Cold Gas RCS for the NEA Scout CubeSat

AIAA SPACE 2017

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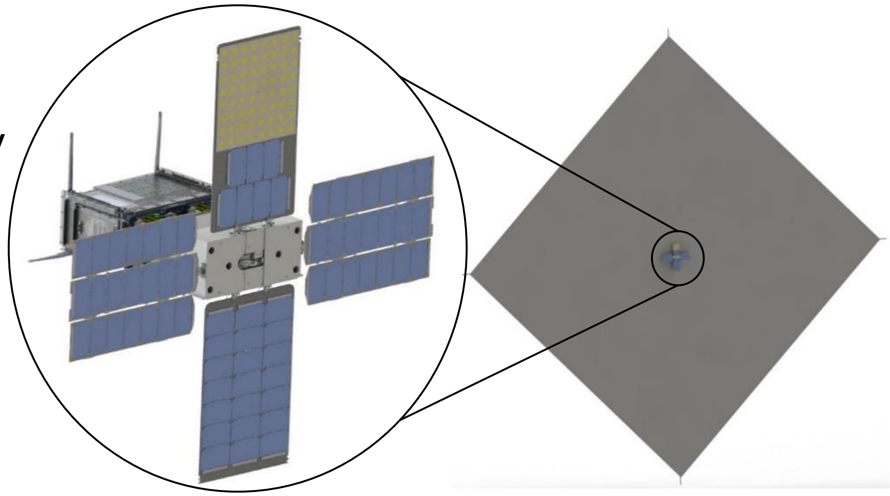
Near Earth Asteroid (NEA) Scout Overview

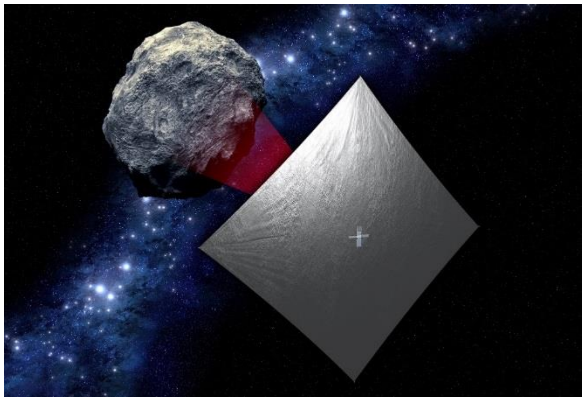
The Near Earth Asteroid Scout will

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

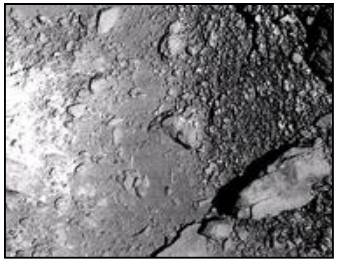


Key Spacecraft & Mission Parameters

- 6U cubesat
- ~86 m^2 solar sail propulsion system
- Manifested for launch on the Space Launch System (EM-1/2019)
- Up to 2.5 year mission duration



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

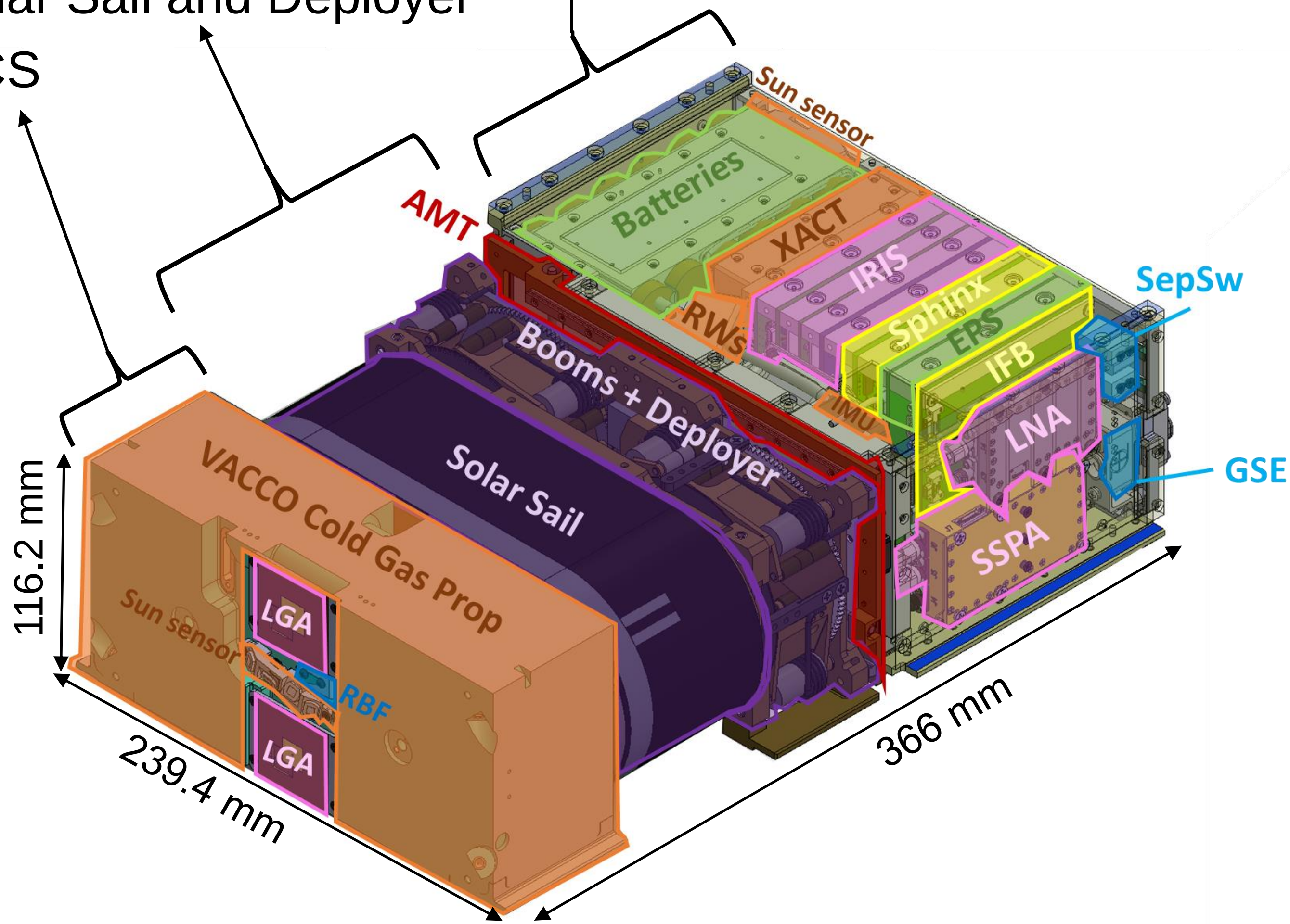


Close Proximity Imaging
Local scale morphology, terrain properties, landing site survey

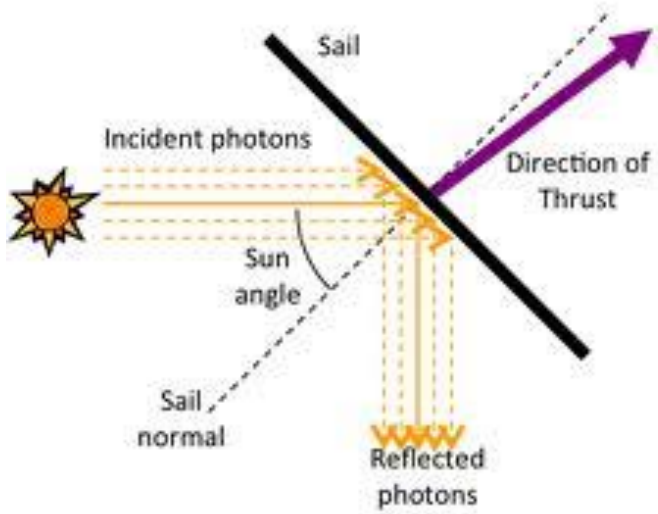
NEA Scout's Mechanical Configuration

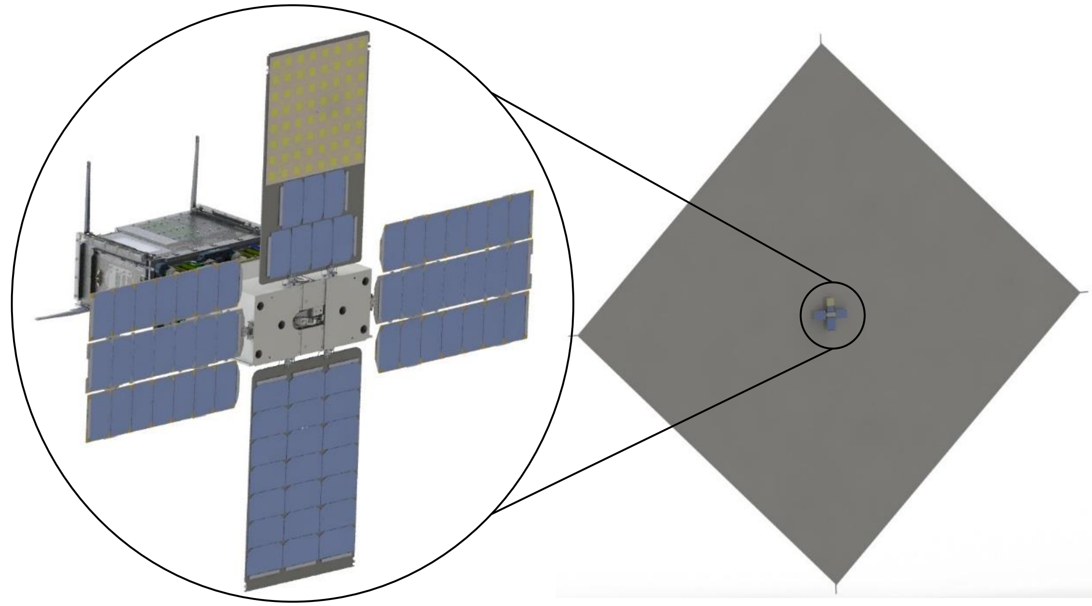
NEA Scout is split into three major parts:

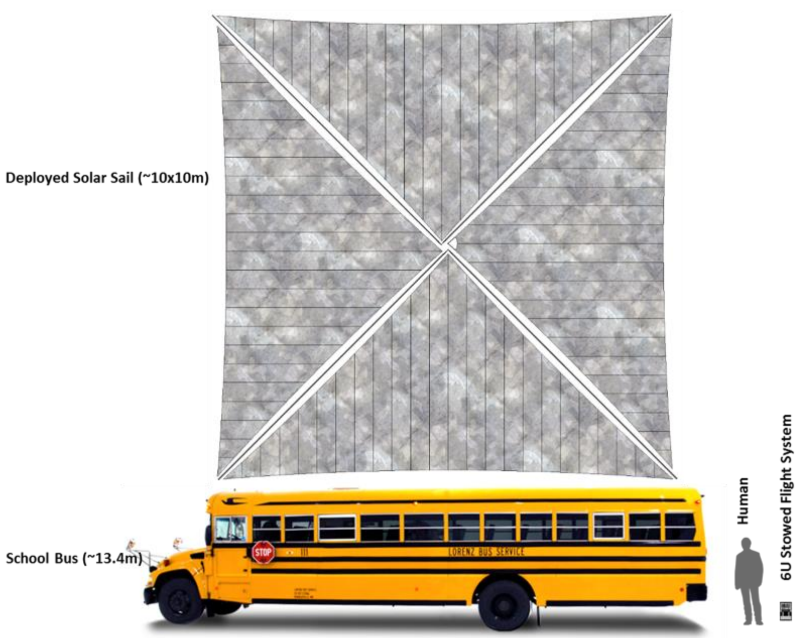
1. Avionics
2. Solar Sail and Deployer
3. RCS



NEA Scout's Solar Sail



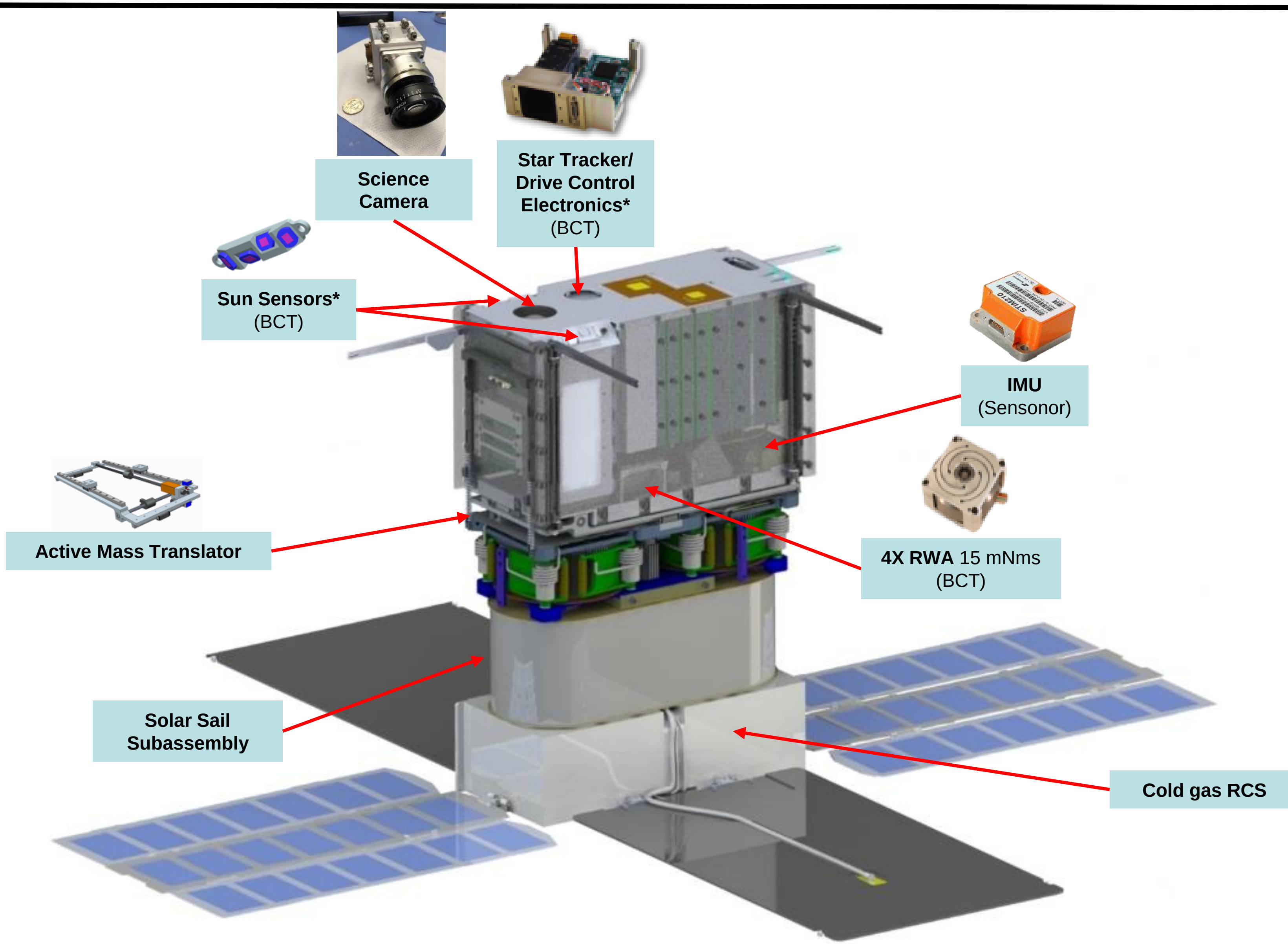




Light reflects off of the Solar Sail, providing a small but continuous amount of thrust.

'Fuel' never runs out.

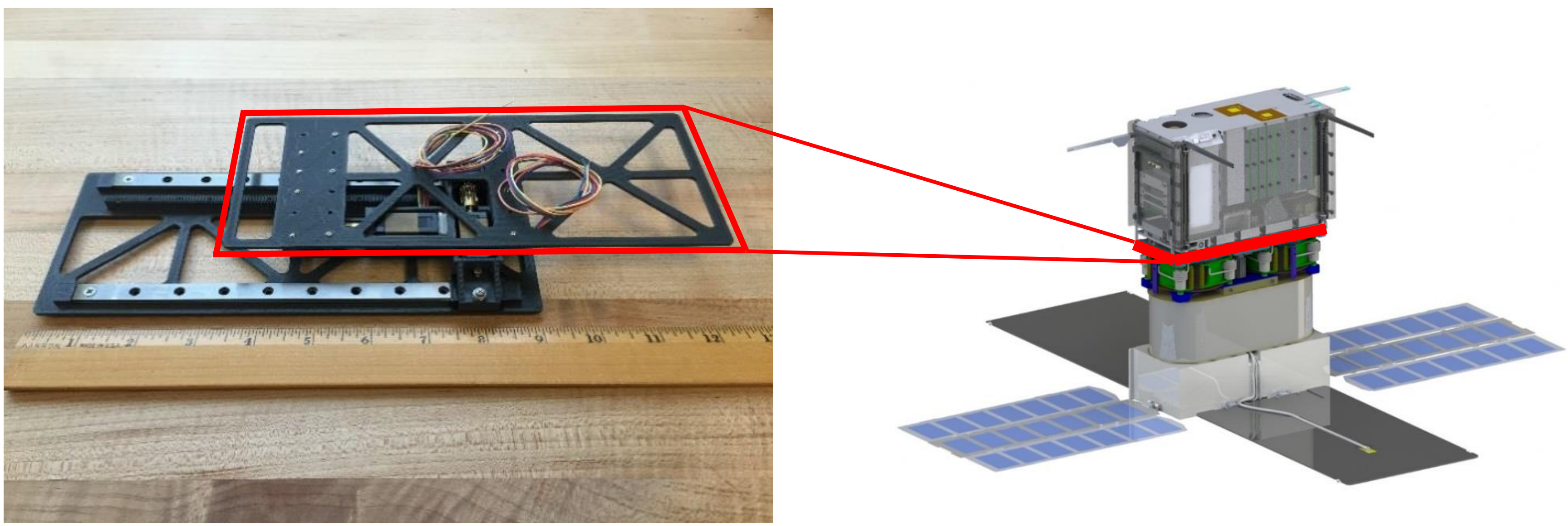
NEAS Control System Overview



NEA Scout's Active Mass Translator (AMT)

The AMT allows NEA Scout's two *halves* to move relative to each other.

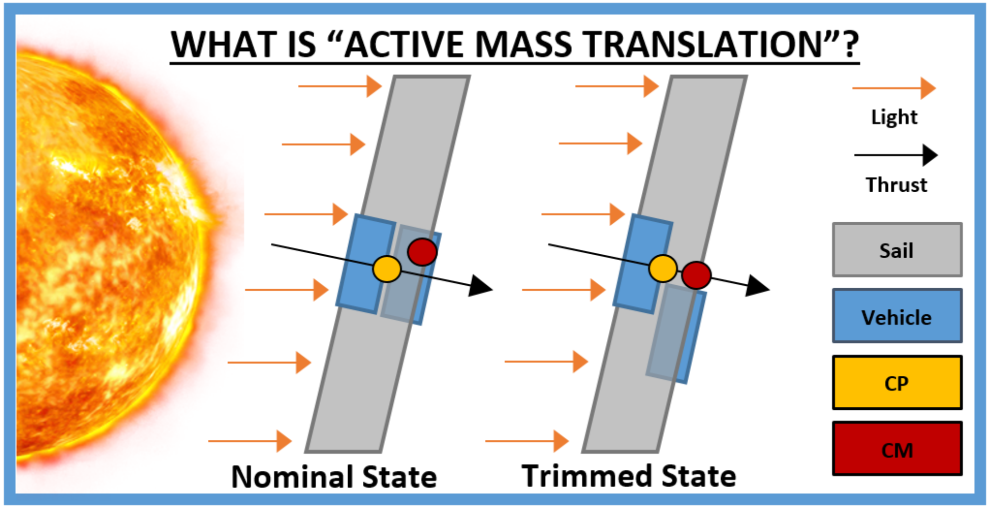
The AMT shifts the CM to trim the solar sail torque.

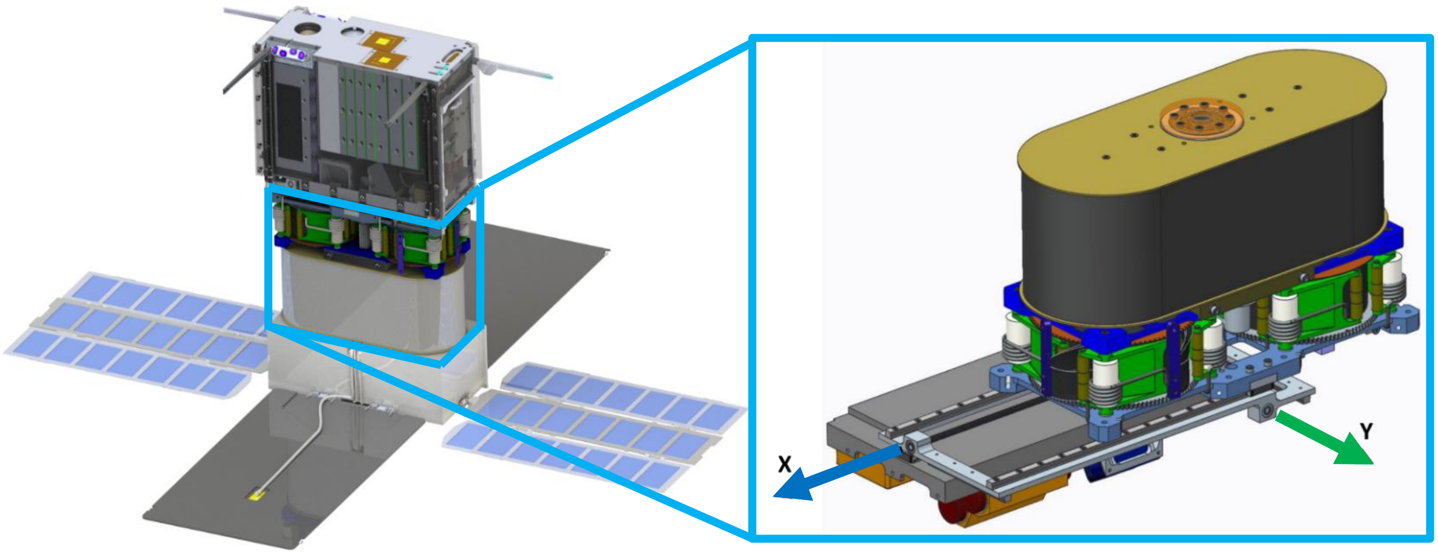


NEA Scout's Active Mass Translator (AMT)

The AMT shifts the CM relative to the solar sail's Center of Pressure (CP).

The solar torque can be trimmed or reversed (allowing for reaction wheel desaturation).





NEA Scout’s Reaction Control System

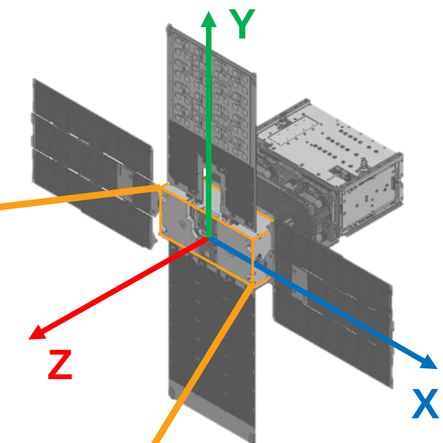
Occupies about 2U of volume on NEA Scout.

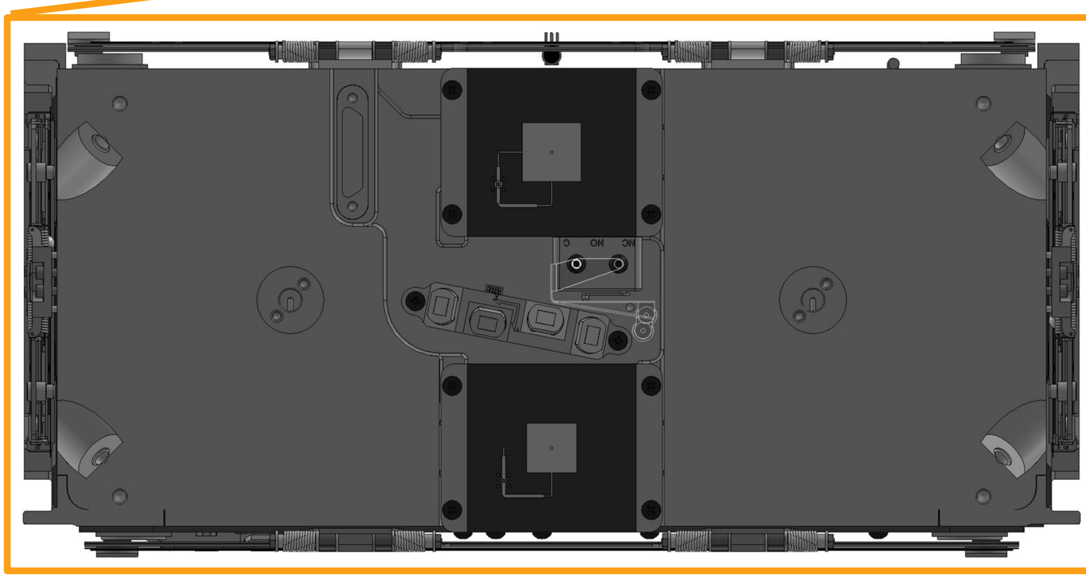
Holds 1.25kg of R236fa (refrigerant) propellant.

Two axial jets (Z-axis) for thrust maneuvers.

Four canted jets for attitude control.

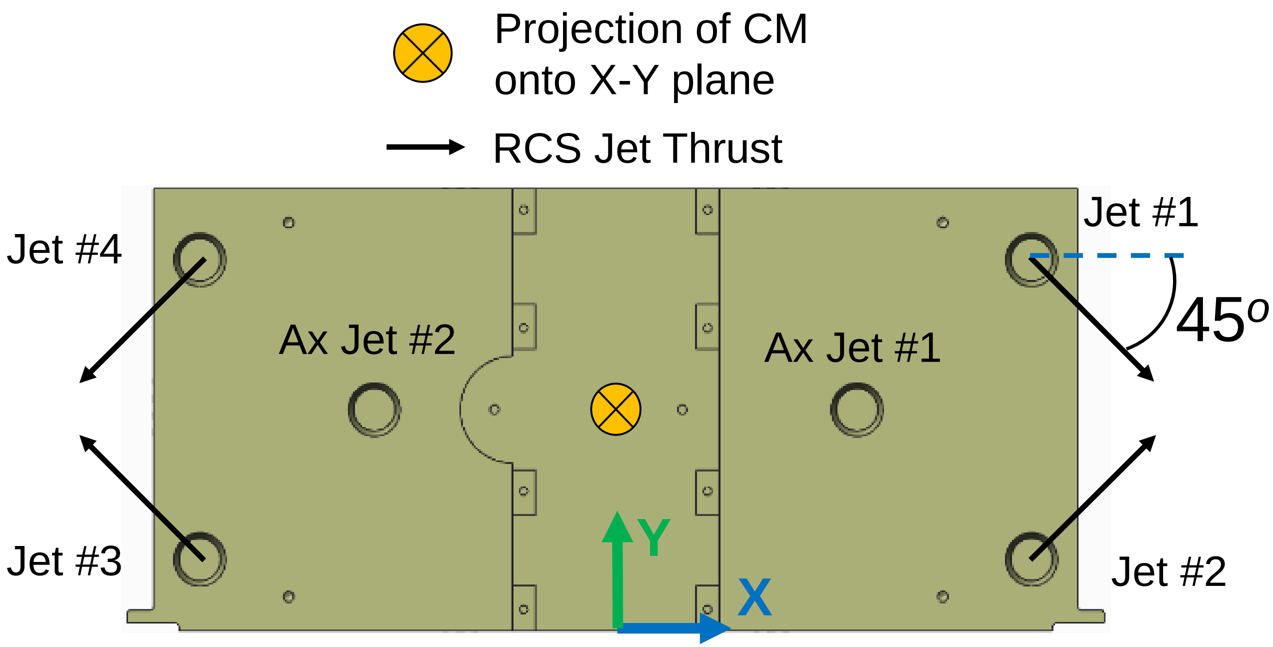
Each Jet produces 0.025 N of thrust.

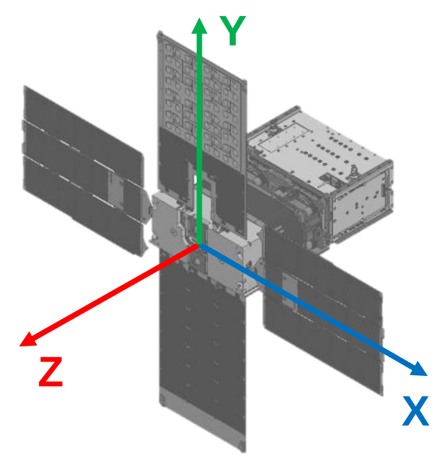




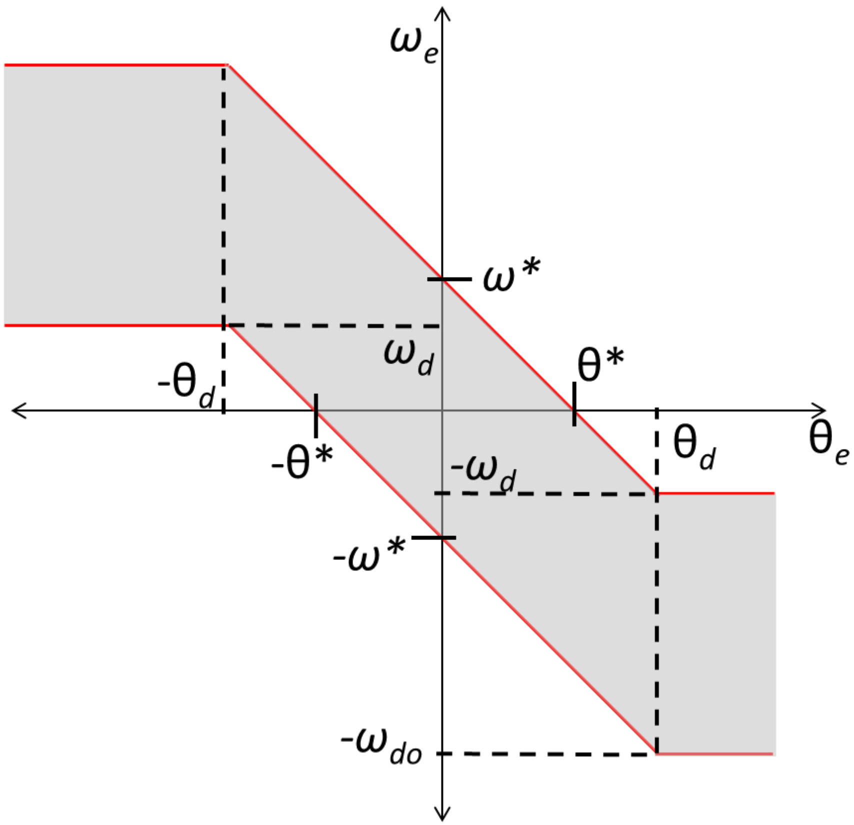
RCS Forces and Jet Selection

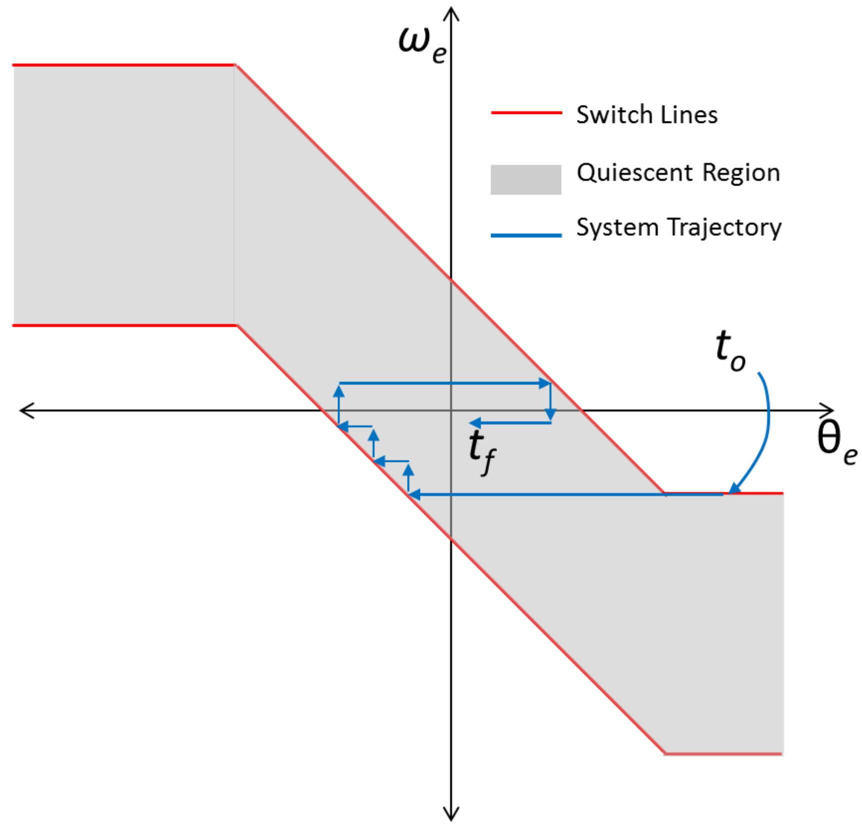
Body Axis	Jet 1	Jet 2	Jet 3	Jet 4	Mx (N-mm)	My (N-mm)	Mz (N-mm)
+X	1	0	0	1	**3.534**	0.007	-0.008
-X	0	1	1	0	**-3.159**	0.007	0.008
+Y	1	1	0	0	0.188	**6.792**	0.230
-Y	0	0	1	1	0.188	**-6.778**	-0.230
+Z	0	1	0	1	0.188	0.007	**4.211**
-Z	1	0	1	0	0.188	0.007	**-4.211**





RCS Control Logic – Phase-Plane



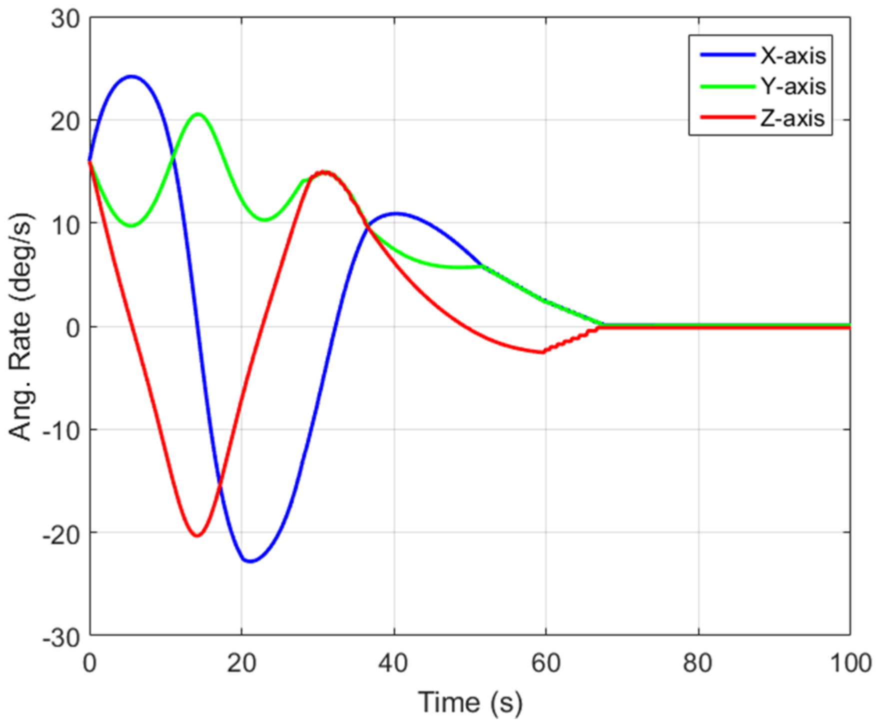


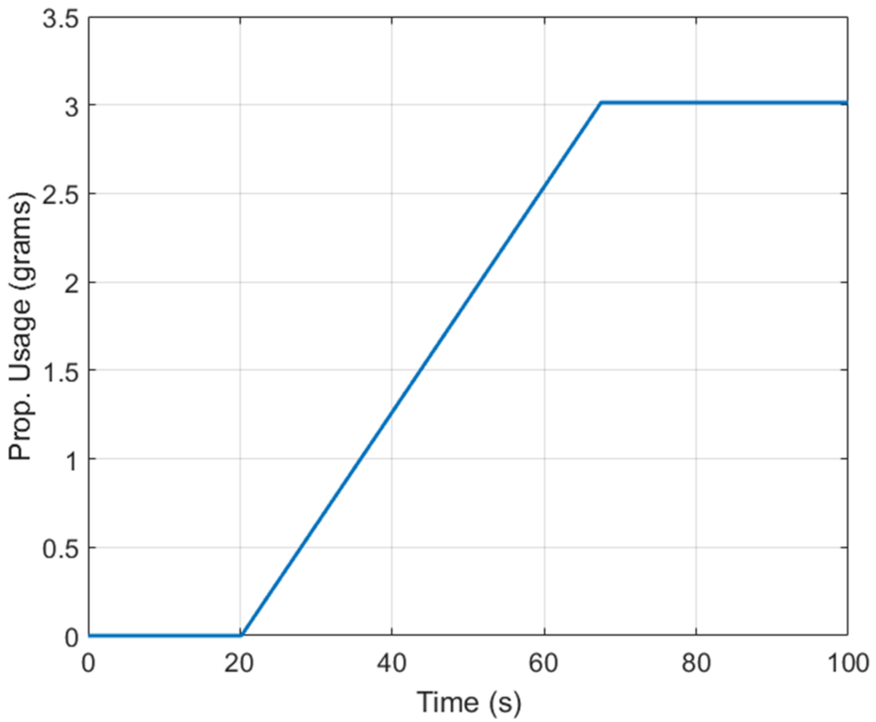
RCS Control Performance - Detumble

Control engaged at *t* = 20s.

Nulls the rates within 1 minute.

Uses 3 grams of propellant.

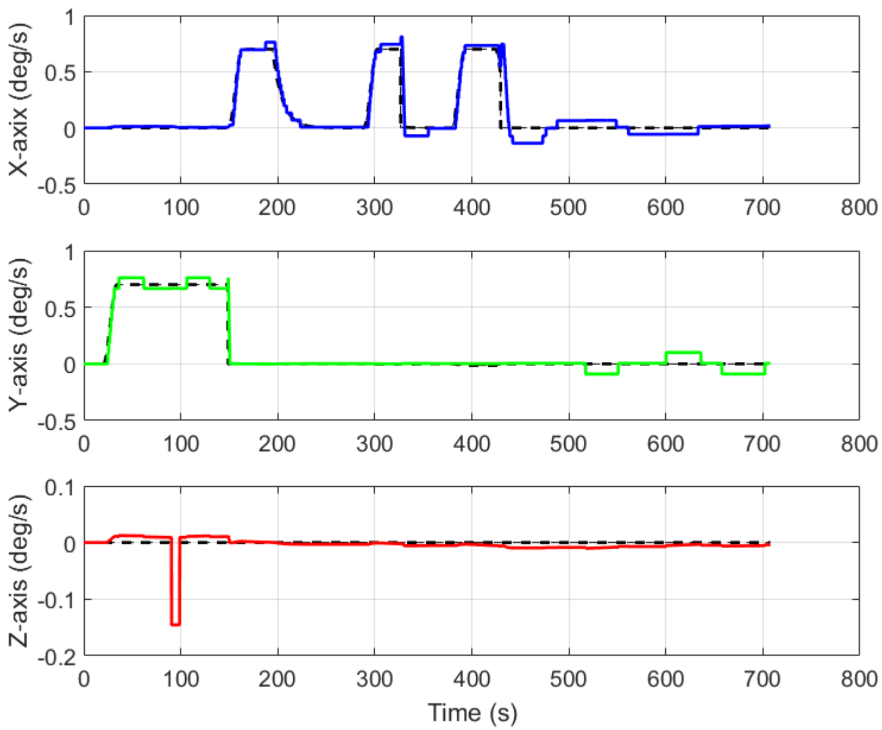


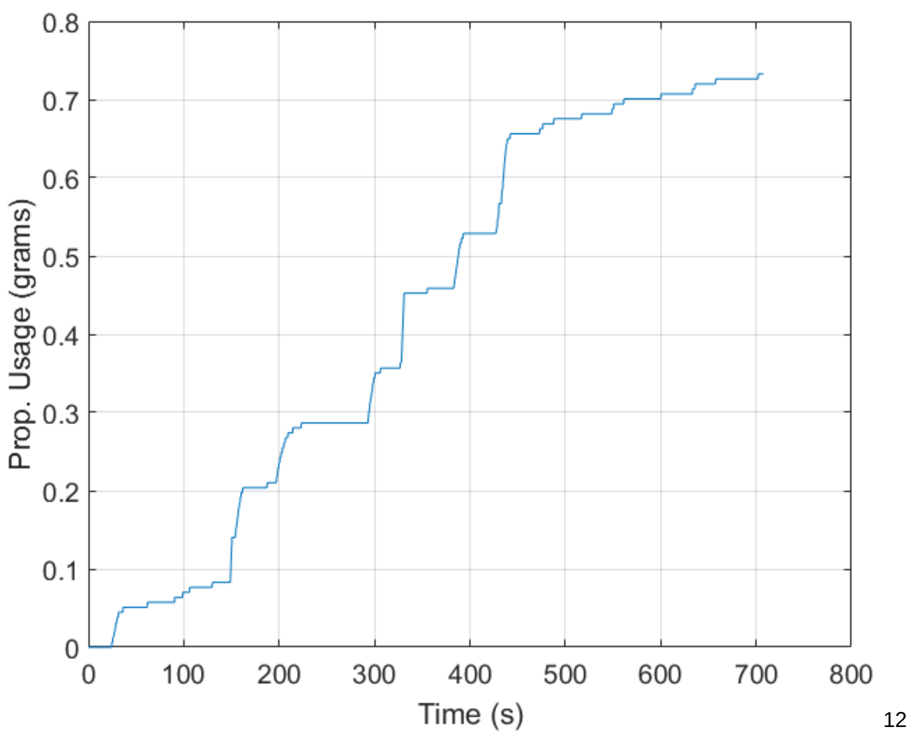


RCS Control Performance – Sun Pointing

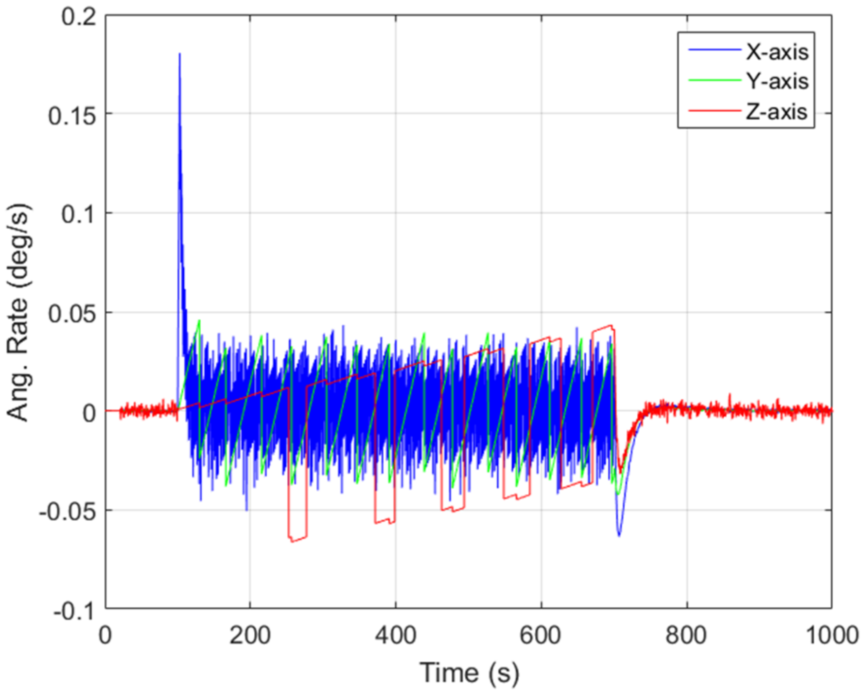
After nulling the rates, the RCS' second requirement is to point toward the sun for charging.

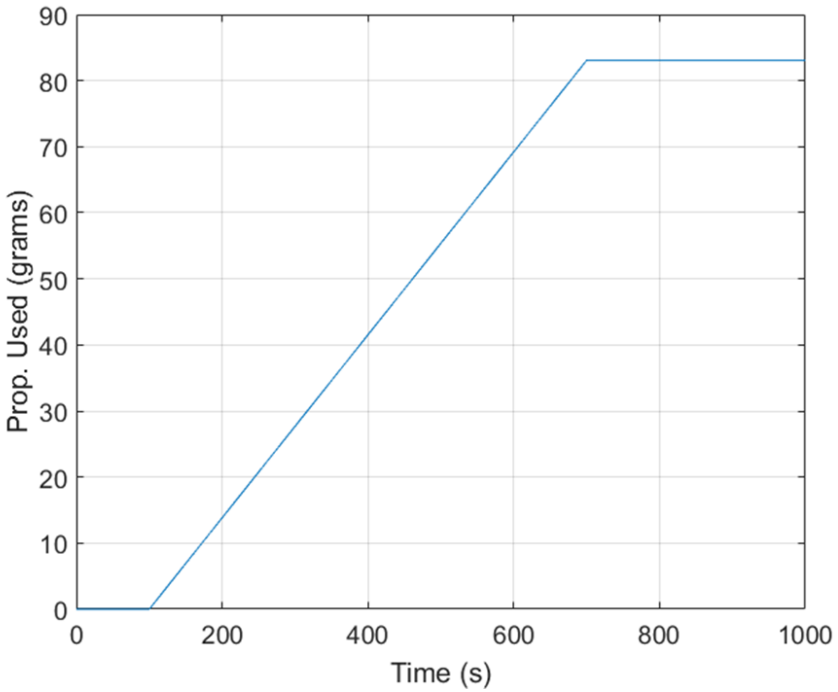
This is an autonomous maneuver that uses sun-sensors to locate the sun.



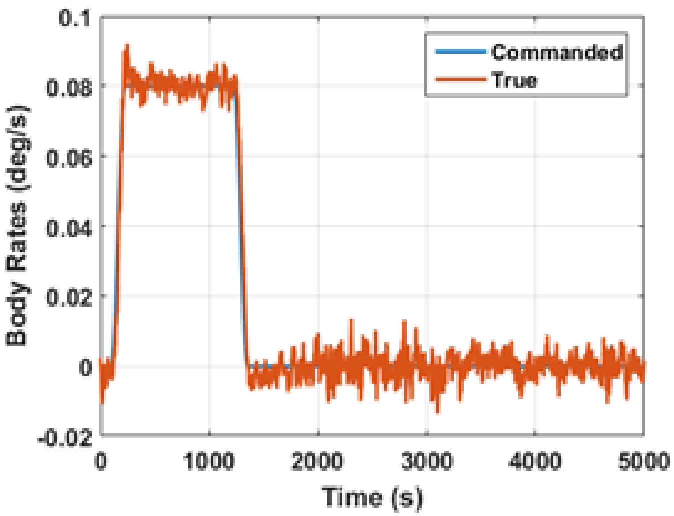


RCS Control Performance - TCM

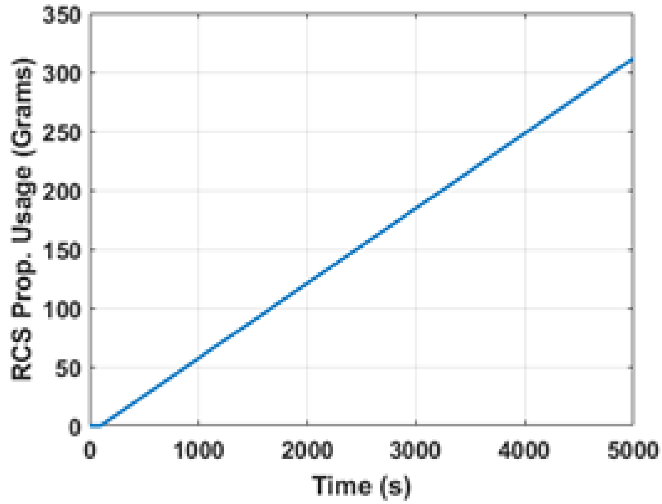




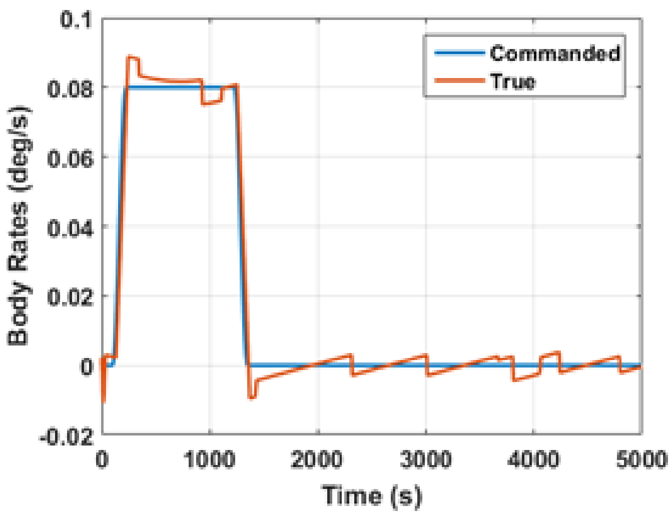
RCS Control Performance – Sail Flex Avoidance



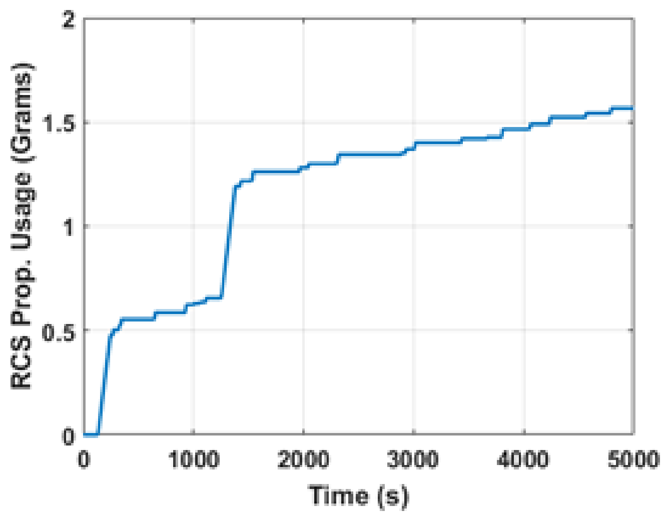
(a)



(b)

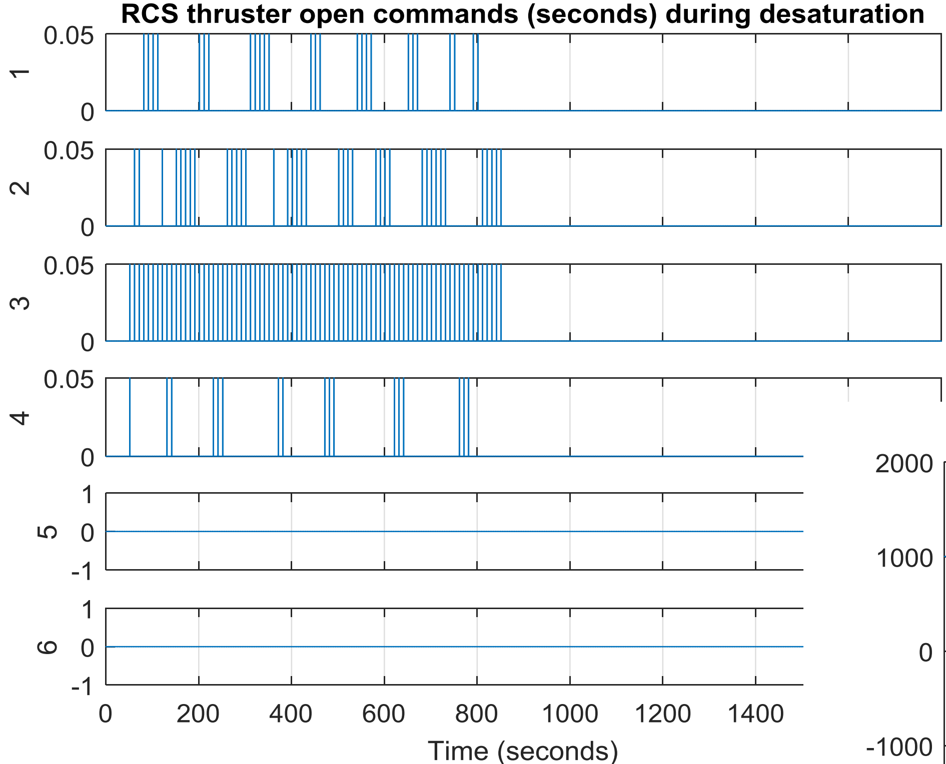


(a)



(b)

RCS Control Performance – Mom. Management

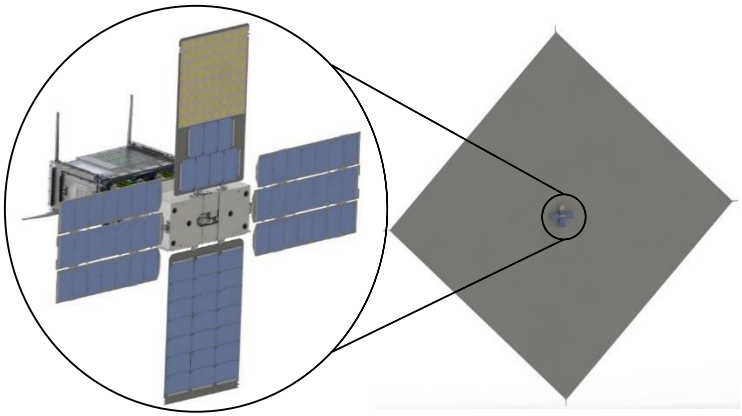


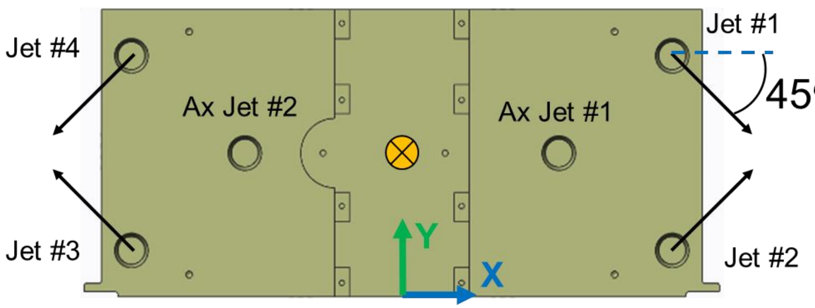
Conclusions

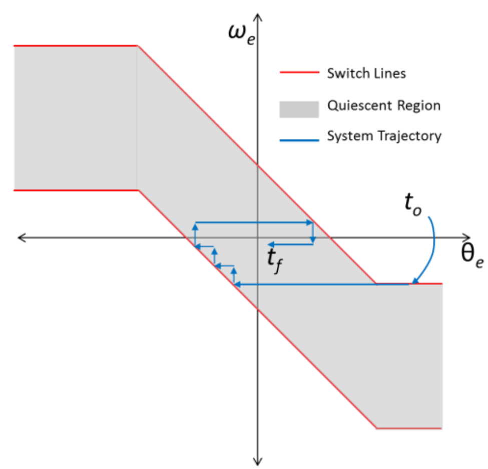
NEA Scout uses a cold gas RCS system for propulsion.

The RCS has four canted jets for attitude control and two axial jets for thrust maneuvers.

The RCS utilizes a simple control logic known as a phase-plane.

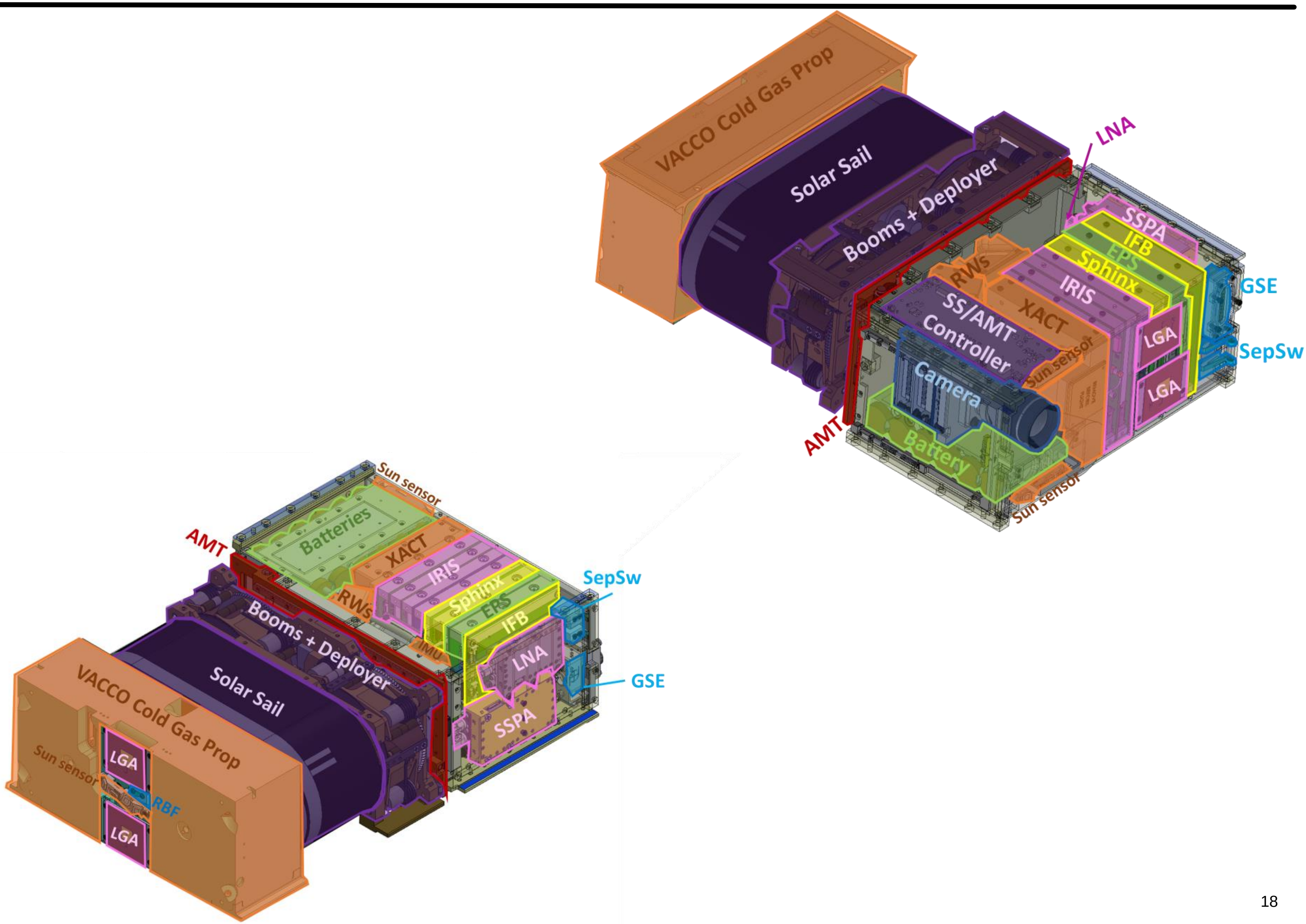






BACKUP

NEA Scout Mechanical Layout (alt. view)

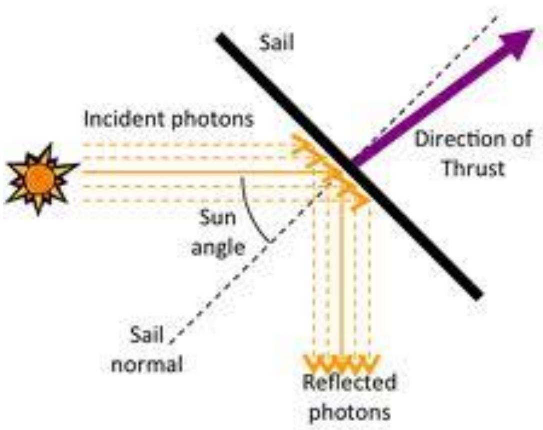


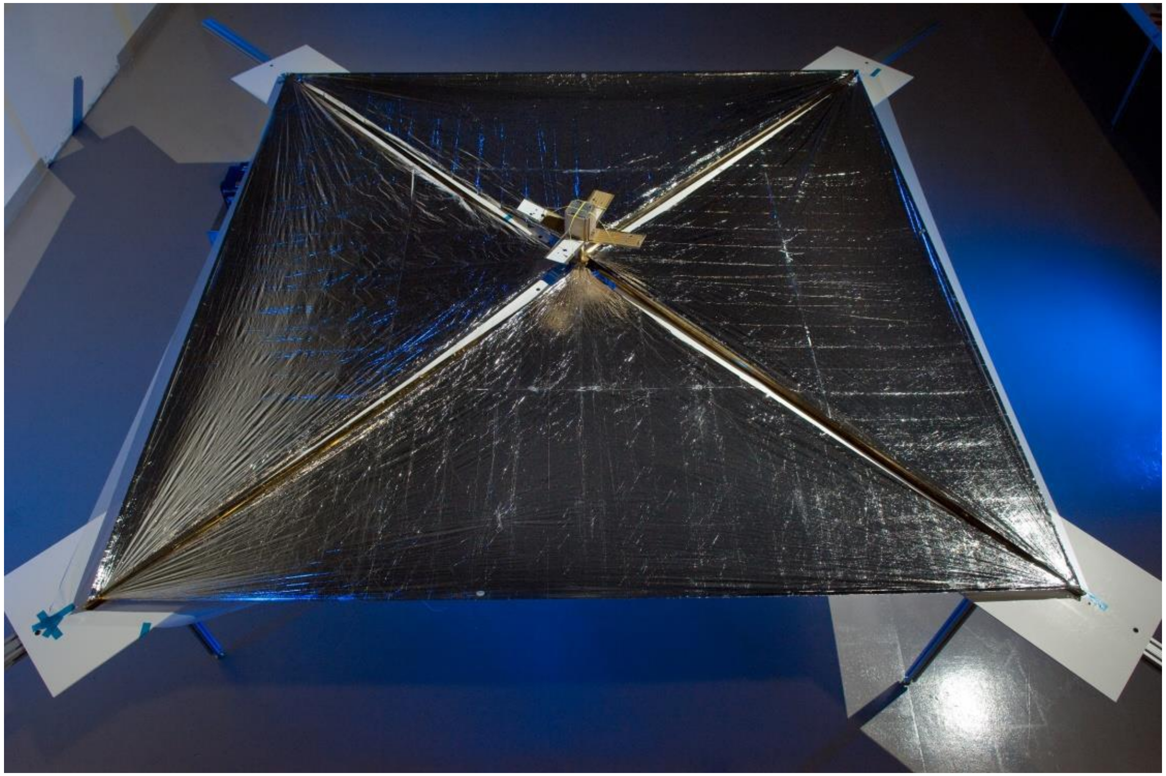
NEA Scout Solar Sail Technology

Light reflects off of the Solar Sail

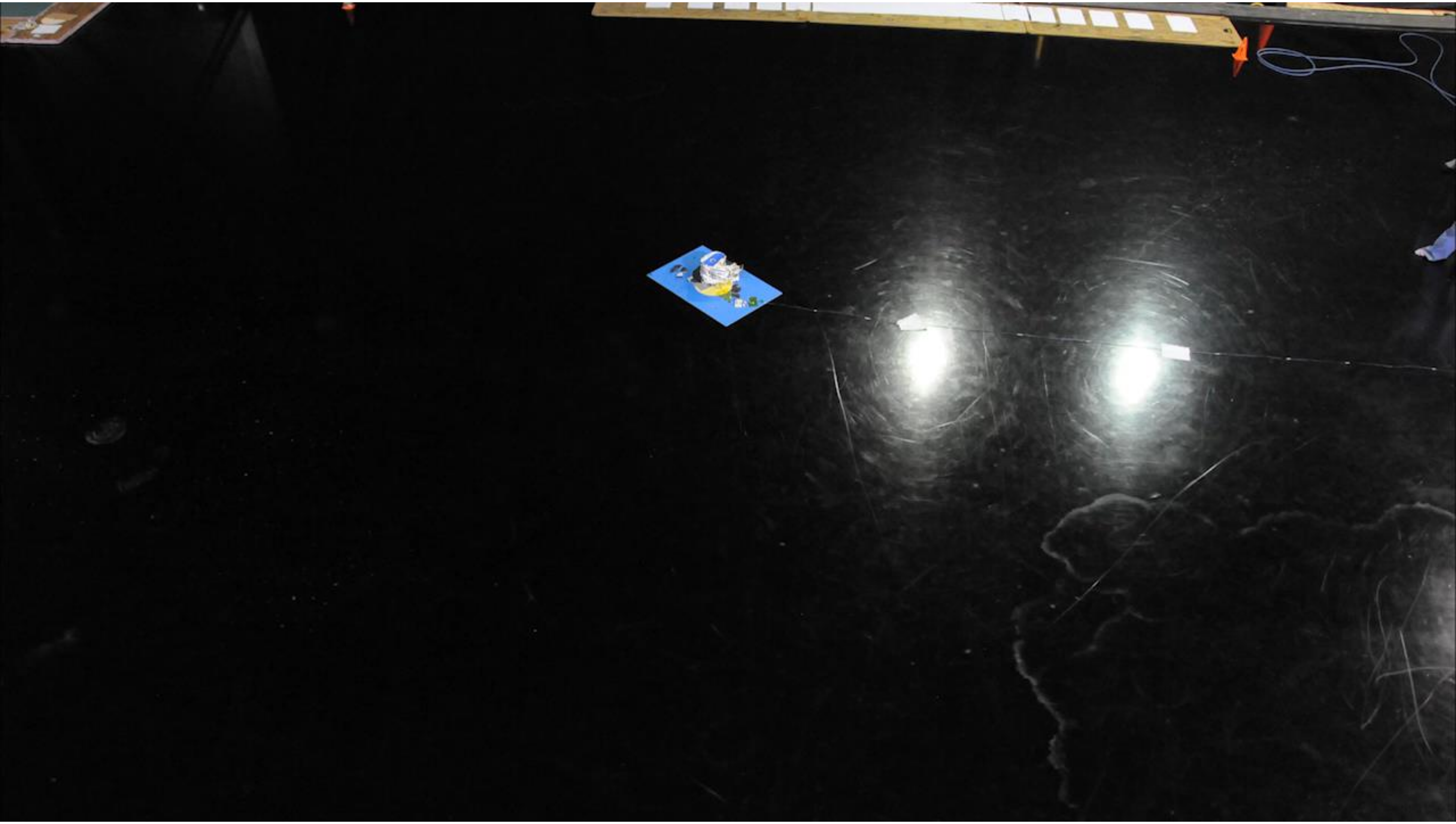
Provides a small but steady amount of thrust

'Fuel' never runs out!



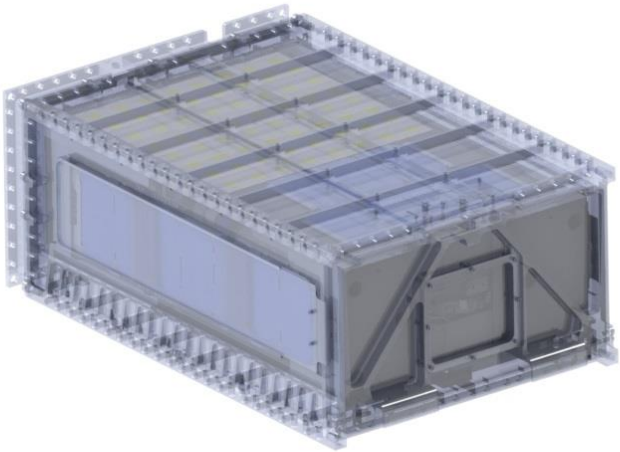


1st Full Scale Solar Sail Ground Deployment

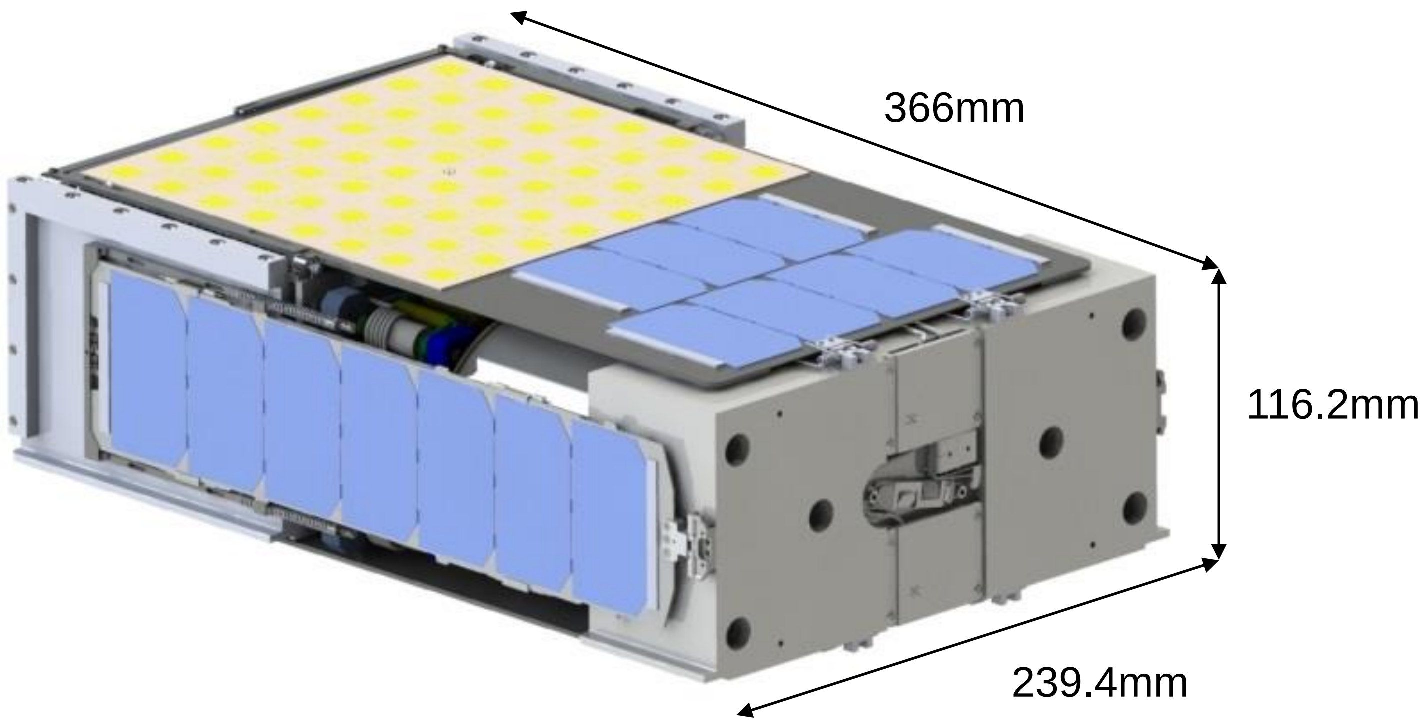


Simulated NEA Scout Mission CONOPS

Flight System Configuration – Stowed

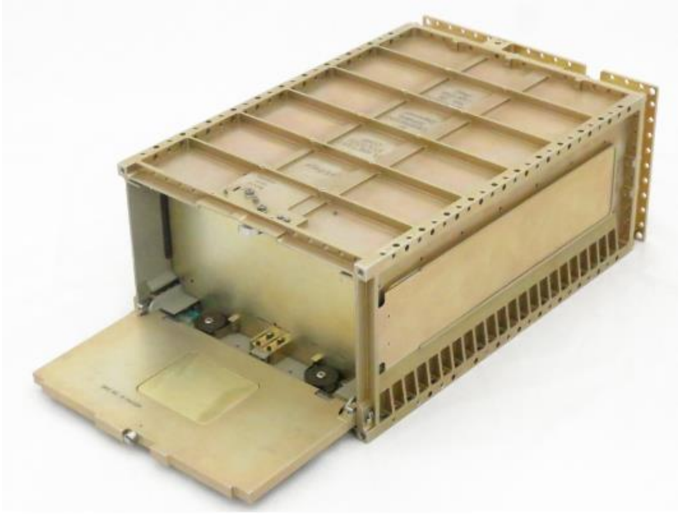


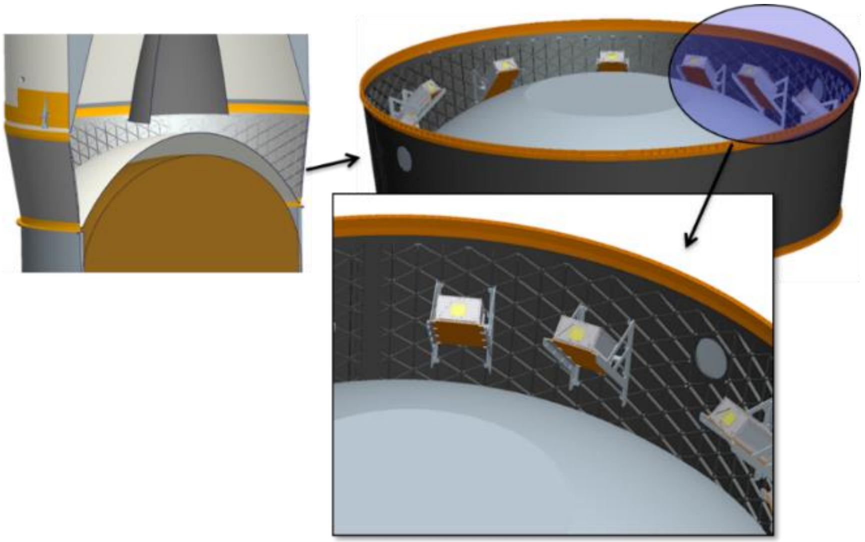
NEAS Inside PSC
6U Dispenser



SLS Interface

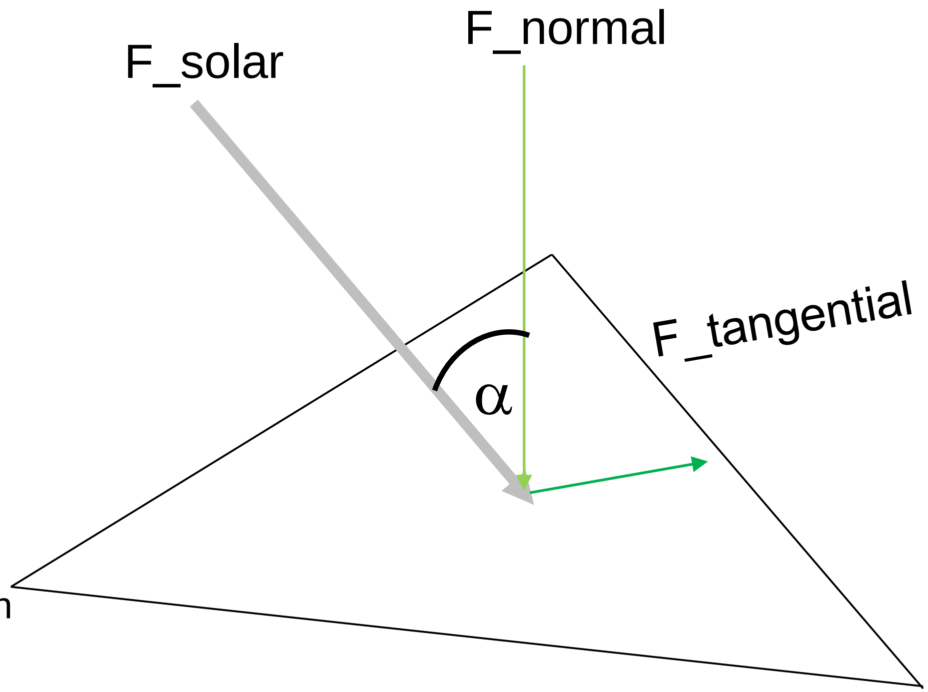
- Manifested on SLS EM-1; mounted in MSA and housed within Planetary Systems Corp. Cannisterized Satellite Dispenser (CSD)
- Project interfaces with Secondary Payload Office (SLS) and Launch Services Program (Dispenser)
- Handover to GSDO installed in dispenser and powered-off
- After Orion separation, ICPS performs disposal maneuver
- Post-disposal, secondary payload sequencer activated
- Each payload dispensed at designated times via signal from sequencer
- Separation switches on payload activated upon deployment, powering on spacecraft





Thrust Model: Underlying Physics

- **Flat Plate optical model published in Wright and cited by McInnes**
- **Shows tangential and normal components**
- **Tangential component important to torque**



P = solar pressure

A = area

$\tilde{r}$ = total reflectivity

s = fraction of reflection that is specular

α = sun incidence angle

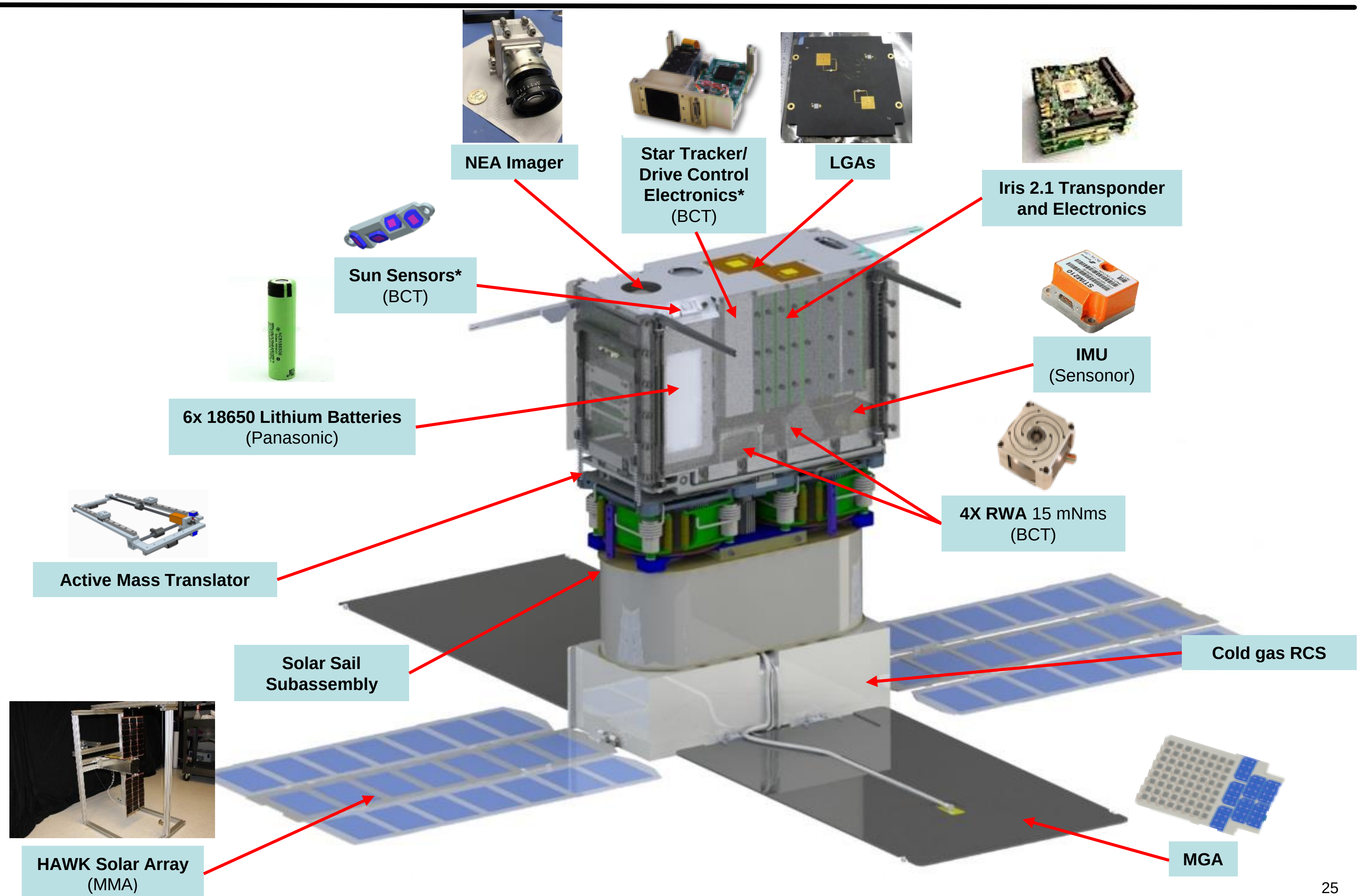
Bf, Bb = front and back side non-Lambertian coefficients

ef, eb = front and back side emissivities

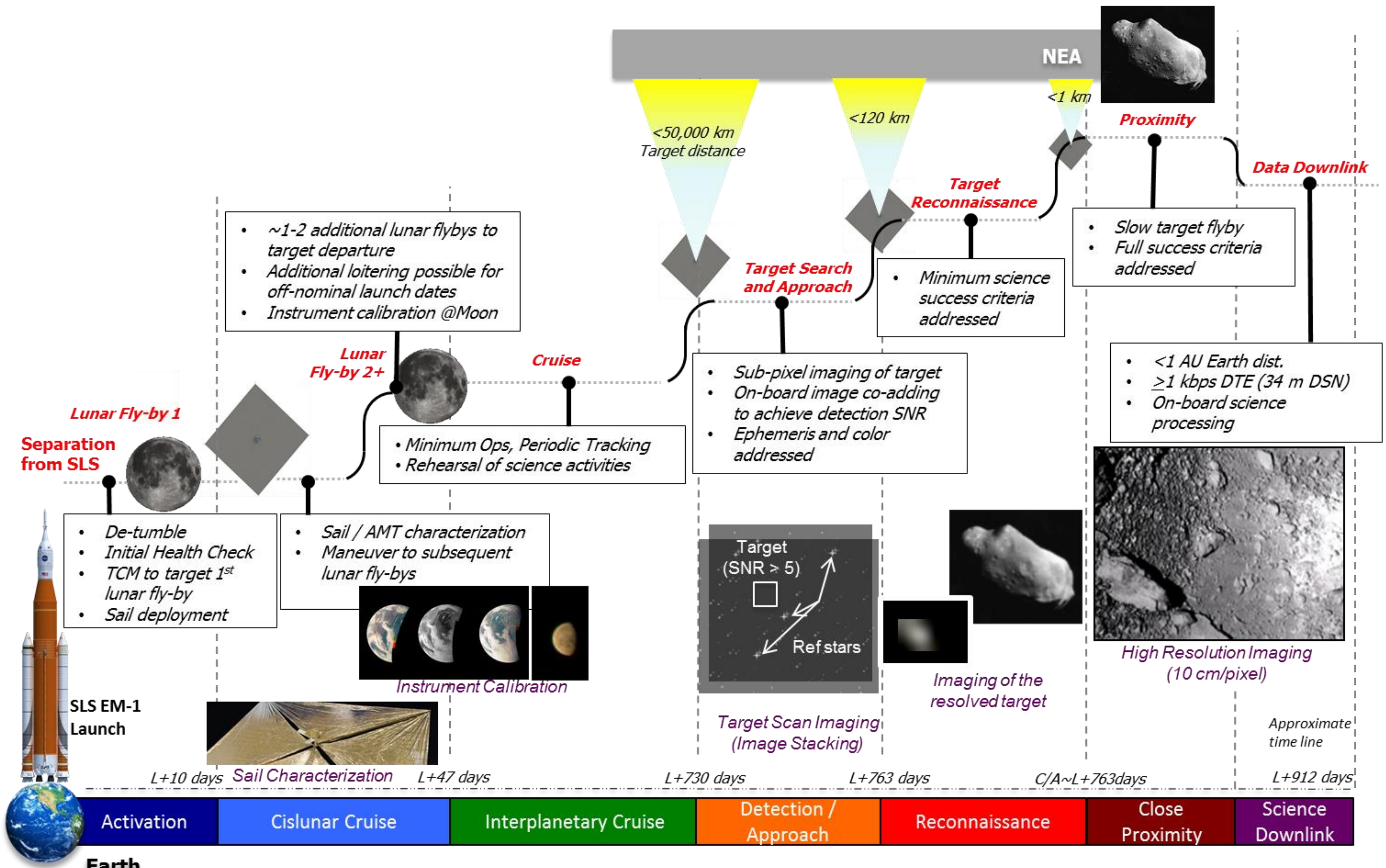
$$f_n = PA\left\{(1+\tilde{r}s)\cos^2\alpha + B_f(1-s)\tilde{r}\cos\alpha + (1-\tilde{r})\frac{\varepsilon_f B_f - \varepsilon_b B_b}{\varepsilon_f + \varepsilon_b}\cos\alpha\right\}$$

$$f_t = PA(1-\tilde{r}s)\cos\alpha\sin\alpha\,t$$

Flight System Overview

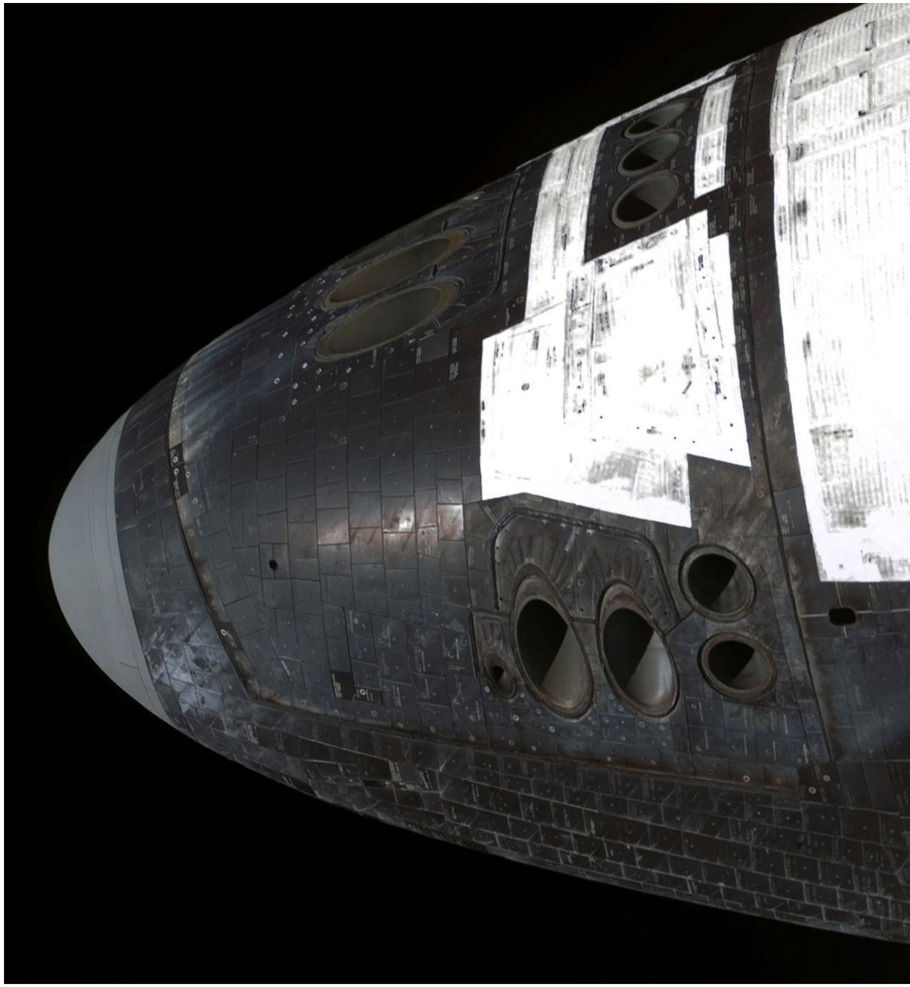


Mission ConOps

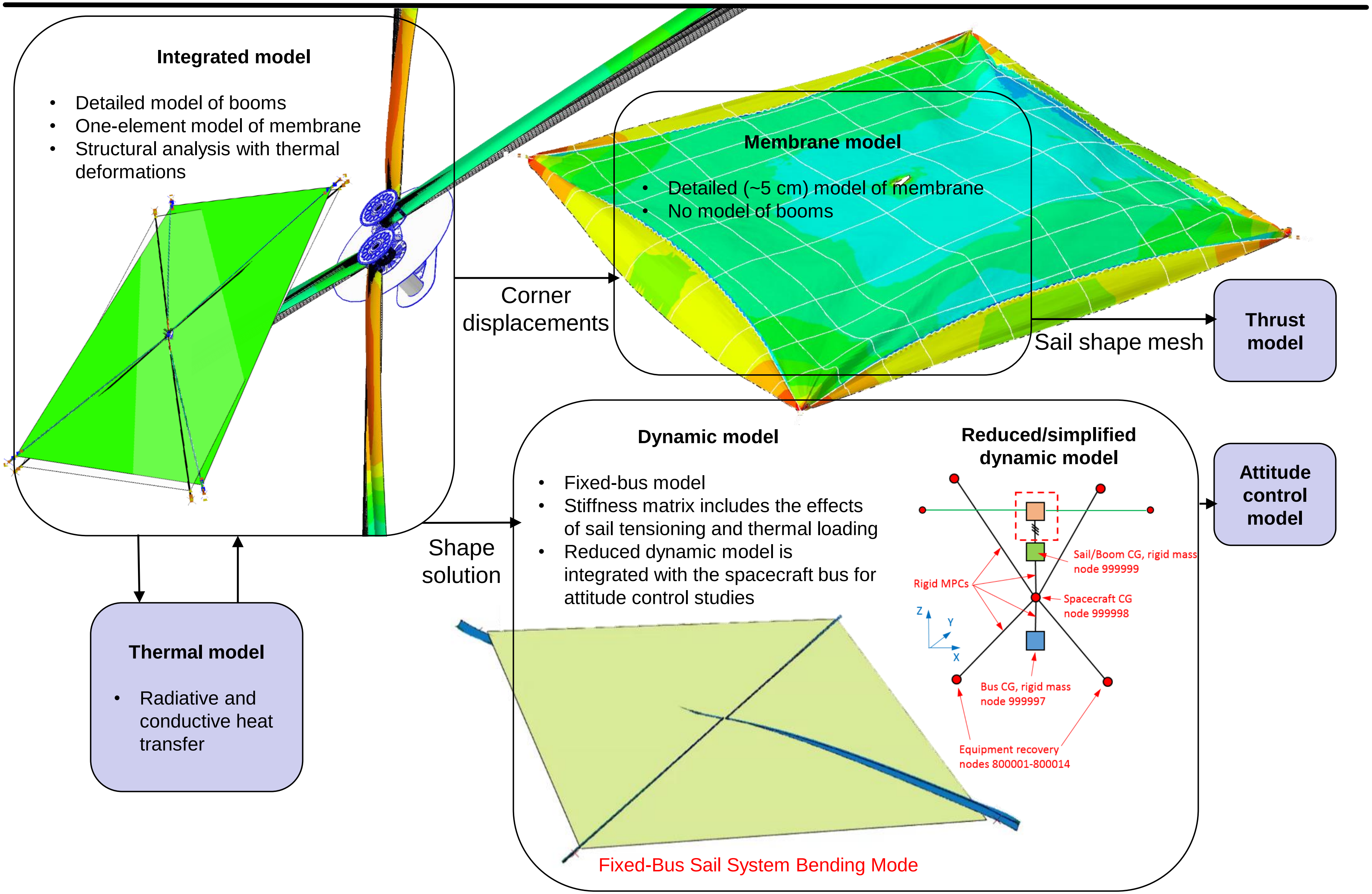


*time not to scale

Other Reaction-Jet Control System (RCS)



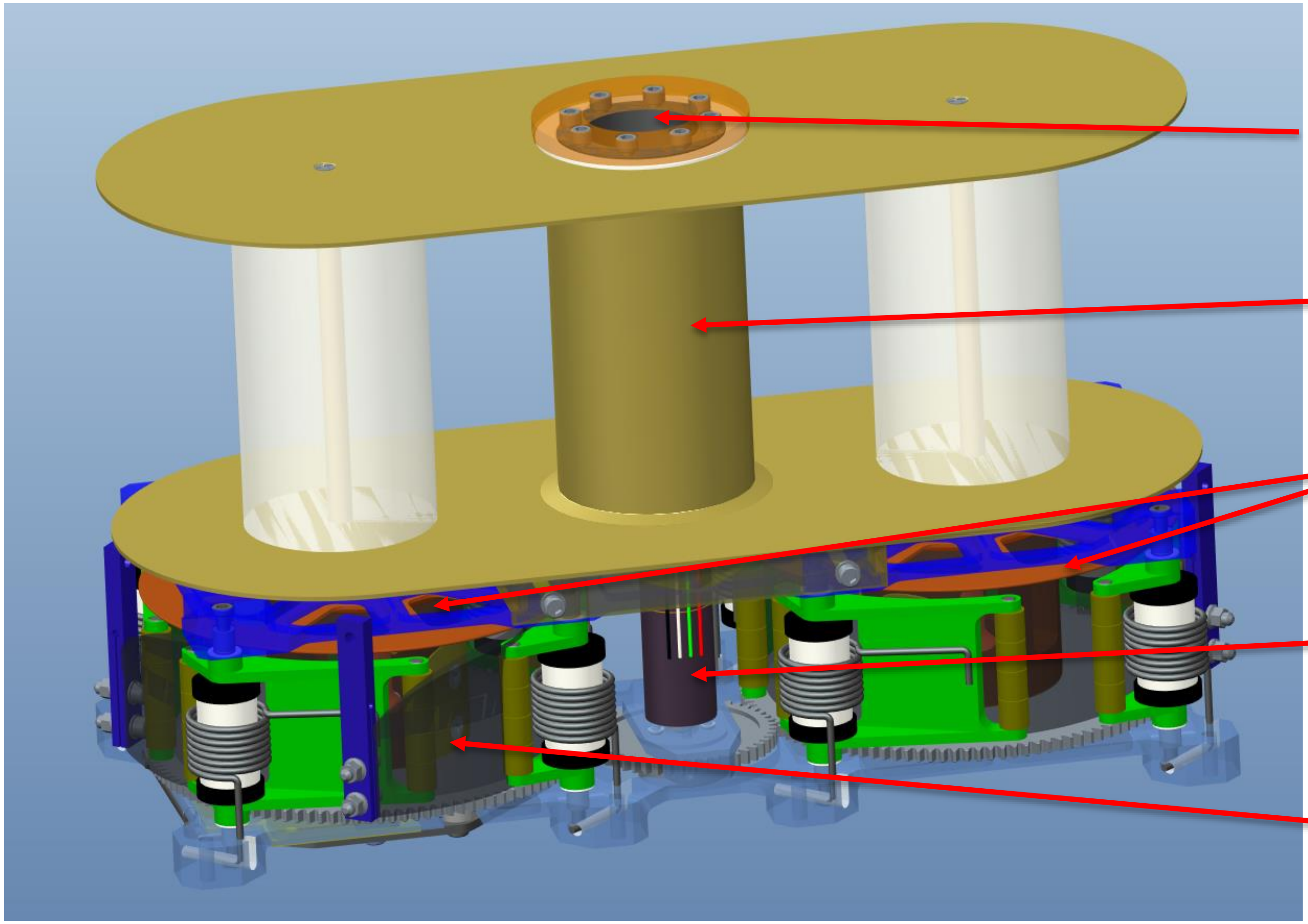
Solar Sail Thrust Model and Analysis Flowchart



Summary & Project Status

- **Summary**
  - Numerous challenges exist in implementing a Solar Sail mission, particularly within a CubeSat form factor
  - Extensive design, analysis, and testing has been performed to-date to address these challenges
  - Difficulty in validating analytical models and performing ground (1G) demonstrations given gossamer nature of Solar Sails
  - NEA Scout flight on SLS EM-1 flight opportunity (2018) will provide a giant leap forward in clarifying our understanding of Solar Sail modeling and performance
- **Project Status**
  - On track for August Design Review with significant flight procurements to follow
  - Flight System integration starts June 2017
  - Manifested on SLS EM-1 for 2018 deep space flight opportunity
  - NEA flyby anticipated in 2021

Solar Sail Subsystem Overview



Spacecraft Wire Channel

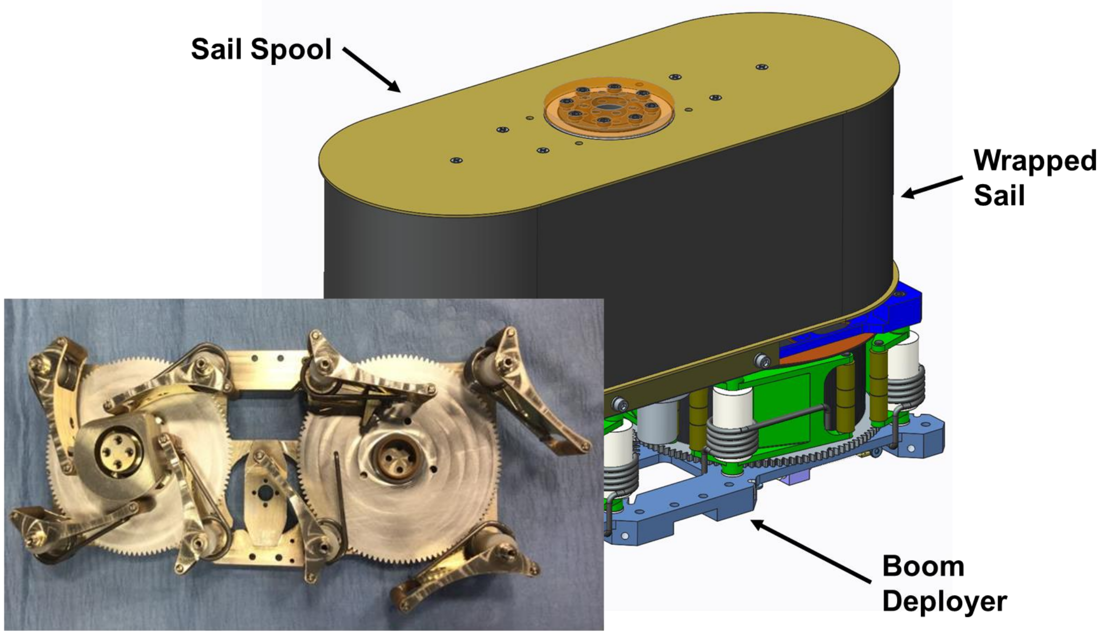
Single Sail Spool

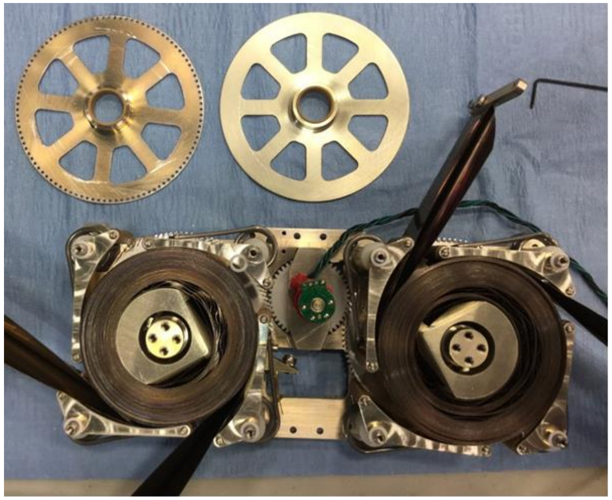
Boom Deployers

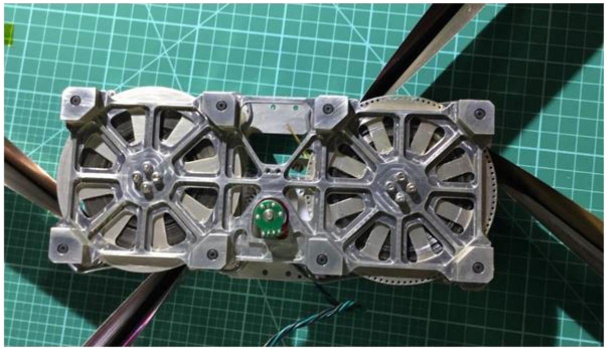
Deployment Motor

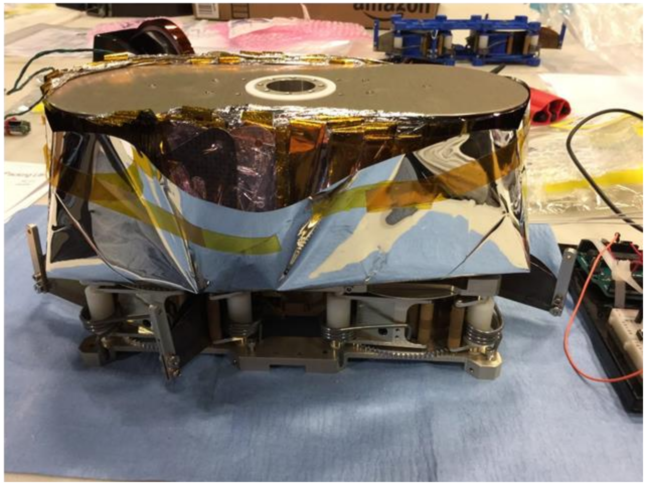
TRAC Booms

Solar Sail Subsystem Overview

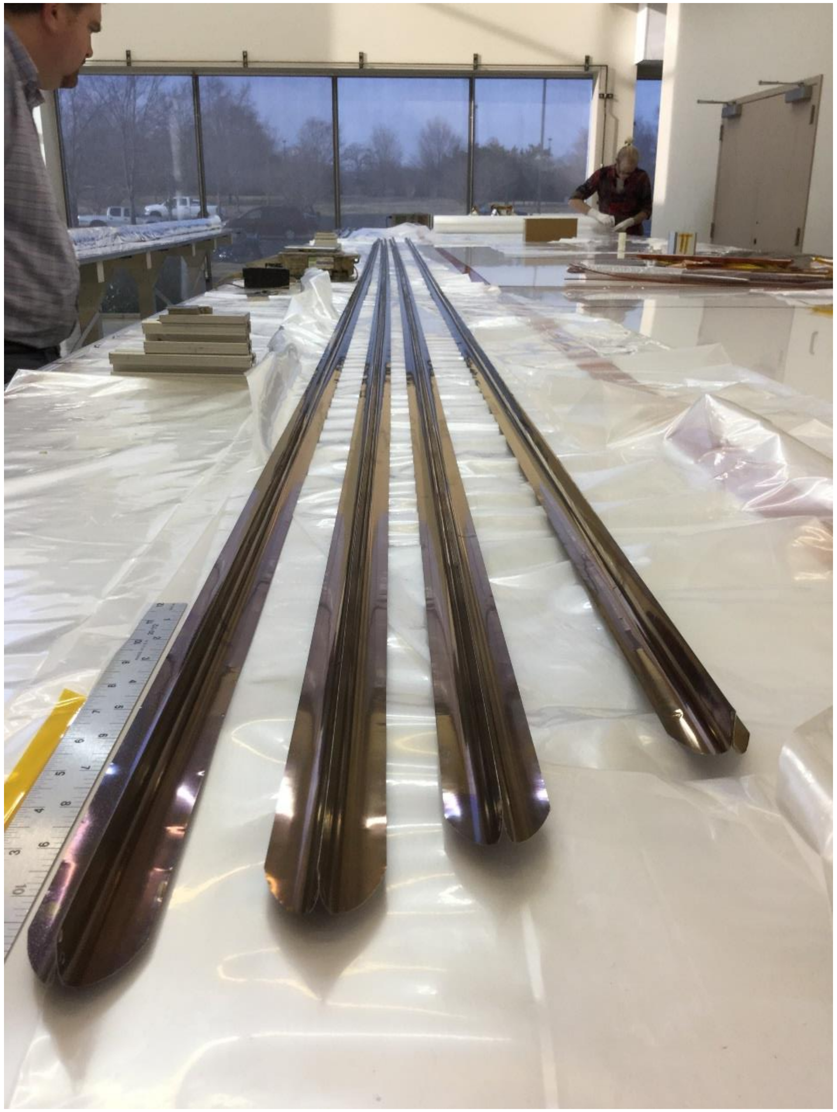






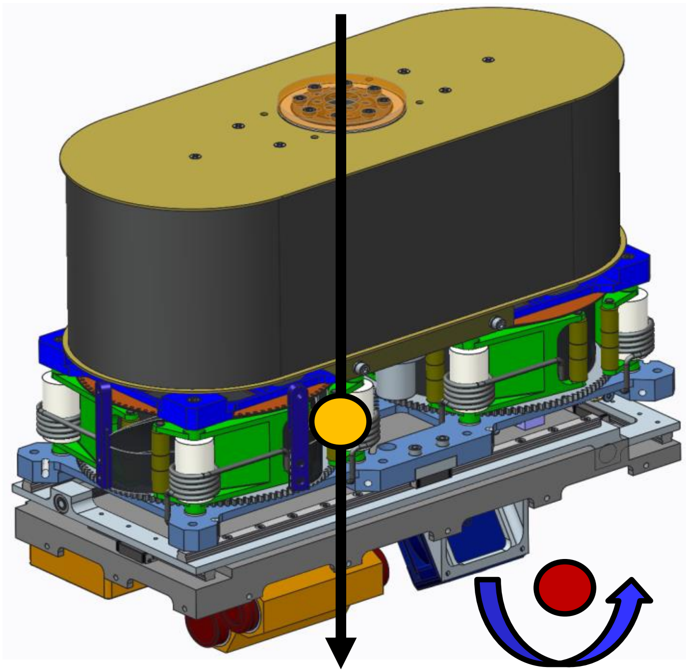


Solar Sail Booms (@NeXolve)



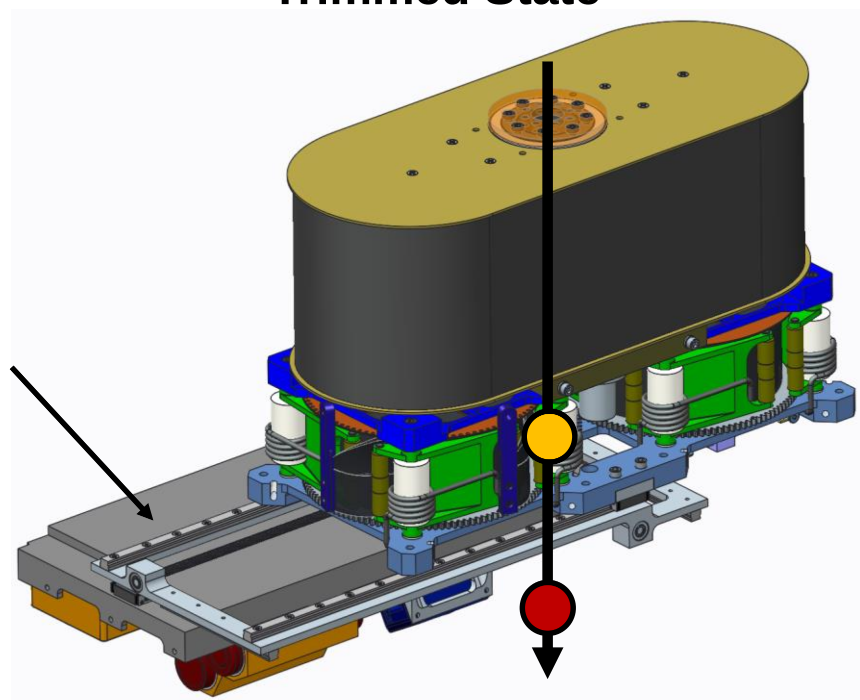
Disturbance Torques: Active Mass Translator (AMT)

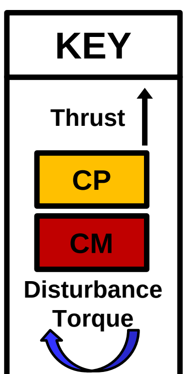
Nominal State

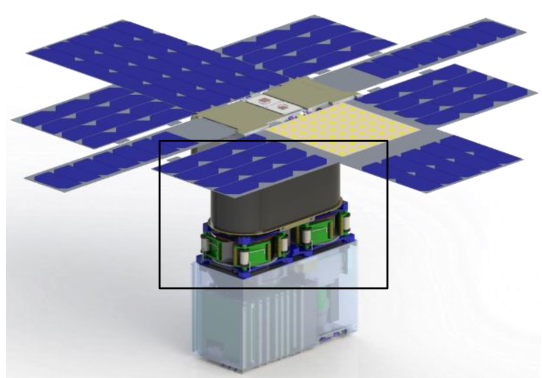


AMT

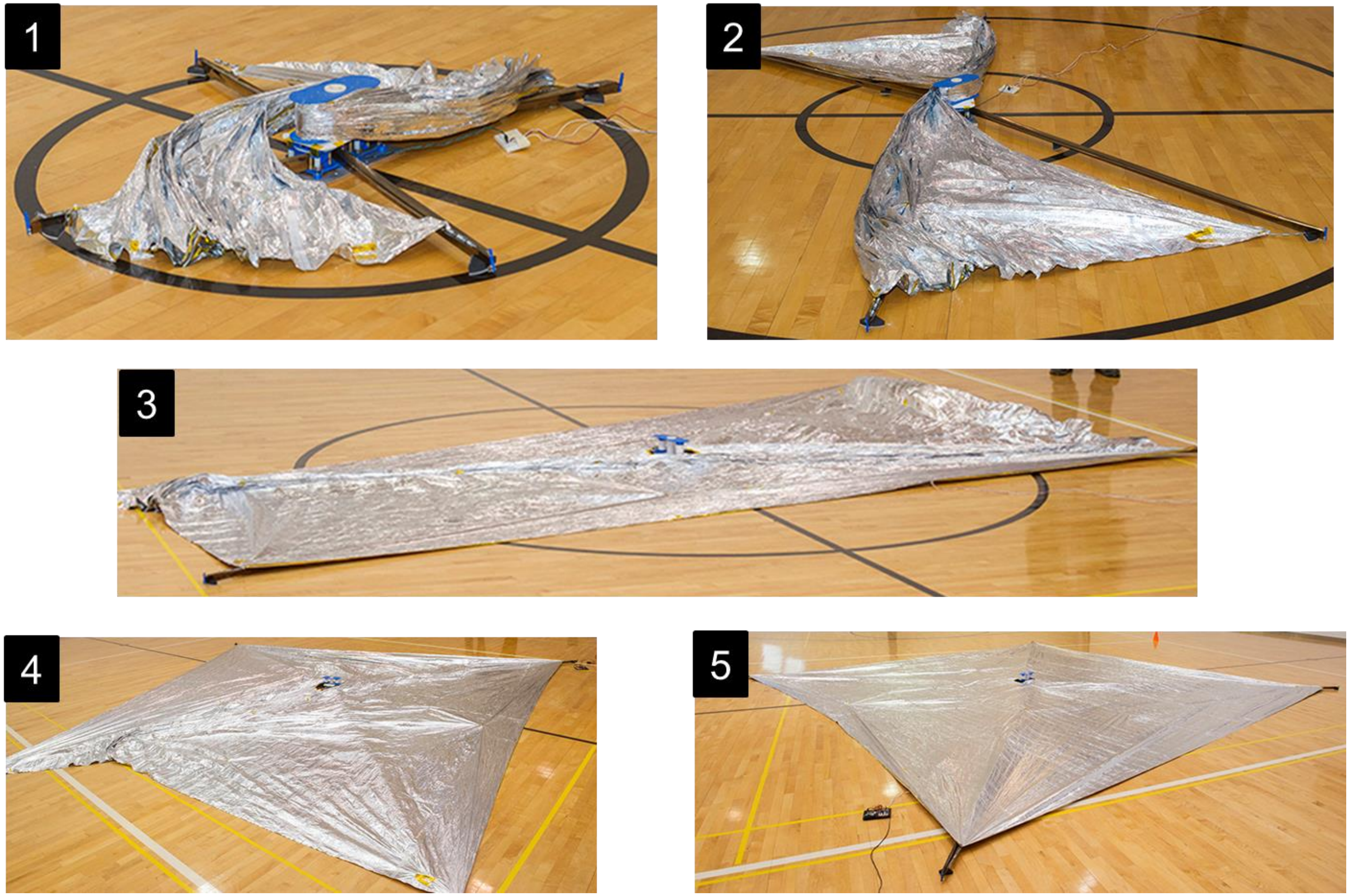
Trimmed State







Transient Solar Sail Deployment – Shape Phases



Single sail membrane drives initial ‘bow tie’ effect: Booms are do not maintain 90deg relative orientation (less predictable induced disturbance force) and direct sunlight on booms drive significant thermal deflections

NEA Scout Science