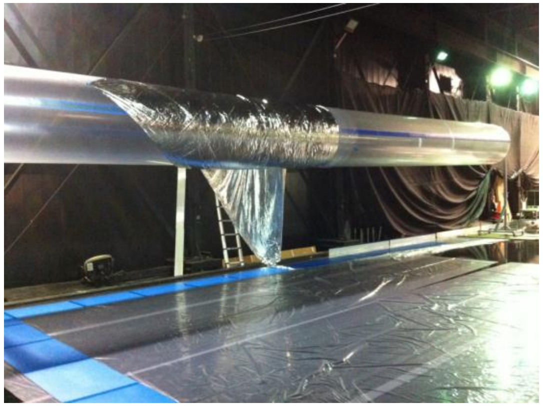


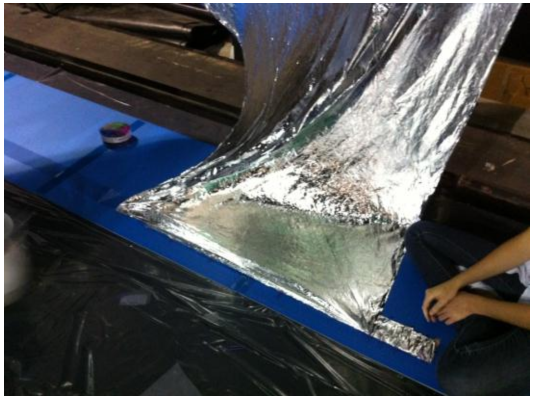
Sail Packing Efficiency

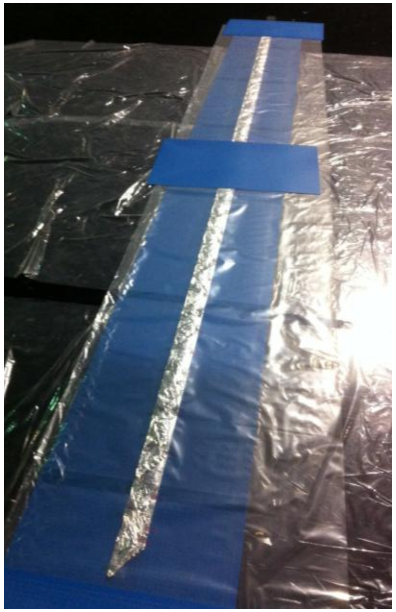
Calculated Value:

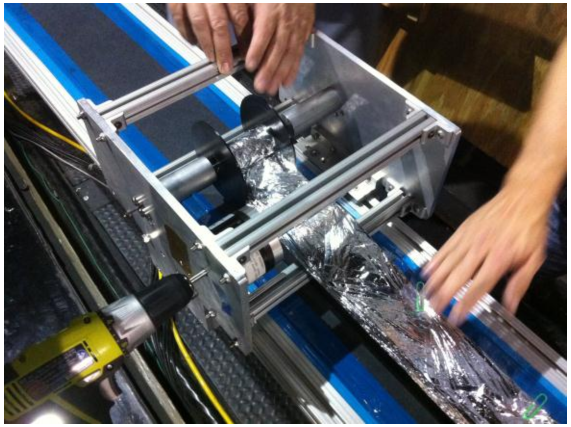
- Fabricated 2 flight size 10m sails from existing 20m CP1 sail.
- Z-folded and spooled 2 sail quadrants onto the hub.
- Calculated new packing efficiency to be **27.5 %**

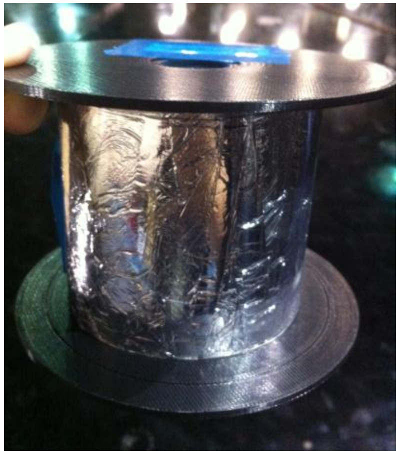
Higher percentage results in tighter packaging and thus more volume margin for design space.







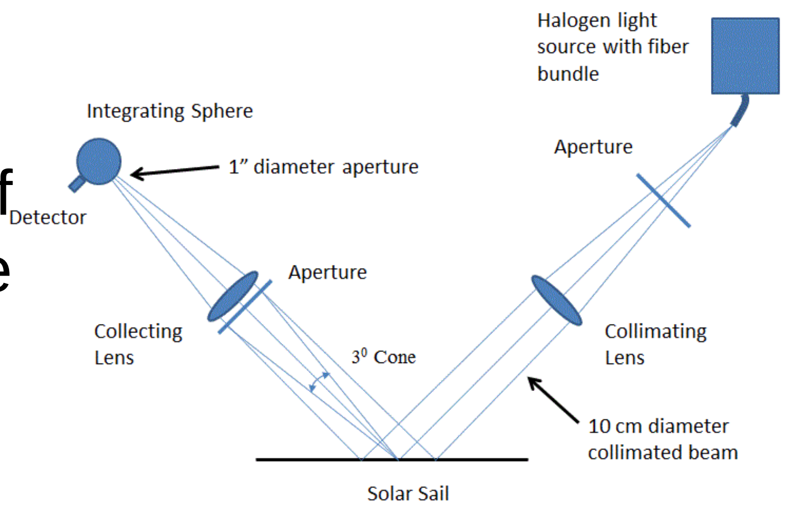


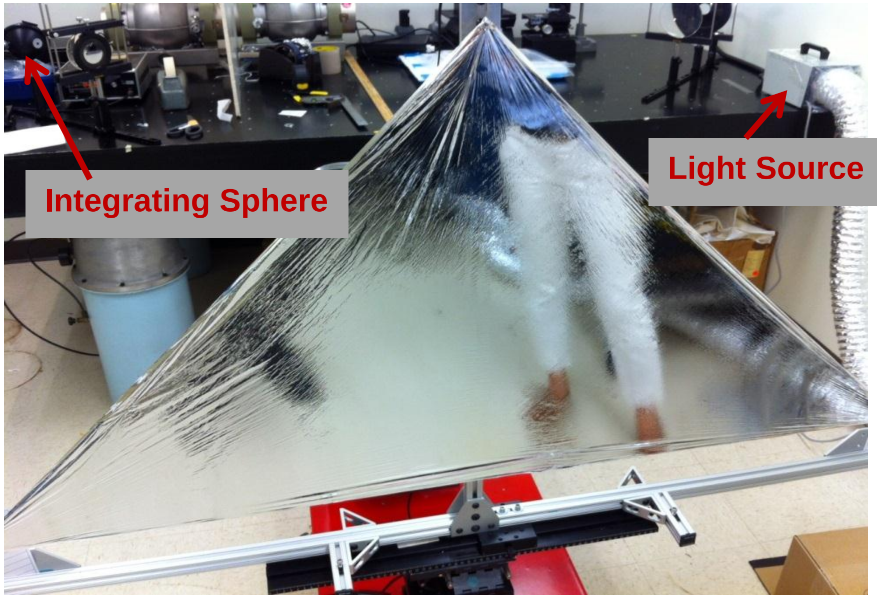


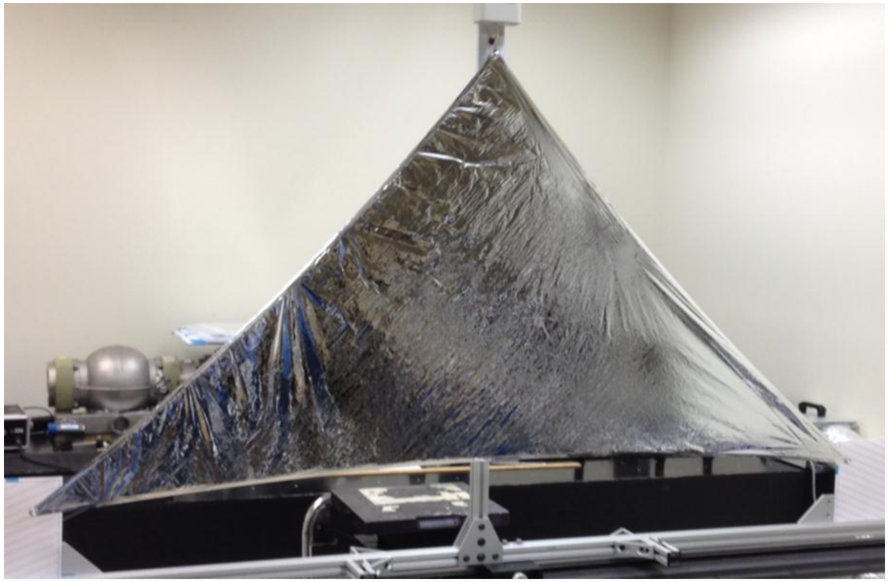
Surface Illumination Test

Lunar Flashlight Requires Surface Illumination:

- Determine the capabilities of the solar sail in regard to the amount of light that the sail can reflect into the desired 3 degree cone onto a surface.

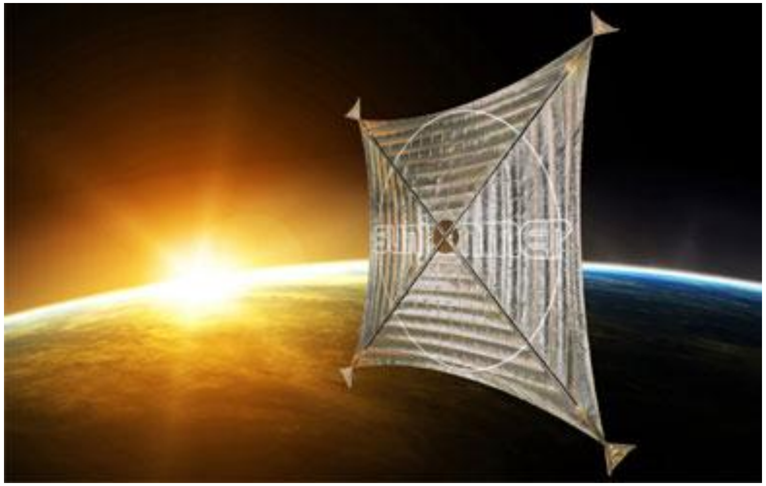




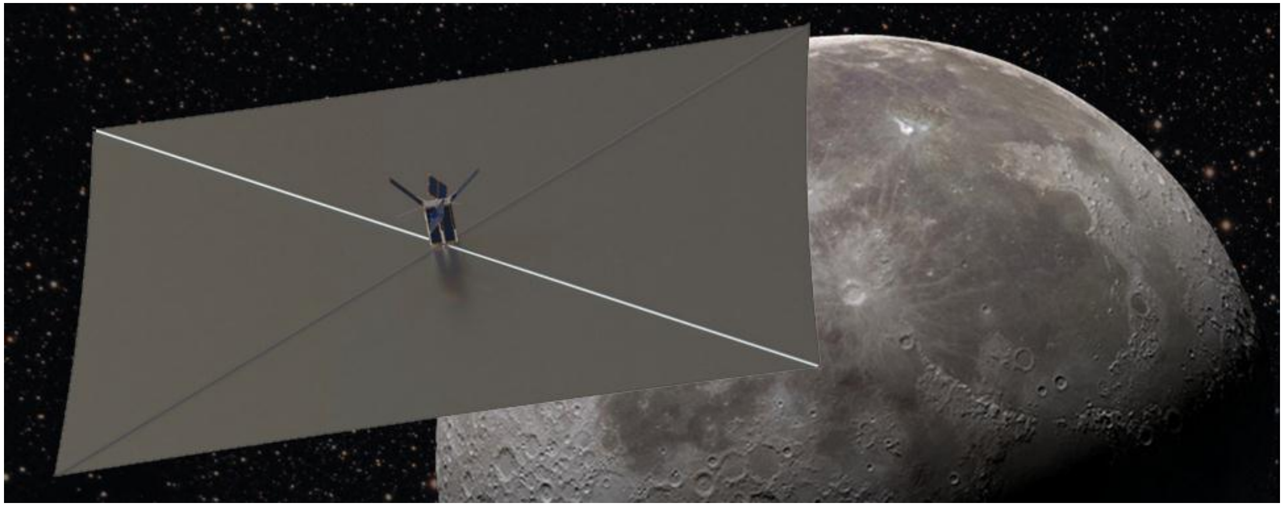


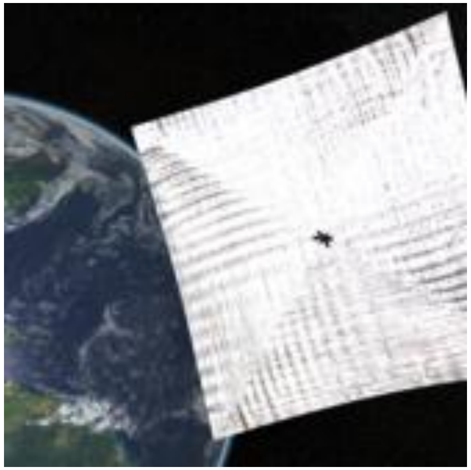
NEA Scout Mission Animation

Planned Missions

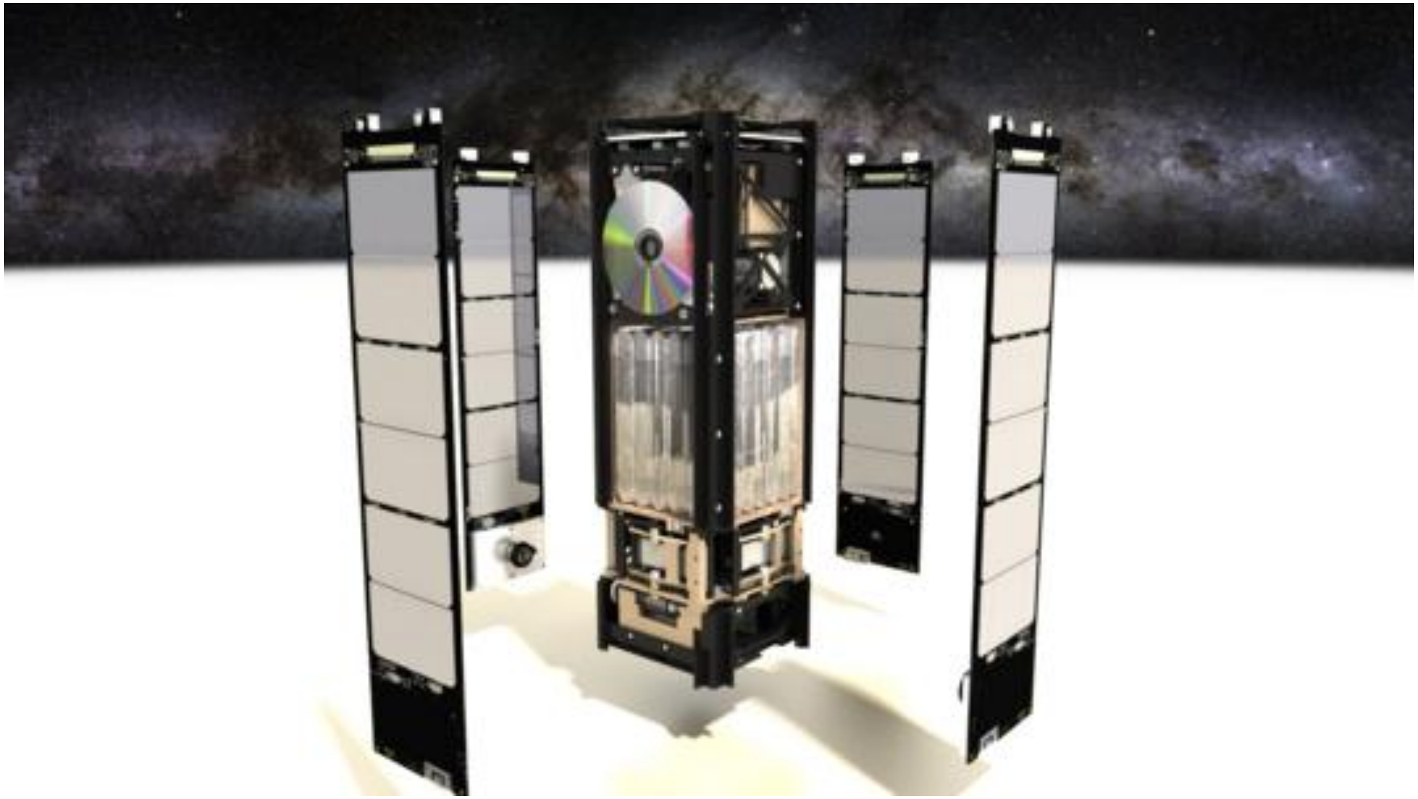


- NASA's *NEA Scout* and *Lunar Flashlight*
- The Planetary Society's *LightSail-A* and *LightSail-B*
- The University of Surrey's *CubeSail*, *DeorbitSail*, and *InflateSail*
- ESA and DLR's *Gossamer 1* and *Gossamer-2*





LightSail-A and -B (The Planetary Society)



- 3U Cubesat design
- Sail Material: aluminized 4.5 micron Mylar film
- 32 square meters solar sail area fully deployed
- LightSail-A (2015) and LightSail-B (2016)

University of Surrey's InflateSail

- **InflateSail** is an <u>inflatable</u>, <u>rigidizable</u> sail for flight in Low Earth Orbit:
  - 3U CubeSat with deployed sail area of 10 m^2
  - Sail supported by bistable booms
  - Inflation is driven by Cool Gas Generators (CGG): low system mass, long lifespan

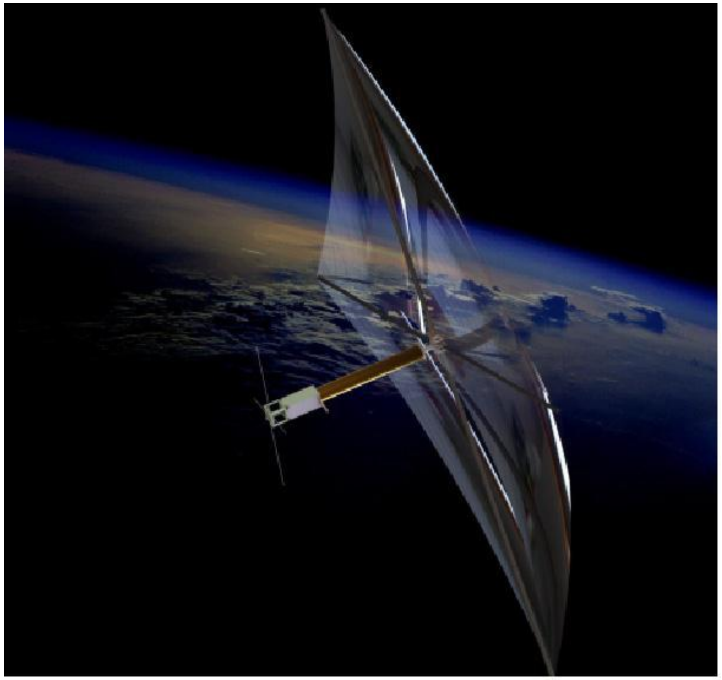
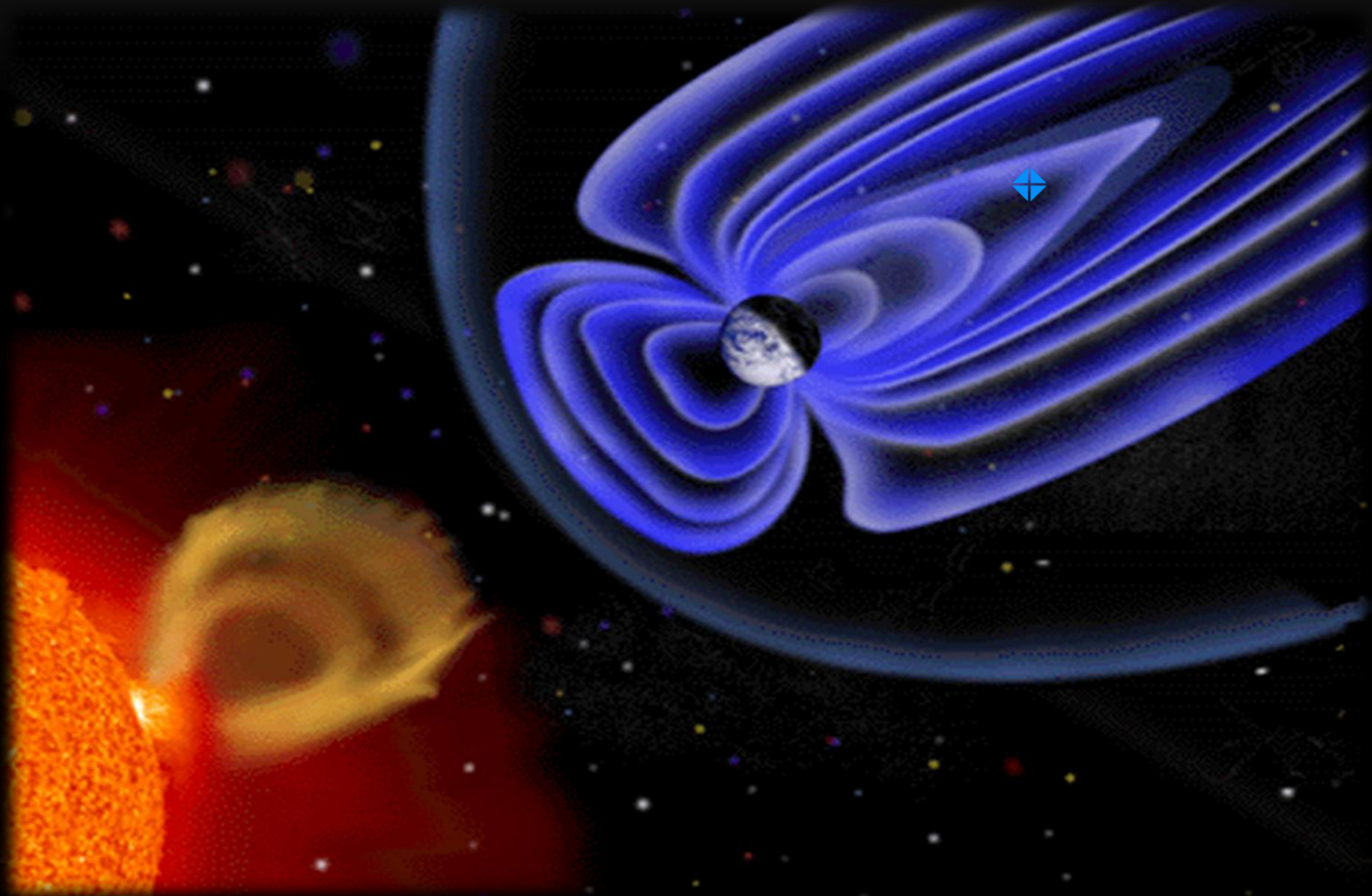


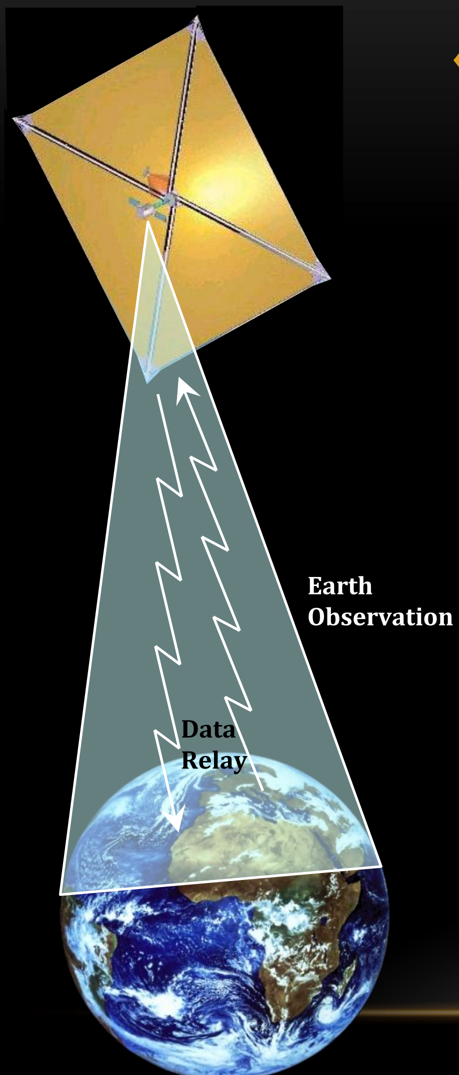
***Fig. 1**: InflateSail design concept*

***Fig. 2**: 80 mg CGG*

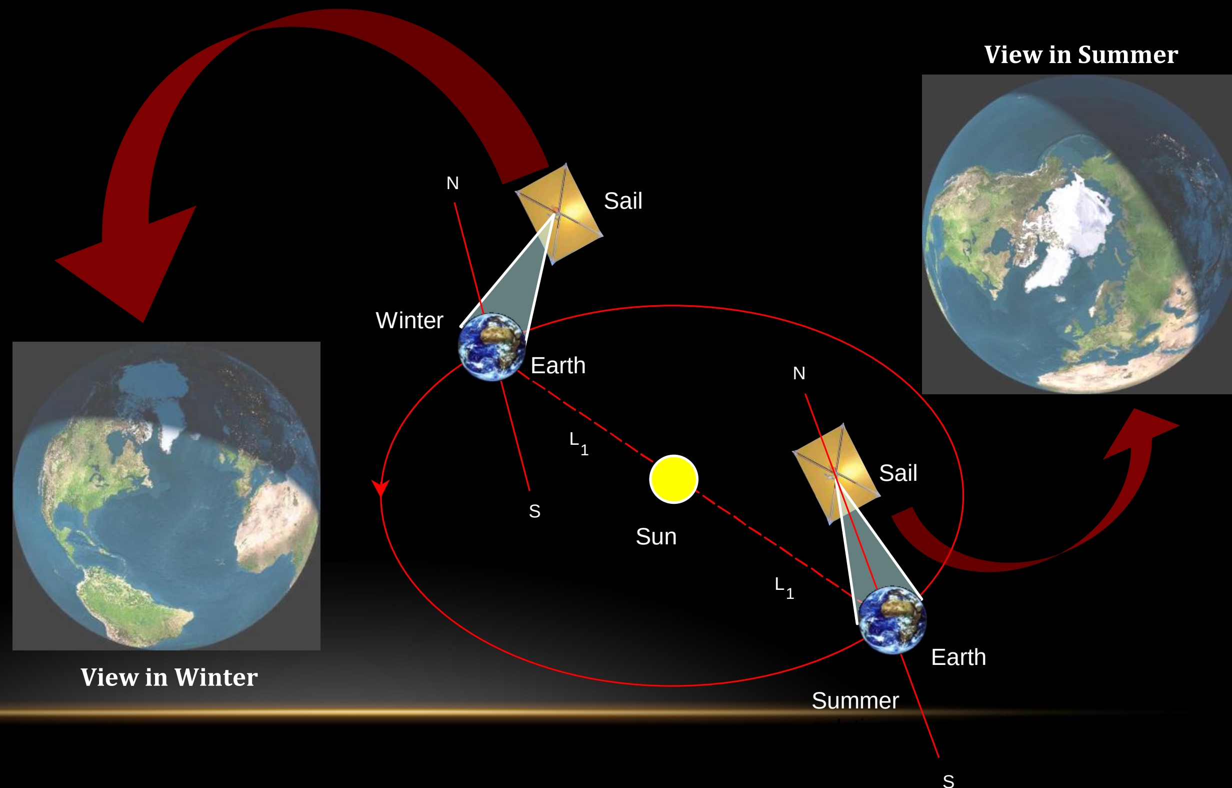
THE FUTURE: SOLAR STORM WARNING



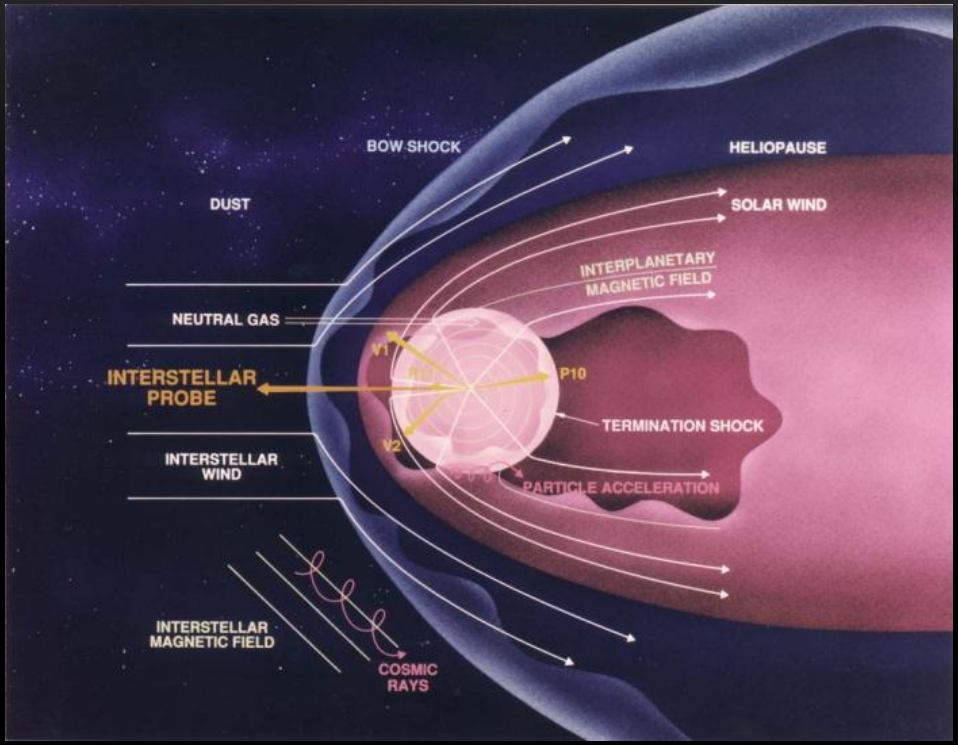
THE FUTURE: POLE SITTER MISSION



- Continual coverage of the polar regions
  - Altitudes ranging from 0.75 million km to 3.5 million km, depending on the sail performance and inclination chosen

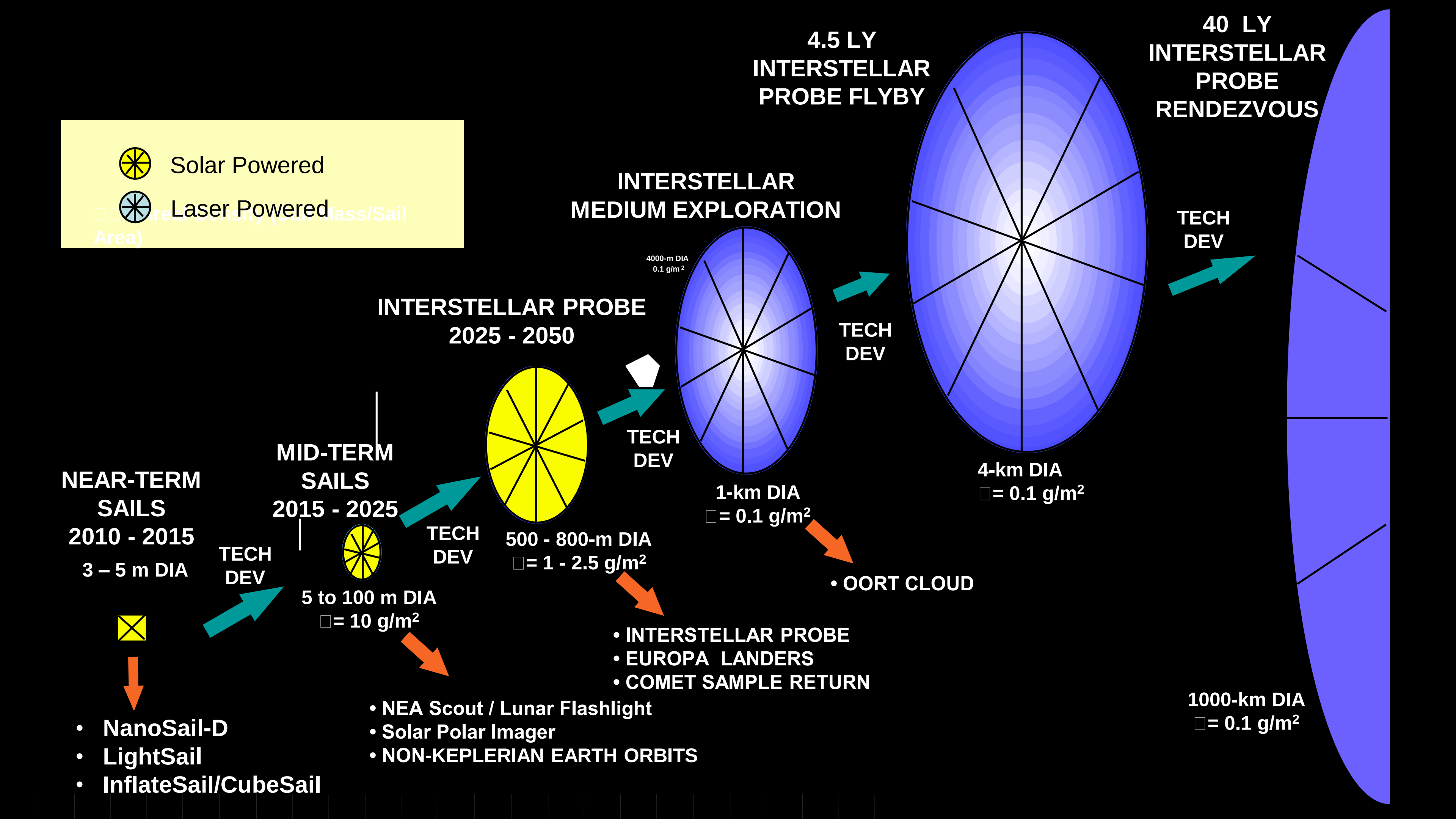


THE FUTURE: INTERSTELLAR PROBE

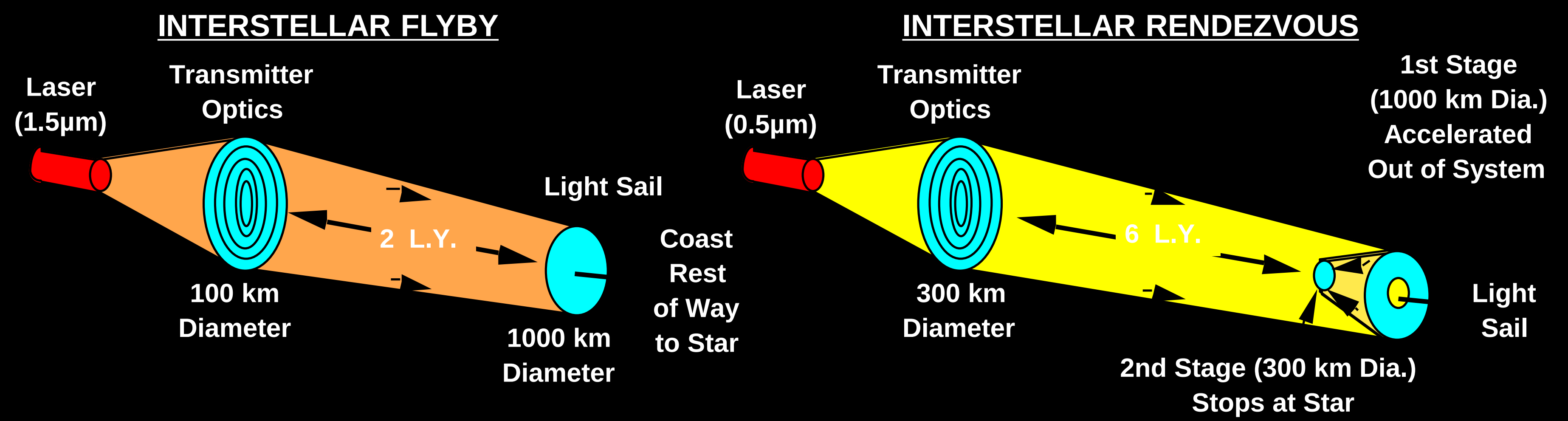


- A mission to beyond the Heliopause
  - 250 AU minimum
  - Reach 100 AU 10 years from launch
  - 15-20 AU/year target velocity
- 500-800 m diameter solar sail
- 1 g/m^2
- Survivable to T > 3000K for close solar approach

Near-Term Solar Sail Applications Lead to Interstellar Capability with Laser Sails



Interstellar Light Sail Concept



We are on our way to the stars…