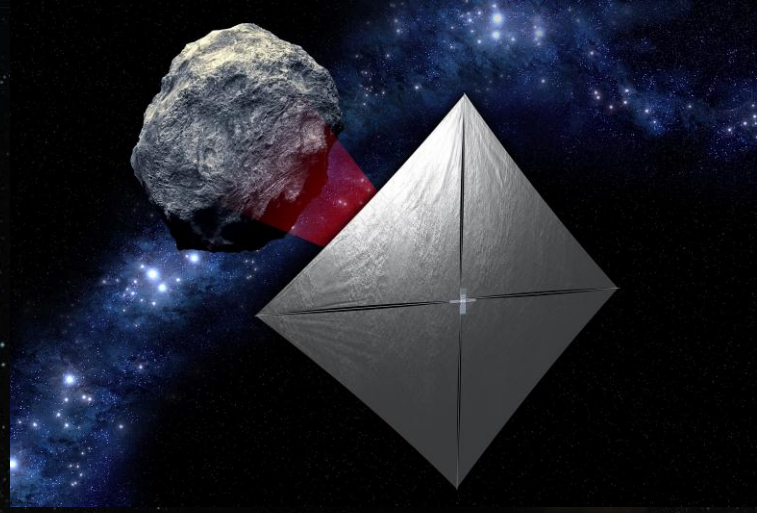
National Aeronautics and Space Administration

# Near Earth Asteroid Scout

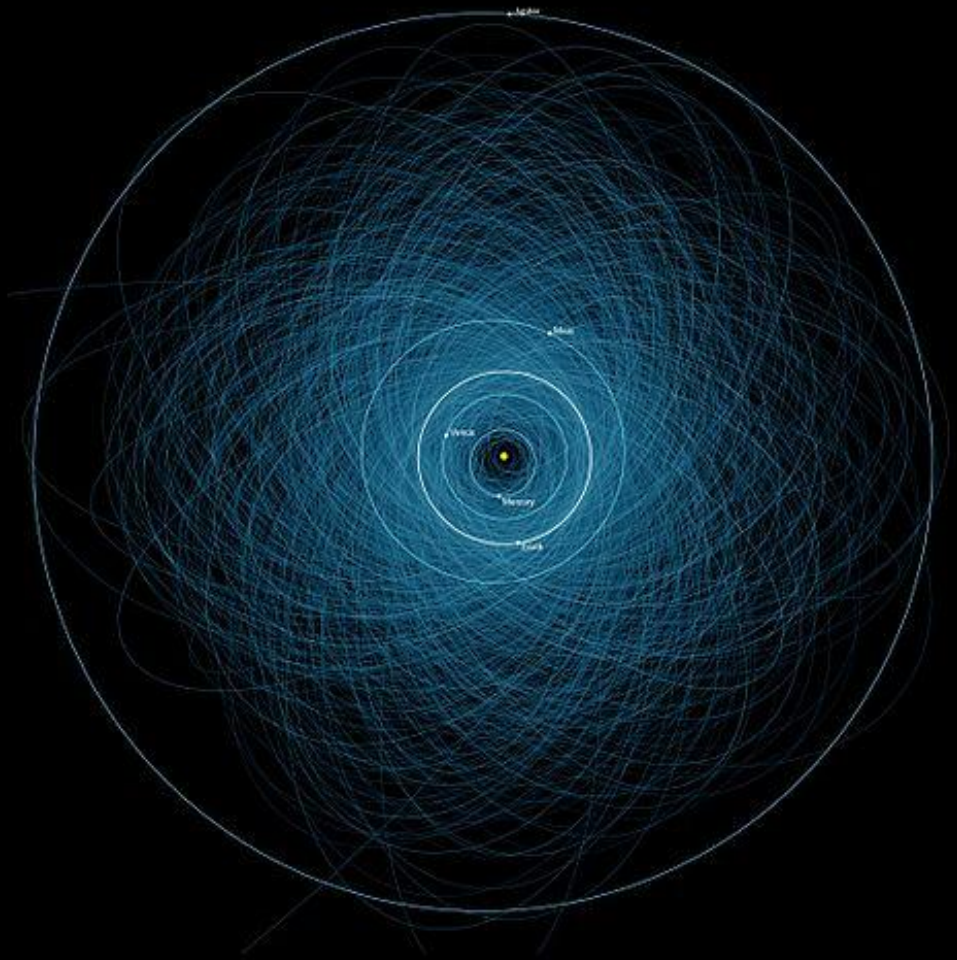
Les Johnson
NASA MSFC



# Near Earth Asteroids – Why Visit One?

- NEA's have orbits that lie partly between 0.983 and 1.3 astronomical units away from the Sun.
- As of February 2015, there have been 867 near-Earth asteroids larger than 1 km discovered, of which 153 are potentially hazardous asteroids.
- NASA would like to send people to explore asteroids in the future and a better understanding of them is needed before we do so.
- Multiple private companies are interest in mining asteroids for profit and they first need to know of what candidate asteroids are composed.

# Orbits of Potentially Hazardous NEA's

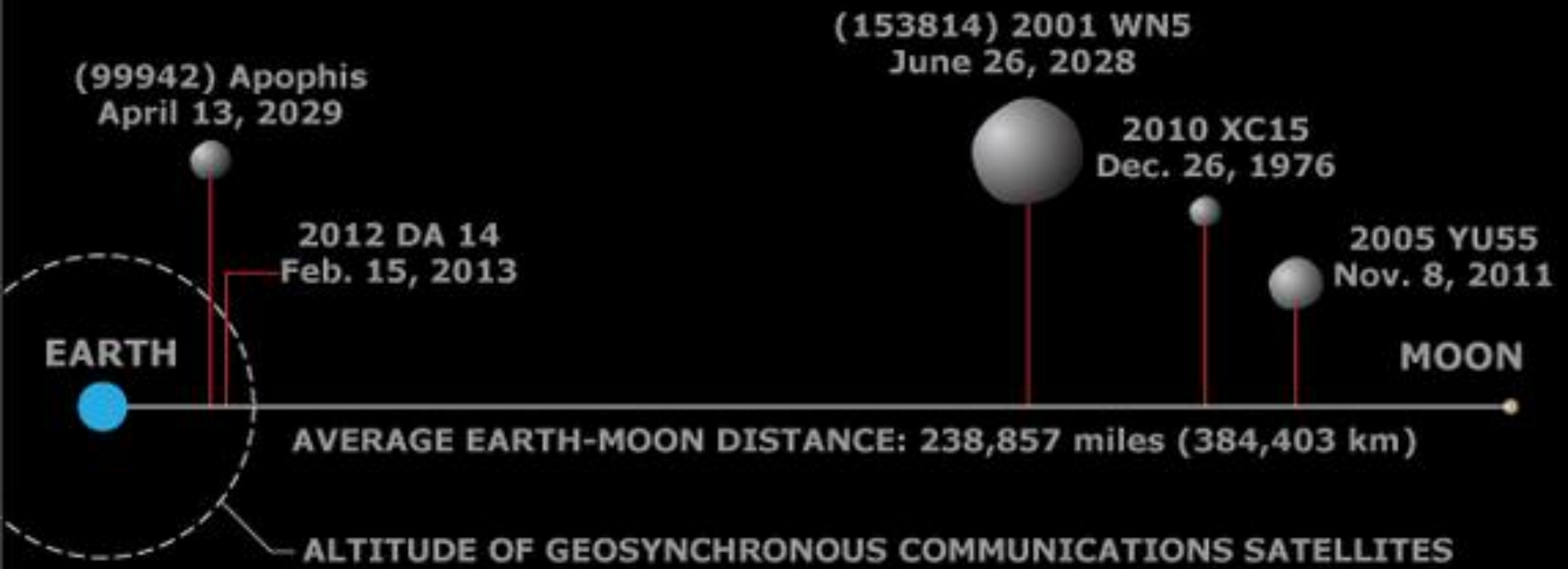


SPACE.COM

www.Space.com

# Famous Flybys of Near-Earth Objects

***Note: asteroids are shown to scale with each other but are greatly magnified compared to the Earth and Moon.***

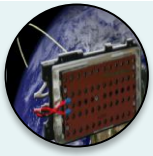



SOURCES: NASA, JET PROPULSION LABORATORY

KARL TATE / © Space.com

# SLS EM-1 Secondary Payloads

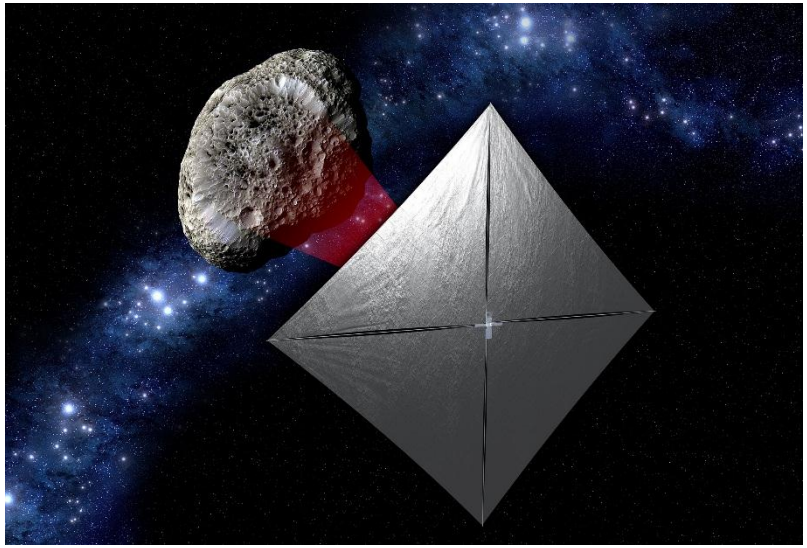
- **HEOMD's Advanced Exploration Systems (AES) selected 3 cubesats for flight on SLS EM1**
- **Primary selection criteria:**
  - Relevance to Space Exploration Strategic Knowledge Gaps (SKGs)
  - Life cycle cost
  - Synergistic use of previously demonstrated technologies
  - Optimal use of available 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**<br>*NASA Centers* | **Strategic Knowledge Gaps Addressed** | **Mission Concept** |
|---|---|---|
| **BioSentinel**<br>***ARC****/JSC*<br>  | **Human health/performance in high-radiation space environments**<br>• 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**<br>***JPL****/MSFC*<br>  | **Lunar resource potential**<br>• 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**<br>***MSFC****/JPL*<br>  | **Human NEA mission target identification**<br>• NEA size, rotation state (rate/pole position)<br>**How to work on and interact with NEA surface**<br>• 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

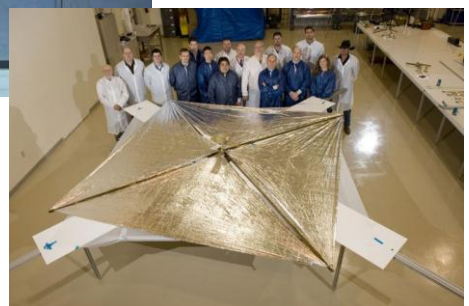


## Key Spacecraft & Mission Parameters

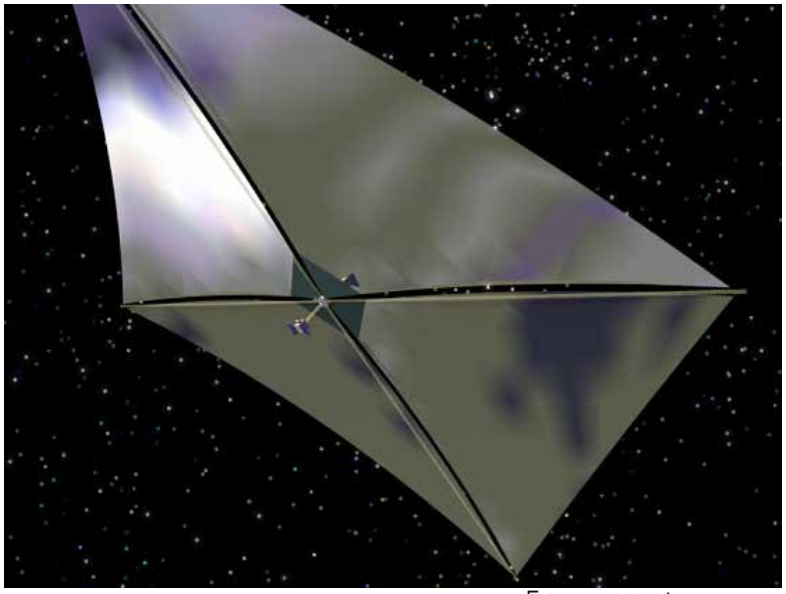
- 6U cubesat (20 cm X 10 cm X 30 cm)
- ~85 $m^2$ solar sail propulsion system
- Manifested for launch on the Space Launch System (EM-1/2017)
- Up to 2.5 year mission duration
- 1 AU maximum distance from Earth

## Solar Sail Propulsion System Characteristics

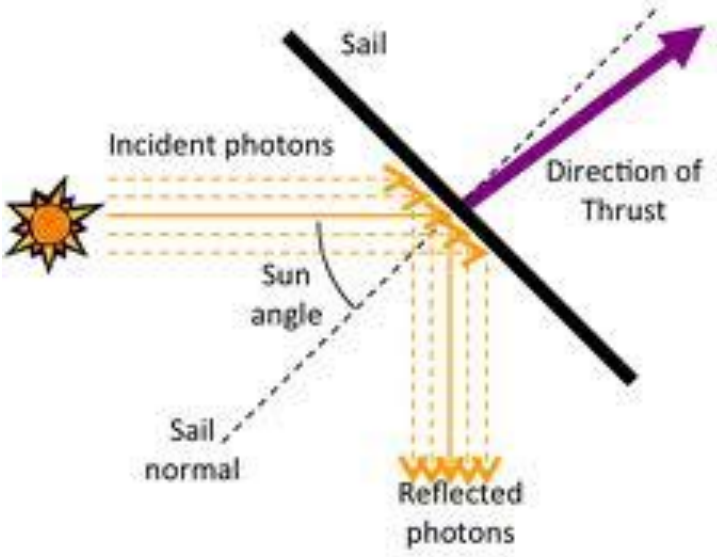
- ~ 7.3 m Trac booms
- 2.5μ aluminized CP-1 substrate
- > 90% reflectivity

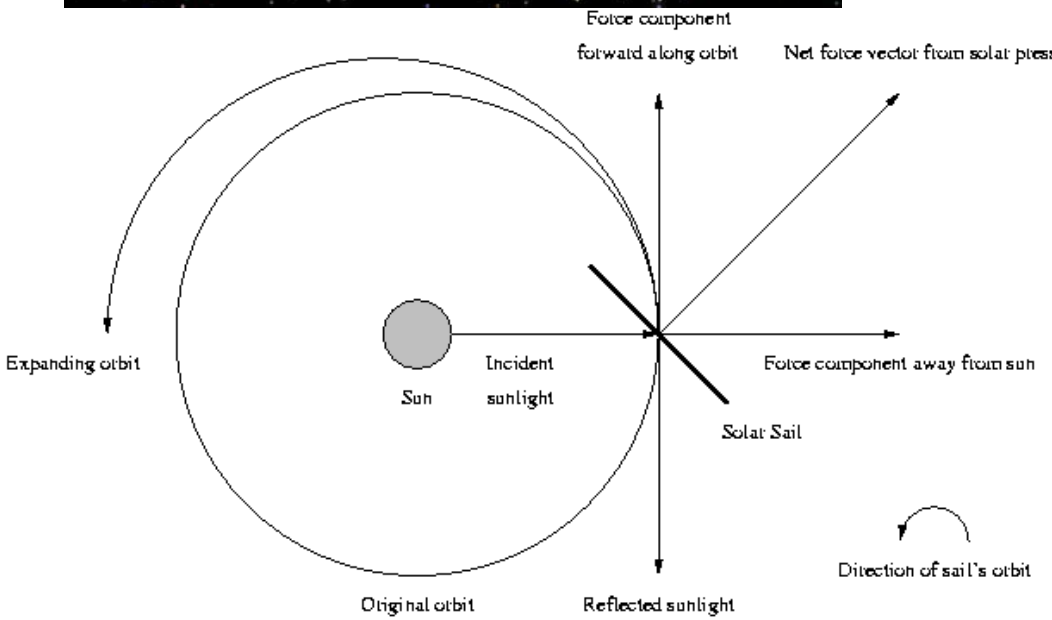


# How does a solar sail work?



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



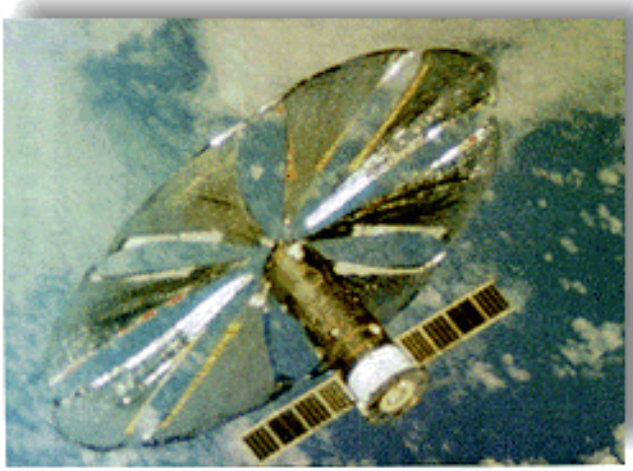



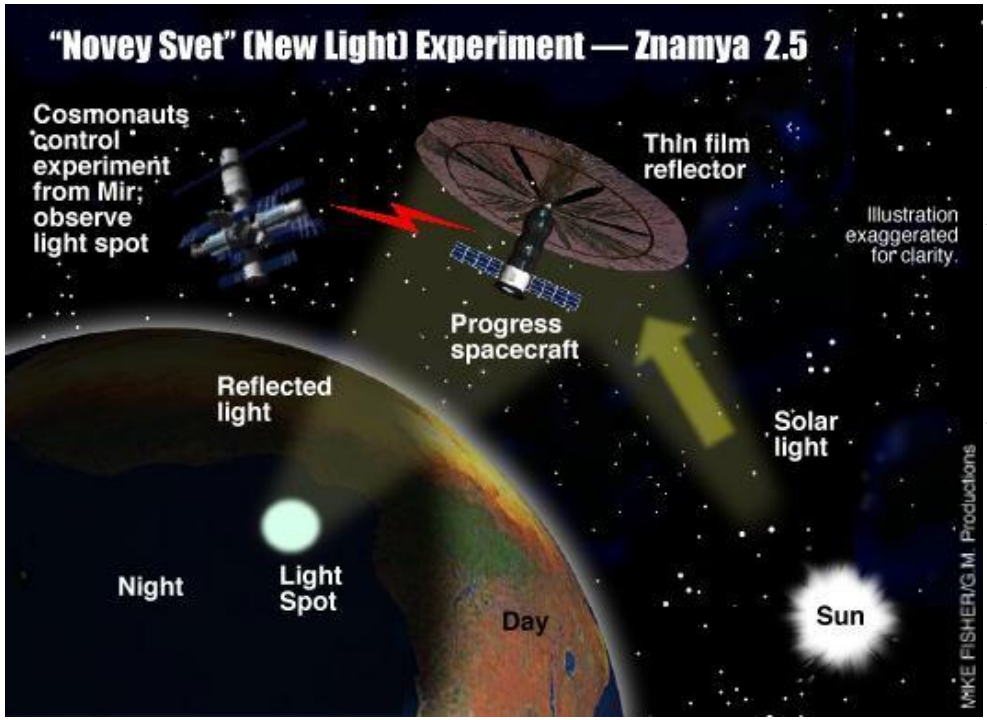
# Echo II 1964
## Solar thrust affect on spacecraft orbit

- 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.

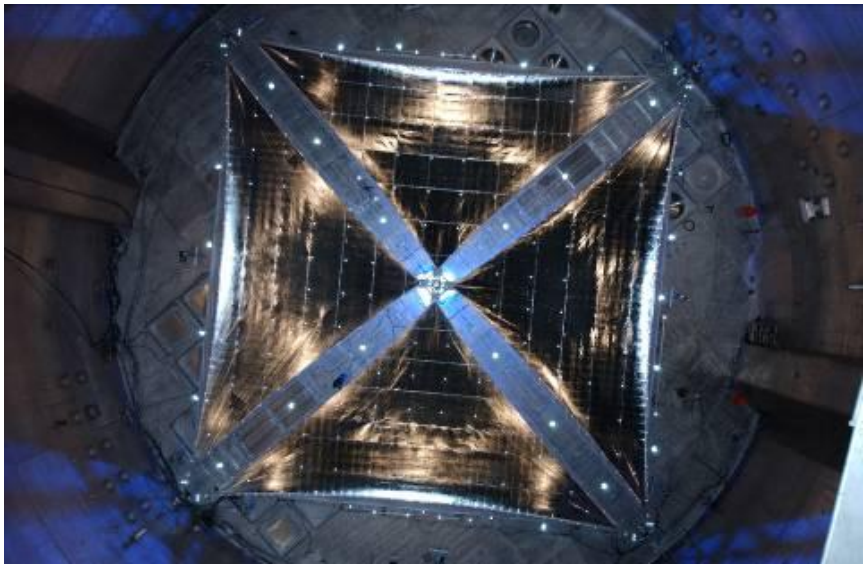
# Znamya (Space Mirror)






- 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.

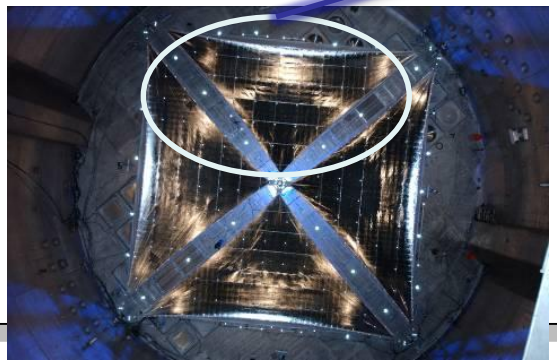
# NASA Ground Tested Solar Sails

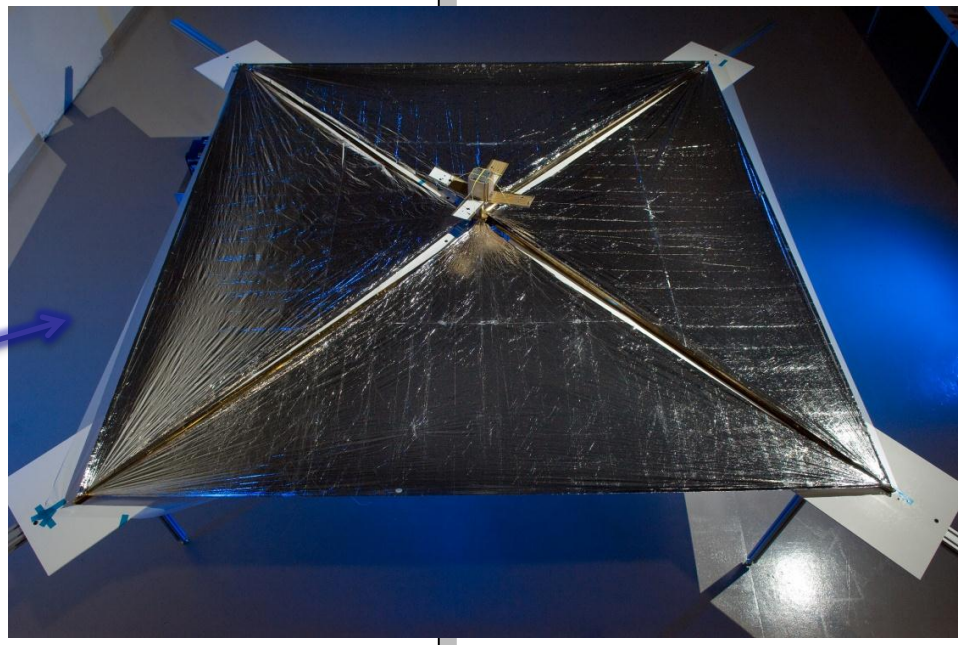


- Two solar sail technologies were designed, fabricated, and tested under thermal vacuum conditions in 2005:
  - 10 m system ground demonstrators (developed and tested in 2004/2005)
  - 20 m system ground demonstrators (designed, fabricated, and tested)
- Developed and tested high-fidelity computational 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

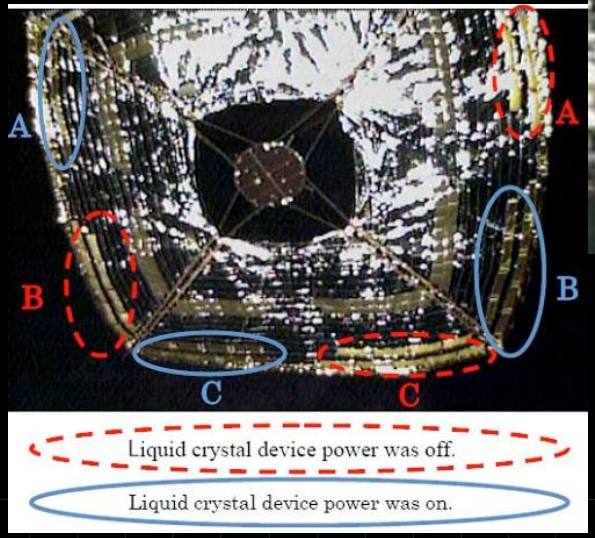
- Mission Description:
  - 10 $m^2$ sail
  - Made from tested ground demonstrator hardware



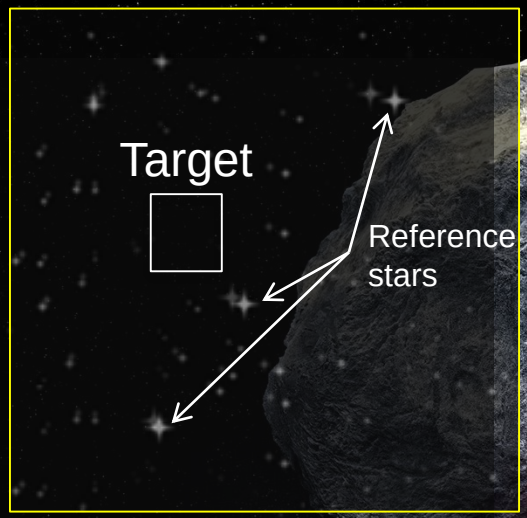


# NanoSail-D in Flight

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

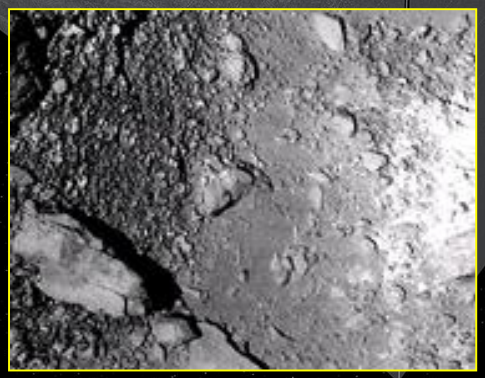
# NEA Scout Science Objectives




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

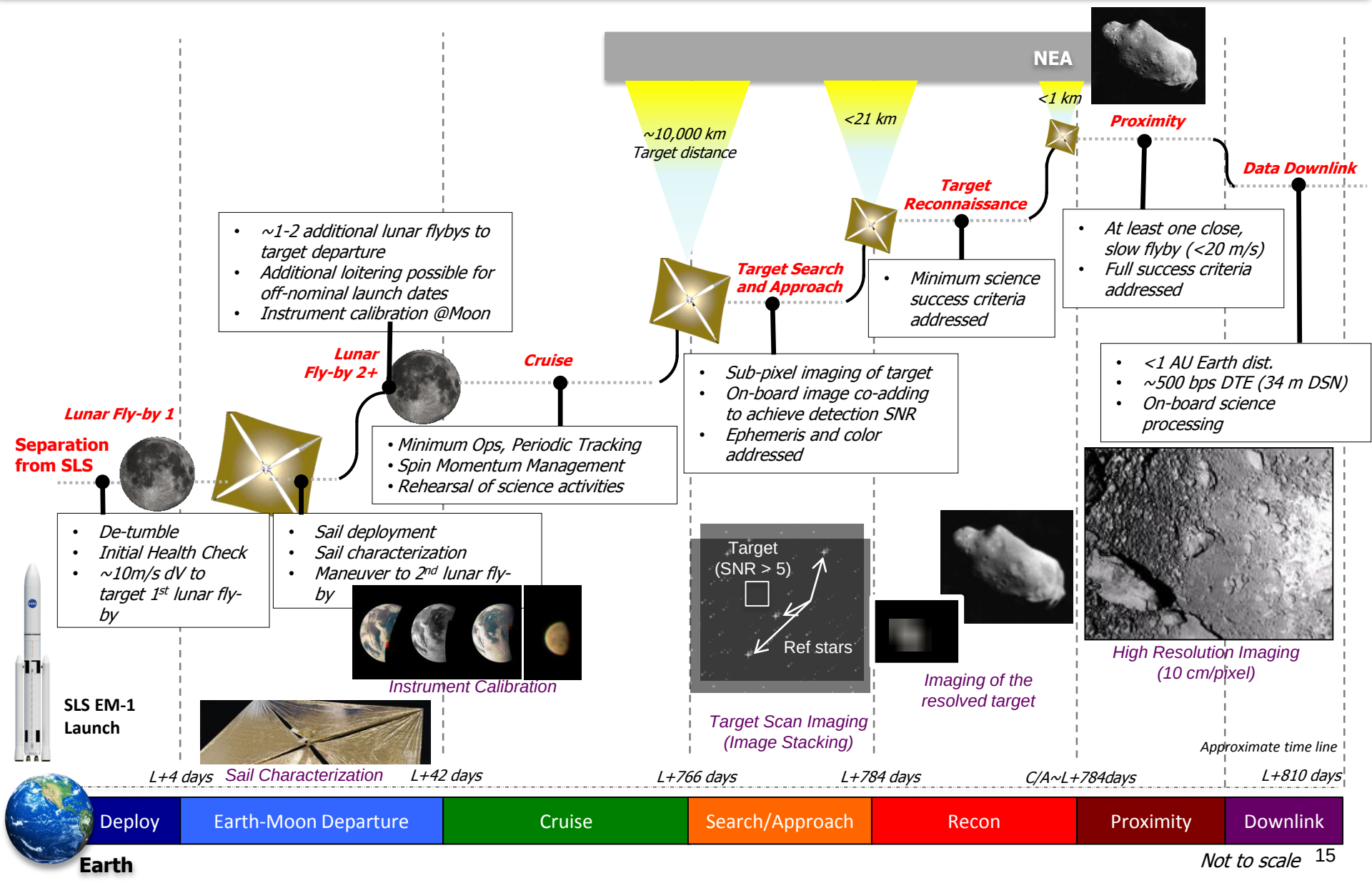
**Target Reconnaissance**
50 cm/px resolution over 80% surface
**SKGs: volume, global shape, spin rate and pole position determination**

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



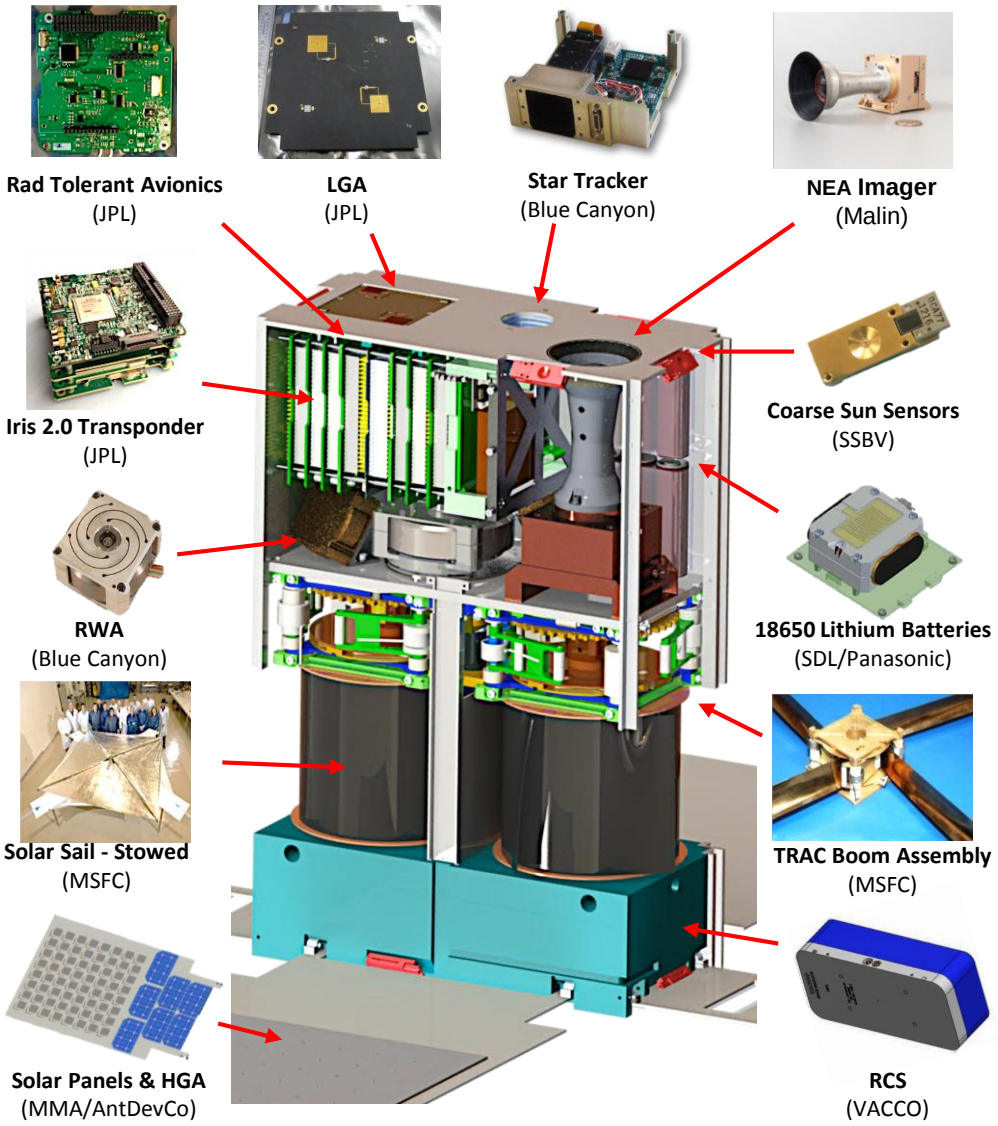
**Close Proximity Imaging**
High-resolution imaging,
10 cm/px GSD over >30% surface
**SKGs: Medium-scale morphology, regolith properties, and local environment characterization**

# NEA Scout Concept of Operations



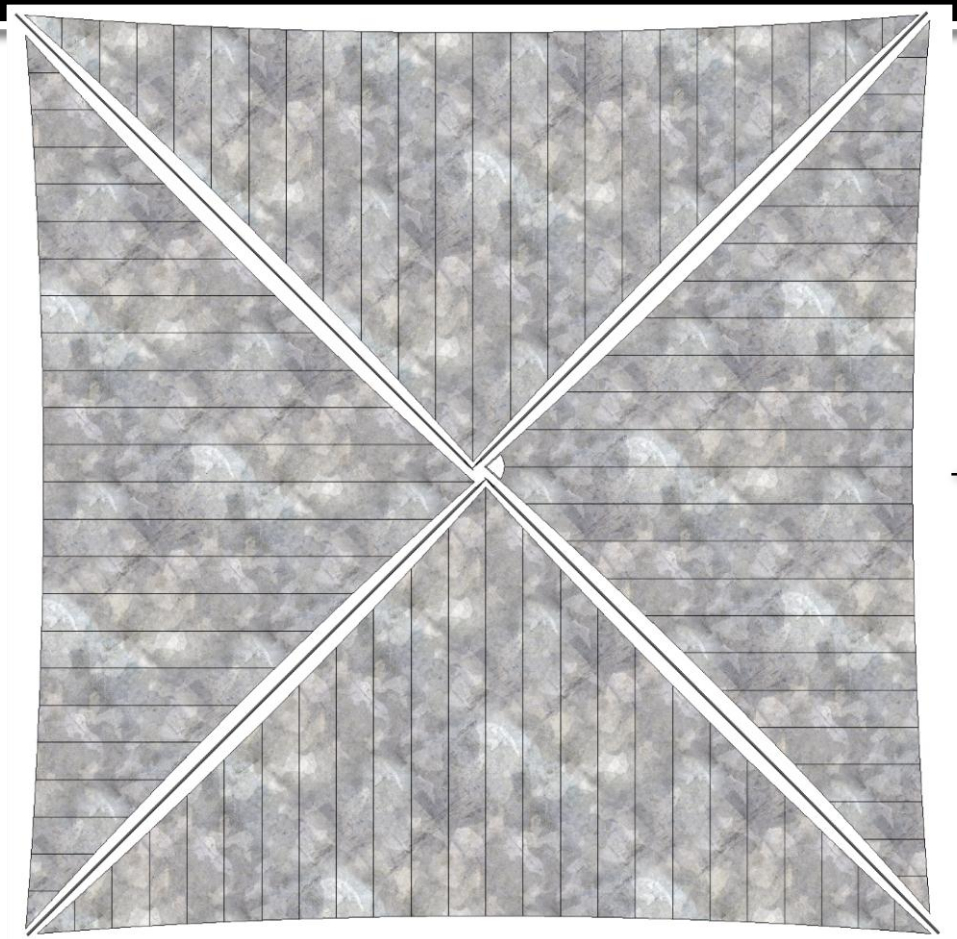
# Flight System Overview

| | |
|---|---|
| **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<br>• Static color filters (400-900 nm) |
| **Mechanical & Structure** | • “6U” CubeSat form factor (~10x20x30 cm)<br>• <12 kg total launch mass<br>• 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)<br>• 6.8 Ah Battery (3s2p 18650 Lithium Cells)<br>• 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<br>• 2 pairs of INSPIRE-heritage LGAs (RX/TX)<br>• 8x8 element microstrip array HGA (TX)<br>• ~500 bps to 34m DSN at 0.8 AU |
| **Attitude Control System** | • 15 mNm-s (x3) & 100 mNm-s RWAs<br>• Zero-momentum slow spin during cruise<br>• VACCO R134a (refrigerant gas) RCS system<br>• Nano StarTracker, Coarse Sun Sensors & MEMS IMU for attitude determination |



# NEA Scout Approximate Scale

Deployed Solar Sail




School Bus

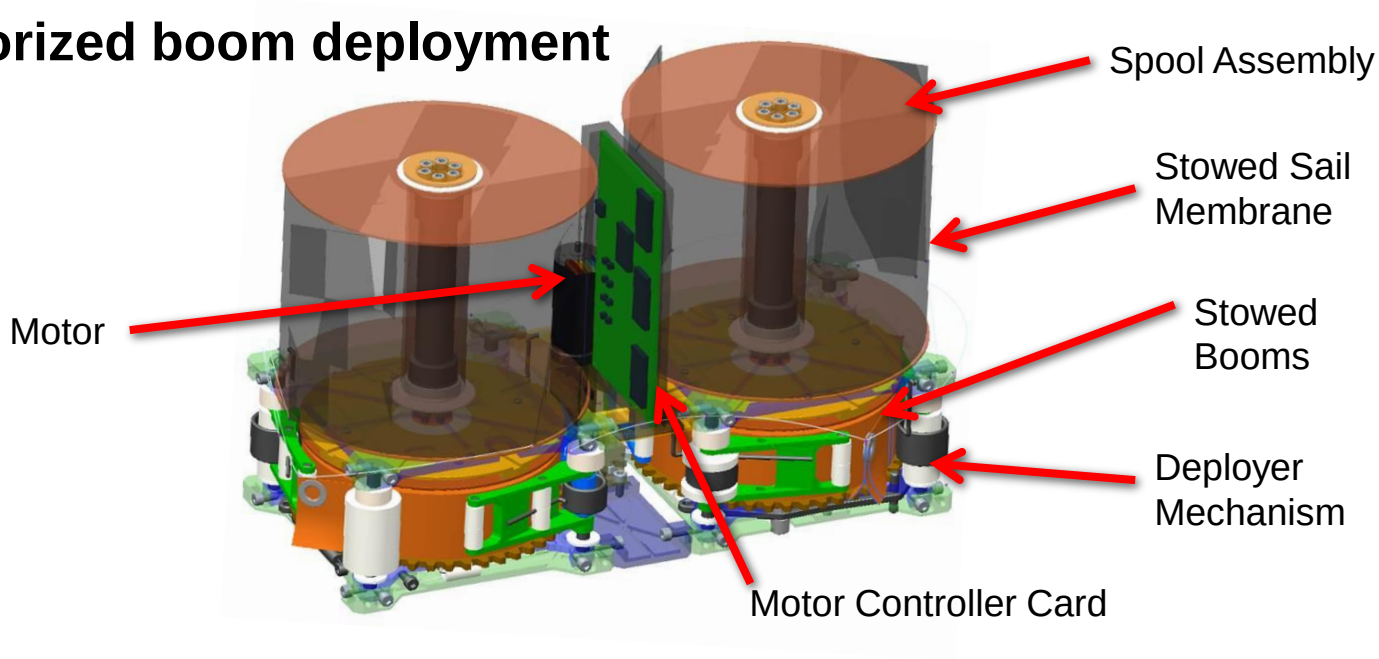
Human

6U Stowed Flight System

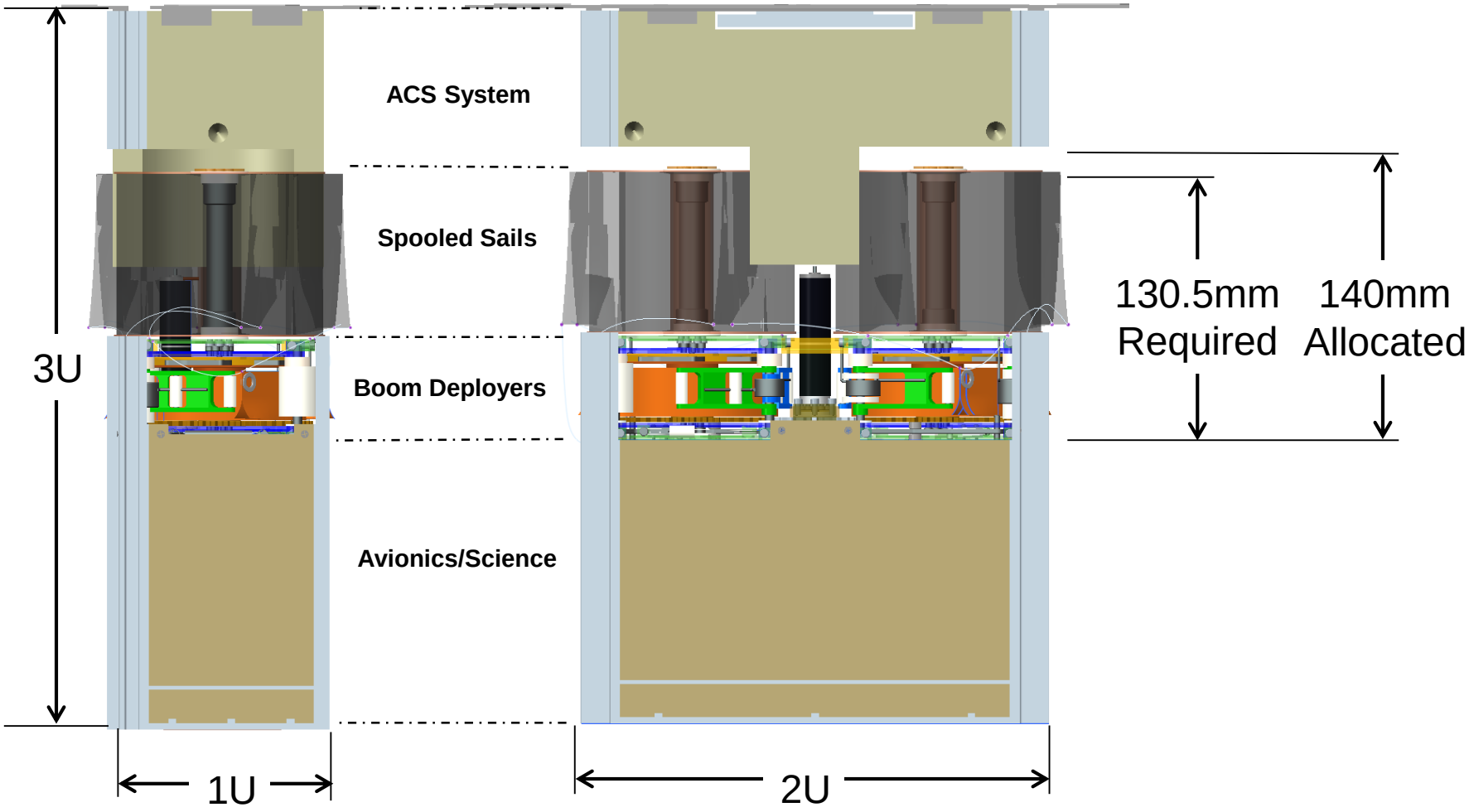
Folded, spooled and packaged in here

# 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

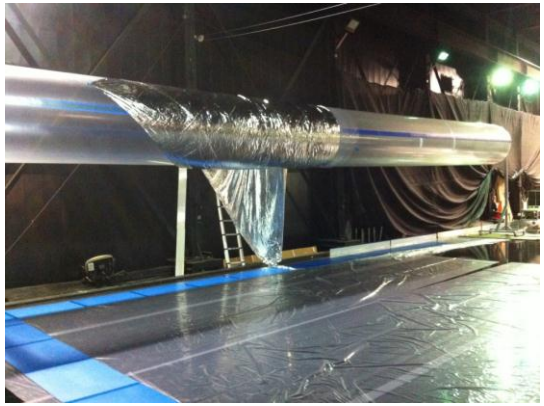


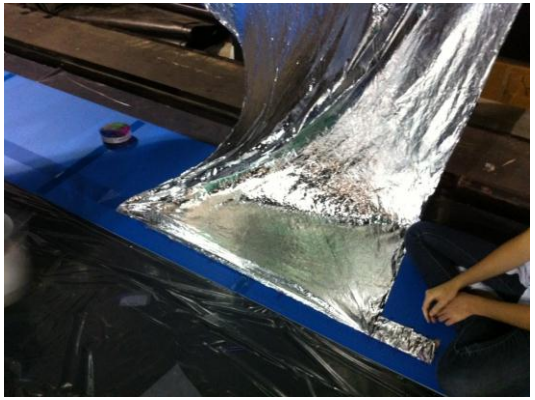
# Sail Packing Efficiency

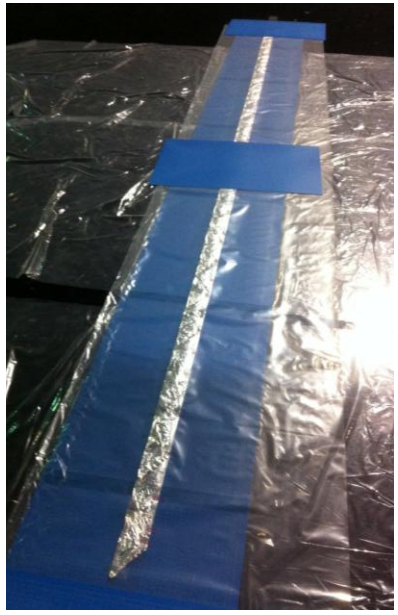
## Calculated Value:

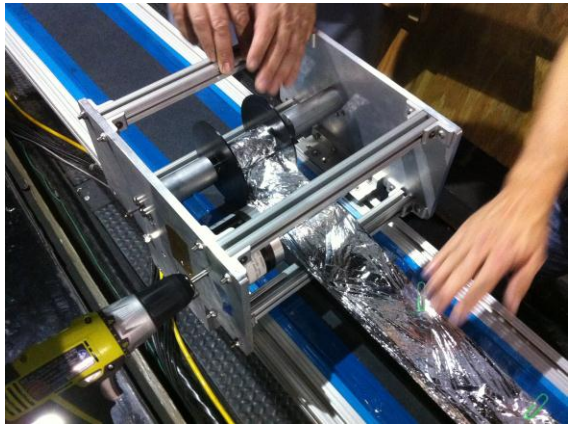
- Fabricated 2 flight size 10m sails from existing 20m CP1 sail.
- Z-folded and spooled 2 sail quadrants onto the hub.
- Calculated new packing efficiency to be **27.5 %**

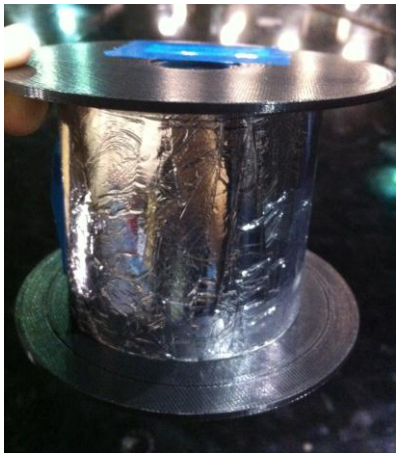
Higher percentage results in tighter packaging and thus more volume margin for design space.







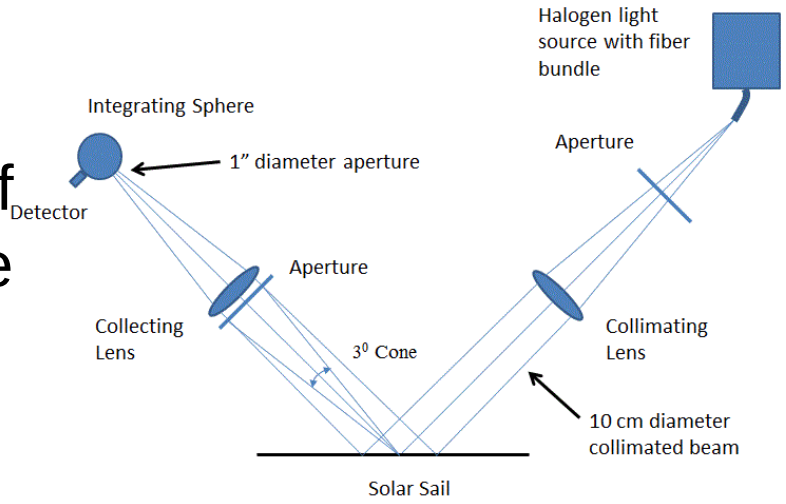


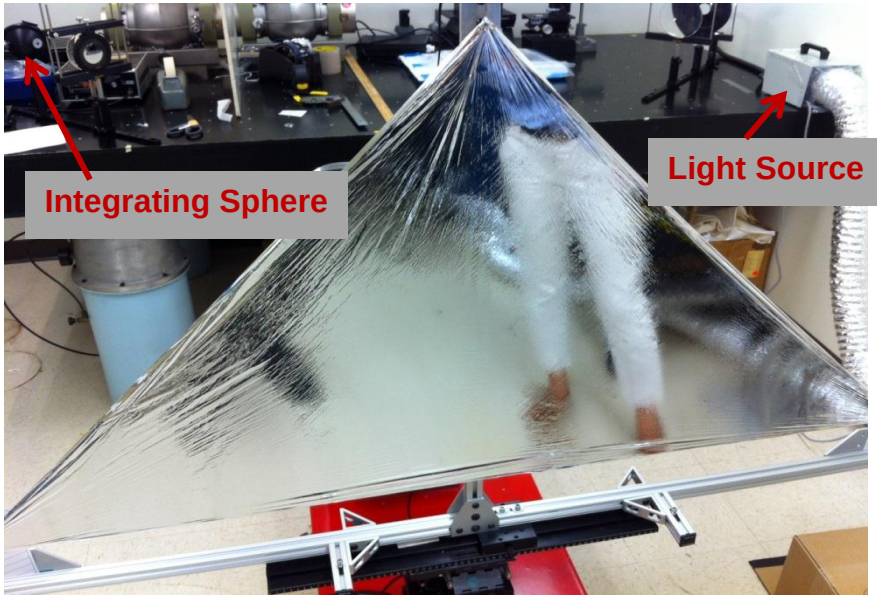


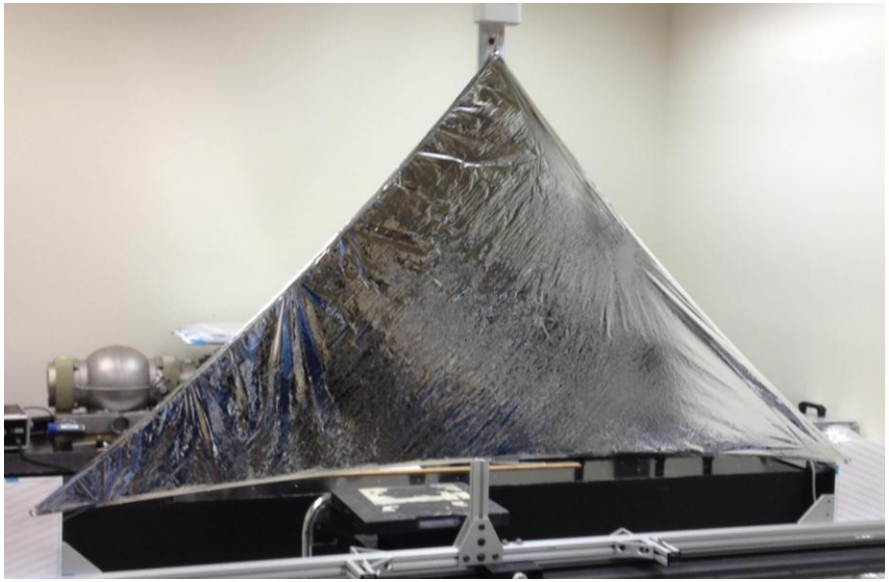
# Surface Illumination Test

**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.



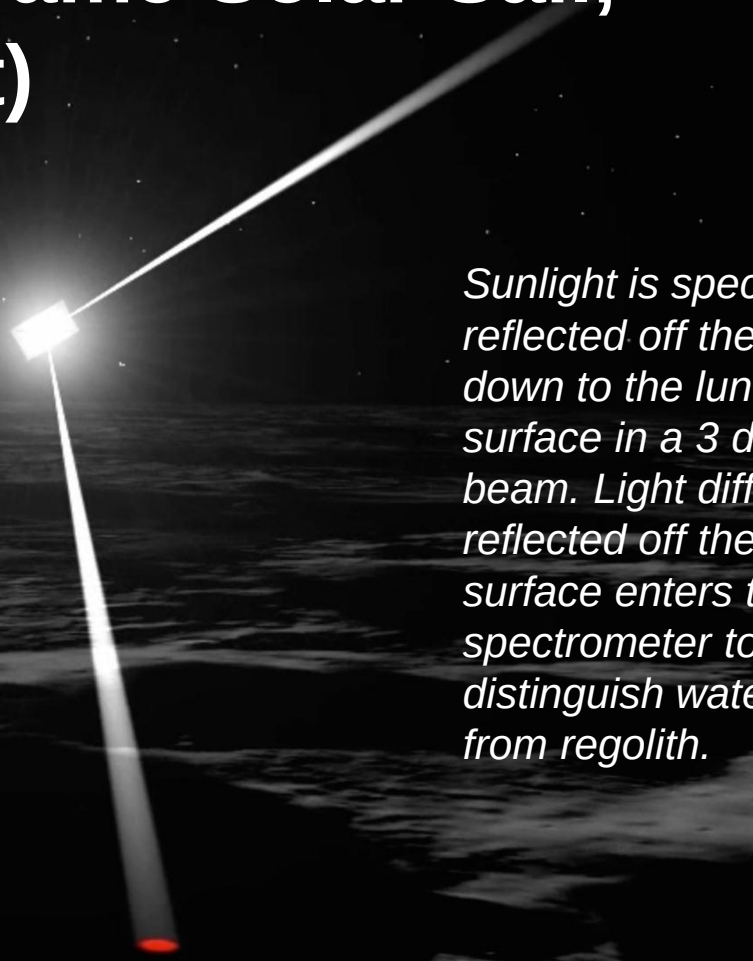



# NEA Scout Mission Animation

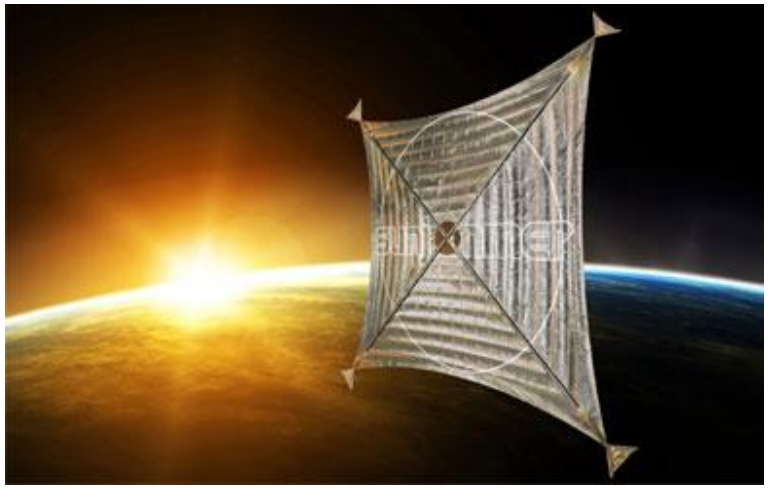
# Lunar Flashlight Science Objectives (Same Spacecraft, Same Solar Sail, Different Instrument)

- **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.

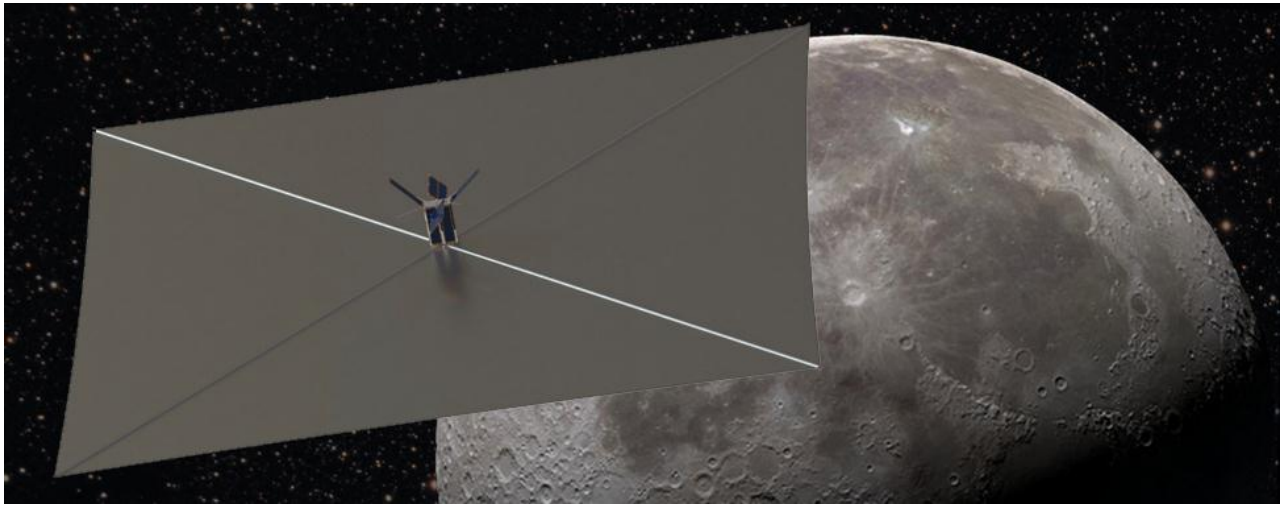


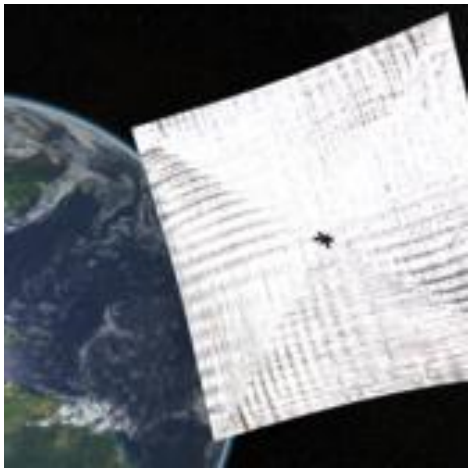
*Sunlight is specularly reflected off the sail down to the lunar surface in a 3 deg beam. Light diffusely reflected off the lunar surface enters the spectrometer to distinguish water ices from regolith.*

# Planned Missions

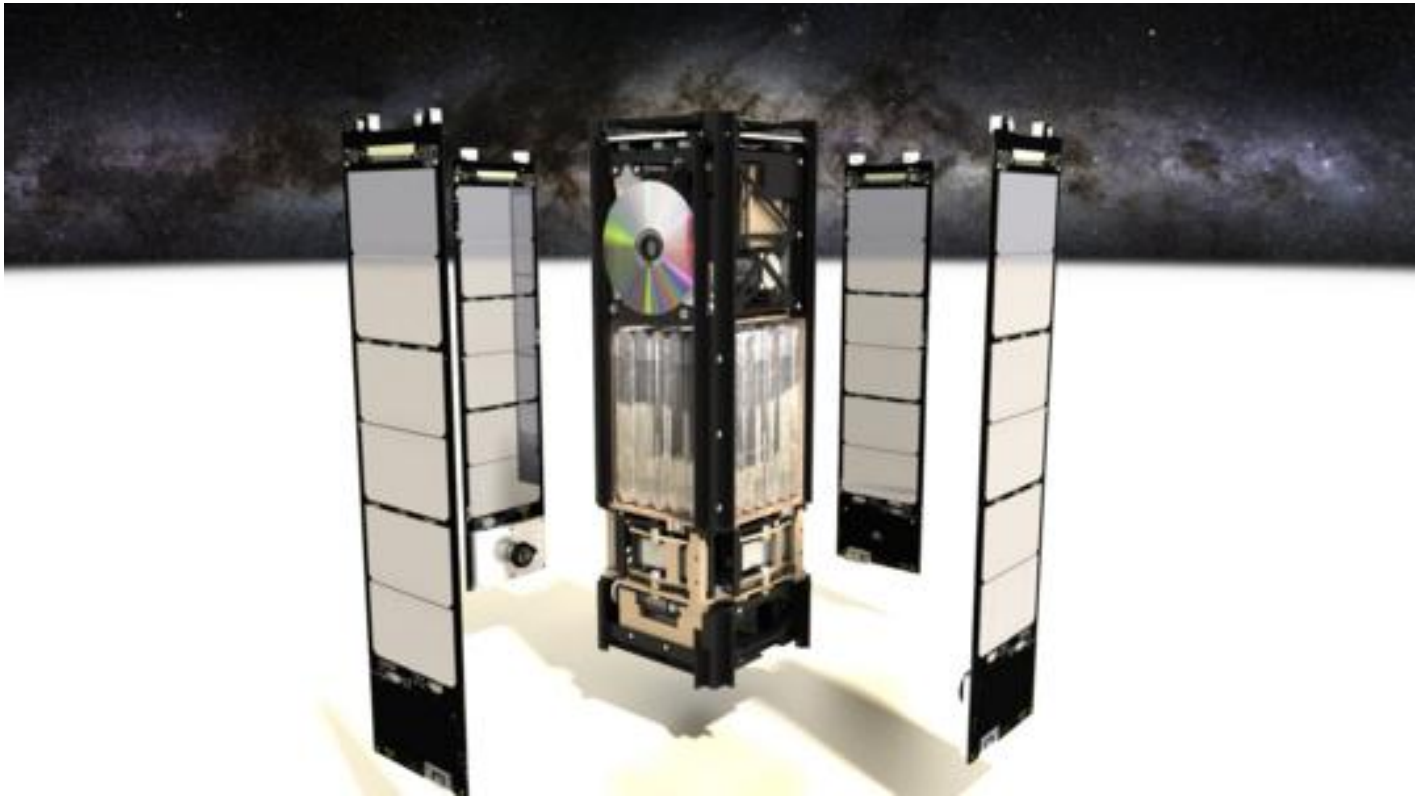


- NASA's *NEA Scout* and *Lunar Flashlight*
- The Planetary Society's *LightSail-A* and *LightSail-B*
- The University of Surrey's *CubeSail*, *DeorbitSail*, and *InflateSail*
- ESA and DLR's *Gossamer 1* and *Gossamer-2*





# 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 inflatable, rigidizable 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

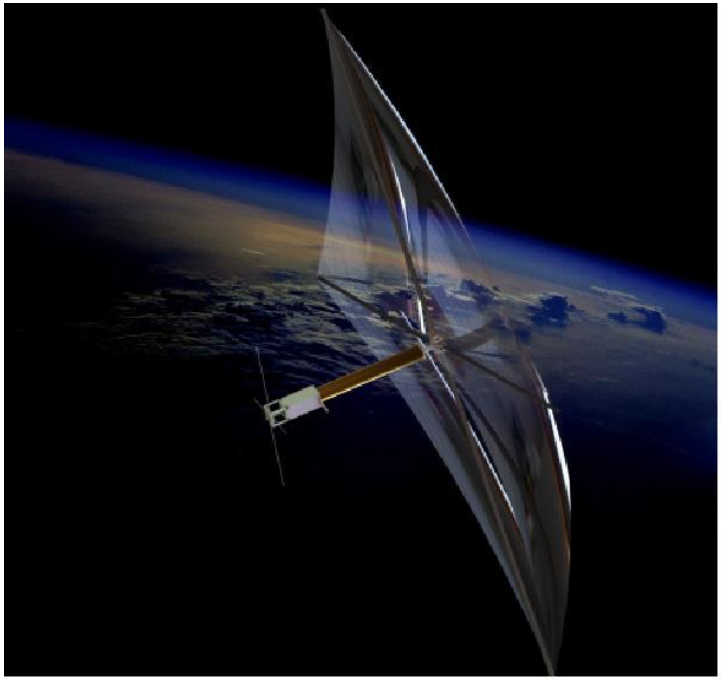


***Fig. 1**: InflateSail design concept*

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

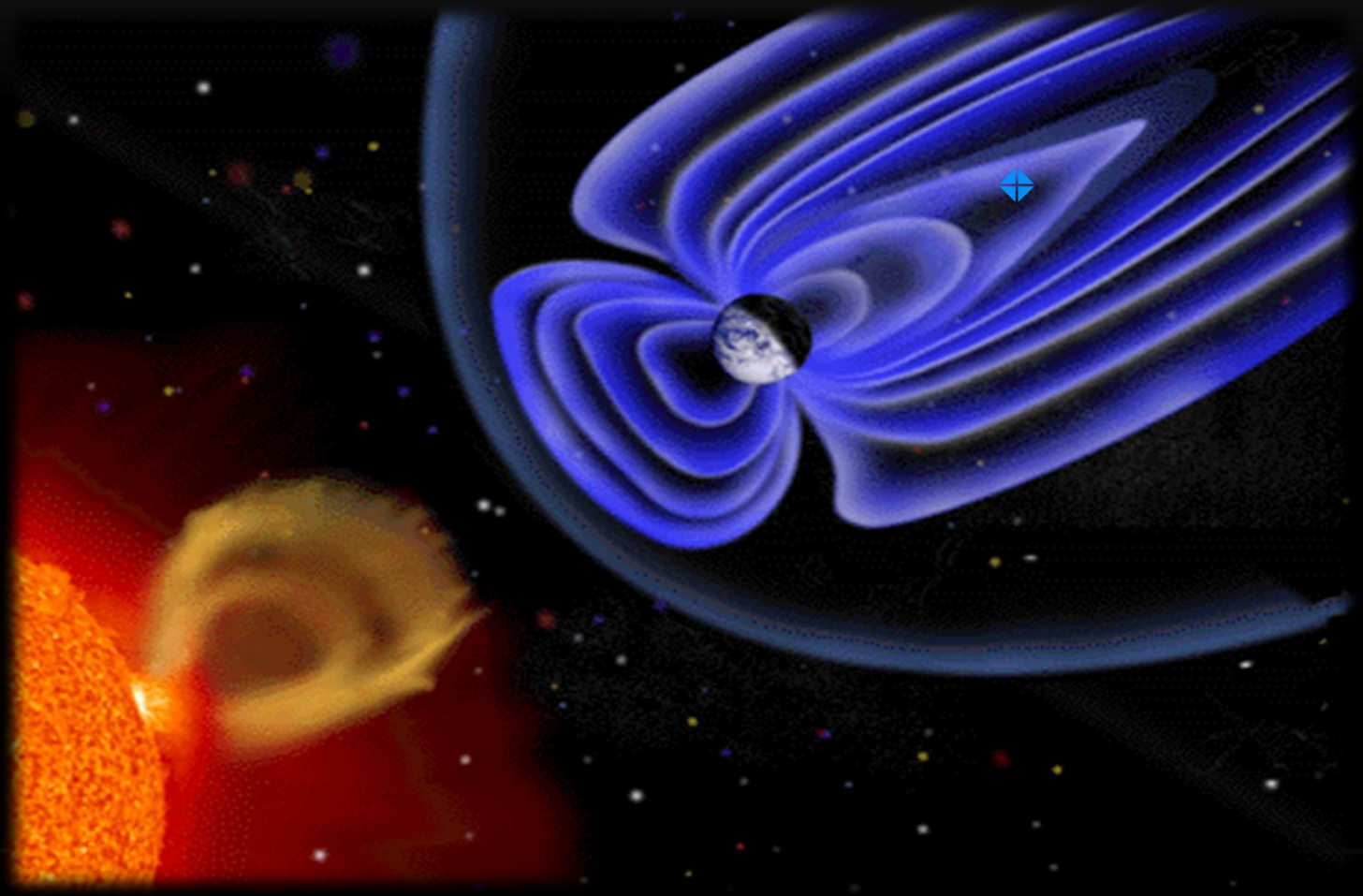
SURREY SPACE CENTRE

CGG technologies COOL GAS GENERATOR

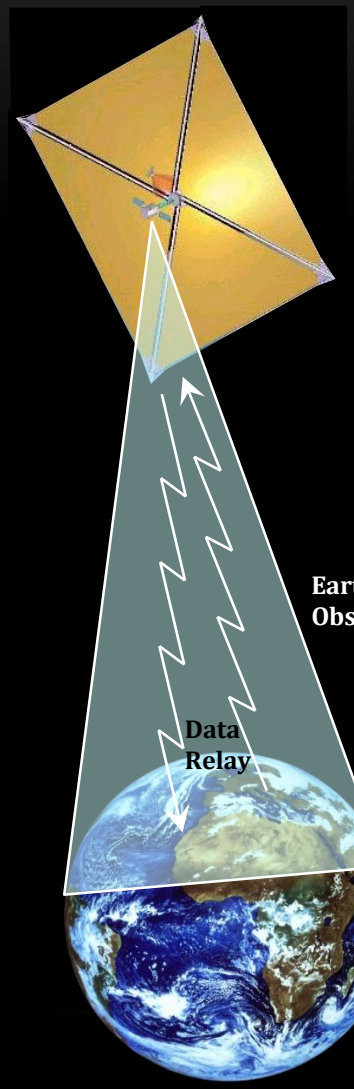
ASTRIUM AN EADS COMPANY

UNIVERSITY OF CAMBRIDGE

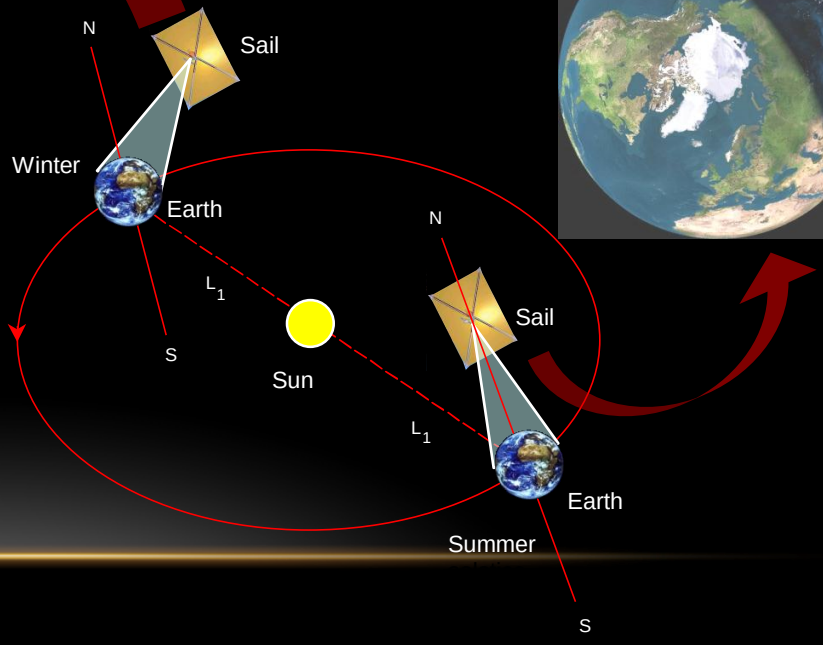
# THE FUTURE: SOLAR STORM WARNING



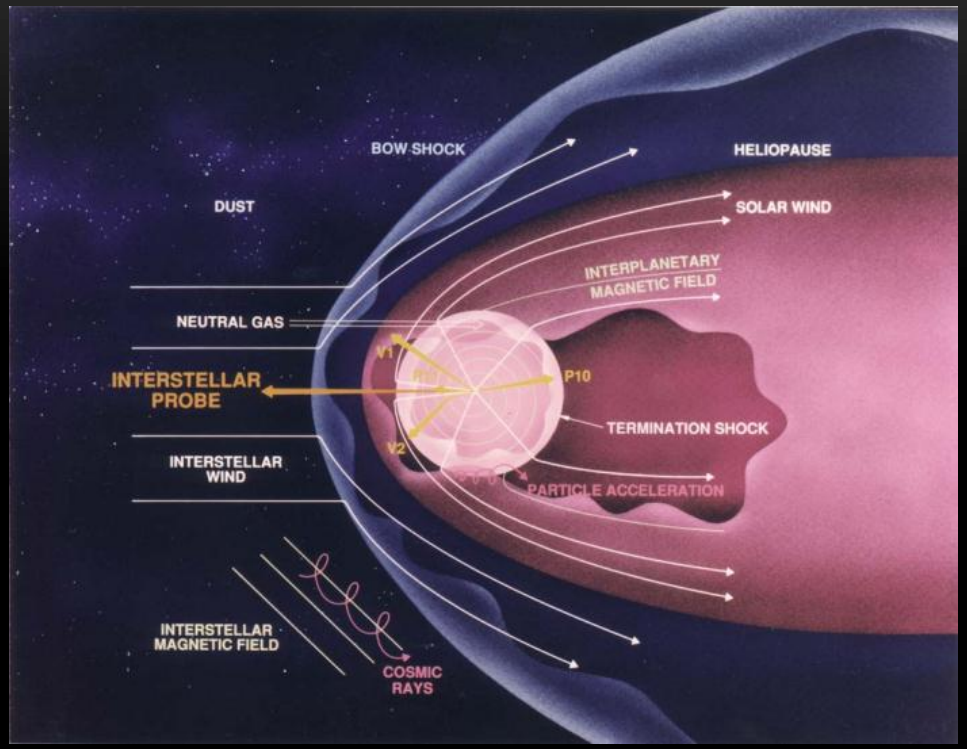
# THE FUTURE: POLE SITTER MISSION




- 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

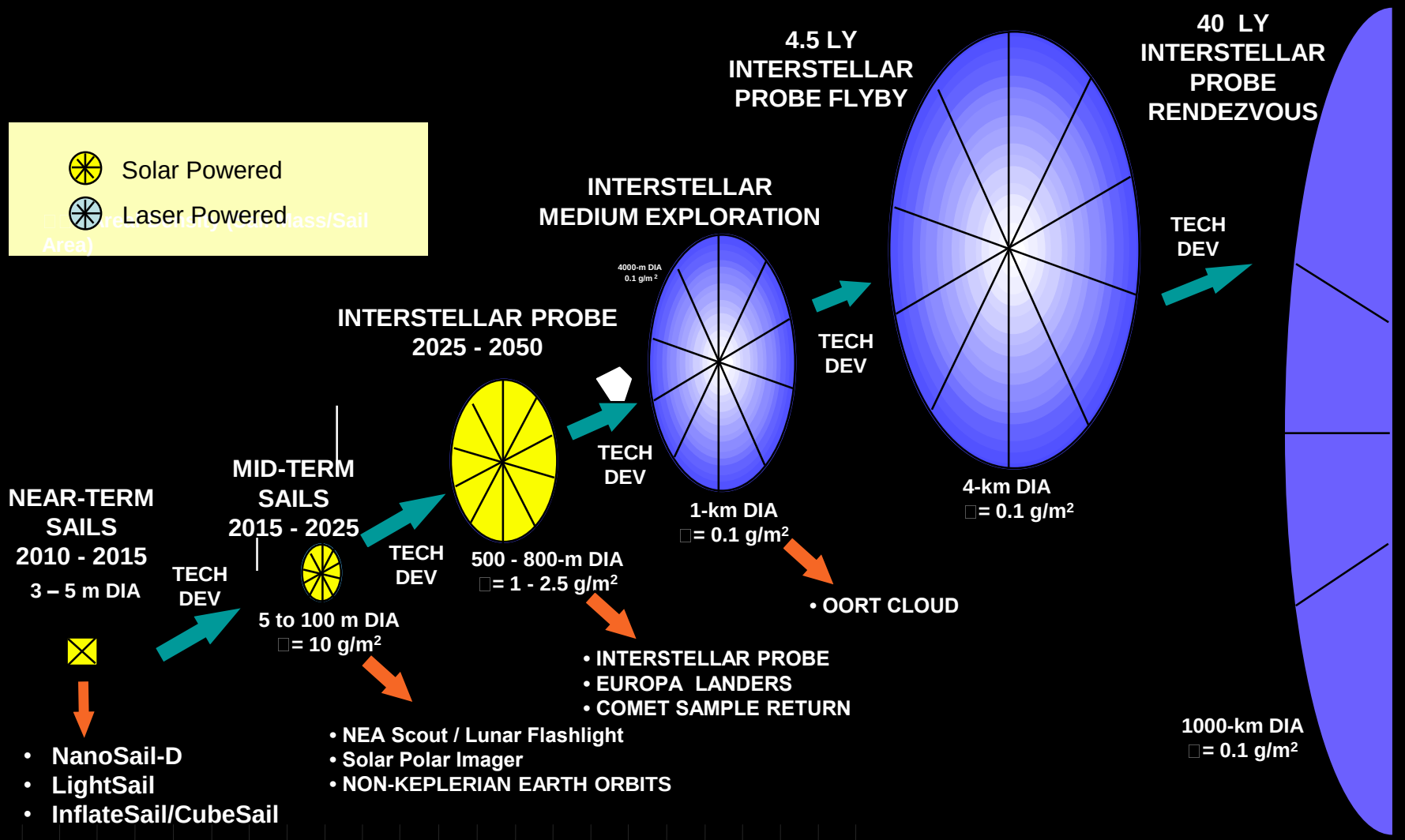



# THE FUTURE: INTERSTELLAR PROBE

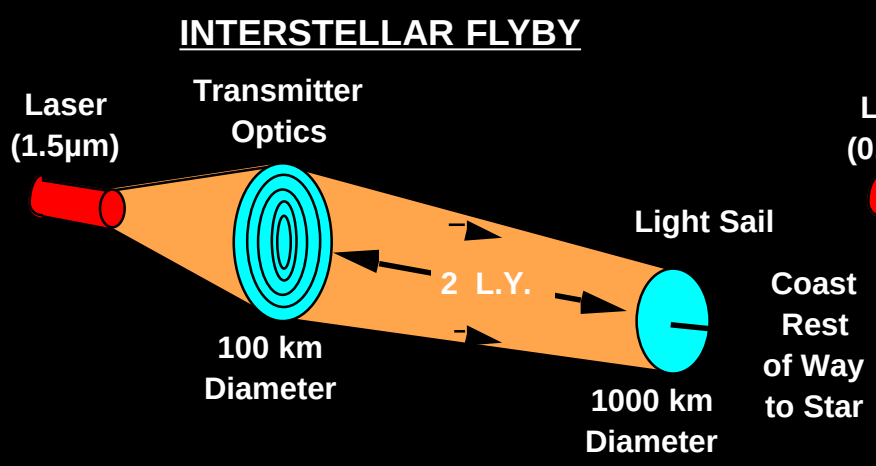


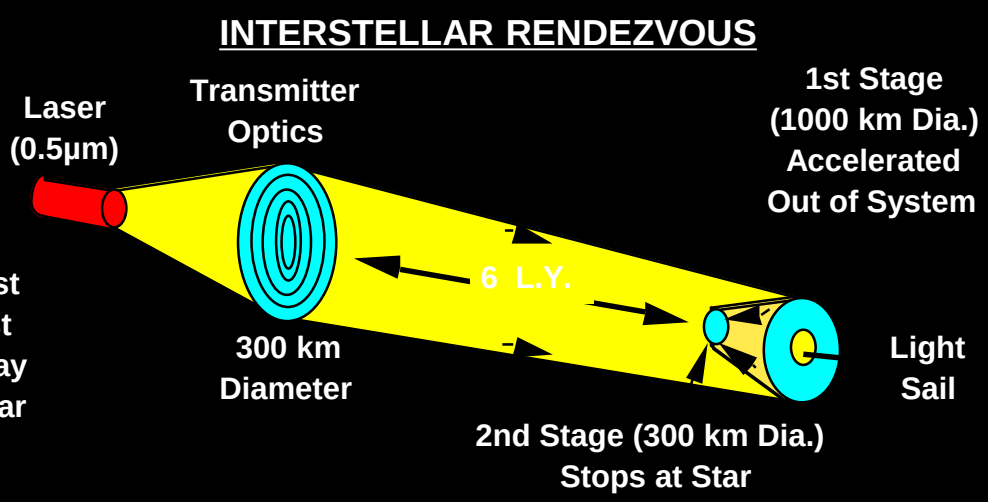

- A mission to beyond the Heliopause
  - 250 AU minimum
  - Reach 100 AU 10 years from launch
  - 15-20 AU/year target velocity
- 500-800 m diameter solar sail
- 1 $g/m^2$
- Survivable to T > 3000K for close solar approach

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

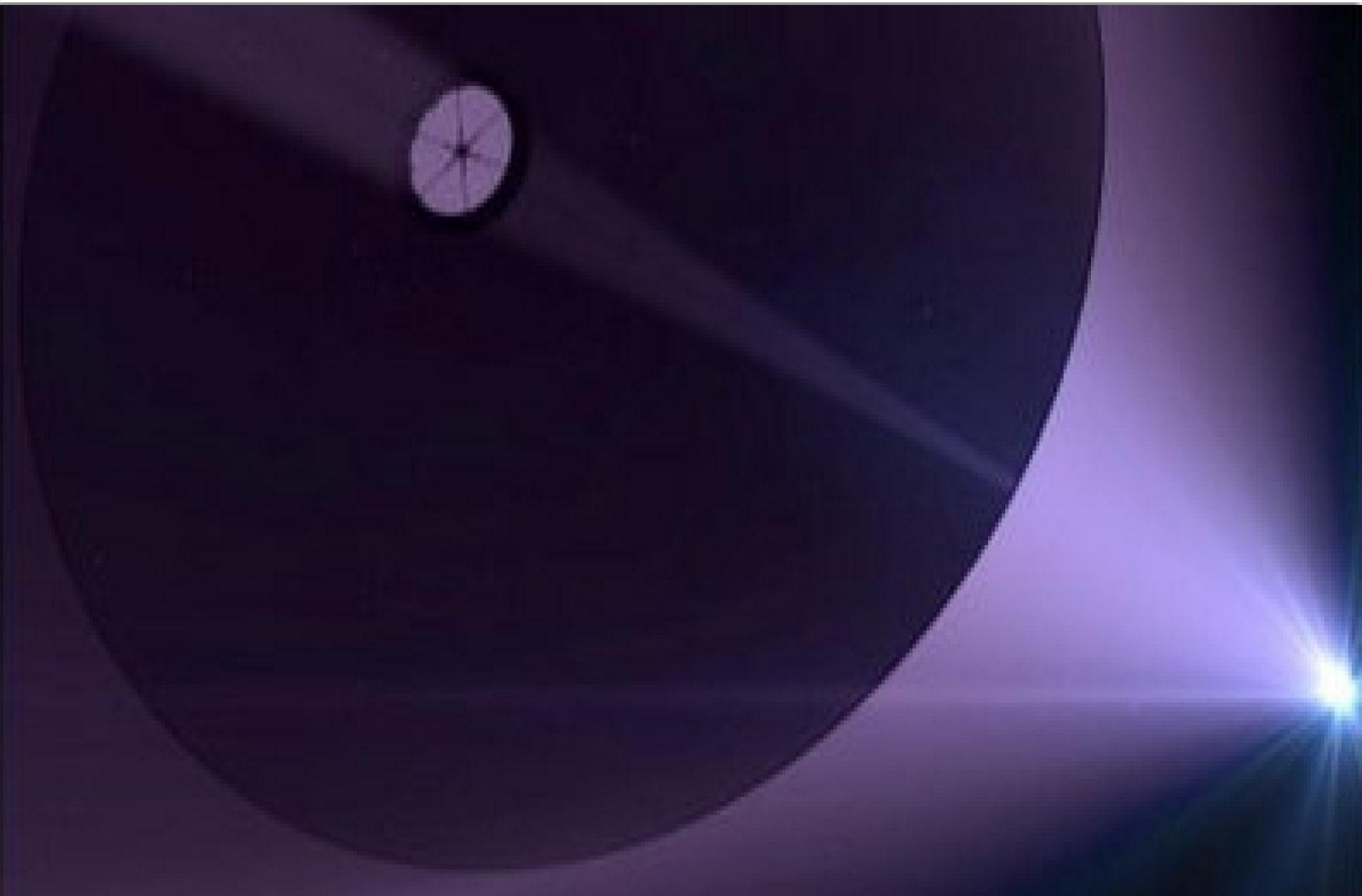


# Interstellar Light Sail Concept



# We are on our way to the stars…



# We are on our way to the stars…

NEA Scout is the next step…