Development of a High Performance, Low Profile Translation Table with Wire Feedthrough for a Deep Space CubeSat

Alex Few

May 4, 2016

43rd Aerospace Mechanisms Symposium

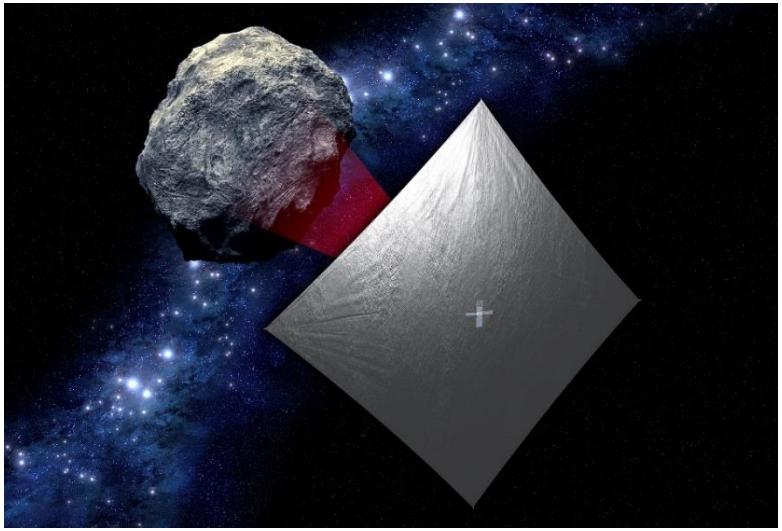
Agenda

- **Near Earth Asteroid (NEA) Scout Overview**
- **Active Mass Translator (AMT) Overview**
  - What is “Active Mass Translation”
  - Definition of Problems and Challenges
- **Current Design State**
- **Takeaways**
  - Innovations
  - Lessons learned
  - Forward Work

NEA Scout Overview

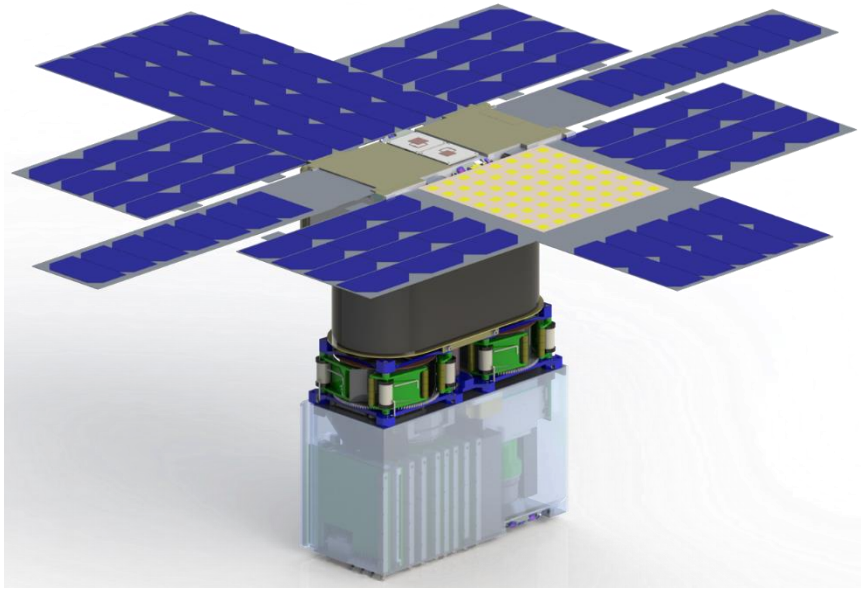
Goal:

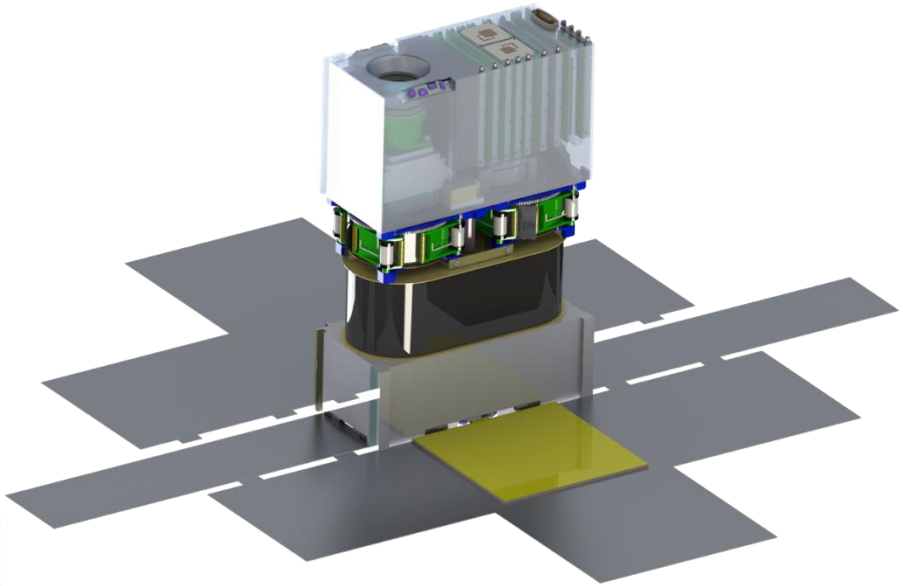
Characterize a NEA during flyby while demonstrating low cost reconnaissance capability



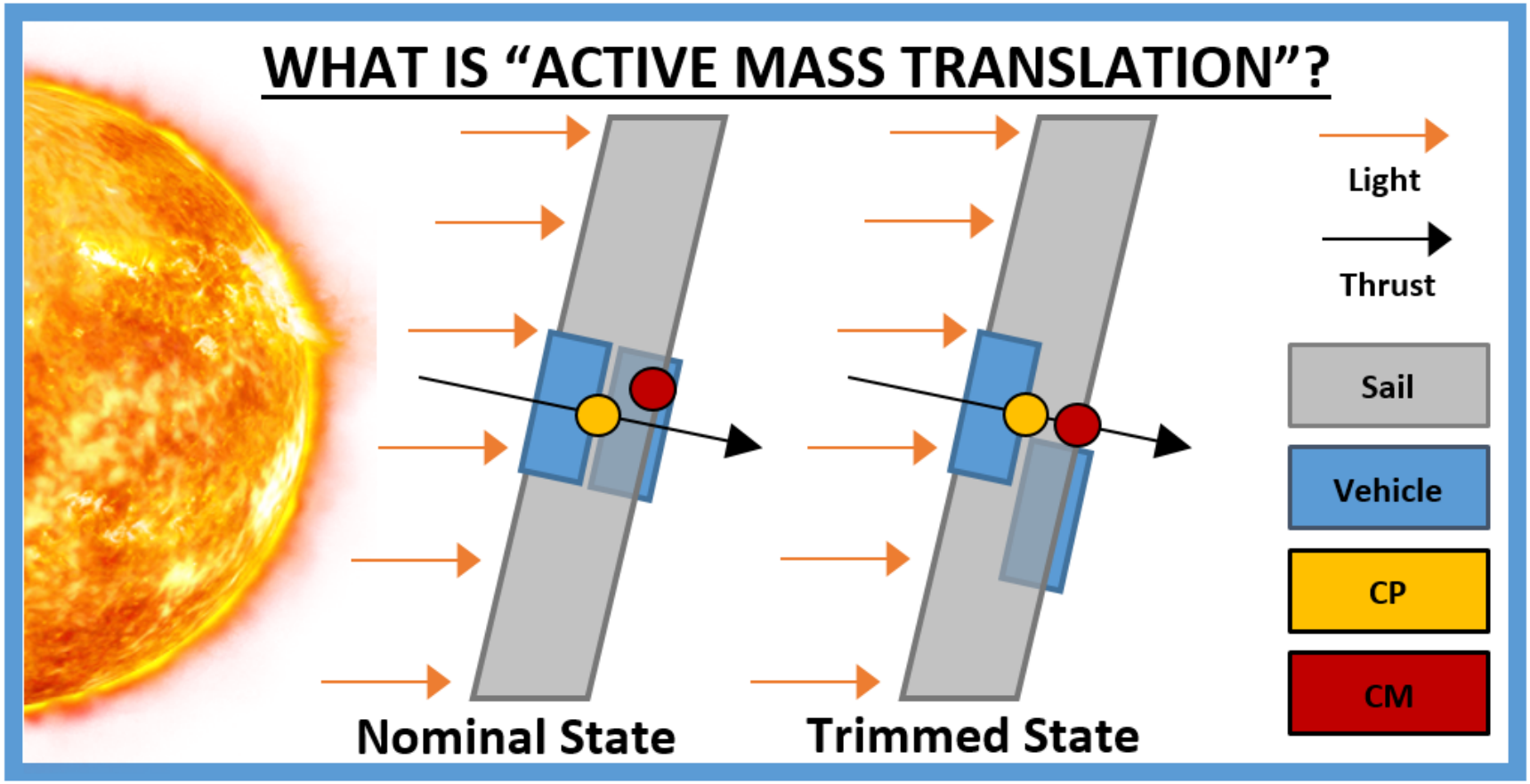
Vehicle and Mission Details:

- **6U CubeSat manifested on SLS Exploration Mission 1**
- **86m^2 solar sail propulsion**
- **2.5 year mission**
- **1.5 x10^8 km (1 AU) distance from Earth**





AMT Overview

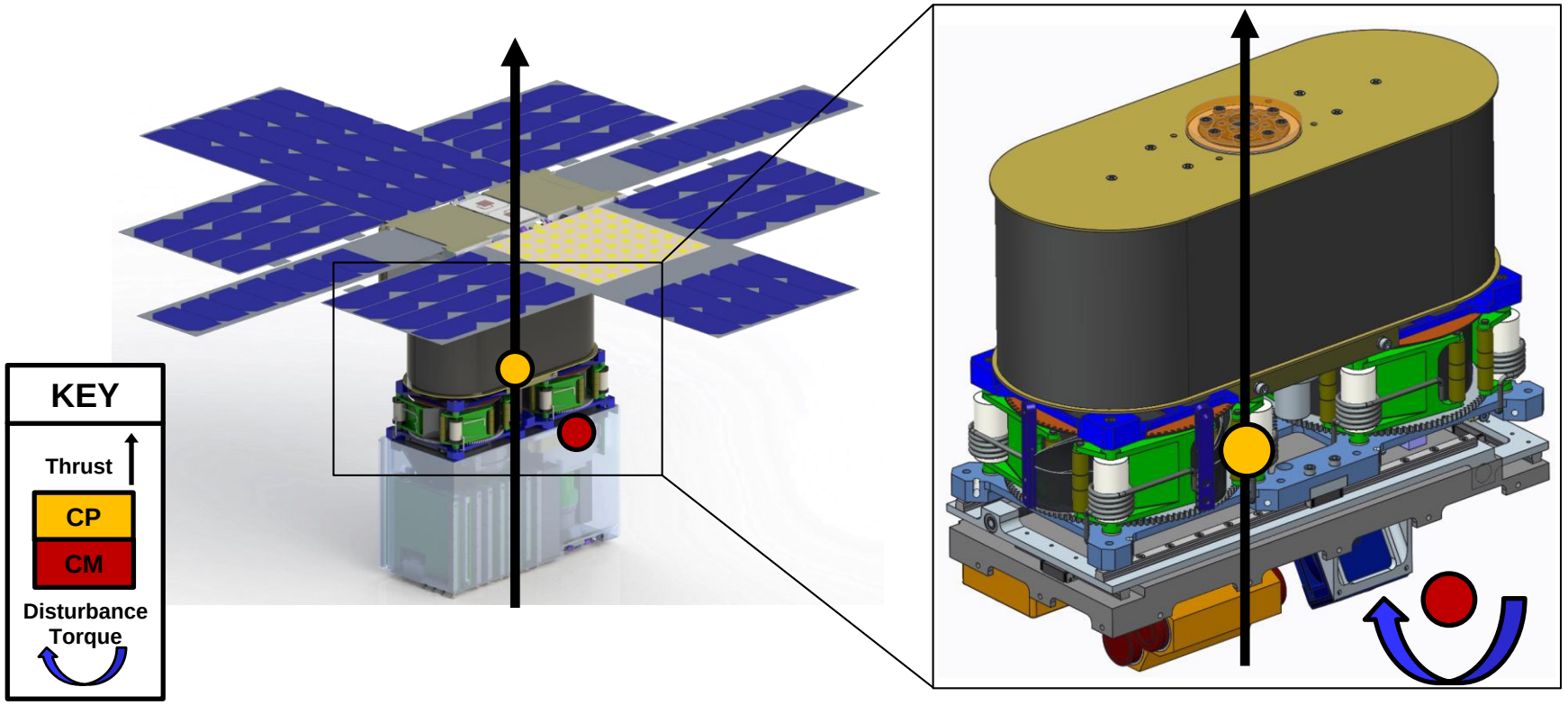


The AMT will move one portion of the NEA Scout relative to the other. This translation of mass will alter the inertial properties of the vehicle and align the CP and CM

AMT Overview

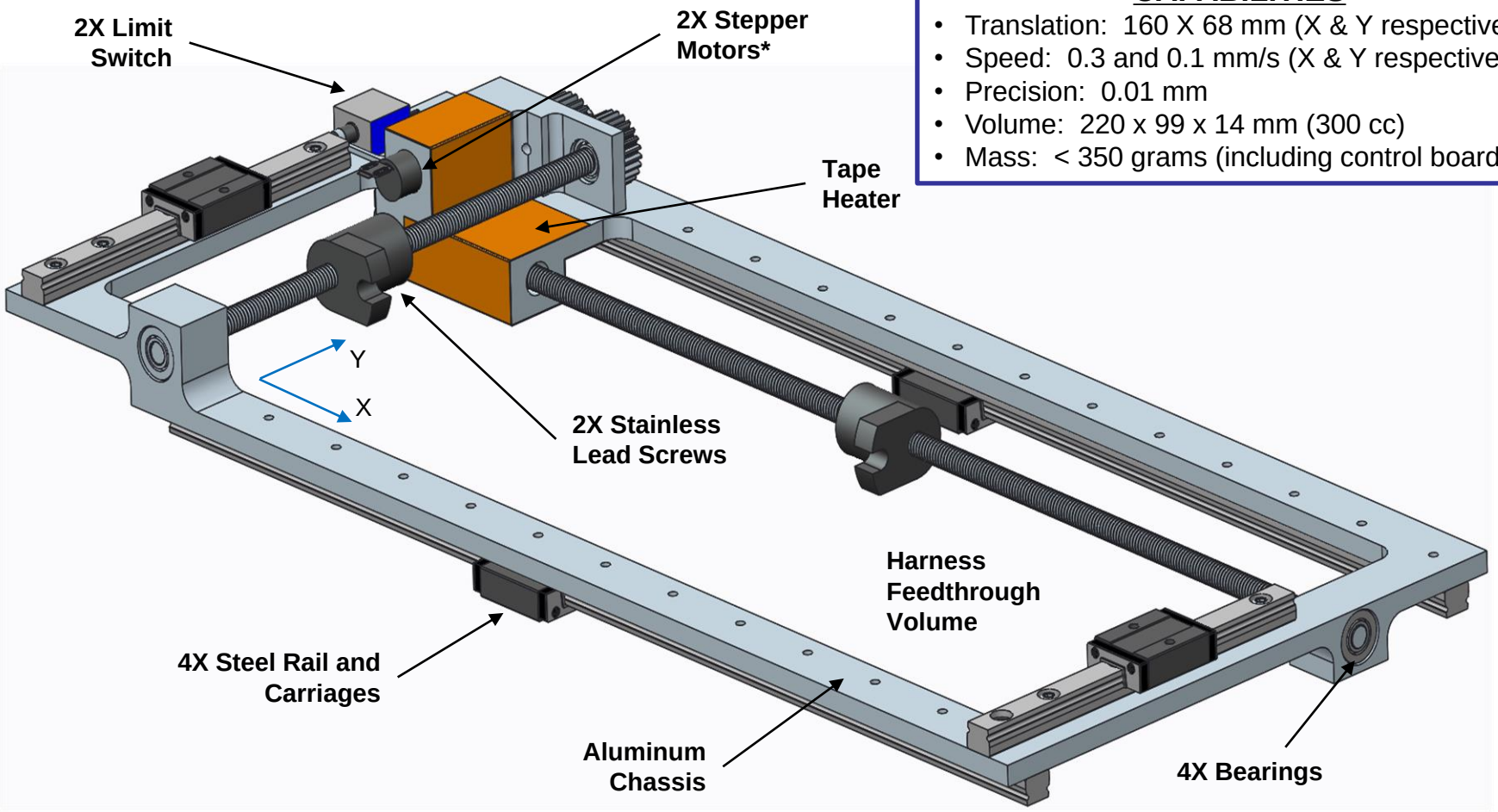
Problems and Challenges

- 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 deeps space environments.



AMT Overview

Current Design State

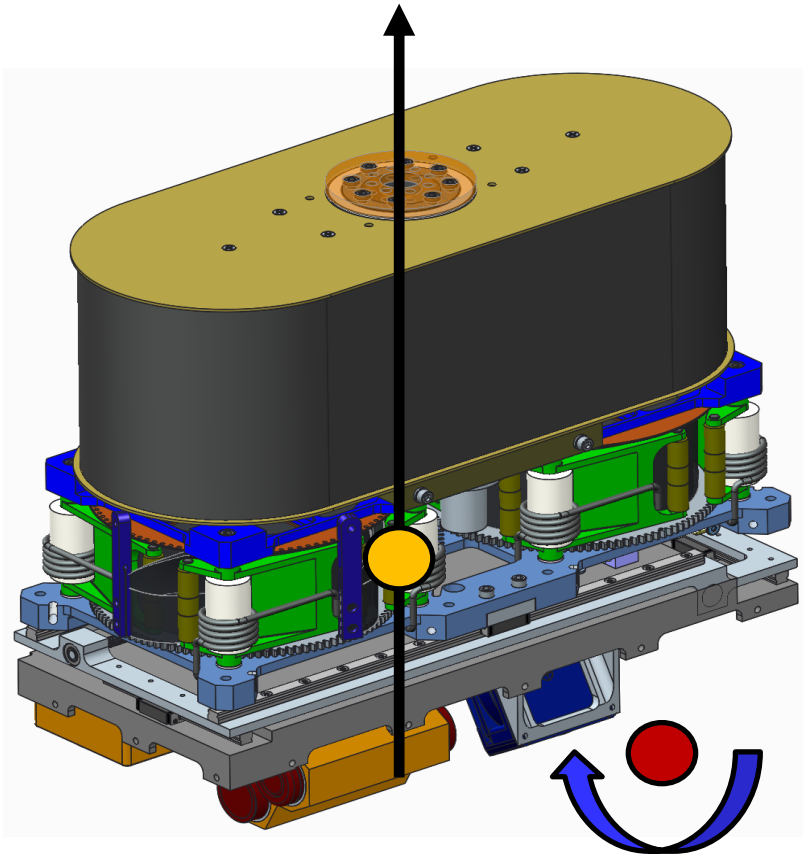


CAPABILITIES

- 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

AMT Overview



Nominal State

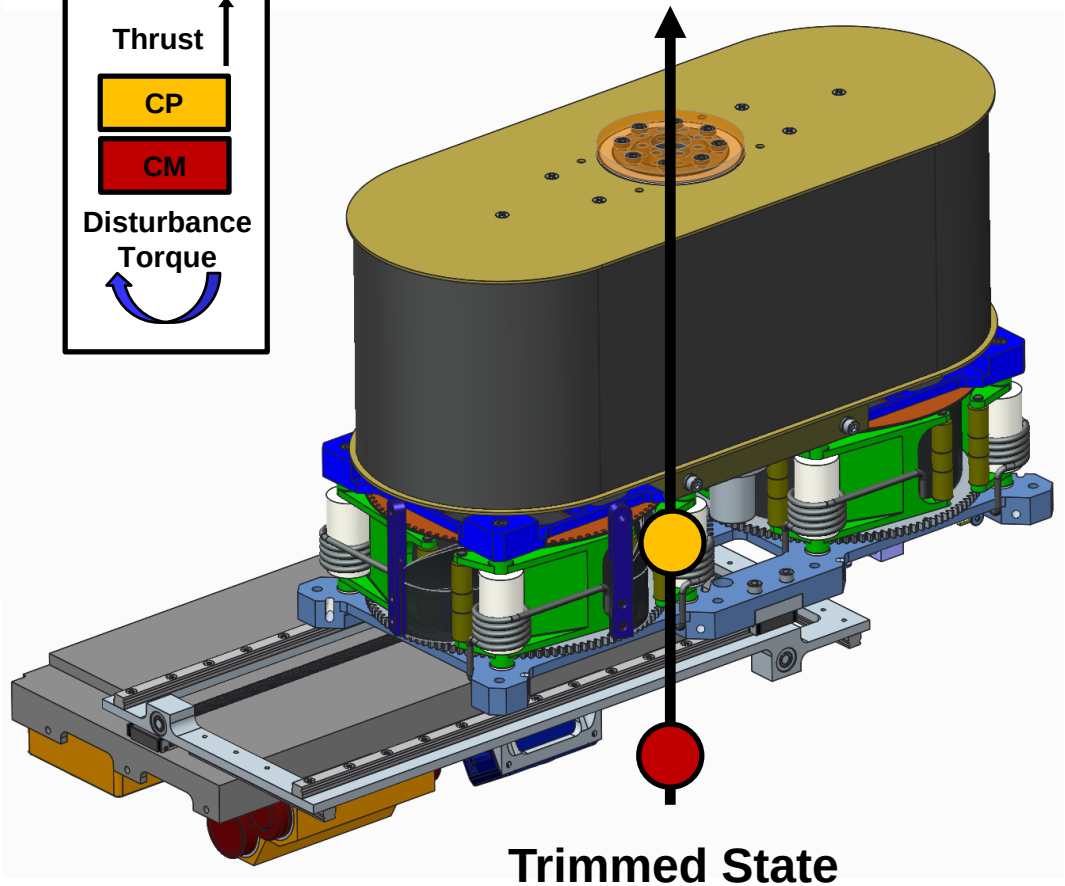
KEY

Thrust

CP

CM

Disturbance Torque



Trimmed State

Takeaways

Innovations

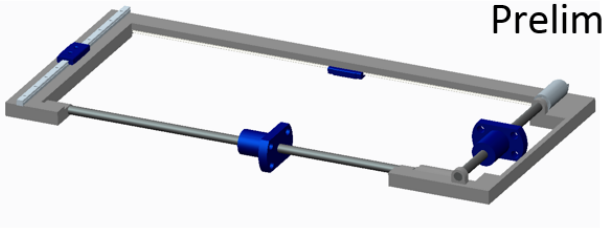
- Unique use of flight system inertial augmentation as trimming mechanism
- Translation Table tailored for deep space CubeSat environments and mechanical demands
- “Inverted” design allows for wire harness to pass through translation stage

Lessons Learned

- Treat CubeSats as they are: lower cost, higher risk projects
- Test as early as possible
- Complete rough thermal and loads analysis between concept and revising phases
- Use additive manufacturing to increase design progress during prototype phase

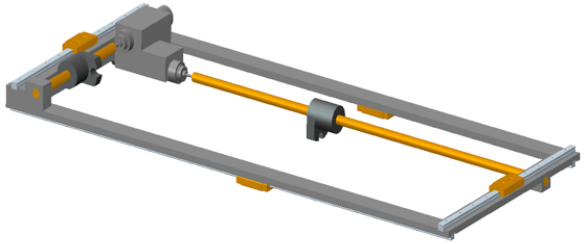
Forward Work

- Wire Bundle design, safety, and routing
- Development Unit Testing (life cycle, thermal vacuum, random vibration)
- Higher fidelity thermal and stress analysis
- Design simplification and mass reduction



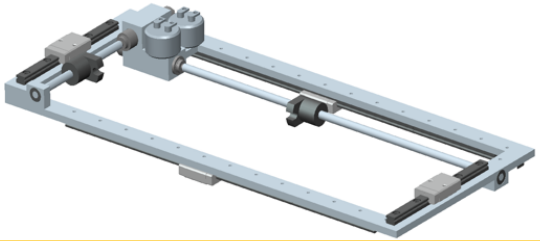
Preliminary Concept
July 2015

Mass	Height
Translation	Harness
Thermal	Strength



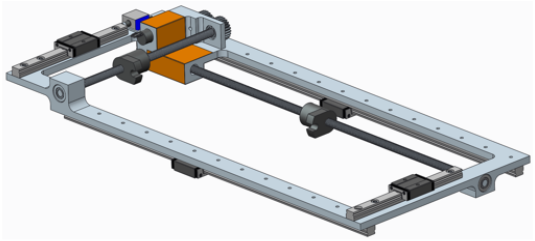
Revision 1
October 2015

Mass	Height
Translation	Harness
Thermal	Strength



Revision 2
December 2015

Mass	Height
Translation	Harness
Thermal	Strength



Revision 3
March 2016

Mass	Height
Translation	Harness
Thermal	Strength

Backup

- **AMS Poster (36” X 48”)**

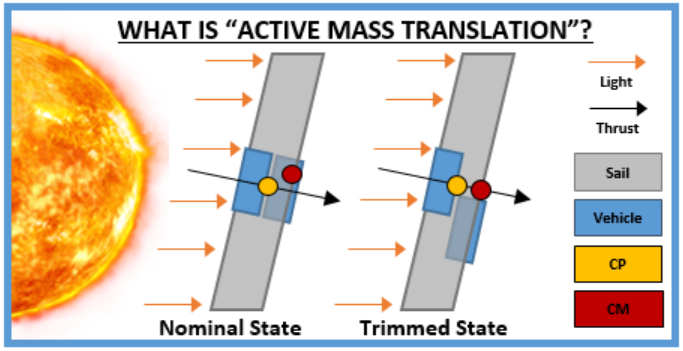
Development of a High Performance, Low Profile Translation Table with Wire Feedthrough for a Deep Space CubeSat

Alex Few
NASA Marshall Space Flight Center

PROBLEM STATEMENT:

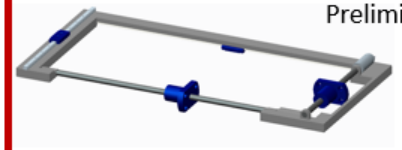
Near Earth Asteroid (NEA) Scout, a 6U cubesat, will use an 86 m^2 solar sail to travel about 1 astronomical unit (1.5 x 10^8 km) to a near-earth asteroid for observation and reconnaissance. Nine months ago, the project introduced a new subsystem called the Active Mass Translator (AMT). The AMT will be designed to overcome a controllability challenge created by a misalignment of the sail's center of pressure (CP) and the vehicle's center of mass (CM). Furthermore, the CP is fore of the CM, creating a naturally unstable vehicle and necessitating an active control mechanism.

WHAT IS "ACTIVE MASS TRANSLATION"?



CHALLENGES:

As with any subsystem introduced late in the design process, there is 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 AMT will reside near the geometric center of the vehicle, splitting the avionics and reaction control systems. The wire harness must pass through the AMT and survive exposure to deeps space environments.

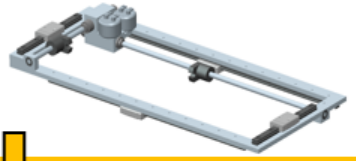


Preliminary Concept
July 2015

Mass	Height
Translation	Harness
Thermal	Strength

Revision 1
October 2015

Mass	Height
Translation	Harness
Thermal	Strength

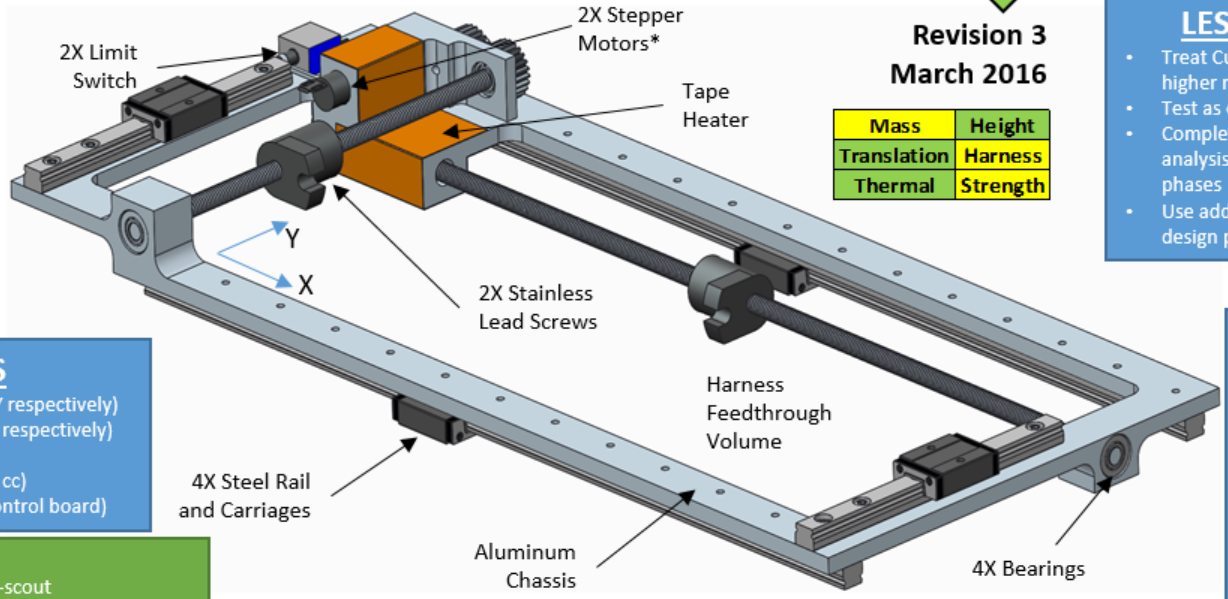


Revision 2
December 2015

Mass	Height
Translation	Harness
Thermal	Strength

INNOVATIONS

- Unique use of flight system inertial augmentation as trimming mechanism
- Translation Table tailored for deep space CubeSat environments and mechanical demands
- "Inverted" Translation Table allowed for wire harness to pass through translation stage



Revision 3
March 2016

Mass	Height
Translation	Harness
Thermal	Strength

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

LESSONS LEARNED

- Treat CubeSats as they are: lower cost, higher risk projects
- Test as early as possible
- Complete rough thermal and loads analysis between concept and revising phases
- Use additive manufacturing to increase design progress during prototype phase

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)

FORWARD WORK

- Wire Bundle design, safety, and routing
- Development Unit Testing (life cycle, thermal vacuum, random vibration)
- Higher fidelity thermal and stress analysis
- Design simplification and mass reduction

MORE INFORMATION
https://www.nasa.gov/content/nea-scout
https://www.youtube.com/watch?v=Ao7gfoW4wkA