Outline

2:00 pm: Introduction & Welcome

2:15 pm: Camera

2:45 pm: Boom

3:15 pm: Mirror Boxes

3:45 pm: On-board Software

4:15 pm: Electronics

Mission Overview

Maria Sakovsky

Motivation: Building Large Space Telescopes

- Mirror dia. of current and planned space telescopes limited by constraints of a single launch
  – Hubble (1990): Ø 2.4 m
  – JWST (2018): Ø 6.5 m
  – HDST (2030+): Ø 11.7 m
- New paradigms needed for Ø 30 m+ segmented primary:
  – Autonomous assembly in orbit
  – Active ultralight mirror segments
- Active mirrors relax tolerances for assembly and manufacturing, correct thermal distortions
- Modular, robust, low-cost architecture

JWST

HDST

Caltech

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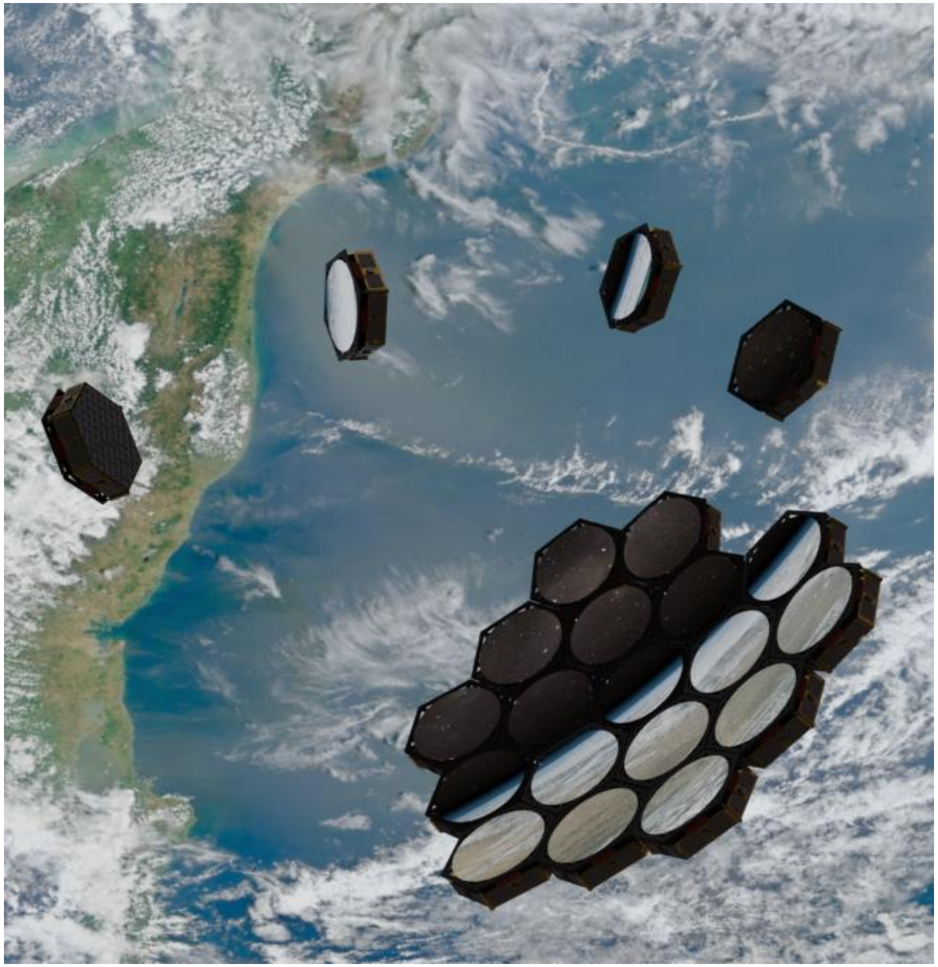

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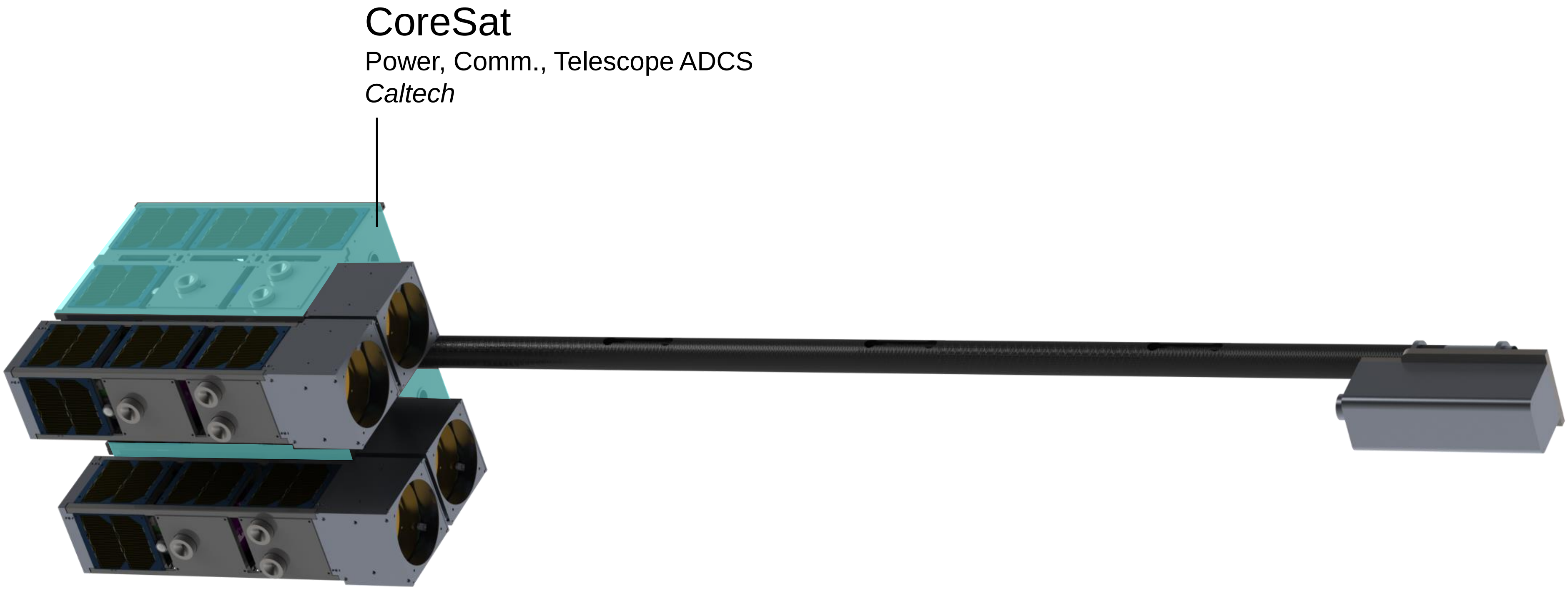
AAReST Objectives

- Demonstrate key technologies:
  - Autonomous assembly and reconfiguration of modular spacecraft carrying mirror segments
  - Active, lightweight deformable mirrors operating as segments in a primary
- Operate for as long as necessary to accomplish the objectives (~90 days)
- Gather engineering data to enable development of the next system

AAReST Spacecraft

Caltech

AAReST Spacecraft



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AAReST Spacecraft

MirrorSat (×1)
Reconfigurable free-flyers
U. of Surrey

CoreSat
Power, Comm., Telescope ADCS
Caltech

MirrorSat (×1)
Reconfigurable free-flyers
IIST

Caltech

AAReST Spacecraft

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Deformable Mirrors (×2)
Active mirror segments
Caltech

MirrorSat (×1)
Reconfigurable free-flyers
IIST

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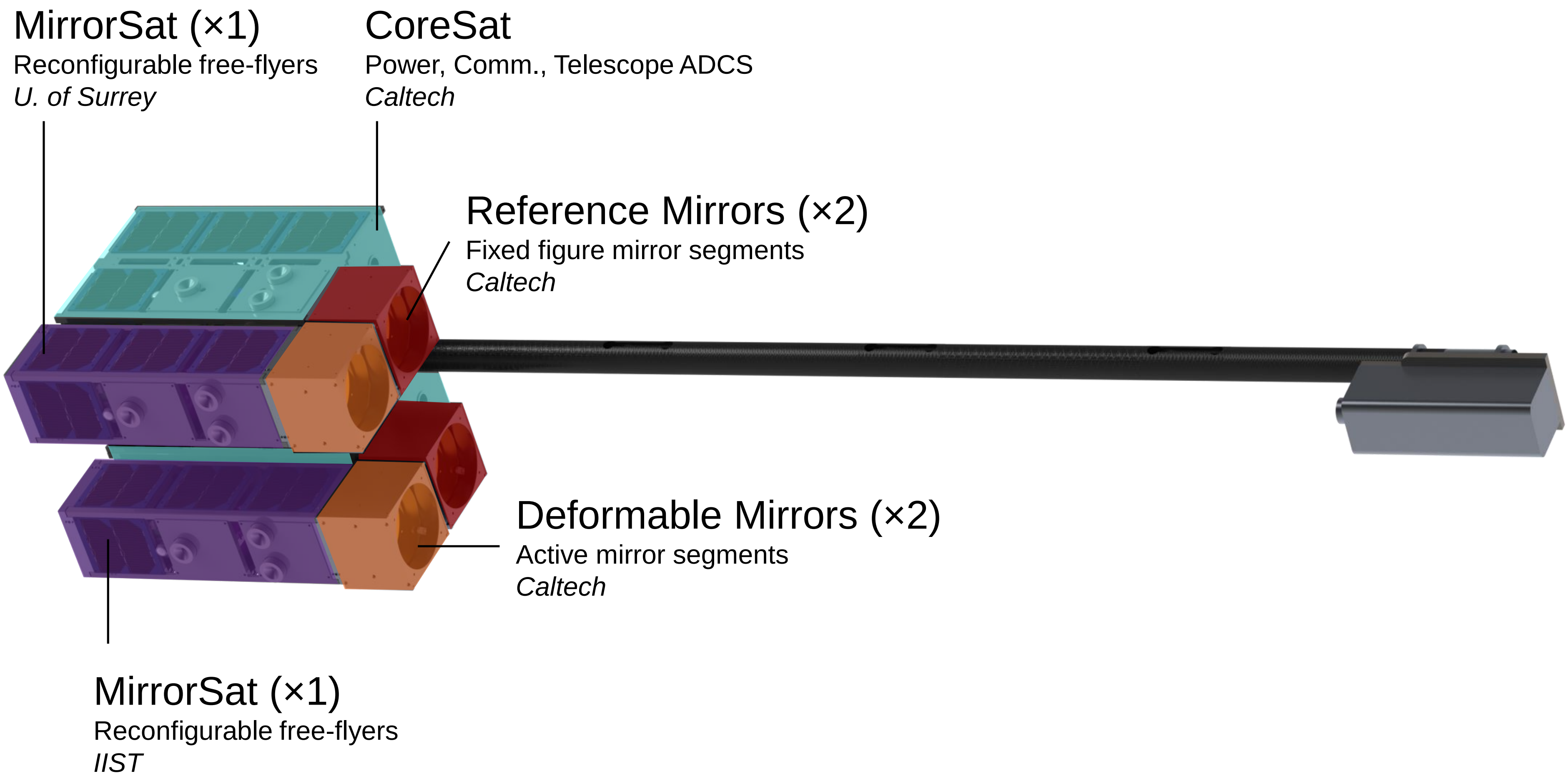
AAReST Spacecraft



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AAReST Spacecraft

MirrorSat (×1)
Reconfigurable free-flyers
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CoreSat
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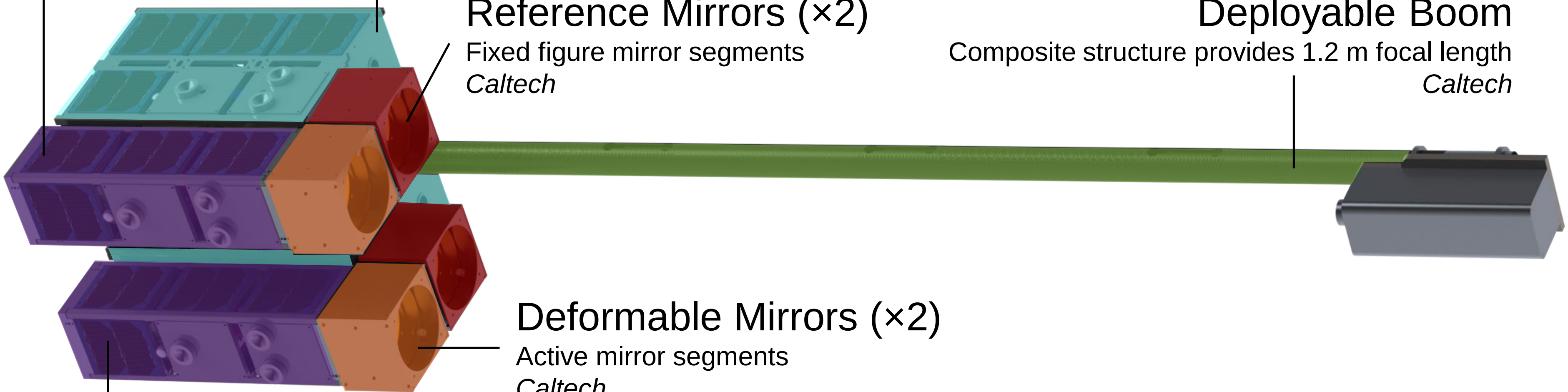
Reference Mirrors (×2)
Fixed figure mirror segments
Caltech

Deployable Boom
Composite structure provides 1.2 m focal length
Caltech



Deformable Mirrors (×2)
Active mirror segments
Caltech

MirrorSat (×1)
Reconfigurable free-flyers
IIST

AAReST Spacecraft

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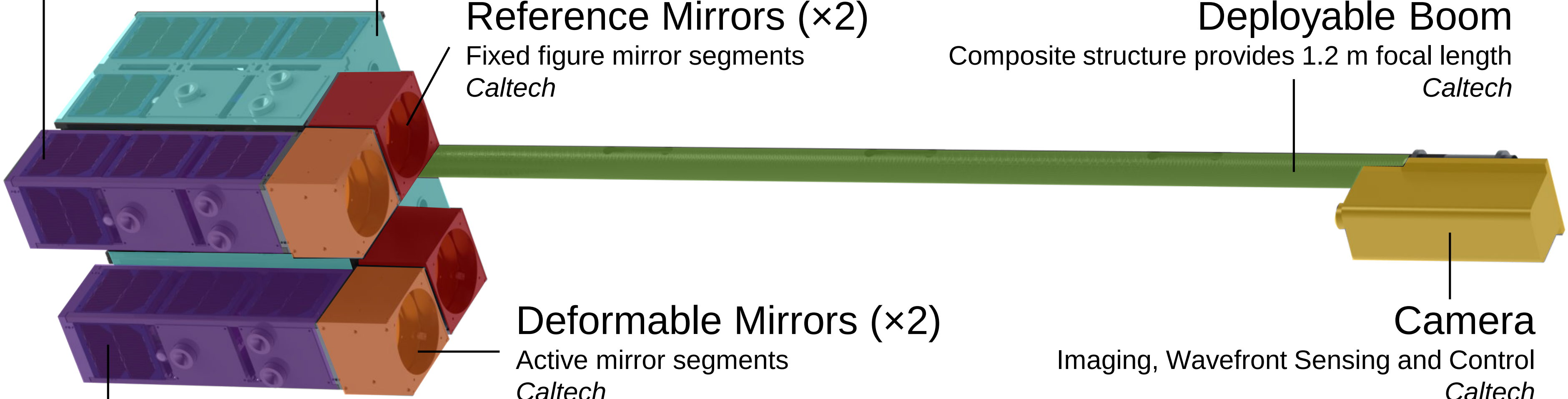

Deformable Mirrors (×2)
Active mirror segments
Caltech

Camera
Imaging, Wavefront Sensing and Control
Caltech

MirrorSat (×1)
Reconfigurable free-flyers
IIST

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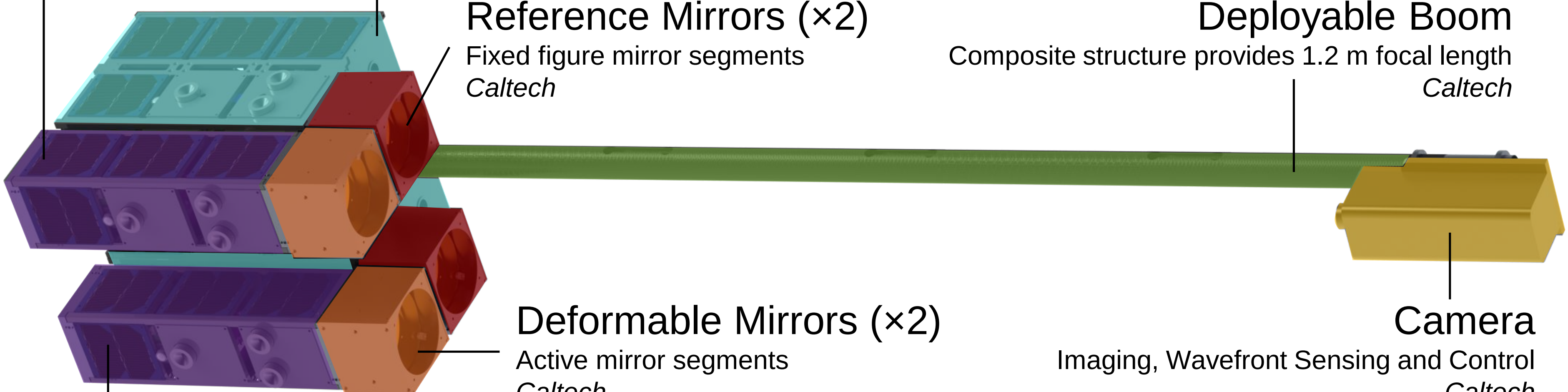
AAReST Spacecraft



Mass: <40 kg Launch Volume: 46 × 34 × 30 cm	Prime focus telescope 465 nm – 615 nm 0.34° field of view 1.2 m focal length	UHF down VHF up	Ref. orbits: ~650 km SSO ISS (400 km, 52 deg. incl.)

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Mission Requirements

- Minimum mission
  1. Produce one focused image from a deformable mirror
     - 80% encircled energy radius from point source < 25 µm
  2. Perform at least one in-flight autonomous spacecraft reconfiguration maneuver to demonstrate space assembly capability
- Extended mission
  1. Produce one focused image from a deformable mirror after reconfiguration
  2. Coalign images to improve SNR and demonstrate precursor to co-phasing
  3. Produce at least two images of other sources (e.g. Earth and Moon) for outreach purposes

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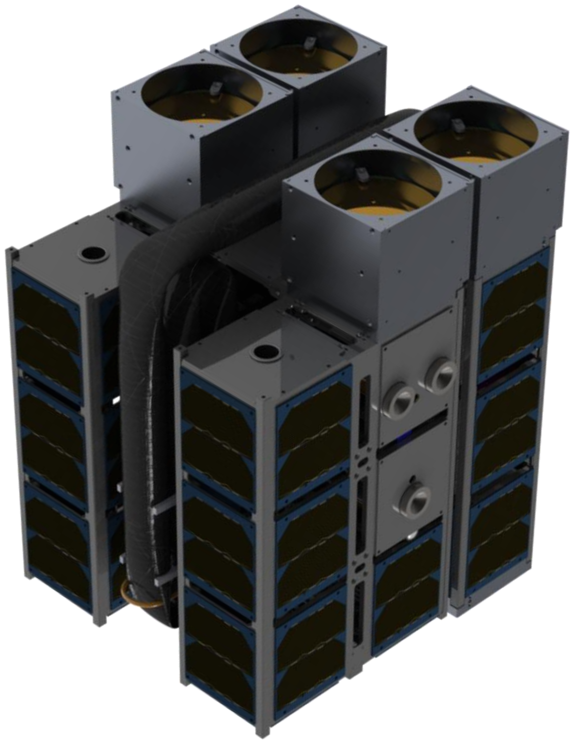
Concept of Operations

1. Launch	2. Telescope Deployment	3. Telescope Calibration & Imaging	4. Reconfiguration	5. Telescope Recalibration & Imaging	6. Extended Mission



Launch in a compact, stowed volume

- 46 cm × 34 cm × 30 cm

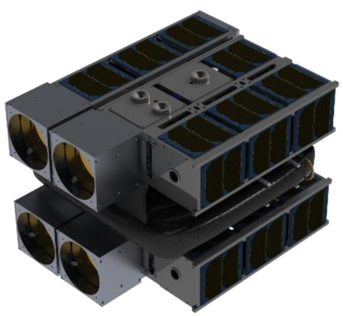
Caltech

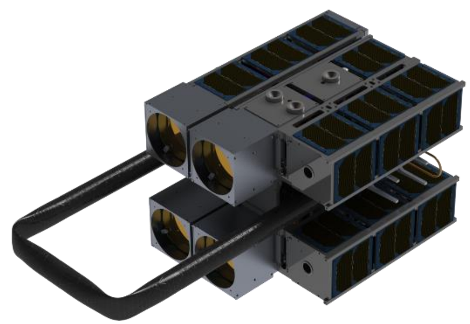
Concept of Operations

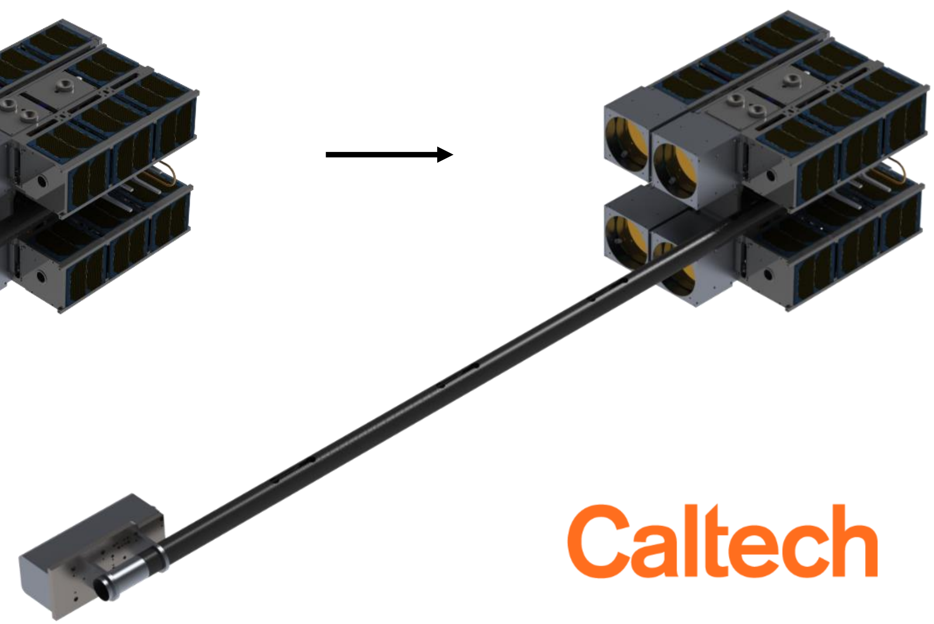
1.	2.	3.	4.	5.	6.
Launch	Telescope Deployment	Telescope Calibration & Imaging	Reconfiguration	Telescope Recalibration & Imaging	Extended Mission

- Turn on, verify satellite components
- Stabilize attitude, temperature

- Deploy boom in two stages:
  1. Boom segments unfold
  2. Camera is released
- Uncage deformable mirrors







Concept of Operations

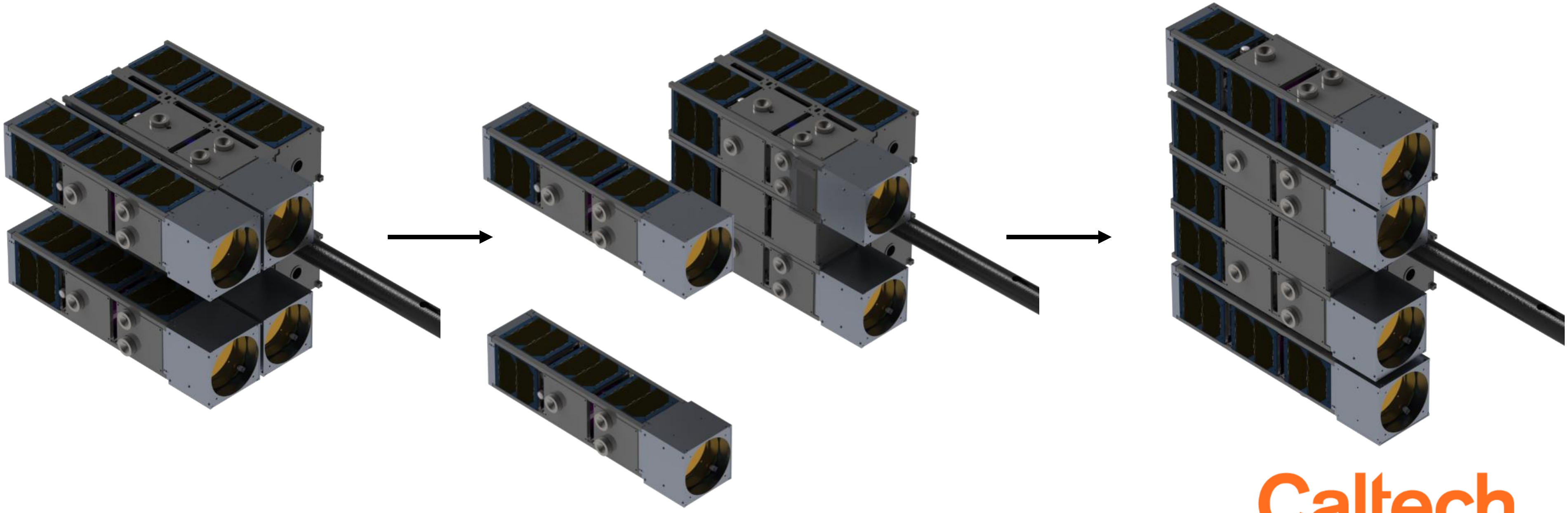
1.	2.	3.	4.	5.	6.
Launch	Telescope Deployment	Telescope Calibration & Imaging	Reconfiguration	Telescope Recalibration & Imaging	Extended Mission

- Telescope points to a bright reference star
- Calibrate:
  - Segment tip/tilt/piston
  - Deformable mirror surface figure
- Camera provides feedback for segment calibration

Concept of Operations

1. Launch	2. Telescope Deployment	3. Telescope Calibration & Imaging	4. Reconfiguration	5. Telescope Recalibration & Imaging	6. Extended Mission

- MirrorSats release from CoreSat (one at a time)
- Fly out ~1 m
- Re-dock into "wide" configuration



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Concept of Operations

1. Launch	2. Telescope Deployment	3. Telescope Calibration & Imaging	4. Reconfiguration	5. Telescope Recalibration & Imaging	6. Extended Mission

- Co-align star images from different segments to improve SNR
  - Pre-cursor to co-phasing
- Produce images of extended sources (e.g. Moon, Earth) for outreach

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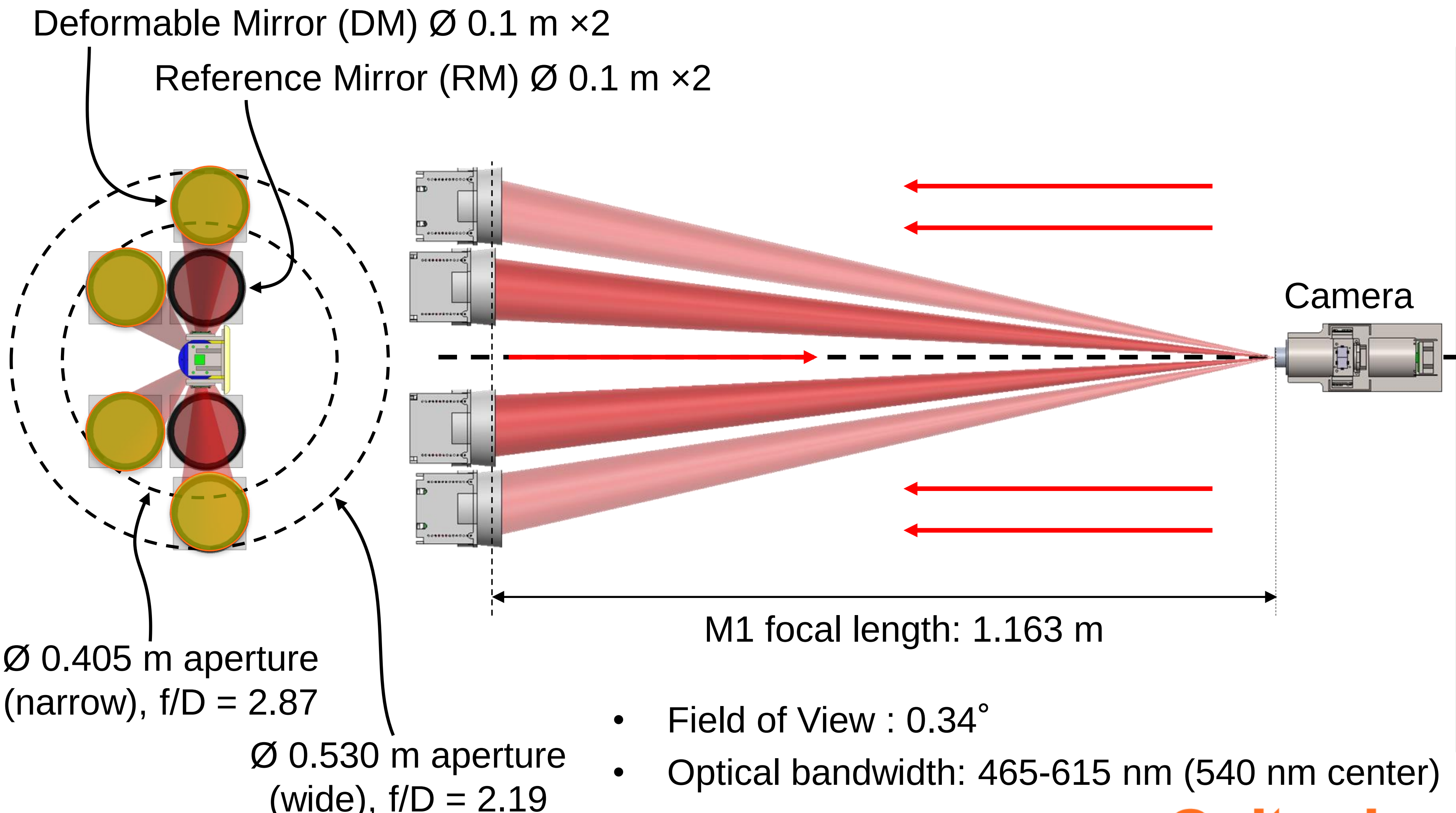
AAReST Optical Overview



- Field of View : 0.34°
- Optical bandwidth: 465-615 nm (540 nm center)

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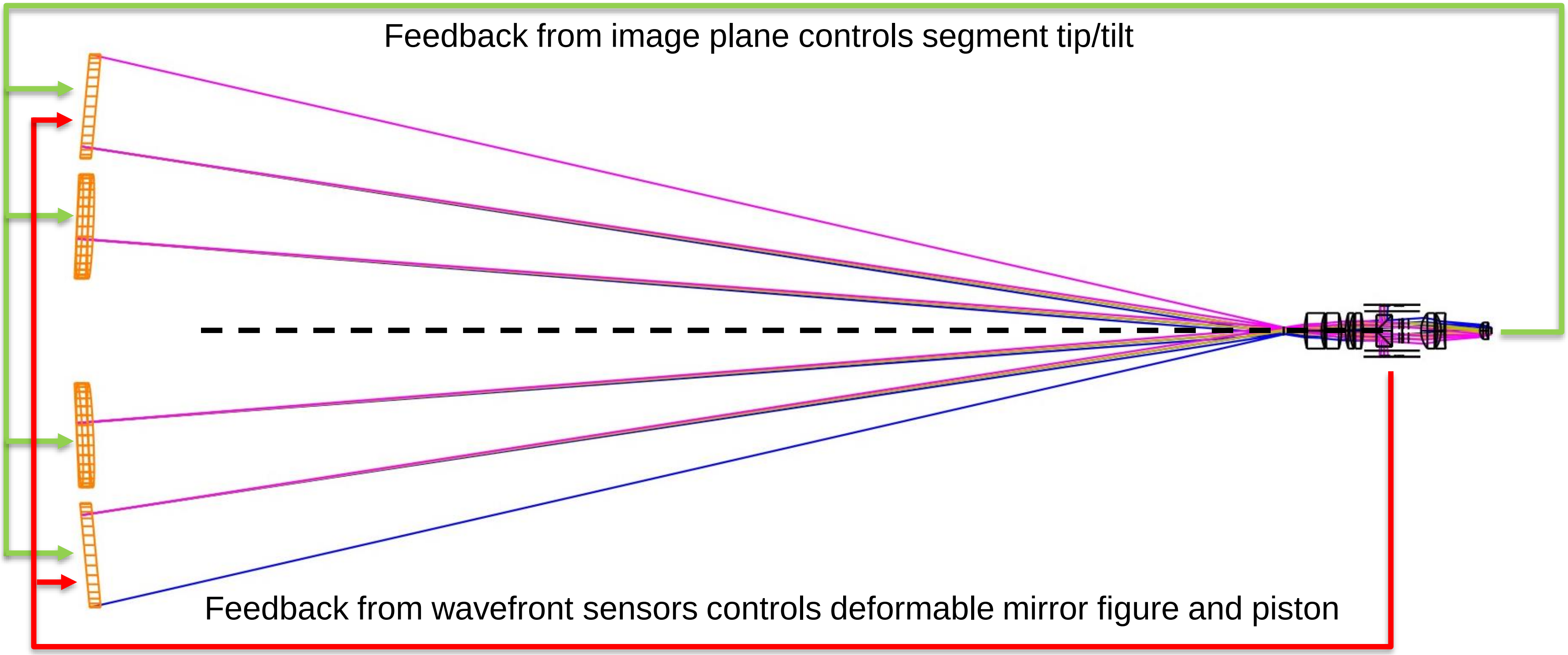
Telescope Alignment and Control

- Actuators:
  - 3 rigid body motion (RBM) actuators per segment
  - 41 piezoelectric actuators per deformable mirror
- Sensors:
  - Image plane camera
  - Shack-Hartmann Wavefront Sensors (SHWS)



Caltech

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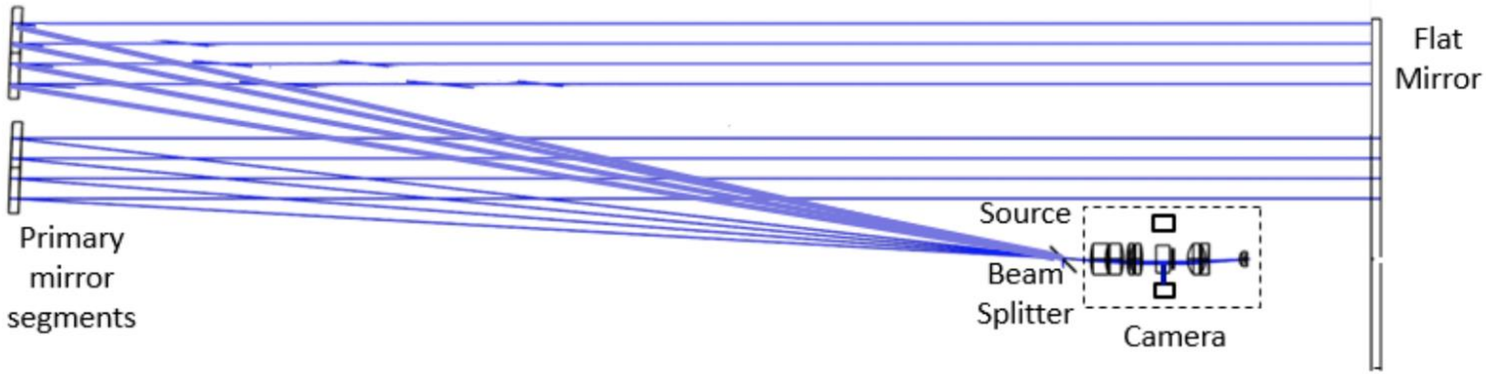

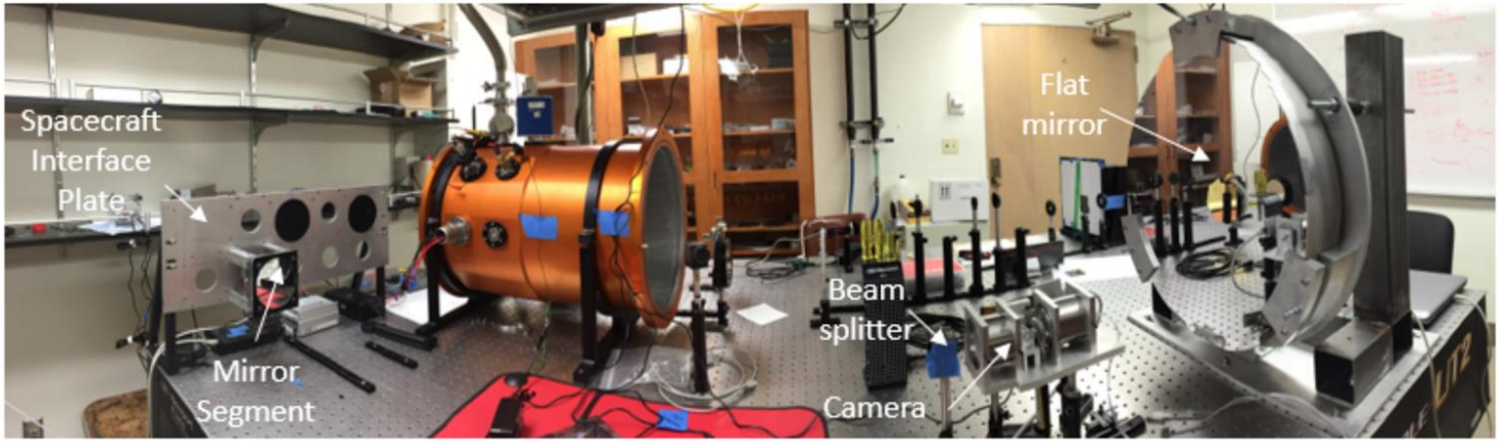

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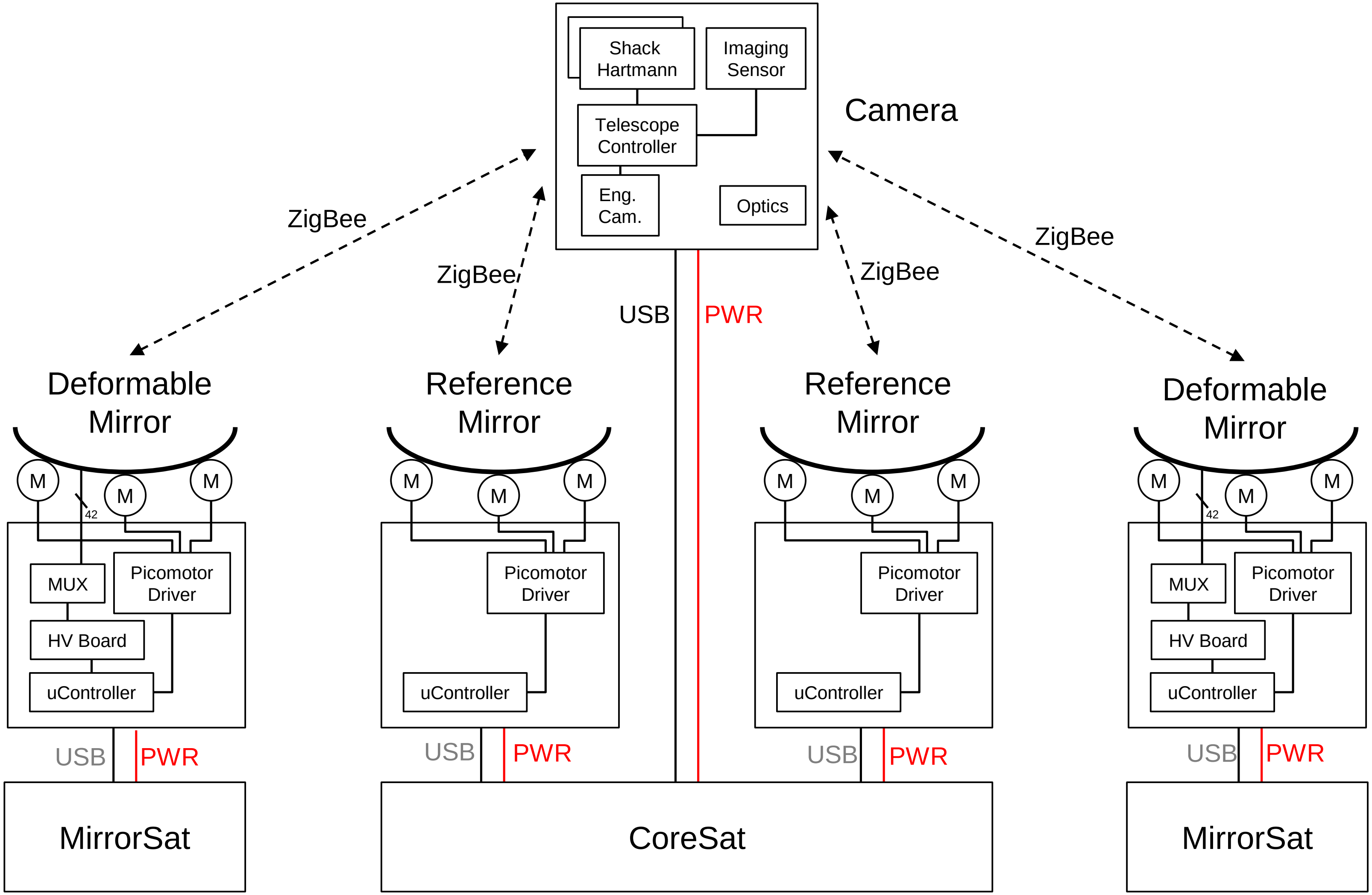
AAReST Payload Block Diagram



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Team Responsibilities

- Caltech
  - Deformable mirrors
  - Telescope system
  - Boom
  - CoreSat
- University of Surrey
  - MirrorSat x1
  - Docking system
  - Mission ops
- Indian Institute of Space Science and Technology
  - MirrorSat x1
- JPL
  - Class instructors
  - Project management

Caltech Team

- Ae105 class designs, builds, analyzes, tests components
- Ae205 class provides mentorship and guidance
- JPL class instructors, project manager
- JPL provides mirror manufacturing facilities
- Postdocs, upper-year grad students, SURF students provide focused support

Outline

2:00 pm: Introduction & Welcome

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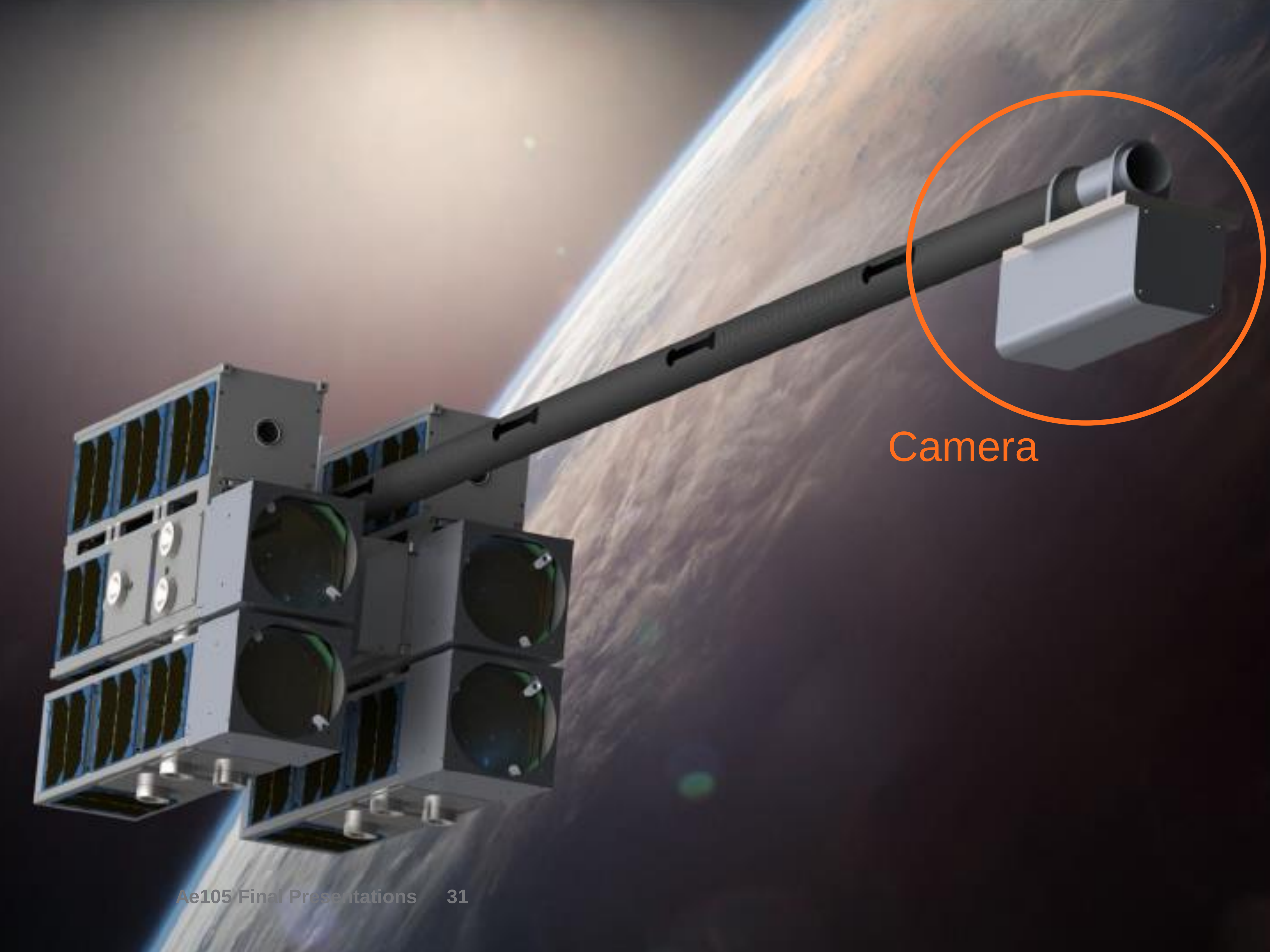
4:15 pm: Electronics

AAReST Camera Team

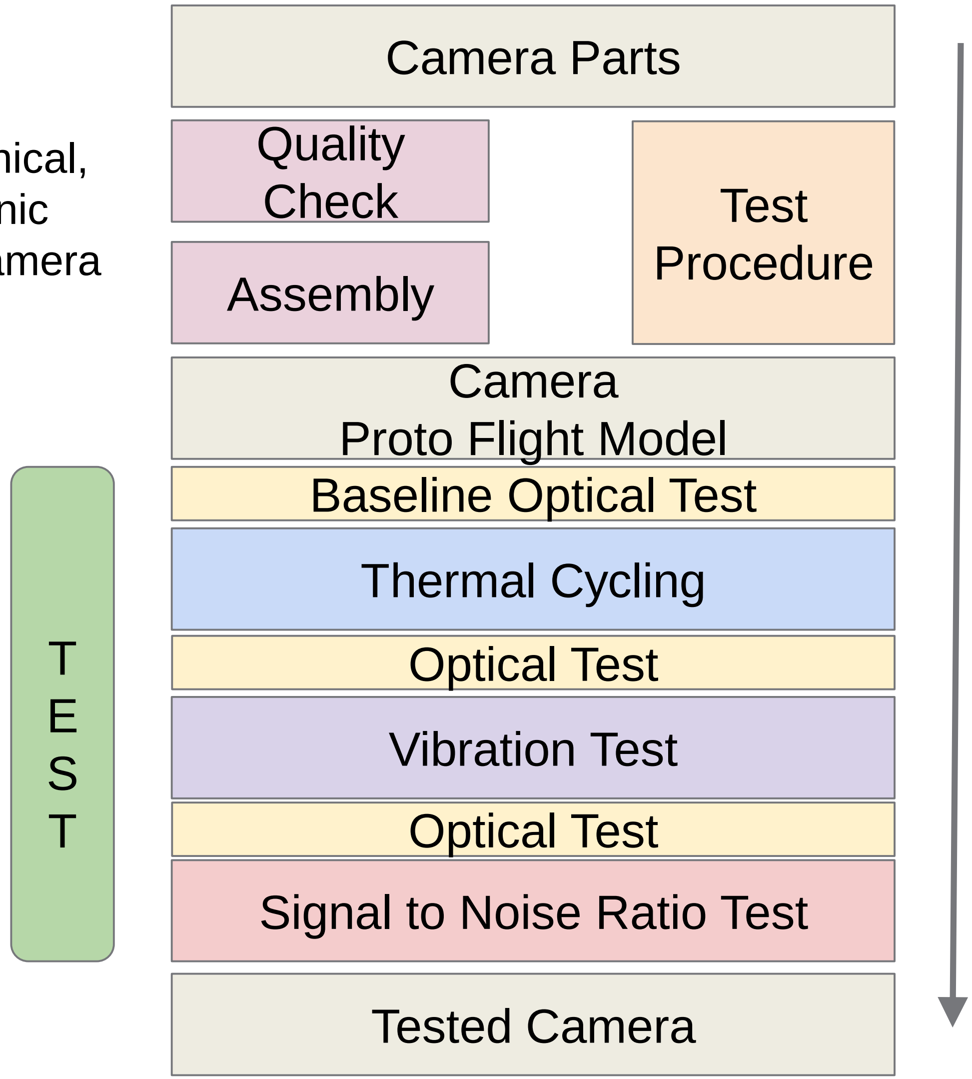
Frederick Berl
Carlos Gonzalez
Kimberly Liu
Erika Schibber
William Yu

Mentor: Maria Sakovsky


Camera

Project Workflow

Goals:
Integrate the mechanical, optical and electronic components of the camera



Goal:
Create assembly and test procedures

Goal:
Test the camera to verify it work as expected and won't break during launch

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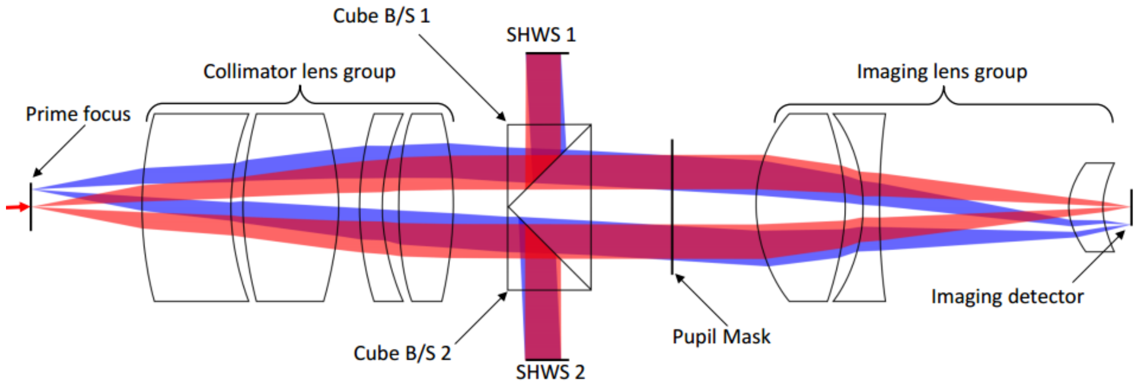
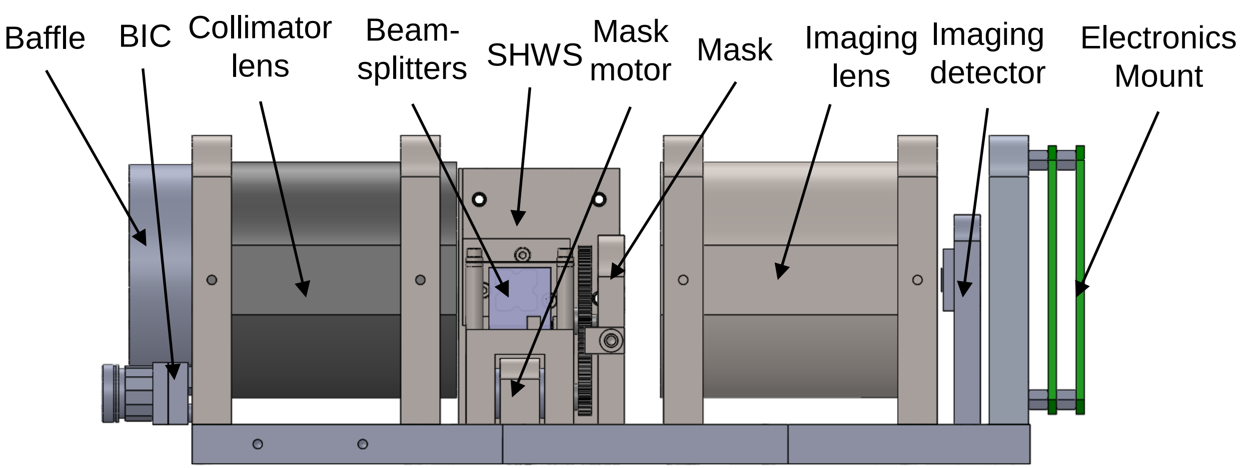
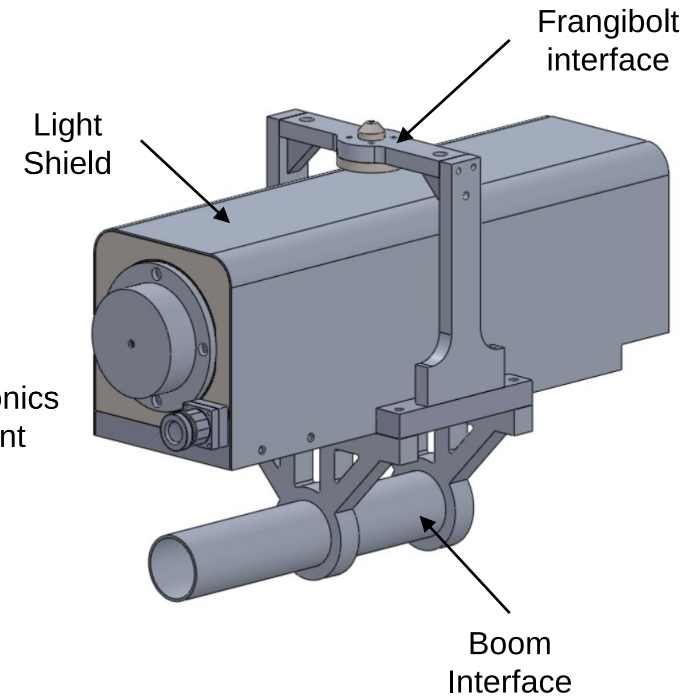
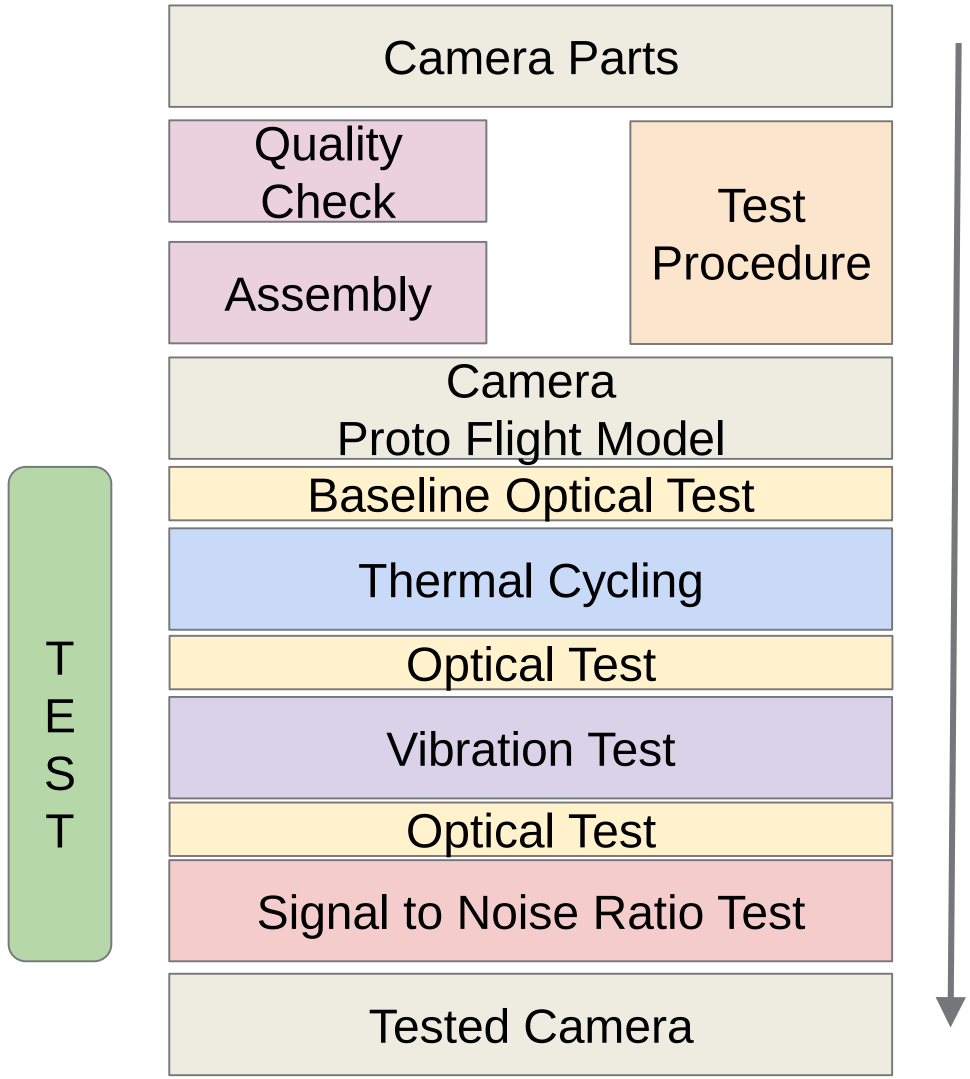
The Camera


Cube B/S 1
SHWS 1
Collimator lens group
Imaging lens group
Prime focus
Imaging detector
Pupil Mask
Cube B/S 2
SHWS 2


Baffle
BIC
Collimator lens
Beam-splitters
SHWS
Mask motor
Mask
Imaging lens
Imaging detector
Electronics Mount


Frangibolt interface
Light Shield
Boom Interface

Project Workflow



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Assembly and Quality Check: Tasks

- Design assembly procedures
  - ✓ Created a set of comprehensive procedures
    - Cleaning, RTV application, and Assembly/Clean room procedures
- Quality Checking
  - ✓ Measured every part and checked if it was within specifications
  - ✓ Made sure parts fit together
    - Sent out parts that very clearly weren't within spec to be fixed (i.e. parts that didn't fit together)
- Camera Assembly
  - ✓ Fully assemble all available parts in the clean room using the relevant procedures

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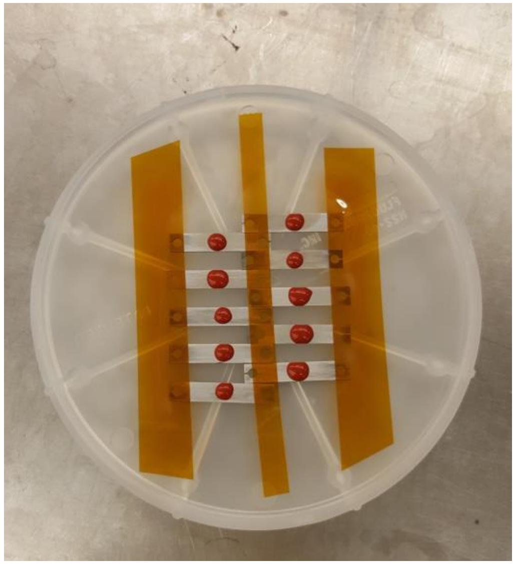
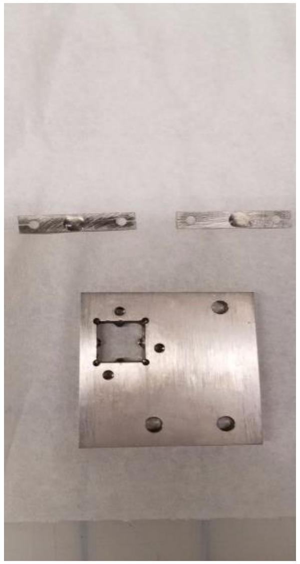
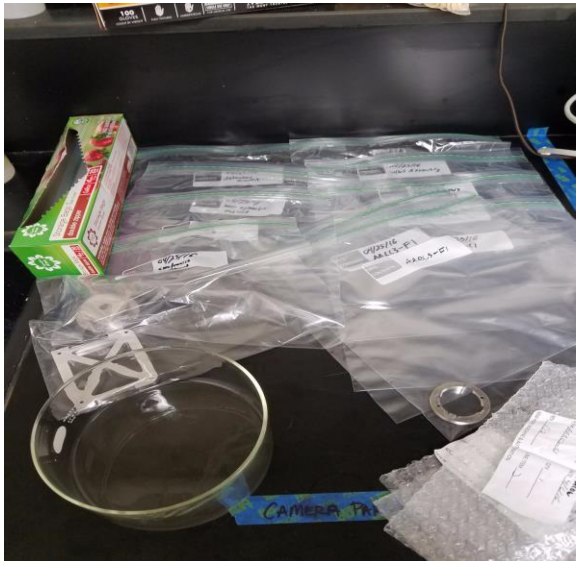
Assembly and Quality Check: RTV Test and Cleaning

Procedures are in place to apply RTV silicone, as well as to clean the parts and minimize their exposure to dust.







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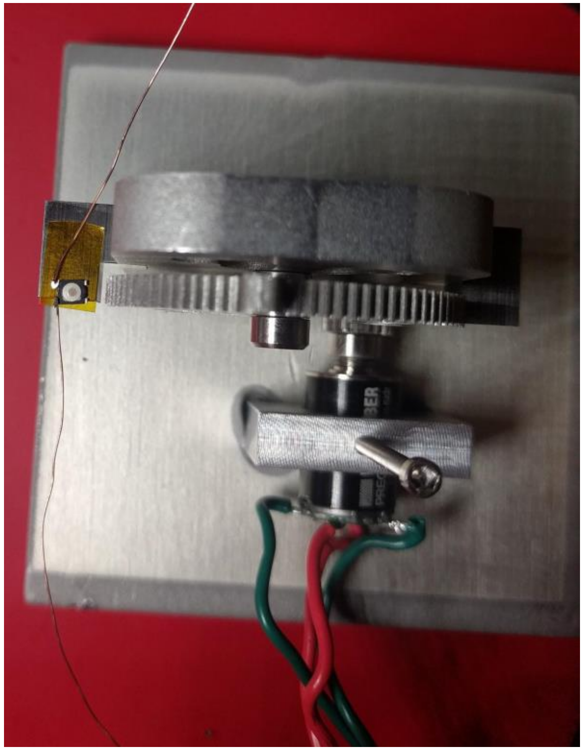
Mask Test

- Mask mechanism verification
  - ✓ Verify mask is rotated by stepper motor
  - ✓ Design limit switch mechanism
  - ▲ Find consistent mask rotation step sequence

- Stepper motor does not have enough torque to affect limit switch
  - Using two strips of conducting tape
- Mask jams occasionally during rotation
  - Postpone test until bearing is inserted



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Assembly and Quality Check: Assembled Camera

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Mass Budget

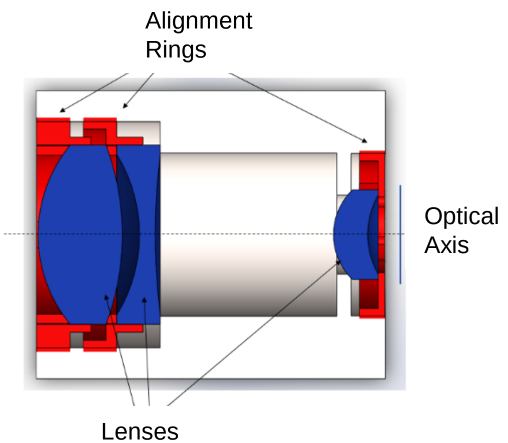
Camera Team Mass Budget				
Component	**As Designed (g)**	**Margin (%)**	**As Designed + Margin (g)**	**Measured (g)**
Metrology Plate	482	5	506	458
Collimator, Focal Group, and Beam Splitters	1238	5	1300	1148
Lens Mounts (4x)	320	5	336	304
Electronics Package (Al)	253	30	327	252
Fasteners & Wiring	181	20	217	181
SHWS Board and Mount (2x)	308	5	323	302
Light Shielding and Baffile	155	5	163	150
Boom Inspection Camera	17	5	18	17
Image Detector w/ Mount	45	5	48	44
Mask and Motor Assembly (Al)	48	5	51	54
Frangibolt and Boom Bracket (Al)	218	5	229	218
Total	**3263**		**3517**	**3128**

Assembly and Quality Check: Deviations from test-as-you-fly

Cleaning Procedures

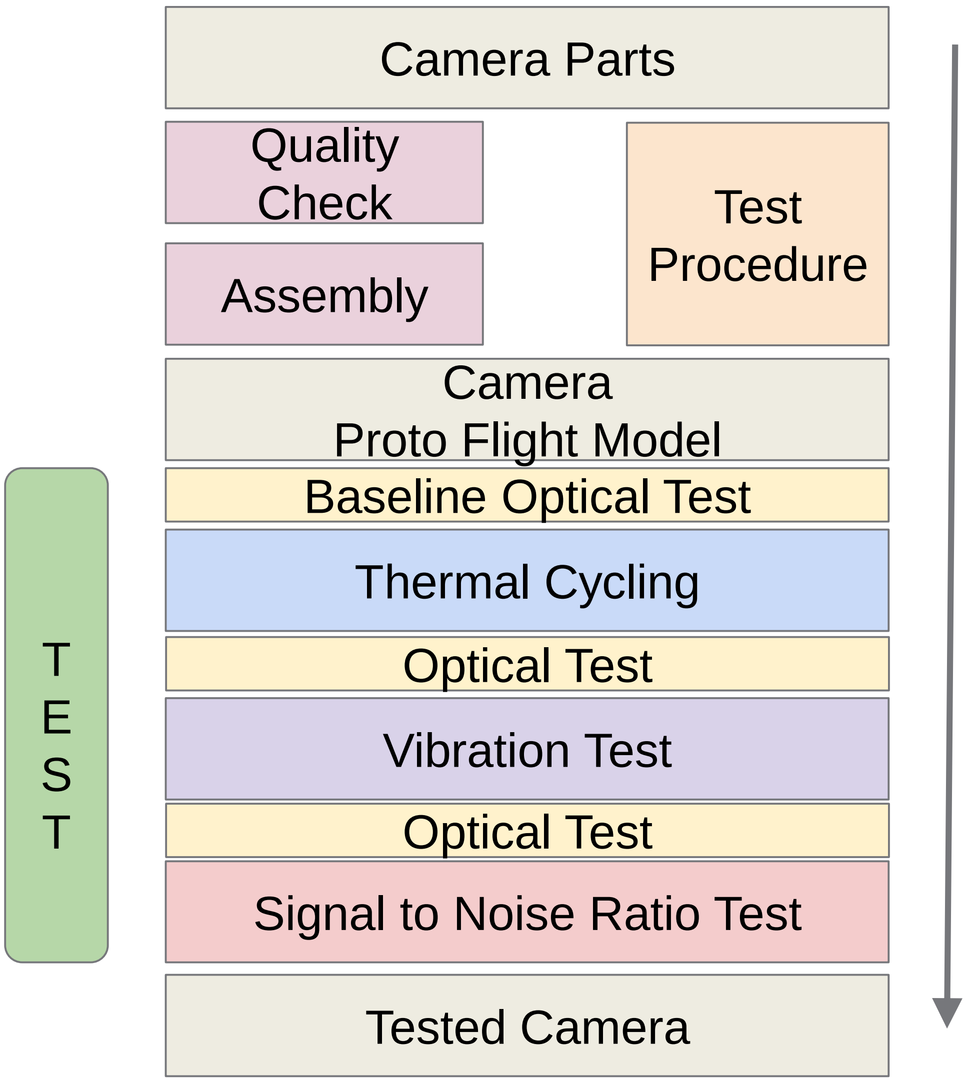
Item	Reason	Impact	Action
Isopropyl Alcohol leaves residue	The IPA was meant to be dried with compressed air	Low	Dry with compressed air/nitrogen

Assembly Procedures



Item	Reason	Impact	Action
Bolt stuck in titanium plate (lens barrel assembly)	Defective bolt snapped while torqueing	Low	Glue long rod to the bolt unscrew it
Beam splitters not properly mounted	One detent does not screw in all the way	Low	Get a new detent
RTV spacer on lens R3 (Spacer AARC6)	Lens was loose	Low	Send barrel back to shop

Project Workflow



Thermal: Tasks

- Design test procedures
  - ✓ Research effects of condensation and ambient pressure
  - ✓ Finish procedures document
- Thermal testing
  - ▲ Preliminary tests
  - ▲ Full test
  - ✓ Post-test structural/optical verification

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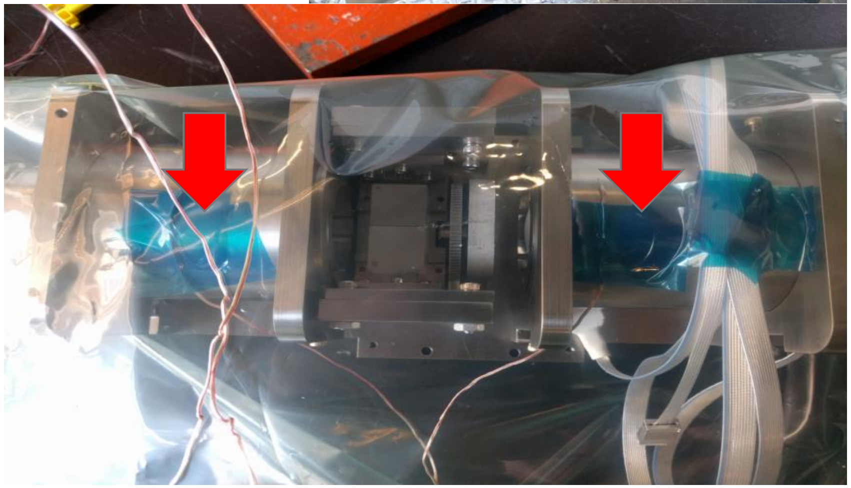
Thermal: Setup

- Equipment:
  - Instron 500 Series Environmental Chamber
    - Not under vacuum
    - Possibility of condensation

- Set up:
  - Vacuum bag
    - Tape seal
    - Nitrogen purge
  - Two thermocouples



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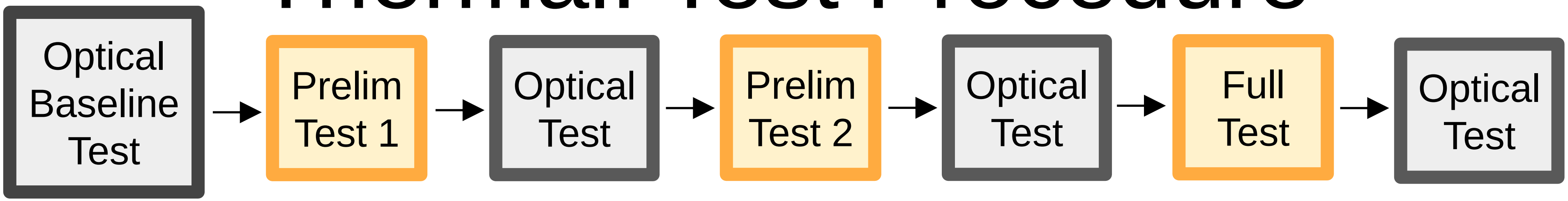
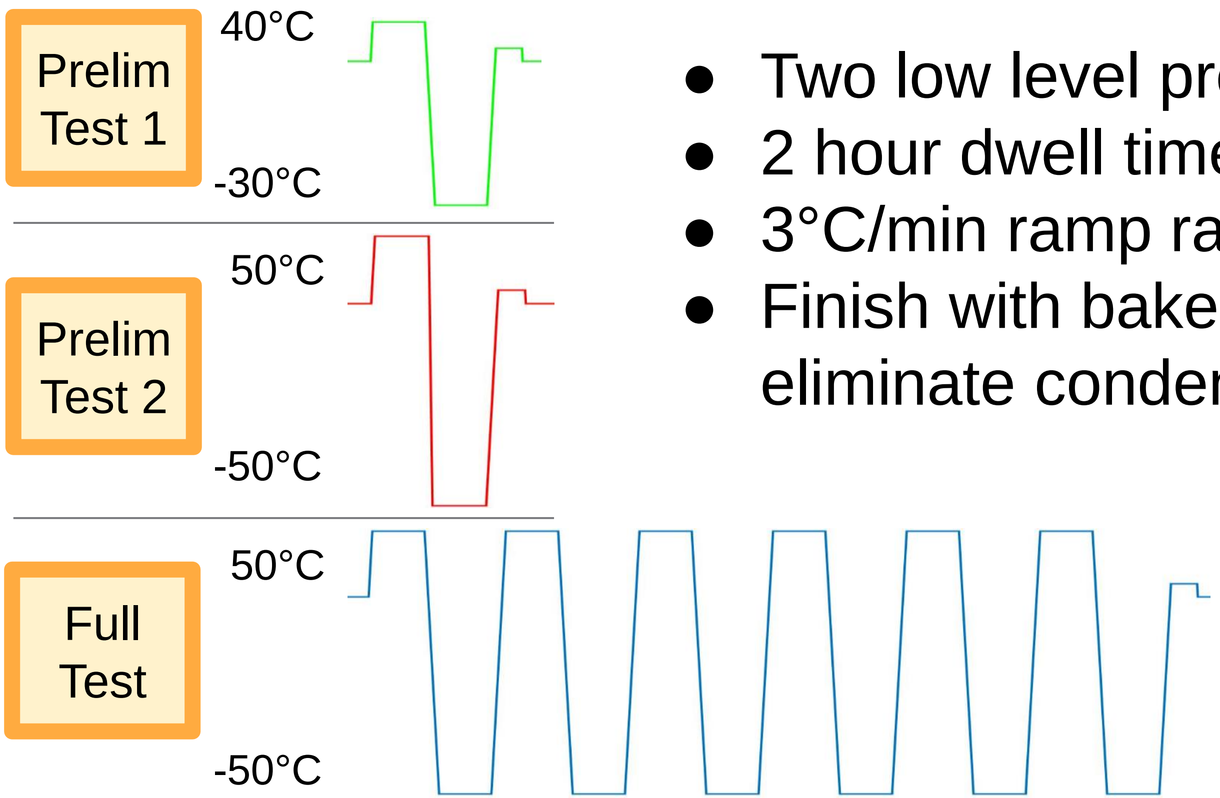
Thermal: Test Procedure





- Two low level preliminary tests
- 2 hour dwell time
- 3°C/min ramp rate
- Finish with bake at 30°C to eliminate condensation

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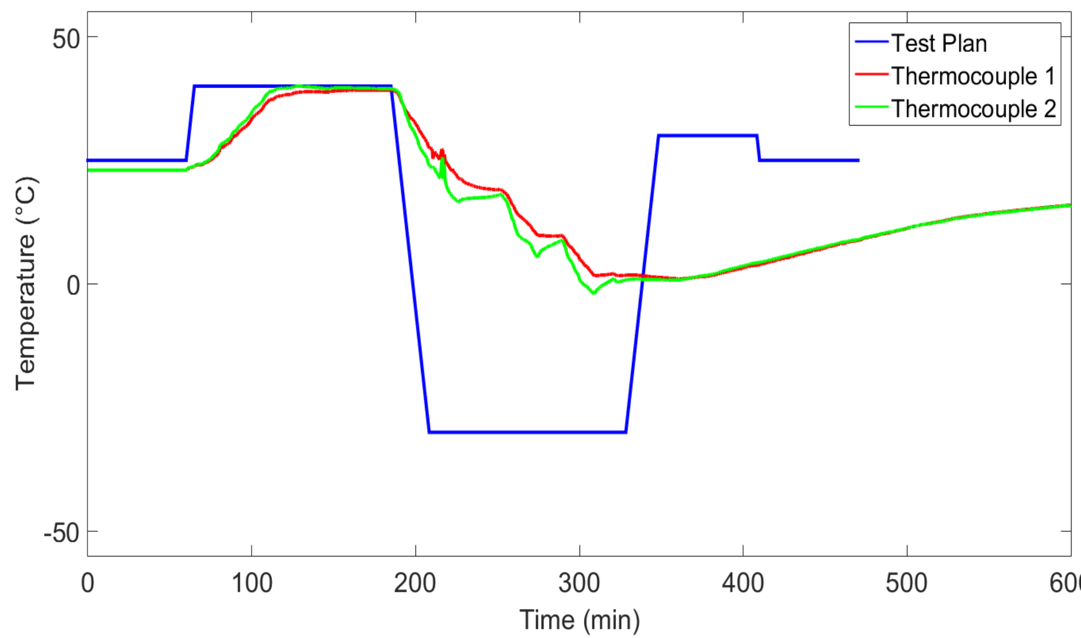
Thermal: Test Procedure

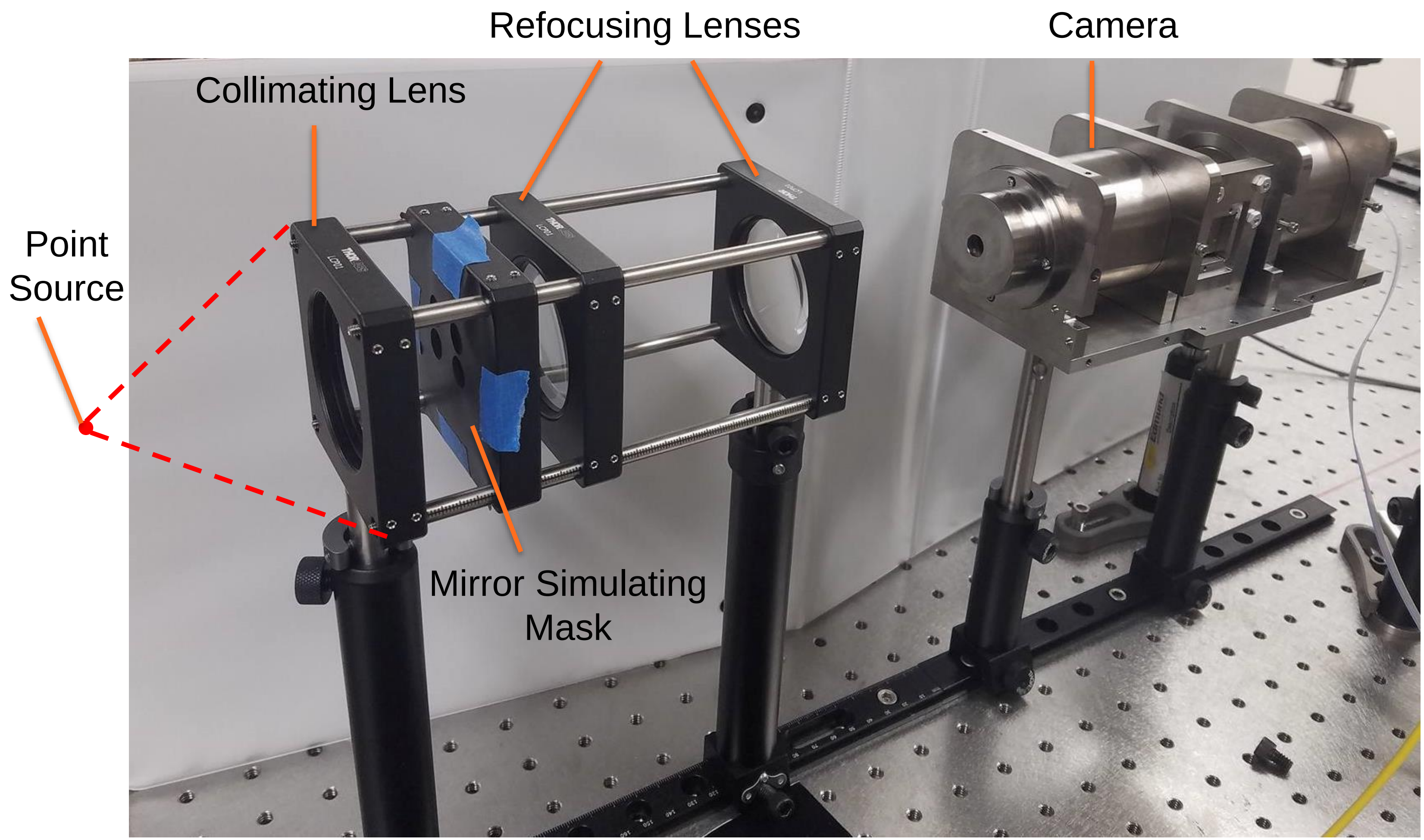
Plan:	Room Temp →	40°C →	-30°C →	30°C →	Room Temp
Actual:	Room Temp →	40°C →	0°C →	40°C →	Room Temp

- Thermal lag:
  - ~ 0.15°C/min
  - 1 hour dwell time
- Thermocouples show 5°C gradient across camera
- Slow conducting nitrogen in bag

Plan vs Actual



Thermal: Optical Test Setup



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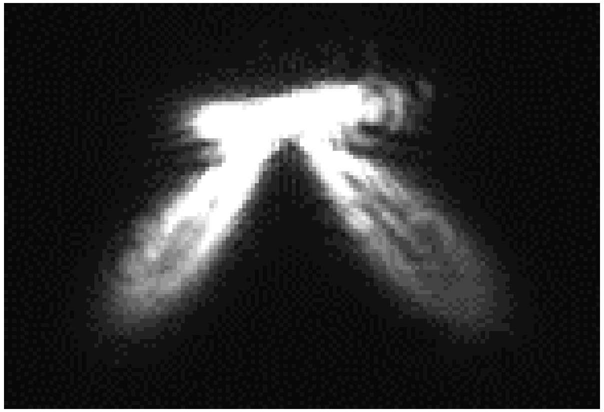
Thermal: Optical Test

Pre Thermal



Post Thermal

Imaging Detector Spot Size Comparison

Simulated	Pre-thermal	Post-thermal
400 x 260 um	~350 x 230 um	~350 x 230 um

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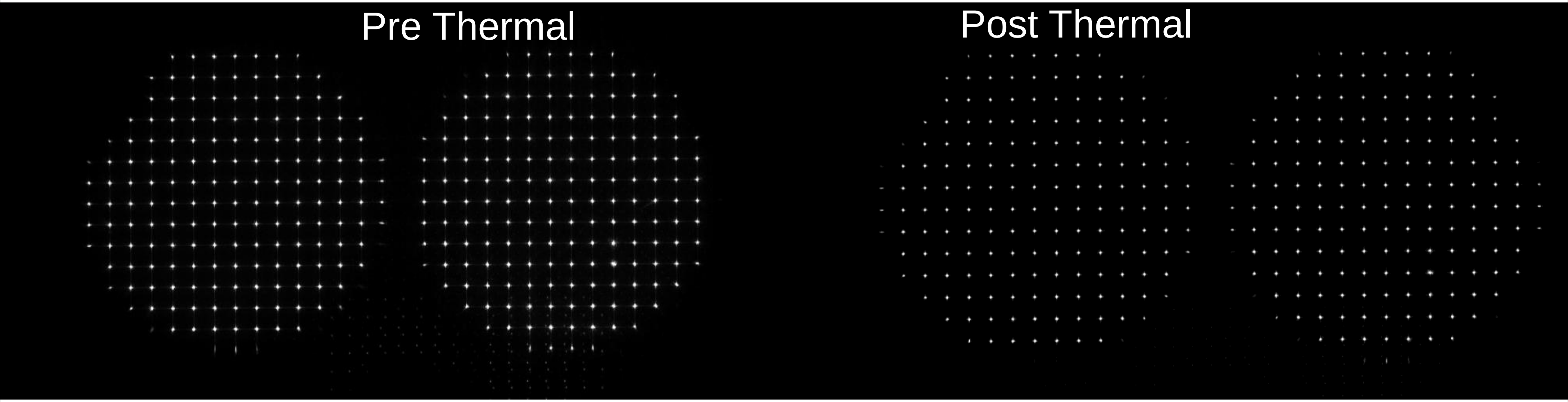
Thermal: Optical Test



SHWS Spot Number Comparison

	Predicted	Pre Thermal	Post Thermal
Mirror 1	~153	153	151
Mirror 2	~153	152	153

SHWS Spot Size Comparison

- Diffraction limited
  = 4 pixels diameter
- Measured
  = ~4-5 pixel diameter

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Thermal: P/F Criteria

Criteria	Result
• Heating/cooling rates	Out of Spec
• No signs of condensation on interior of vacuum bag	Some condensation, no adverse effects noted
• No obvious physical damage	Pass
• No loose parts	Pass
• Optical performance meets the requirements	Pass

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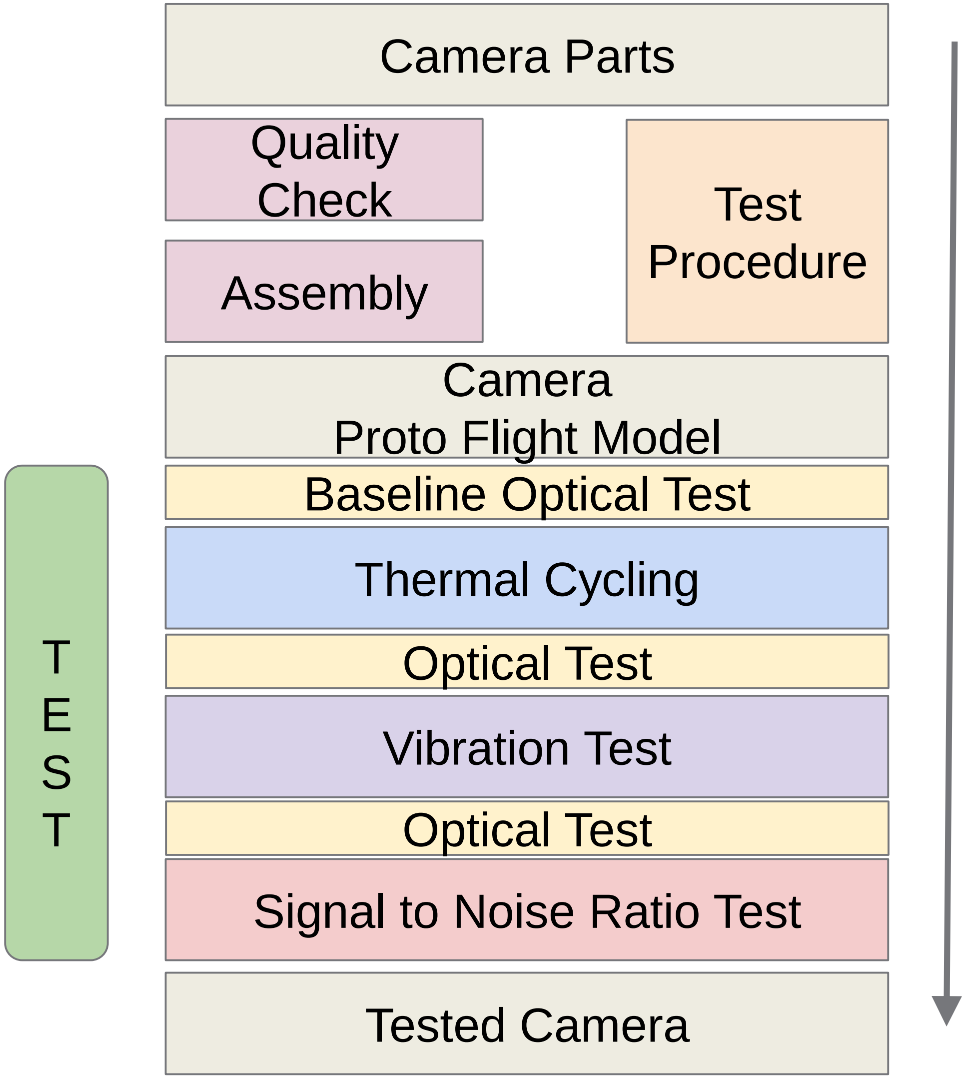
Project Workflow



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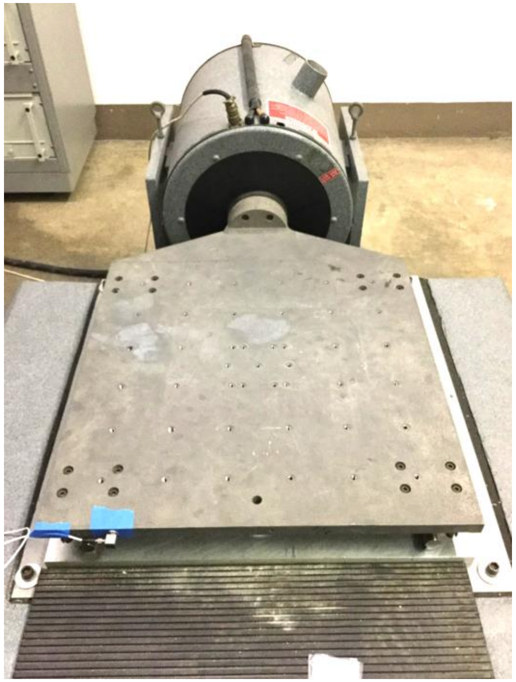
Vibration Testing: Tasks

- Test preparation
  - ✓ Create procedures document
  - ✓ Manufacture camera mounts
- Vibration tests
  - ▲ Set up and run vibration test
  - ▲ Post-test optical verification



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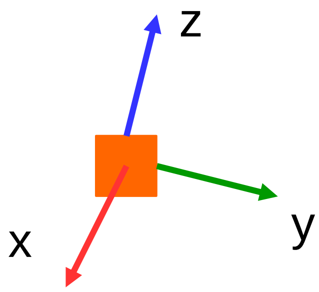
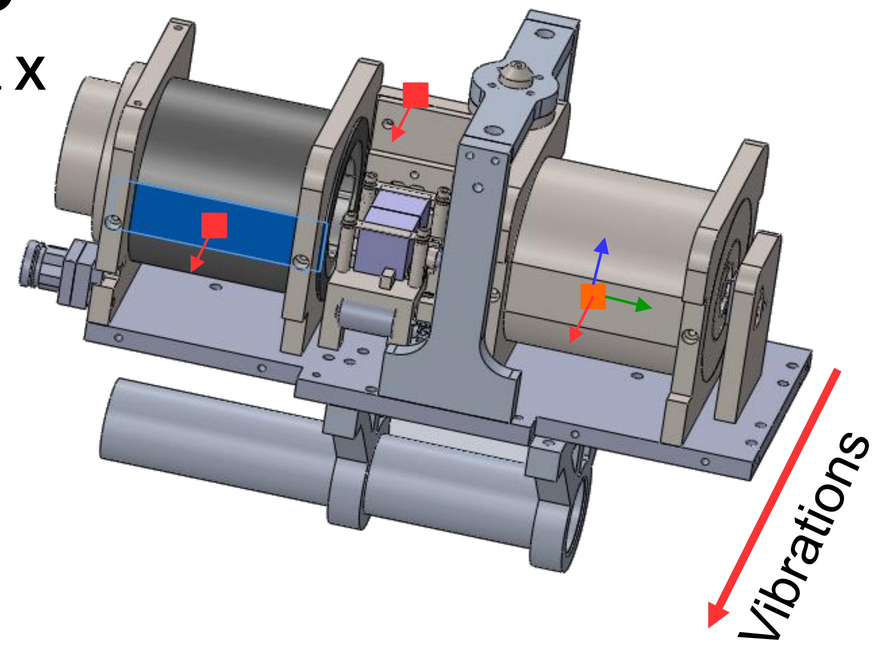
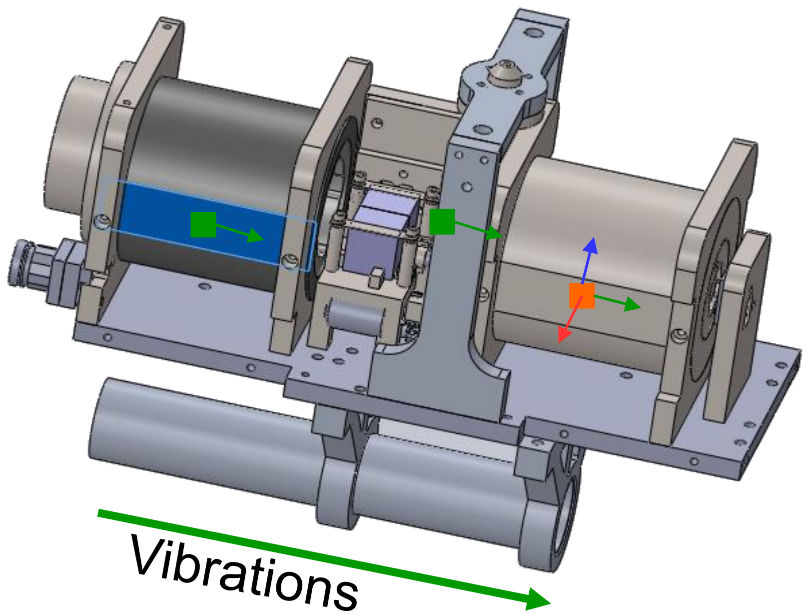
Vibration Testing: Instruments



Vibration X to camera X

Lens barrel 1: triaxial
Lens barrel 2: uniaxial
SHWS: uniaxial
Interface plate: triaxial





Vibration X to camera Y

Lens barrel 1: triaxial
Lens barrel 2: uniaxial
Mask: uniaxial
Interface plate: triaxial

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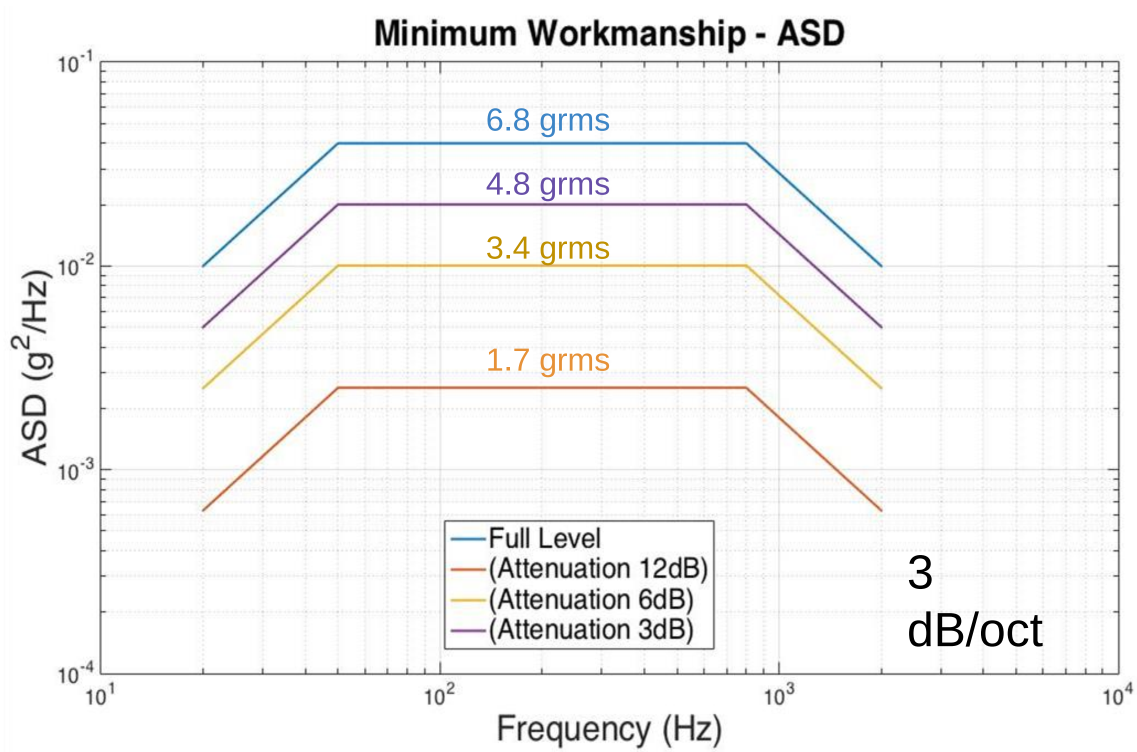
Vibration Testing: Test Sequence and Input Profiles

White Noise → -12 dB → White Noise → -6 dB → -3 dB → White Noise → Full Level → White Noise



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Vibration Testing: Checks

Run

- **Pre-Run**
  - Spectrum
  - Torque
- **Post-Run**
  - Signature
    - Frequency shift < 5%
    - Amplitude shift < 10%
  - Accelerometers
    - Signal
    - Correct polarization
    - No saturation
  - Torque
    - No change
  - Visual Inspection
    - Failures (e.g corners, lenses area)
  - Optical Test

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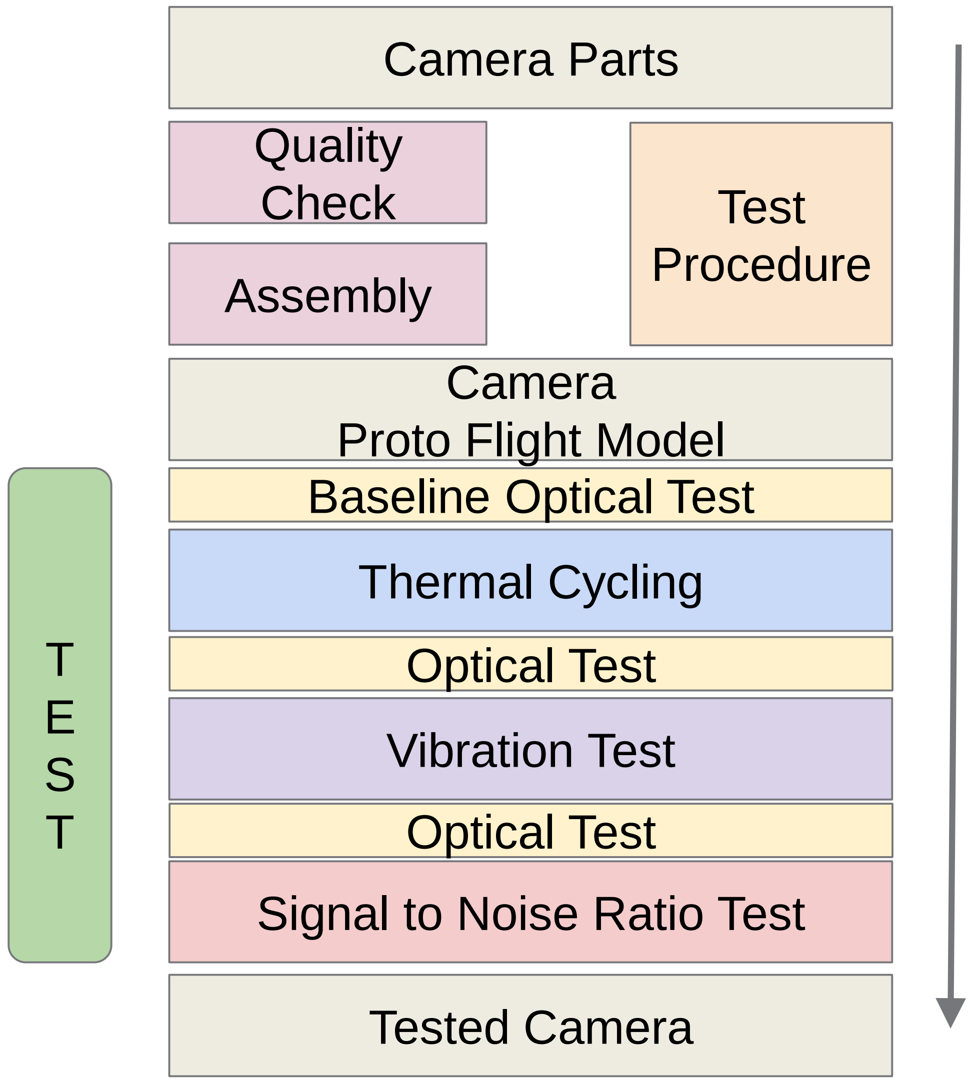
Vibration Test: Flight Deviations from test-as-you-fly

Item	Reason	Impact	Action
Electronic boards not included	PCB and other electronics not ready yet	Low	Dummy PCBs to be used
Boundary conditions do not match flight	One plane of contact during test	Medium	
Vibration table has strong resonance at 1500 Hz	Vibration table needs maintenance	High	Postpone test for maintenance
Vibration table produces large Y- and Z-axis vibrations	Vibration table needs maintenance	High	Postpone test for maintenance

Caltech

Project Workflow



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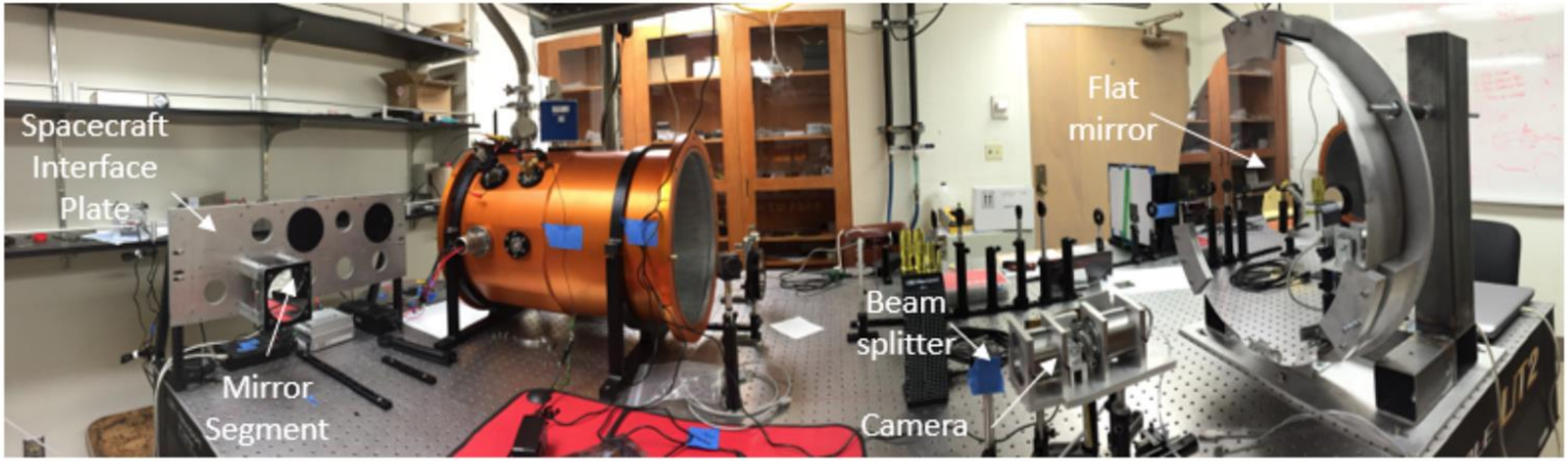
Signal to Noise Ratio Test

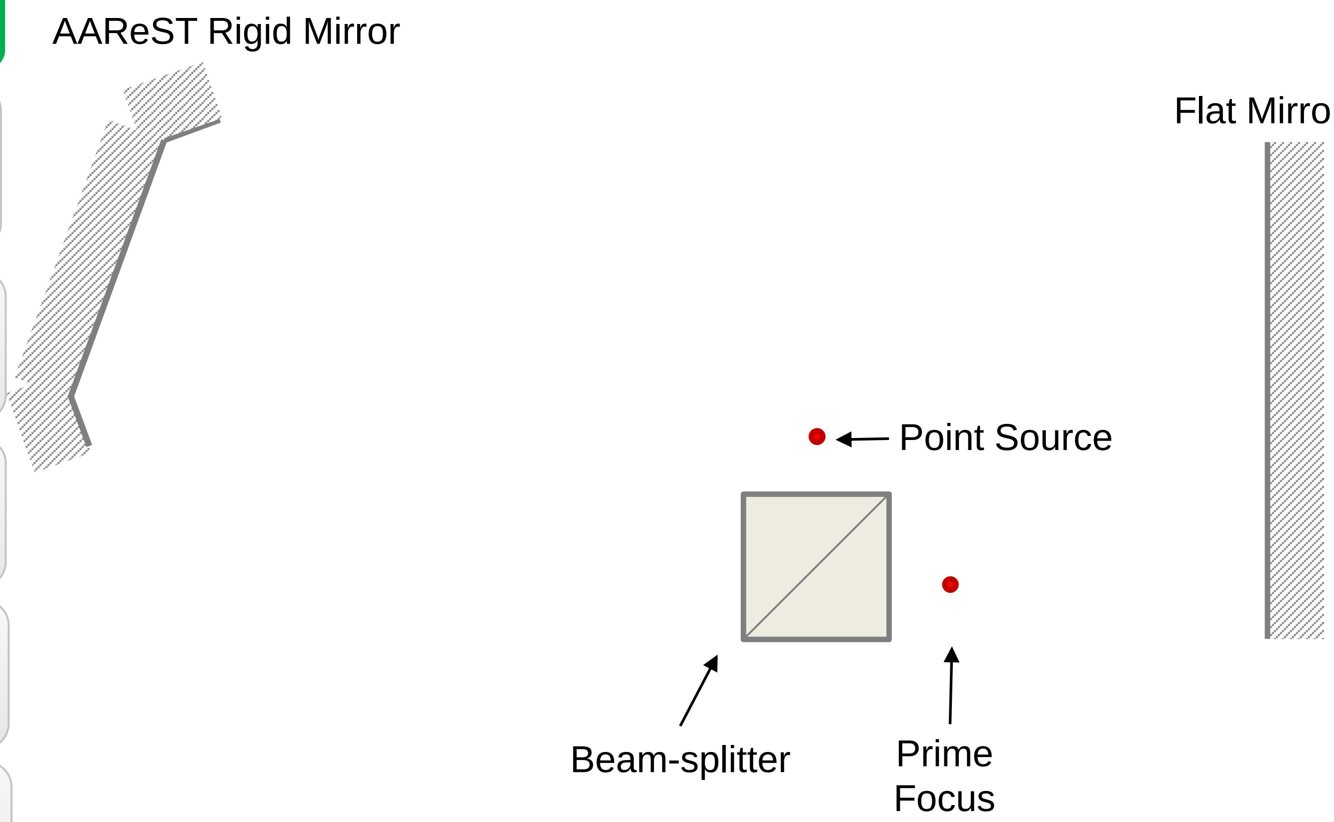
Goal: Verify SNR > 100 for the camera

How? Use a calibrated photodiode to measure intensity of white light source and adjust until it matches our expected star



Signal to Noise Ratio: Setup

1	Align mirrors
2	Align photodiode at prime focus
3	Red Laser → White Light Source
4	Vary intensity white light until desired voltage is reached
5	Photodiode → Camera
6	Take picture and calculate SNR



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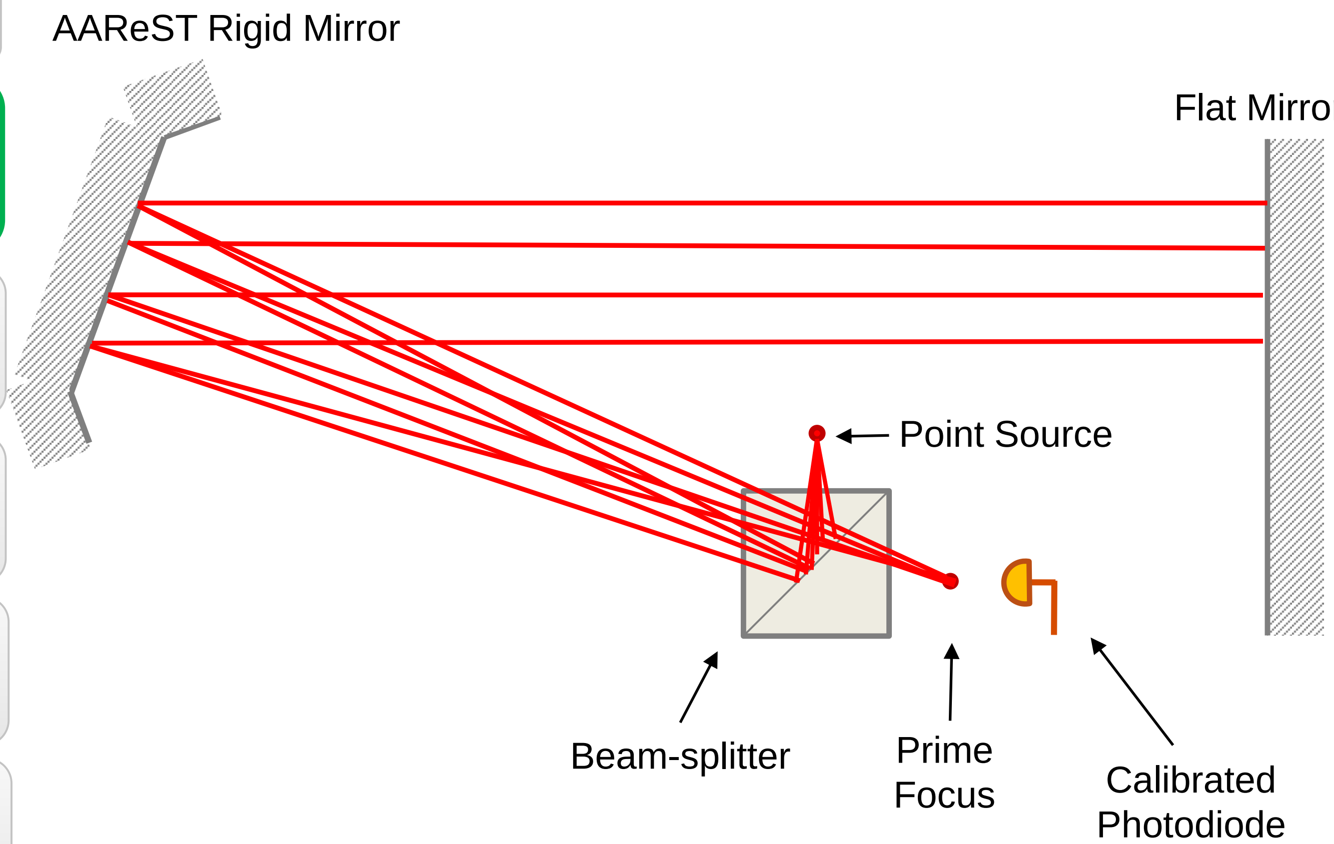

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Signal to Noise Ratio: Setup

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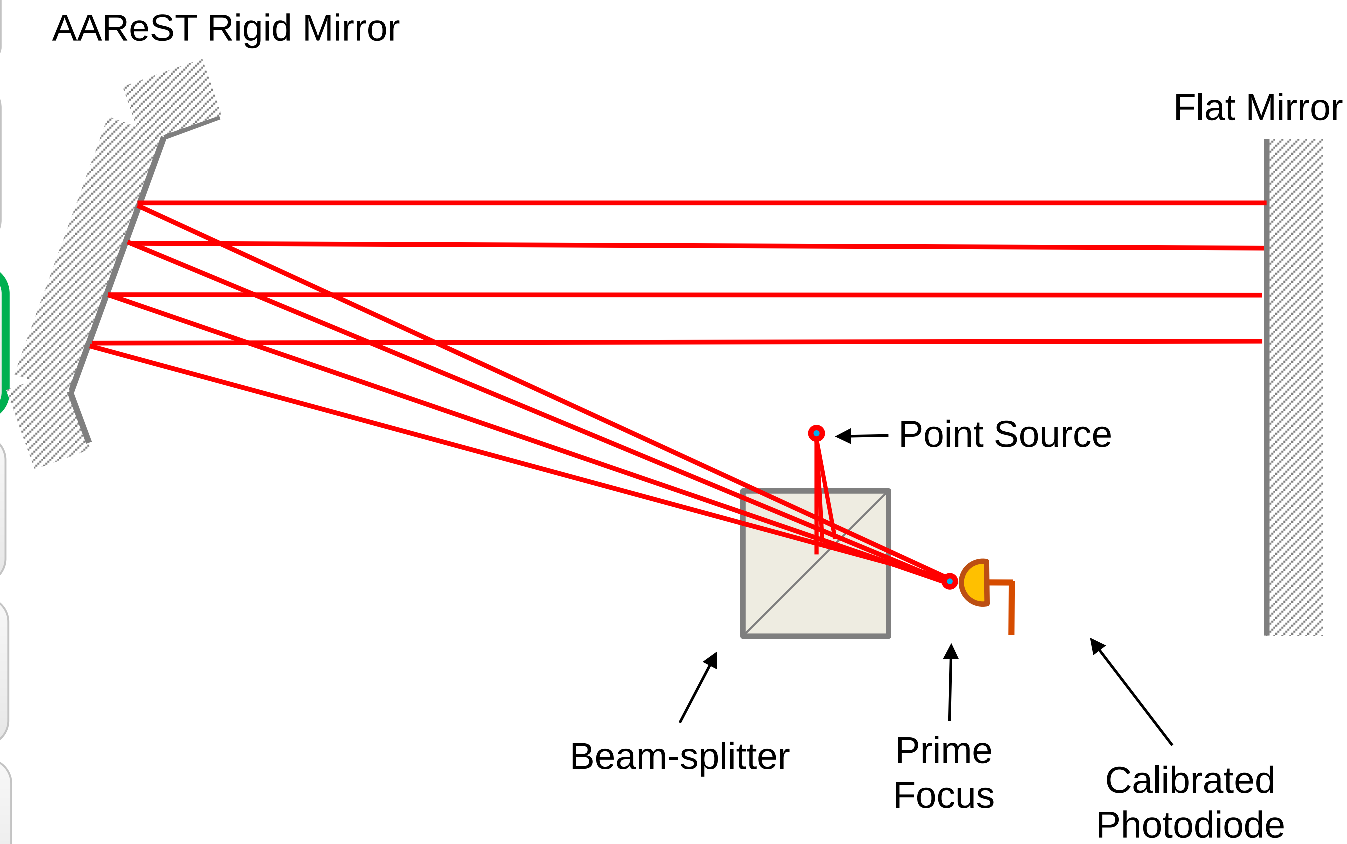

Caltech

Signal to Noise Ratio: Setup

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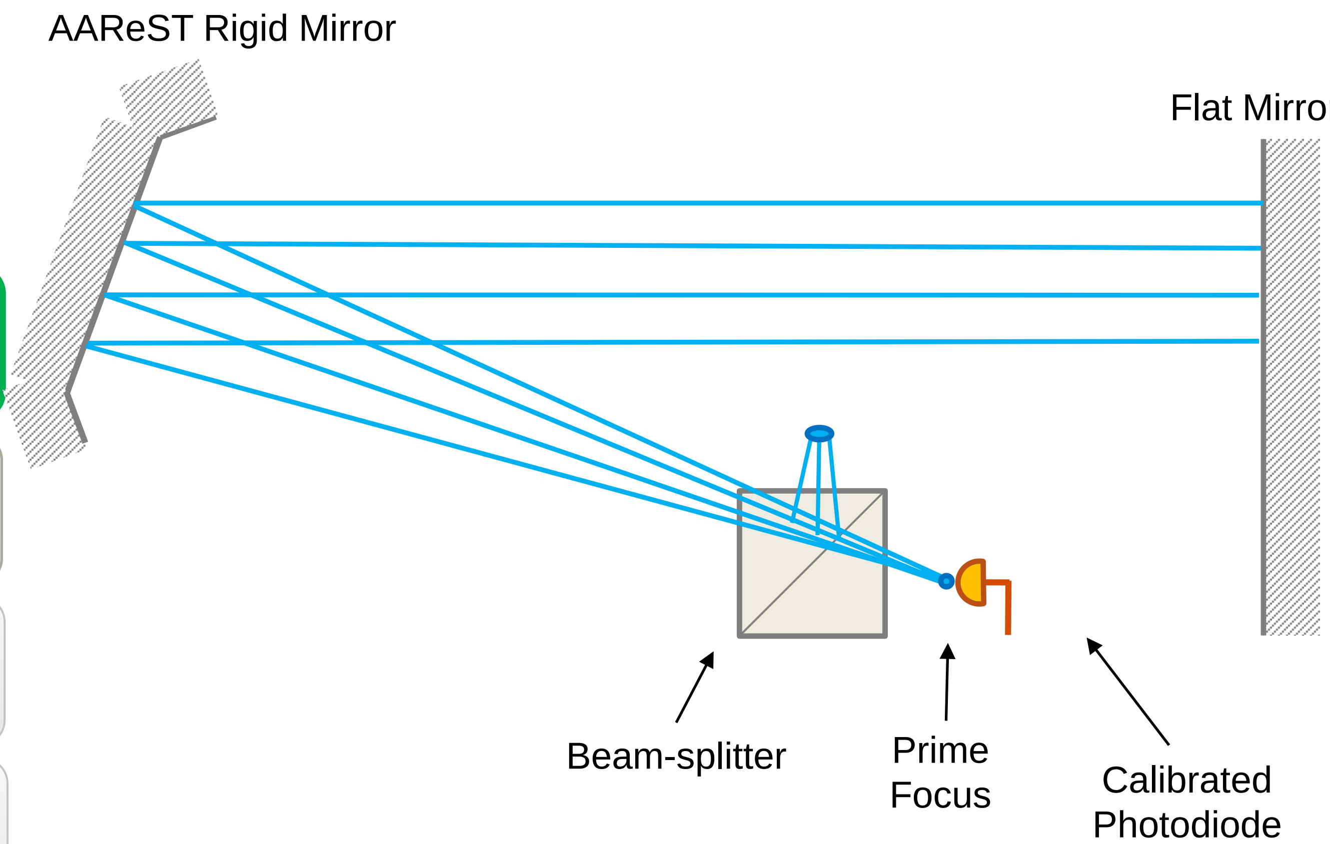

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Signal to Noise Ratio: Setup

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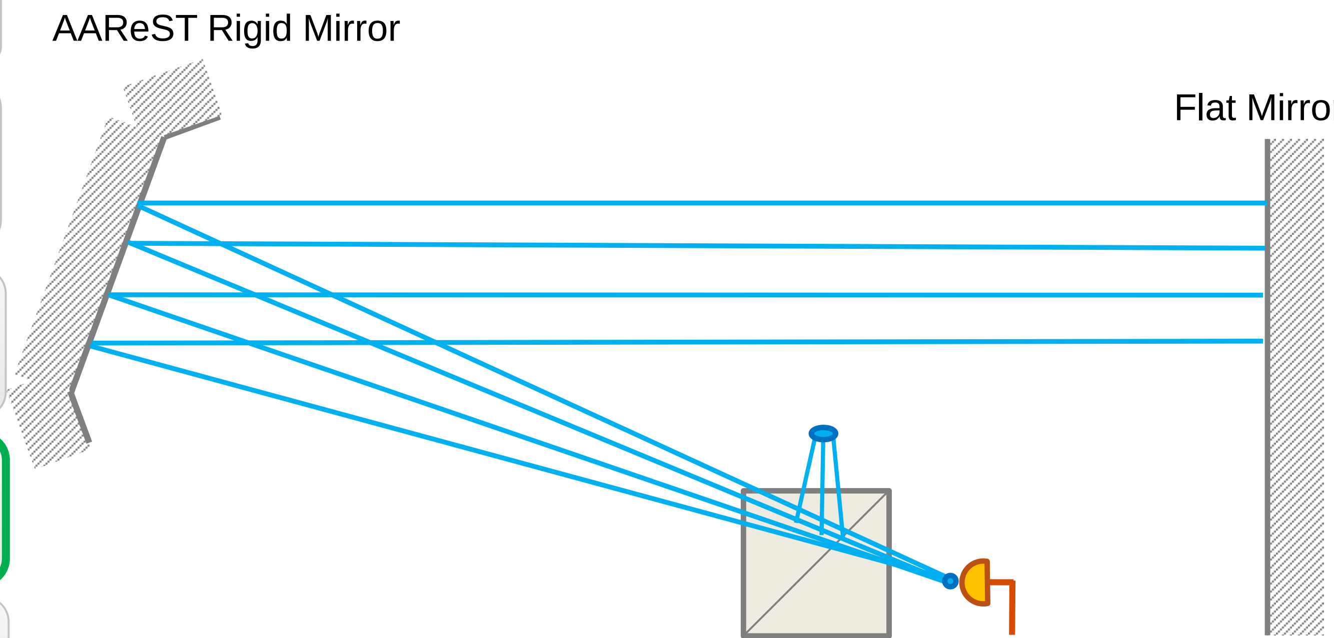

Desired Voltage

2.6 mV

Filtered Voltage

1.8 mV

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Signal to Noise Ratio: Setup

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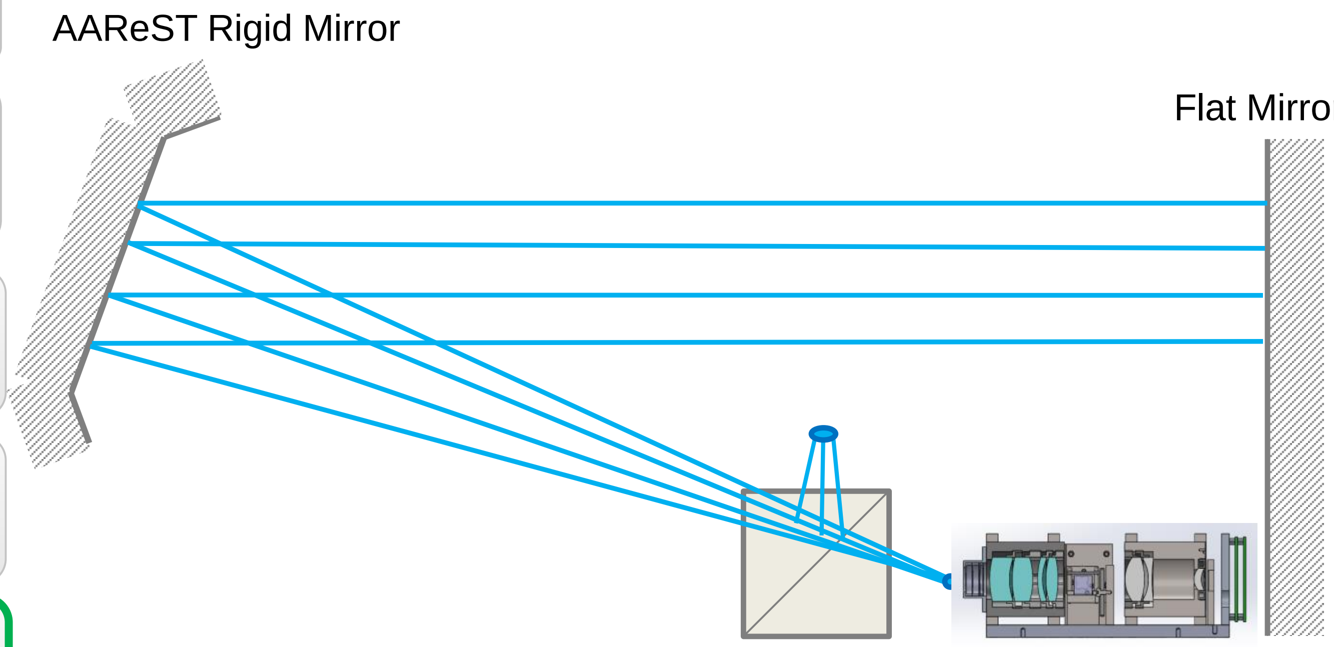

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Signal to Noise Ratio: Setup

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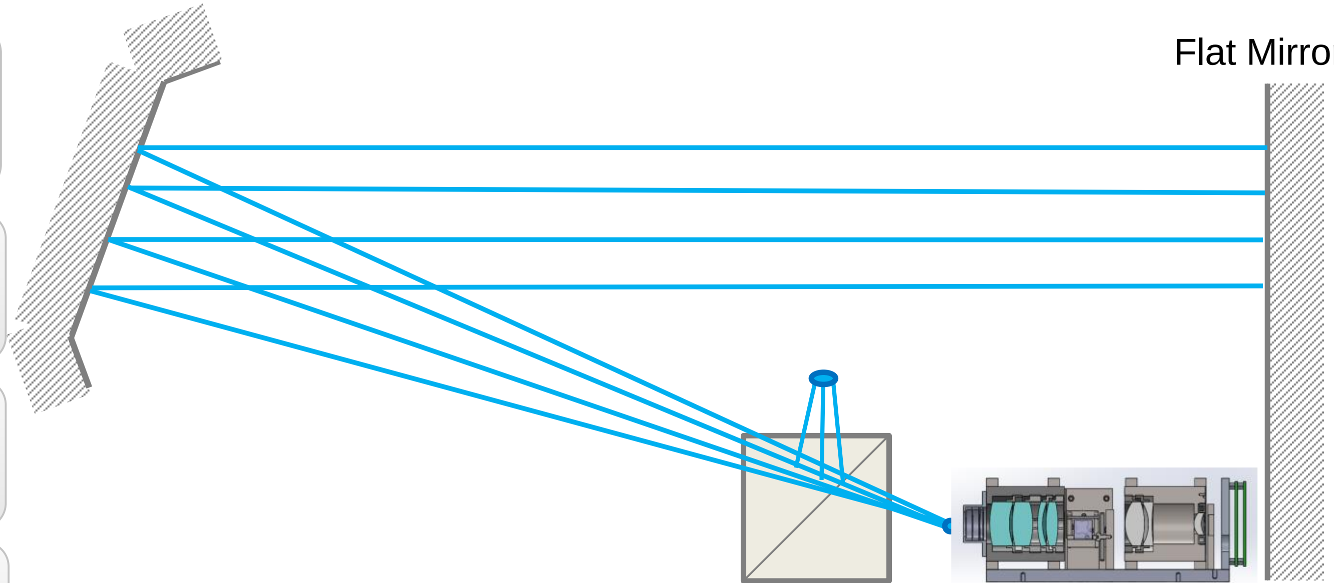

Picture and SNR Calculation!

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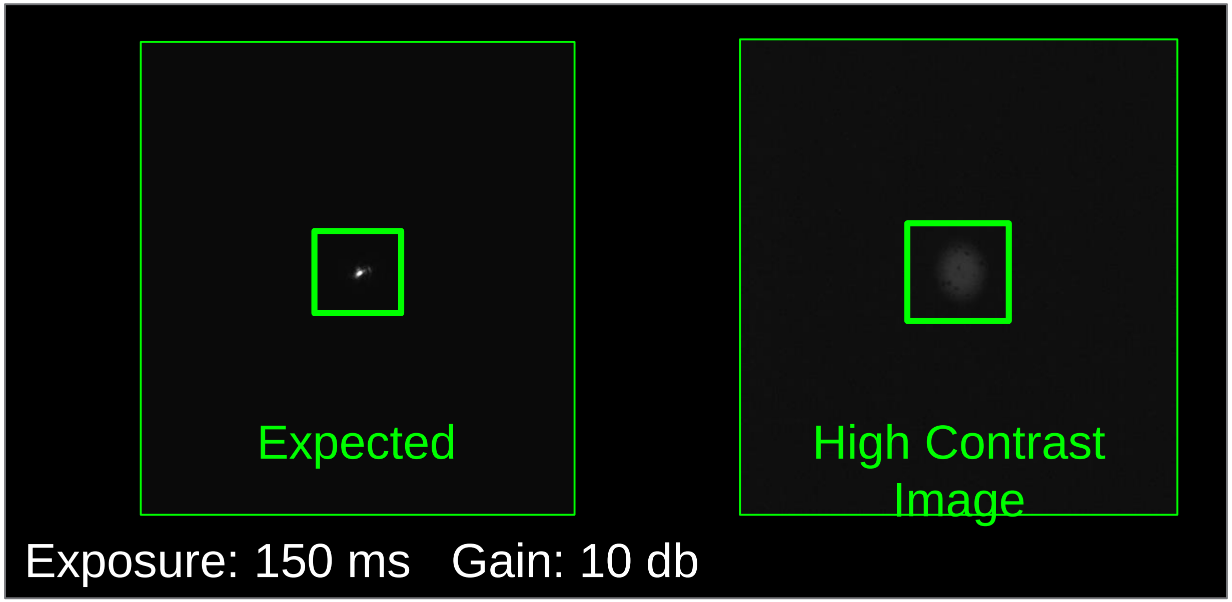
SNR Calculation



$$\mathrm{SNR} = \frac{\mathrm{mean}(\mathrm{Signal} - \mathrm{Background})}{\mathrm{RMS}(\mathrm{Background})}$$

Criteria	Result
SNR > 100	51.89

Test deviations:

- Light not point source
  - Mask blocks larger beams from image detector
- Incorrect intensity: light source too dim

Summary: Status of Tests

Test	Comments	Status
Optical Baseline	New camera images consistent with previous	Pass
Thermal	Thermal lag	Need to improve setup
Mechanical	Reliable step sequence	Missing bearing
Vibration	No vibration modes of table in test frequency range	Vibration table out of service
SNR	Point light source intensity	Inadequate optical fiber

(green)	Pass
(yellow)	In-Progress

(grey)	Postponed
(red)	Fail

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Summary: Future Work

- ❑ Thermal testing w/ new setup
- ❑ Vibration testing w/ fixed table
- ❑ SNR measurement w/ correct light intensity
- ❑ Integrate electronics
- ❑ Integrate light shielding
- ❑ Finalize external interfaces
- ❑ Integration to satellite

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Thank you!

Questions?

Outline

2:00 pm: Introduction & Welcome

2:15 pm: Camera

2:45 pm: Boom

3:15 pm: Mirror Boxes

3:45 pm: On-board Software

4:15 pm: Electronics

Boom Subsystem Validation Team

Fabien Royer

Federico Presutti

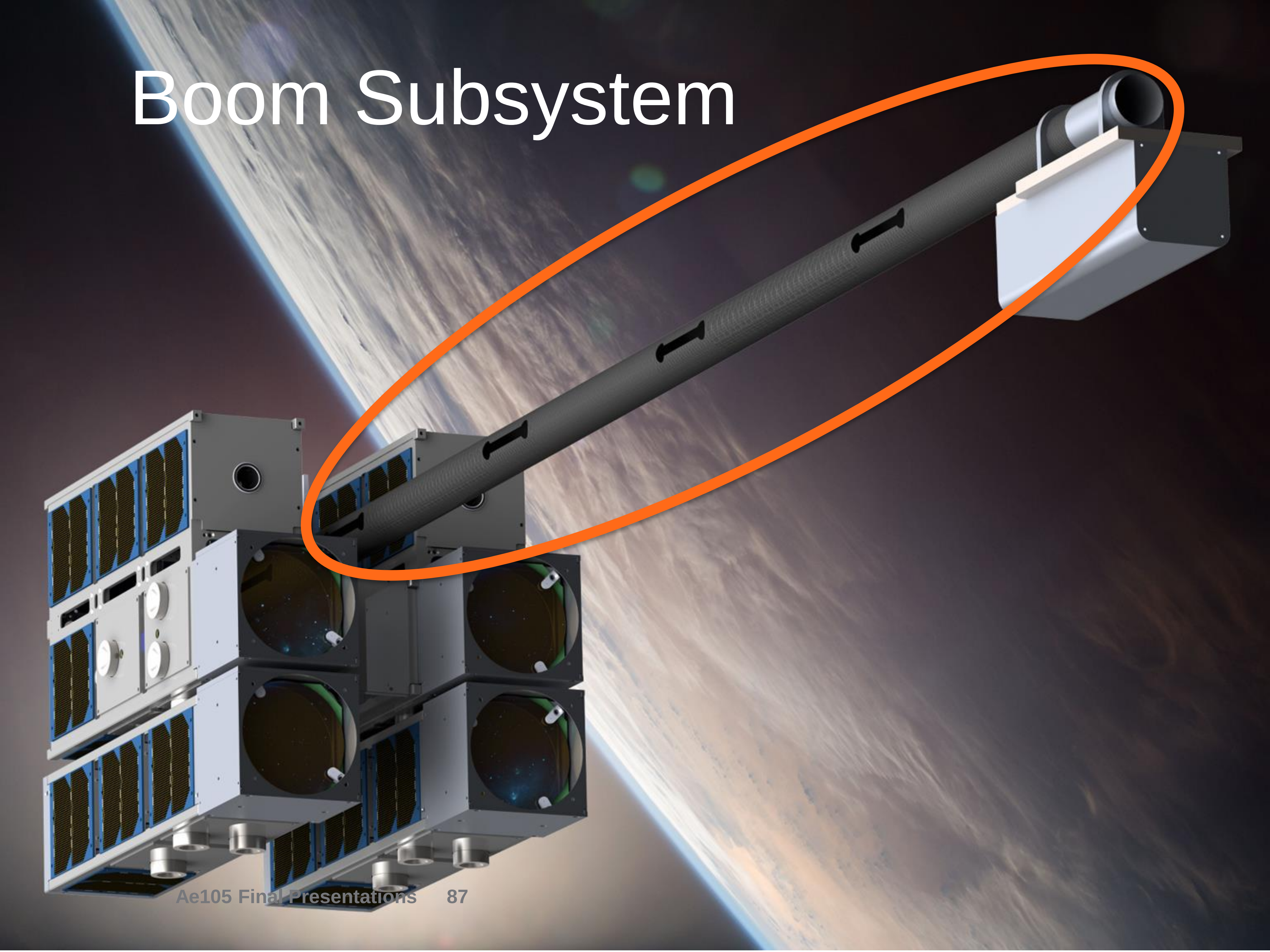
Joaquin Garcia-Suarez

Thomas Peterson

Mentor:

Christophe Leclerc

Boom Subsystem



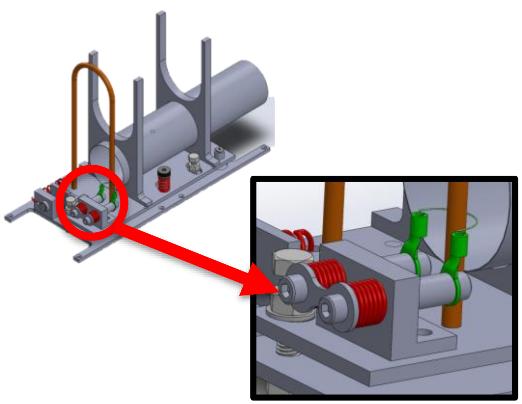
Boom Subsystem Overview

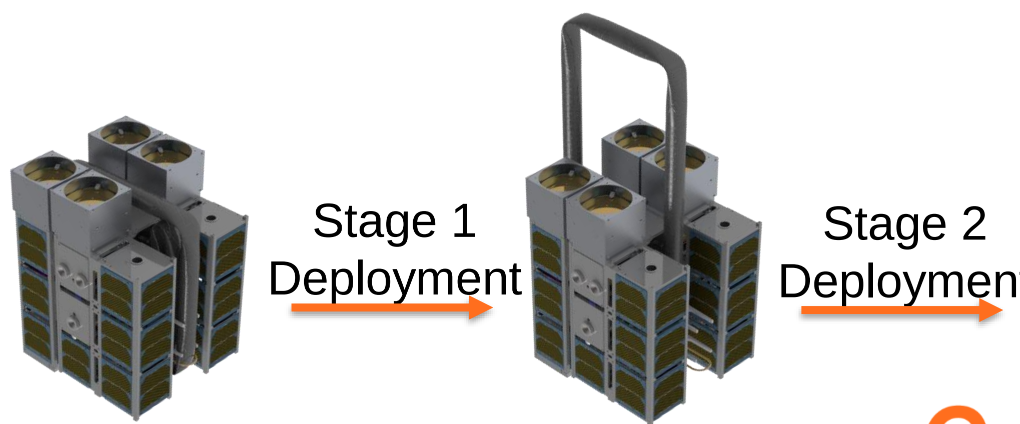
Introduction

- The hinged composite boom is responsible for bearing and deploying the camera
- Newest boom designed last year; some features to be retested

Team Responsibilities:

- Validate structural integrity and proper deployment of boom subsystem
- Ensure repeatability of boom alignment for optical applications
- Define structural details of boom connection to CoreSat





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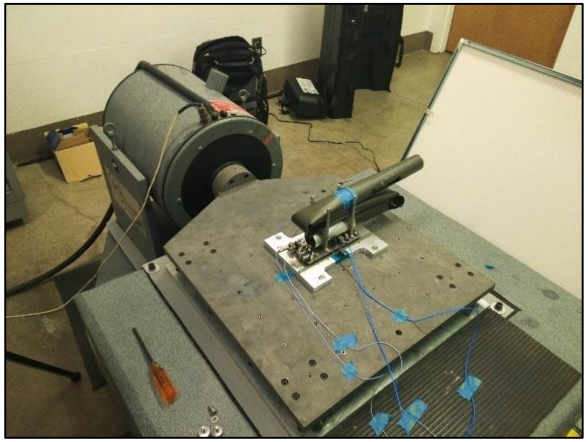
Tasks Overview

Boom-mount connection design

Stage 2 Deployment Testing

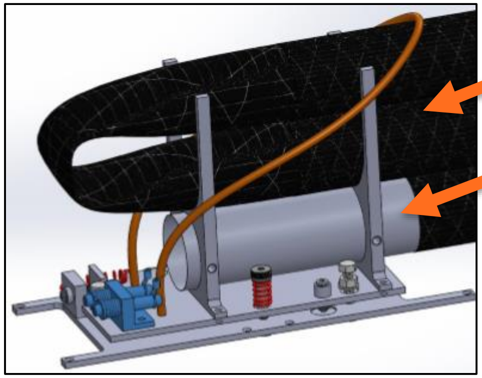
Vibration Testing



Accuracy Testing

Boom-Mount Interface Design

Objective: design the final connection to survive LEO conditions



Aluminum CTE	
21.8 ppm/°C	
Boom CTE	
Axial	**~1.0 ppm/°C**
Circum.	**21 ppm/°C**

Deal with **CTE mismatch**

- Stresses arise at the interface due to different deformations of the materials
- Operation thermal conditions: **+60°C to -60°C**

Our choice:

LOCTITE EA 9394 AERO
Epoxy Paste Adhesive
(KNOWN AS Hysol EA 9394)

- Appropriate thermal and mechanical properties and low outgassing

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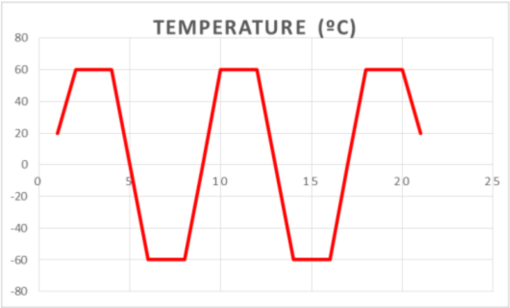
Design of Boom-Mount Fixation

Testing structural integrity of the connection:

- Prepared connection sample for test (following bonding procedure)
- Used environmental chamber to test thermal cycle
- Mechanical load applied



Conclusions:

- Expected mechanical and thermal loads do not trigger failure

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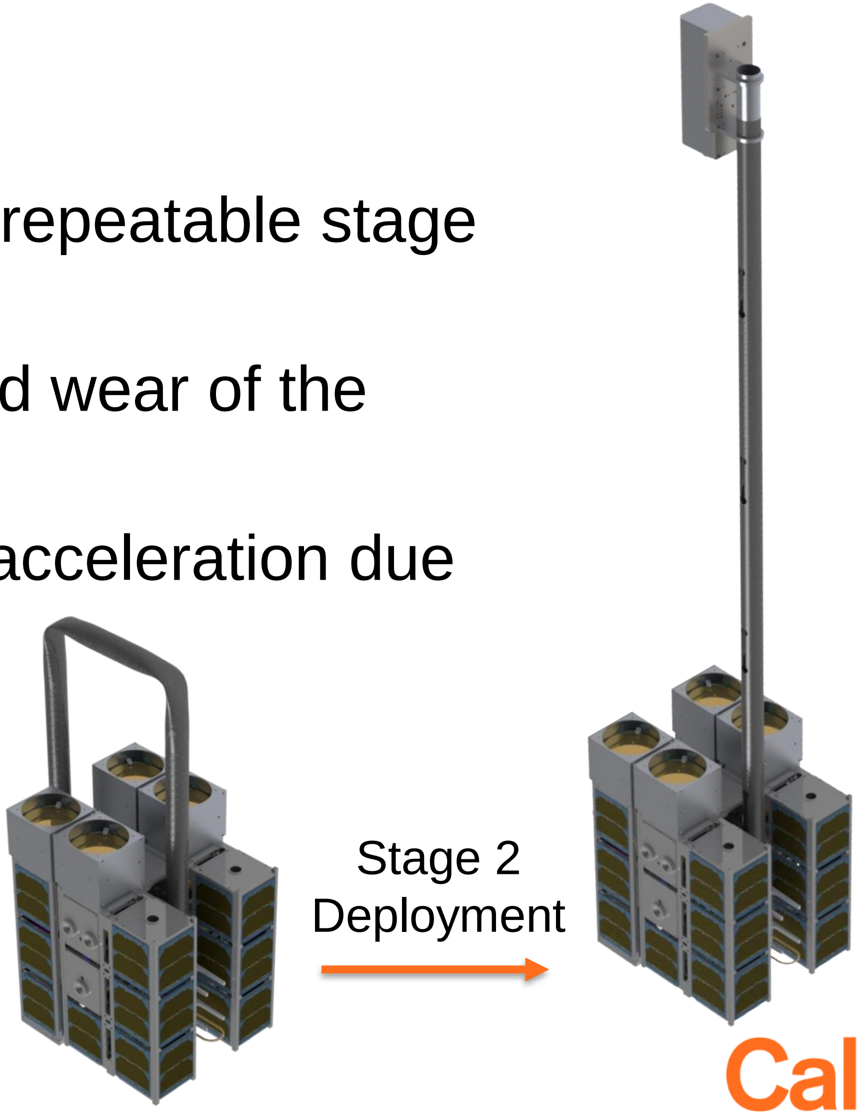
Stage 2 Deployment Test

Objectives:

- Ensure a reliable and repeatable stage 2 deployment
- Track deterioration and wear of the composite boom
- Determine maximum acceleration due to deployment



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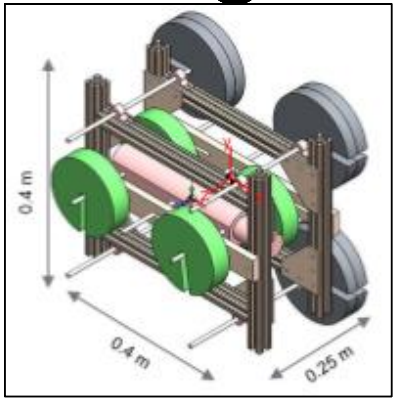
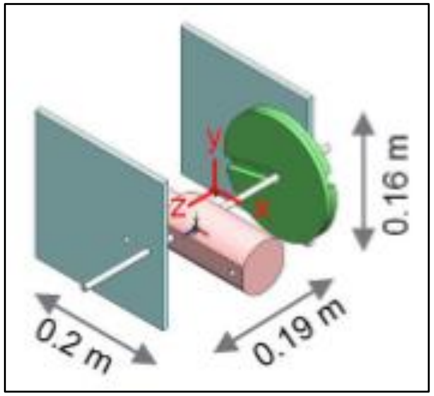
Stage 2 Deployment Testing



CoreSat mass model

	Mass (kg)	
Part	2014	2016
Camera	2.98	3.43
CoreSat	27.74	27.74



Camera mass model

Stage 2 Deployment Results

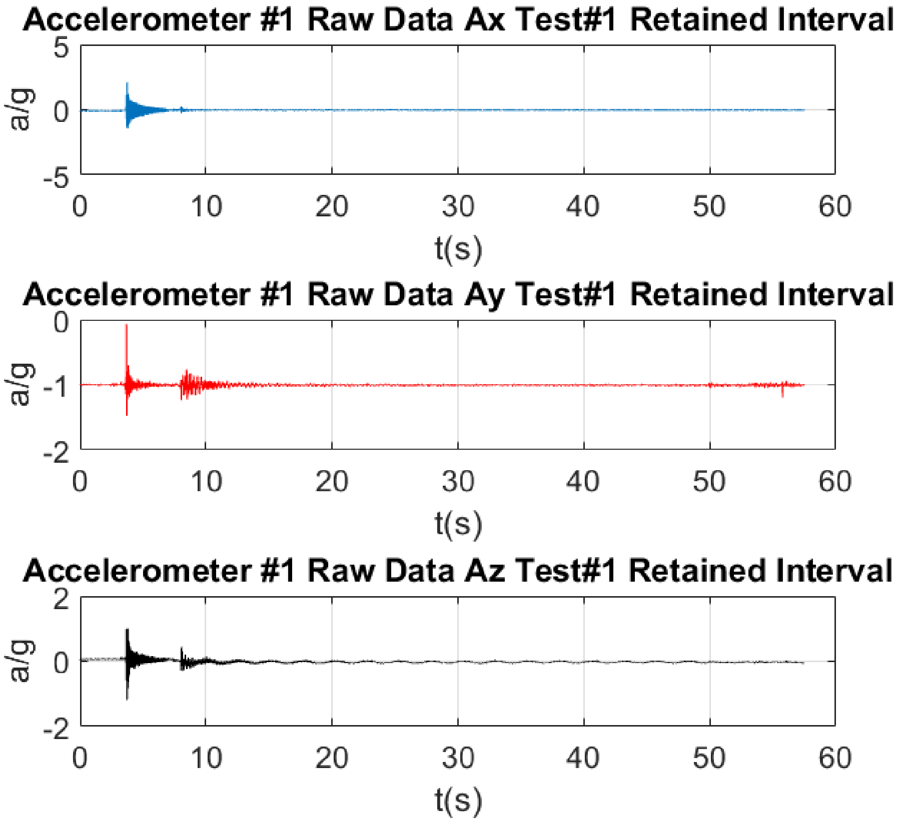
- Boom deterioration:
  - Tests will be performed preflight; need to be sure tests will not compromise boom and deployment
  - First sign of wear of the composite matrix after the third test (3 cycles folding/deployment)
  - By seventh test, no cracks had formed on the boom, but more visible signs of wear on the matrix

- Repetitive deployment pattern:
  - In agreement with previous tests (2014)
  - In disagreement with computer simulations; needs updating

Boom hinge by final test

Stage 2 Deployment Results

- Maximum accelerations on camera:
  - About **1g**
  - Loads due to deployment are expected to be smaller than those during to launch
  - Ex: at least 2g axial and lateral shocks expected from Delta IV rocket launch



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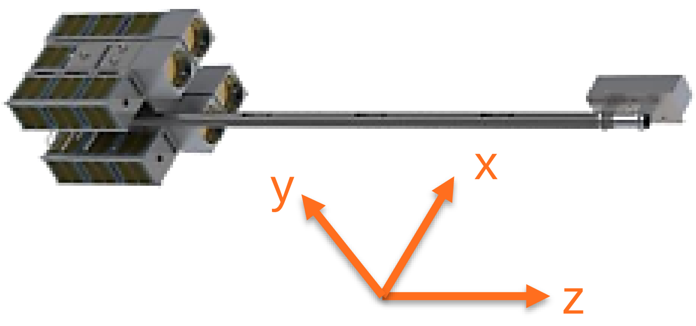
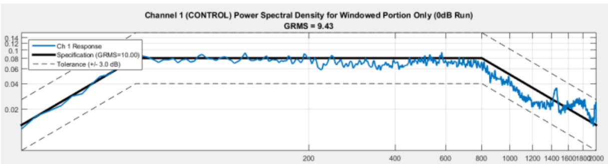
Boom Natural Frequencies

- Discrete Fourier Transform of acceleration profile was used to analyze boom natural frequencies
- Need to avoid disturbances from satellite components inducing vibrations at natural frequencies (e.g. reaction wheel)



Observed Frequency (Hz)	Inferred Corresponding Mode	Approximate Decay Time (s)
3	Torsion around boom axis + bending in xz plane	5
11	Torsion higher mode	5
13	**Bending in xz plane**	**20**

Vibration Testing Objectives



Survive launch vibration phase

Acceptance level test (10 gRMS, 30g peak)

Random vibration Input direction:

- X-axis
- Y-axis

Accurate position of the camera

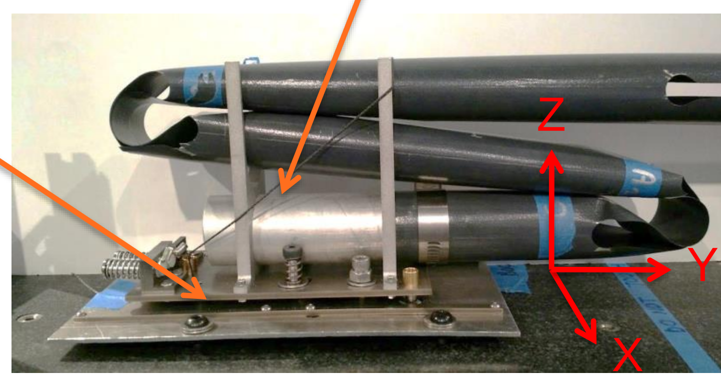
Vibration induced displacements of the adjustable components

Separation device functional

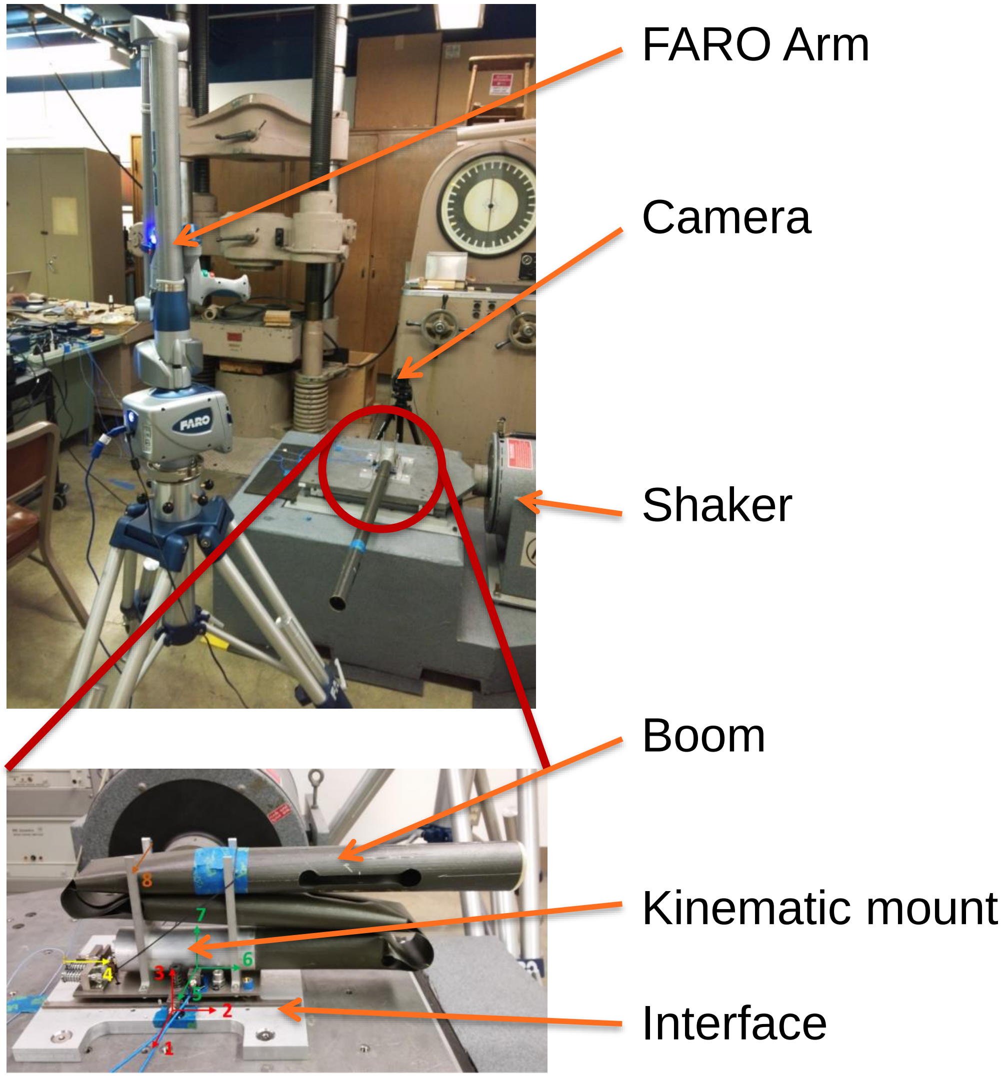
Evolution of the Vectran cable tension

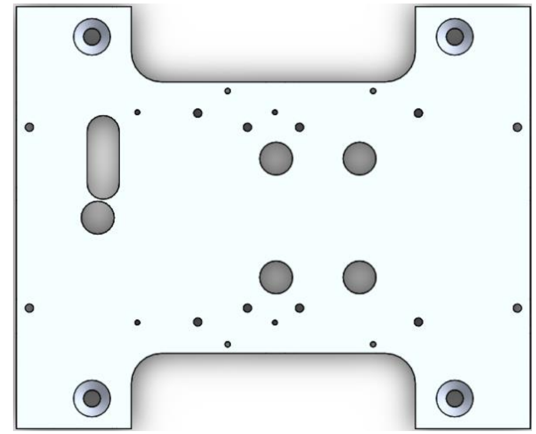
System undamaged

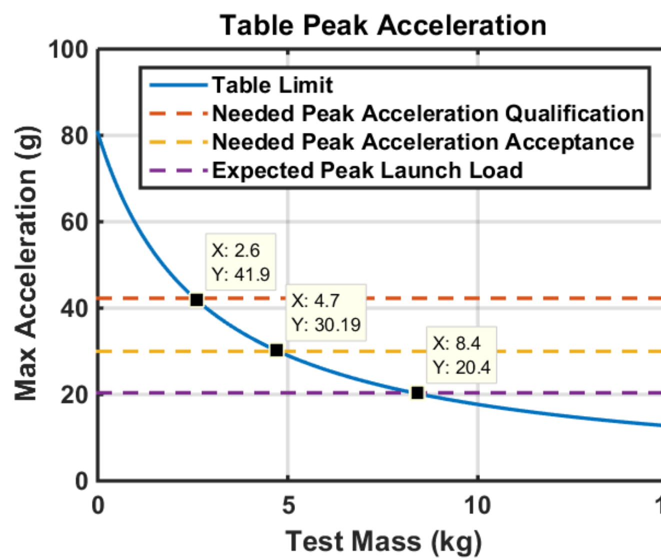
Structural integrity and mechanical response



Testing setup and interface







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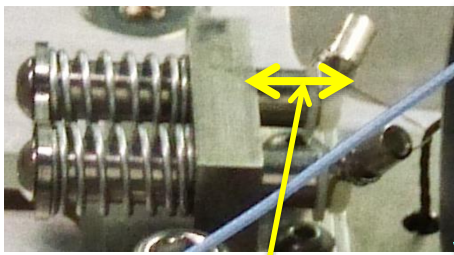
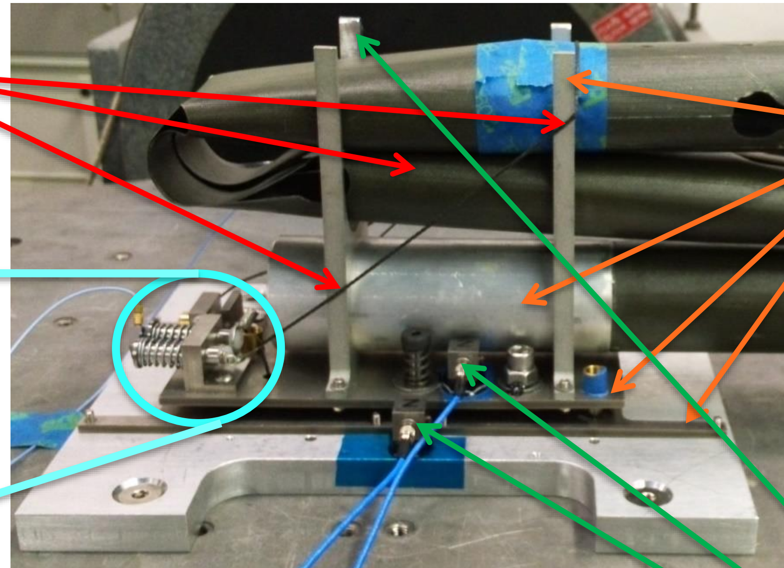
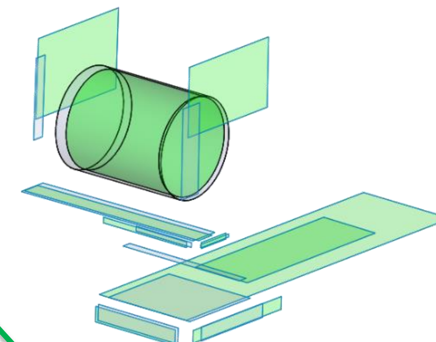
Results: observations

Thorough visual inspection

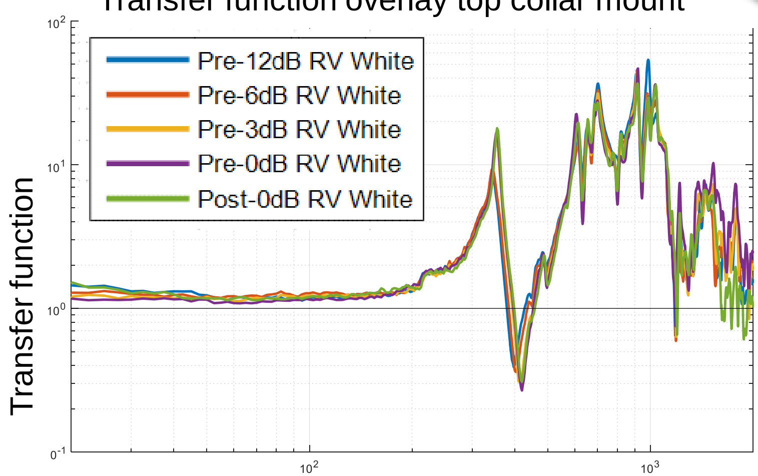




Faro arm measurements: relative displacements

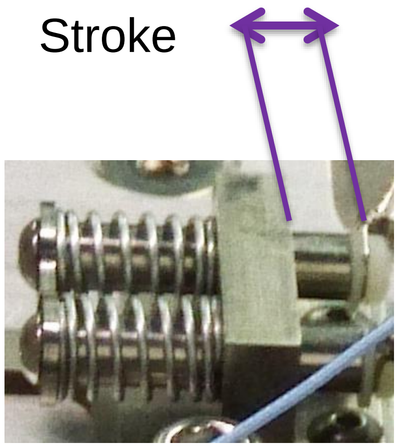


Stroke of the separation device: Tension of the Vectran cable



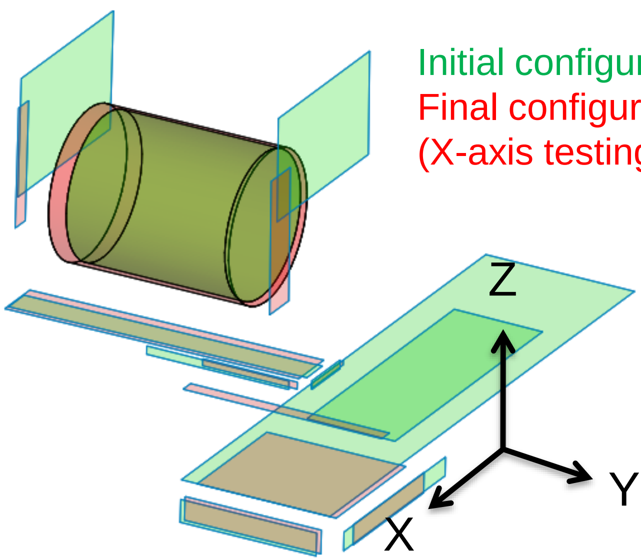
Accelerometers: Structural integrity

Quantitative results



Stroke X-axis test (mm)	Stroke Y-axis test (mm)	Relative loss of stroke X-axis test (%)	Relative loss of stroke Y-axis test (%)
5.58	7.08	16.9	6.2

- Requirement: final stroke > 3mm



Initial configuration
Final configuration
(X-axis testing)

Displacements Y-axis testing	
Mandrel axis linear displacement (mm)	dx: 0.032, dz:0.009 (dy: 0.052)
Mandrel axis angular displacement (°)	0.037
Camera displacement (modulus) (mm)	0.9 mm

- Requirement: lateral displacement < ± 3 mm

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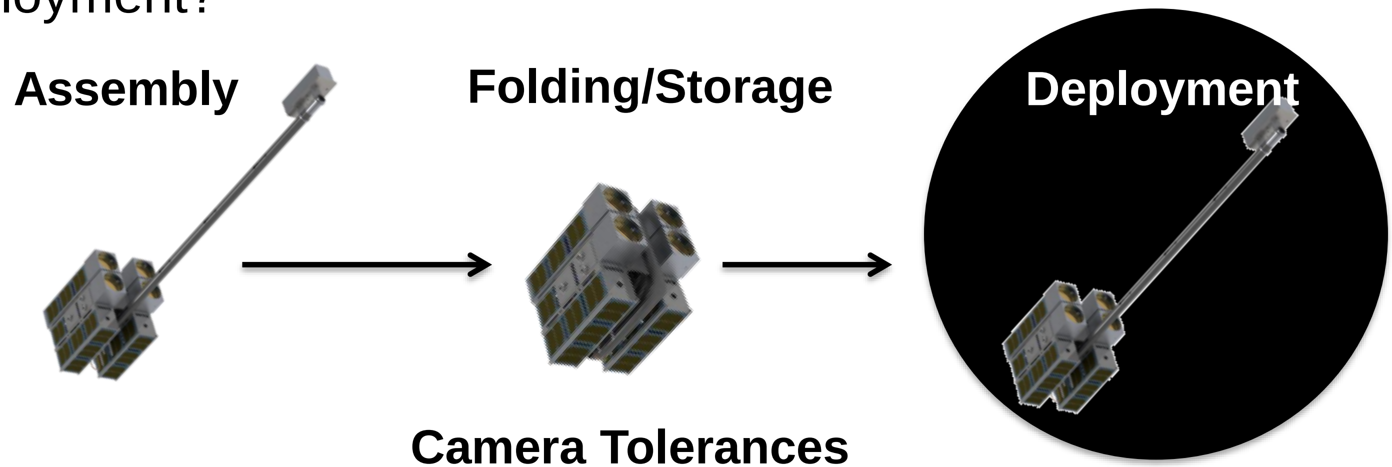
Accuracy Testing Criteria

- Verify the **repeatability** of camera alignment, after the boom is folded and stored for some time
- If the boom is aligned during assembly, will it still be aligned after deployment?



Camera Tolerances

Requirements	Value
Focal length	1163 ± 1mm
Maximum admissible lateral offset	± 3 mm
Maximum admissible angular offset	± 1°

Accuracy Testing Methods

- **Challenge:** Boom is 1.5 meters long and flexible; we need to measure position with millimeter accuracy and without touching it.
- **Solution:** FARO Arm measuring device with optical scanning tool.

Simulated storing the boom for seven months in folded configuration by aging process – 2000 seconds at 96 C°

Procedure:

1. Scan the camera end of the boom
2. Scan the coresat end of the boom
3. Fit each point cloud to a cylinder in matlab
4. Determine the position of the camera end relative to the coresat end
5. See how the position changes after folding and aging

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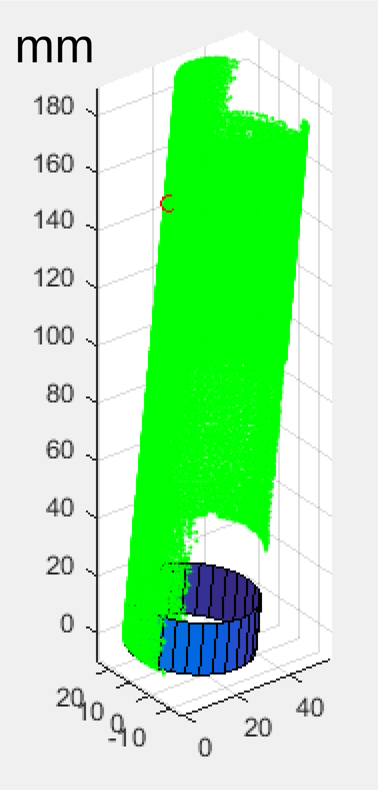
Accuracy Testing Results



Cylinder Fit to Point Cloud

	Length Change	Lateral Change	Angular Change
Requirement	± 1mm	± 3mm	± 1º
Folding	0.1 mm	0.5 mm	0.1º
Aging	3.0 mm	1.0 mm	0.2º

- Axial displacement after aging is larger than expected – 3 mm elongation
- Could be a problem with our measurement system or with the boom itself
- Needs further investigation

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Conclusions

- Found a reliable method of performing the boom-mount connections
- Changes in boom do not affect maximum acceleration experienced by boom during stage 2 deployment
- Repeatable pattern of natural frequencies observed in stage 2 deployment
- Kinematic mount validated under vibration environment
- Validated the accuracy of the boom position after folding and storage

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Future work

- Analysis of the vibration modes and comparison with the simulations
- Stage 1 and stage 2 deployment tests with aged booms
- Repeat the Stage 2 deployment computer simulation adding constraints to match experimental results
- Error quantification for the vibration test results
- Vibration test of the full system (full boom in launch configuration)
- Investigate large axial displacement of the boom after aging

Thanks for your attention
Any questions?

Outline

2:00 pm: Introduction & Welcome

2:15 pm: Camera

2:45 pm: Boom

3:15 pm: Mirror Boxes

3:45 pm: On-board Software

4:15 pm: Electronics

Mirror Box

Jake Larson, Sheila Murthy, Catherine Pavlov, Tyler Okamoto, Anand Kumar

Mentor: Serena Ferraro


Rigid Mirror Boxes
Deformable Mirror Boxes

Project Overview

Key Purposes of Mirror Boxes:

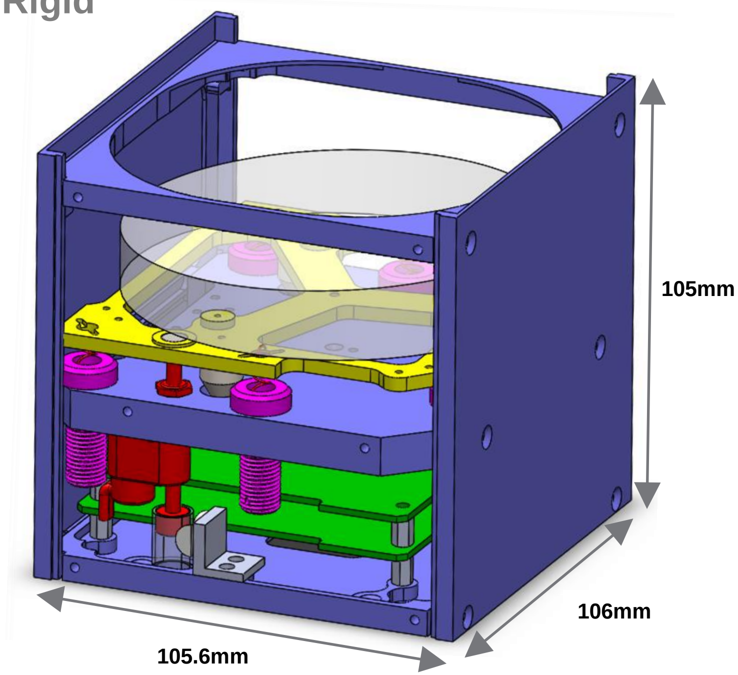
- House mirrors and electronics
- Restrain mirrors during launch
- Provide rigid body rotation and axial motion of the mirrors

Mirror Boxes Objectives:

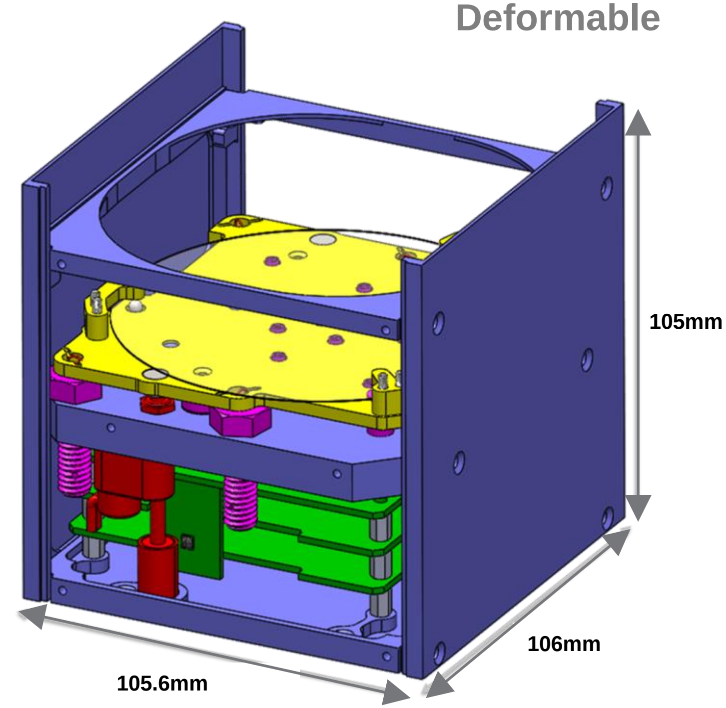
- Develop assembly methods and documentation
- Design and manufacture Mirror Box parts
- Test epoxy and picomotor limit switches
- Perform vibration testing with proto-flight components
- Future work: Perform optical and mechanical testing on both boxes

Mirror Boxes Overview

Rigid



Deformable



- Mirrors & Mounts
- Launch Restraint System
- Frame
- Picomotors
- Electronics

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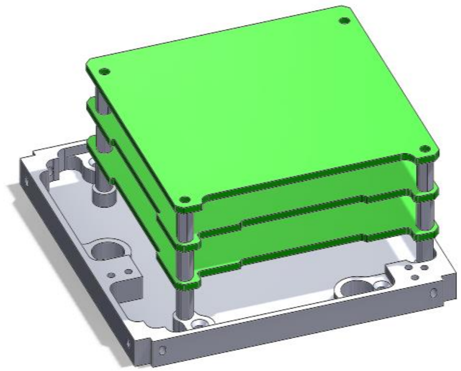
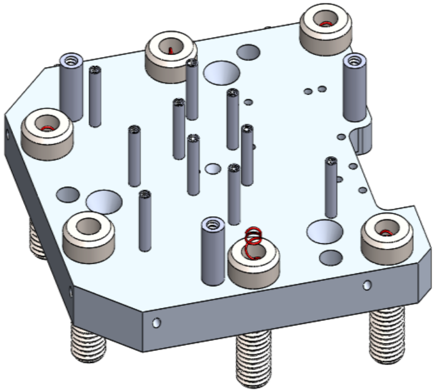
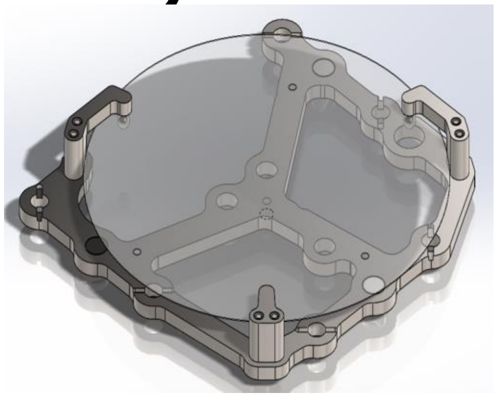
Mirror Box Assembly



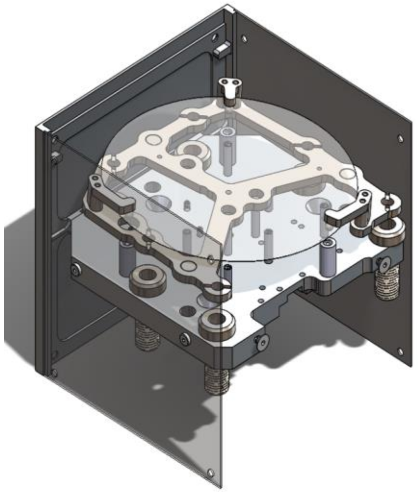
Base with PCBs

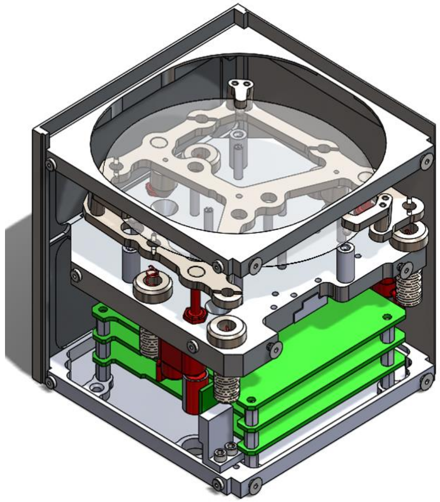


Reference Plate



Mirror Plate





- Both boxes are assembled using similar procedures which integrate the three primary subsystems of the boxes
- These procedures are codified in assembly documents

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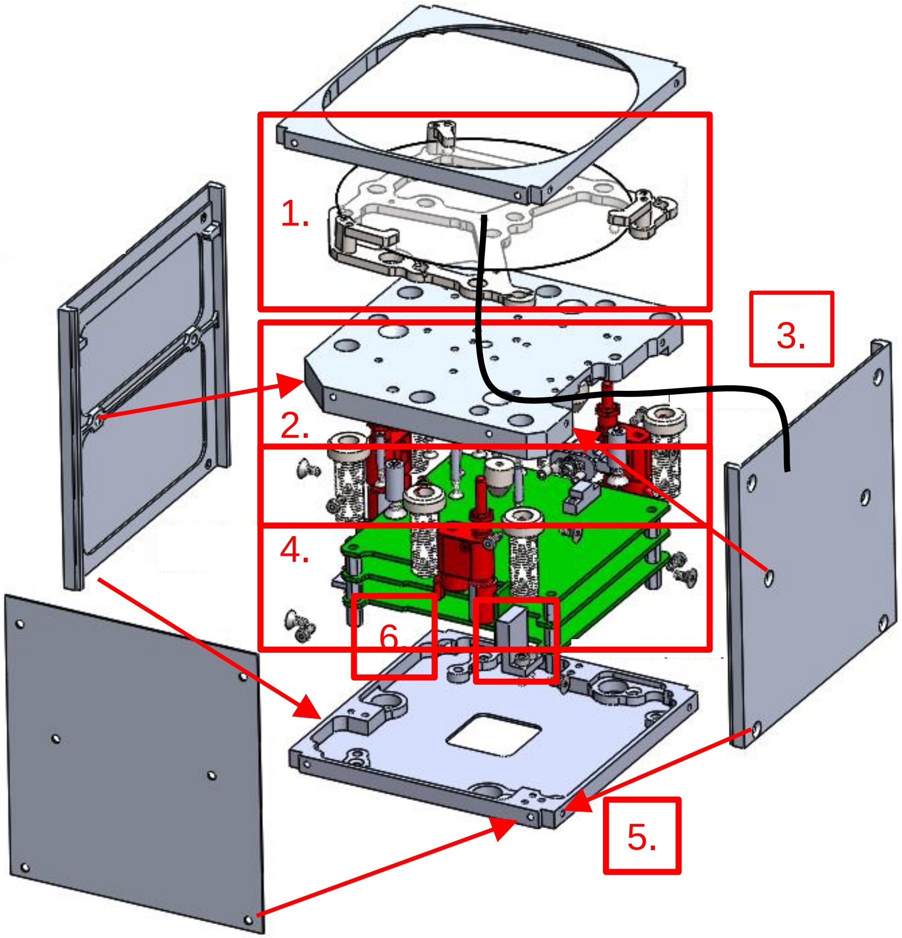
Assembly overview

1. Mirror plate + mirror
2. Reference plate + picomotors
3. Mirror plate + reference plate connected via Vectran™ tensioning
4. Electronics boards mounted on base plate
5. Mirror assembly and walls attached to base plate
6. Optical encoder mounts attached to base plate



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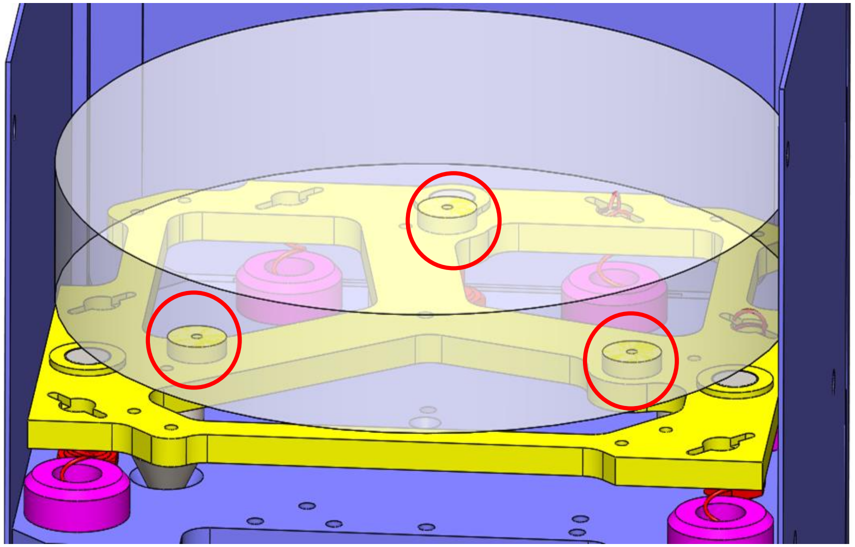
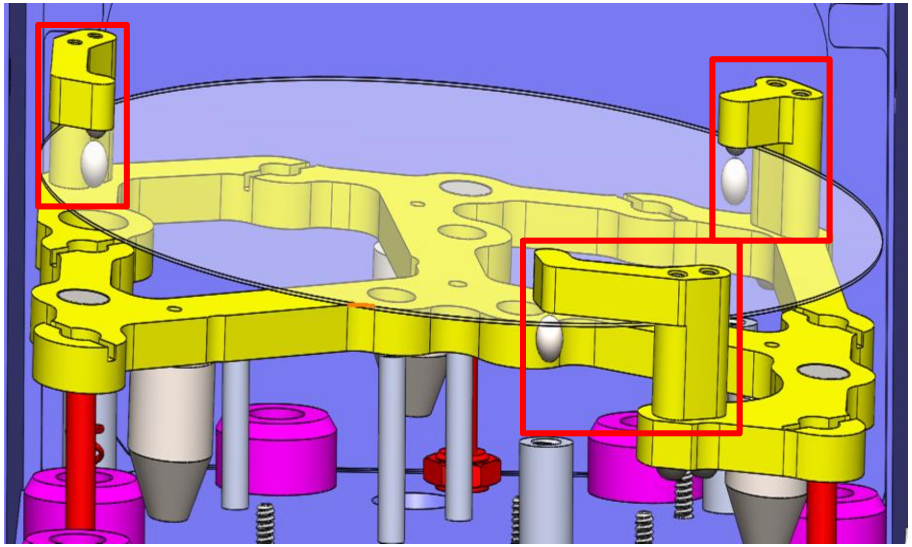
Securing the Mirrors

Rigid



Attached at three raised pads with epoxy

Deformable



Attached to mounting posts with magnet & ball bearing pinches

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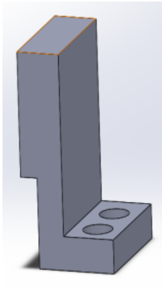
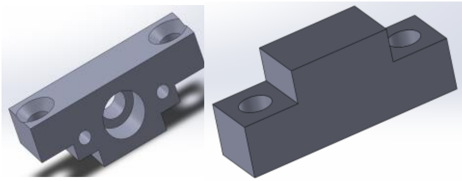
Designed and Manufactured Components

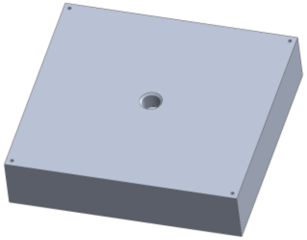
- Optical Encoder Bracket
    - Picomotor optical encoder



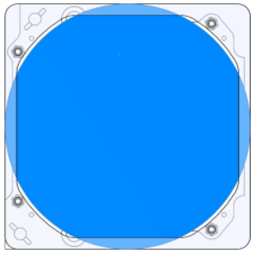
- Shaft & Clamp Inserts
    - Launch restraint & separation devices



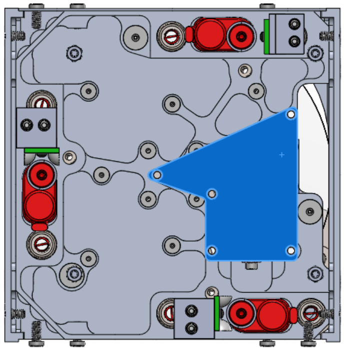
- Representative Mirror Mass
    - Vibration testing



- Optical Mirror Mask
    - Rigid mirror alignment



- Separation Device Lid
    - Contain Vectran after deployment



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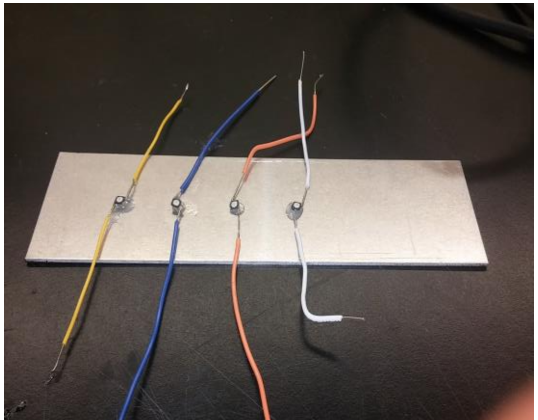
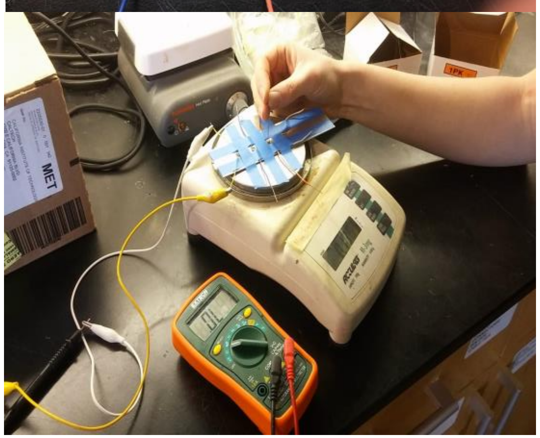
Limit Switch Test

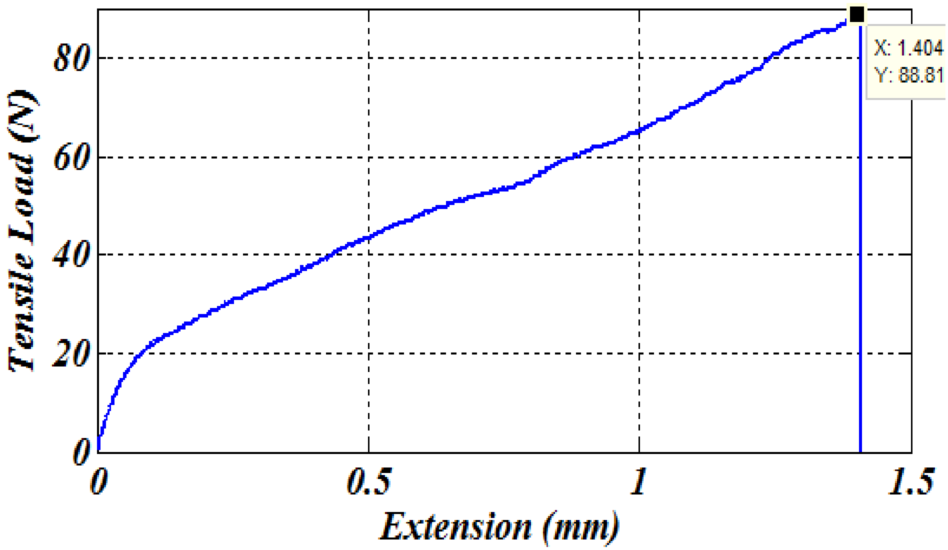




- Picomotors provide **13 N** of force when translating
- Need a fail-safe mechanism to restrain over-actuation
- Nano-miniature Top-Actuated Tact Switch
- Determined force needed to activate switch to ensure they were up to spec
- Mean depression force: **1.02 N**
- Overall Std. Dev: **.09 N**
- The switches were within the force range provided by the manufacturer of **1N +- 25%**

Epoxy Bond Test

- Rigid Mirror Box: Mirror is glued to mirror plate
- Peak Acceptance: 40g -> ~ **42N** on each pad
- Epoxy Name: Loctite EA 9394 AERO
- Tensile test
  - Failure at **88.8N**
  - Debonding from mirror surface



- Limitations: Outgassing properties of 1.5%
- Need to take this strength and compare it with vibration results

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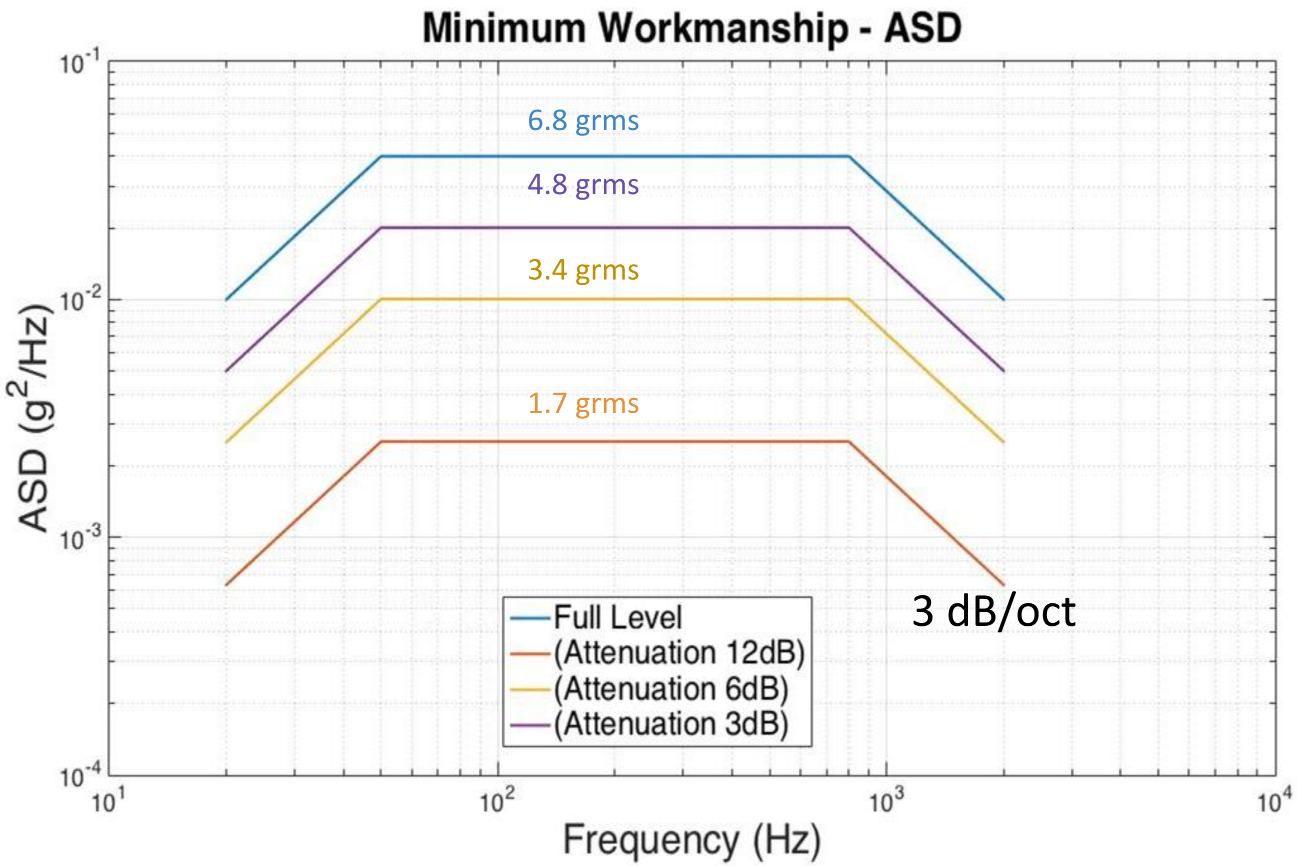
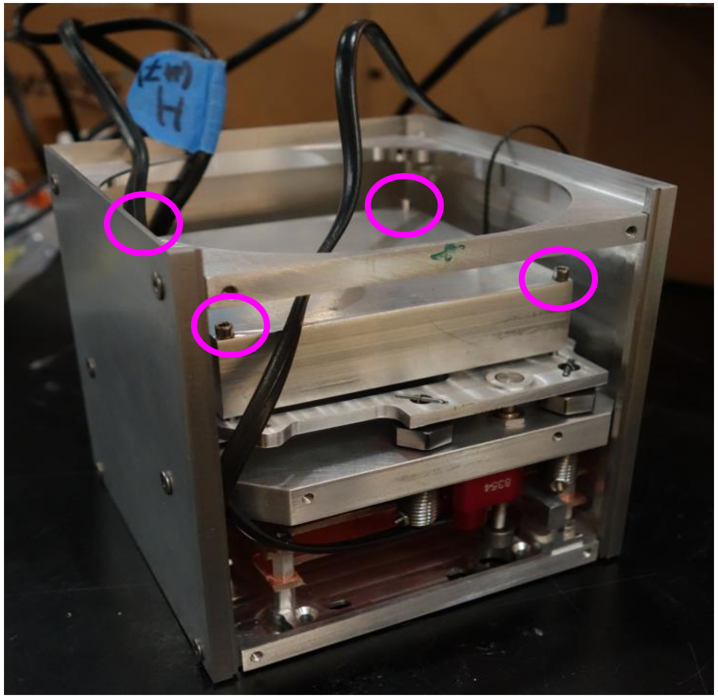
Vibration Testing: Test Sequence and Input Profiles

White Noise → -12 dB → White Noise → -6 dB → White Noise → -3 dB → Full Level → White Noise



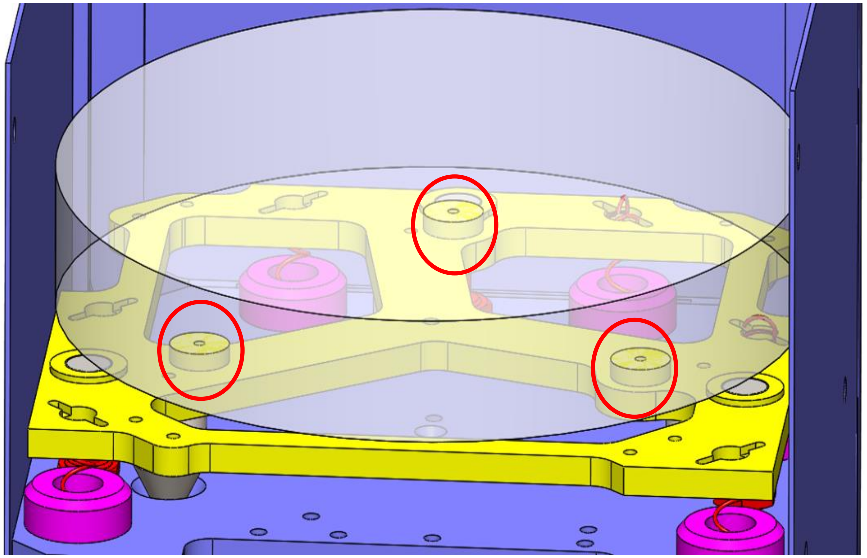
Substituting the Mirror

Vibration Testing



Aluminum Mass Screwed to Mirror Plate

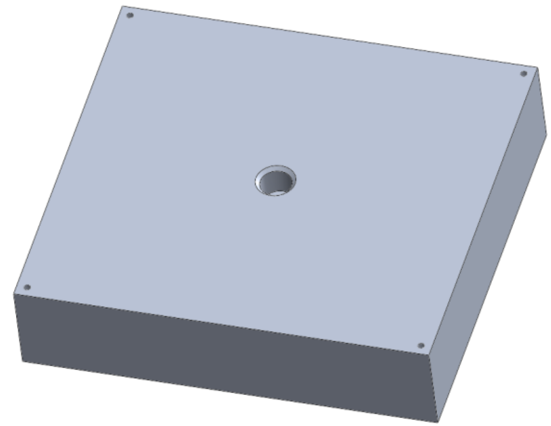
Flight

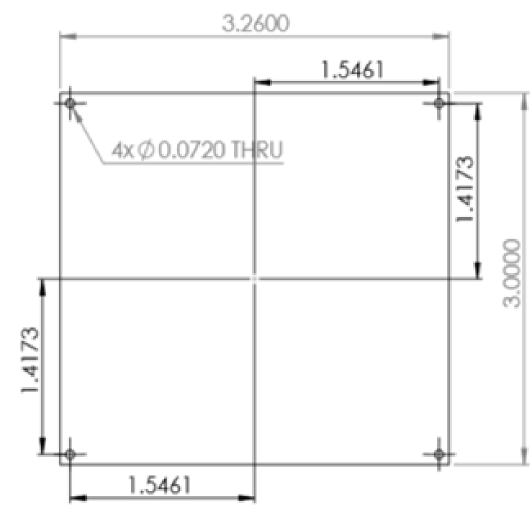


Rigid Mirror Epoxied to Pads on Mirror Plate

Substitute Mirror Mass Design and Manufacture

- Mass: 323.5g
- Density comparable to Zerodur
- ¾” aluminum rectangular block
- Secured to mirror plate via 2-56 1” long screws
- Dimensions large enough to secure to mirror plate spare holes and small enough to fit within box
- Milled down to size and drilled holes





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Deviations From Test As You Fly (TAYF)

Proto-Flight Boxes	Flight Boxes	Impact
Aluminum Mirror Mass	Actual Rigid Mirror	High
Screws attach rigid mirror to mirror plate	Epoxy bond applied between mirror and mirror plate	High
Picomotors have large RJ45 network wires and are not vacuum-compatible	Picomotors will have encoded Kapton® and will use a vacuum-compatible model	Medium
No additional sensing equipment	Temperature Sensors with wiring	Medium
Manually Cut Glass Fiber Boards	Electronics PCBs	Low
Optical Encoder Brackets	Optical Encoder Brackets with PCB and Encoder	Low

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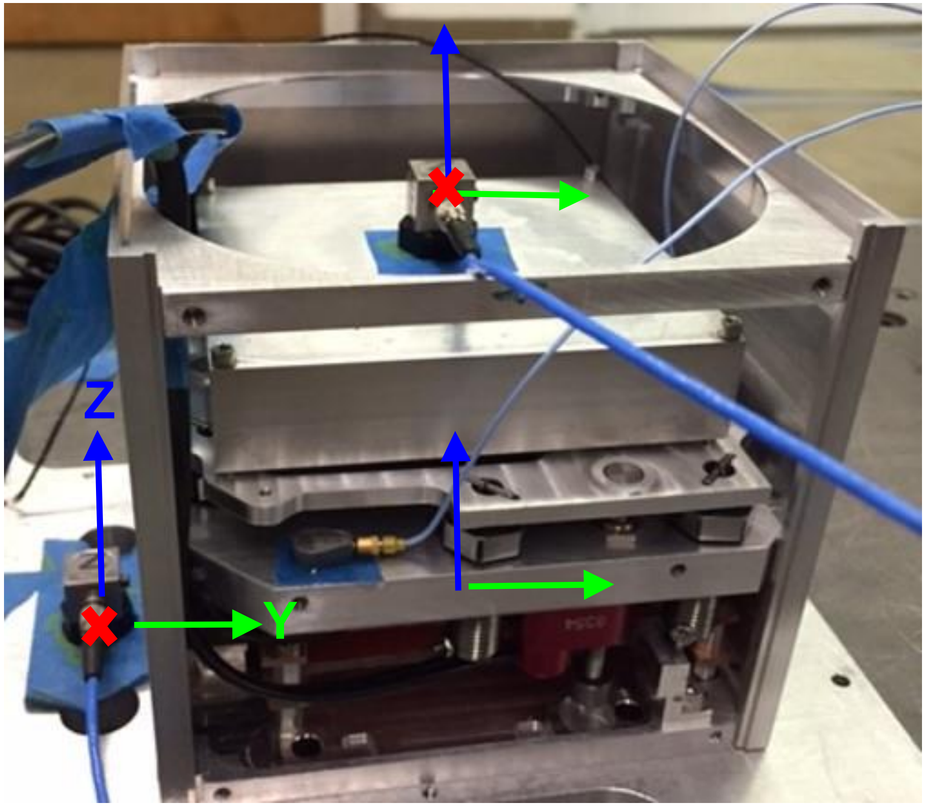
Accelerometer Placement

- The signal was input in the **Y direction**
- Accelerometers recorded:
  - All 3 axial responses of the mirror mass
  - All 3 axial responses of interface plate (control)
  - vertical **Z axis** of reference plate
  - input **Y axis** of the reference plate
- Accelerometer locations chosen to identify accelerational load particular to mirror mass from that of entire system



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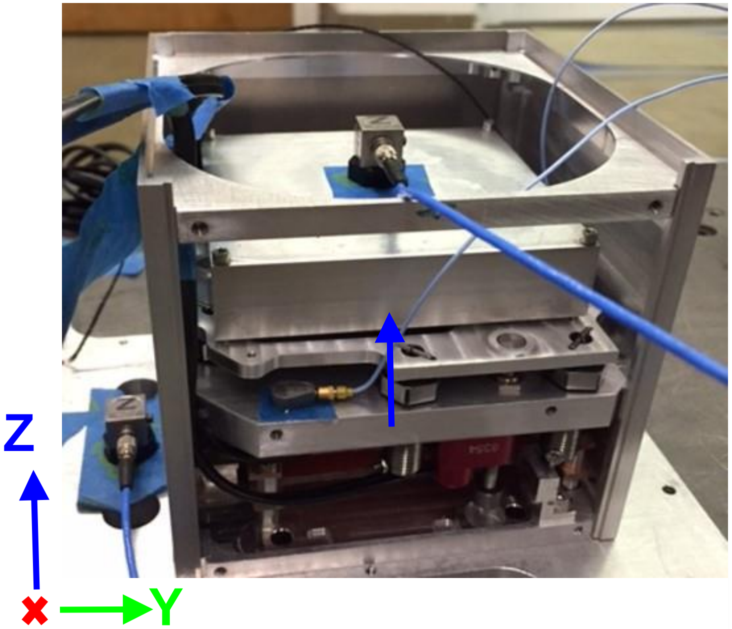
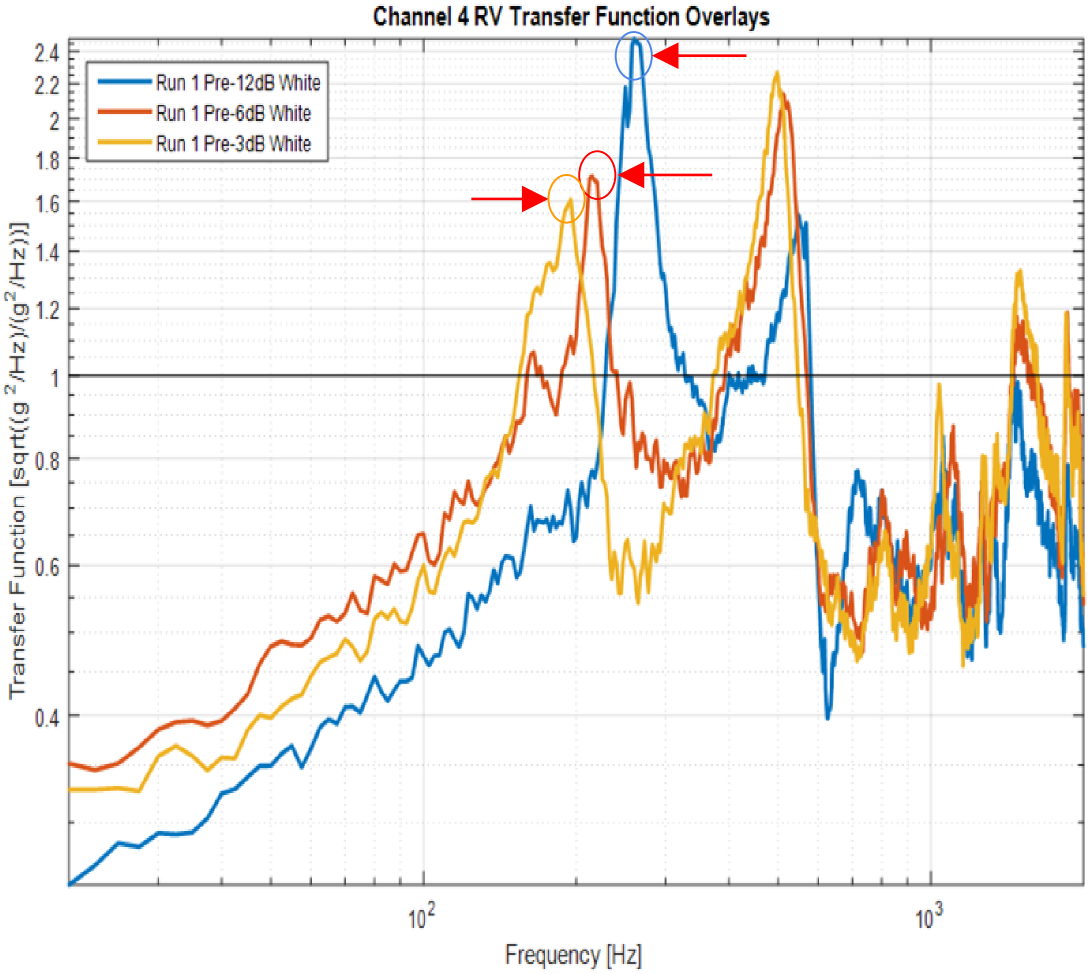
Ch4: Reference Plate Z-Axis White Noise Test 1 Results





- **20% shift** in resonance frequency after the -12dB test
- These shifts continued after -6dB, signalling **structural changes in the test article**
- Inspected the time history and PSDs for more information

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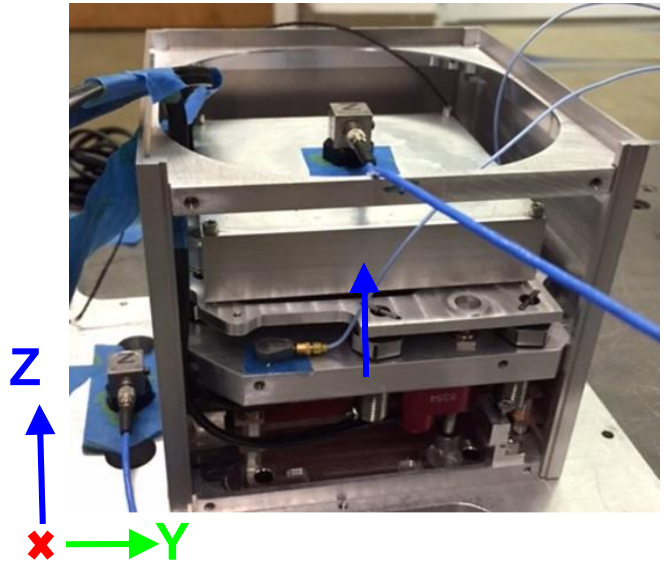
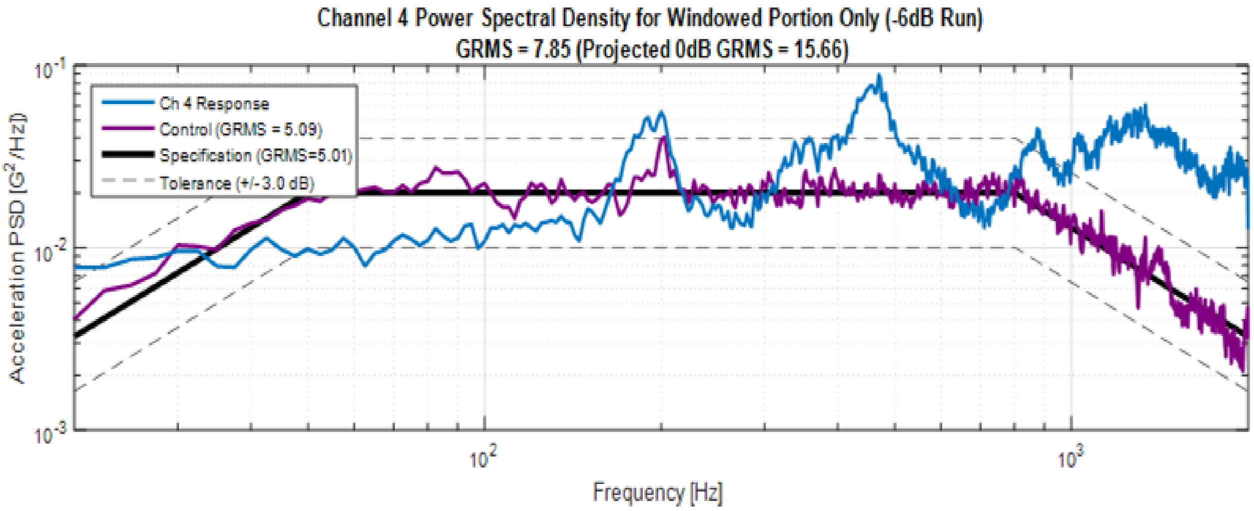
Ch4: Reference Plate Z -6 dB Test 1 Results

- The vertical axis of the reference plate experienced unexpectedly large amplification
  - Max acceleration: **122.67 g**
  - GRMS: **7.85**
- Cross-Coupled Response
- First Mode of a Thin Plate
- Continued the search for answers with the mirror mass...





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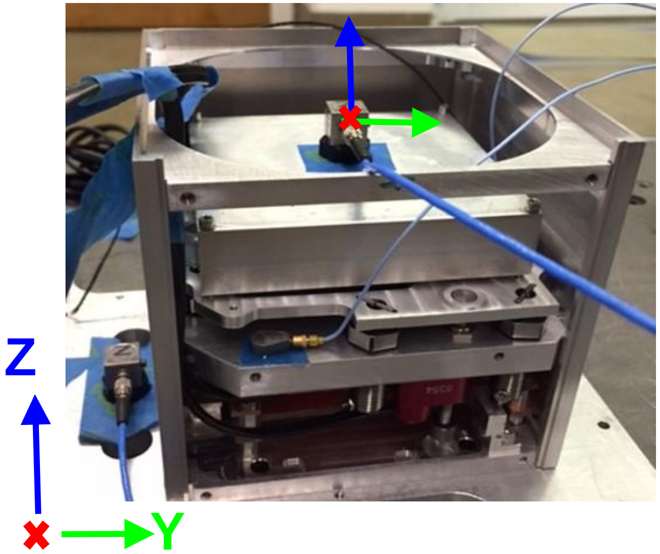
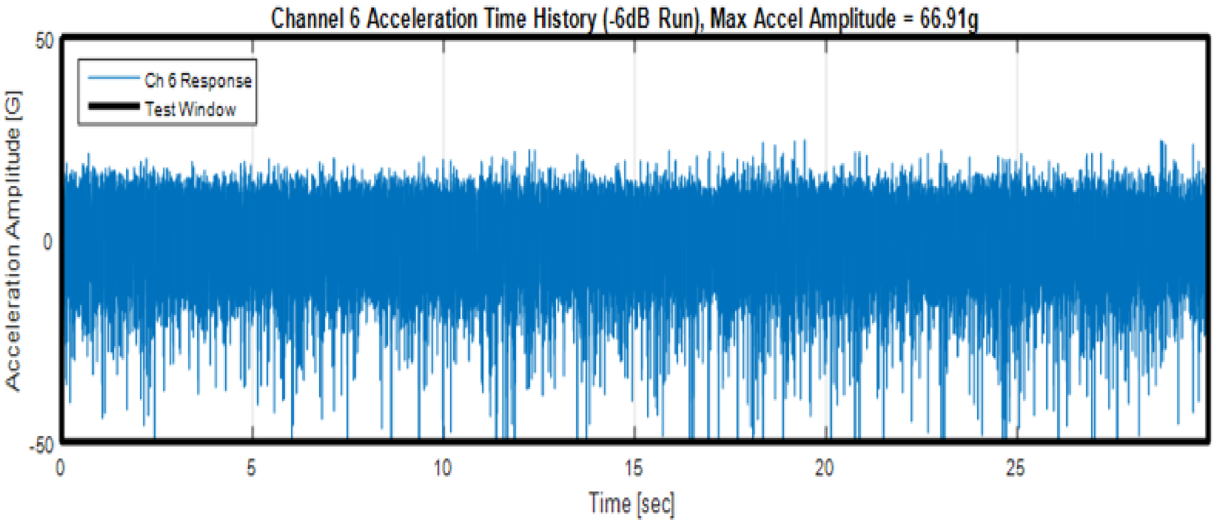
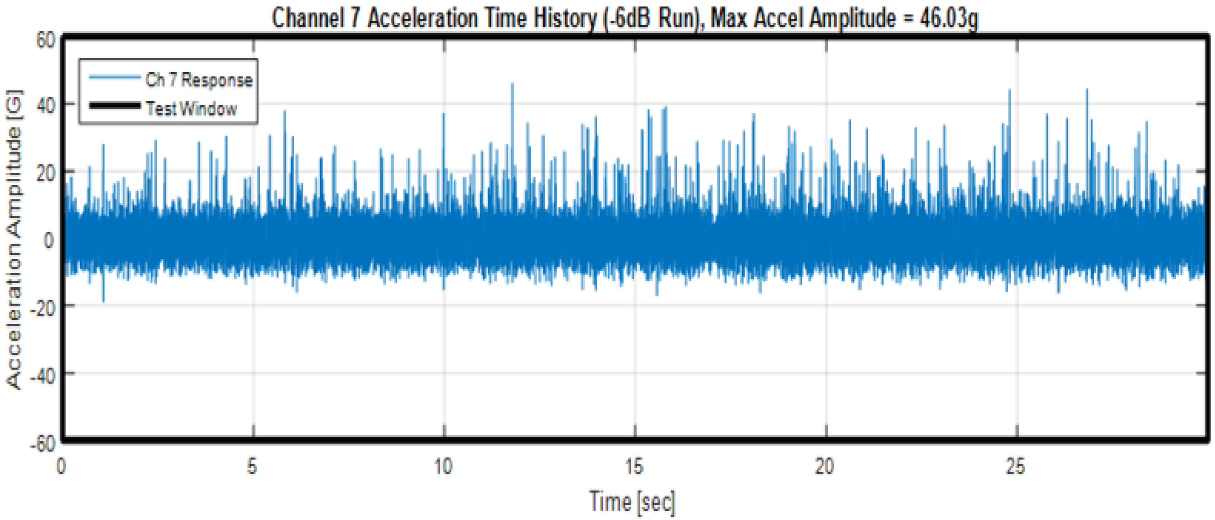
Ch6 & Ch7: Mirror Mass Y & Z-Axis -6 dB Test 1 Results







- Mirror Mass vertical and input axes responses were one-sided
  - **Upon visual inspection, the mirror mass was loose, and was slapping the reference plate and walls/wires**

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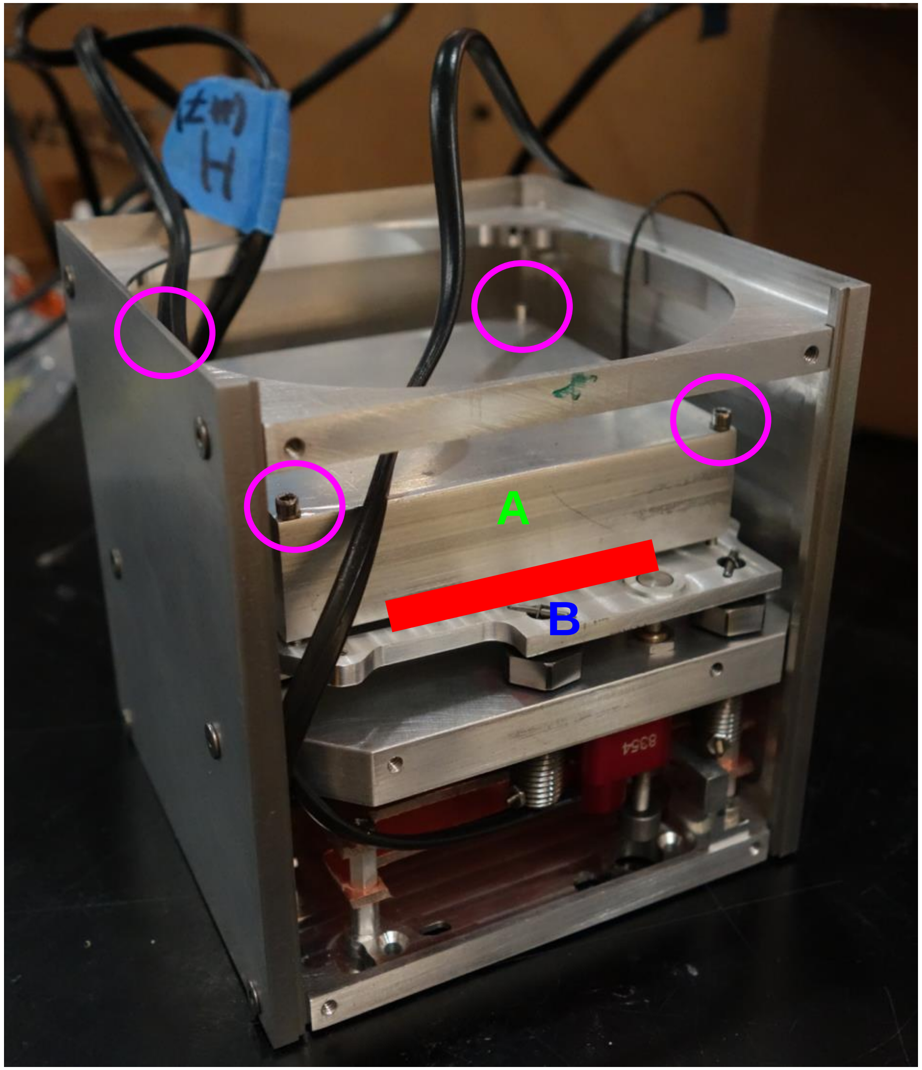
What does a "loose mirror mass" mean, and how do we fix it?

- The Rigid Mirror will be attached to the Mirror Plate using epoxy

- For vibration testing purposes, the **Mirror Mass** is attached to the **Mirror plate** using **screws**

- Improper securement of the mass appeared a likely cause of the unexpected test results

- To eliminate the excess spacing between the Mirror Plate and Mirror Mass, washers were added to the corner screws, along with **foam** between the two pieces



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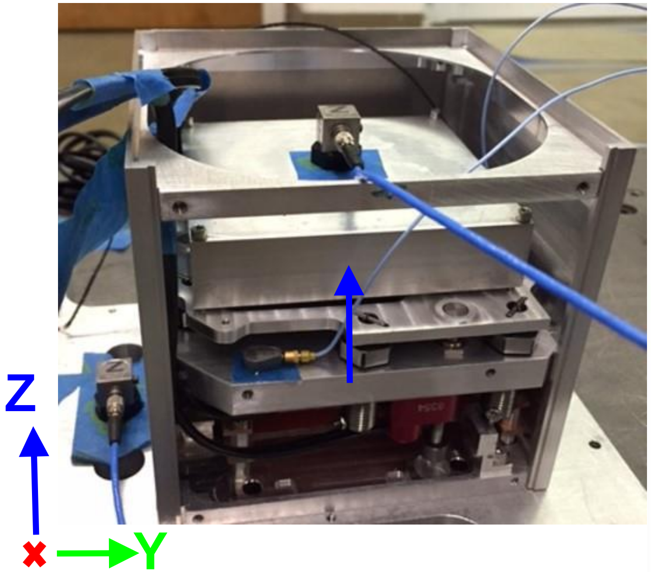
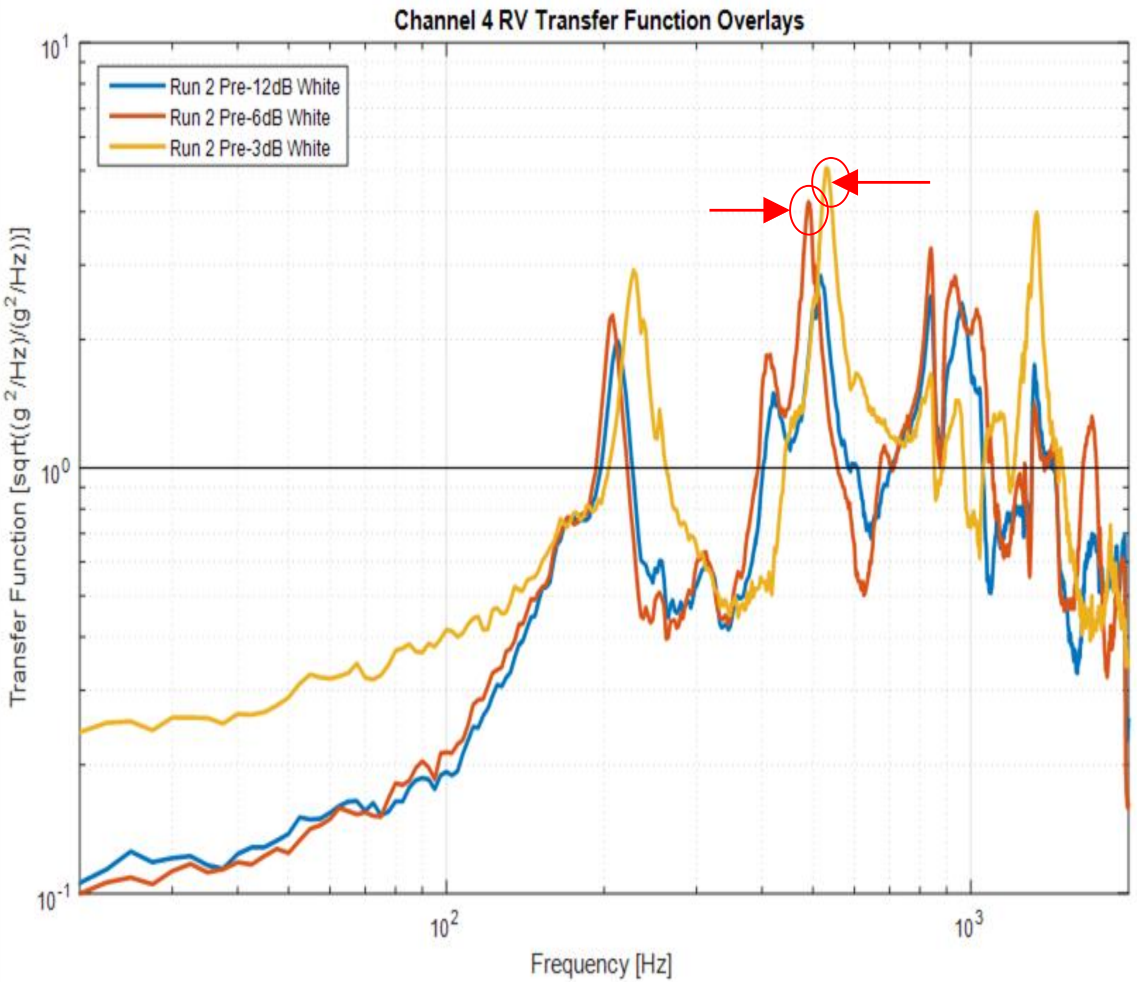
Ch4: Reference Plate Z-Axis White Noise Test 2 Results



- All screws were confirmed secure with a torque wrench
- After properly securing the mirror mass, the reference plate had acceptable, smaller frequency shifts



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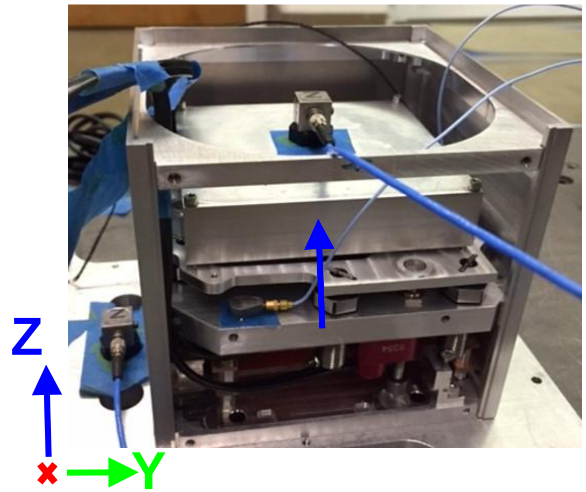
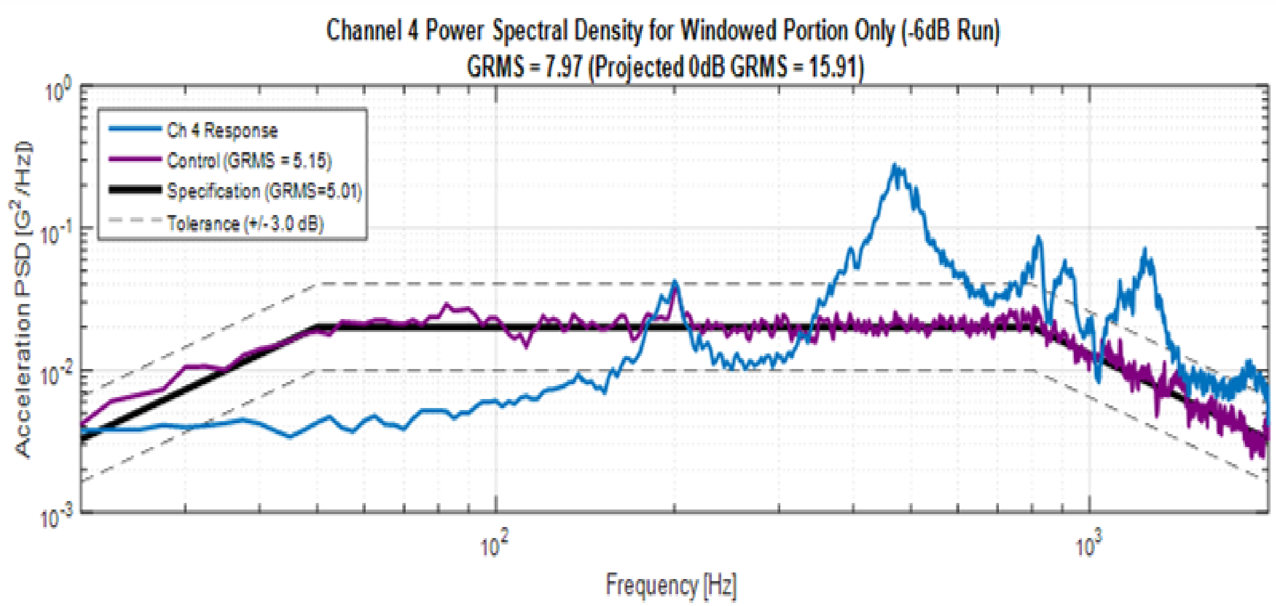
Ch4: Reference Plate Z -6 dB Test 2 Results

- After securing the reference plate, the amplification was lessened
  - Max acceleration: 84.46g (122.67g)
  - GRMS: 7.97 (7.85)
- Preliminary projections from this data raise possible **concerns about the epoxy bond strength**
- Solutions include increasing pad size for larger bond area





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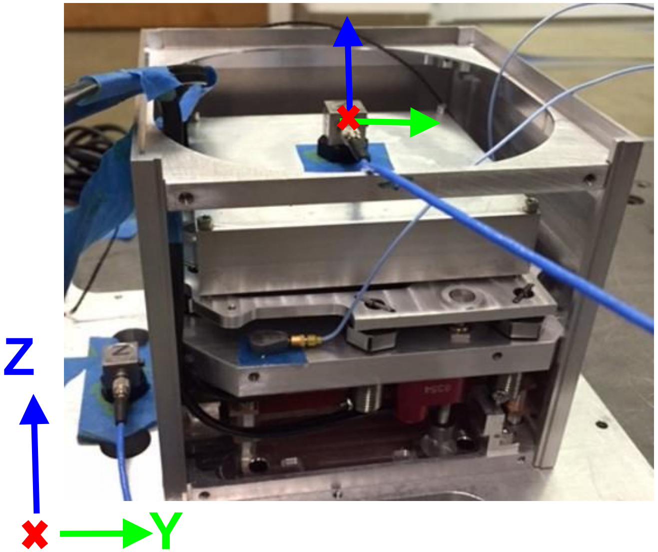
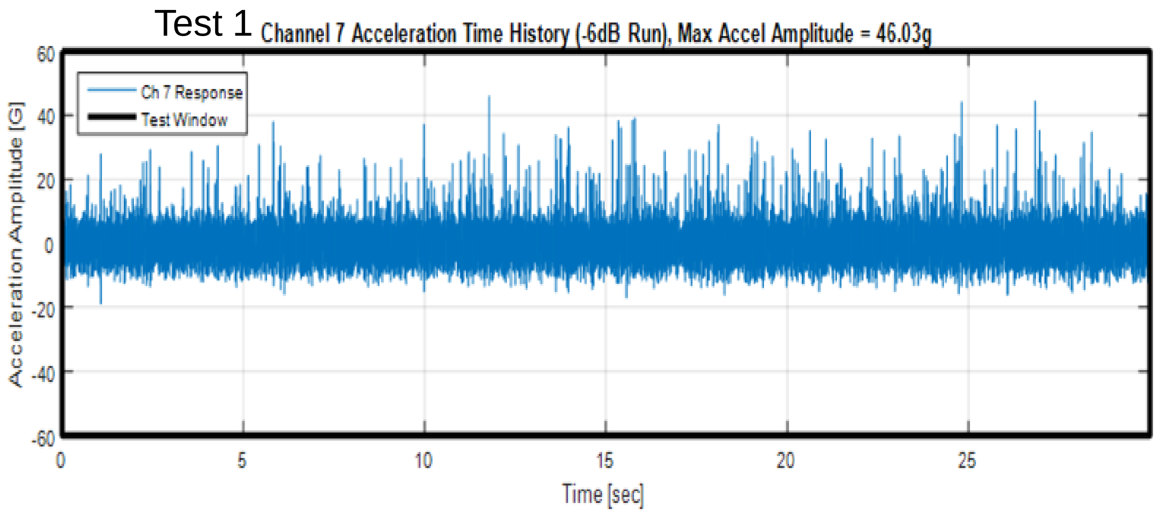
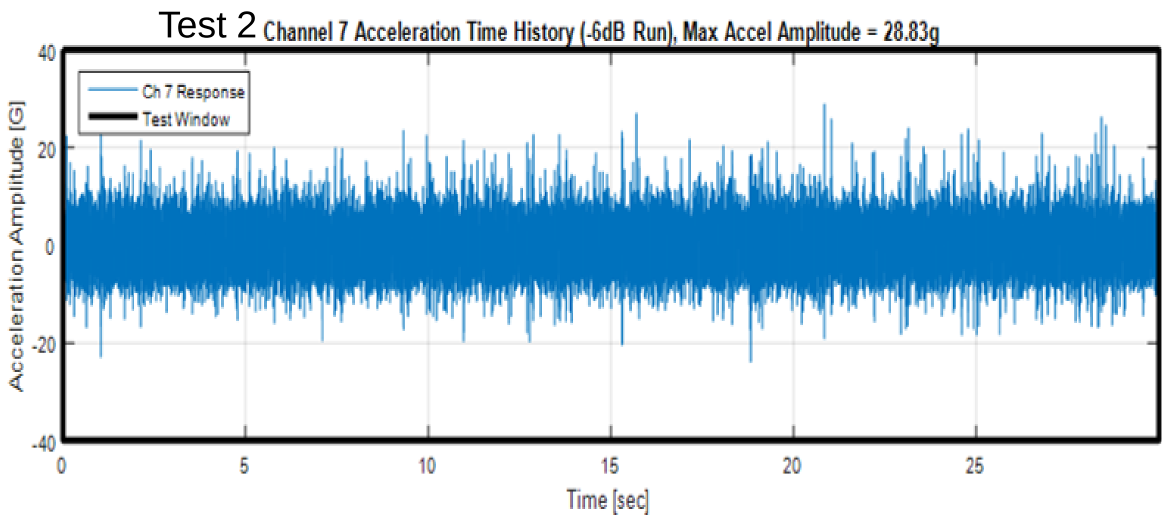
Ch6 & Ch7: Mirror Mass Y & Z-Axis -6 dB Test 2 Results







- Mirror Mass Response now displayed expected two-sided peaking
- Upon visual inspection, box displayed no signs of structural failure

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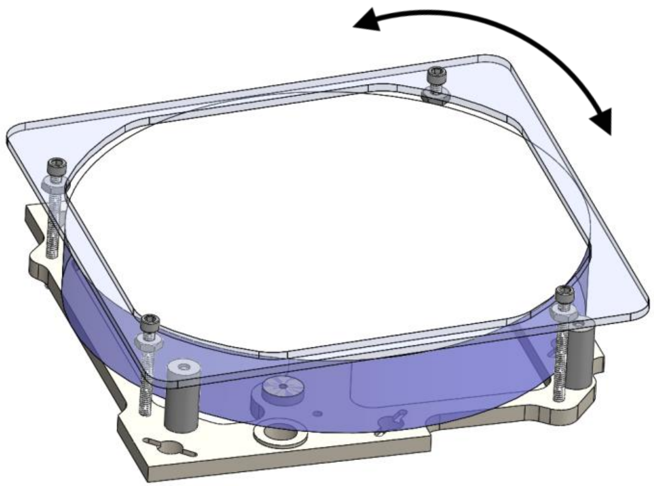
Vibration Testing Conclusions

- Potential to exceed bonding strength at full level loading
- Box structure withstands very high peak loading
- Shaker table needs to be fixed so Y and Z axis can be accurately assessed

Rigid Mirror Mask Design and Manufacture

- After Vibration Testing, need to optically align the mirror for a “true assembly”
- Need to maintain mirror position during optical alignment
  - Box is rotated to apply epoxy to underside of mirror
- Designed and manufactured a mask to secure the mirror during optical testing and assembly



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Summary of Tasks

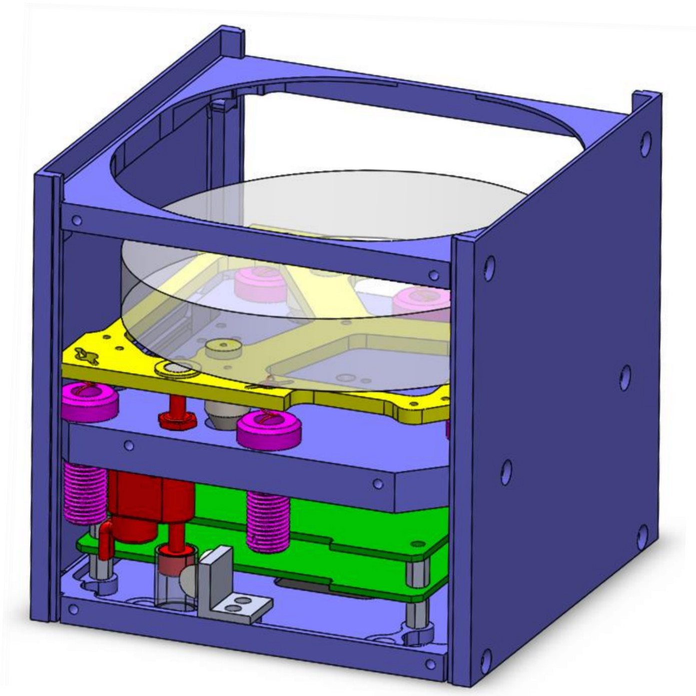
Completed Work

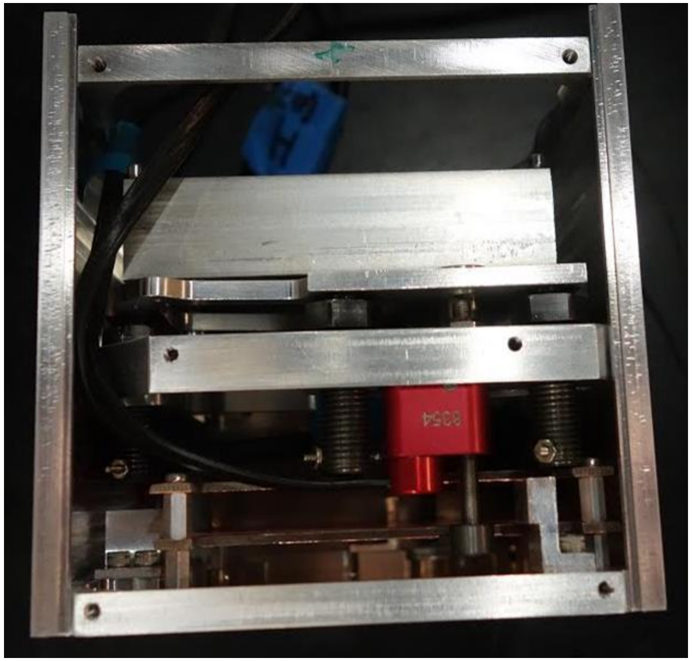
- Designed and manufactured components
- Limit switch and Epoxy Bond Test
- Assembly of both boxes
- Assembly documents
- Rigid box vibration testing in y
- Rigid box optical testing preparation

Future Work

- Vibration testing of rigid mirror in x and z
- Vibration testing of deformable mirror box
- Complete assemblies with real mirrors
- Optical testing and alignment verification
- Separation device mechanism test

Concluding Remarks





The Mirror Boxes have progressed from CAD models to real, assembled equipment and undergone a first round of vibration testing

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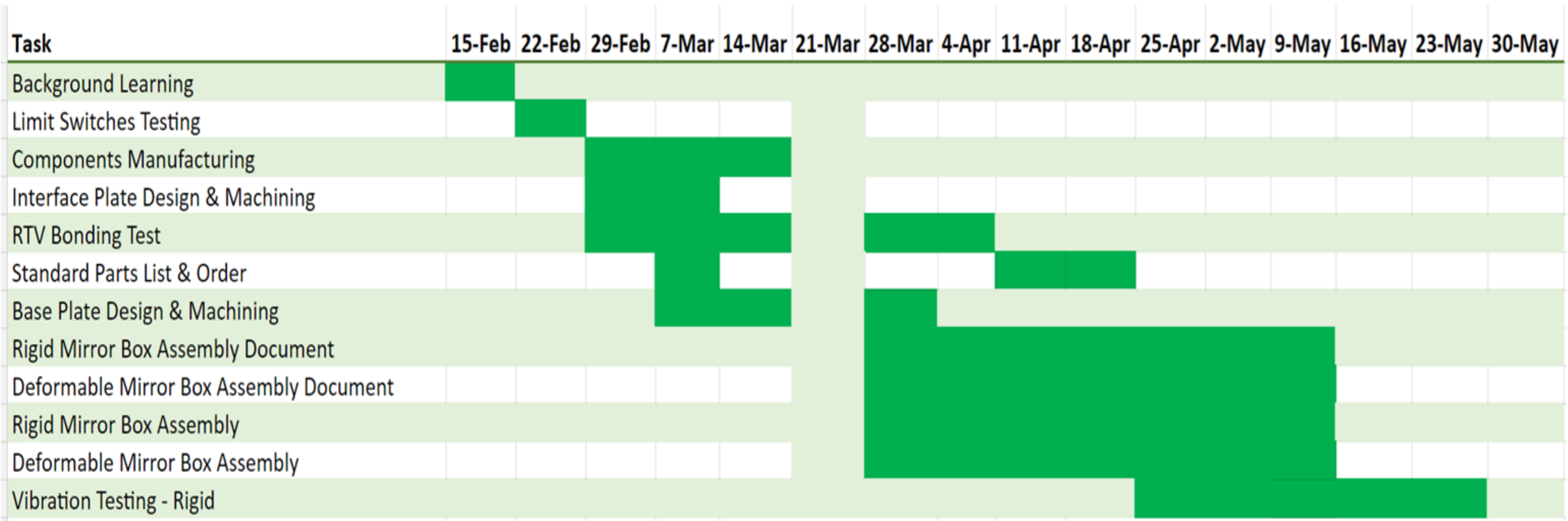
Backup Slides

Schedule



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Assembly Documents

I. Materials Required
   A. Principle Materials
   B. Shims for Pillars
II. Summary Instructions
III. Assembly
   A. Mirror Plate
      1. Epoxy of vees and springs
      2. Mounting mirror
   B. Reference Plate
      1. Shims
      2. Separation Device
      3. Picomotors
   C. Electronics Plate
   D. Integration
      1. Vectran Cable
      2. Attaching Walls
      3. Optical Encoders

AAReST Deformable MirrorBox Assembly Document

Serena Ferraro
Project Supervisor, California Institute of Technology

Jake Larson and Catherine Pavlov
Rigid MirrorBox Members, California Institute of Technology

These instructions detail the recommended assembly method for the Deformable MirrorBox for the AAReST project. This includes assembling the base electronics plate, assembling the reference plate, and assembling the mirror plate. For the MirrorBox containing the rigid mirrors, please see the Rigid MirrorBox Assembly Document.

AAReST Rigid MirrorBox Assembly Document

Serena Ferraro
Project Supervisor, California Institute of Technology

Anand Kumar, Sheila Murthy, and Tyler Okamoto
Rigid MirrorBox Members, California Institute of Technology

These instructions detail the recommended assembly method for the Rigid MirrorBox for the AAReST project. This includes assembling the base electronics plate, assembling the reference plate, and assembling the mirror plate. Special steps are required in order to mount and calibrate the optical assembly before the RTV silicone can be applied. For the MirrorBox containing the deformable mirrors, please see the Deformable MirrorBox Assembly Document.

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Reference Plate Subsystem

- Need to limit axial excitation of Deformable Mirror
- Soft silicone pads are epoxied to the pillars
- Shims are placed below the pillars to ensure equal compression of the material at all locations,

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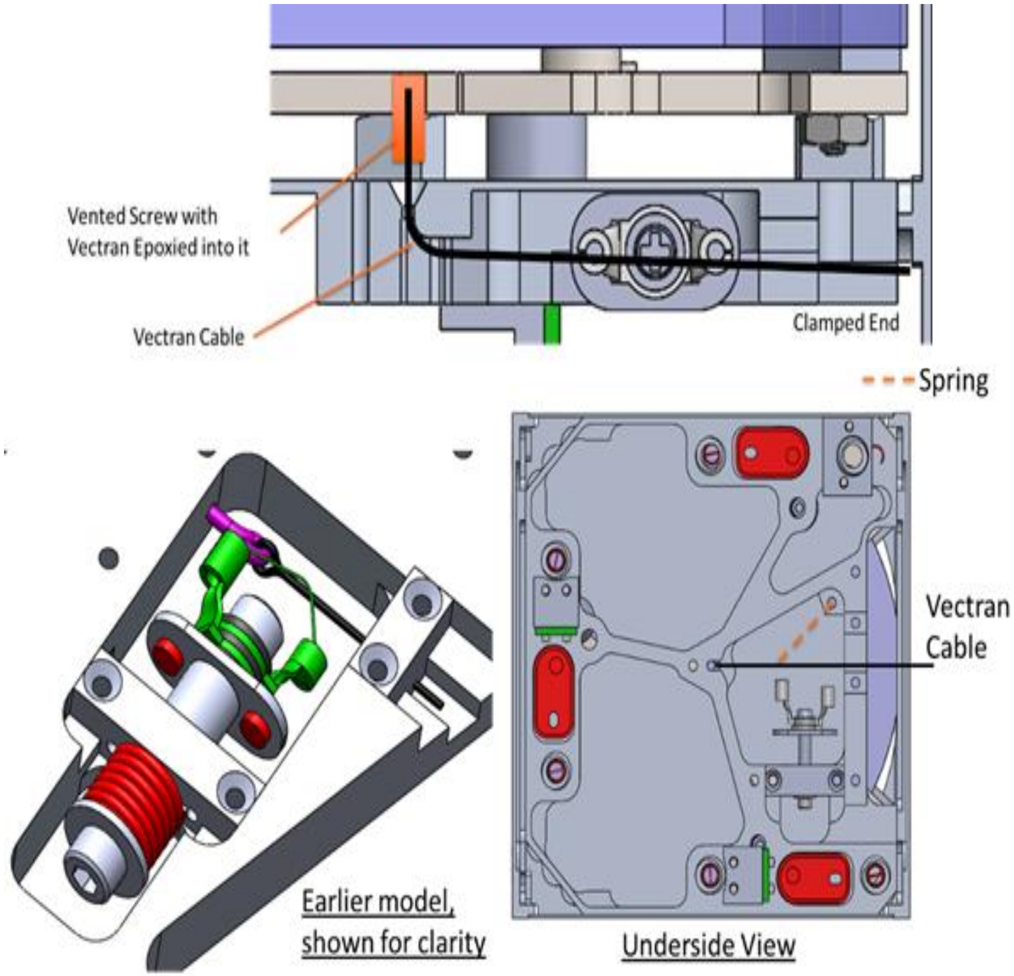
Tensioning the Vectran for Assembly



- The Launch Restraint and Separation devices secure and release the mirror during and after launch
- The mirror is secured with Vectran Cable, tensioned to 200N
- The mirror is released by activation if a NiChrome wire severing mechanism, burning and cutting the cable

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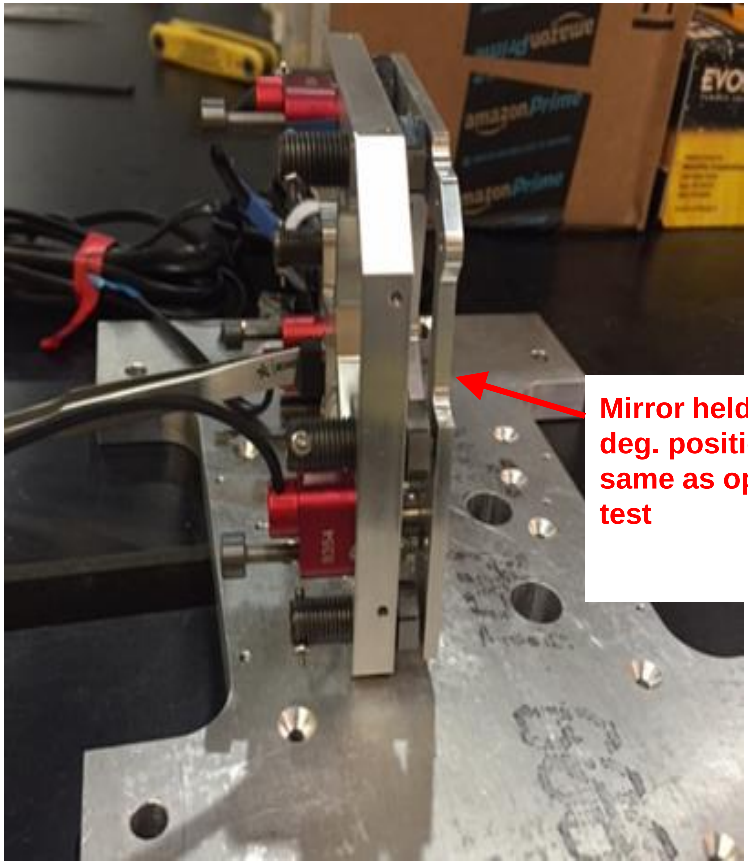
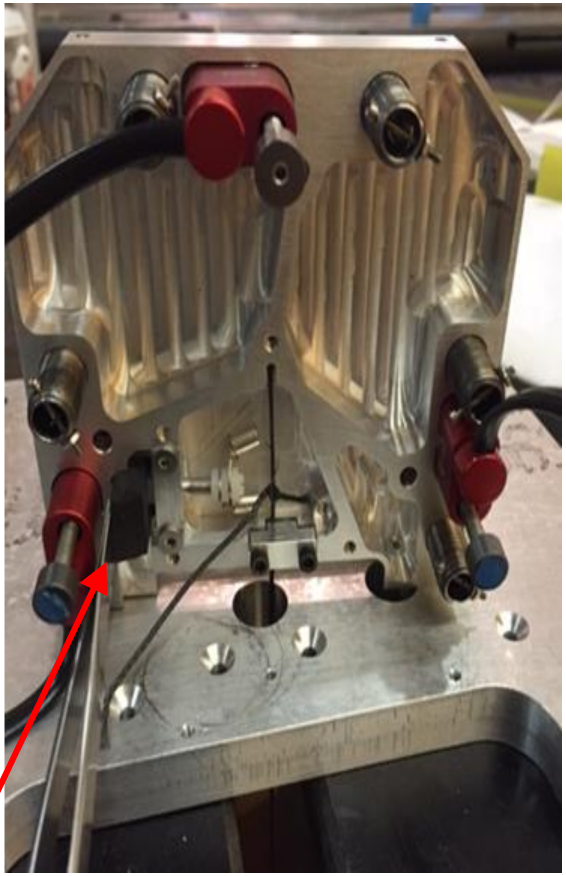
Tensioning the Vectran for Assembly



Mirror held in 90 deg. position, same as optical test



Stopper

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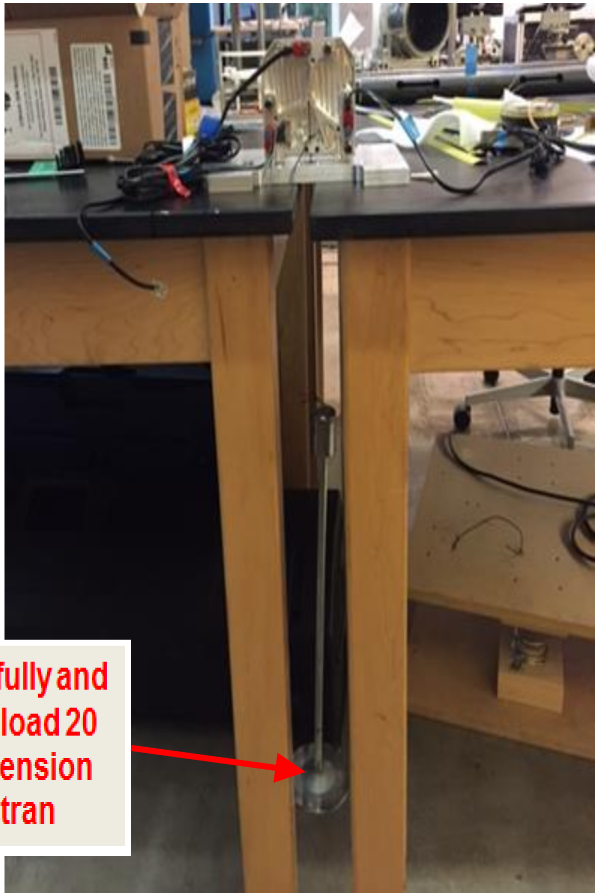
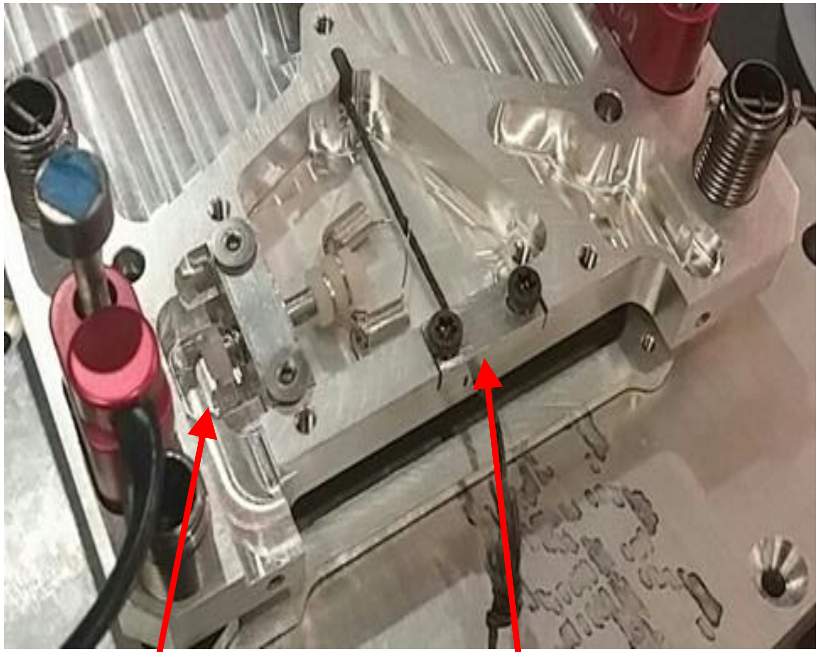
Tensioning Vectran for Assembly





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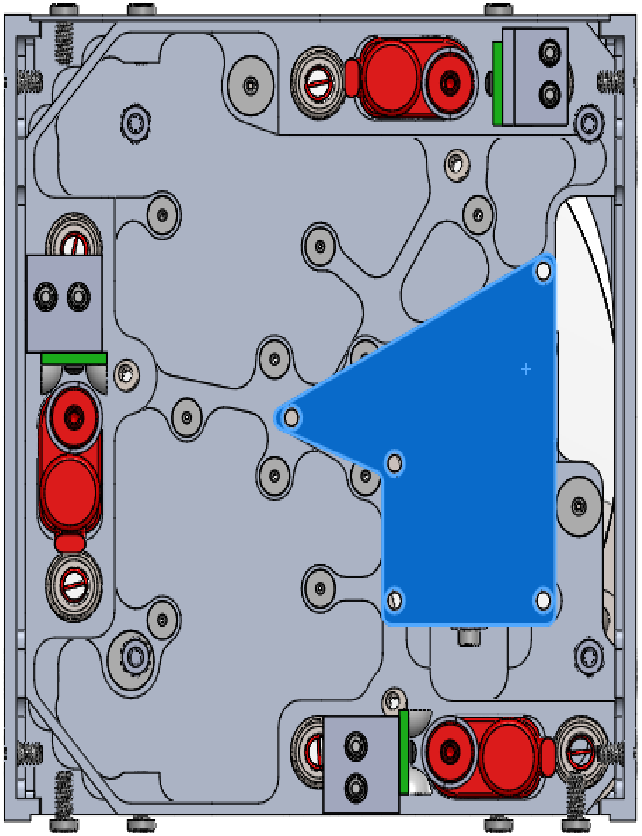
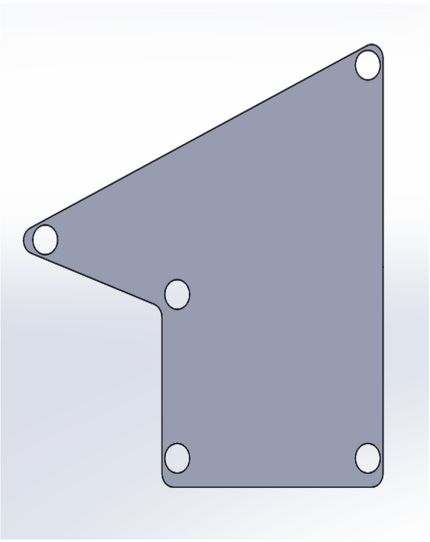
Reference Plate Lid

- After vectran is cut, there will be loose vectran cable
- Lid designed to keep vectran pieces contained after mirror deployment, as well as protect surroundings from heat and current in burnwire





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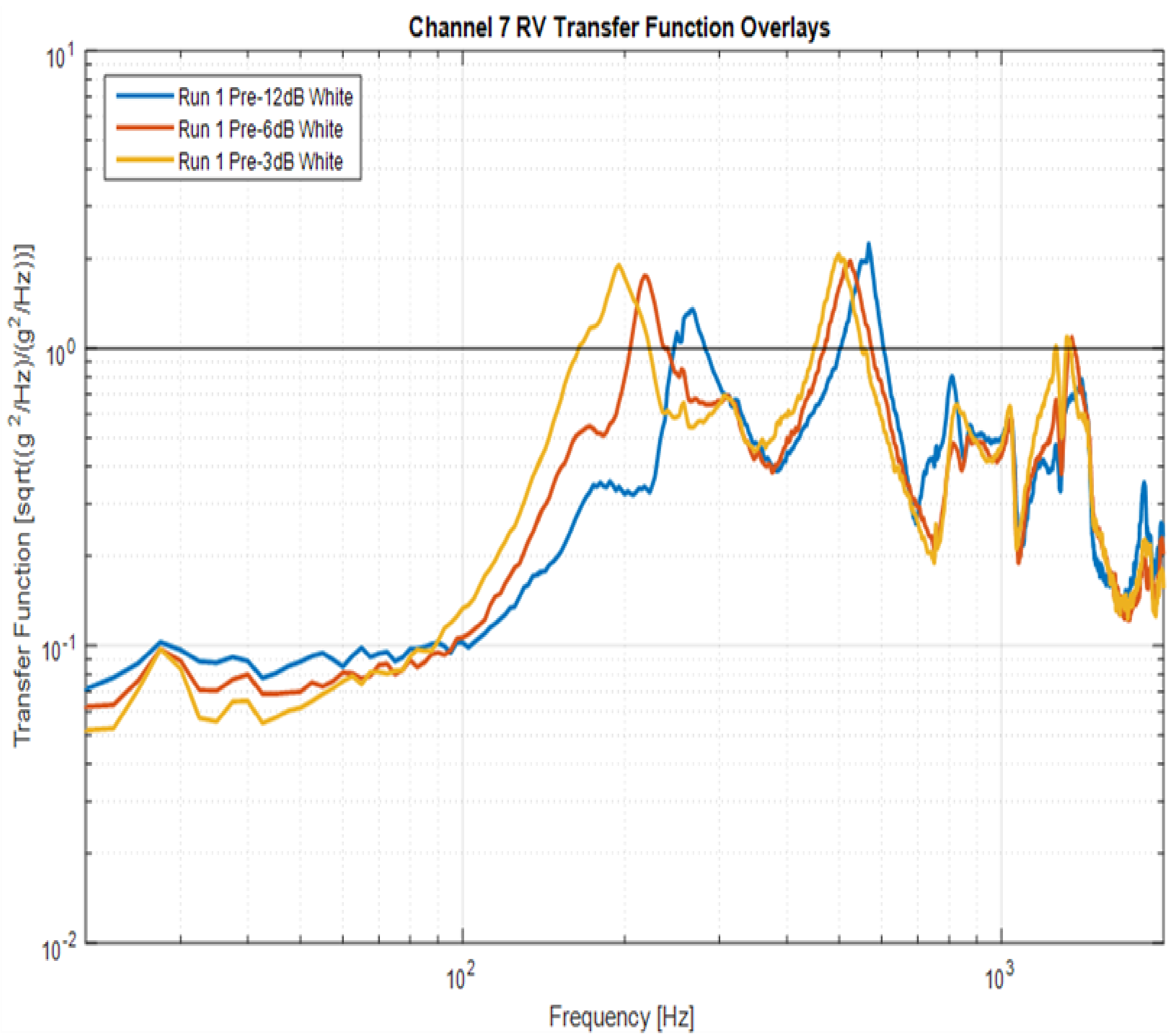
Transfer Function for Mirror Mass Z Axis Run 1



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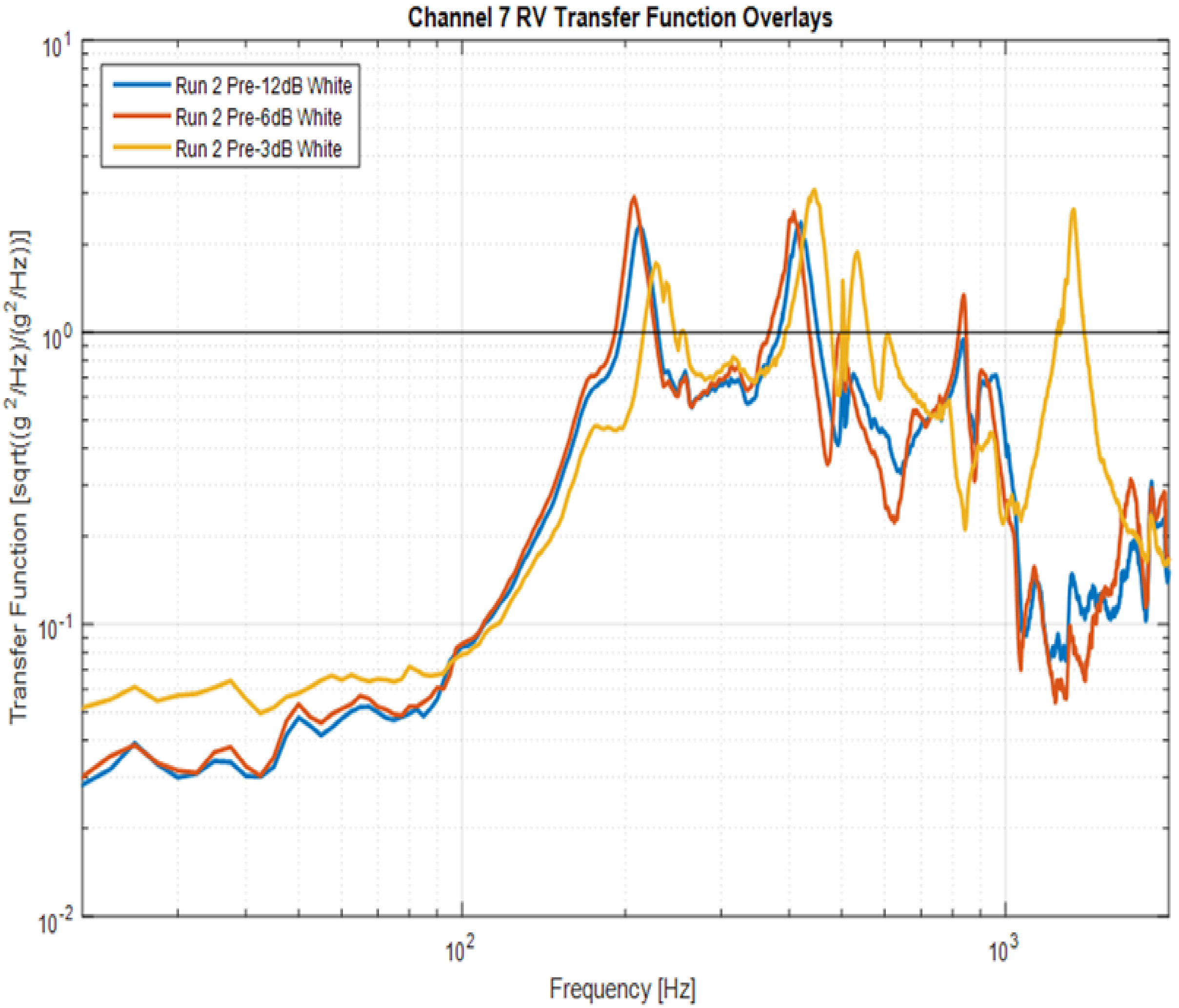
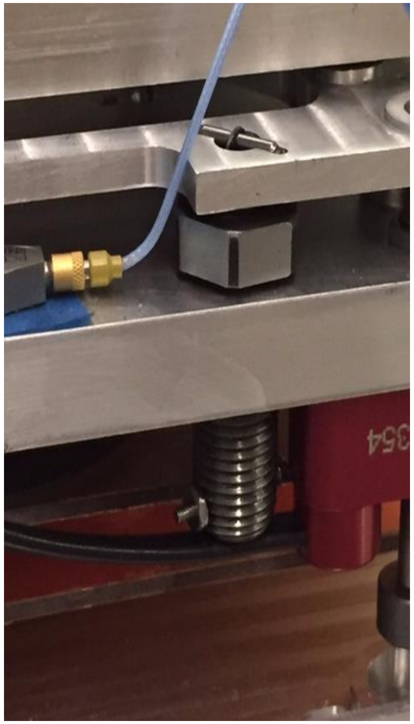
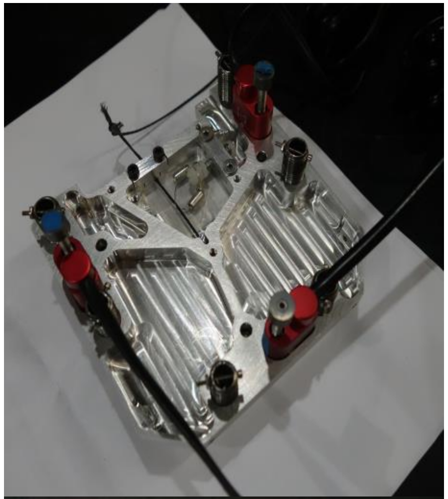
Transfer Function for Mirror Mass Z Axis Run 2

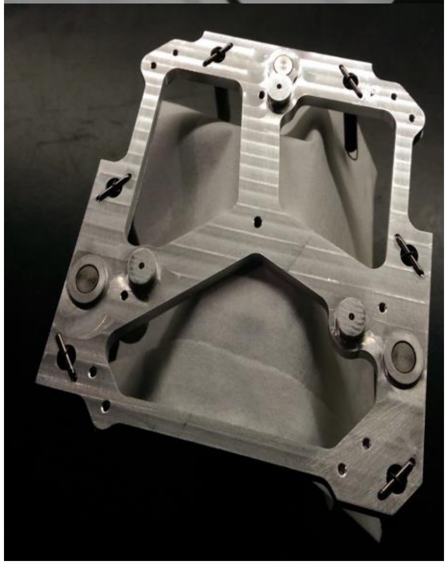


Second Set of Rigid Box Vibration Test Results

- -12 dB test had normal accelerations (right?)
- Assembly flaw identified during -6 dB test
  - Rattling noise in box: a picomotor is too close to adjacent spring tube pin
  - Spring tube couldn't fully tighten to reference plate
  - Solution: either shorten pin insert or change position







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Outline

2:00 pm: Introduction & Welcome

2:15 pm: Camera

2:45 pm: Boom

3:15 pm: Mirror Boxes

3:45 pm: On-board Software

4:15 pm: Electronics

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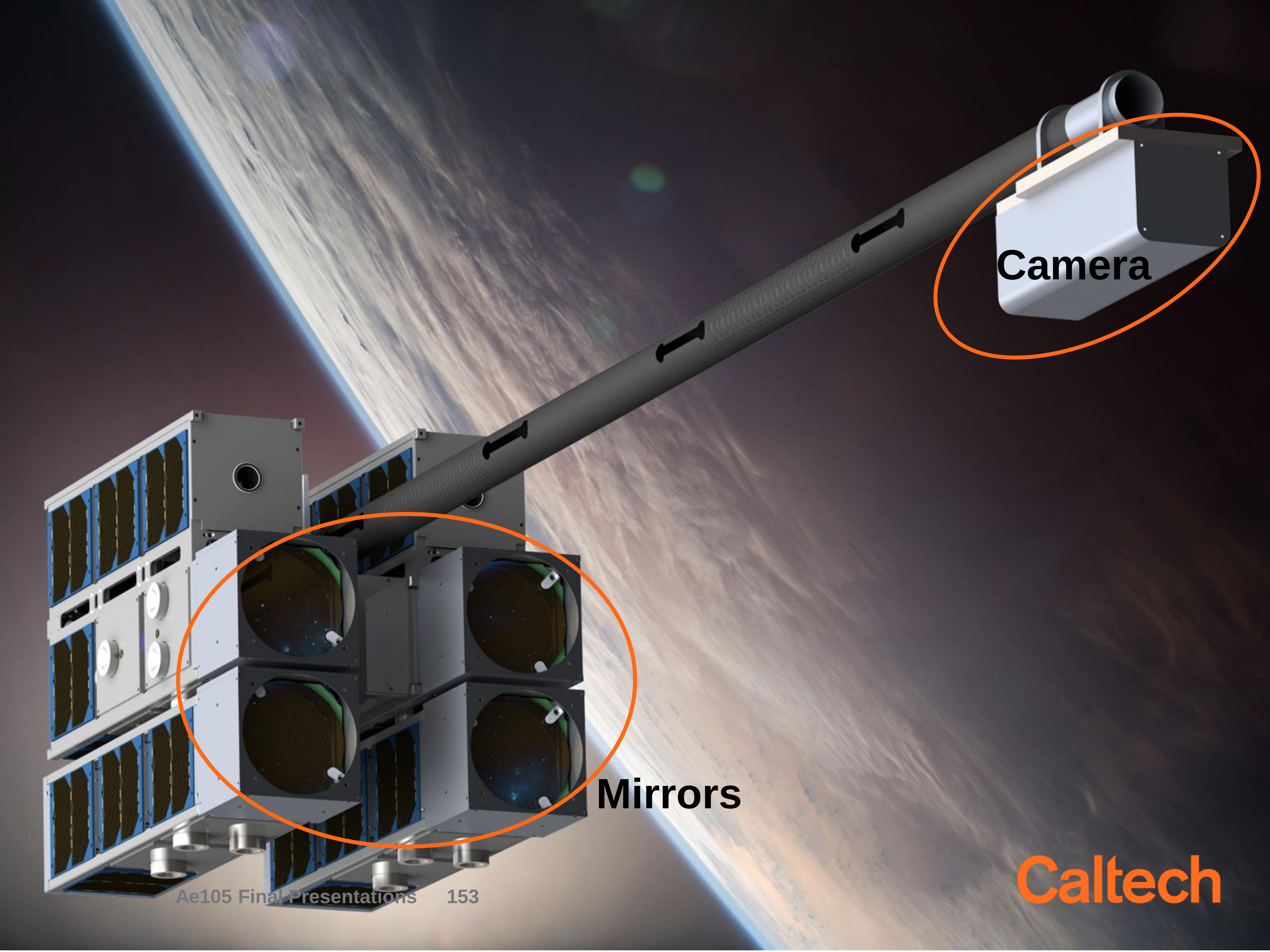
AAReST
Onboard Software (OBSW)

Gautham Sholingar
Abbas Tutcuoglu
Arjun Sadanand
Daniel Pastor
Juliana Kew

Mentors:
Thibaud Talon
Yuchen Wei


Camera
Mirrors
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High-Level Overview

Main Objectives

- 1x focused image from Deformable Mirror (DM)
- ≥2 images of other sources

Camera

- Capture image and perform analysis
- Control **mirror alignment**

Mirror

- **Reflects/focuses** light onto camera via 2 Rigid & 2 Deformable Mirrors
- Receives command from camera to **adjust mirrors**

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Agenda – Mirror OBSW

1. High Level Overview
2. Mirror Positioning
3. Communications
4. Results and Future Work

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Project Tasks - Mirror

Task I : Software

- Implement algorithm to **minimize Root Mean Square (RMS)** error of mirror position (<40 nm)
- Test implementation using **Google Testing Framework**

Task II: Comm. Protocols

- **Implement wireless communication protocol** between mirrors and camera
- Monitor device health using thermal sensors

Task III: Hardware

- Manufacture **reliable encoder**

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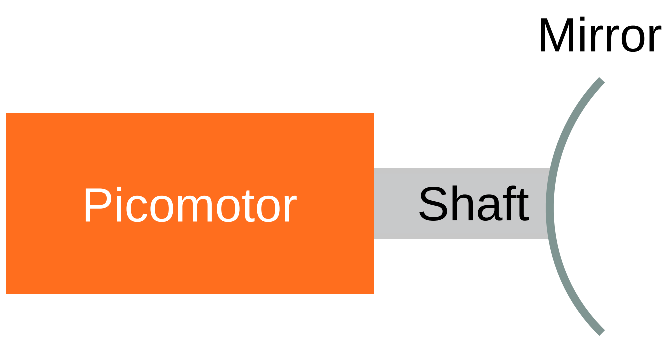
Mirror Actuation

- Each mirror controlled by **3 picomotors**
- Each DM additionally controlled by **41 electrodes**
- Use **picomotors** to enable **tip, tilt and piston motion** for the rigid and deformable mirrors



Forward Step

$\Delta z = 28\text{nm} \quad \pm 6\text{nm}$

Backward Step

$\Delta z = -40\text{nm} \quad \pm 8\text{nm}$

- Picomotor behavior is a **stochastic process**.
- How to **estimate** shaft head location?

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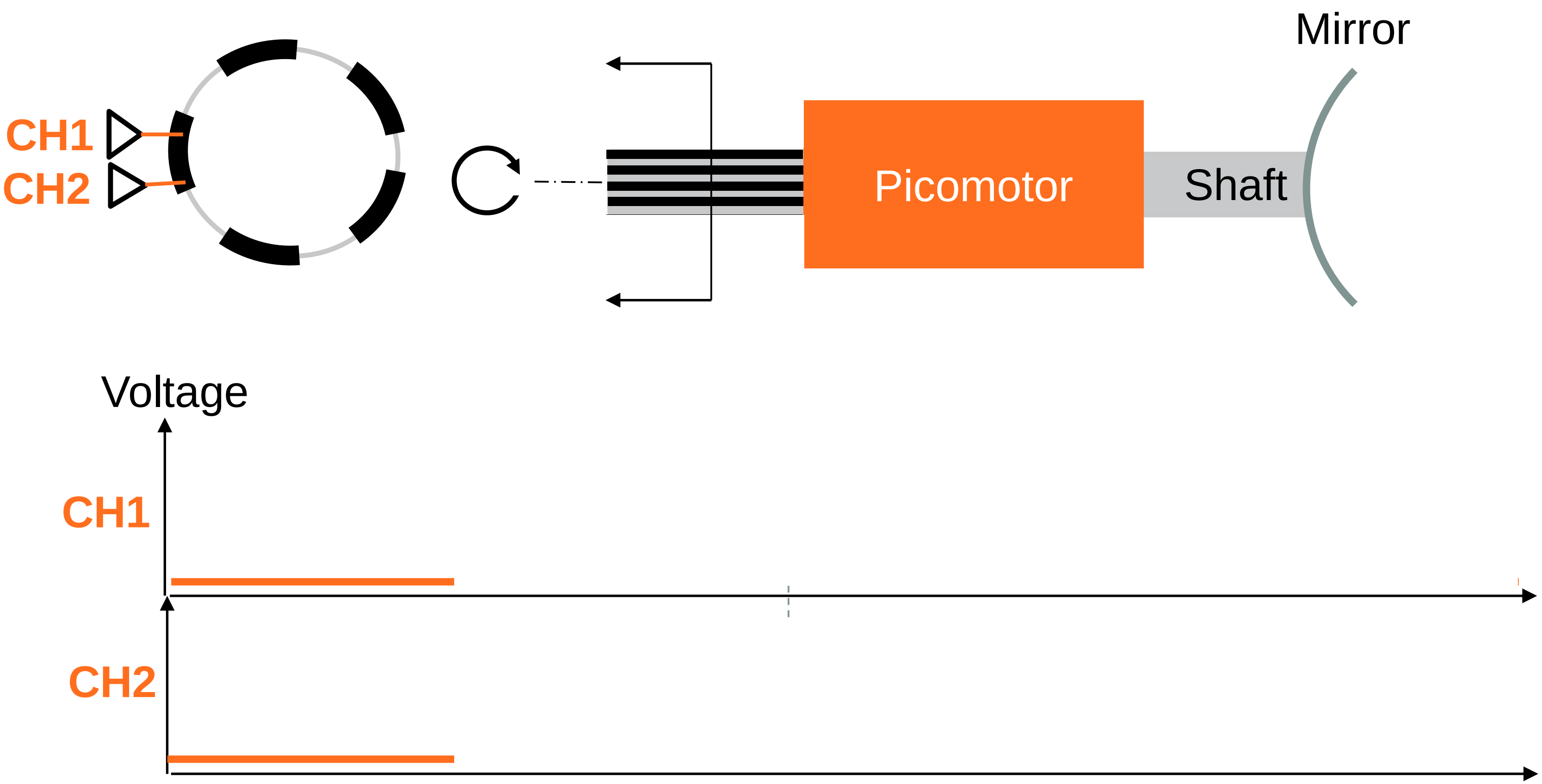
Need for Encoders

Encoders help estimate mirror position within an interval



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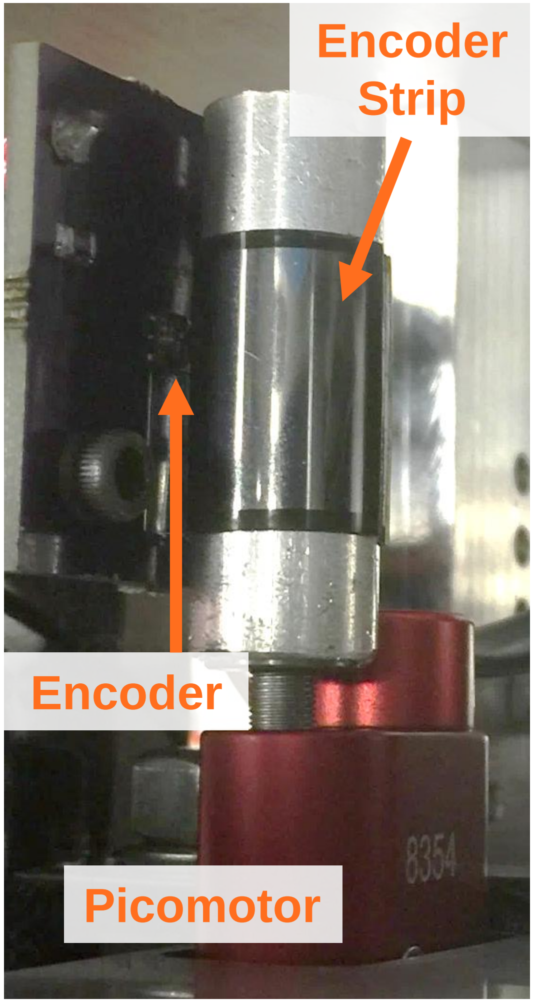
Challenges with Encoder

Encoder Strip

- Encoder strip (right) tailored to use on **flat surfaces**
- Consisting of **3 layers** → glossy top layer **delaminates** upon curving
- **Previous solution:** Tested position estimation algorithms in a **simulator** using Google Testing Framework
- **Permanent solution:** Achieved curvature at **elevated temperatures**



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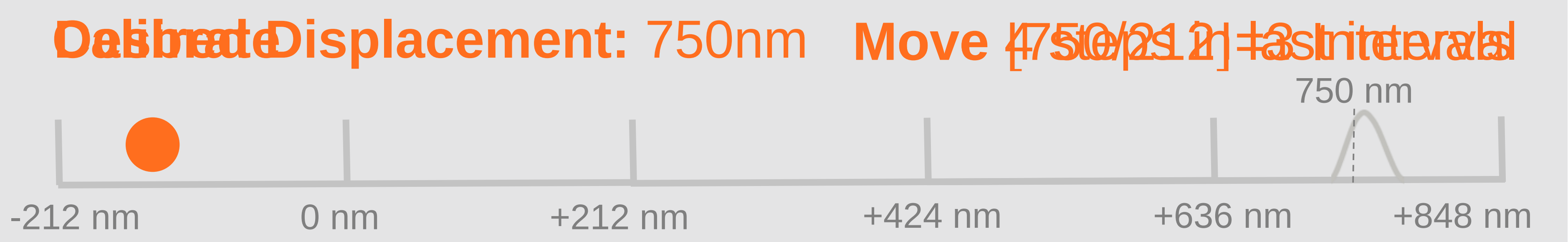
Final Result

- **Step 1**: Exact position unknown → **Calibrate** encoder
- **Step 2**: Receive **desired location** from camera team
  → calculate how many **interval-jumps** to be made
- **Step 3**: Adjust for stochastic variation to minimize RMS error in a **deterministic way**
  → **calculates** no. of **picomotor steps** needed



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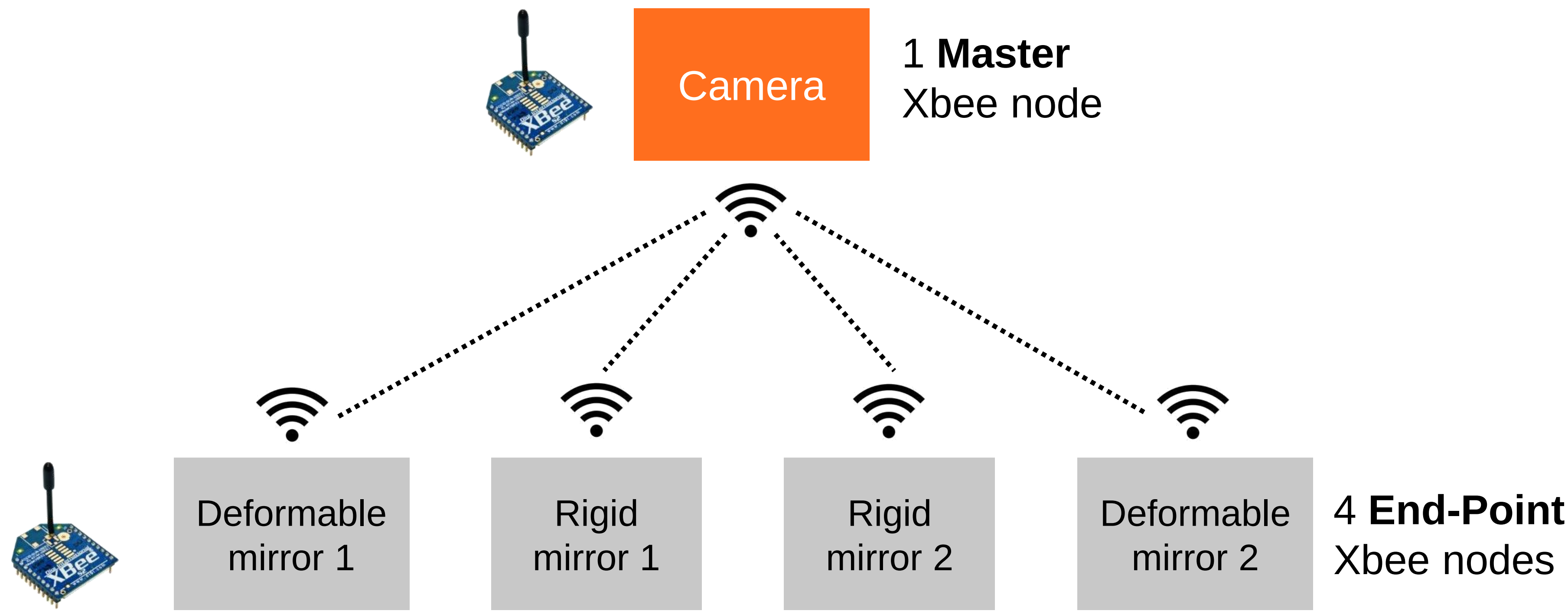
Wireless Communications

Objective: Establish a robust **Wireless communication** system between the **Mirror MCUs** and **Camera CPU** using **Xbee** wireless radio modules



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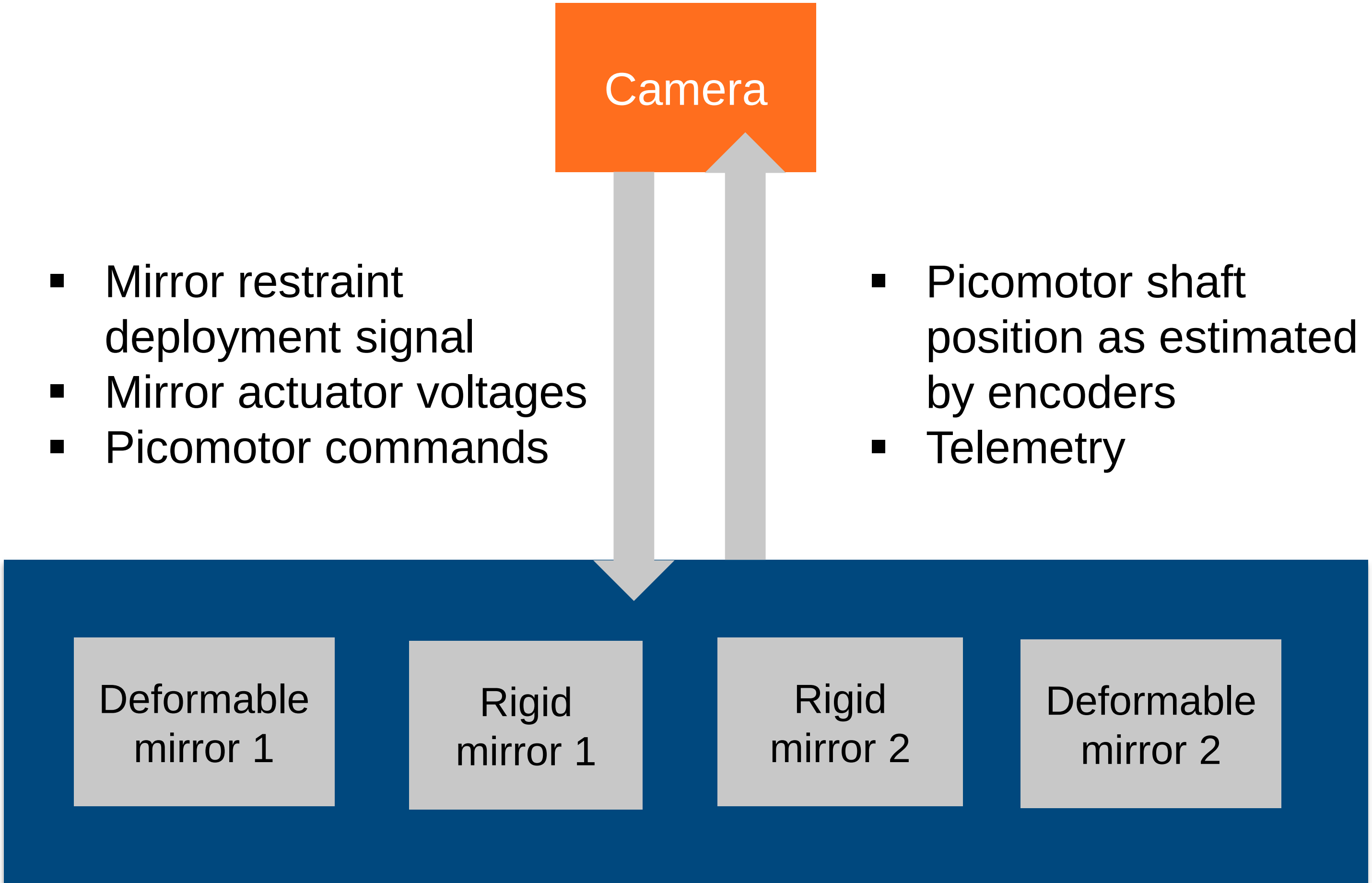
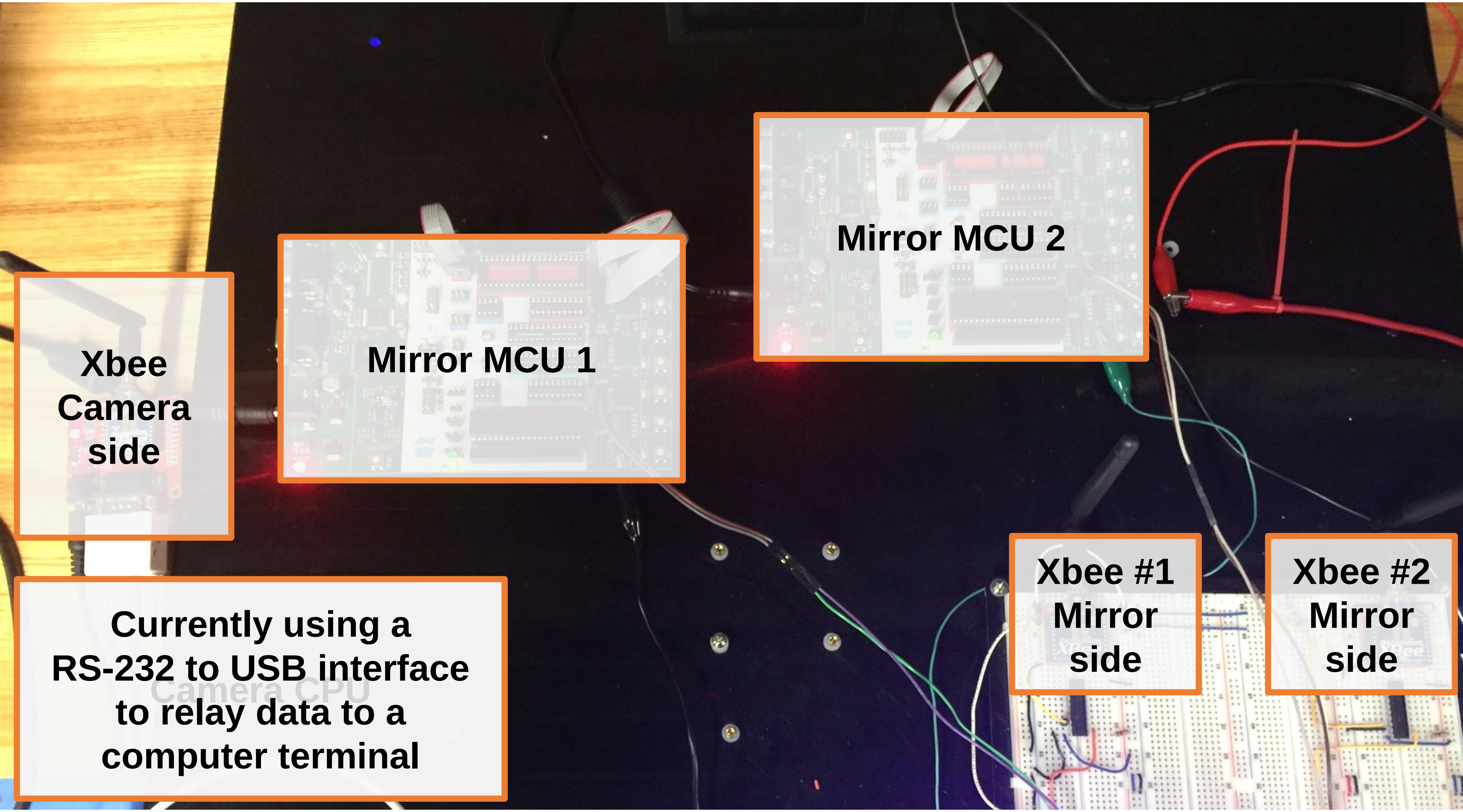
Xbee Communications



- Mirror restraint deployment signal
- Mirror actuator voltages
- Picomotor commands

- Picomotor shaft position as estimated by encoders
- Telemetry

Xbee Communications Testbed



Xbee Communications

- Communication packets:

0x05	0xA7BB01
1 byte address	3 bytes of data

- Application Programming Interface **(API)** mode enables **data verification**, **checksums** and **point-to-point** communication

- Interface Control Document **(ICD)** created to explain message types and protocol

- **Current progress**: Two-way communication established between 1 Master Xbee and 2 End-Point Xbee modules

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Hardware Monitoring

MCU's connected hardware

- Thermal Sensors
- High Voltage Board

Needs **protocol to communicate** with MCU (ATMega 1284):

- Inter-Integrated Circuit (**I2C**)
- Serial-Peripheral Interface Bus (**SPI**)

Why read off temperature?

→ Hardware could overheat
→ Temperature monitoring required for thermal control

Caution: protocols require **robust error handling**
[e.g. due to other interfering communication processes]

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Thermal Sensor Testing

Two thermal sensors [I2C]

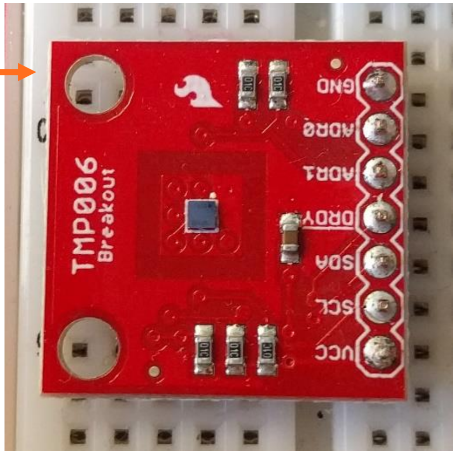
- **MCP9801** [Conduction-based]
- **TMP006** [Radiation-based]

Testing

- Reliable testing difficult due to **environmental conditions**

Observations

- Currently require **contact** between thermal sensors and targets
- Need to **calibrate** sensor measurements



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Results

Software-Level

- Implemented **algorithm** to lower RMS error under 40nm
- Tested **simulator** using **Google-Testing** framework
- Established **Xbee communication** between 1x master and up to 2x slaves
- Tested health monitoring via I2C with **thermal sensors**

Hardware-Level

- Manufactured a **reliable encoder** via heat treatment
- Tested **wireless picomotor** actuation

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Future Work

- Actuate a **combination of 3 picomotors** to achieve **tip, tilt and piston** functionality
- Test **calibration** and position **estimation** using picomotors
- Integrate **4 End-Point Xbee modules** and **implement protocol** for messages
- **Close the loop** to demonstrate camera image correction using picomotor actuation

AAReST OBSW: Camera

Outline

1. Background & Motivation
2. Task Overview & Progress
3. Hardware Constraints
4. Future Work

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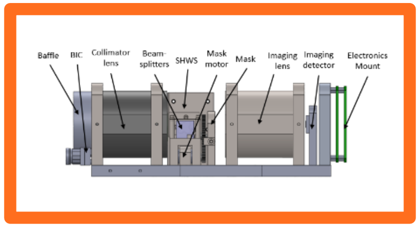
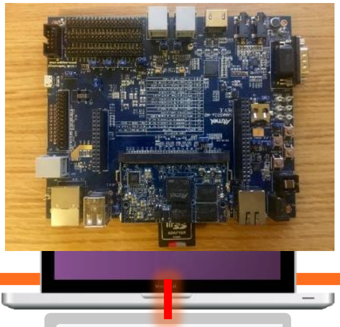
Camera Hardware

Cameras

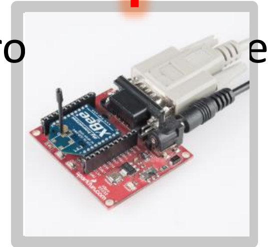


Flight CPU



Gro e

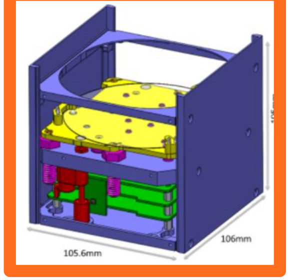
Xbee



Other electronics (temperature sensor, power management,…)

EaghTestConfiguration

Mirror Boxes



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Camera Task Overview

Task I

- Implement and improve spot centering algorithm
- Establish bidirectional communication with mirrors
- Test all functionality

Task II

- Design and test hardware monitor functions

Task III

- Design and test shape correction algorithms

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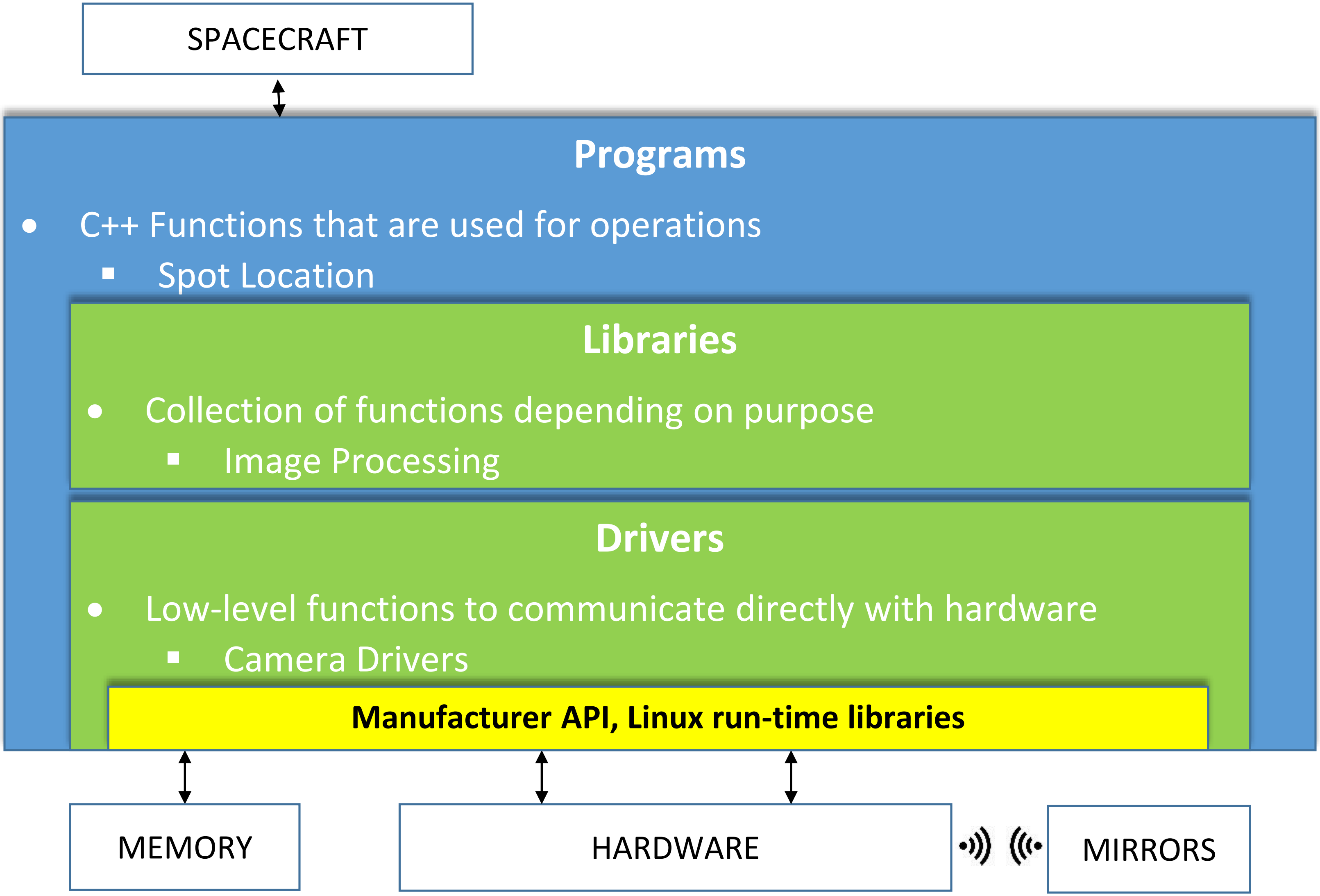
Software Architecture



Testing Environment

OBSW Testing & Verification

- Google Test Framework
  - Overarching testing environment

Test Scripts

- Scripts that test functionality of code
  - Test all possible use cases
  - Use cases derived from Interface Control Documents

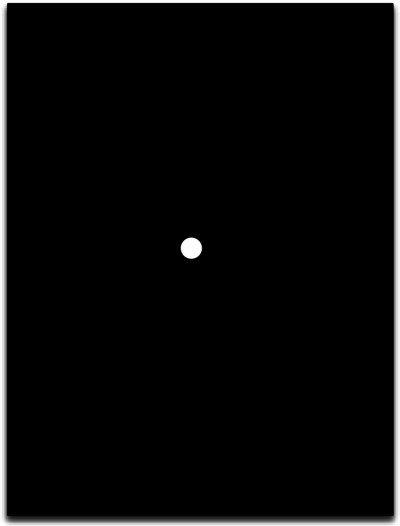
Programs

- List of functions that are used during operations

Task I: Centering Algorithm Introduction

AAReST has four mirrors

- Two rigid, two deformable
- Upon deployment, telescope needs to be aligned
  1. Calibrate picomotor motion via spot displacement
  2. Align optical axes of rigid mirrors
  3. Align optical axes of deformable mirrors
  4. Final iteration



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Task I: Centering Algorithm Development

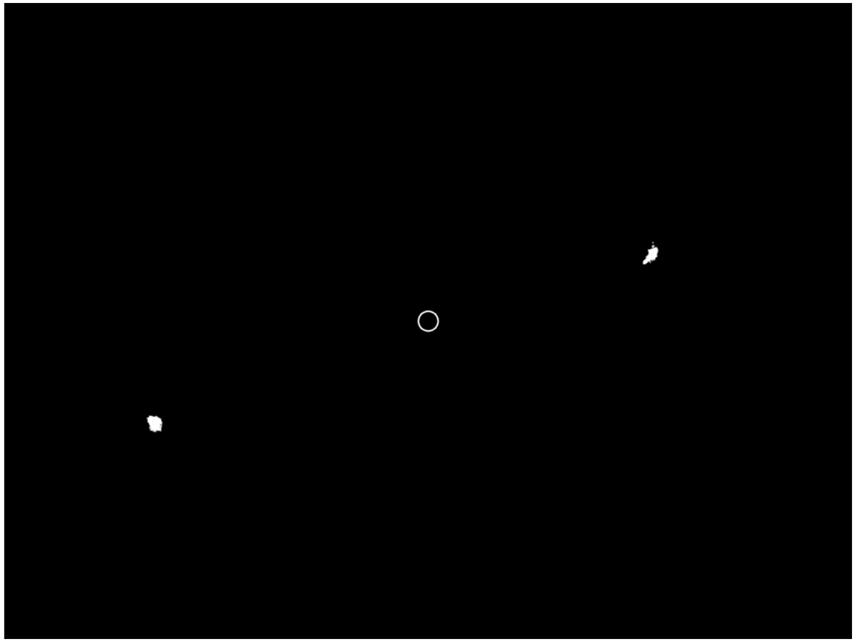
Designed and wrote software to:

- Take images
- Filter images
- Locate and track spots on sensor
- Send actuation commands to the mirrors
- Implement error handling

Generated Interface Control Documents (ICD)

- Clearly defines software interface and functionality

Demonstration in lab



Note: Spots are from saturated laser source. These are much larger than expected in flight.

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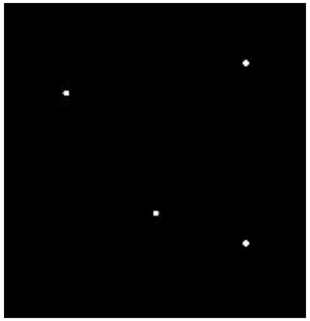
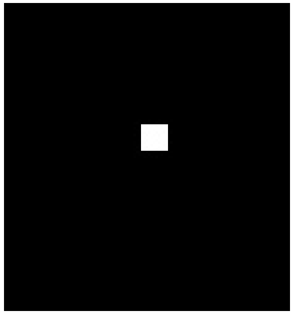
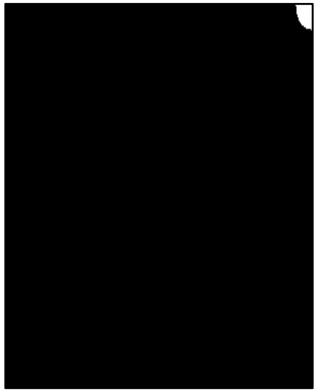
Task I: Centering Algorithm Testing

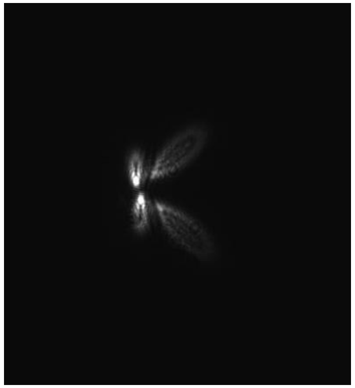
Tested spot location and tracking algorithms:

- Tested expected cases
  - 4 normal spots
  - Square-shaped spot
- Tested fringe cases
  - Spot on the edge
  - Defocused image (expected in space)
- Resolved encountered bugs
  - All tests now passed









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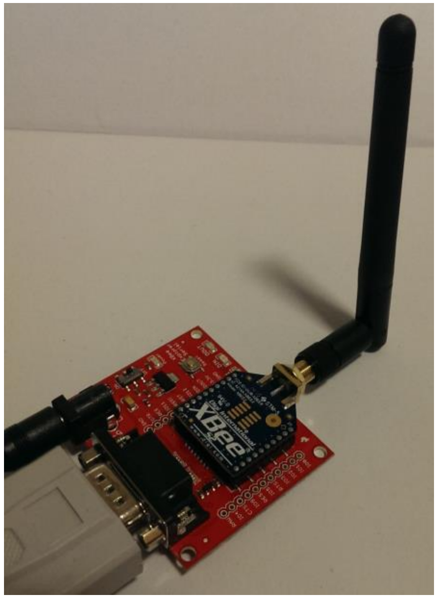
Task I: XBee Communications

- Wrote drivers for Xbee communication between flight CPU and mirror MCUs
  - Implemented as C++ class using the open source C library libxbee
- Designed and implemented communication software
  - Used communication protocol set by mirror software team
- Tested and verified wireless communication link with mirror MCU
  - Verified data exchange by C program



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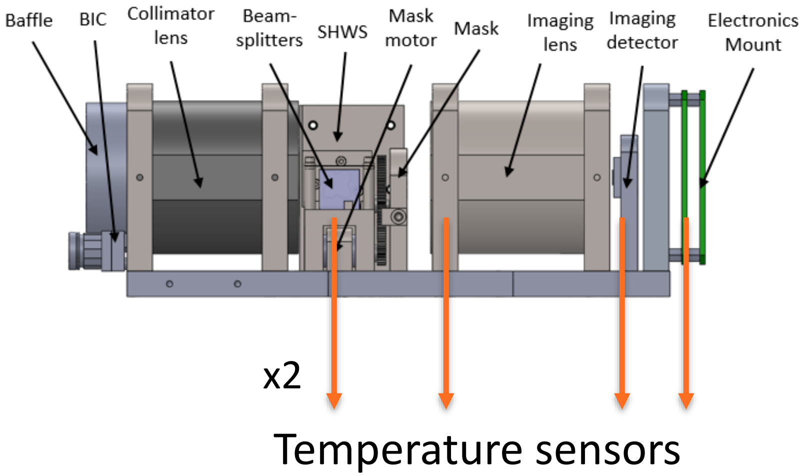
Task II: Hardware Monitoring Software

Hardware health needs to be monitored

- 5 sites for temperature monitoring
  - External temperature sensors are accessed via I2C
- Implemented status monitoring for imaging camera
  - All parameters are accessed via camera API

Sensor position assigned by camera/electronics team



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Task II: Hardware Monitoring Software Testing

Hardware error handling

- Ensure break in camera communication is properly handled
- Designed and implemented error handling function
  - Need to test by disconnecting camera during communication

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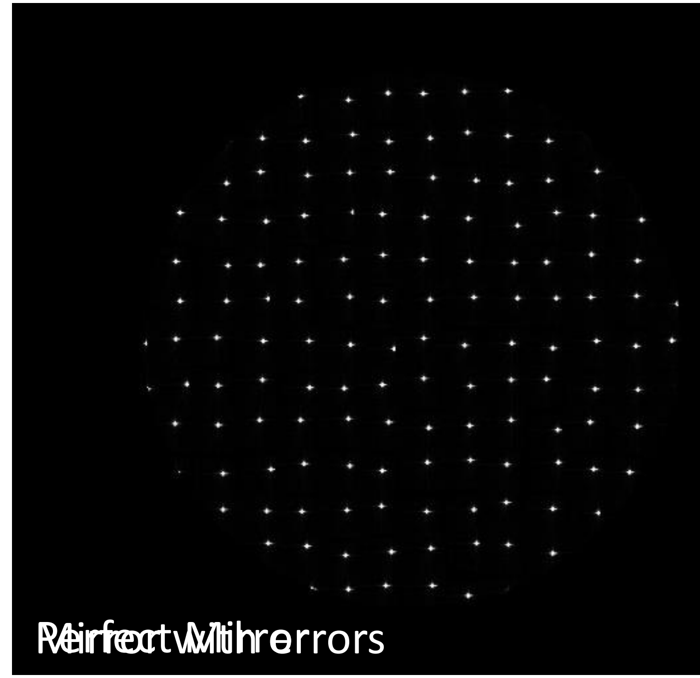
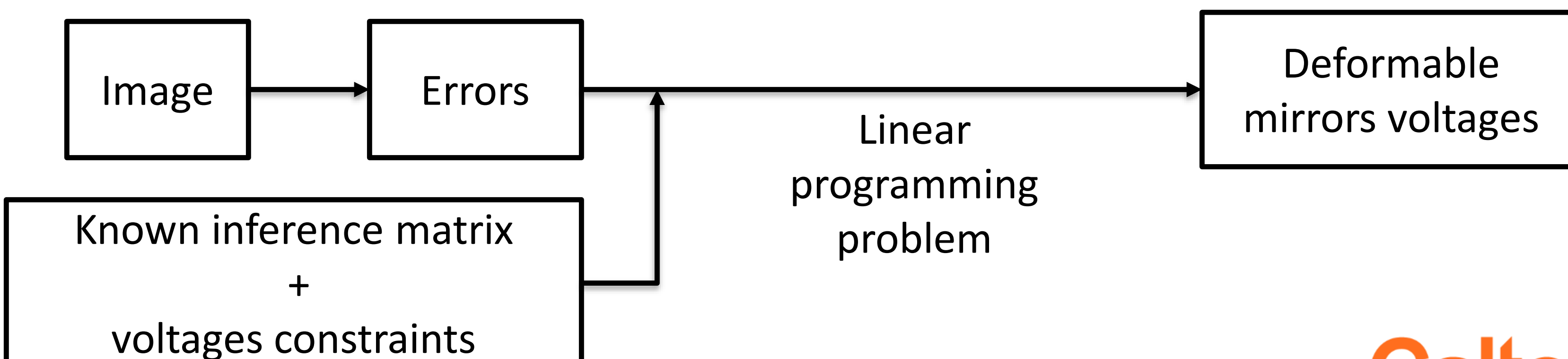
Task III: Shape Correction Algorithm

- Use Shack-Hartmann wavefront sensors (SHWS)
- Given known effect for each deformable mirror + voltage constraint, compute required voltages to minimize voltages





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Task III: Shape Correction Progress

- Provided with already written code
  - Get an image
  - Compute the errors
  - Solve the linear programming problem
- Updated to work with current code
- Wrapped into C++ Objects

Hardware Constraints

Shape correction algorithms tested with previously taken images

- Baumer camera unavailable for use
- Software test with SHWS under way

Software not yet tested with all four mirrors

- Lab currently has two rigid mirrors
- Deformable mirror still in development

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Future Work

Durability tests

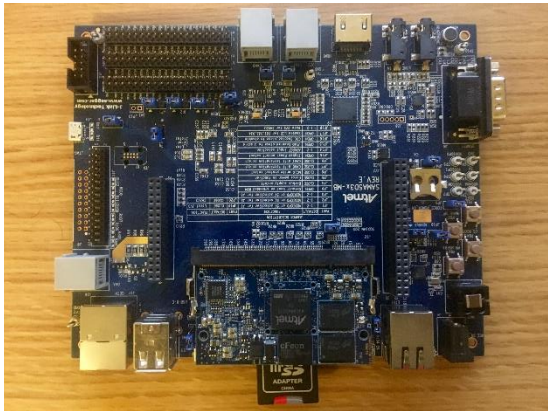
- Run camera for an extended period and ensure proper operation

Verify functionality of final centering algorithm

- Use four mirrors
- Test on flight hardware

Verify functionality of shape correction algorithms

- Perform unit-test with flight hardware



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Acknowledgements:

- Thibaud, Yuchen, Kathryn

Questions?

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Outline

2:00 pm: Introduction & Welcome

2:15 pm: Camera

2:45 pm: Boom

3:15 pm: Mirror Boxes

3:45 pm: On-board Software

4:15 pm: Electronics

AAReST Electronics Team

Andre Sukernik Saumya Vij

Mentors

Ashish Goel

Stephen Bongiorno

AAReST Electronics

Camera
Saumya

Mirror Box
Andre

Mirror Box Electronics

Andre Sukernik

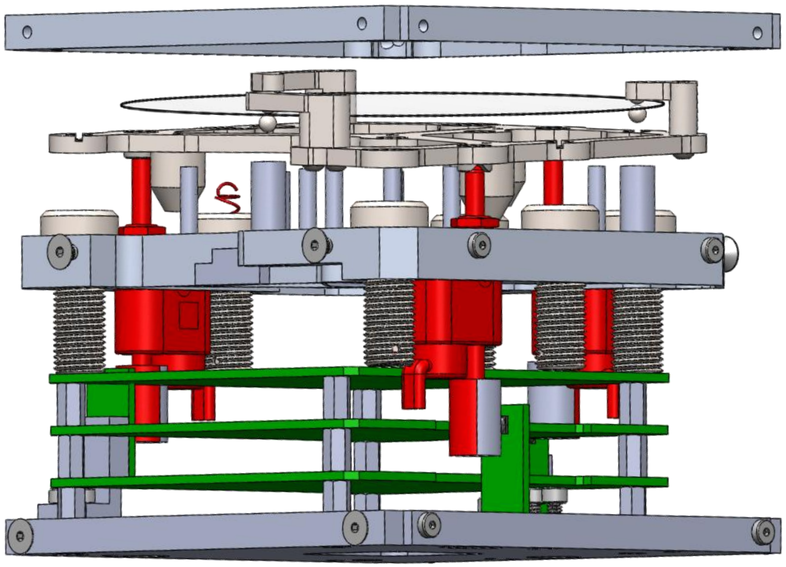
Mentors

Ashish Goel

Stephen Bongiorno

Outline

- System Overview
- Project Objectives
- Design Overview
- Printed Circuit Boards
- Schedule



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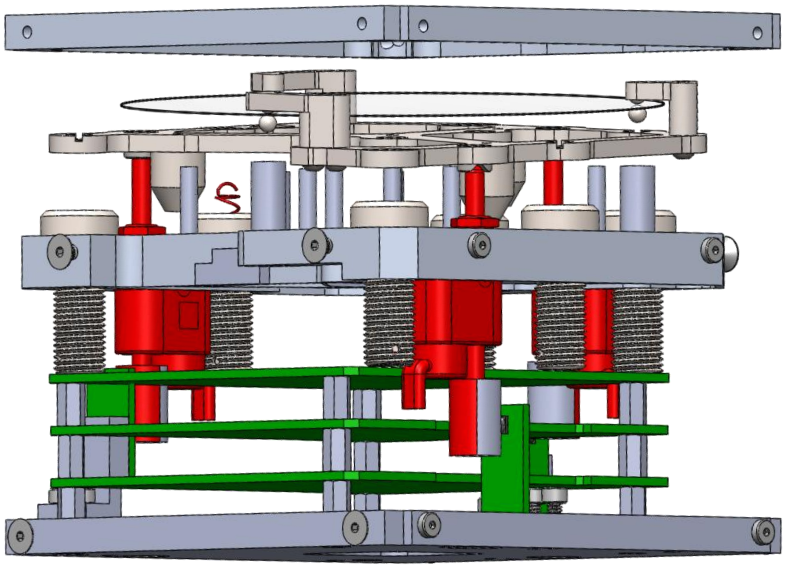

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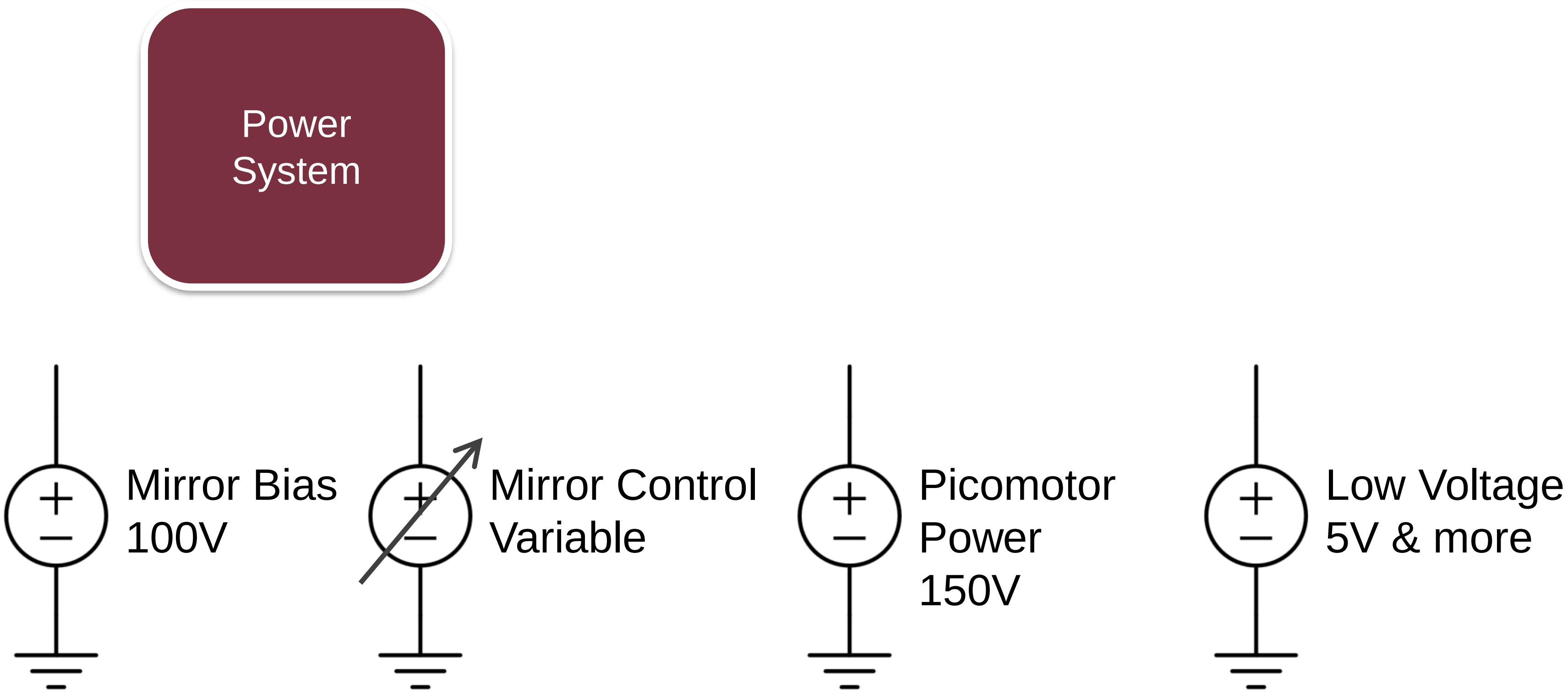
Mirror System Overview



Deformable Mirror Array Proof of Concept

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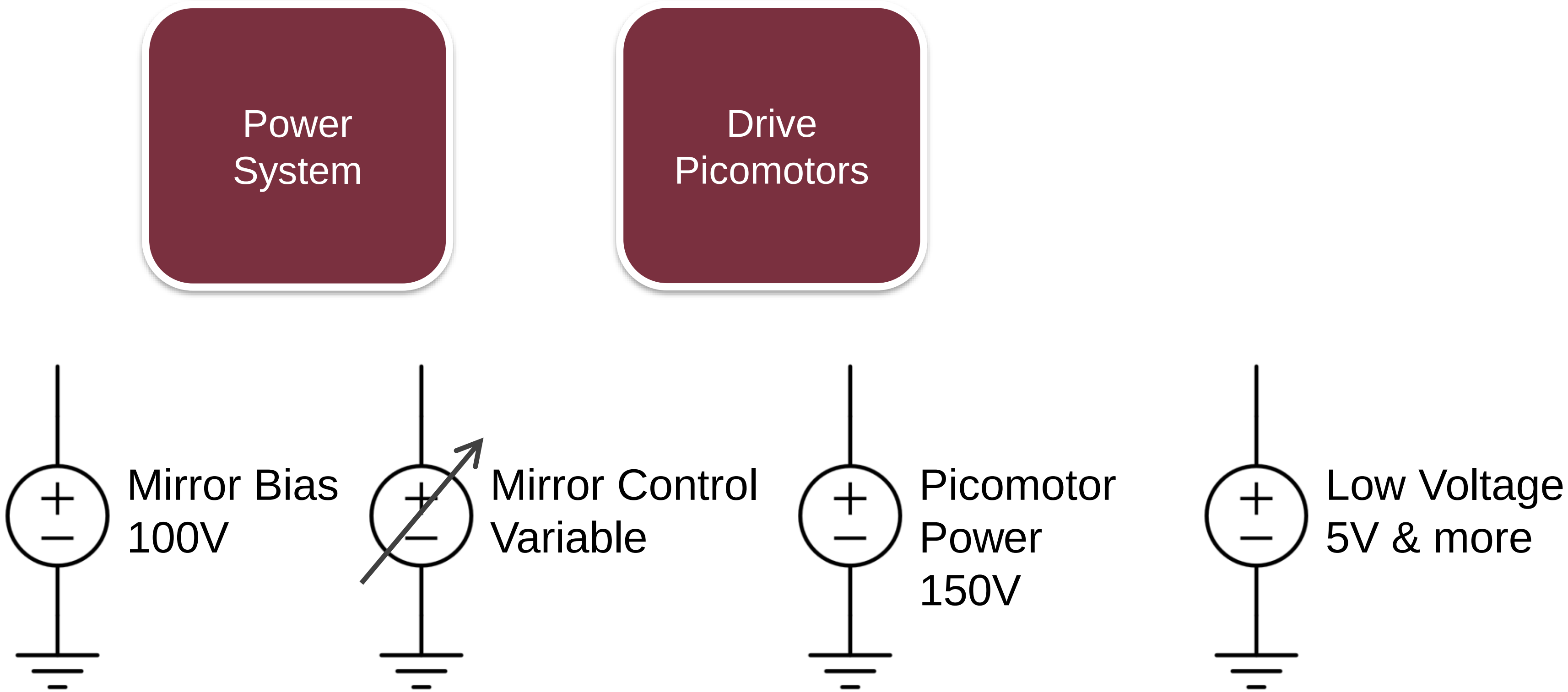
Mirror System Overview



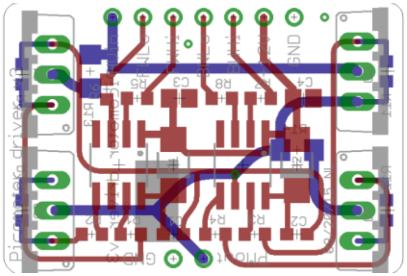
Deformable Mirror Array Proof of Concept

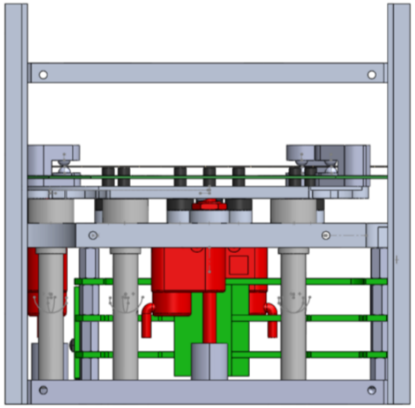
Mirror System Overview

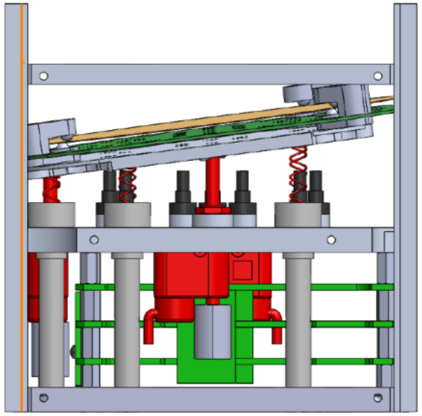
Power System

Drive Picomotors

Driver Circuit x3







Deformable Mirror Array Proof of Concept

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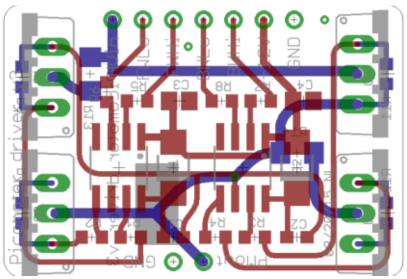
Mirror System Overview

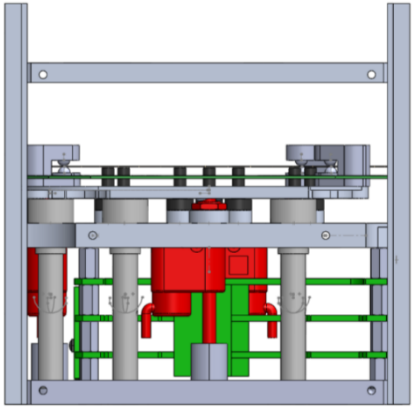
Power System

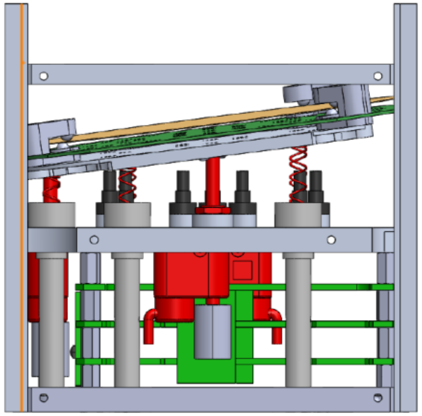
Drive Picomotors

Communicate

Driver Circuit x3







Deformable Mirror Array Proof of Concept

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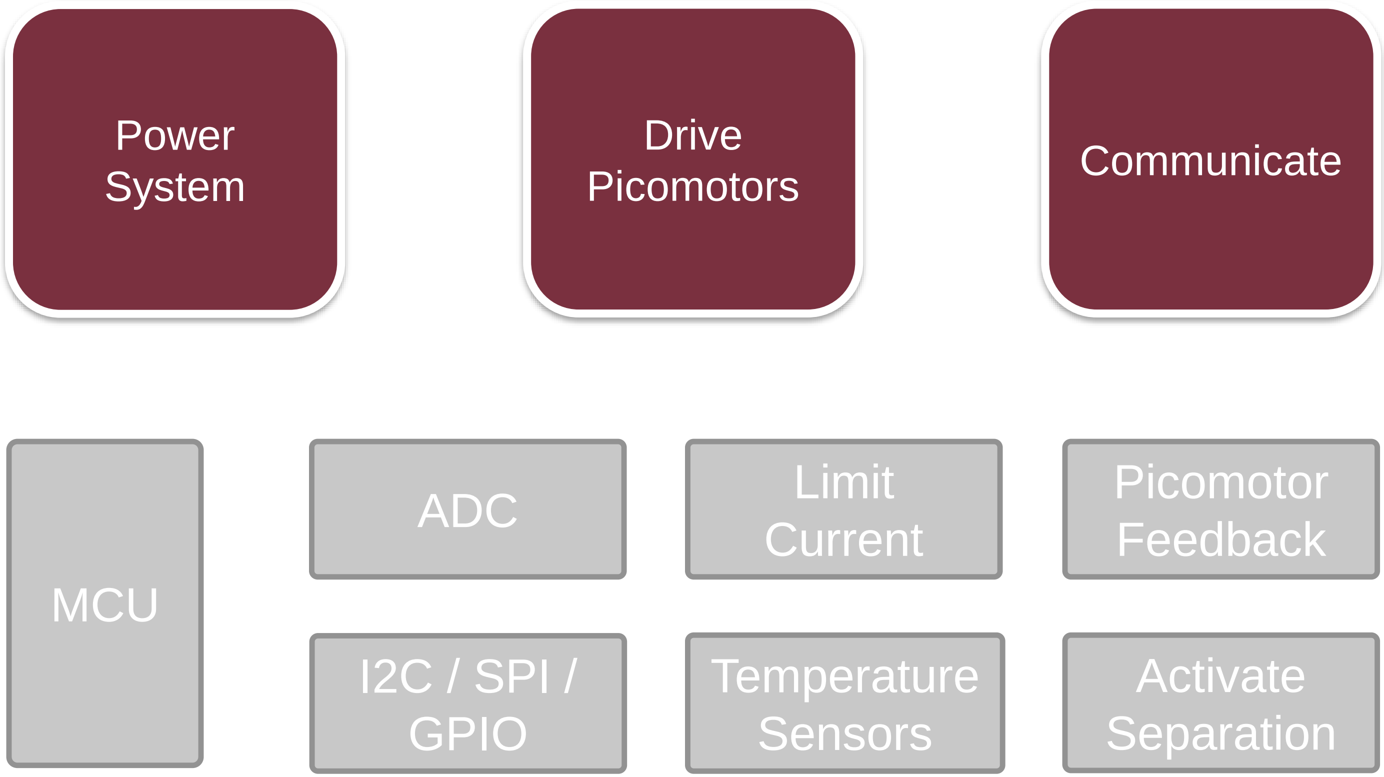
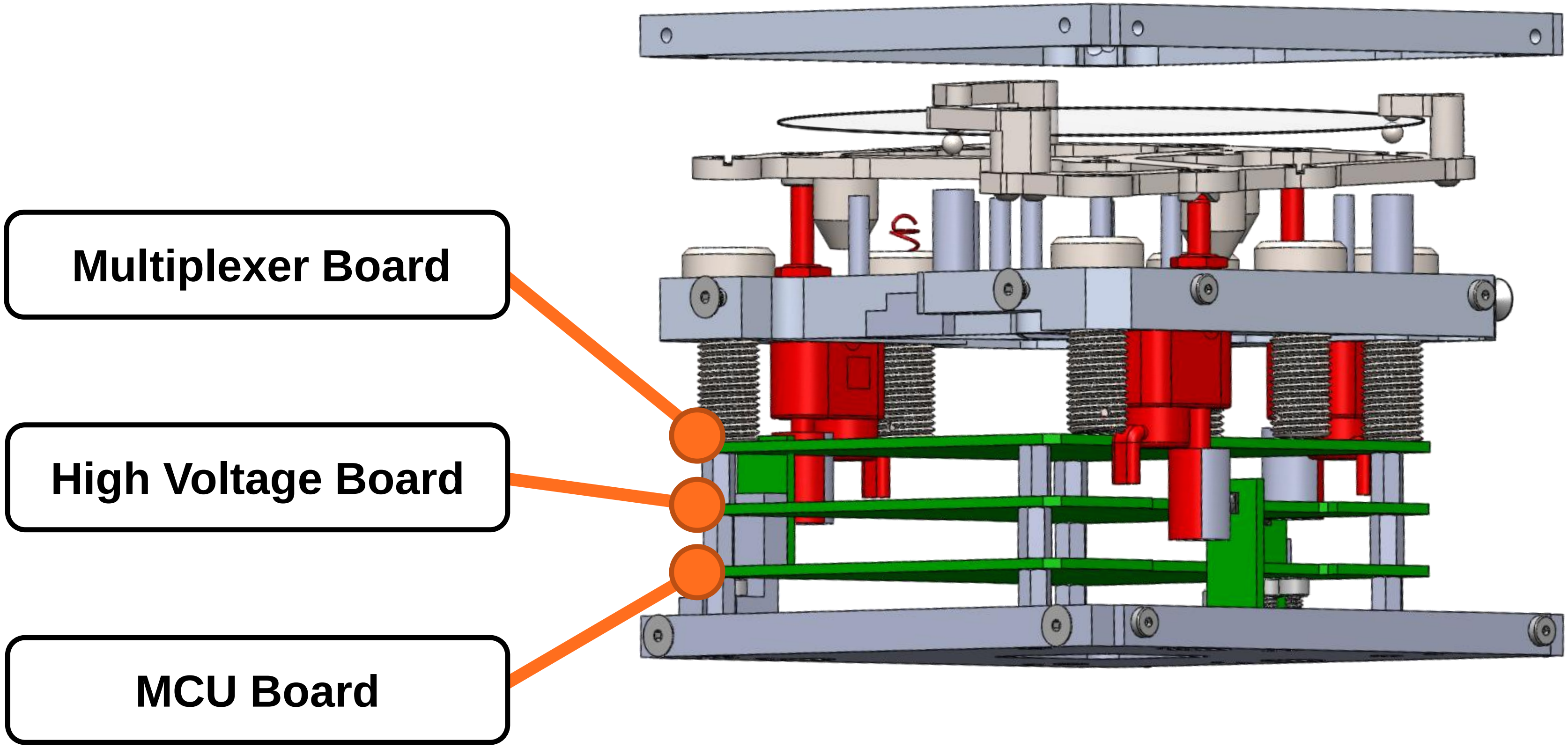


Deformable Mirror Array Proof of Concept

Mirror System Overview



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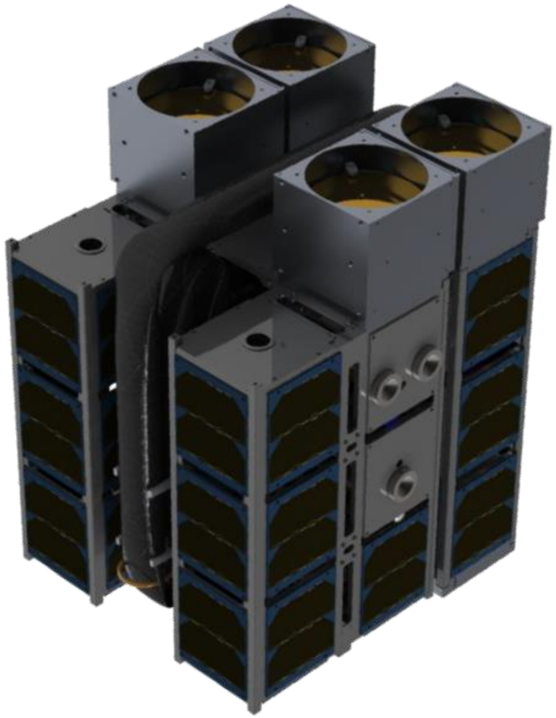
Project Objectives

- Select components
- Convert high level diagrams into detailed schematics
- Layout printed circuit boards
- Focus on 2 boards – High Voltage, MCU



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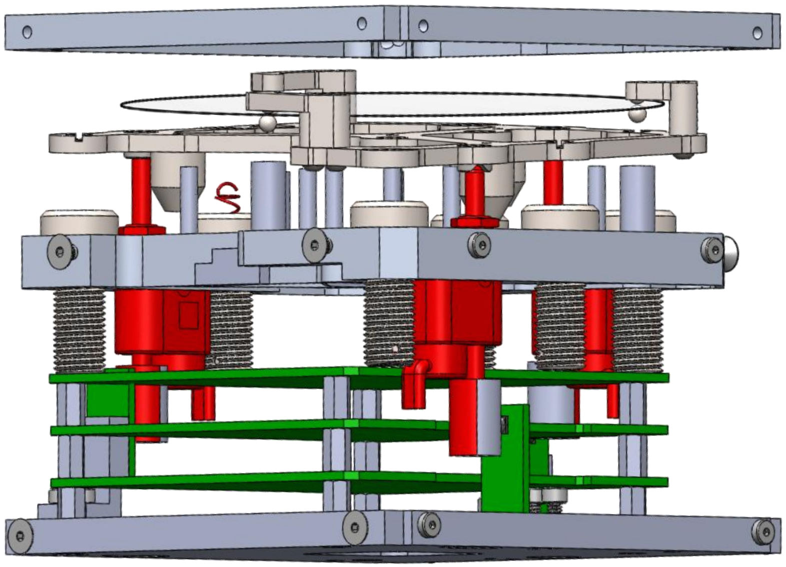

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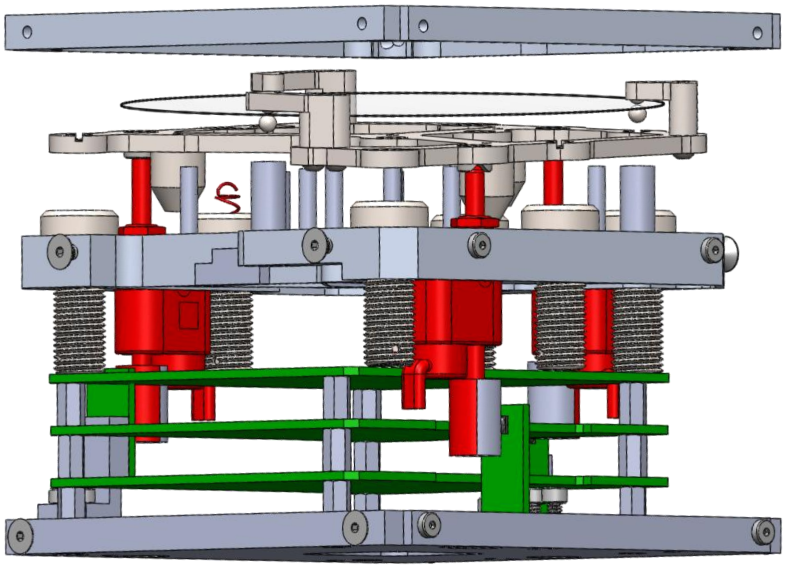

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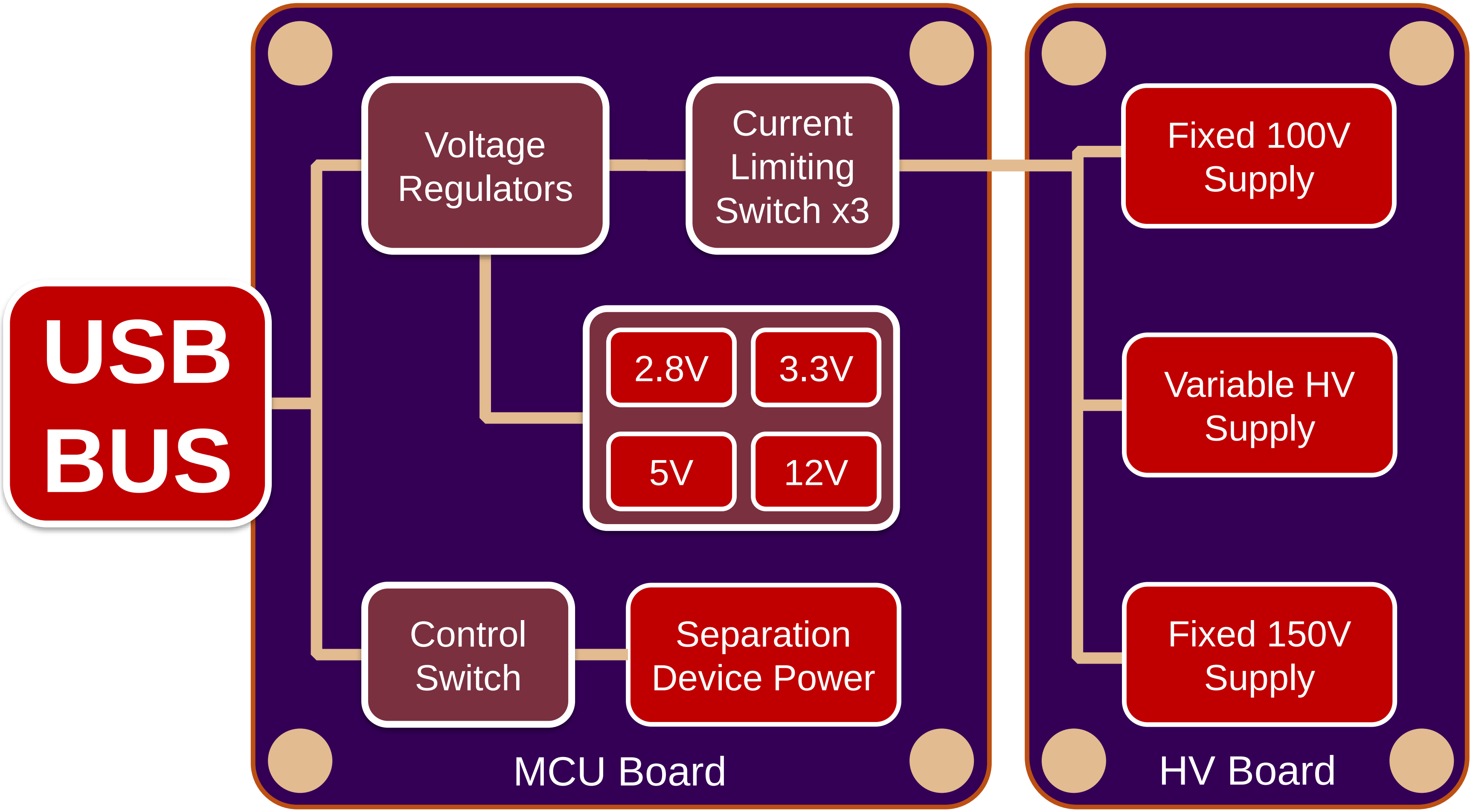
Power Distribution



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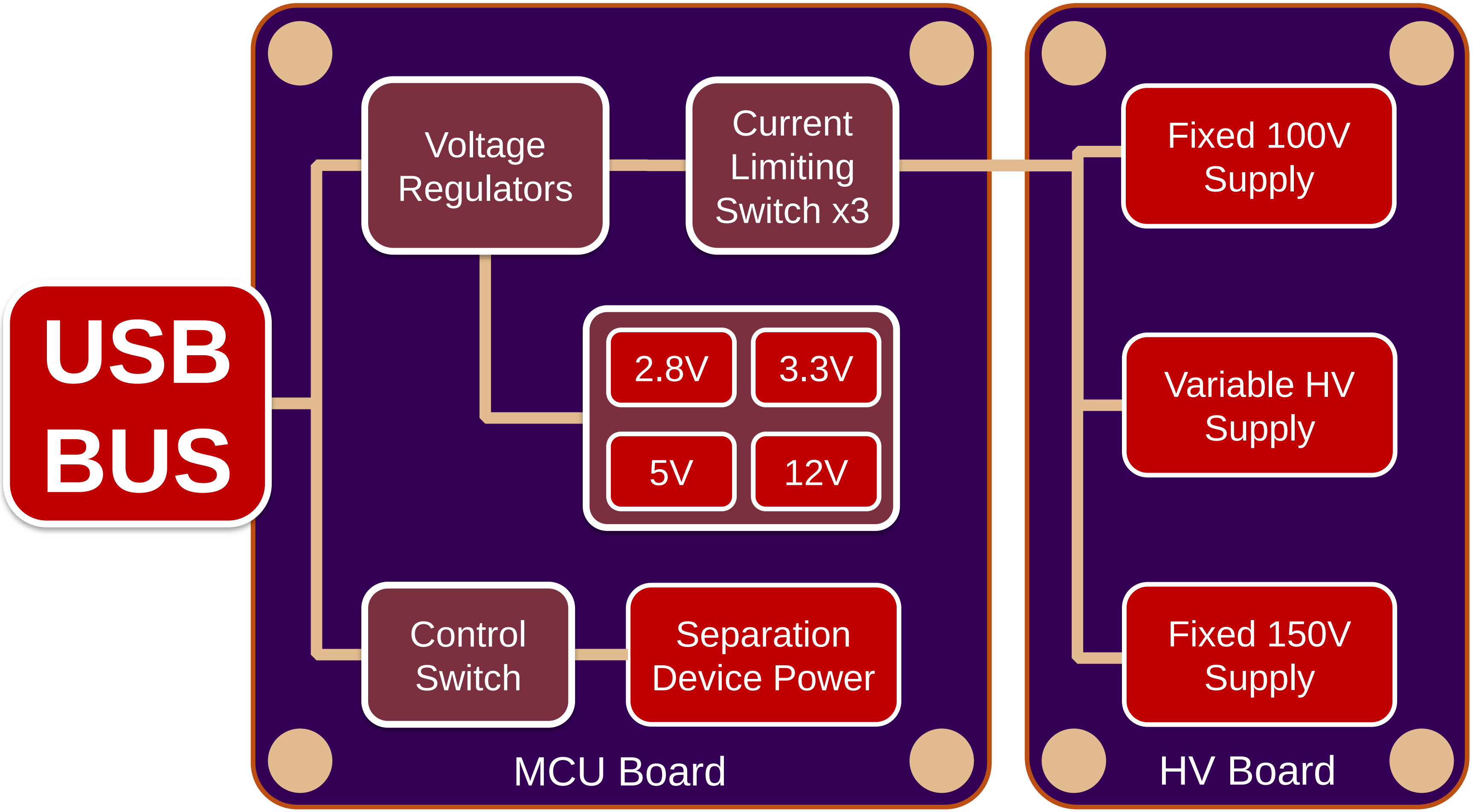
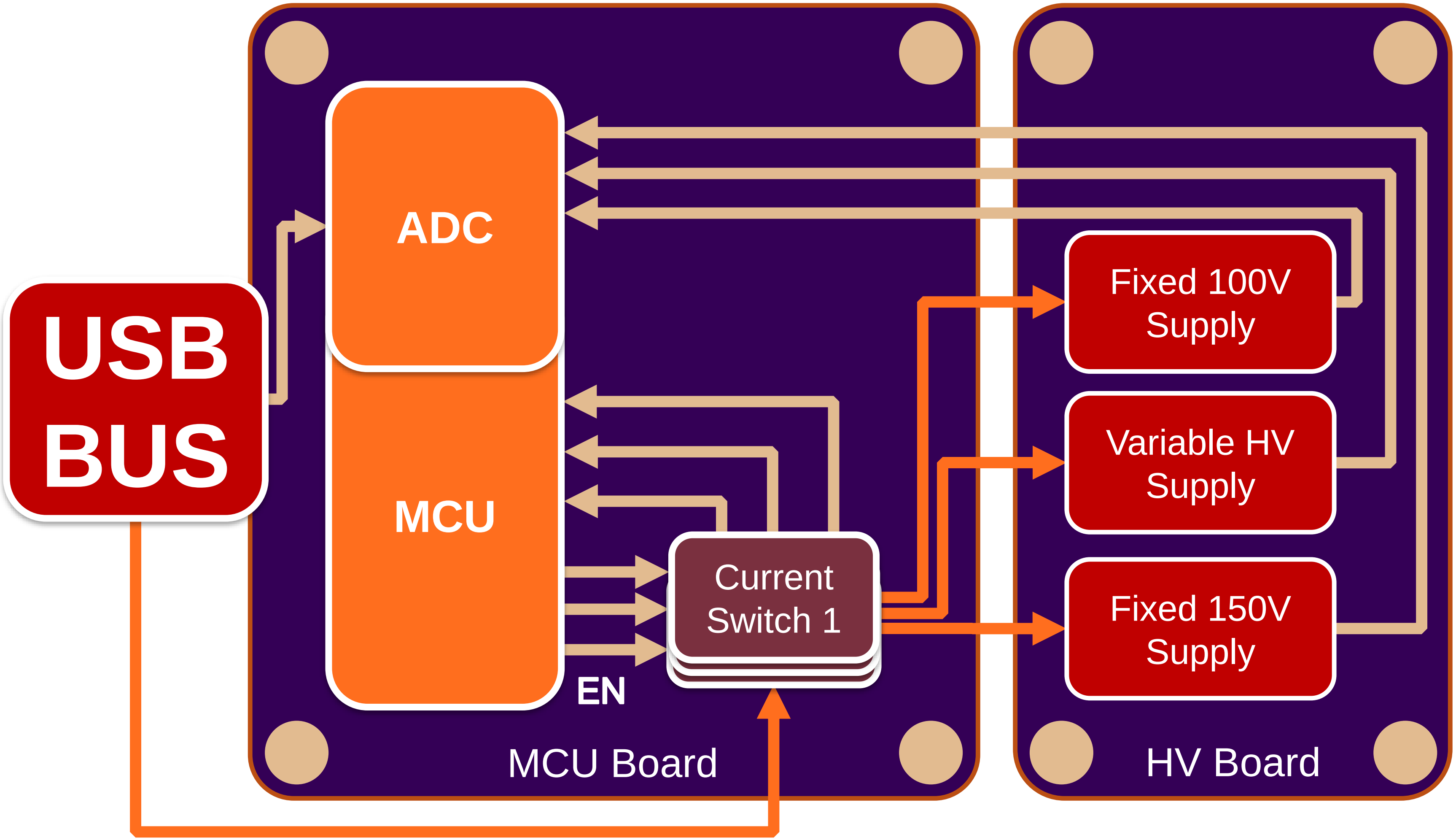


Power Control & Monitoring



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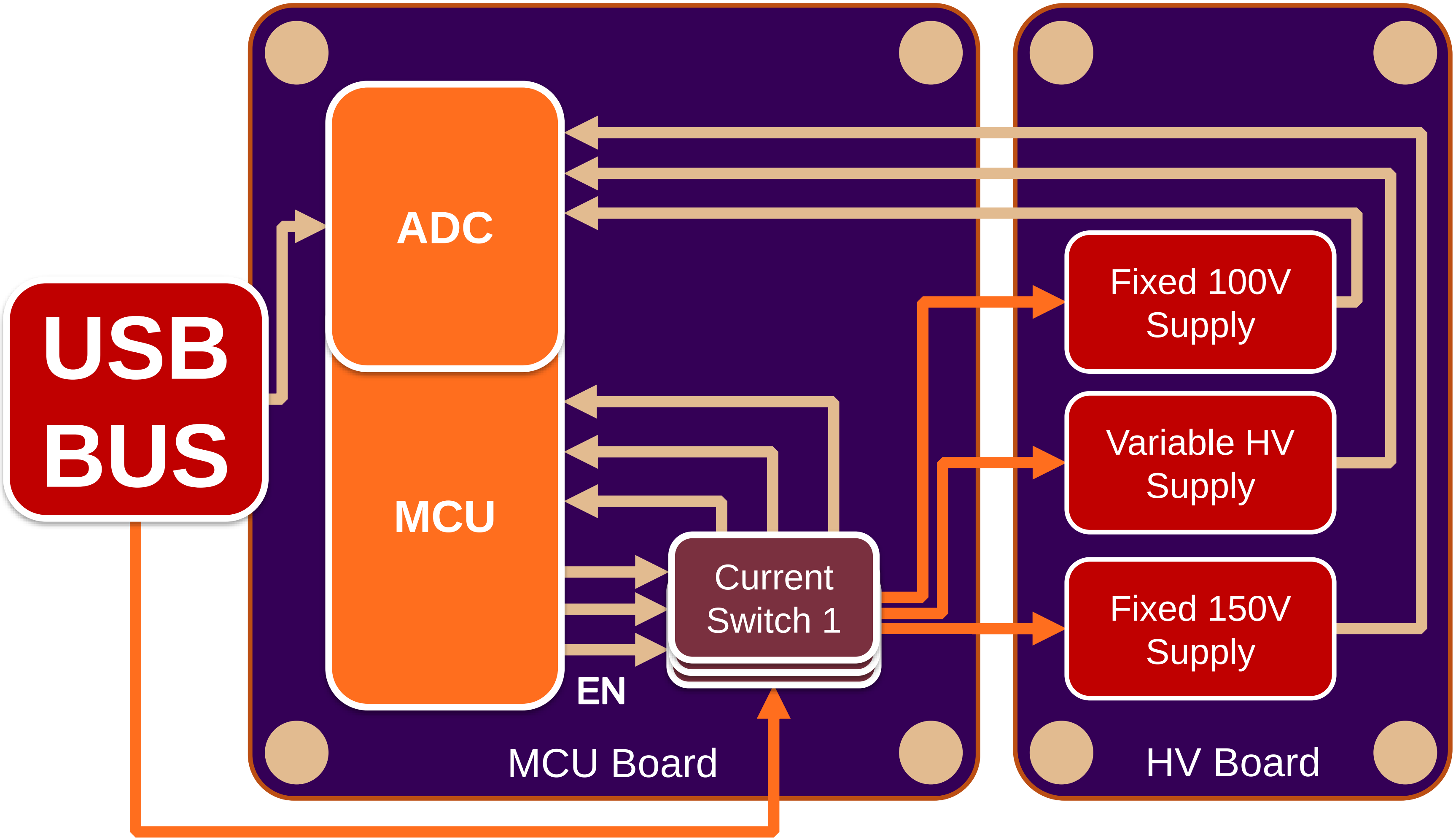
Power Control & Monitoring



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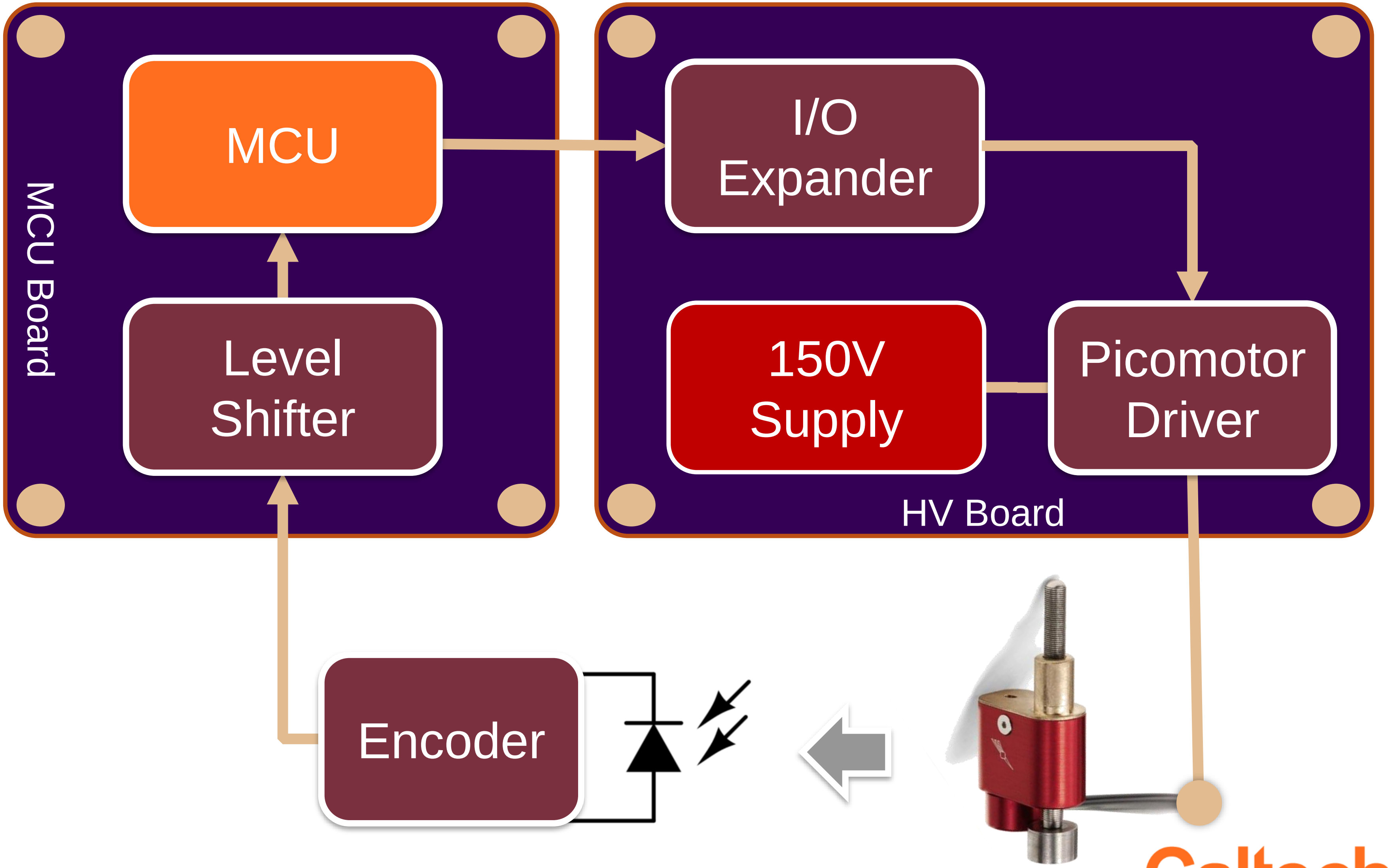
Picomotor Control



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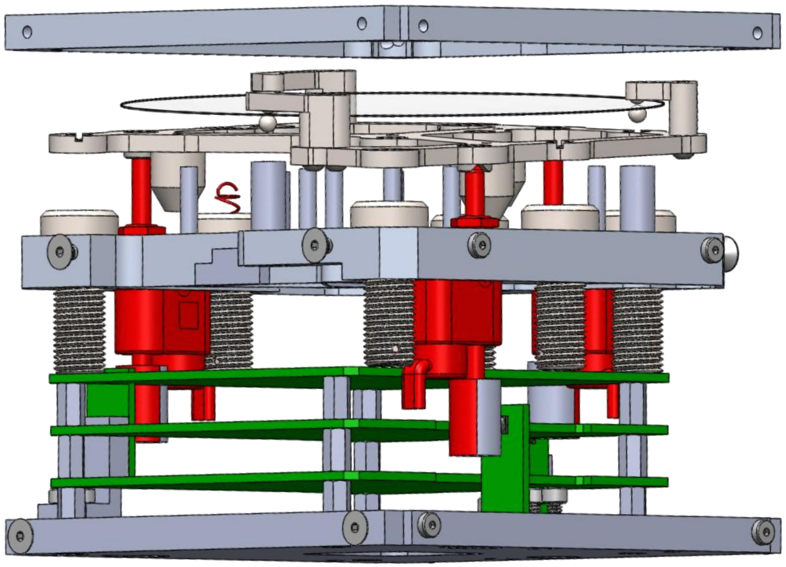

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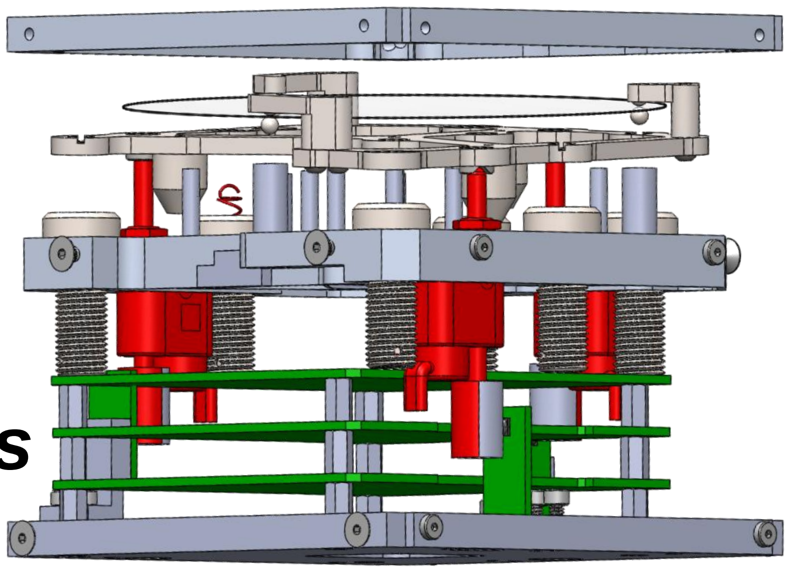

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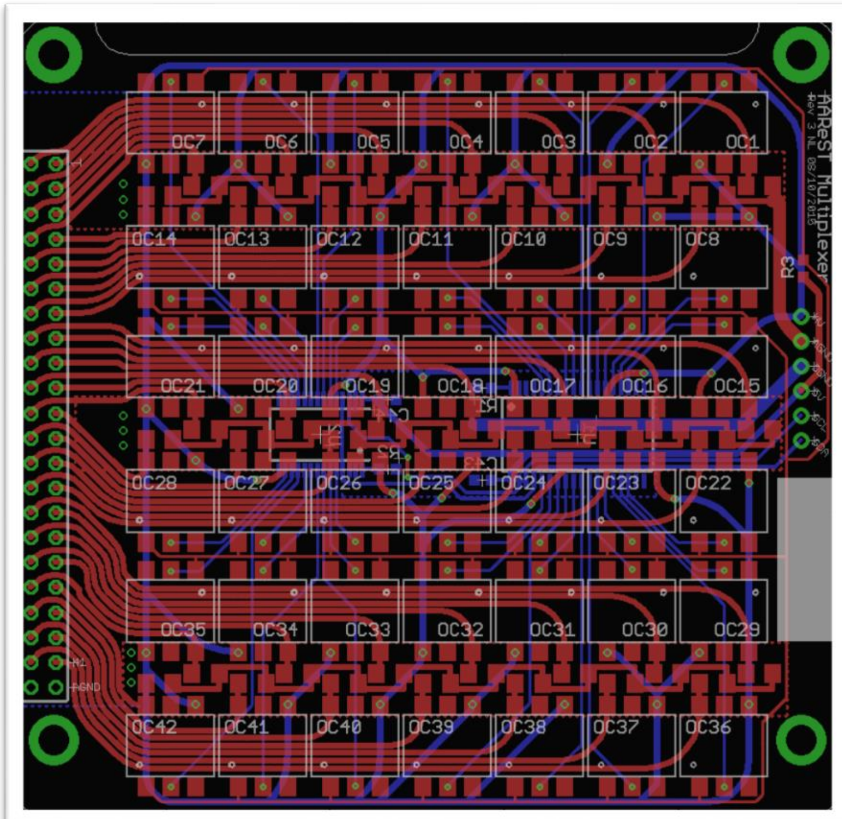
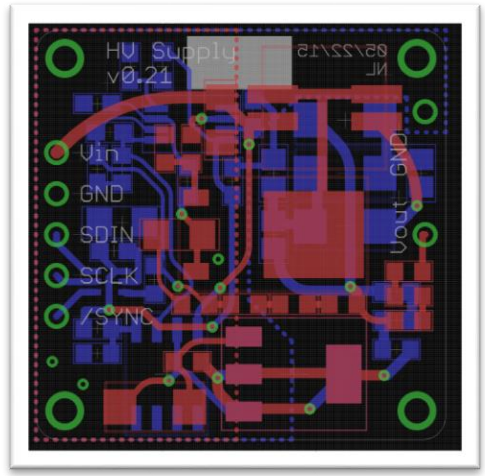
Existing Components

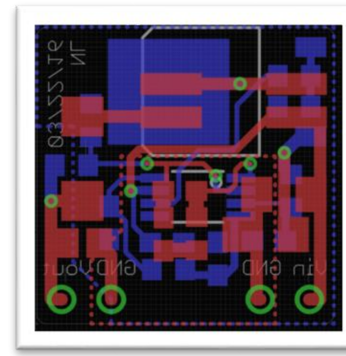
Multiplexer Board

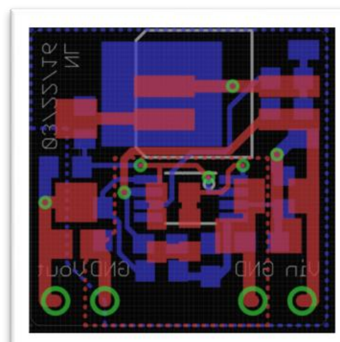


Variable Supply

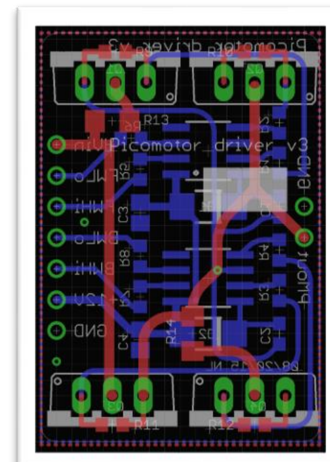


150V Supply





100V Supply



Picomotor Driver

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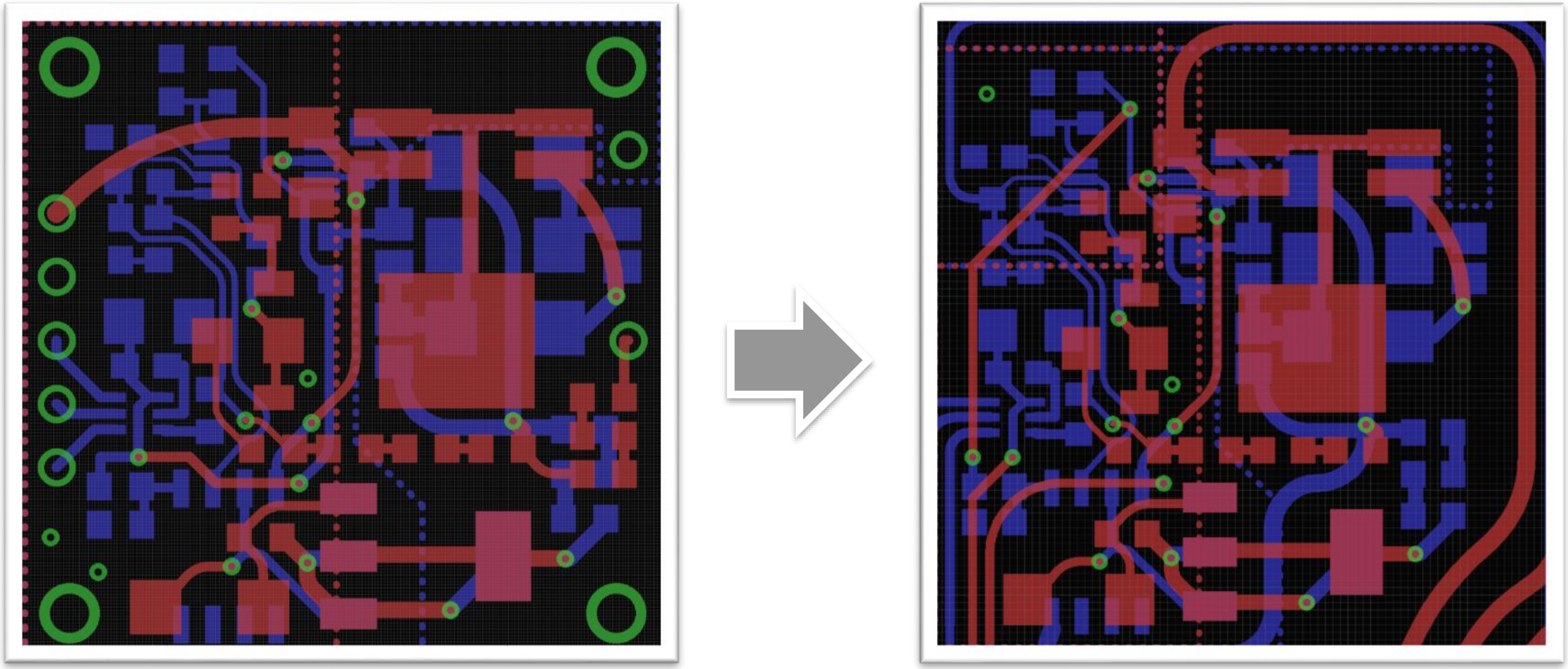
Component Adaptation Example



Variable Supply

- Remove mounting holes
- Add monitoring capability
- Minor functional changes

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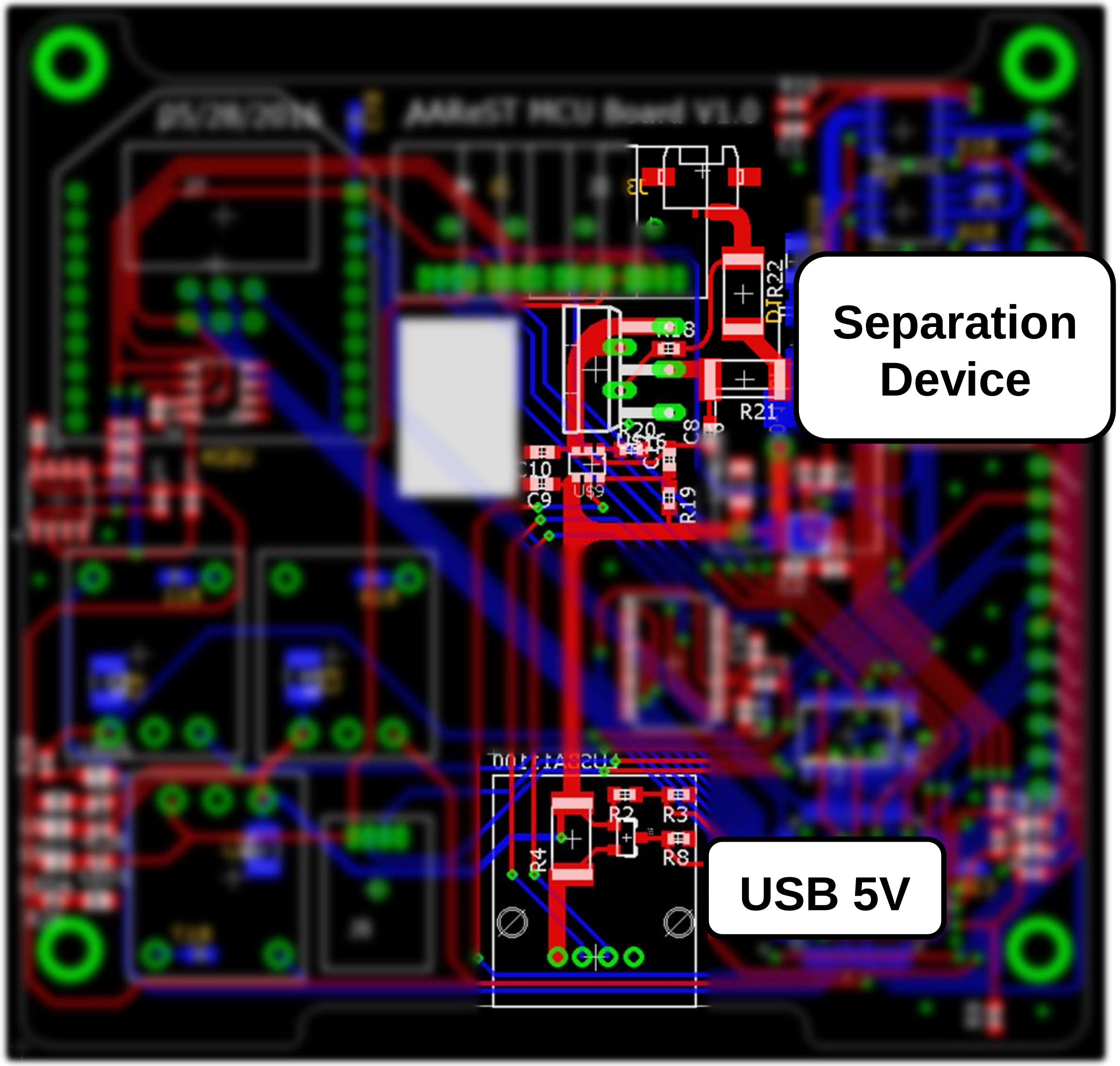
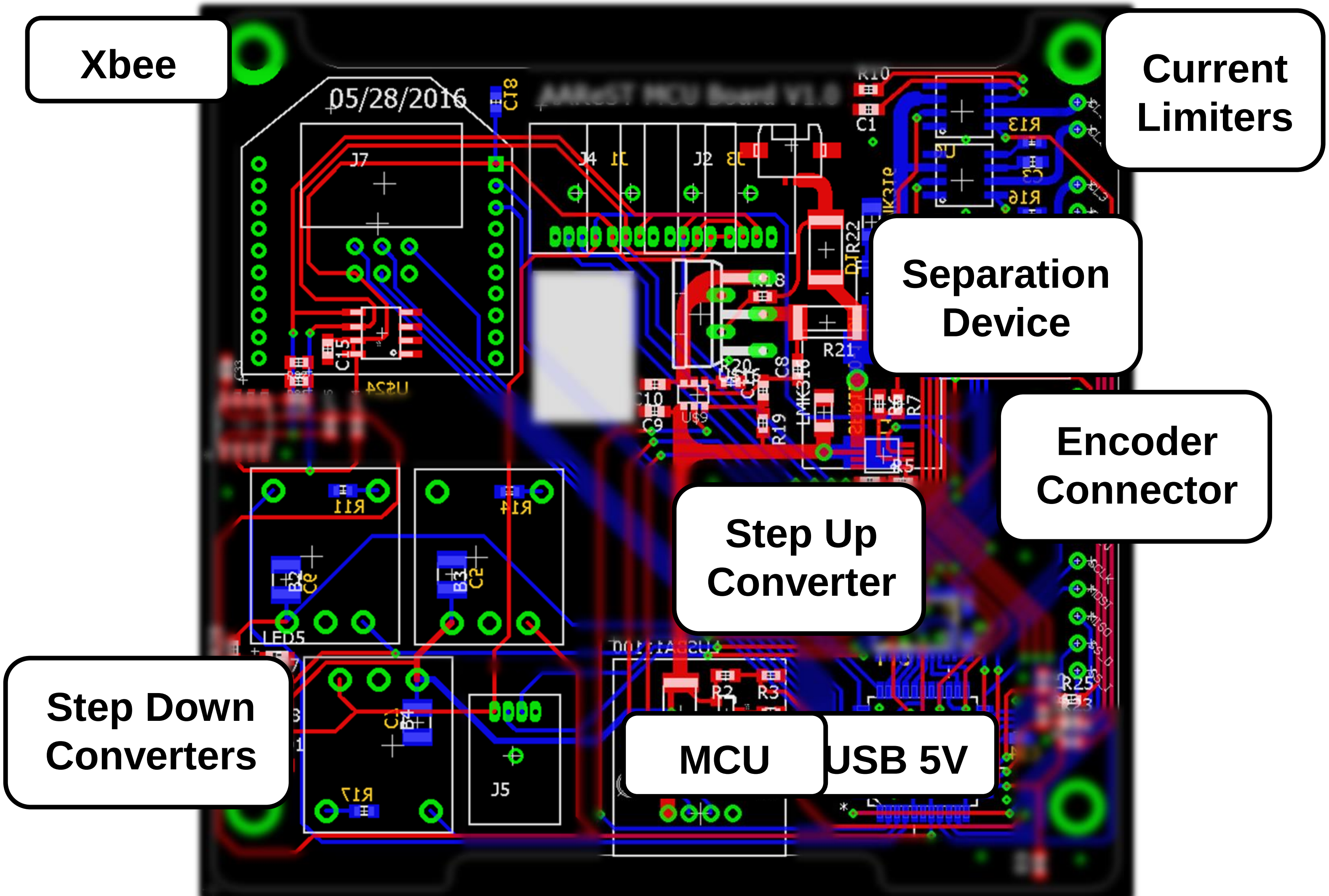
MCU PCB



MCU PCB



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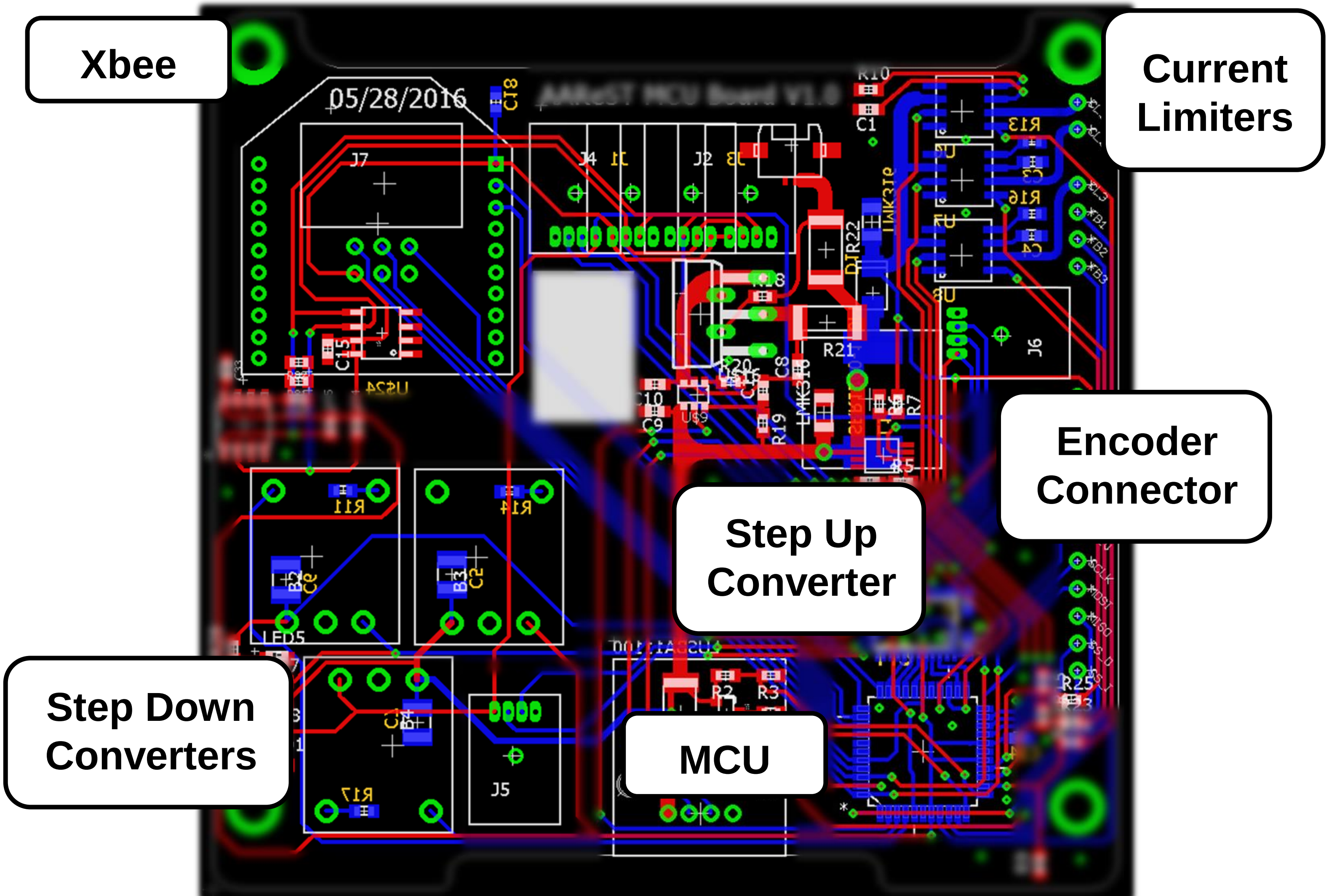
MCU PCB



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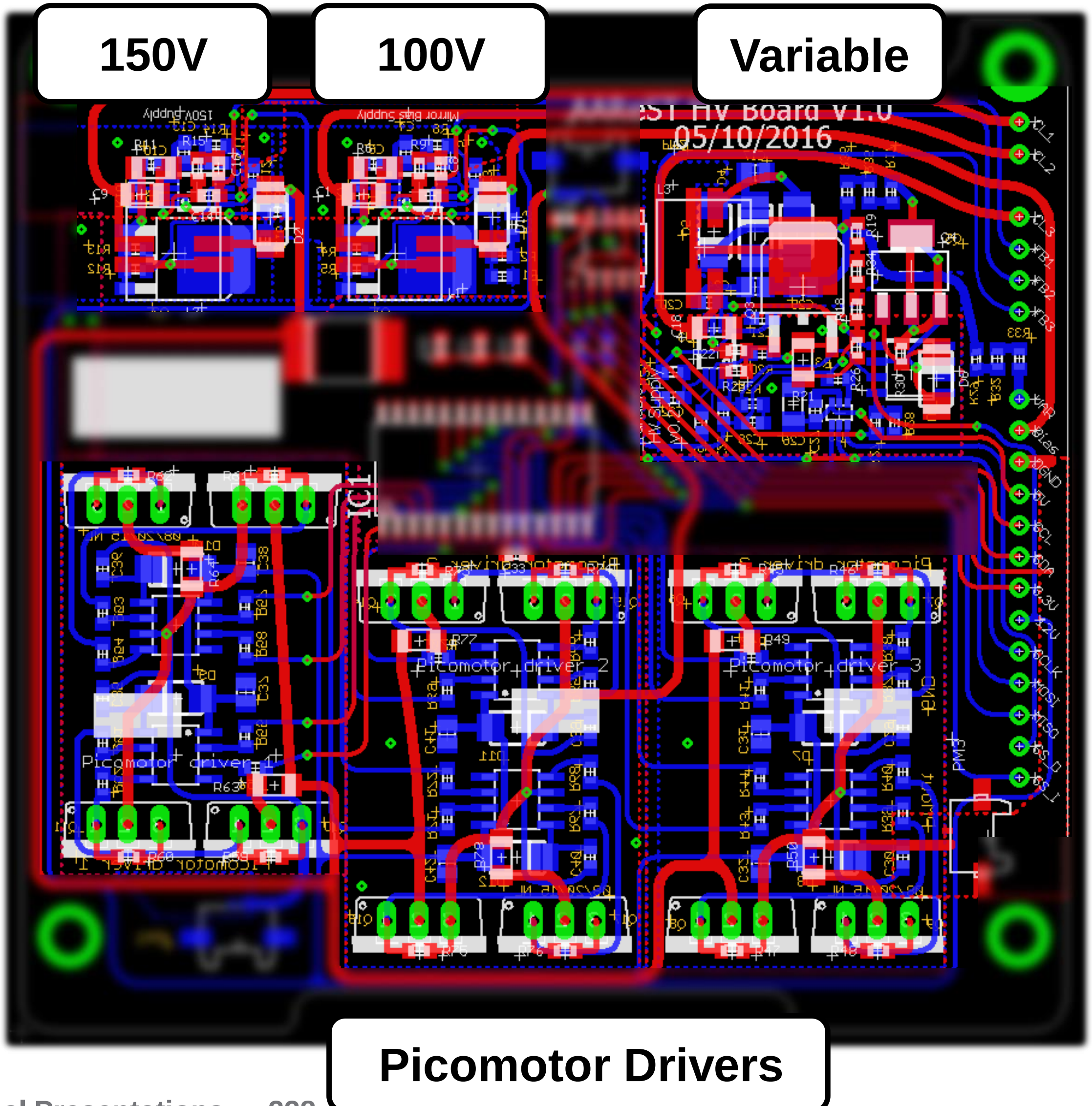
High Voltage PCB



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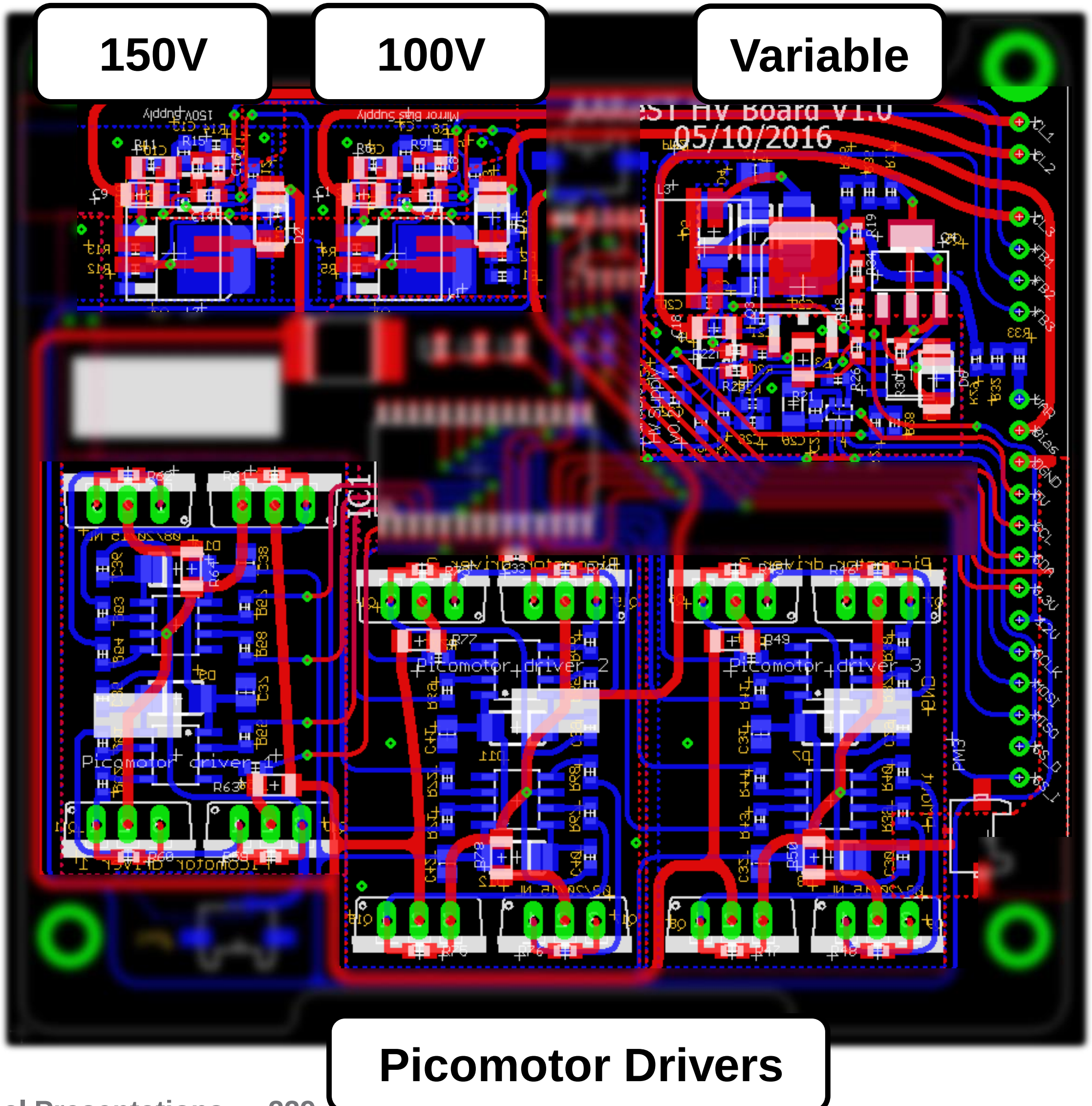
High Voltage PCB



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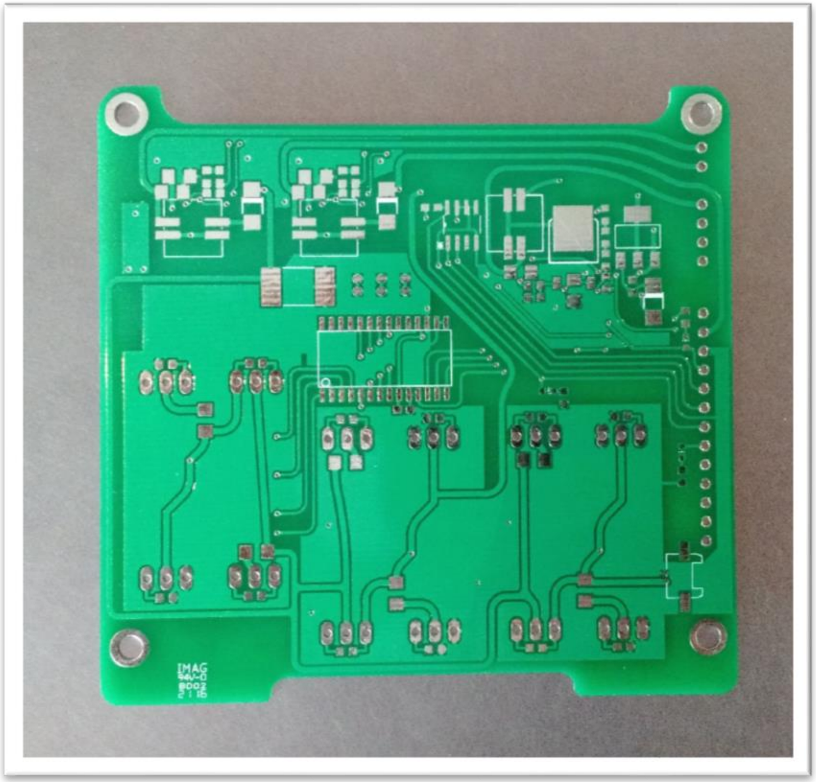
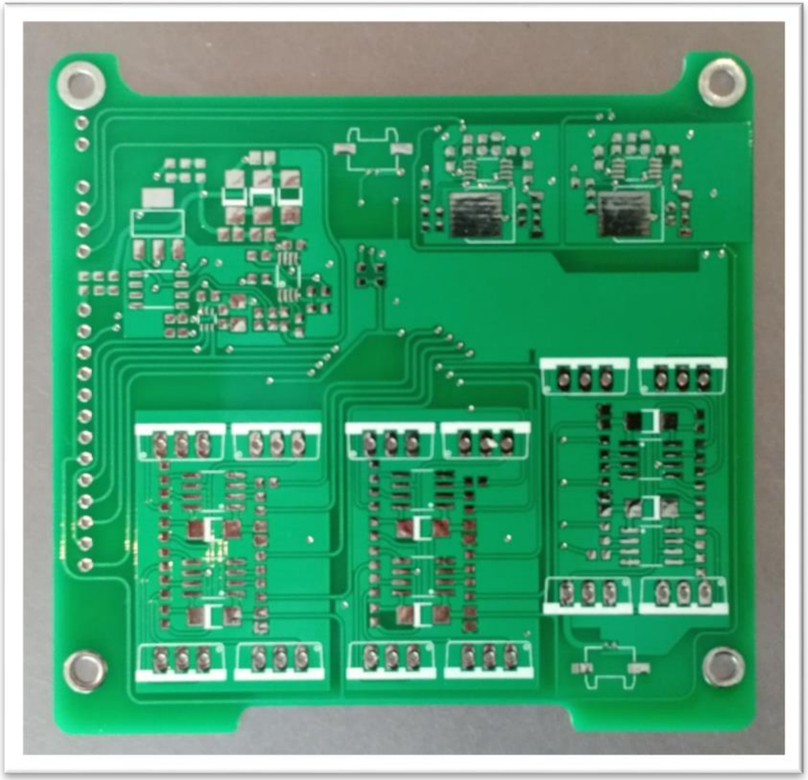
High Voltage PCB





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Presentation Outline

- System Overview
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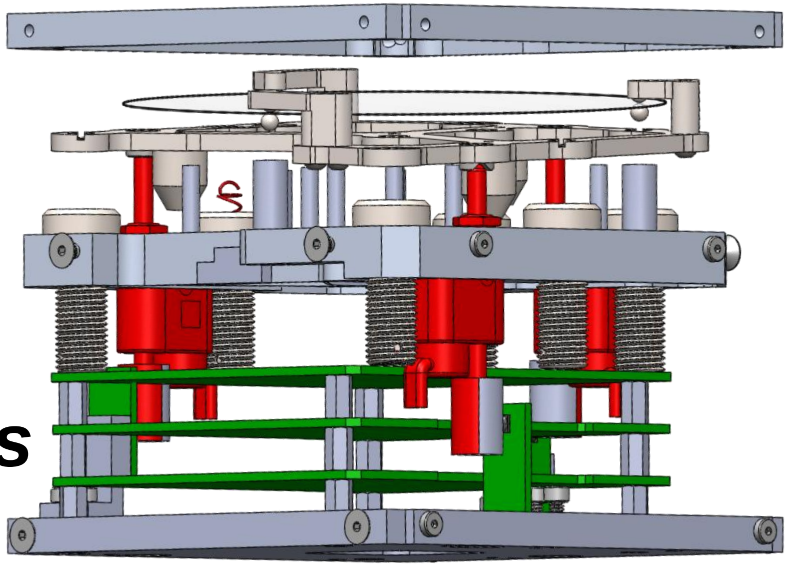
- ***Printed Circuit Boards***
- Schedule



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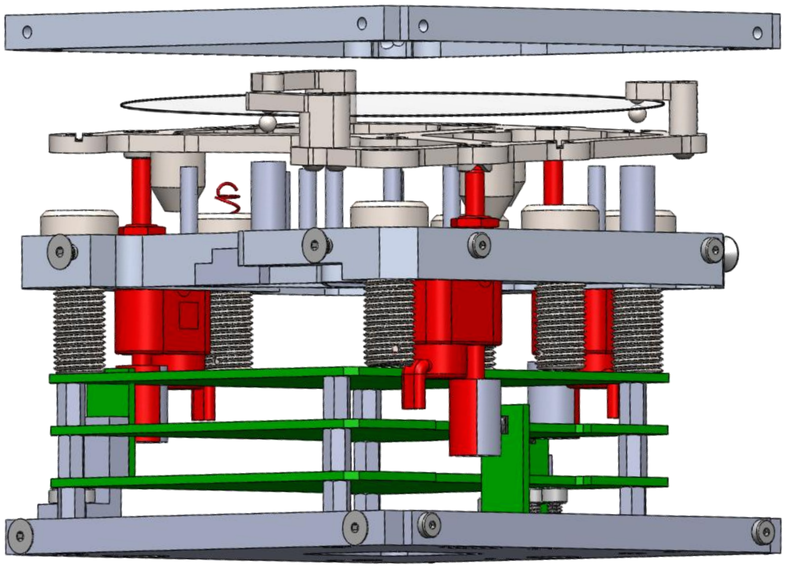
Presentation Outline

- System Overview
- Project Objectives
- Design Overview
- Printed Circuit Boards
- ***Schedule***



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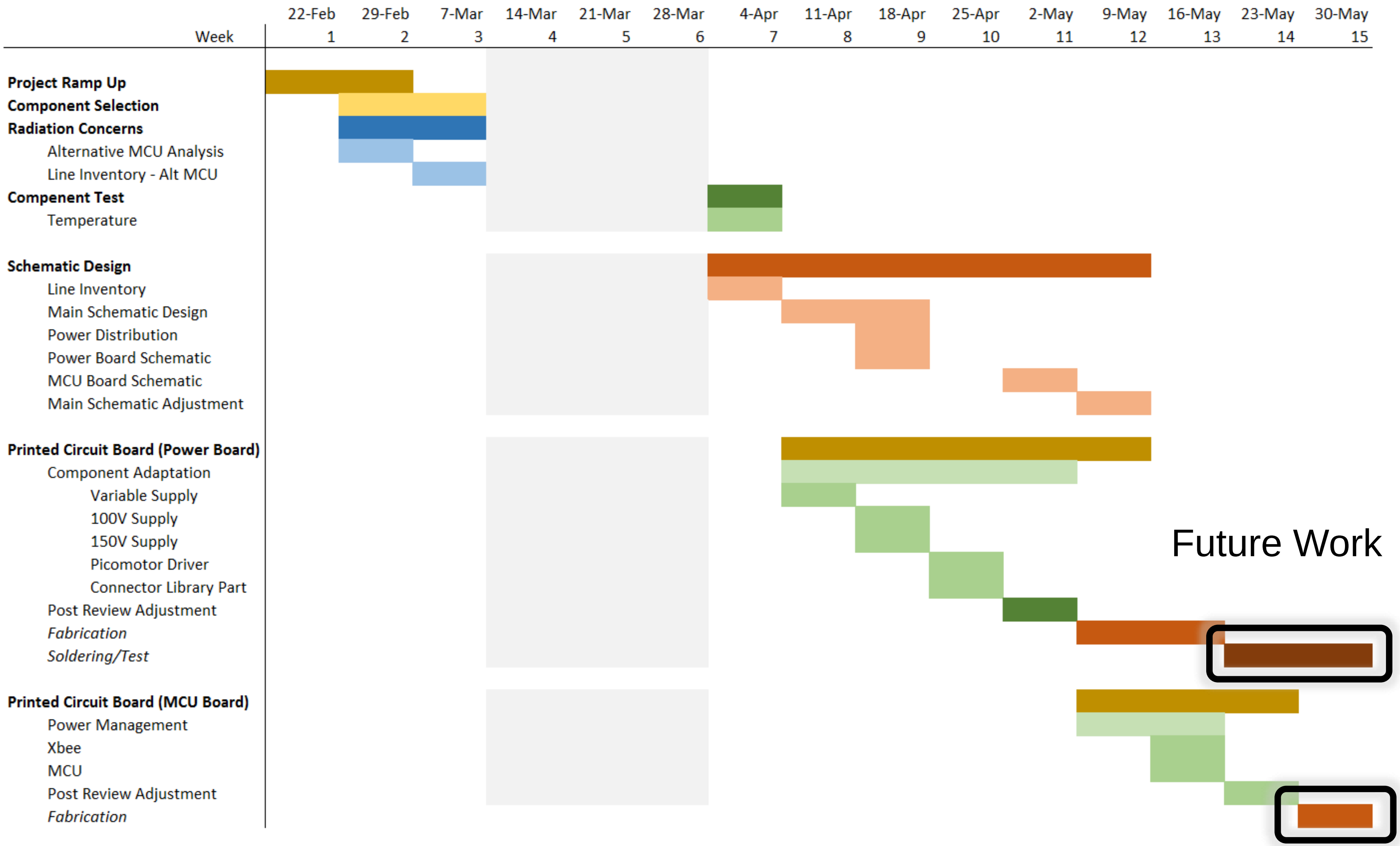
Schedule


Week
22-Feb 1
29-Feb 2
7-Mar 3
14-Mar 4
21-Mar 5
28-Mar 6
4-Apr 7
11-Apr 8
18-Apr 9
25-Apr 10
2-May 11
9-May 12
16-May 13
23-May 14
30-May 15
Project Ramp Up
Component Selection
Radiation Concerns
Alternative MCU Analysis
Line Inventory - Alt MCU
Compenent Test
Temperature
Schematic Design
Line Inventory
Main Schematic Design
Power Distribution
Power Board Schematic
MCU Board Schematic
Main Schematic Adjustment
Printed Circuit Board (Power Board)
Component Adaptation
Variable Supply
100V Supply
150V Supply
Picomotor Driver
Connector Library Part
Post Review Adjustment
Fabrication
Soldering/Test
Printed Circuit Board (MCU Board)
Power Management
Xbee
MCU
Post Review Adjustment
Fabrication
Future Work

Camera Electronics

Saumya Vij

Mentors:
Ashish Goel
Stephen Bongiorno

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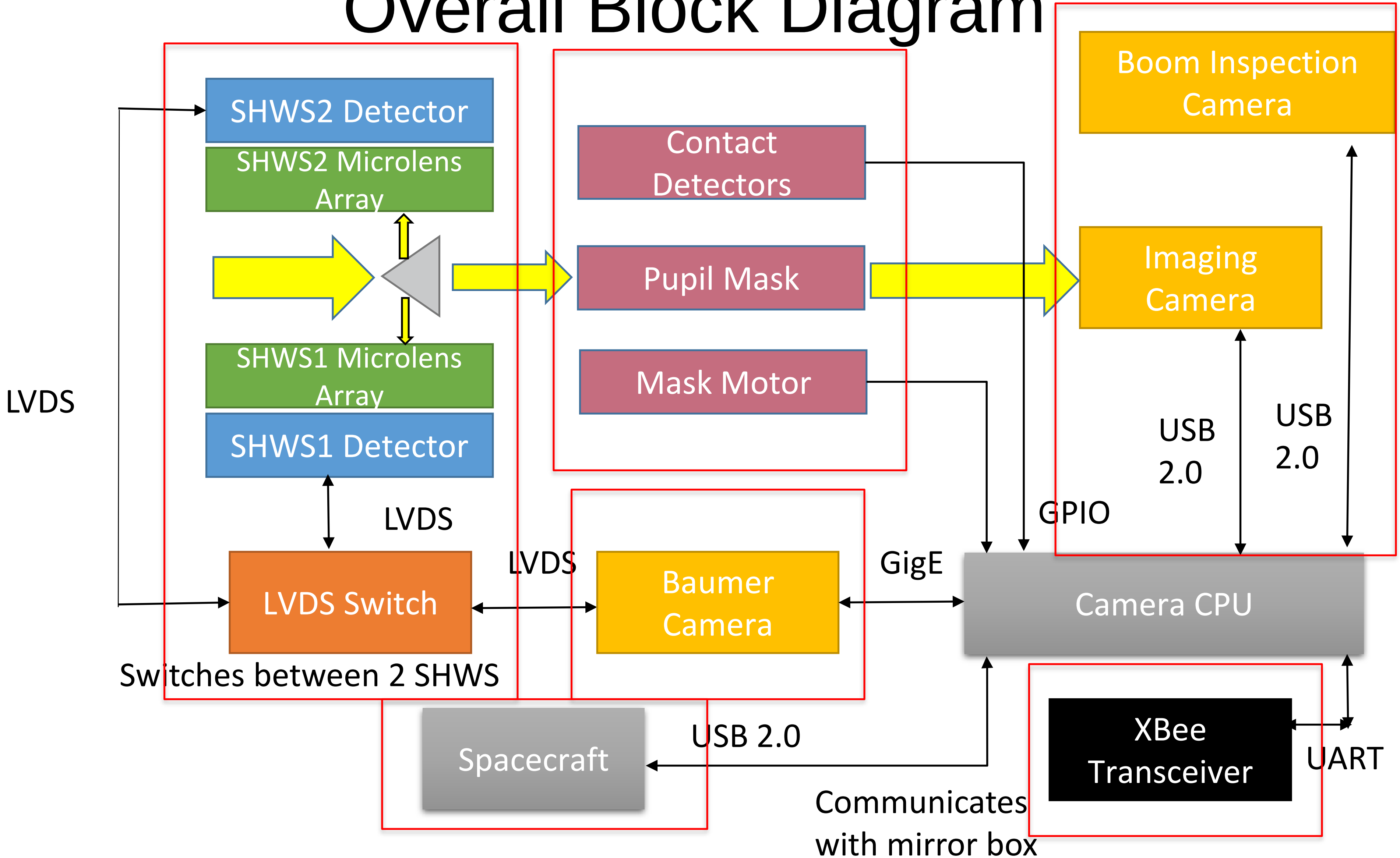
Outline

- Overview of camera electronics
- Task list
- Details of each task completed
- Schedule/Future work

Overall Block Diagram



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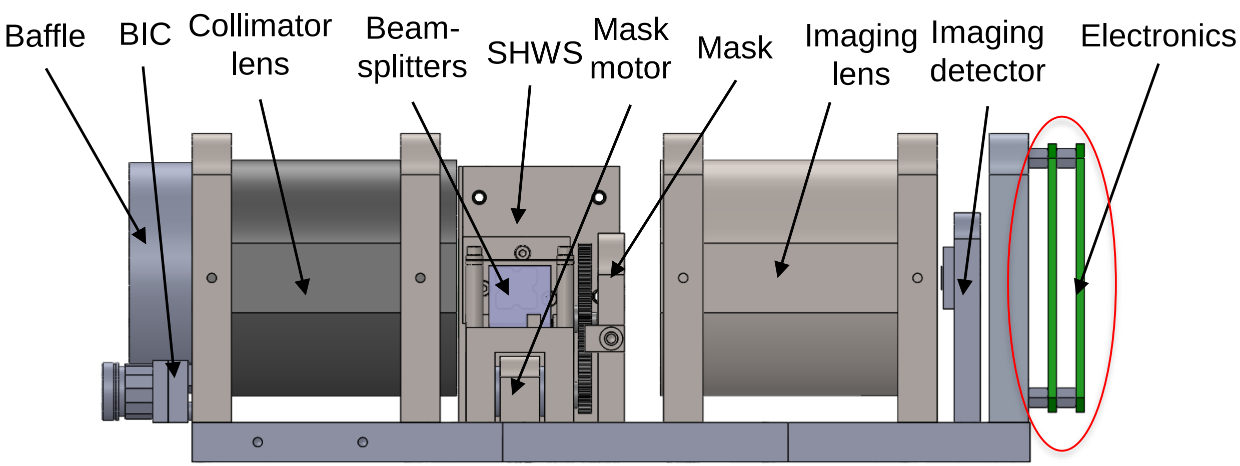
Camera CAD Model



3 circuit boards in the camera

- **Support board for baumer camera**
- **SHWS (Shack-Hartmann Wavefront Sensor) board**
  - LVDS (Low Voltage Differential Signal) switch
  - Mask motor driver
- **Motherboard**
  - Telescope CPU daughter board
  - XBee daughter board
  - Connectors for peripherals

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Task List

- Ramp up on camera, previous work done & EAGLE tool for PCB layout
- LVDS (Low Voltage Differential Signal) switch selection, ordering & testing
- PCB design & layout
  - Motherboard
  - SHWS module board
- PCB fabrication
- PCB testing

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Task List

- Ramp up on camera, previous work done & EAGLE tool for PCB layout
- LVDS (Low Voltage Differential Signal) switch selection, ordering & testing
- PCB design & layout
    - Motherboard
    - SHWS module board
- PCB fabrication
- PCB testing

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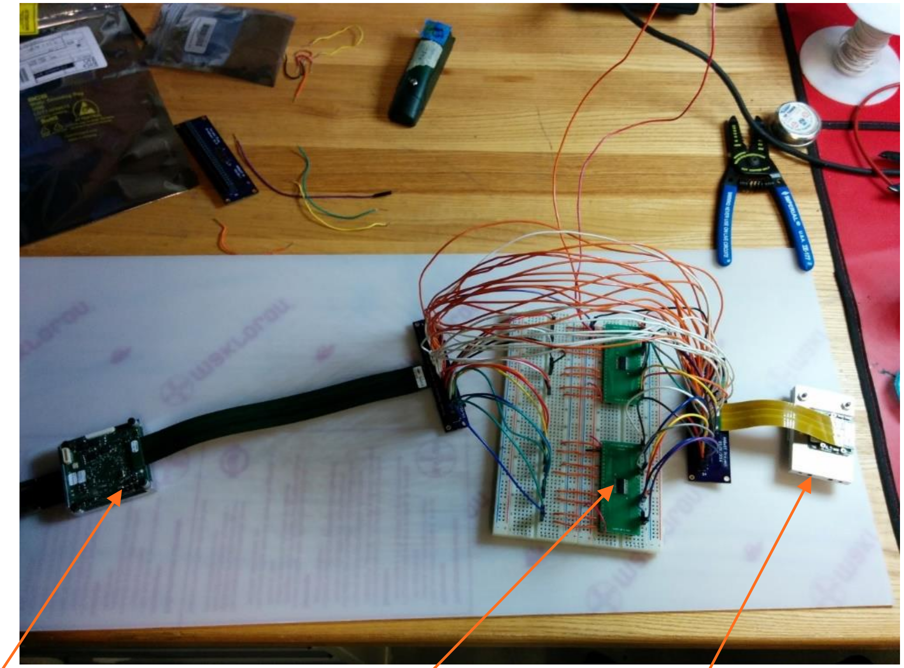
LVDS Switch Testing

- ✓ Phase 1: Direct testing
- ✓ Phase 2: Crosstalk characterization
- ✓ Phase 3: Testing with 1 SHWS and Baumer camera
- Phase 4: Testing with 2 SHWS and Baumer camera
  - 2nd SHWS damaged during testing
  - Testing be completed after we receive the 2nd SHWS back from repair



Baumer Camera

LVDS Switches

SHWS

Results

- Positive - meets requirements
- Very low cross-talk noise
- Successfully switches at required rate (@ 2 Hz) between ON & OFF state of 1 SHWS

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Task List

- Ramp up on camera, previous work done & EAGLE tool for PCB layout
- LVDS (Low Voltage Differential Signal) switch selection, ordering & testing
- PCB design & layout
  - Motherboard
  - SHWS module board
- PCB fabrication
- PCB testing

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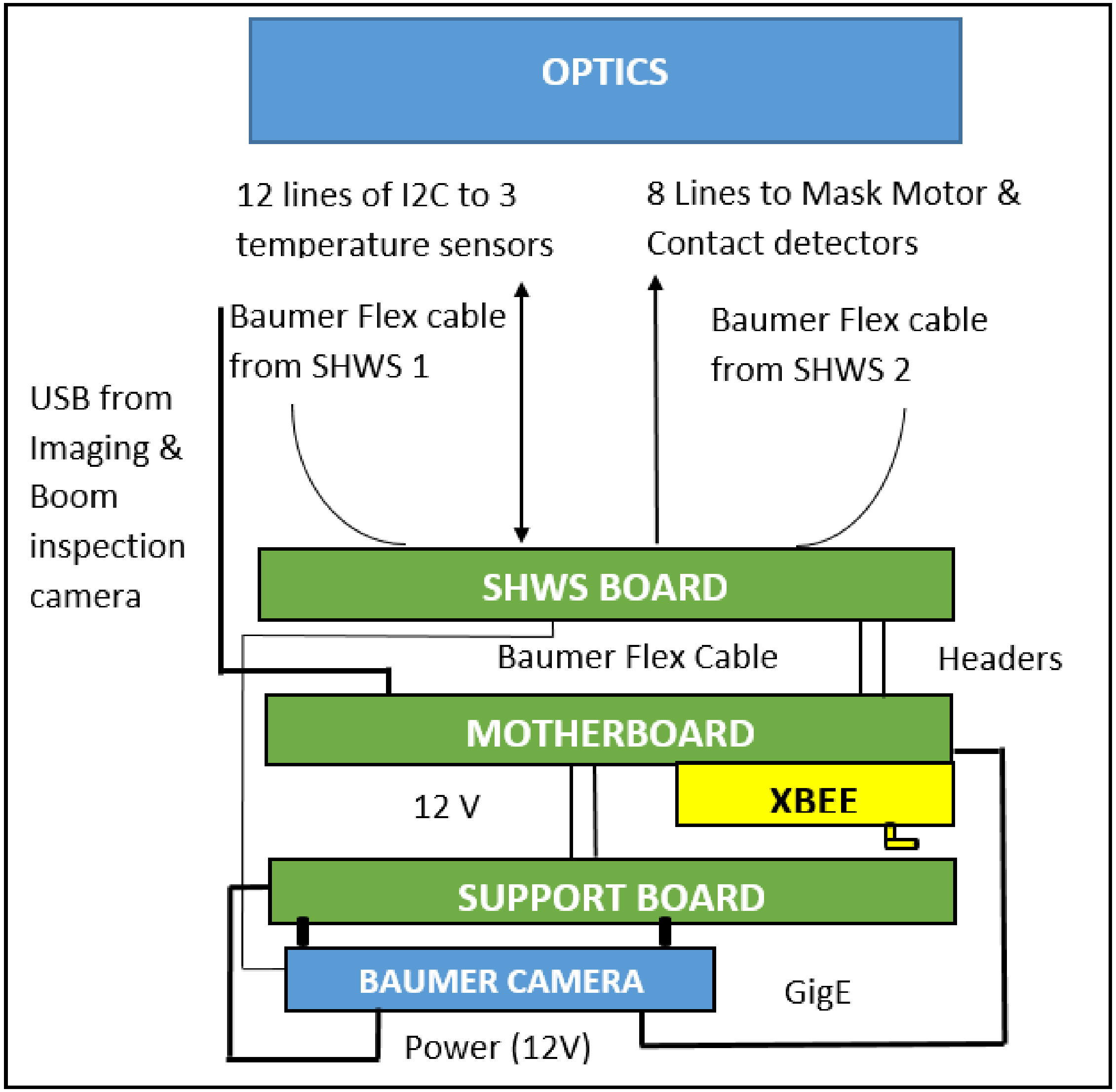
On Flight Placement of Boards



Chassis

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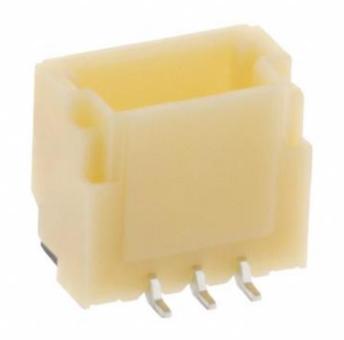
Connectors

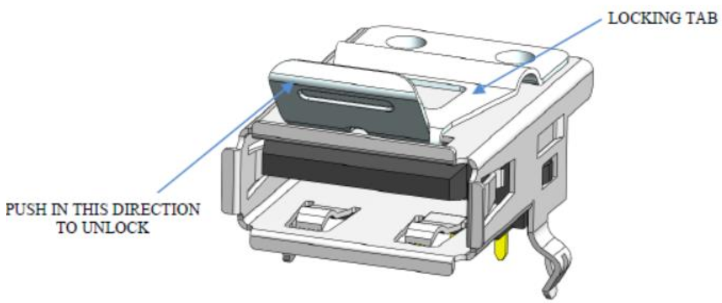
- Need to have a mechanical locking feature for vibration resilient connection
- Insulating material should be low-outgassing

GigE - Pulse Jack

ITT Cannon MDM Series for I2C and Mask Motor driver



JST BM03B SRSS For Baumer camera connection



LUSBA11100 for all USB connections – Like a regular USB type A connector but with locking

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Task List

- Ramp up on camera, previous work done & EAGLE tool for PCB layout
- LVDS (Low Voltage Differential Signal) switch selection, ordering & testing
- PCB design & layout
  - Motherboard
  - SHWS module board
- PCB fabrication
- PCB testing

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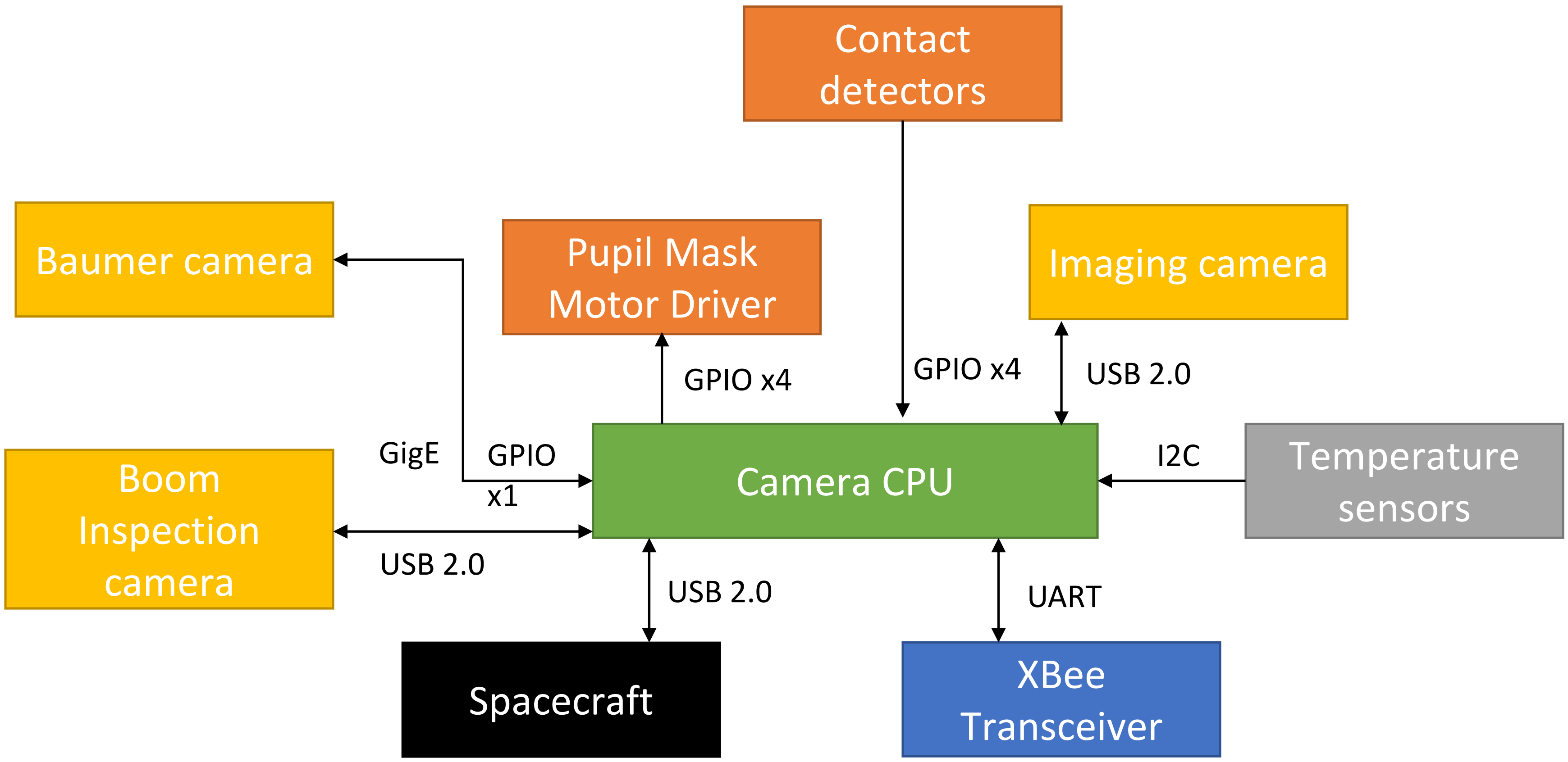
Motherboard Block Diagram



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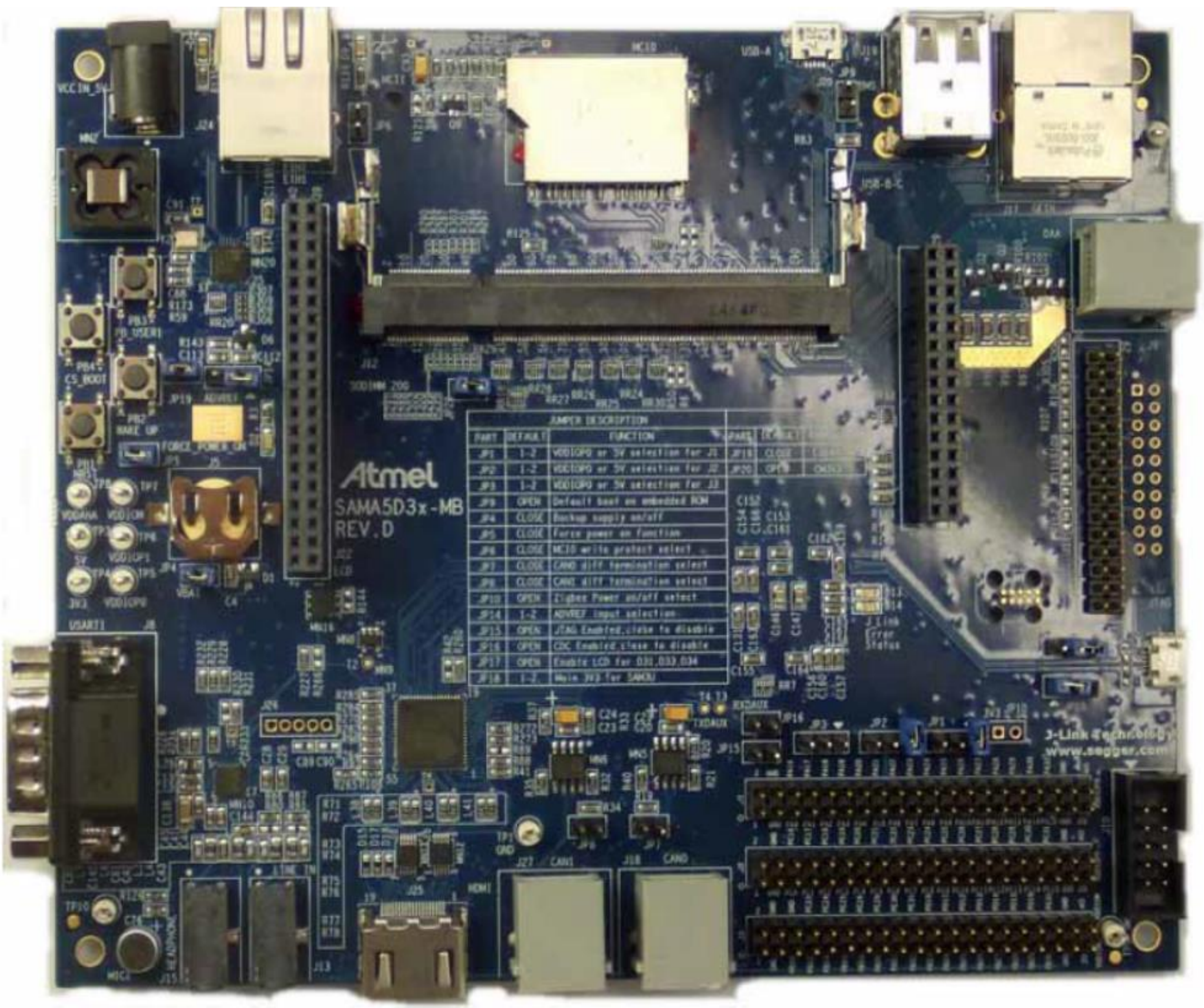
Motherboard Design

165 mm



135 mm

Actual Dev board size

75 mm

65 mm

Requirement for AAReST

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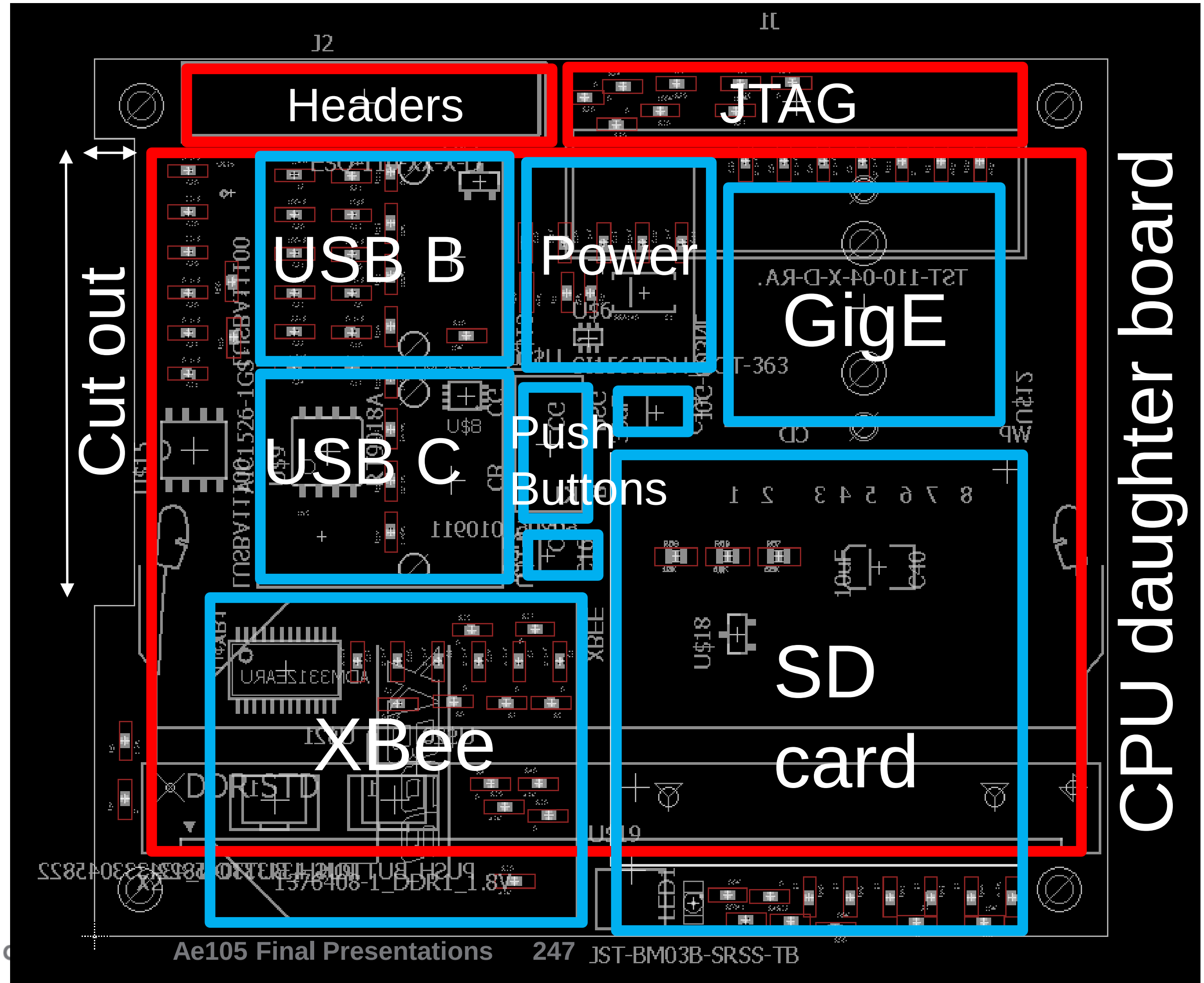
Motherboard - Layout of Components



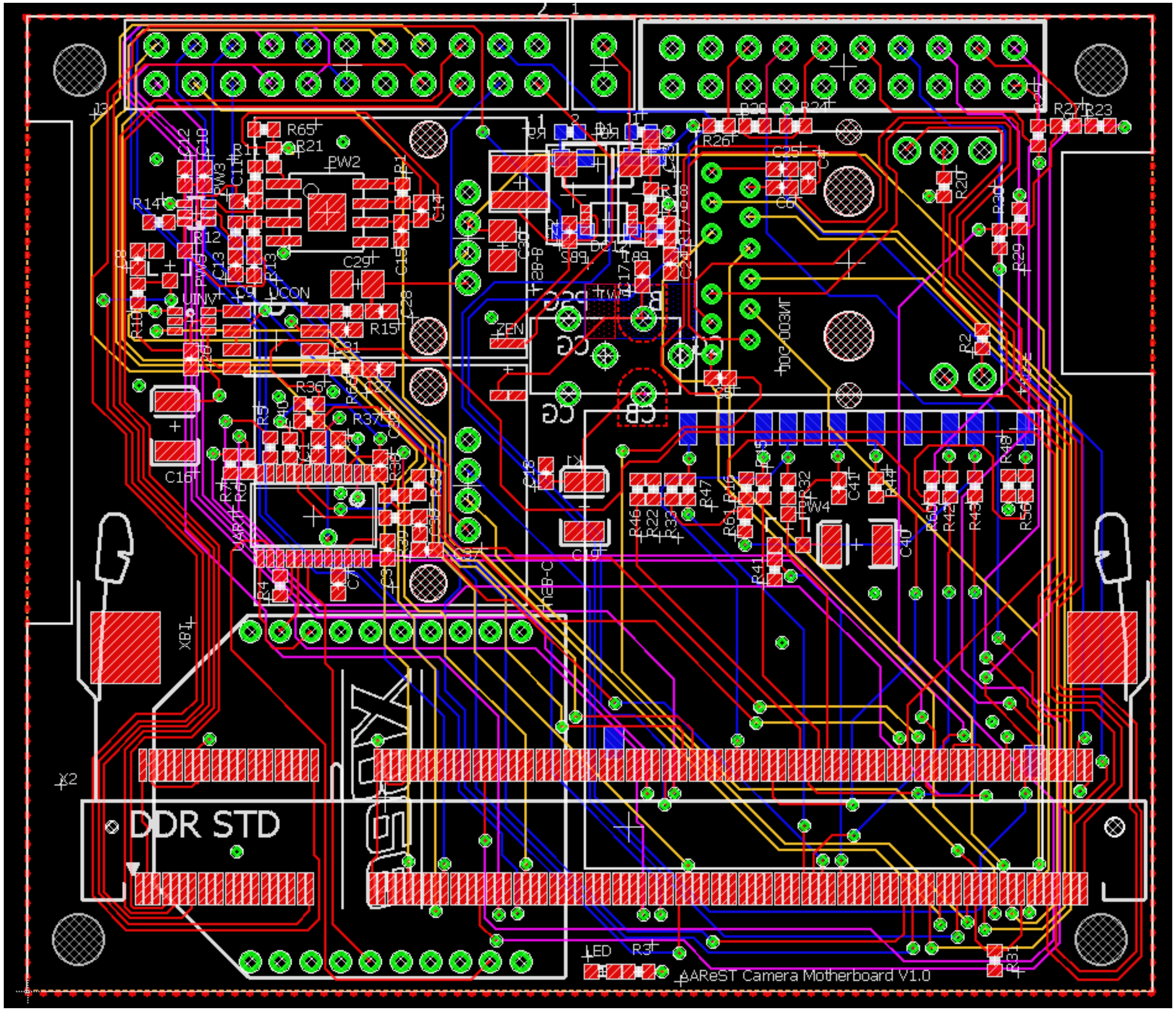
Components:

- 22 + 2 pin headers to interact with SHWS
- USB B & USB C to communicate with imaging & boom inspection cameras
- Power management circuit
- GigE for baumer camera
- 2 push buttons
- SD card
- XBee module
- JTAG headers
- CPU daughter board

Top side

Bottom side

Motherboard – Final Look



- Final board with completed routing
- 4 layer board
- Has been sent for fabrication

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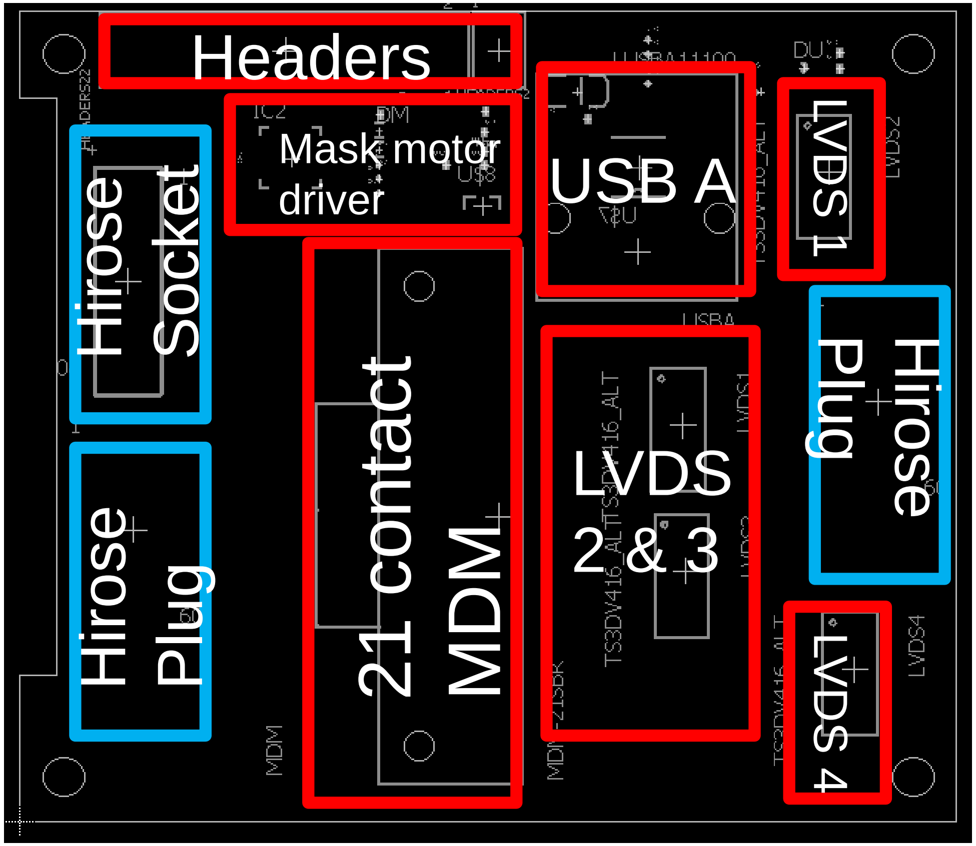
Task List

- Ramp up on camera, previous work done & EAGLE tool for PCB layout
- LVDS (Low Voltage Differential Signal) switch selection, ordering & testing
- PCB design & layout
  - Motherboard
  - SHWS module board
- PCB fabrication
- PCB testing

SHWS – Layout of Components



Top side

Bottom side

Components:

- 22 + 2 pin headers to interact with MB
- USBA to communicate with spacecraft
- 2 Hirose Plugs to receive SHWS signals
- 1 Hirose Receptacle for Baumer camera
- 21 pin MDM connector for mask motor, contact detectors, 3 temperature sensors
- 4 LVDS switches
- Mask motor driver circuit

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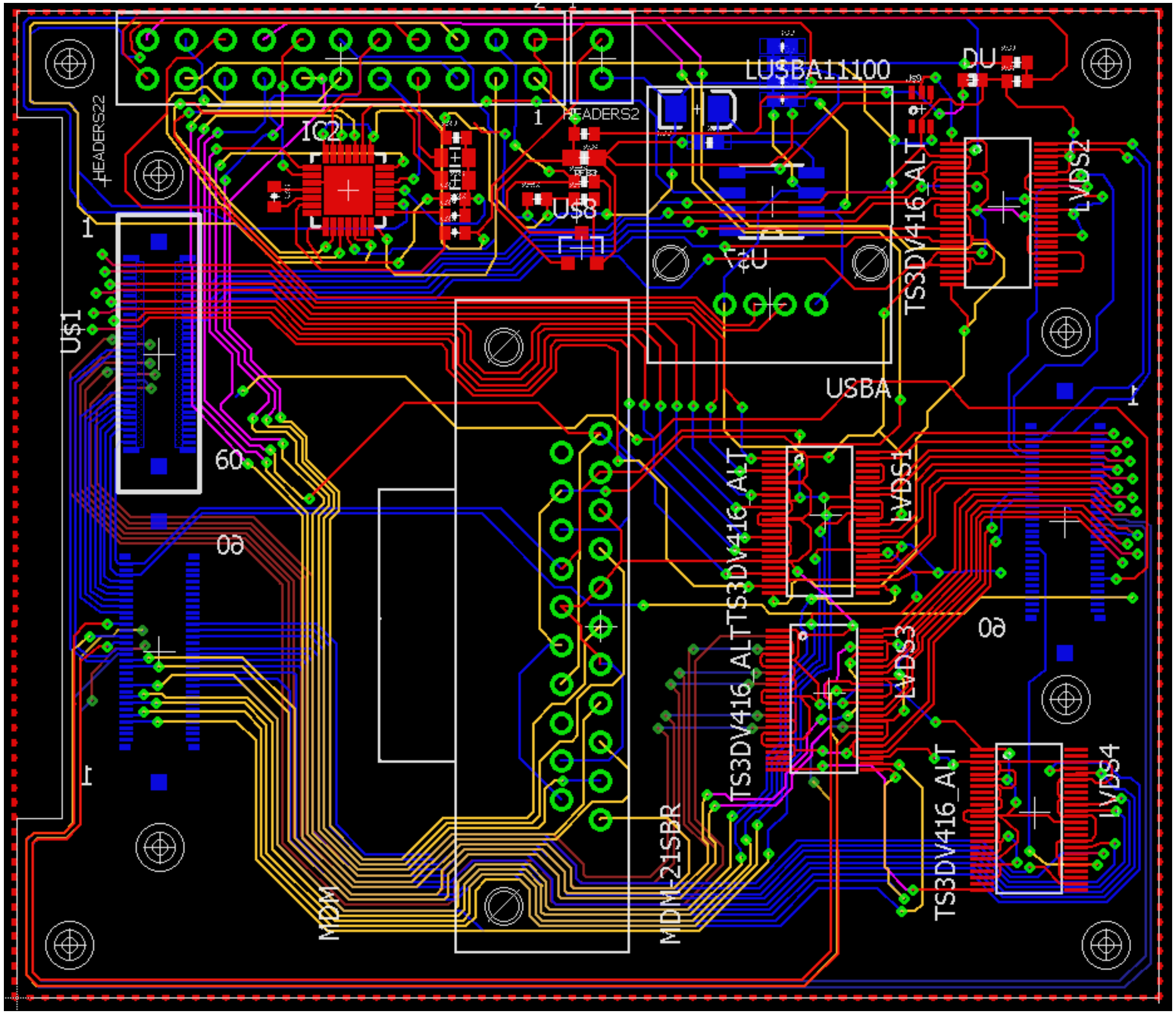
SHWS Board



- Current board
- 4 layer board
- Some changes being made before sending it out for fabrication

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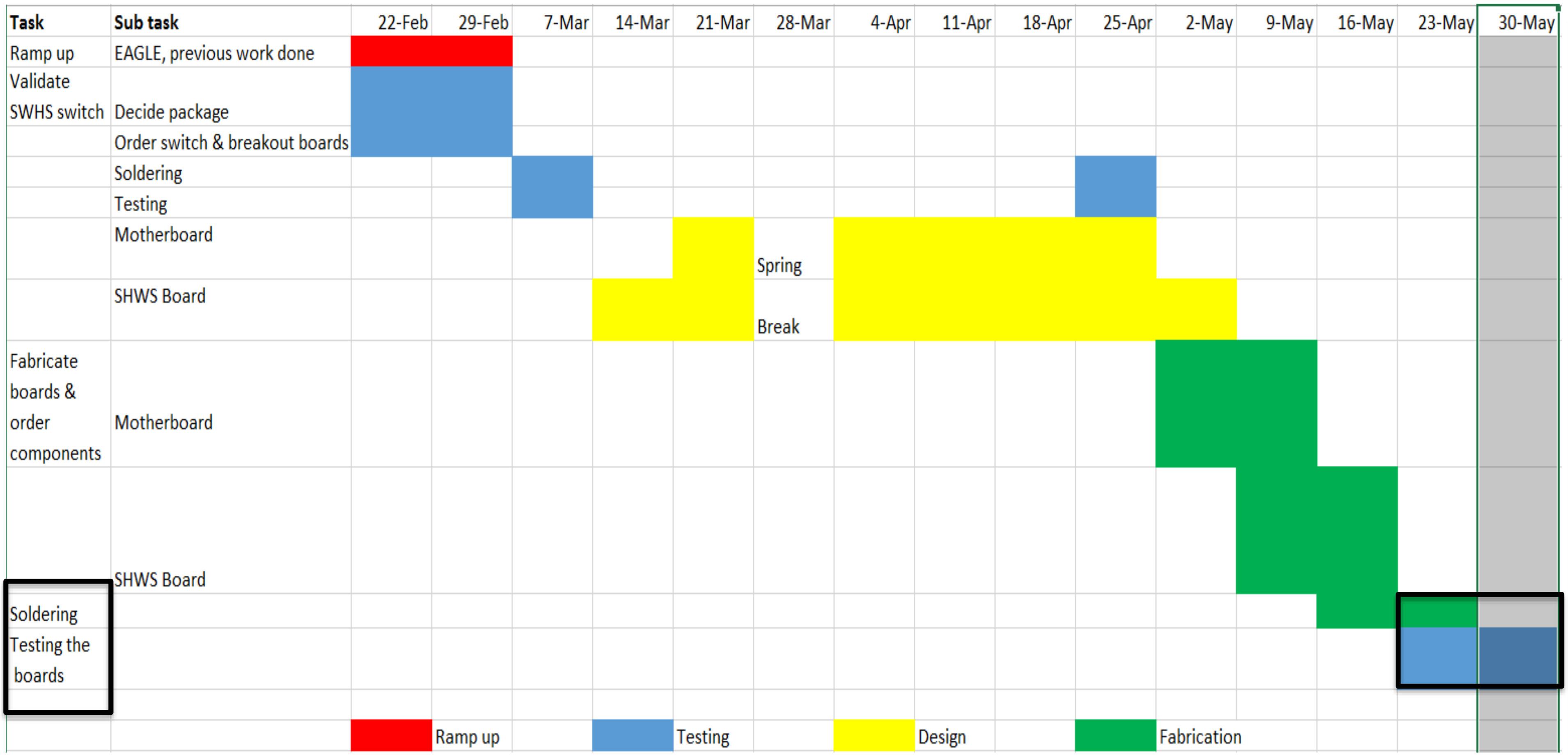
Schedule



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AAReST Electronics

Thank you for your attention!

Questions

Andre Sukernik Saumya Vij

Mentors: Ashish Goel
Stephen Bongiorno

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