Science Mission Directorate

2018 Technology Demonstration Industry Day

Technology Demonstration MO

Technology Title: Solar Sail Propulsion System

Affiliation: NASA Marshall Space Flight Center

Assumptions: Technology required to be at TRL 5 by 2021

Technology Description, Current Performance Metrics, and Performance Goals

- Solar Sail Propulsion System developed for the Near Earth Asteroid (NEA) Scout mission including sail, booms, deployer, active control of center-of-mass/center-of-pressure offset for momentum management, thrust models, and flight trajectory algorithms.
- Propellantless interplanetary propulsion to achieve high DV missions without fuel limitations.
  - Sail Area: 86 square meters
  - Characteristic Acceleration: 0.06 mm/sec^2
  - Current design fits within 2.5U (1U = 10cm X 10cm X 10cm

Current TRL

4*

TRL By May 2021

5/6

Industry State of the Art Technology Performance

- JAXA demonstrated spin-stabilized sail, interplanetary sail propulsion using ~200 m^2 in 2010.
- LightSail-A demonstrated Earth orbital sail deployment of 32 m^2 in 2015
- Composite booms scalable to sizes larger than NEA Scout 6.8m booms demonstrated
- 2.5 micron aluminized Colorless polymer-1 solar sail

Technology Development Challenges to Meet TRL Goal

Many Heliophysics destinations will require sails larger than NEA Scout, up to 1000 m^2 in area. To achieve this goal, the following will be required:

1) Flexible and robust support structure
2) Momentum management systems
3) Scaled thrust models
4) Advancements in large flexible membrane dynamic analysis
5) Ground processing improvements reducing handling risks
6) Embedded attitude control and power generation technologies

Potential HPD Science Application (Optional)

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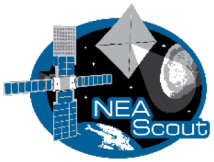
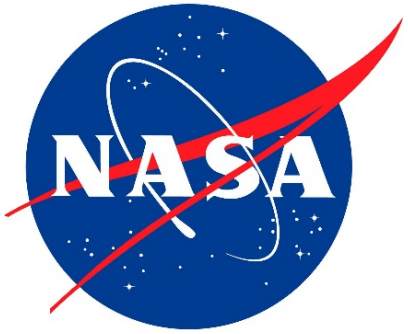
Additional Comments

- *The current TRL for the sails larger than NEA Scout. NEA Scout solar sail is TRL-6.
- STMD partnership between University of Maryland and NASA MSFC explored potential technologies to embed attitude control devices into sail material
- Future technology infusion potential with thin-film photovoltaics



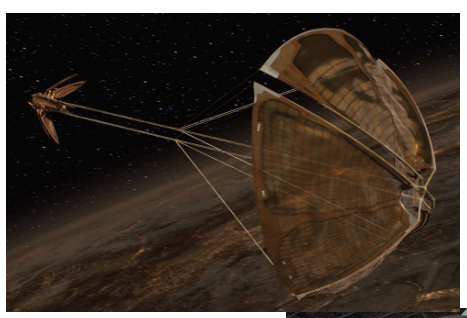
Solar Sail Development Since 2000

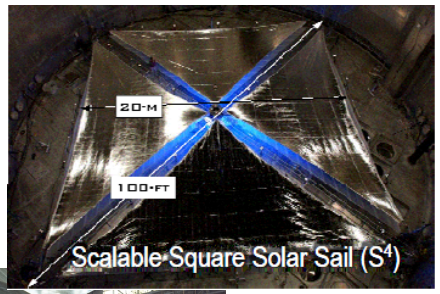
- **NASA**
  - In-Space Propulsion
  - Nanosail-D
  - Sunjammer Technology Demonstration Mission*
  - Near Earth Asteroid Scout
- **The Planetary Society**
  - Lightsail-A
  - Lightsail-II
- **International**
  - IKAROS
  - Gossamer
  - InflateSail
  - DeorbitSail
  - Cubesail
  - JAXA Power Sail

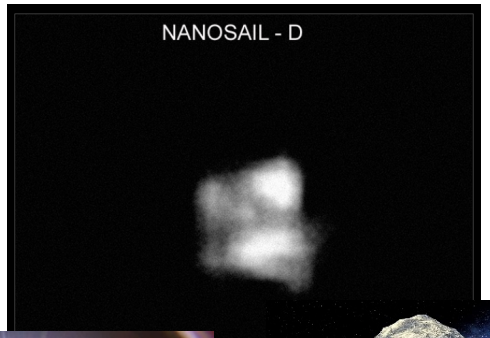


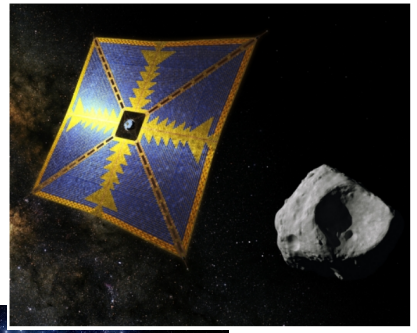
History of Solar Sails

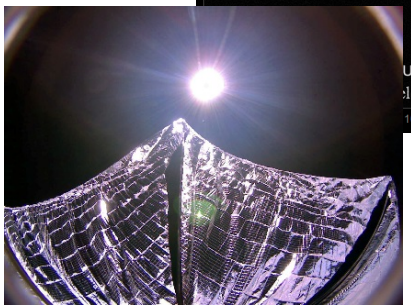
- **Technology is continuing to evolve from large ground demonstrators to flight missions!**

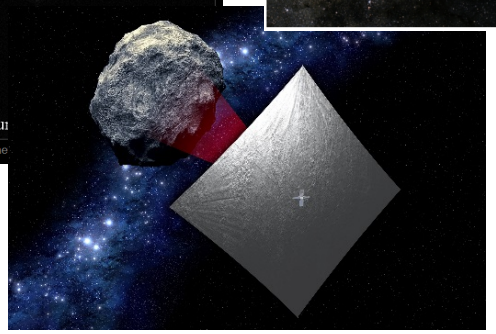








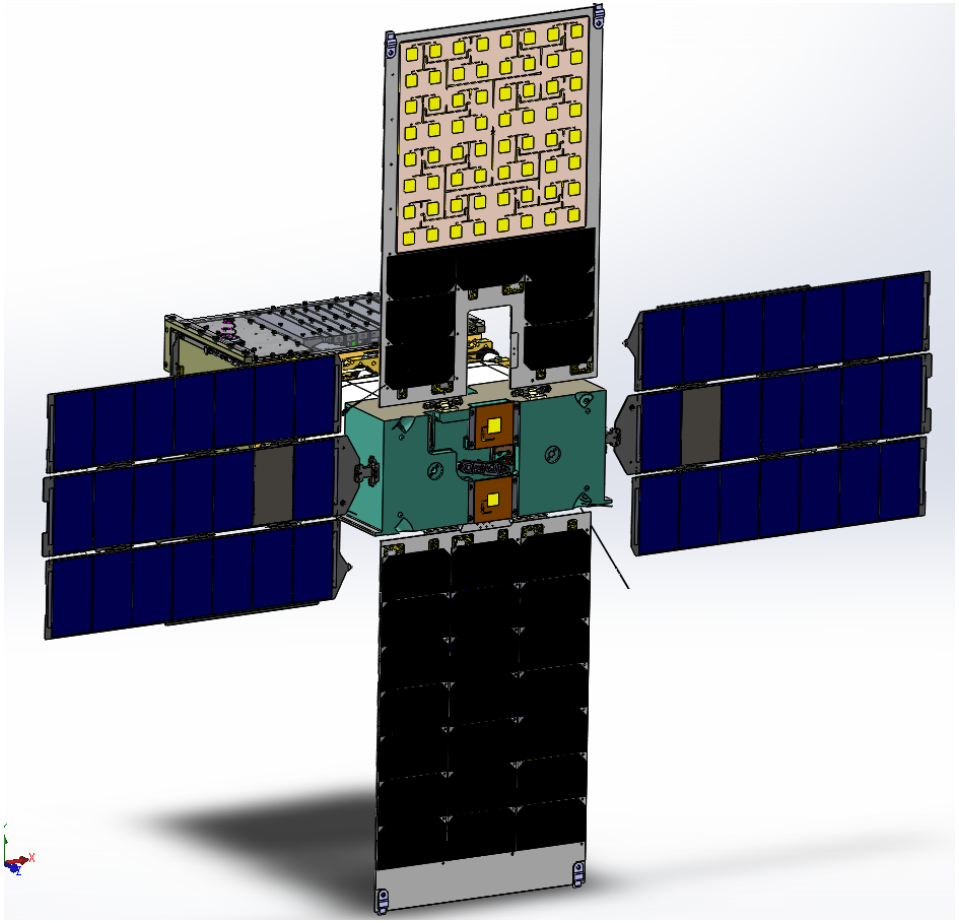


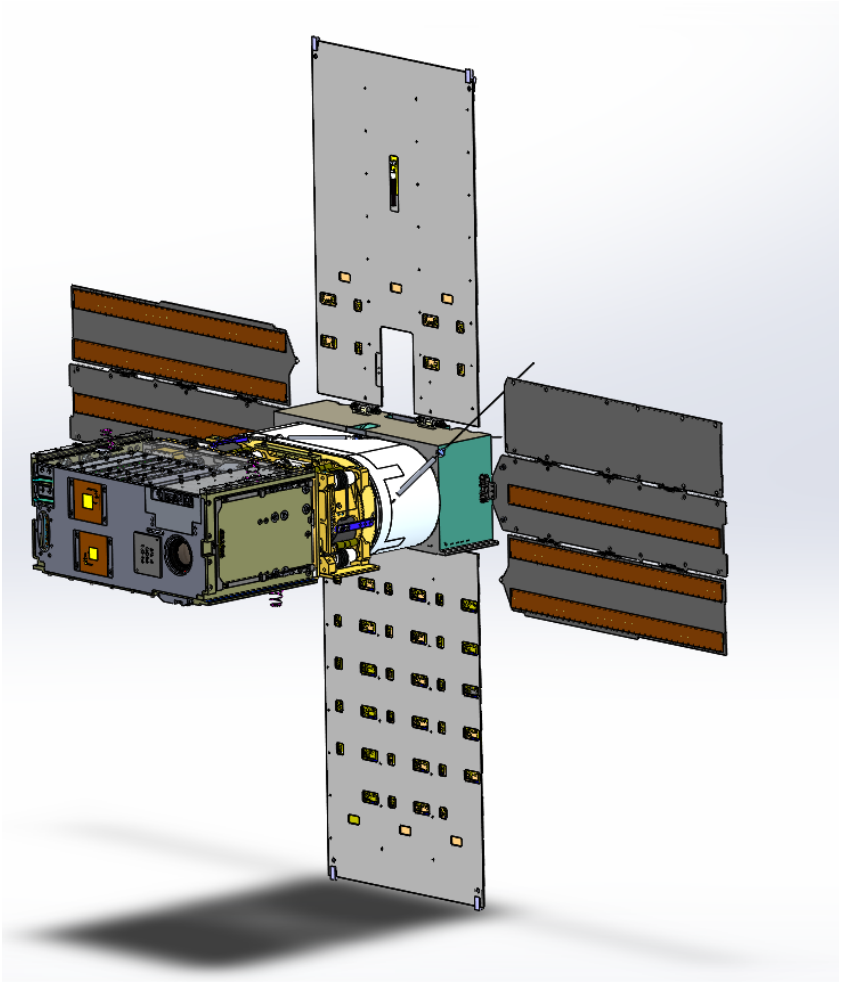


Science Fiction → Ground Demonstrators → Low Earth Orbit Demos → Interplanetary Travel → Interstellar Travel

[1]Source: Colin McInnes, Solar Sailing: Technology, Dynamics, and Mission Applications

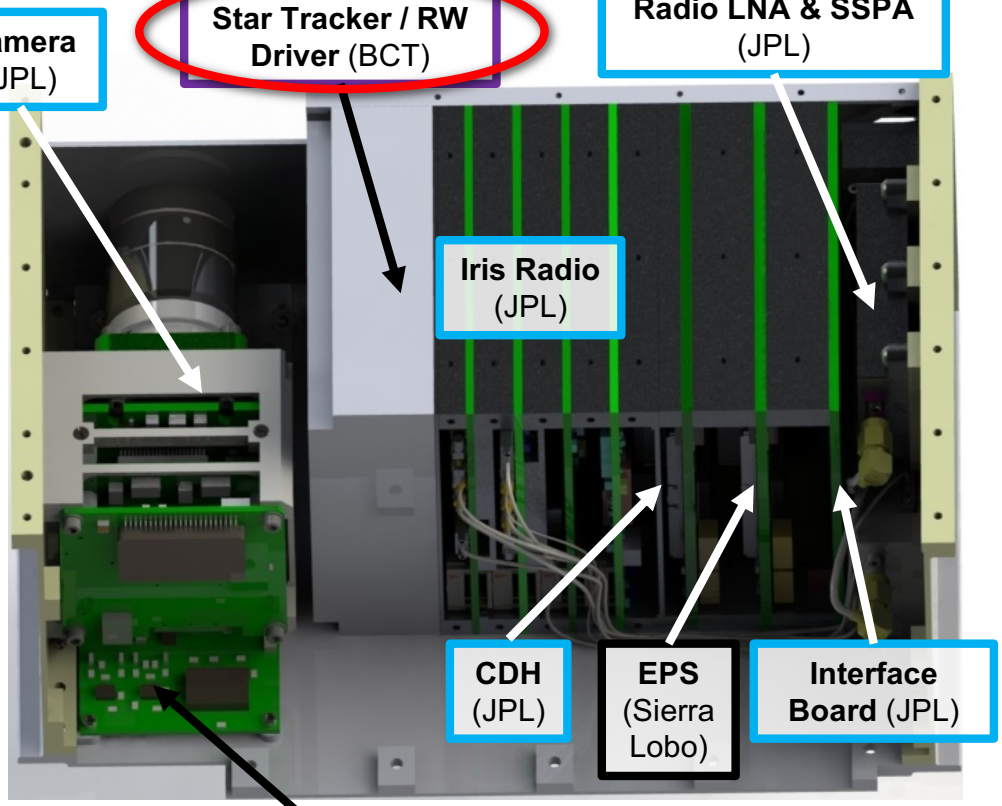
Near Earth Asteroid Scout Spacecraft





Flight System Overview

A fully functional planetary spacecraft in a shoebox



Camera (JPL)

Star Tracker / RW Driver (BCT)

Radio LNA & SSPA (JPL)

Rx & Tx LGA (JPL)

GSE Connector & Sep. Switches (COTS)

Sun Sensors (BCT)

Iris Radio (JPL)

Reaction Wheels (4) (BCT)

Solar Panel Restraints X4 (MMA/TBD)

CDH (JPL)

EPS (Sierra Lobo)

Interface Board (JPL)

AMT (MSFC)

2Ux3U Solar Panel 3 Strings (TBD)

Sail (MSFC)

IMU (Sensonor)

Solar Sail / AMT Controller Board (MSFC)

RCS (VACCO)

HaWK Solar Panel 3 Strings X2 (MMA)

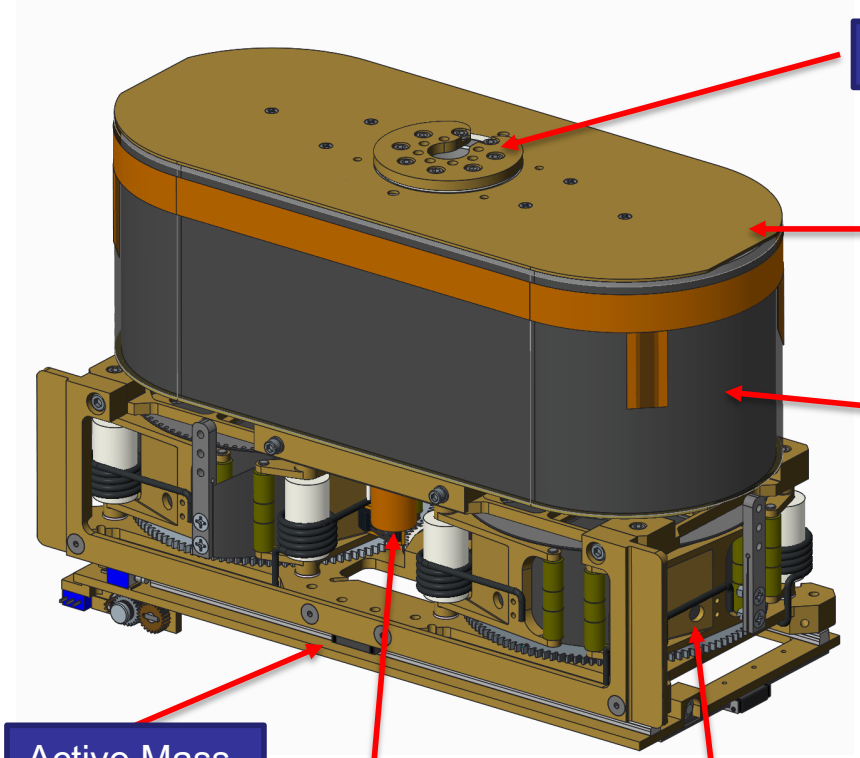
Sail Deployer (MSFC)

(Hidden) Rx & Tx LGA, Sun Sensor (JPL/BCT)

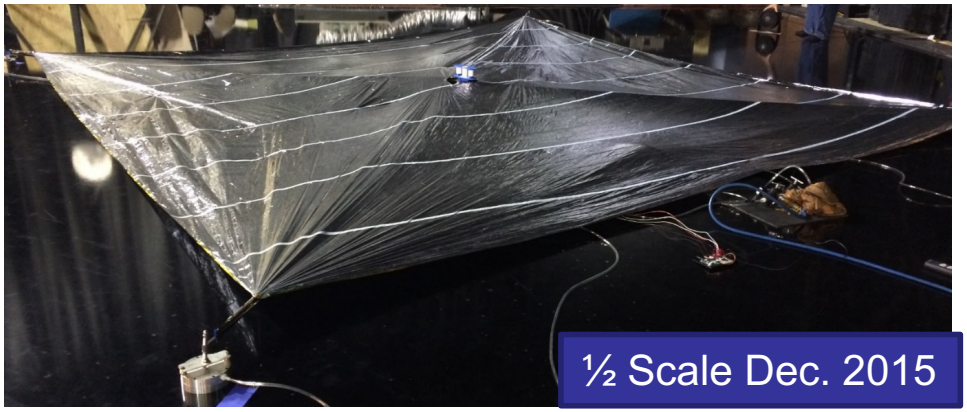
2Ux3U Solar Panel and MGA (BCT)

SBIR

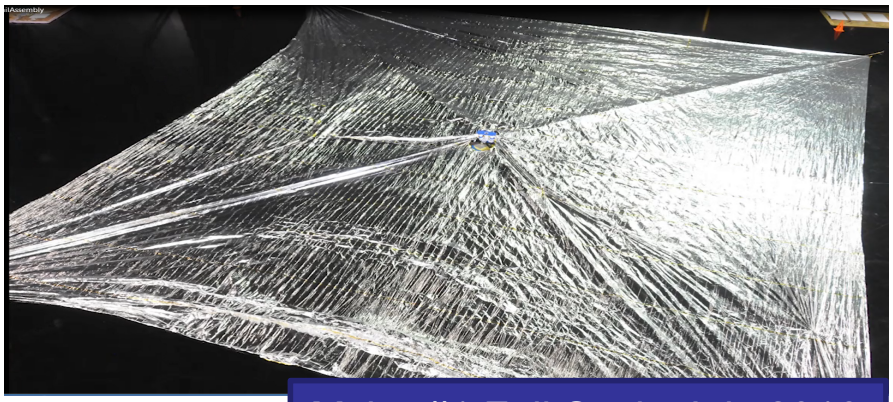
Solar Sail Subsystem



Half Scale Ground Deployments to Full Scale

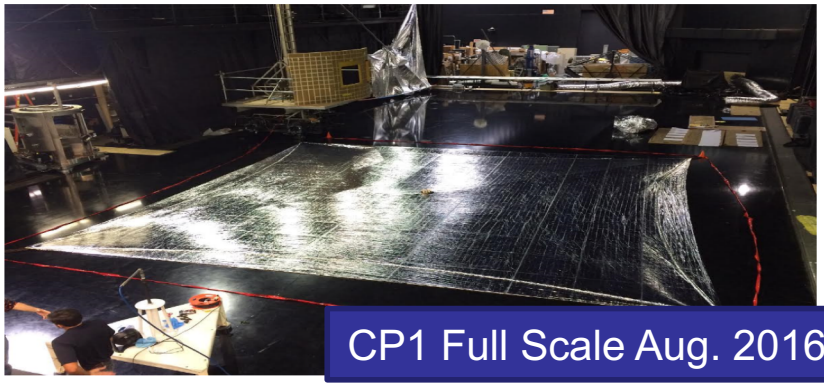


½ Scale Dec. 2015



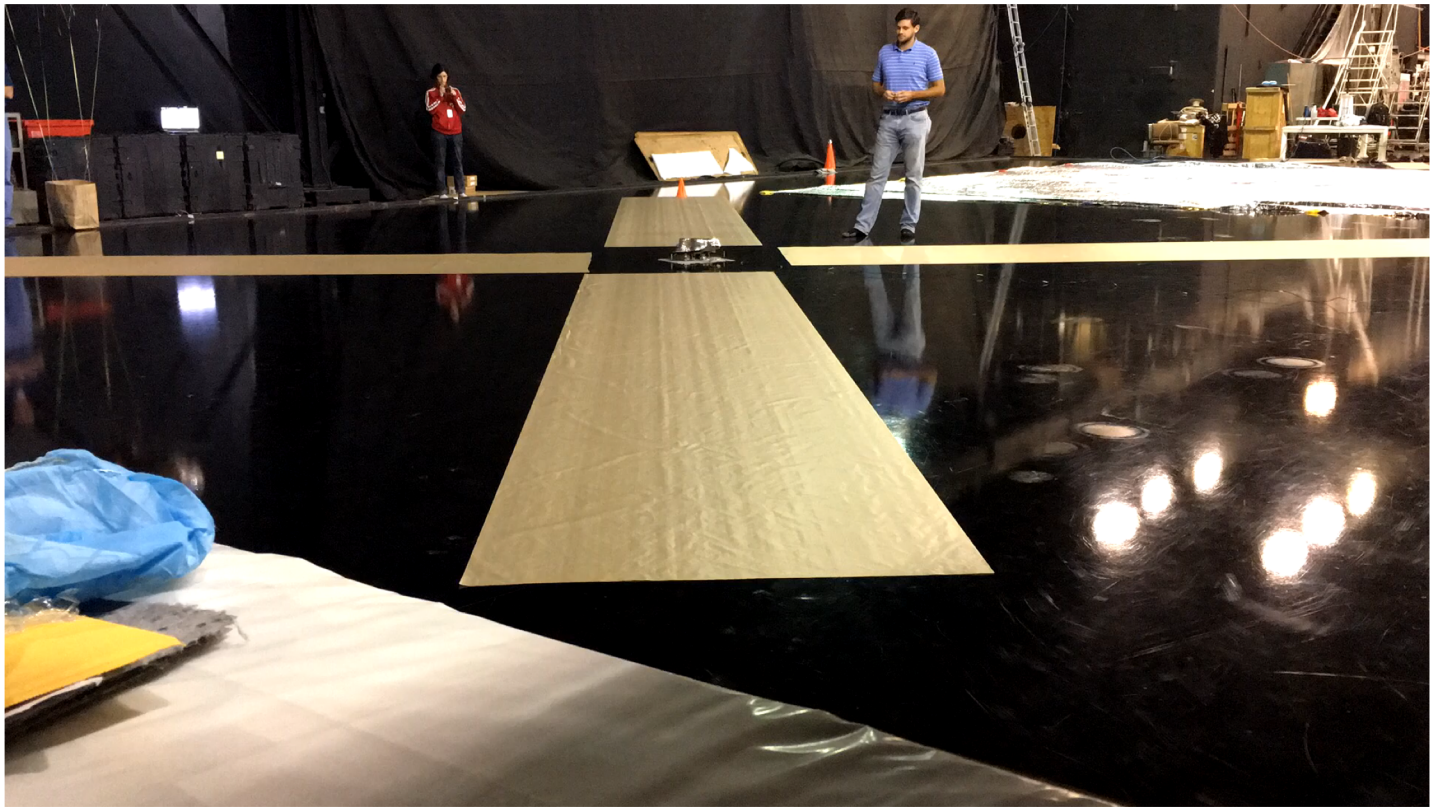
Mylar #1 Full Scale July 2016

½ Scale Jan. 2016

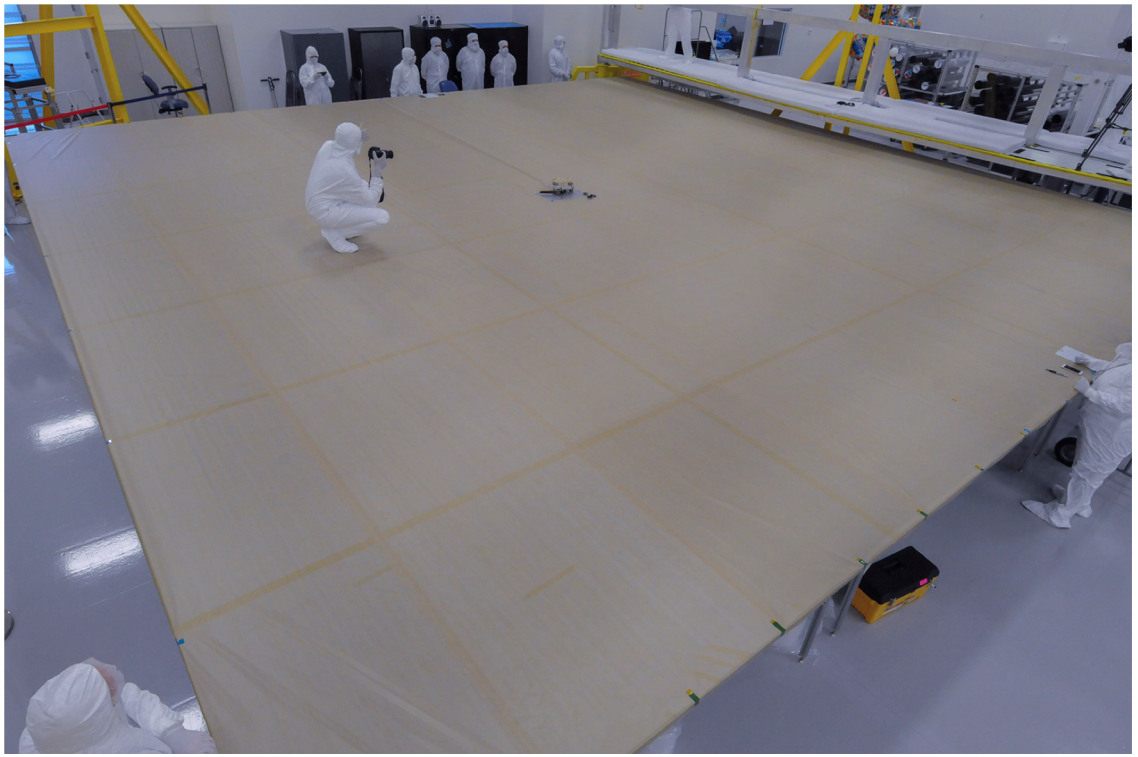


CP1 Full Scale Aug. 2016

EDU Deployment Test at Flight Robotics Laboratory



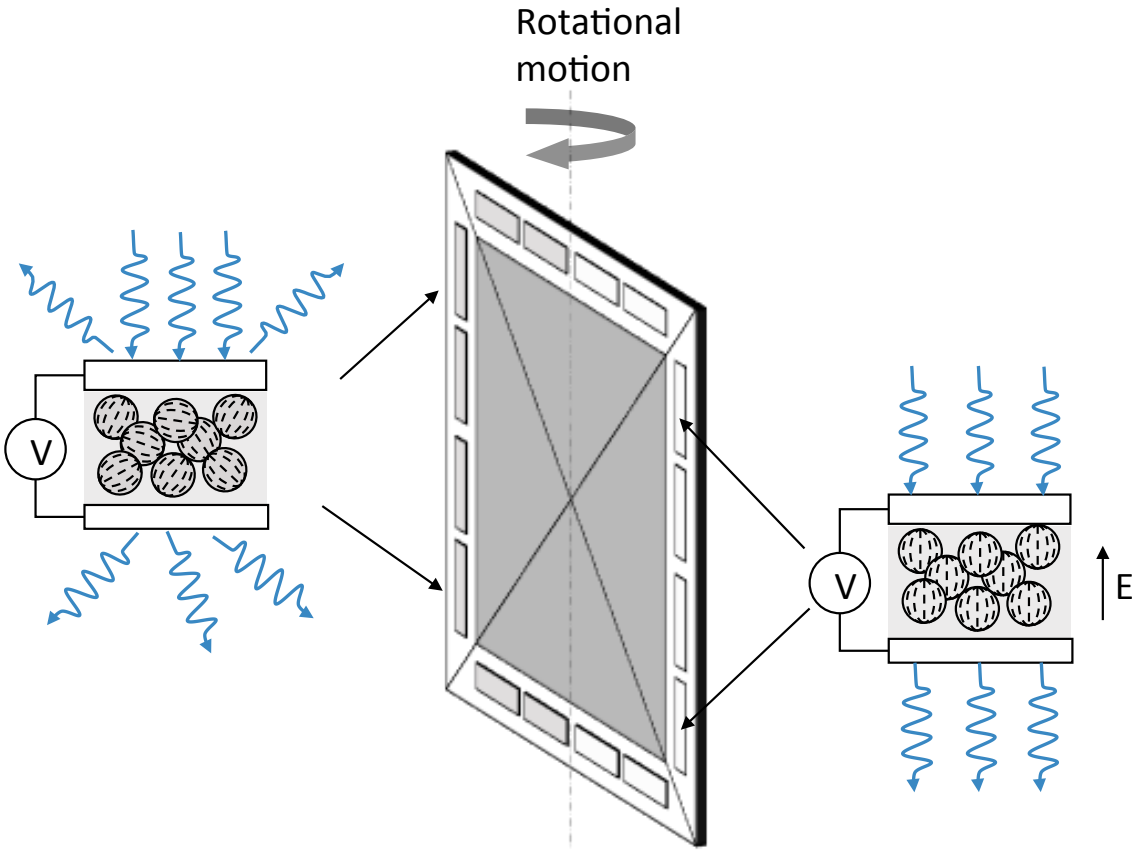
EDU Deployment Test at NeXolve Facility

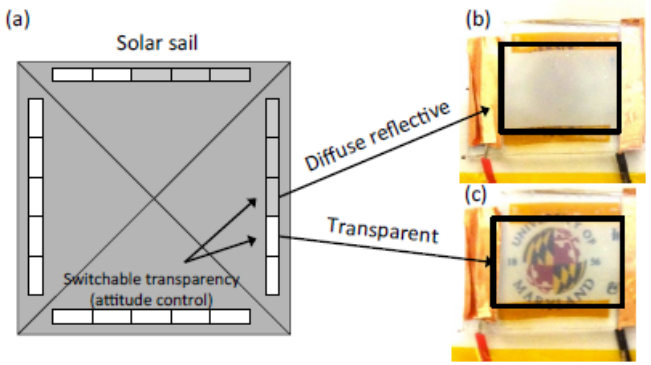


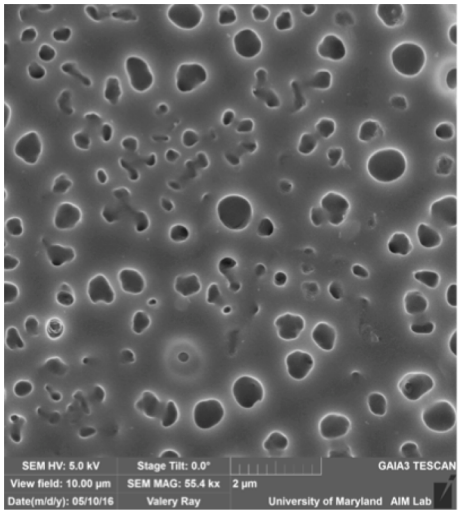
EDU Testing included ascent vent, random vibration, thermal vacuum, and full scale deployments

STMD Collaborative Partnership FY16-17

- **Smallsat Technology Partnership: NASA-University Collaborations**
  - MSFC/UMD Partnership: Propellantless Attitude Control of Solar Sails Utilizing Reflective Control Devices
  - Taking a terrestrial application and researching potential usage in space





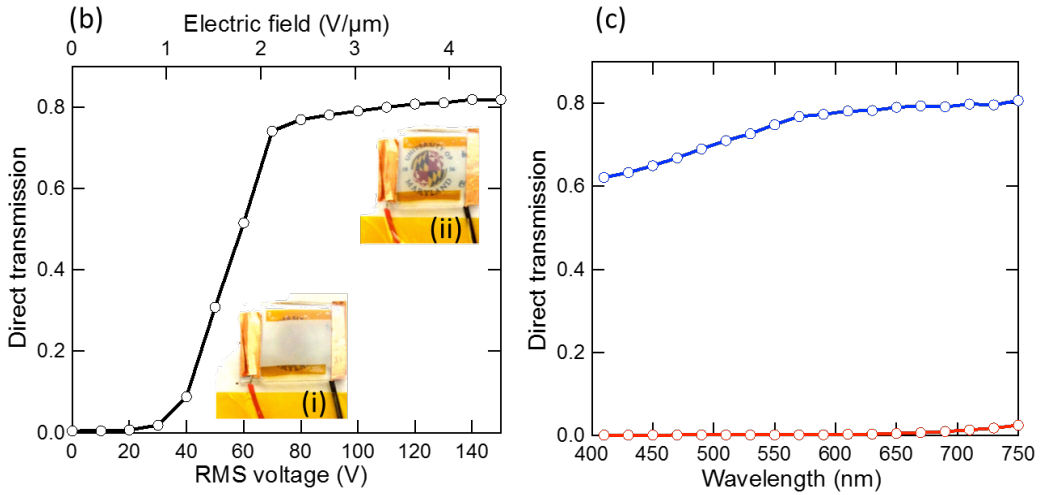


https://www.nasa.gov/directorates/spacetech/small_spacecraft/index.html

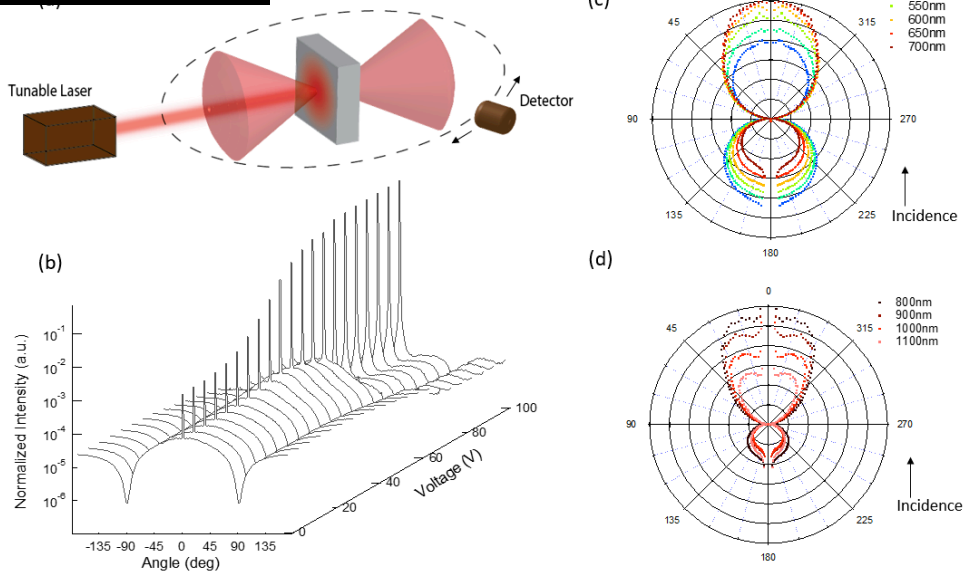
http://www.nasa.gov/content/smallsat-technology-partnership-selections-nasa-university-collaborations

Reflective Control Device Characterization Research

Switching behavior



Angular dependence



	μm	V
A	35	80
B	22	50
C	15	35
D	8	20
E	5	13

Questions?