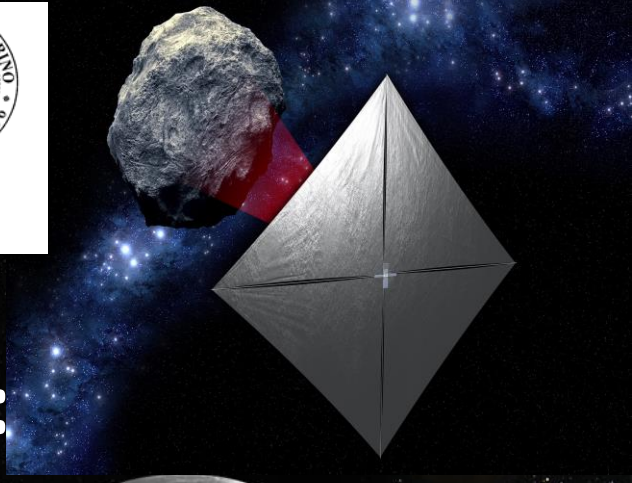
INTERNATIONAL ACADEMY OF ASTRONAUTICS
9th IAA SYMPOSIUM ON THE FUTURE OF SPACE EXPLORATION:
TOWARDS NEW GLOBAL PROGRAMMES

Torino, Italy, July 7-9, 2015



NEA Scout and Lunar Flashlight: Two Near-Term Interplanetary Solar Sail Missions

Les Johnson, Barbara Cohen, and
Leslie McNutt (NASA MSFC)
Julie Castillo-Rogez (NASA JPL)

Space Launch System (SLS) 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

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

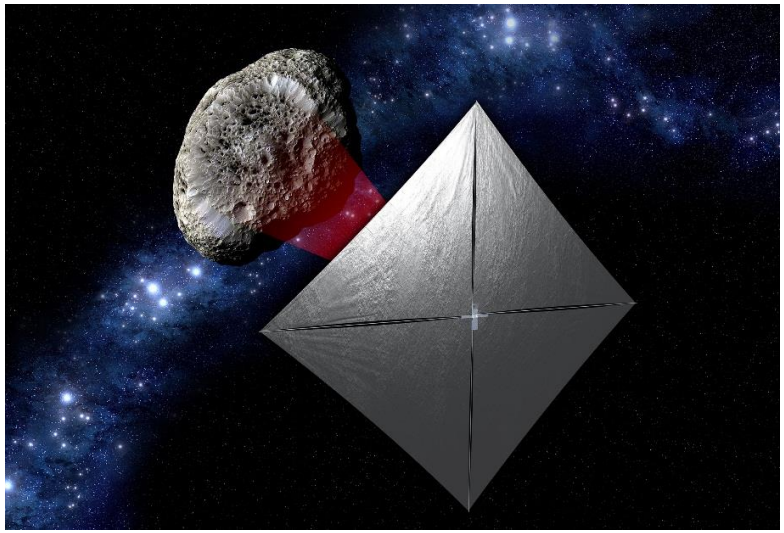
NEA Scout / Lunar Flashlight Roles and Responsibilities

- Near Earth Asteroid Scout
  - Project Manager: Leslie McNutt (MSFC)
  - Science PI: Julie Castillo-Rogez (JPL)
  - Solar Sail PI: Les Johnson (MSFC)
  - Spacecraft System: JPL
  - Solar Sail System: MSFC
- Lunar Flashlight
  - Project Manager: John Baker (JPL)
  - PI: Barbara Cohen (MSFC)
  - Spacecraft System: JPL
  - Solar Sail System: MSFC

Near Earth Asteroid Scout Overview

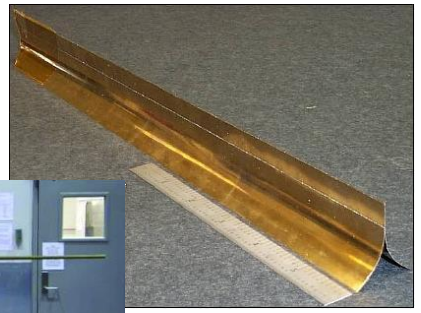
The Near Earth Asteroid Scout Will

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



Key Spacecraft & Mission Parameters

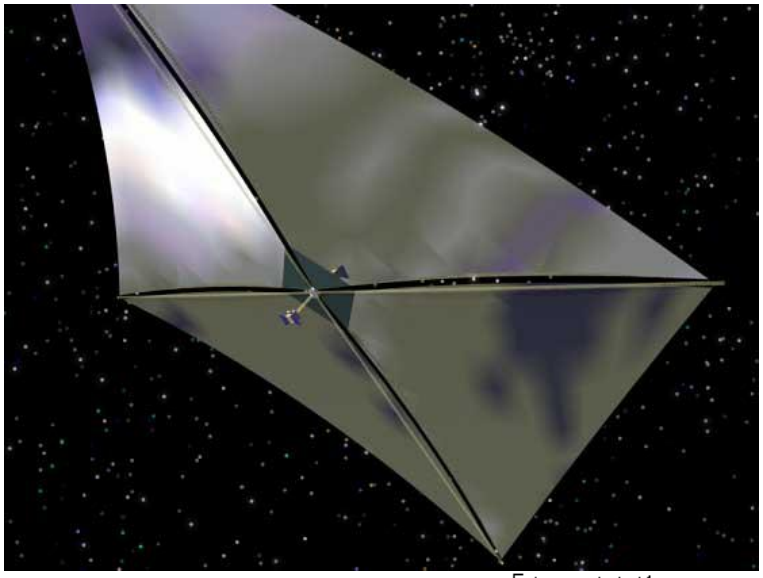
- 6U cubesat (20 cm X 10 cm X 30 cm)
- ~85 m^2 solar sail propulsion system
- Manifested for launch on the Space Launch System (EM-1/2018)
- Up to 2.5 year mission duration
- 1 AU (93,000,000 mile) maximum distance from Earth



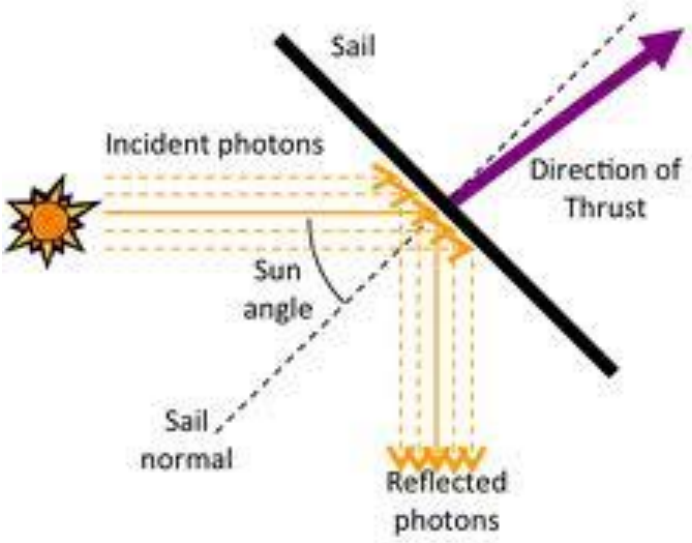
Solar Sail Propulsion System Characteristics

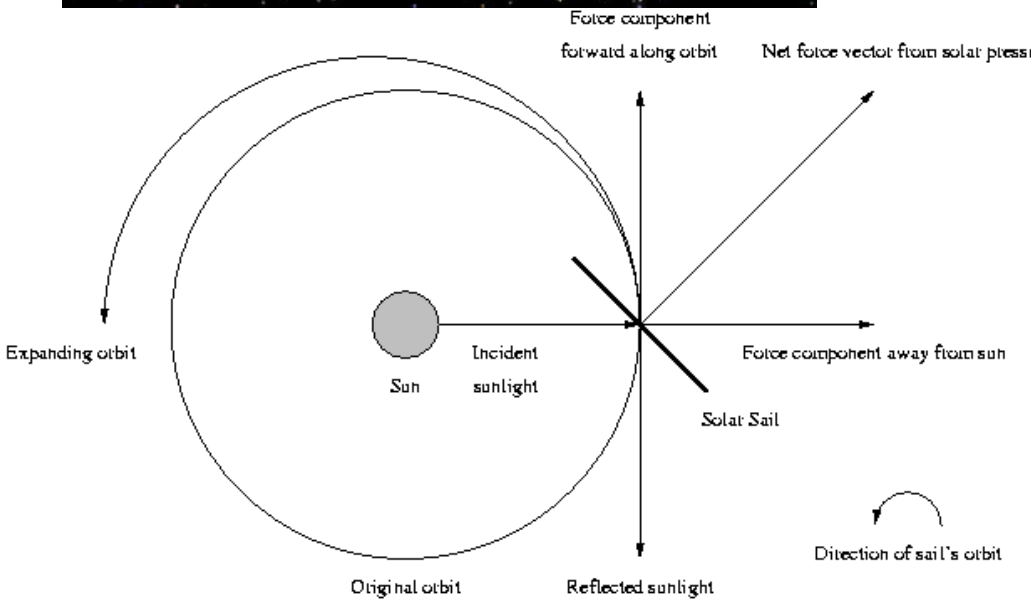
- ~ 7.3 m Trac booms
- 2.5μ aluminized CP-1 substrate
- > 90% reflectivity

How does a solar sail work?



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

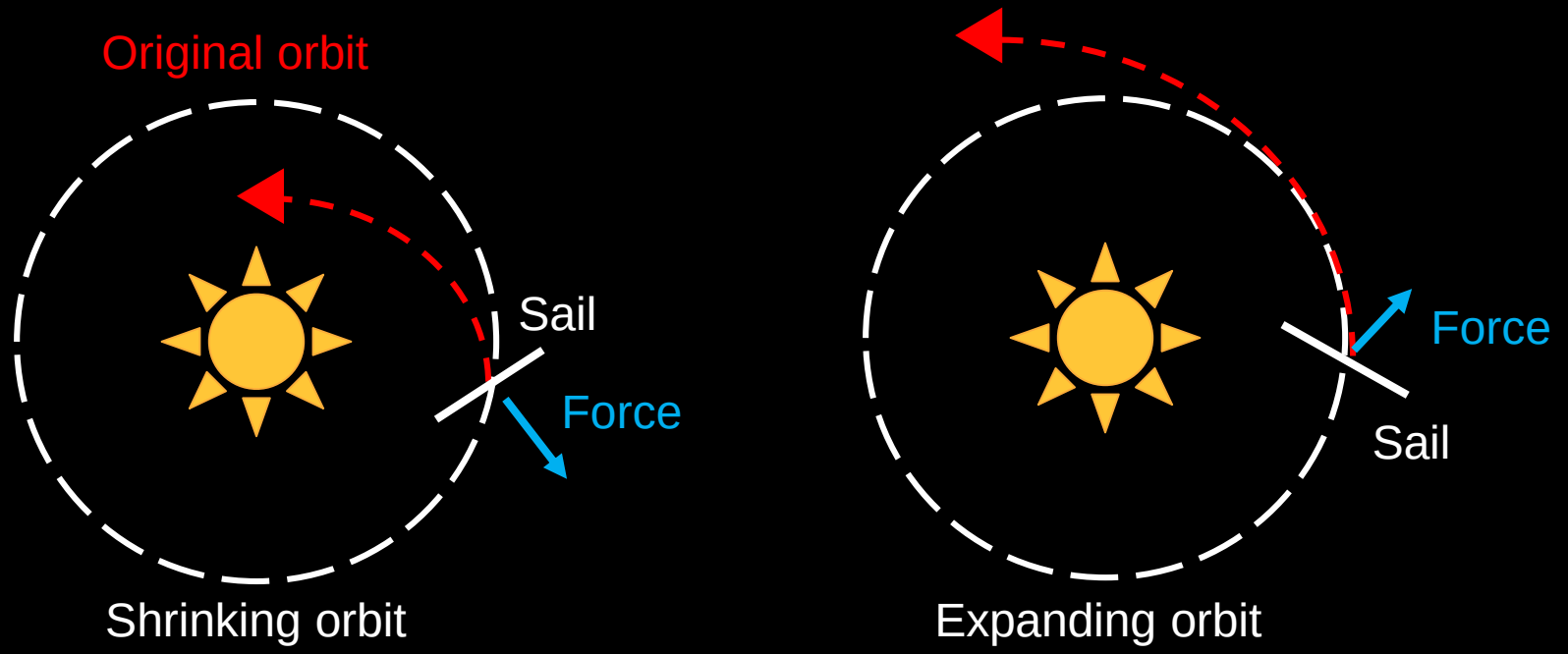




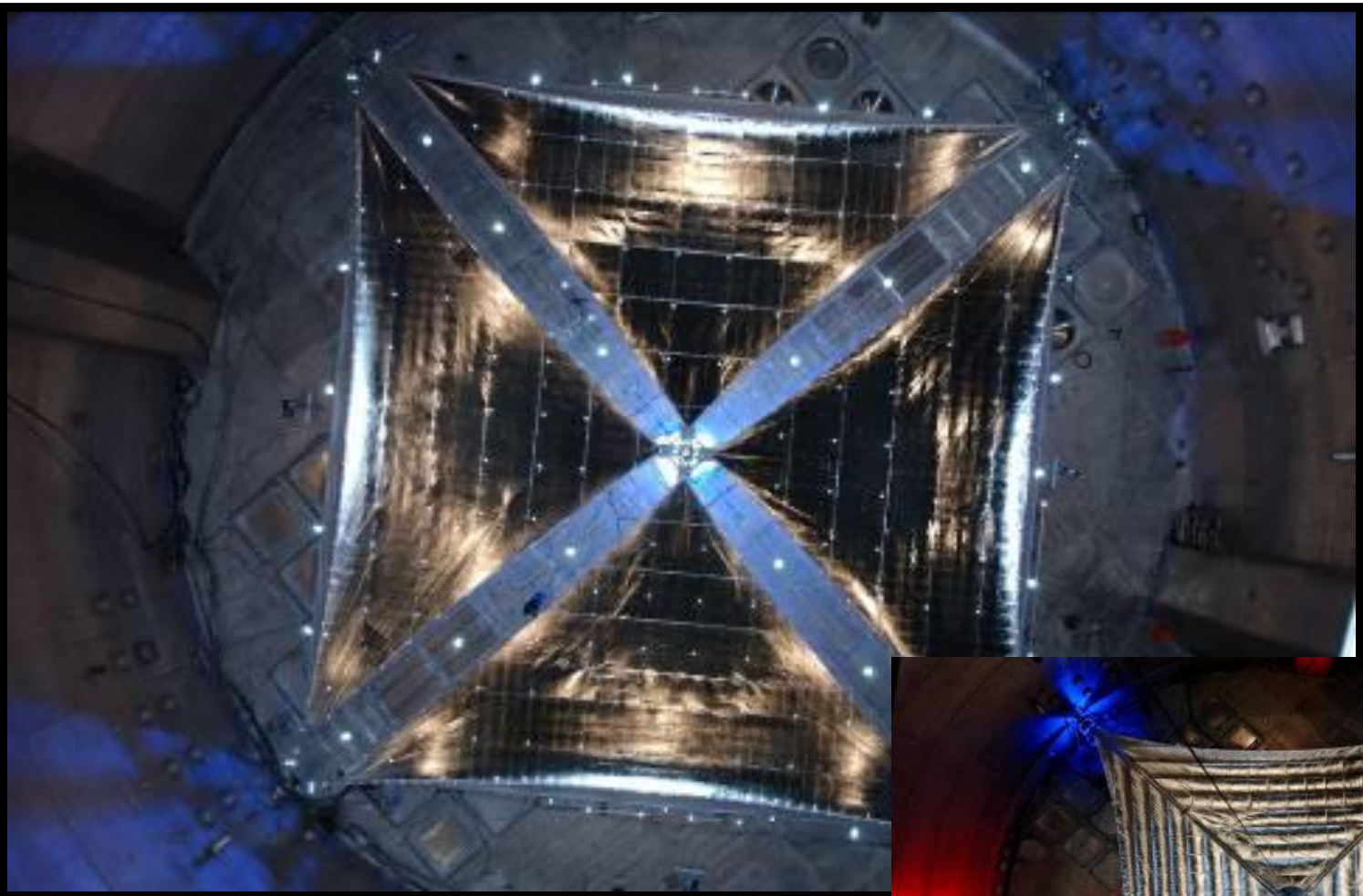
Solar Sail Trajectory Control

- Solar Radiation Pressure:

Inward and outward Spiral

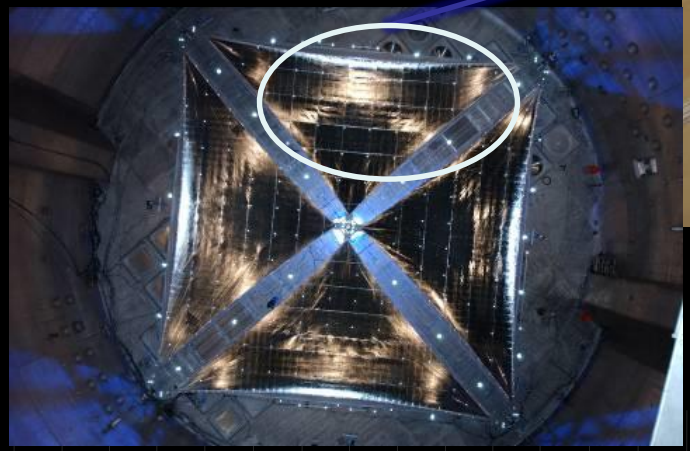


NASA Ground Tested Solar Sails

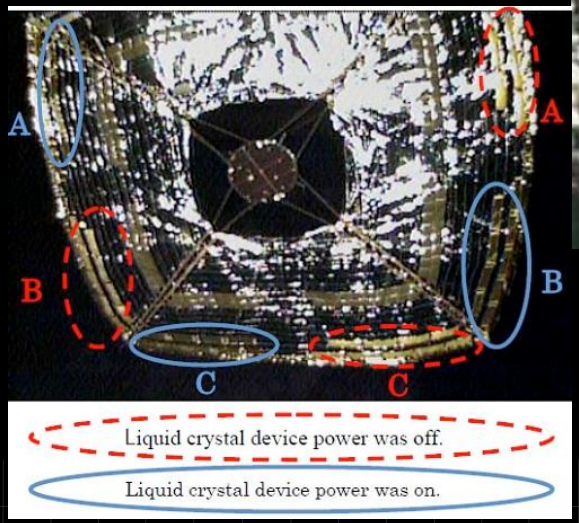


NanoSail-D Demonstration Solar Sail

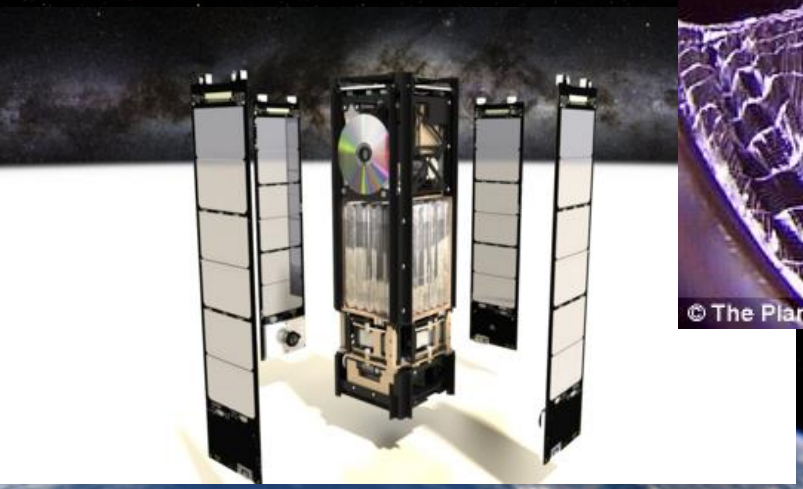
- 10 m^2 sail
- Made from tested ground demonstrator hardware

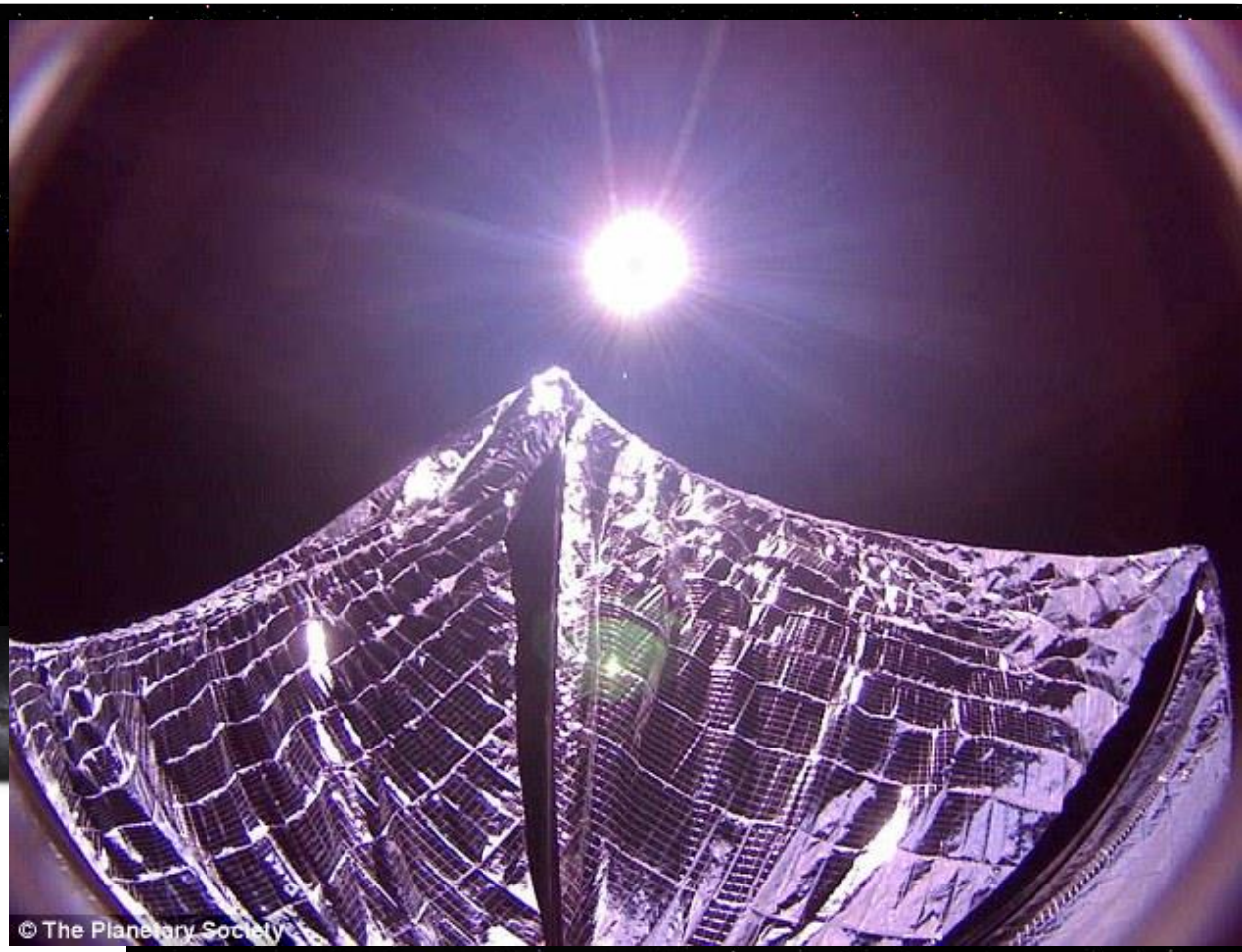


Interplanetary Kite-craft Accelerated by Radiation of the Sun (IKAROS)



LightSail

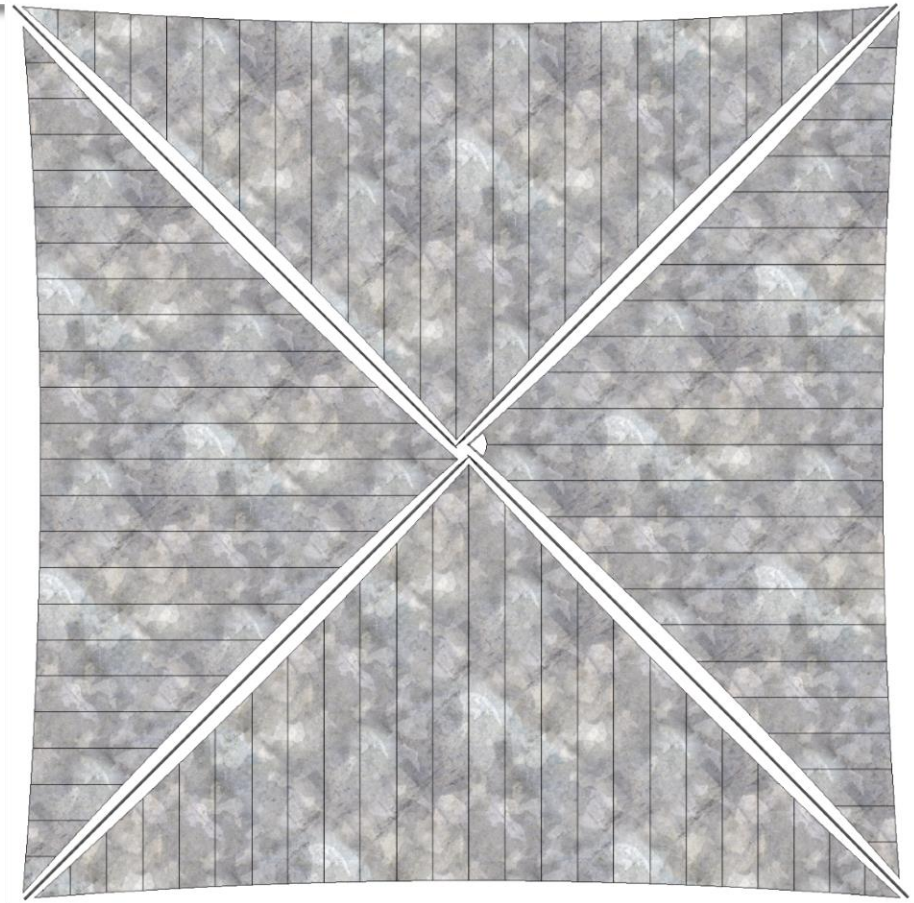




- Aluminized 4.5 micron Mylar film
- 32m^2

NEA Scout Approximate Scale

Deployed Solar Sail



School Bus

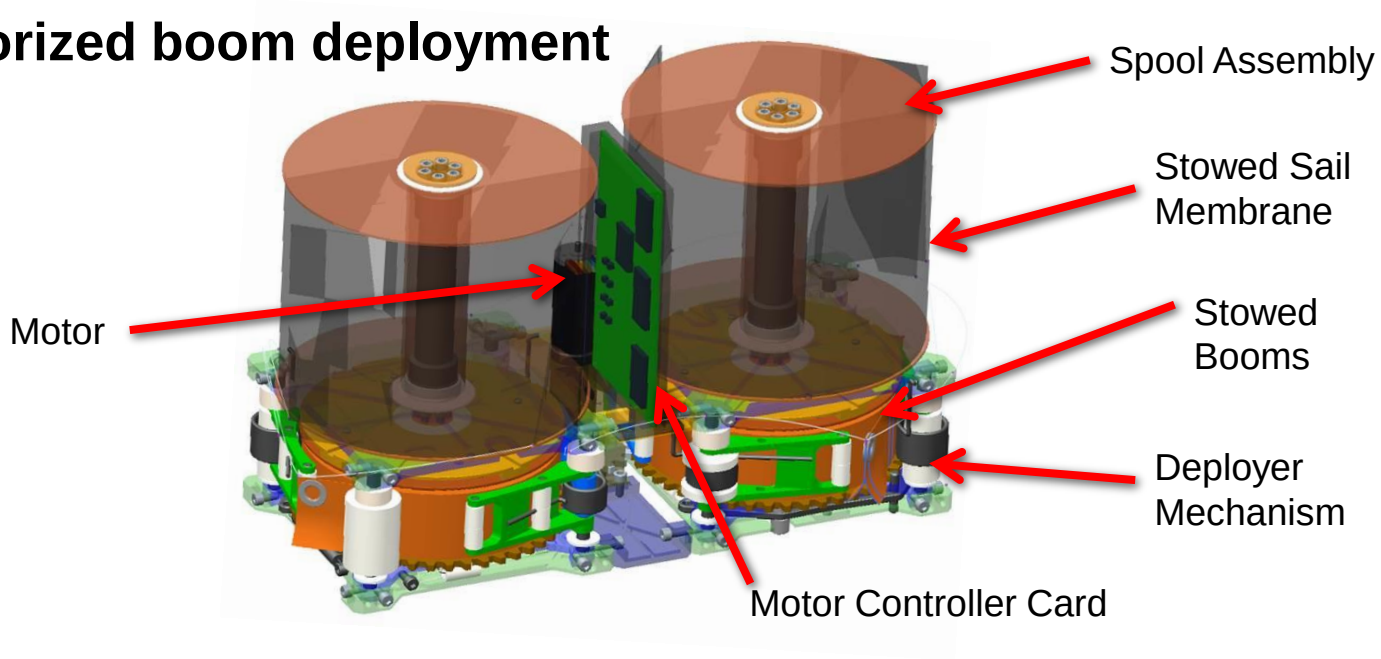
Human

6U Stowed Flight System

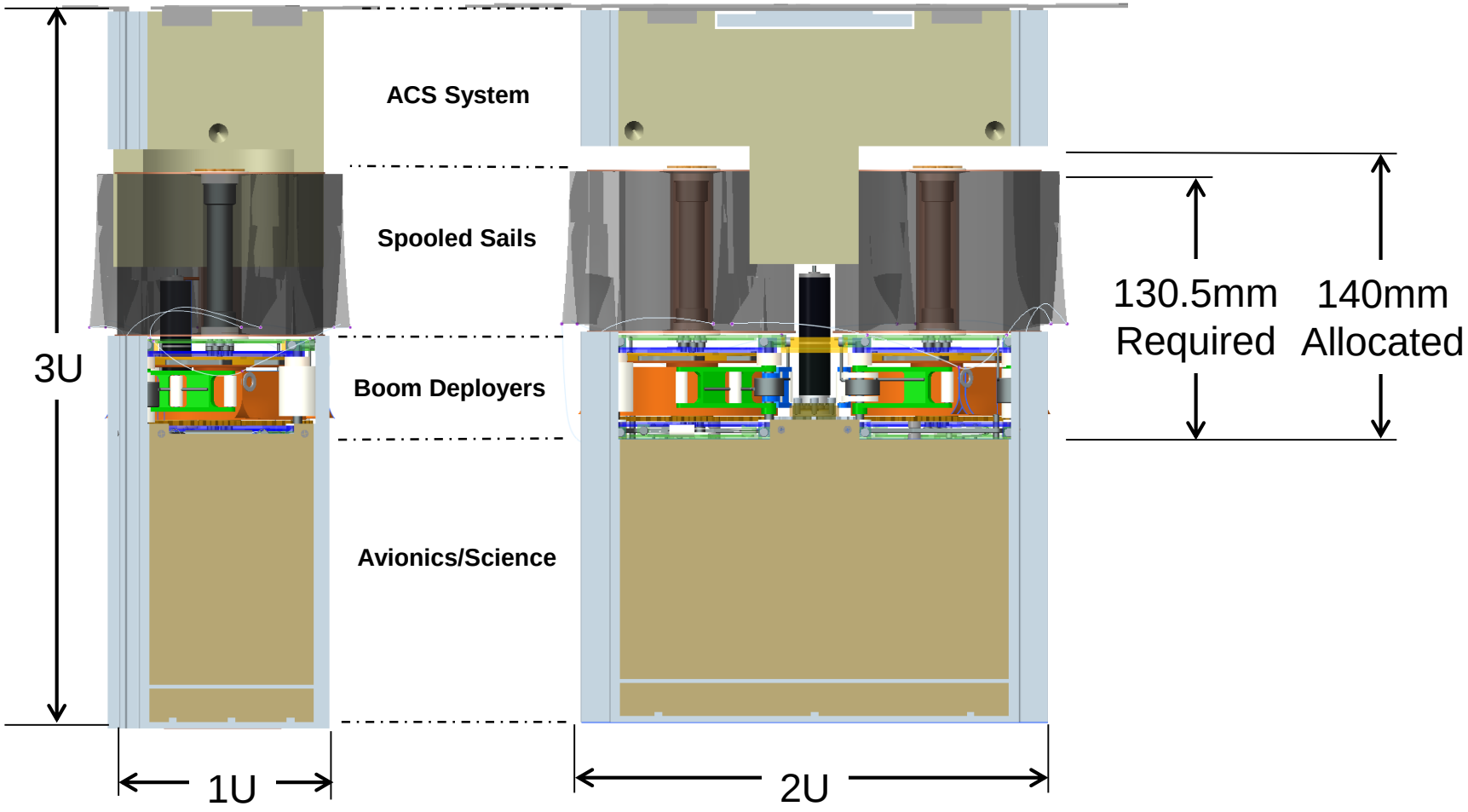
Folded, spooled and packaged in here

Solar Sail Mechanical Description

- 4 quadrant sail – redesign in progress to single piece sail
- 85 m^2 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

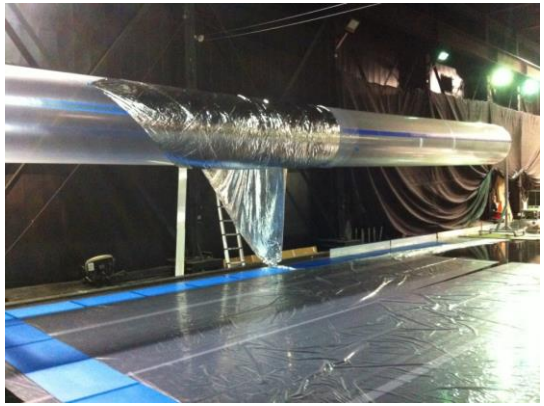


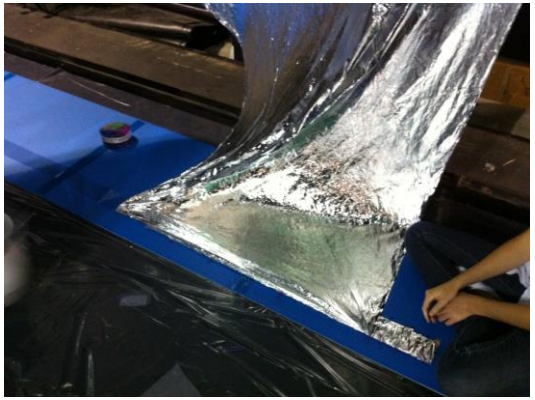
Sail Packing Efficiency

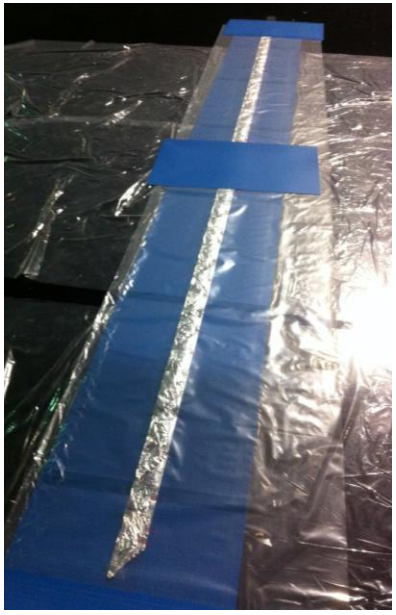
Calculated Value:

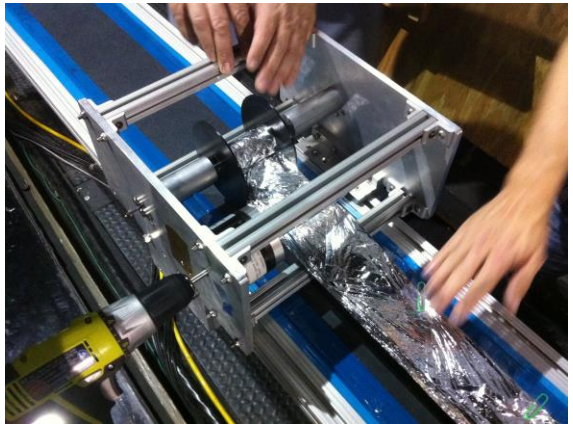
- Fabricated 2 flight size 10m sails from existing 20m CP1 sail.
- Z-folded and spooled 2 sail quadrants onto the hub.
- Calculated new packing efficiency to be **27.5 %**

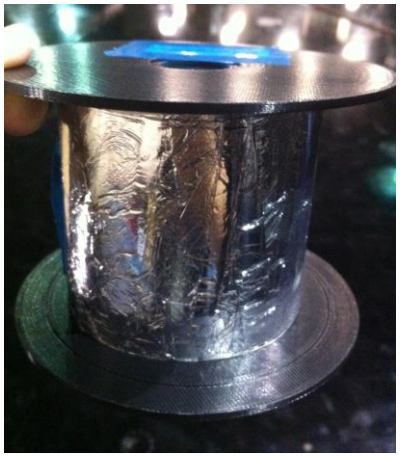
Higher percentage results in tighter packaging and thus more volume margin for design space.





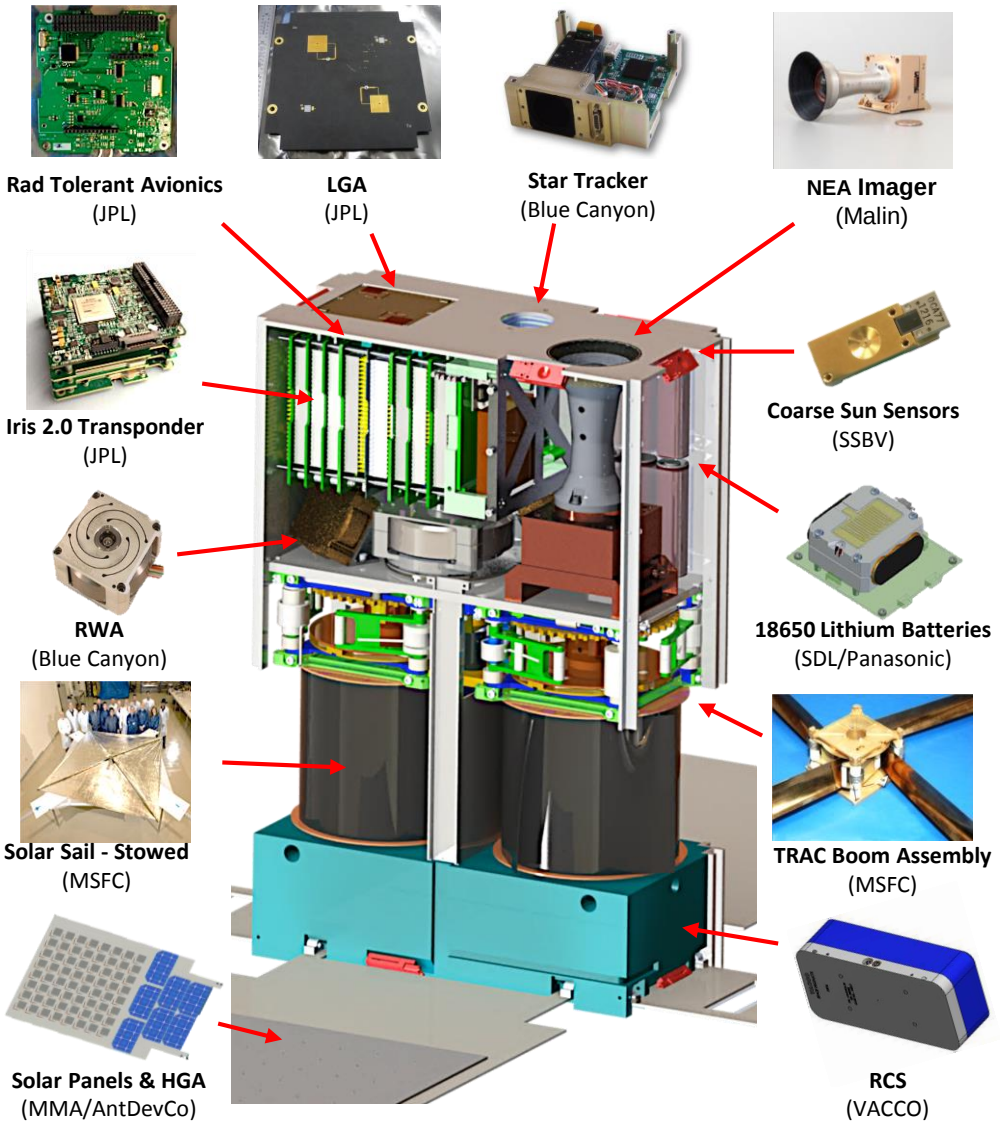






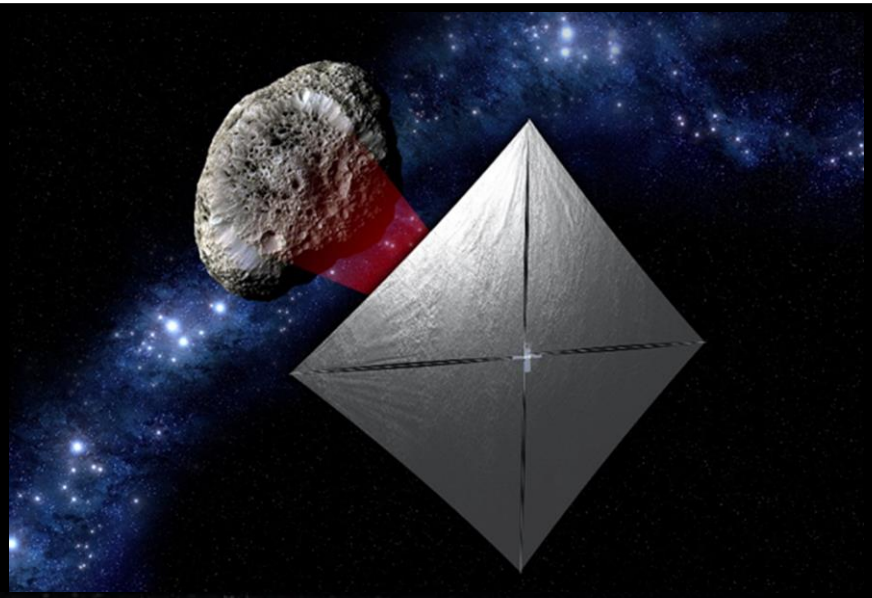
NEA Scout Flight System Overview

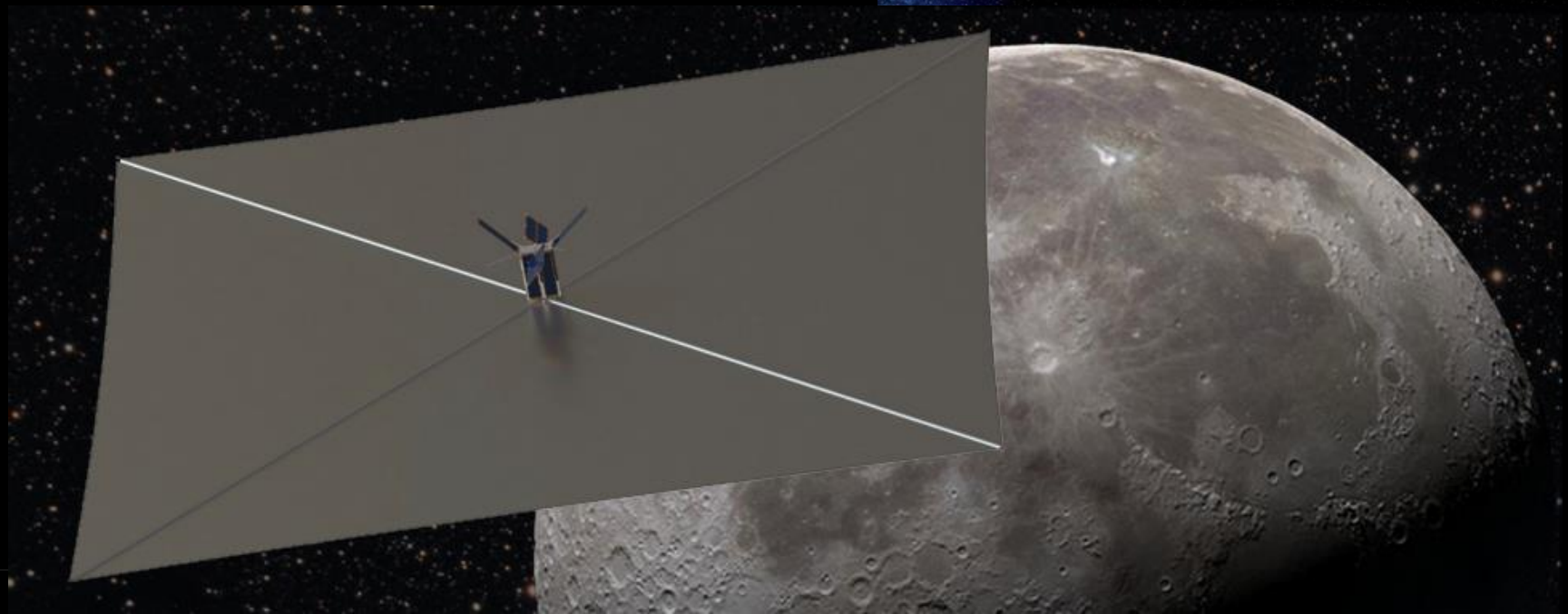
Mission Concept	• Characterize a Near Earth Asteroid with an optical instrument during a close, slow flyby
Payload	• Malin Space Science Systems ECAM-M50 imager w/NFOV optics • Static color filters (400-900 nm)
Mechanical & Structure	• "6U" CubeSat form factor (~10x20x30 cm) • <12 kg total launch mass • 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



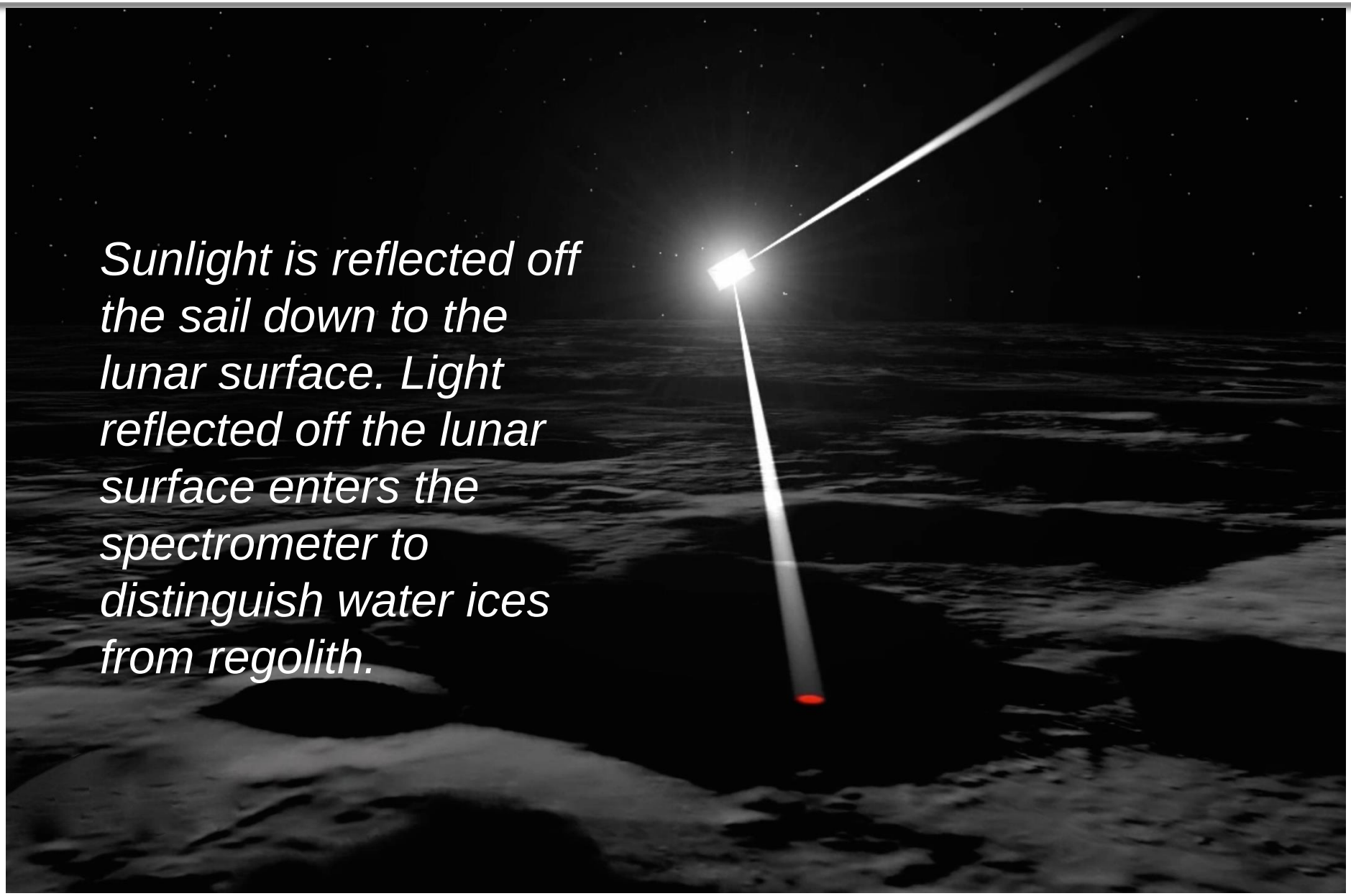
NEA Scout and Lunar Flashlight

Both Use Solar Sail Propulsion and 6U CubeSats





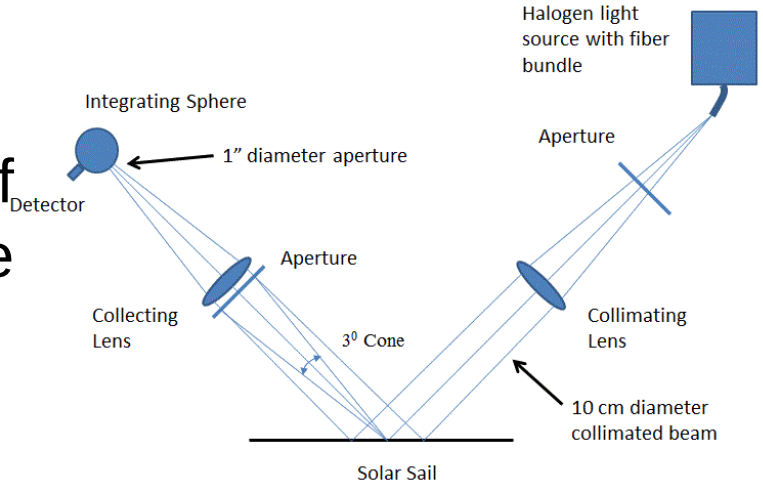
Lunar Flashlight Objective

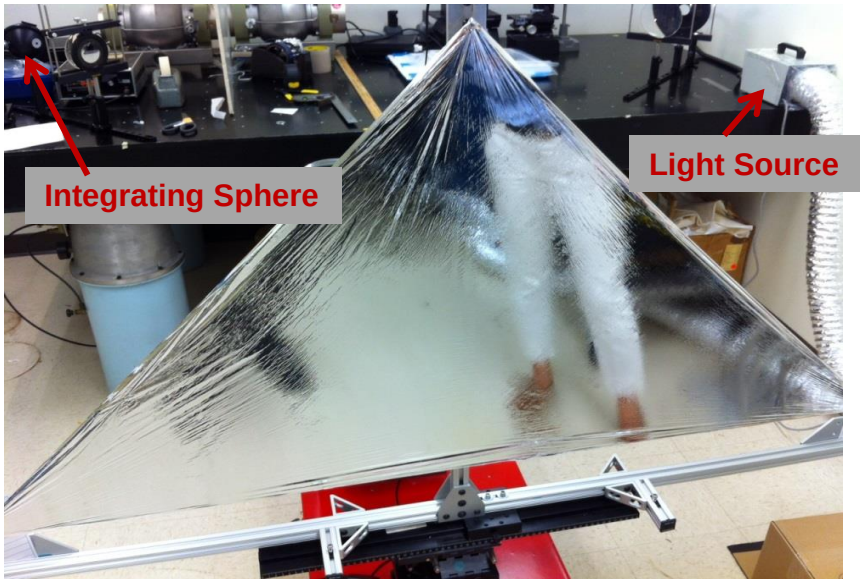


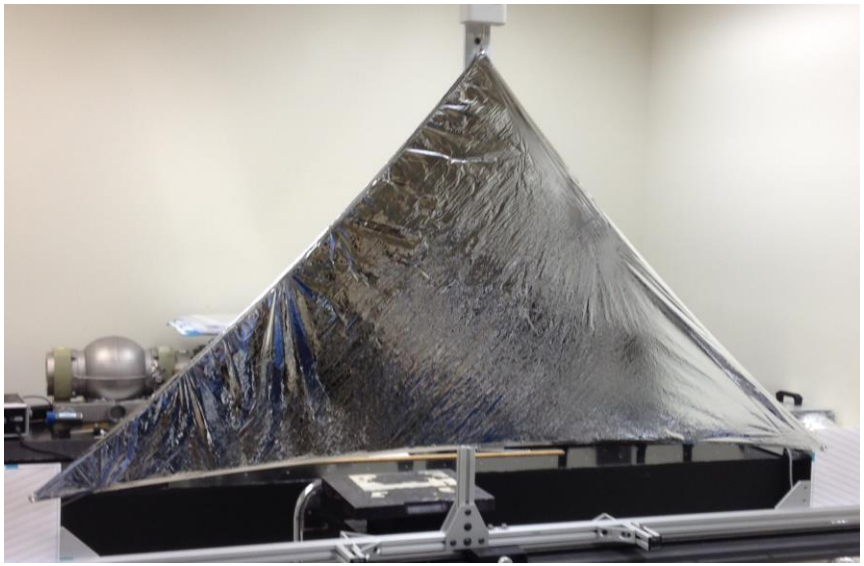
Surface Illumination Test

Lunar Flashlight Requires Surface Illumination:

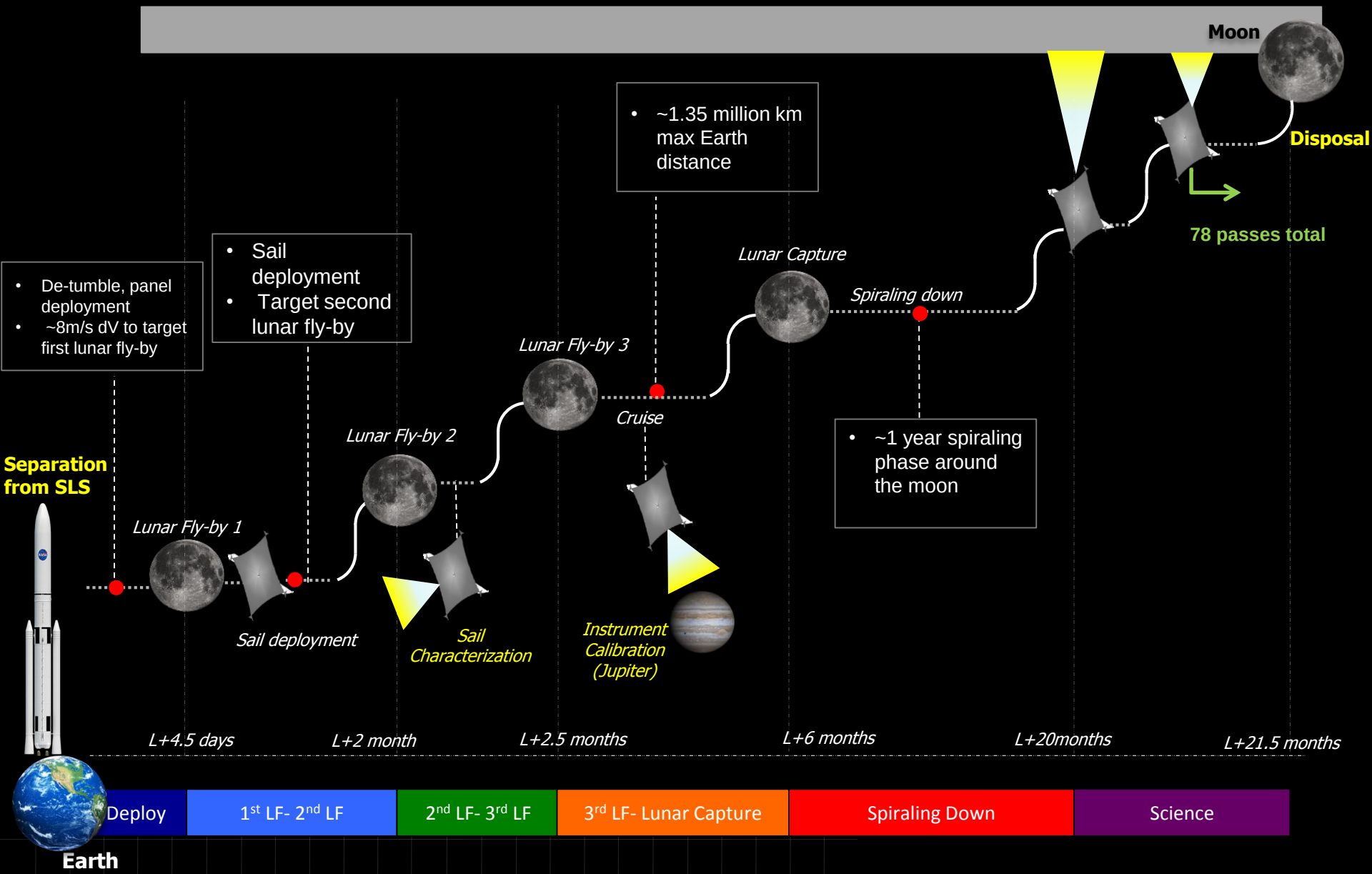
- Determine the capabilities of the solar sail in regard to the amount of light that the sail can reflect into the desired 3 degree cone onto a surface.







ConOps Overview (Lunar Flashlight)



Assembly, Integration, and Test (AI&T): Overview