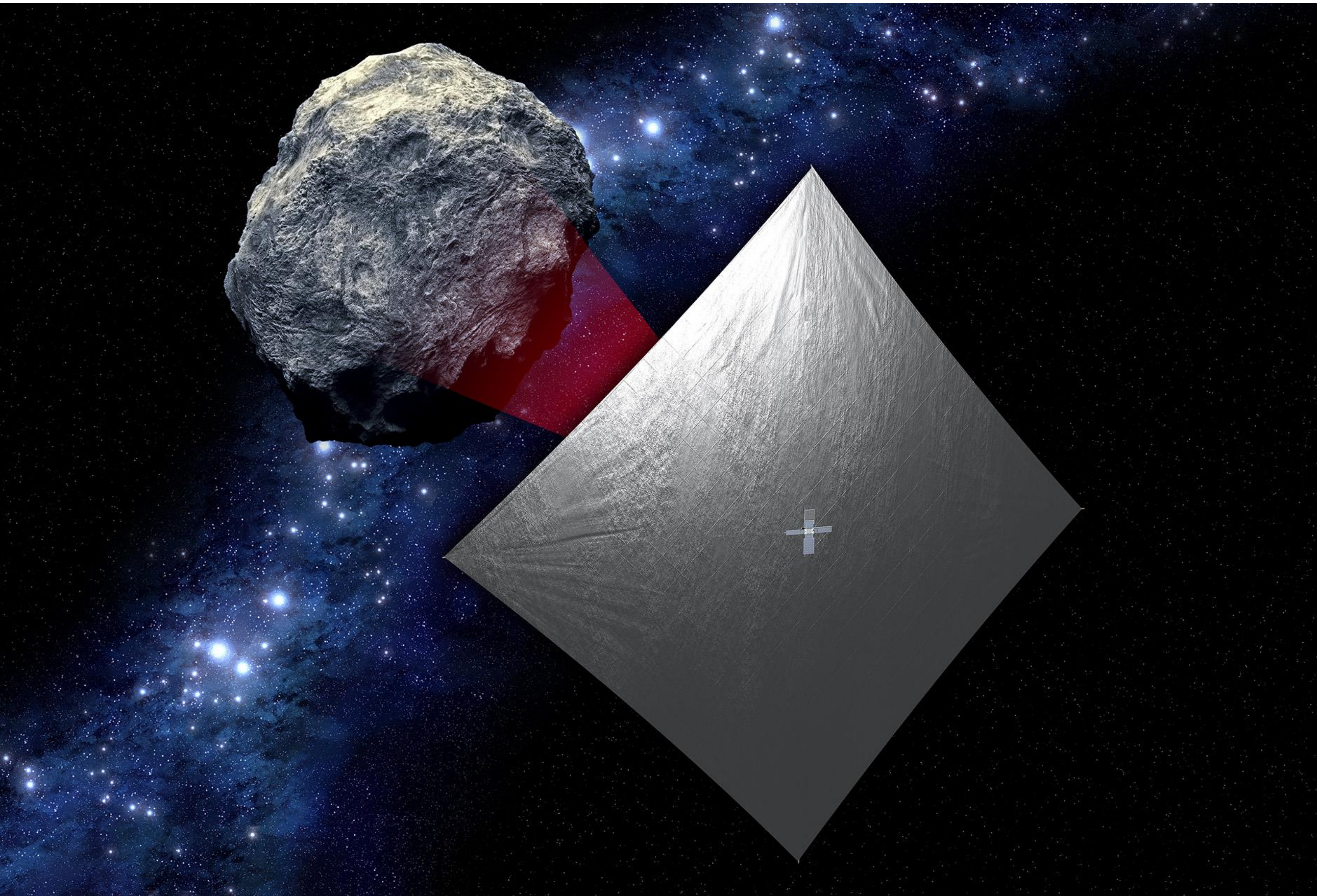
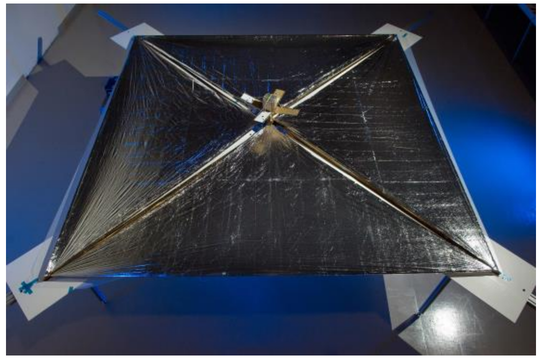
Near Earth Asteroid Scout – NASA's First Interplanetary Solar Sail Mission



Dr. Don Krupp

NASA George C. Marshall Space Flight Center

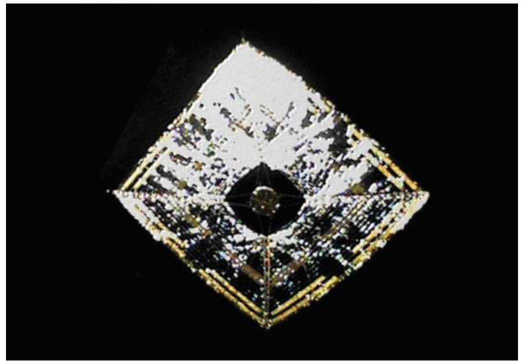
Solar Sail Missions Flown and Planned



NanoSail-D (2010)
NASA/MSFC/ARC

Earth Orbit
Deployment Only

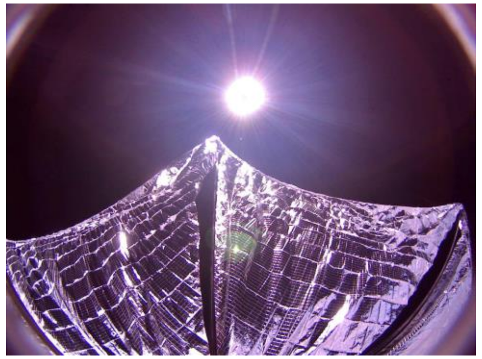
3U CubeSat
10 m^2



IKAROS (2010)
JAXA

Interplanetary
Full Flight

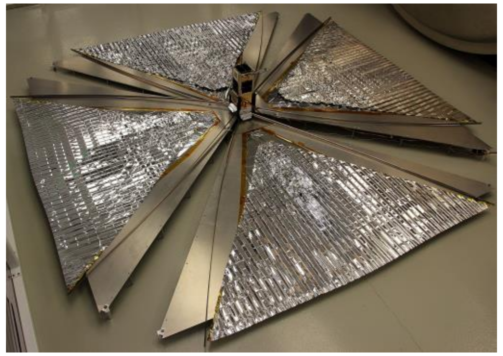
315 kg Smallsat
196 m^2



LightSail-1 (2015)
The Planetary Society

Earth Orbit
Deployment Only

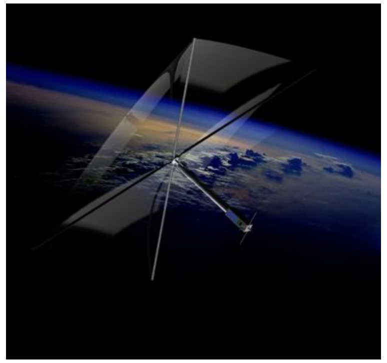
3U CubeSat
32 m^2



CanX-7 (2016)
Canada

Earth Orbit
Deployment Only

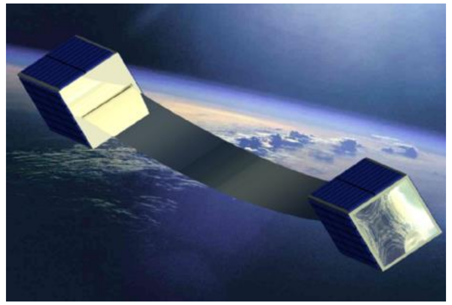
3U CubeSat
<10 m^2



InflateSail (2017)
EU/Univ. of Surrey

Earth Orbit
Deployment Only

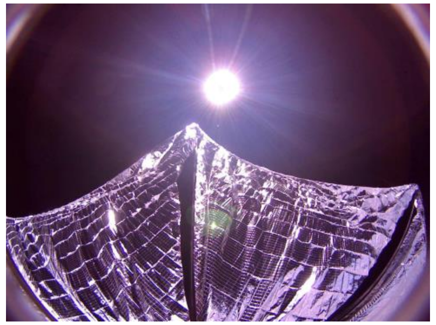
3U CubeSat
10 m^2



CU Aerospace (2018)
Univ. Illinois / NASA

Earth Orbit
Full Flight

3U CubeSat
20 m^2

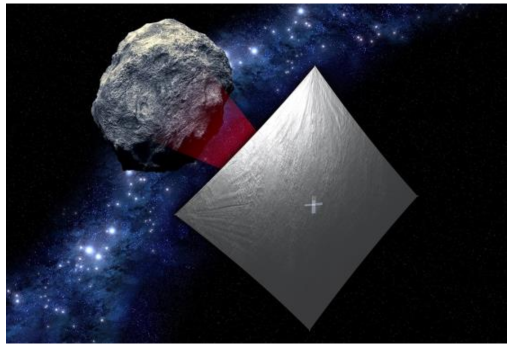


LightSail-2 (2018)
The Planetary Society

Earth Orbit
Full Flight

3U CubeSat
32 m^2

Near Earth Asteroid Scout (2019)
NASA



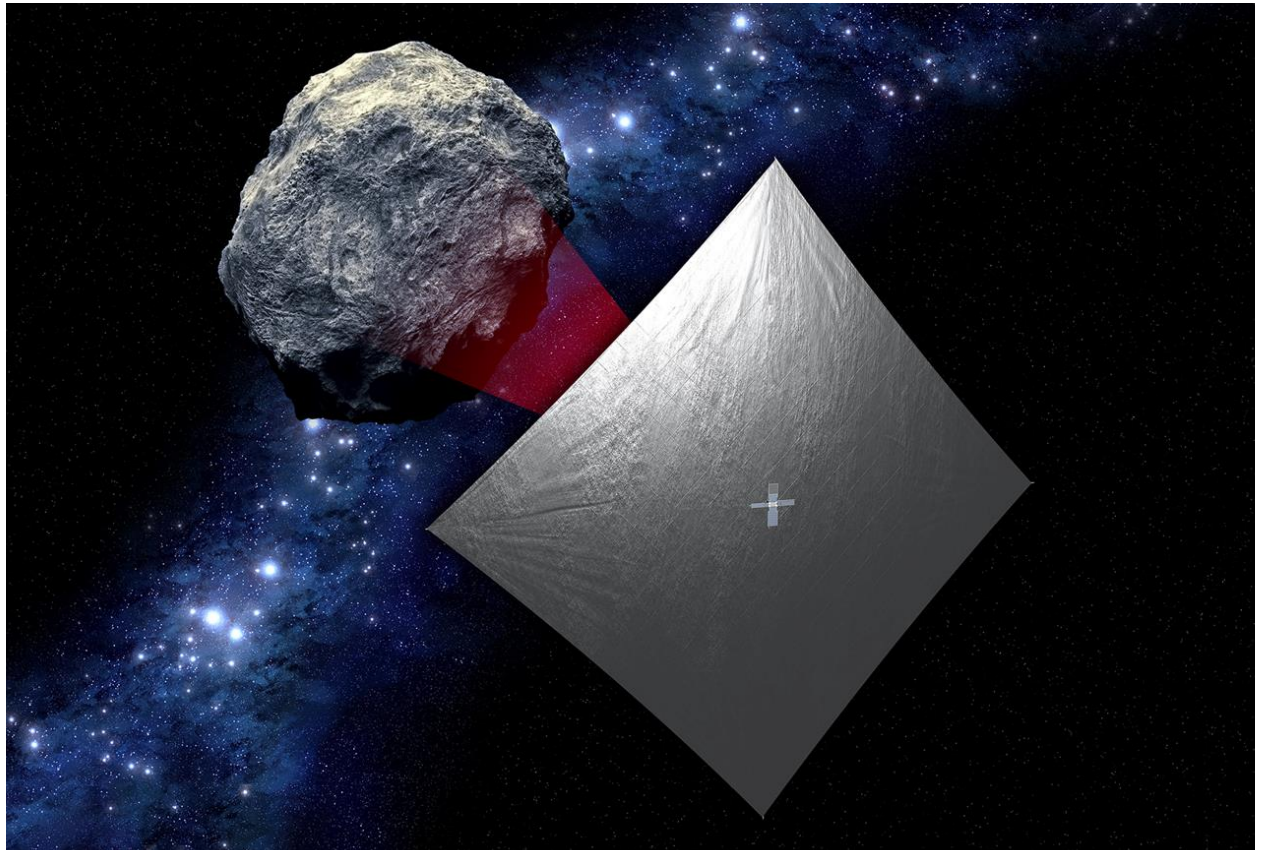
Interplanetary
Full Flight

6U CubeSat
86 m^2

Near Earth Asteroid (NEA) Scout

The Near Earth Asteroid Scout Will

- Image/characterize a NEA during a slow flyby
- Demonstrate a low cost asteroid reconnaissance capability

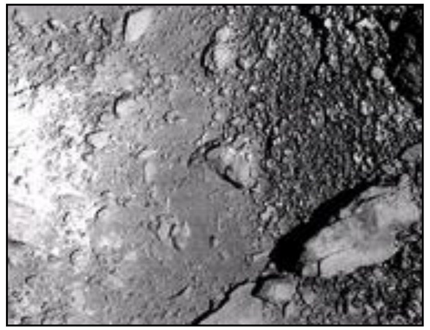


Key Spacecraft & Mission Parameters

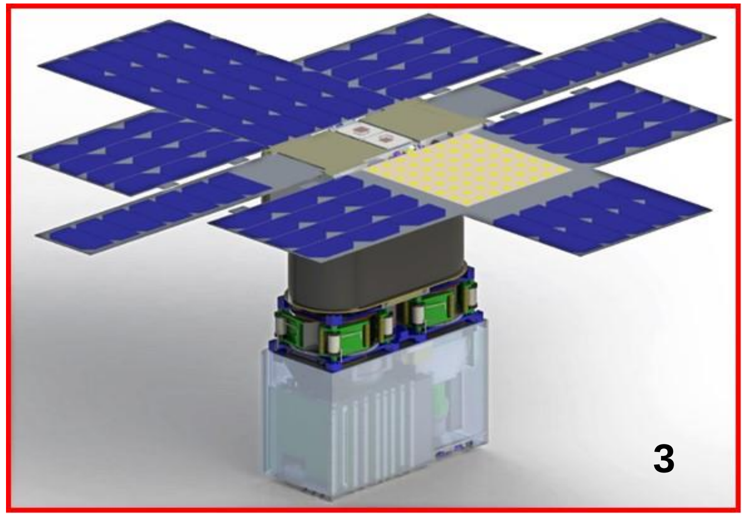
- 6U cubesat (20cm X 10cm X 30 cm)
- ~86 m^2 solar sail propulsion system
- Manifested for launch on the first Space Launch System mission (EM-1)
- 1 AU maximum distance from Earth

Leverages: combined experiences of MSFC and JPL with support from GSFC, JSC, & LaRC

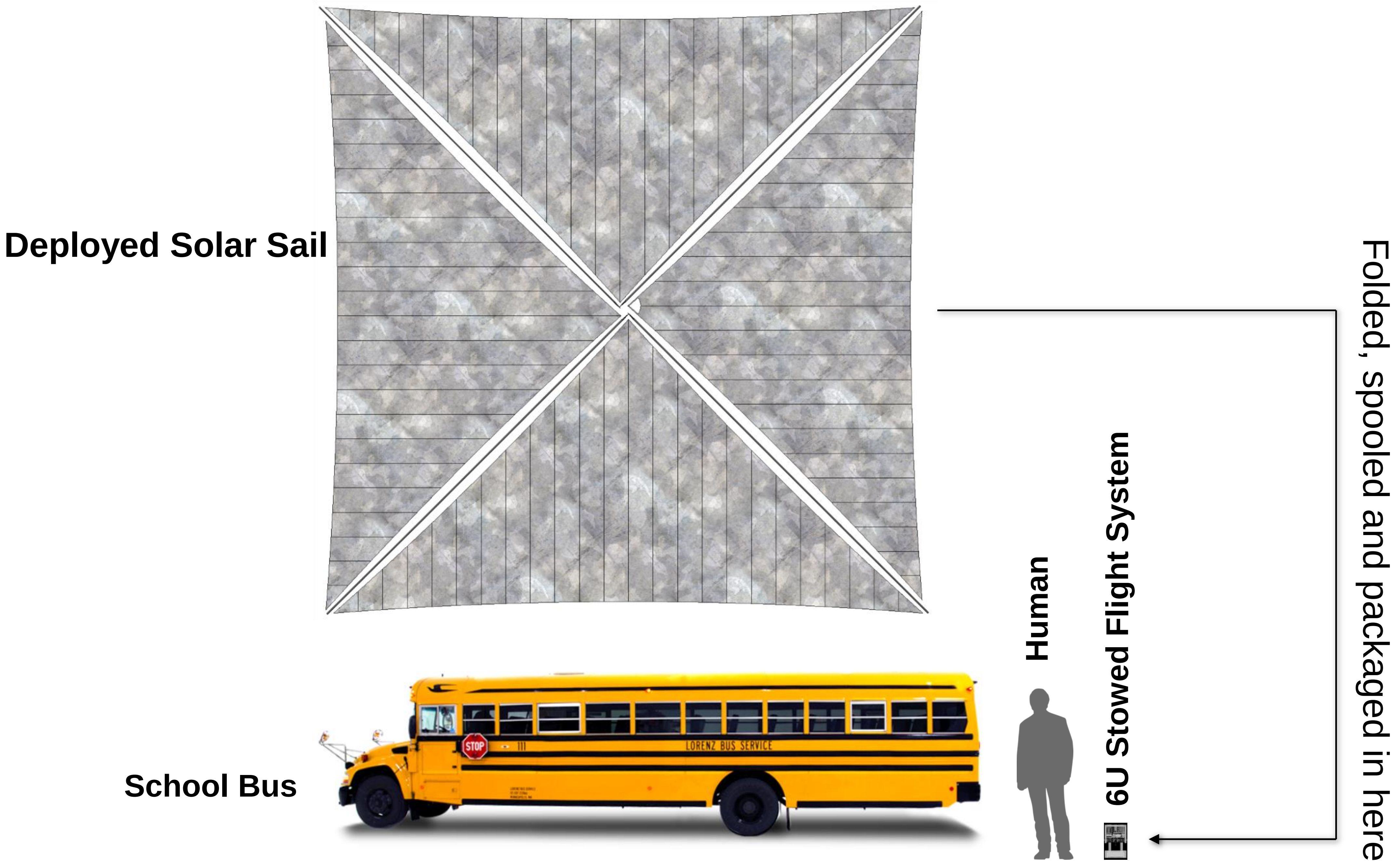
Target Reconnaissance with medium field imaging
Shape, spin, and local environment



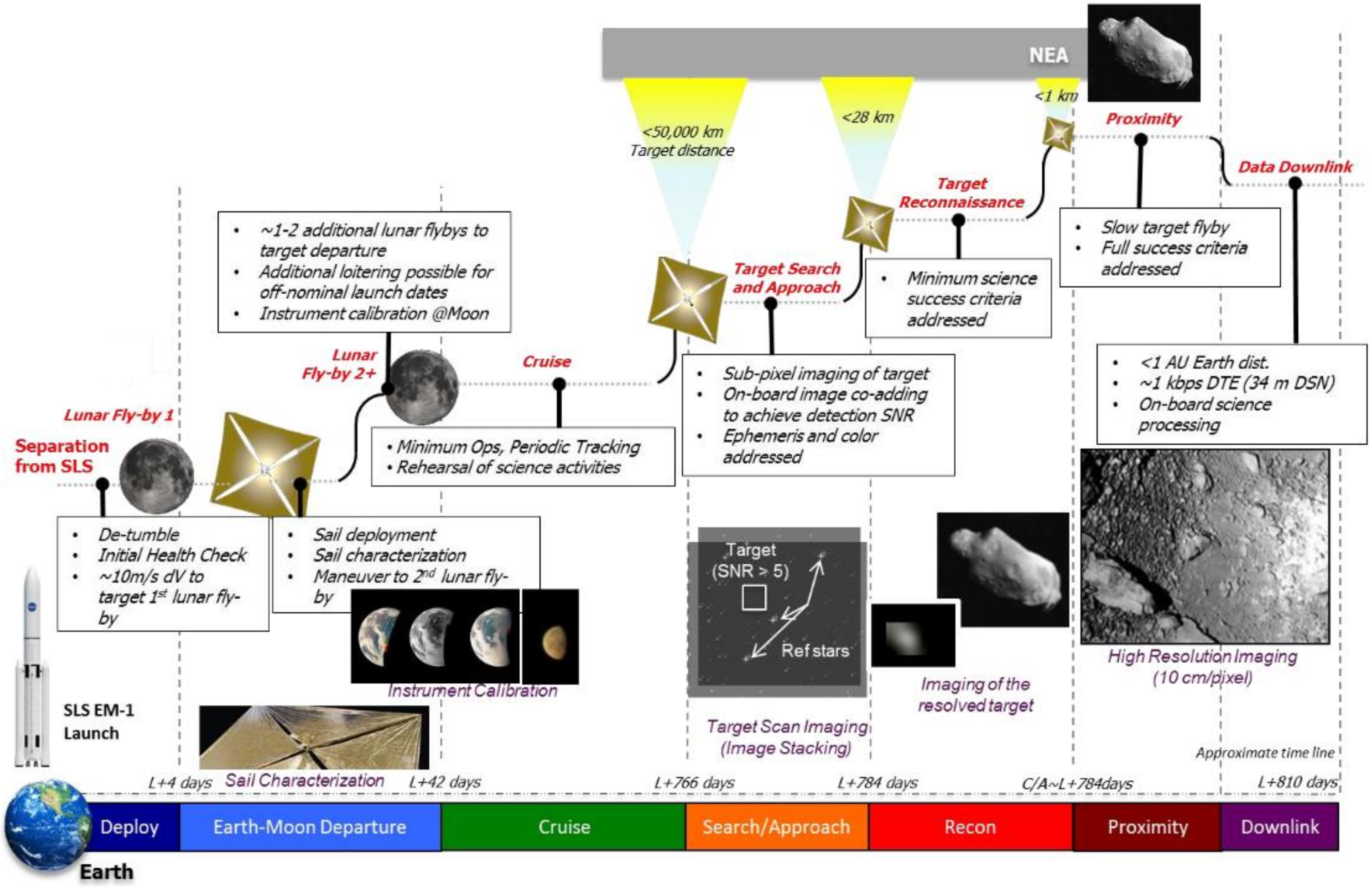
Close Proximity Imaging
Local scale morphology, terrain properties, landing site survey



NEA Scout Approximate Scale



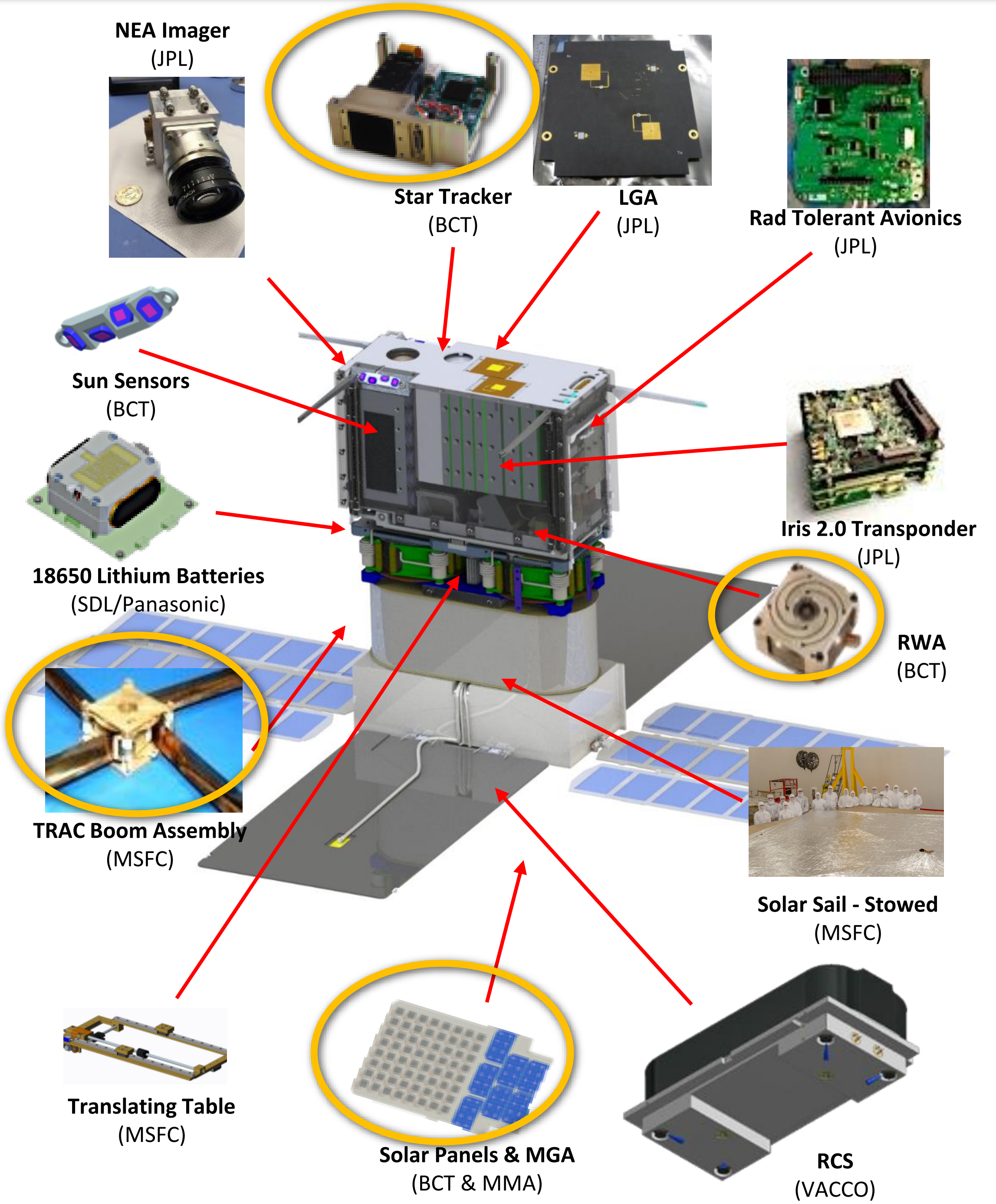
Concept of Operations Overview



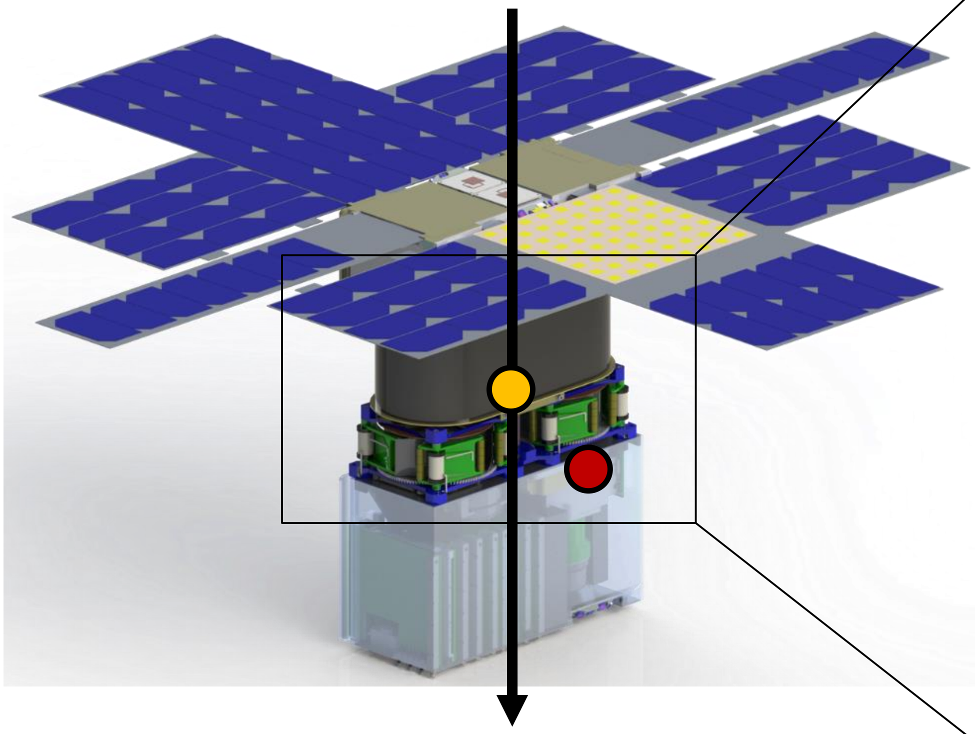
Flight System Overview

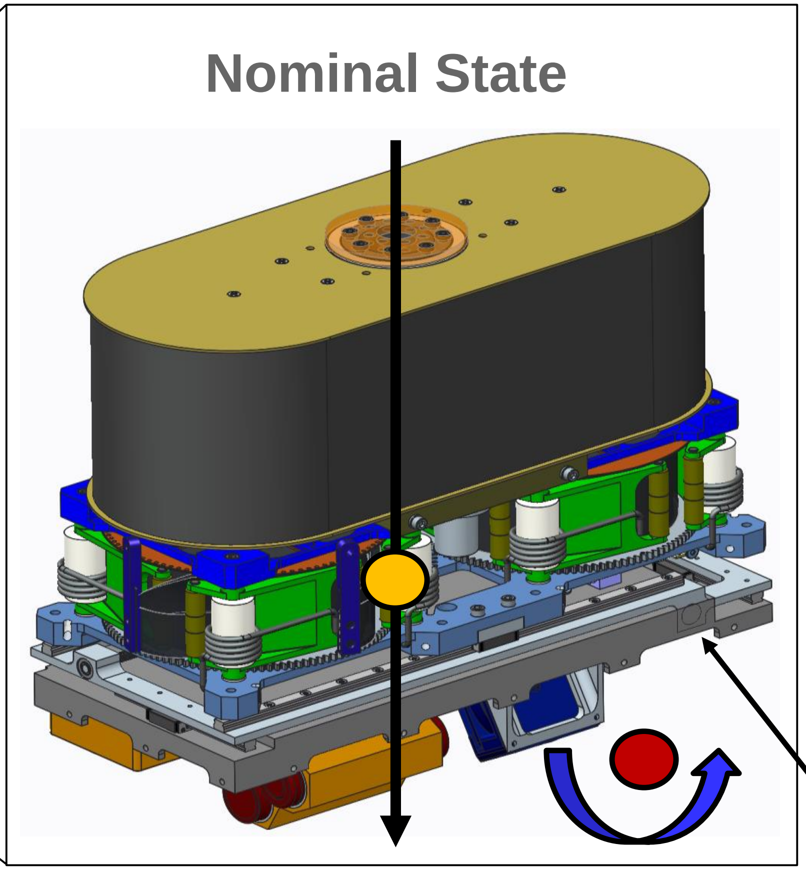
Payload	• Context Camera
Mechanical & Structure	• “6U” CubeSat form factor • <14 kg total launch mass • Modular flight system concept
Propulsion	• ~86 m^2 aluminized CP-1 solar sail (based on NanoSail-D2)
Avionics	• Radiation tolerant architecture
Electrical Power System	• Trifold deployable solar arrays with GaAs cells (~51.2 W EOL at 1 AU solar distance) • 6.2 Ah Battery • 10 -12.3 V unregulated, 5 V/3.5 V regulated
Telecom	• JPL Iris 2.0 X-Band Transponder; 4 W RF output power supports doppler, ranging, and D-DOR • 2 pairs of INSPIRE-heritage LGAs (RX/TX) • 8x8 element microstrip array MGA (TX); ~1 kbps to 34m DSN at 0.8 AU
Attitude Control System	• 15 mNm-s (x3) & 100 mNm-s RWAs • Active mass translation system • VACCO R-236fa (refrigerant gas) ‘warm gas’ RCS system • Nano StarTracker, Coarse Sun Sensors & MEMS IMU for attitude determination

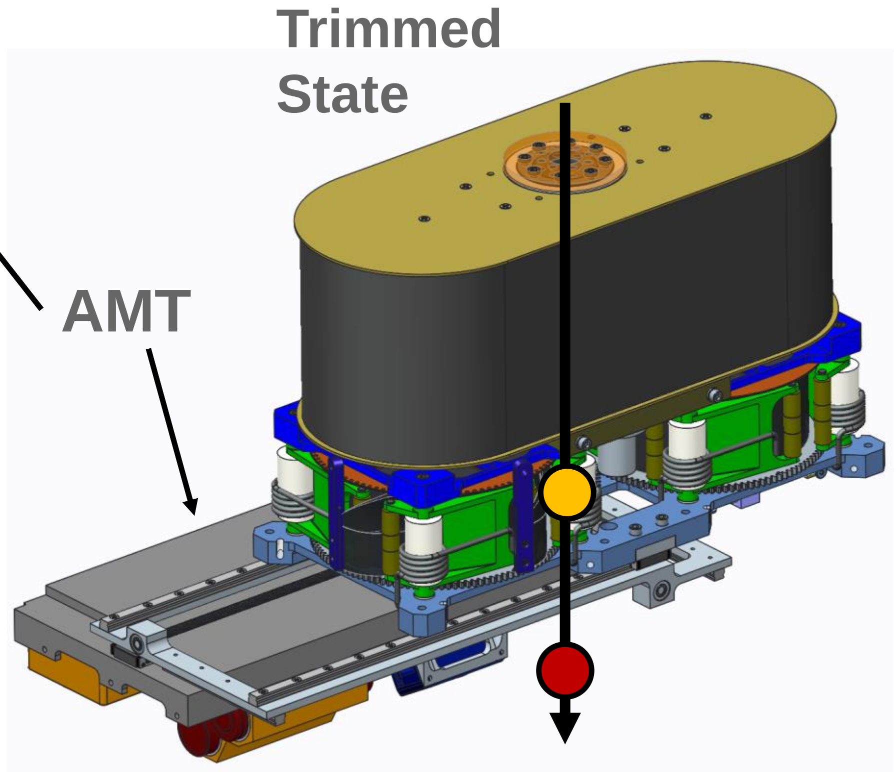
A fully functional planetary spacecraft in a shoebox

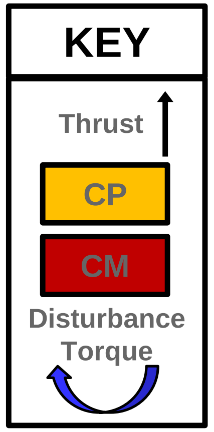


Active Mass Translation (AMT) Overview





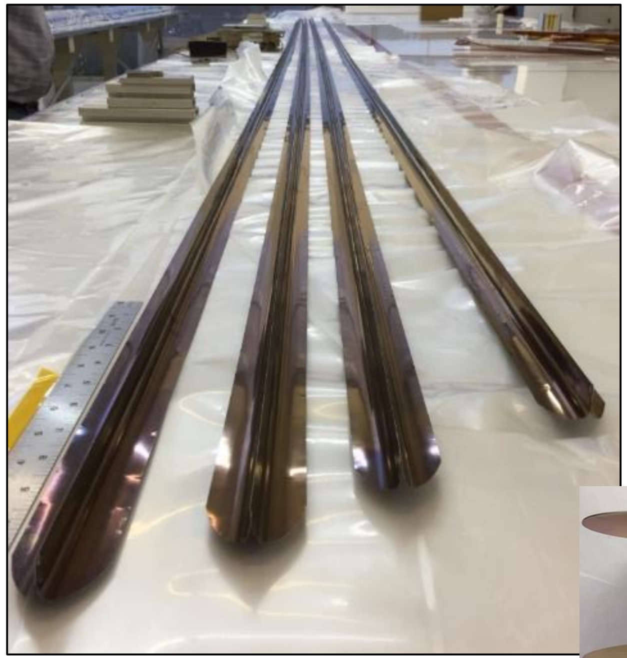


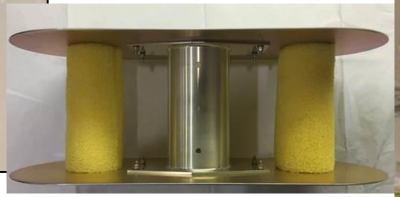


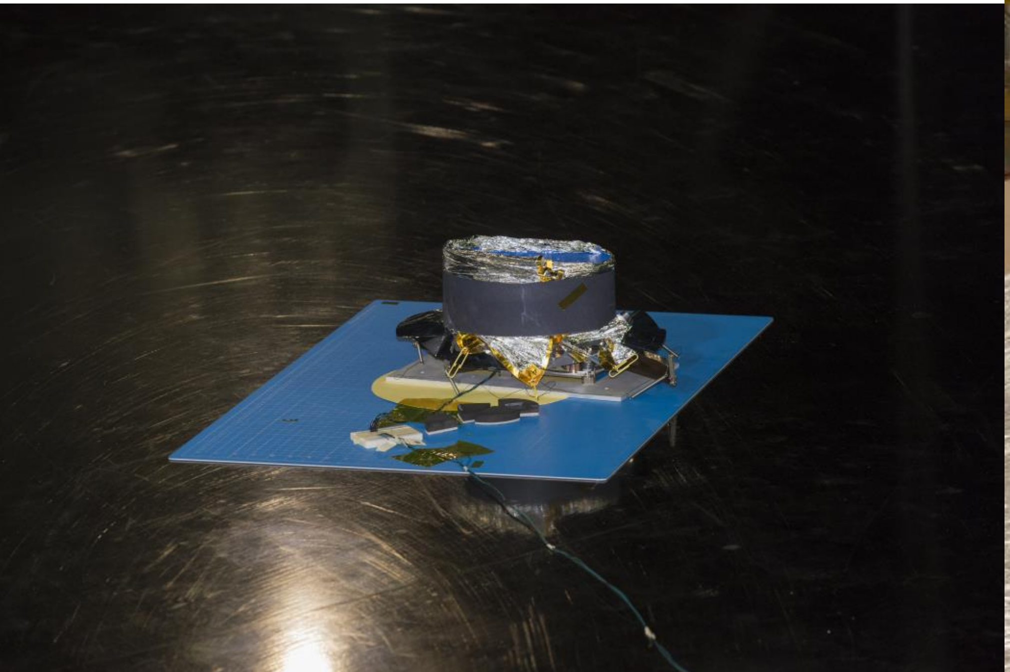
Problems and Challenges

- **NEA Scout's center of mass (CM) and center of pressure (CP) are not collinear with the estimated thrust vector. This creates a *disturbance torque*. Furthermore, the CP is fore of the CM, creating a naturally unstable vehicle and necessitating an active control mechanism.**
- **Little mass and volume available. This challenge is compounded by the vehicle's total mass (14 kg) and volume (6 Liters) requirement. The AMT was originally given 250 grams and a volume of 226 x 105 x 17 mm (400 cc). This *volume* and *mass* will include: an X-Y translation stage, thermal controls, limit switches, and a wire harness. The *wire harness* must pass through the AMT and survive exposure to *deep space environments*.**

On Schedule to Deliver Spacecraft







MSFC Small Spacecraft Experience

DART (2005)
MSFC/Orbital Sciences

Earth Orbit

AR&D Demonstrator

Orbital Express (2007)
DARPA/Boeing/Ball/MSFC

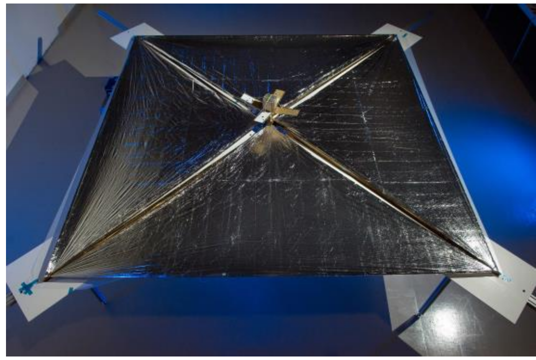
Earth Orbit

AR&D & Refueling Demonstrator

FASTSAT-HSV-01 (2010)
MSFC/Dynetics/USAF

Earth Orbit

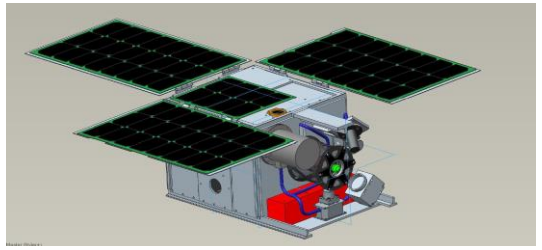
Rapid Development
7 science instruments



NanoSail-D (2010)
NASA/MSFC/ARC

Earth Orbit
Deployment Only

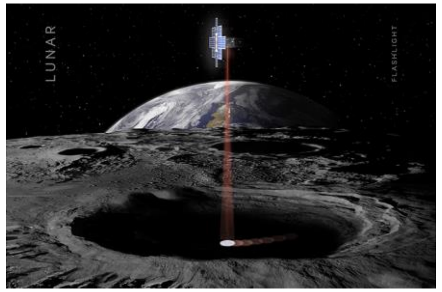
3U CubeSat
10 m^2



Iodine Satellite (iSAT)
NASA/MSFC

Iodine propulsion system demonstrator

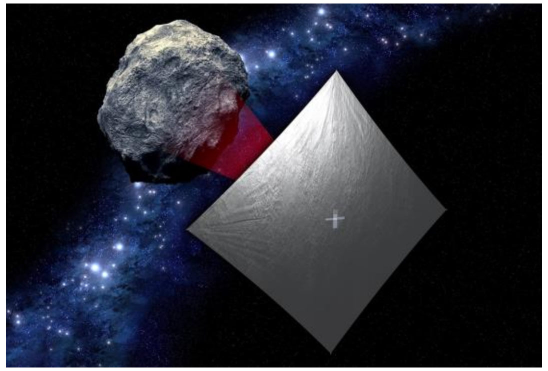
6U CubeSat



Lunar Flashlight (2019)
NASA/MSFC/JPL

Lunar science mission

6U CubeSat



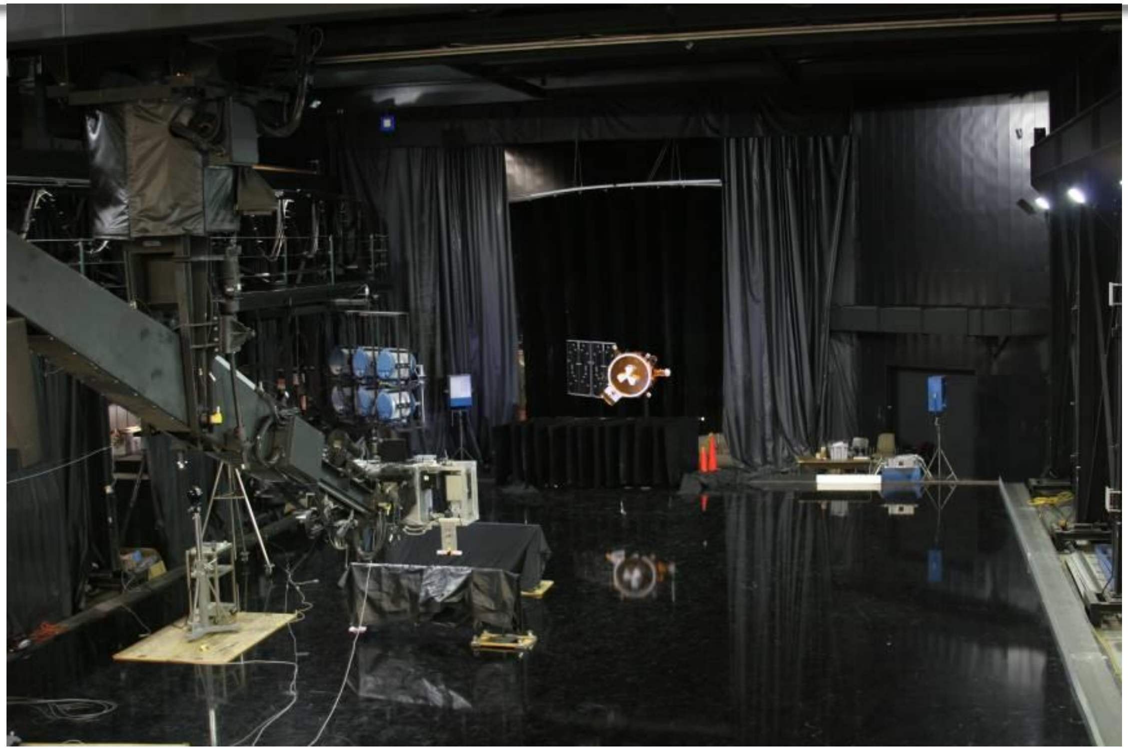
Near Earth Asteroid Scout (2019)
NASA

Interplanetary
Full Flight

6U CubeSat

NASA MSFC Flight Robotics Lab

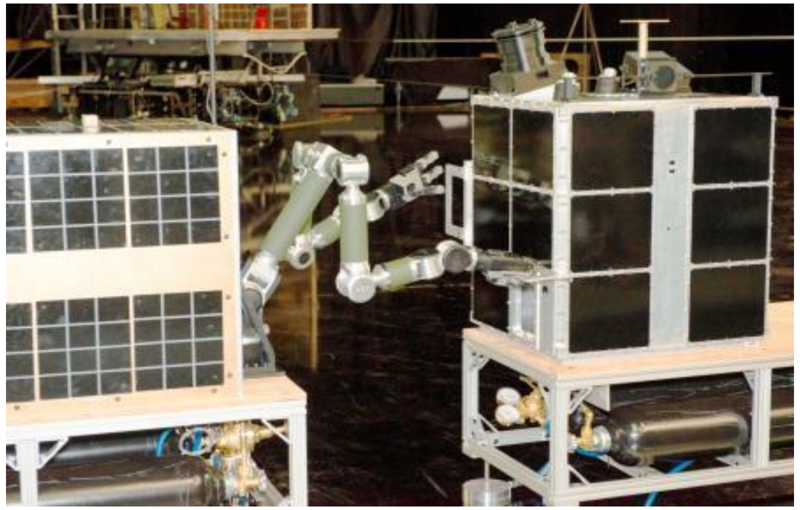
Provides a full scale, integrated simulation capability to support the design, development, test, integration, validation, and operation of orbital space vehicles.



The Flight Robotics Laboratory (FRL) is built on developed technologies: air bearing vehicles, a servo drive overhead robotic simulator, precision target motion controllers, gimbals, and a mobile solar simulator with 6 lights totaling 42 KVA.

The facility is centered around a 44 foot by 86 foot precision air bearing floor - the largest of its kind.

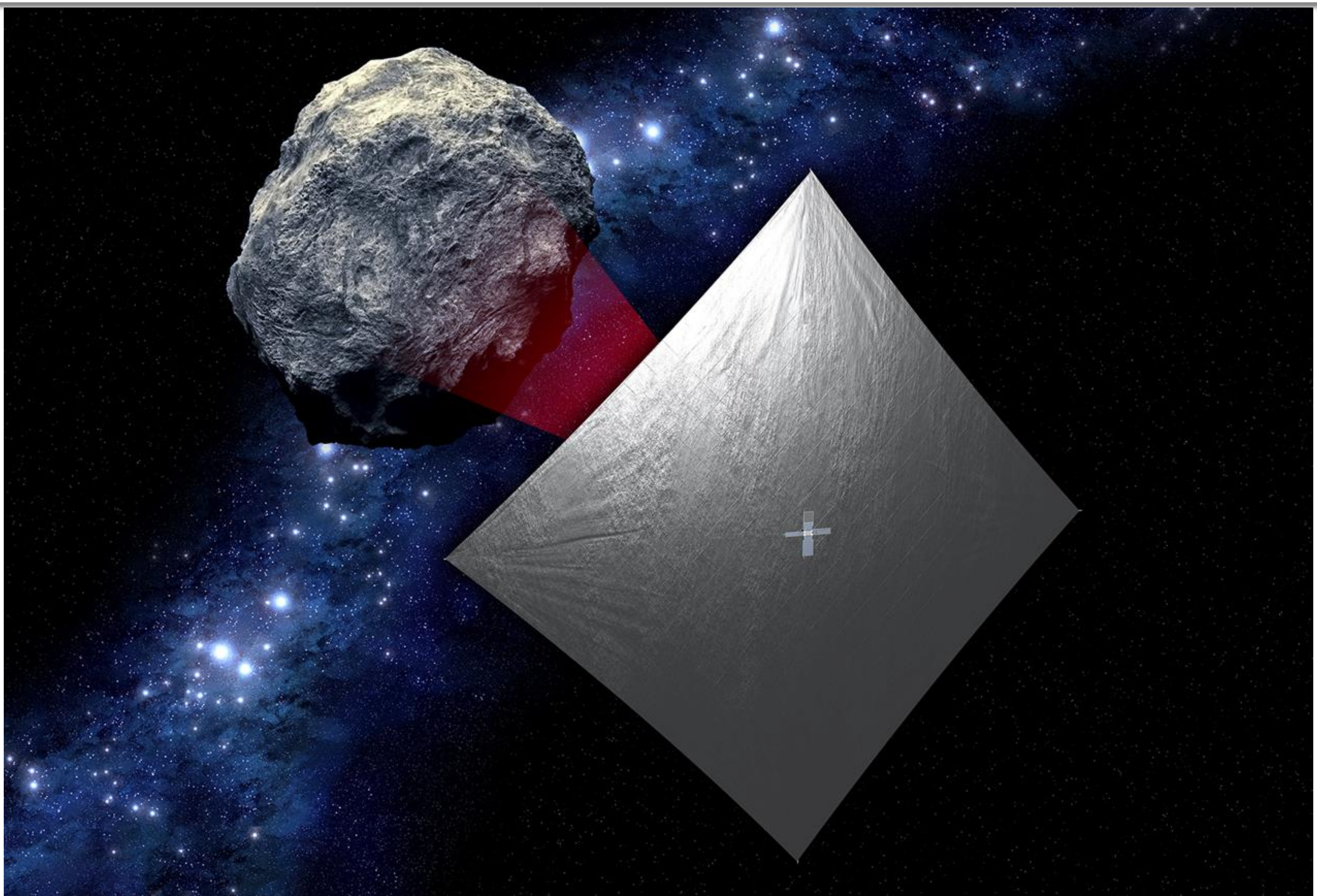
The FRL has air-bearing vehicles ranging in size from 200 lbs to 4000 lbs, each with its own compressed air supply. An 8-Degree-of-Freedom (DOF) overhead gantry (the Dynamic Overhead Target Simulator or DOTS) provides an 800 pound payload capability for simulating relative motion with respect to a fixed target in the facility with a motion envelope of 30’ x 160’ x 20’. A computer system provides inverse kinematics and allows the gantry to act as a target or as the 6 DOF rendezvous vehicle. The target reaction dynamics can be simulated through force/torque feedback from sensors mounted at the payload interface.



Collaboration areas could include sensor testing, system testing, multi-vehicle algorithm simulation and testing, orbital debris tracking, automated capture and manipulation, and wireless video and control.

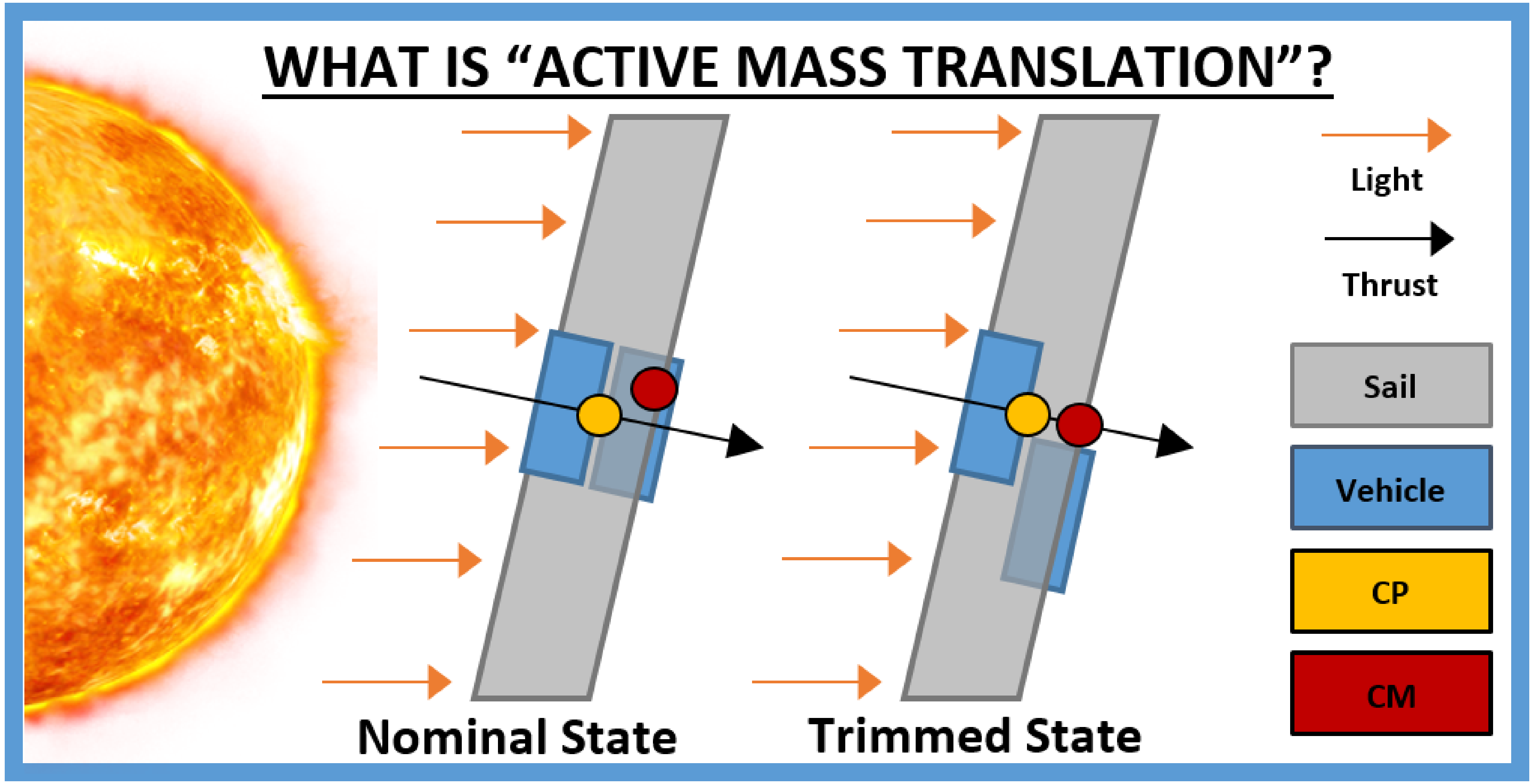
Past DoD collaborations include DARPA’s Orbital Express mission, MARCbot reconfiguration and testing, DART mission to MUBLCom satellite, and sensor tests utilizing Army ranges and facilities.

Questions?



Backup Information

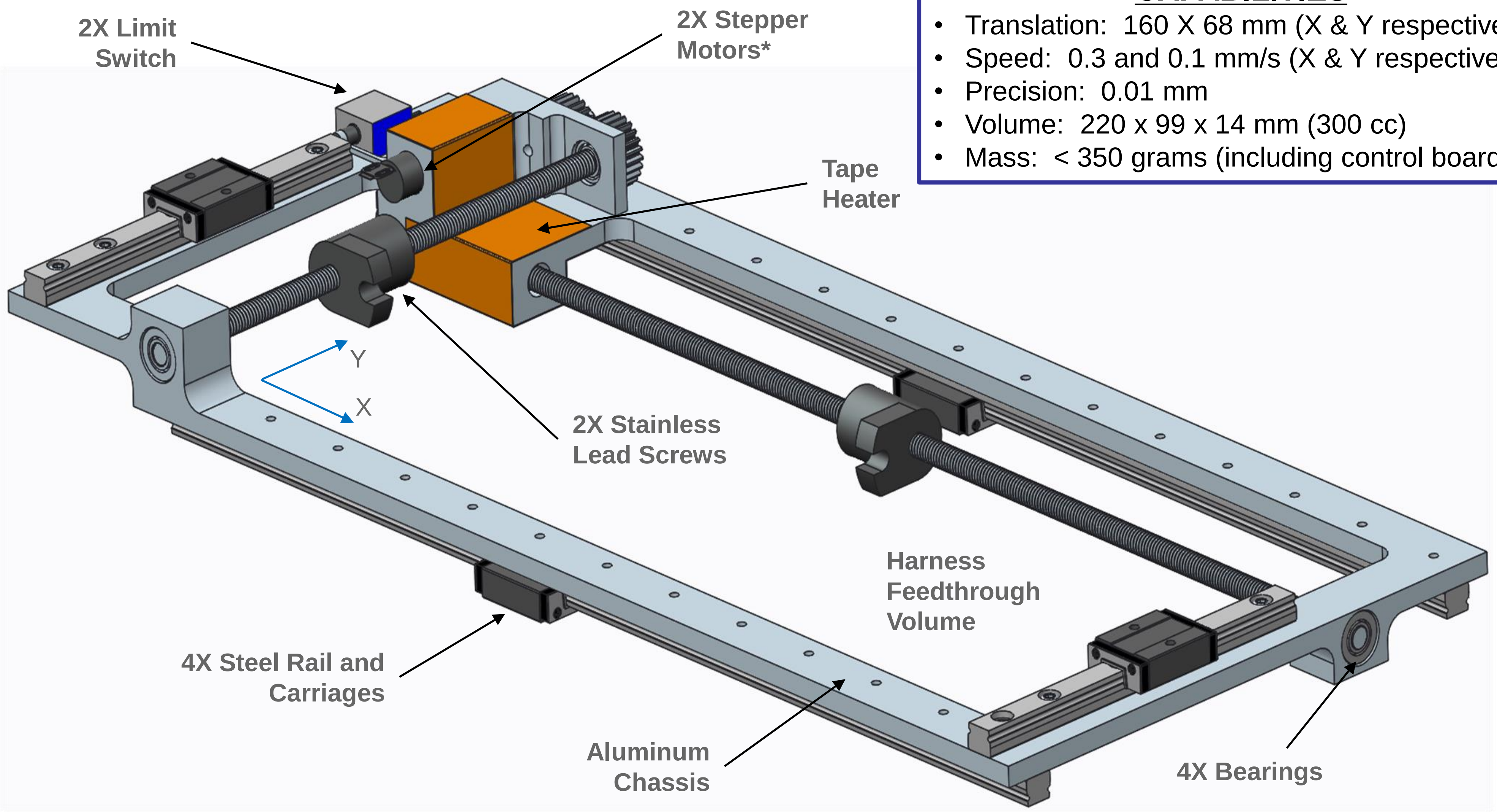
The Need for CM/CP Adjustment



The AMT will move one portion of the NEA Scout relative to the other. This translation of mass will alter the inertial properties of the vehicle and align the CP and CM

AMT Overview

Current Design State

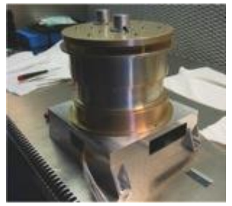


CAPABILITIES

- Translation: 160 X 68 mm (X & Y respectively)
- Speed: 0.3 and 0.1 mm/s (X & Y respectively)
- Precision: 0.01 mm
- Volume: 220 x 99 x 14 mm (300 cc)
- Mass: < 350 grams (including control board)

* Stepper Motors are housed inside of the aluminum block and are not readily visible

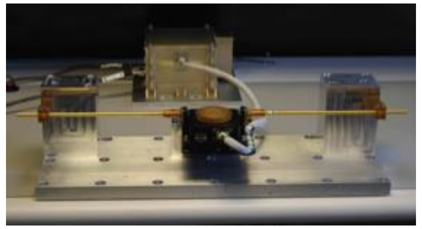
FASTSAT-HSV01
Seven Instruments on One Platform



NASA and USNA Miniature Imager for Neutral Ionosphere Atoms and Magnetosphreric Electrons (MINI-ME)
- Improve space weather forecasting for operational use

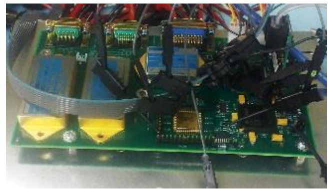
NASA and USNA Thermospheric Temperature Imager (TTI)
- Increase accuracy of orbital predictions for low-Earth orbiting assets

AFRL Light Detection System (LDS)
- Evaluate atmospheric propagating characteristics on coherent light generated from known ground stations



NASA & USNA Plasma Impedance Spectrum Analyzer (PISA)
- Permit better predictive models of space weather effects on communications and GPS signals

NASA + ARMY SMDC + AFRL + VCSI Nano Sail Demonstration (NSD)
- Demonstrate deployment of a compact 10-m^2 solar sail ejected as a CubeSat



NASA MSFC Memory Test Experiment (MTE)
- Flight Demonstration of Ferroelectric Memory technology

AFRL + NASA + AF Miniature Star Tracker (MST)
- Demonstrate small and low-power star tracker