STOUT

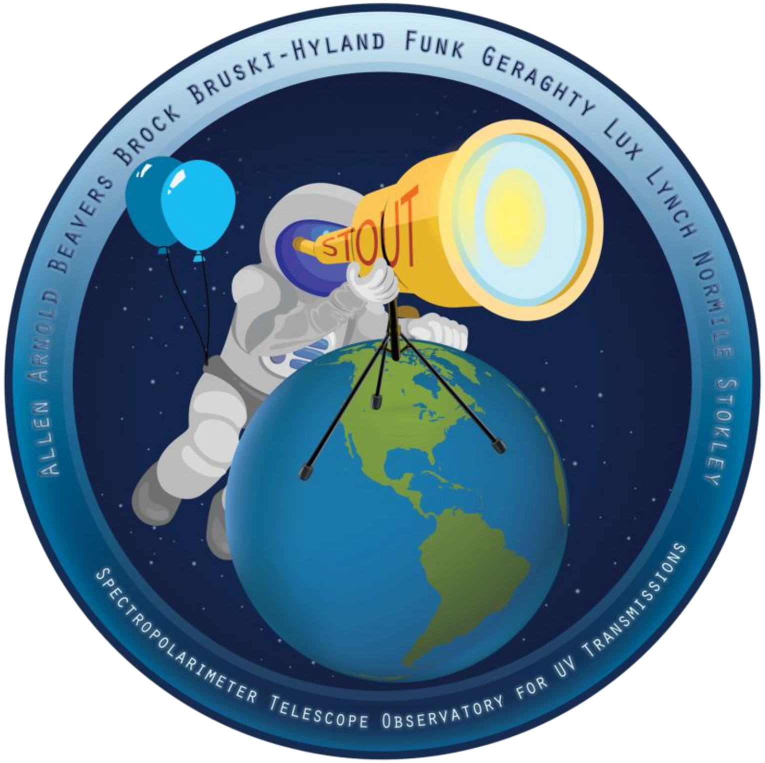
<u>S</u>pectropolarimeter
<u>T</u>elescope
<u>O</u>bservatory for
<u>U</u>ltraviolet
<u>T</u>ransmissions

<u>Presenters</u>:
1. Zach Allen
2. Caleb Beavers
3. Ian Geraghty
4. Matt Normile
5. Dawson Stokley

<u>Advisor:</u>
Francisco López Jimenez

<u>Team Members</u>:
1. Andrew Arnold
2. Darin Brock
3. Matt Funk
4. Josh Bruski-Hyland
5. Andrew Lux
6. Ryan Lynch

<u>Customer</u>:
NCAR High Altitude Observatory
1. Phil Oakley
2. Scott Sewell



Project Overview

Motivation & Project Statement

Motivation:

- ➢ Solar phenomena present catastrophic risks to ground and space based systems
- ➢ Measurements of UV spectra at varying polarization angles can be used to model solar magnetic field structure
- ➢ These models can be used to determine the preconditions to solar activity

Project Statement:

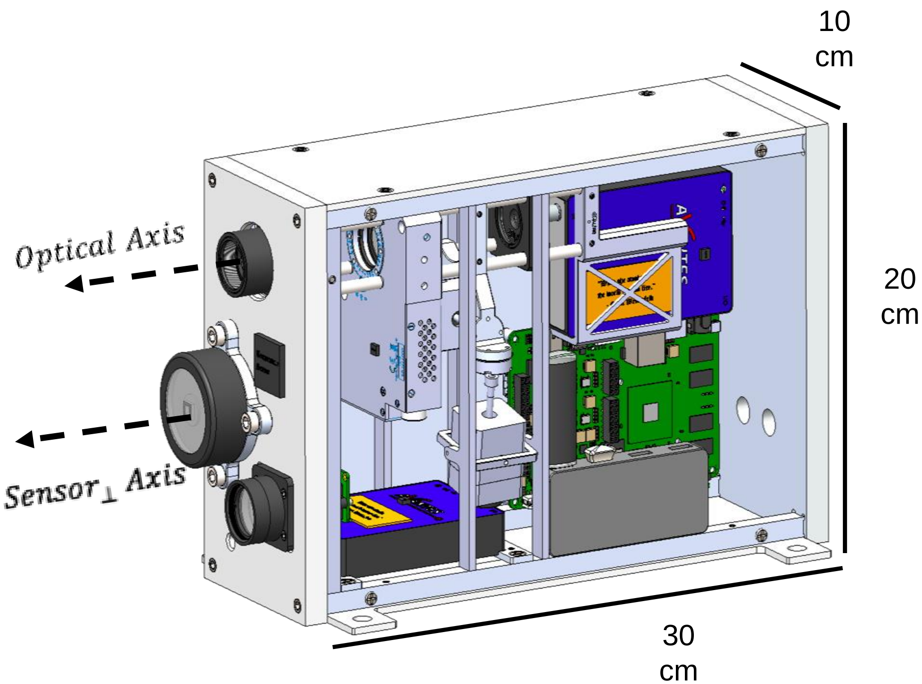
- ➢ STOUT will design and manufacture a 6U CubeSat payload capable of collecting UV spectra measurements and operating in high-altitude balloon flight.
- ➢ The team will utilize a variety of ground tests that simulate the expected high altitude environment in order to calibrate the module's data collection systems and verify the payload's flight readiness.

NASA Gondola

Mission – Summer 2018

- Ground: 8 Hours
  - Powered on and systems check
- Ascent: 2 hours
  - Launched from Fort Sumner, NM
- Flight: 2 weeks at ~40 km
  - Gondola platform puts the system FOV within +/- 5° of the Sun
  - Solar irradiance data collected
  - Polarized UV spectra collected
- Descent: 1 hr
  - Customer retrieves data

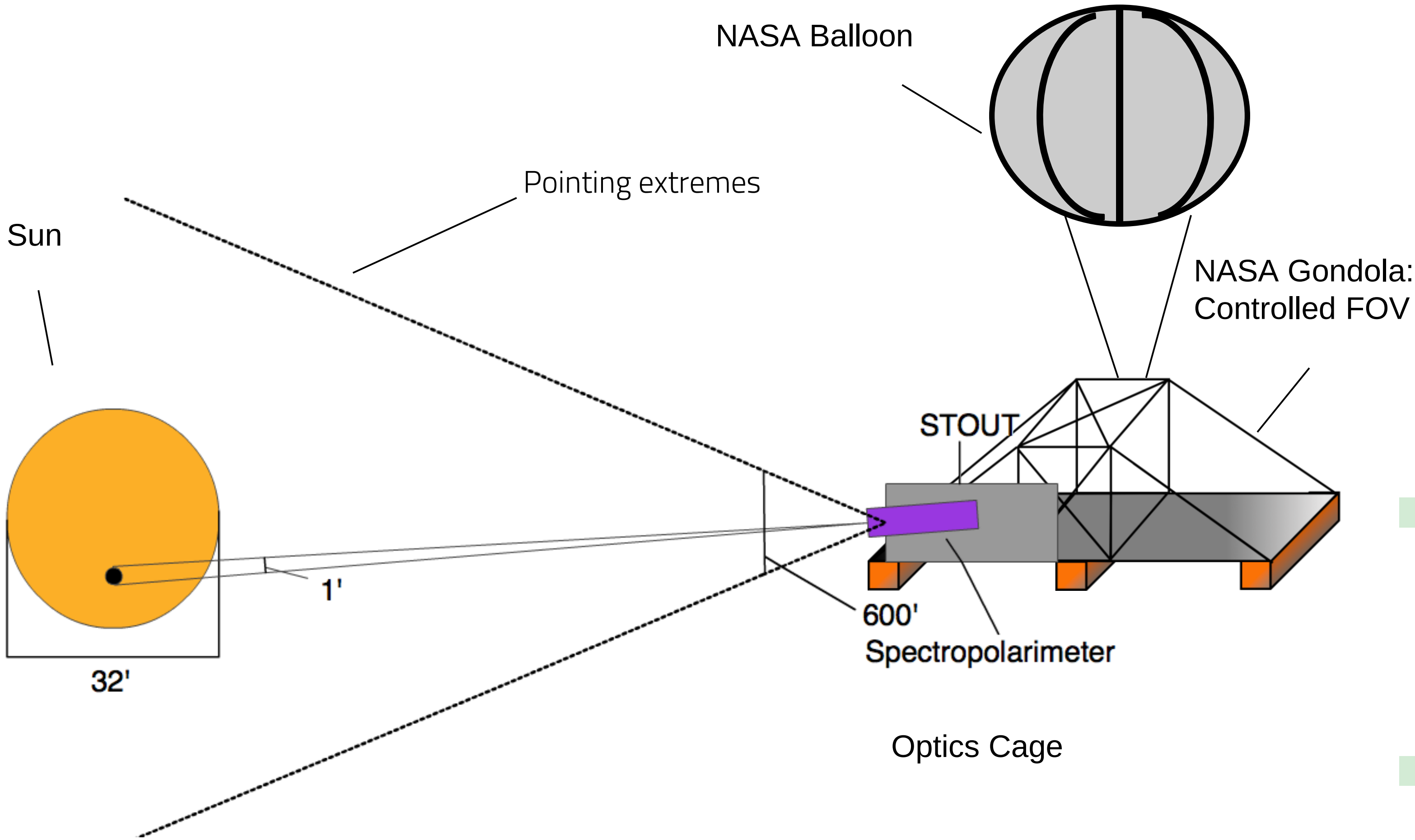
System Overview



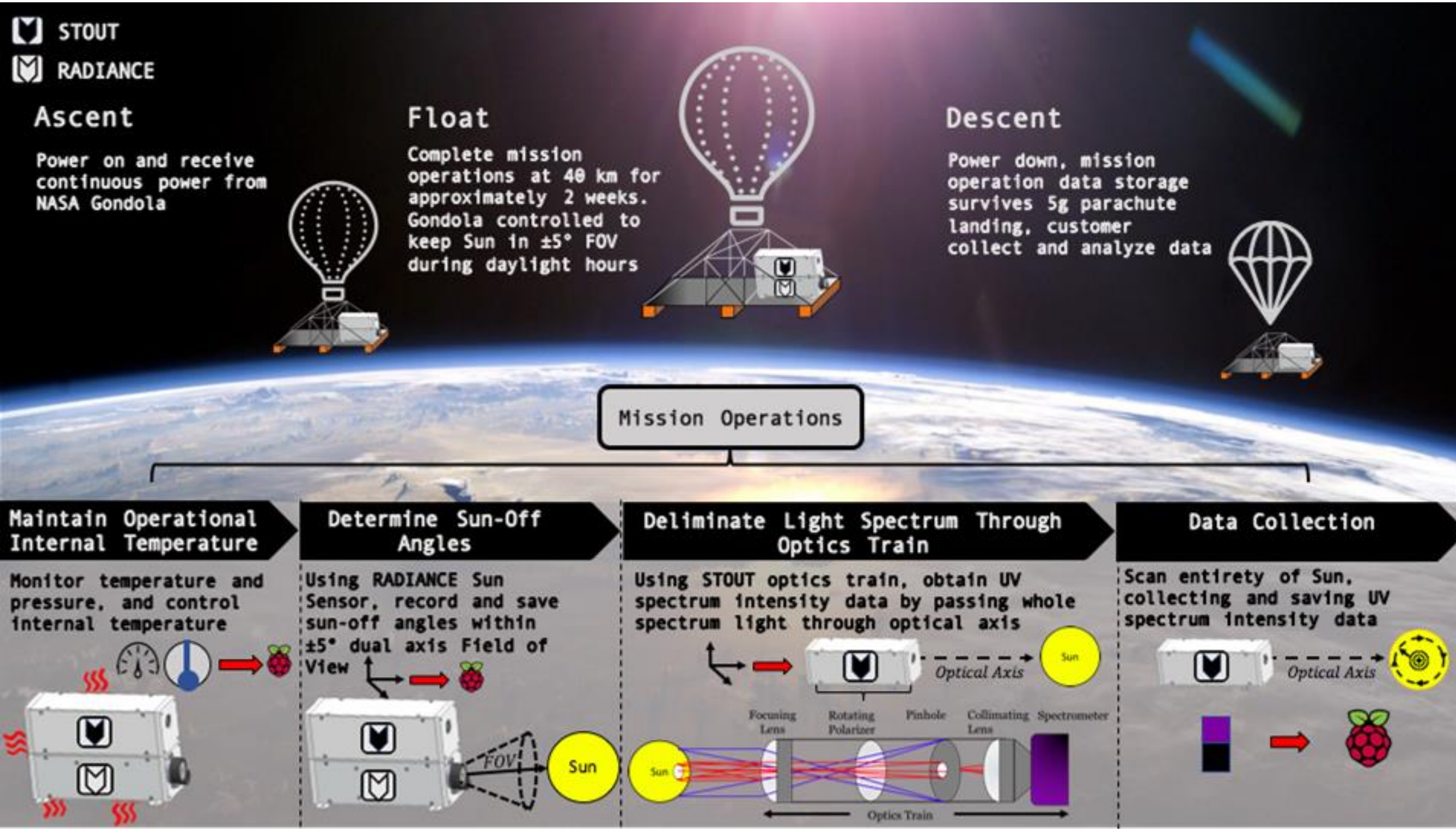
Summary

Parameter	Values
Dimensions	10x20x30 cm
Mass	4.4 kg
Power Consumption	74.5 W
Flight Environment	-70℃ - 20℃
Materials	Aluminum 6061 (Structure) Polyisocyanurate (Insulation)

Pointing Explanation

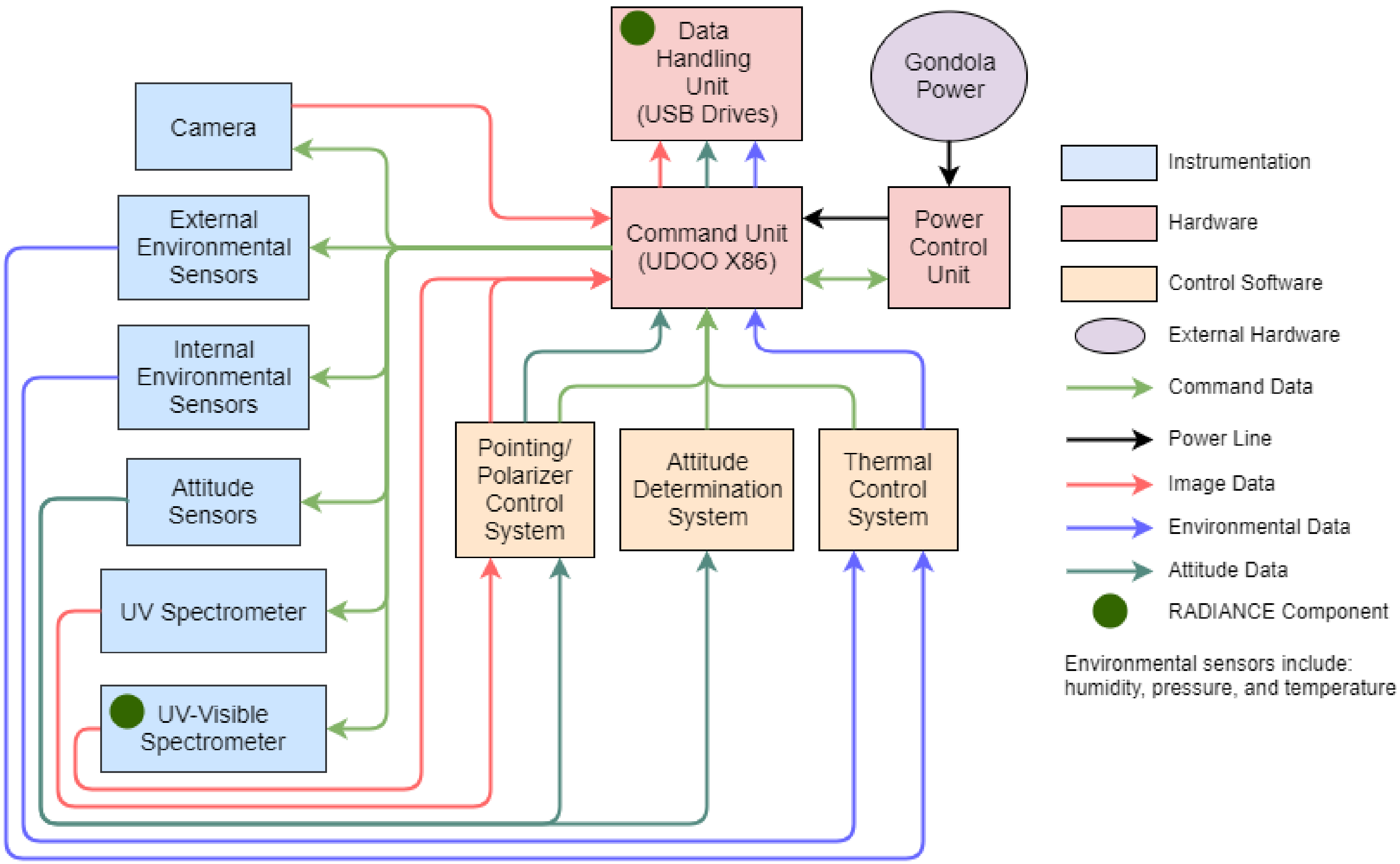


CONOPS



STOUT
RADIANCE
Ascent
Power on and receive continuous power from NASA Gondola
Float
Complete mission operations at 40 km for approximately 2 weeks. Gondola controlled to keep Sun in ±5° FOV during daylight hours
Descent
Power down, mission operation data storage survives 5g parachute landing, customer collect and analyze data
Mission Operations
Maintain Operational Internal Temperature
Monitor temperature and pressure, and control internal temperature
Determine Sun-Off Angles
Using RADIANCE Sun Sensor, record and save sun-off angles within ±5° dual axis Field of View
FOV
Sun
Deliminate Light Spectrum Through Optics Train
Using STOUT optics train, obtain UV spectrum intensity data by passing whole spectrum light through optical axis
Optical Axis
Sun
Focusing Lens
Rotating Polarizer
Pinhole
Collimating Lens
Spectrometer
Sun
Optics Train
Data Collection
Scan entirety of Sun, collecting and saving UV spectrum intensity data
Optical Axis

Functional Block Diagram



Critical Project Elements

Critical Project Element	Concern	Mitigation
Optical Calibration	Allocated time for calibration, complexity of calibration techniques	SBO testing, precision leveling for ADS sensor and optical axis mounting
Software	Developing interrupts, final integration	Validated subsystem sensor software and sub system functionality
Flight Environment	Overheating of UDOO and stepper motors	Peltier devices if EMCS tests show issues

Executive Summary

Changes from MSR

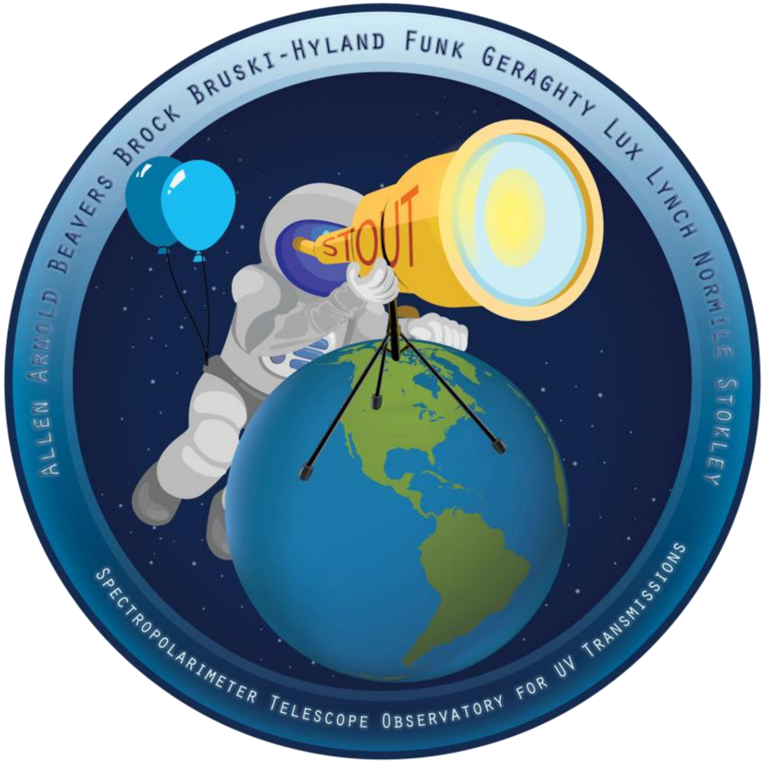
- ➢ No longer 3D printing front gimbal, motor gimble, or motor arm
- ➢ Swapped location of ADS and Camera

Schedule

- ➢ On Schedule:
  - ○ Mechanical Manufacturing
  - ○ Sensor Electronics
- ➢ Behind Schedule:
  - ○ Software (ADS interface, Interrupts)
  - ○ Electrical Power System

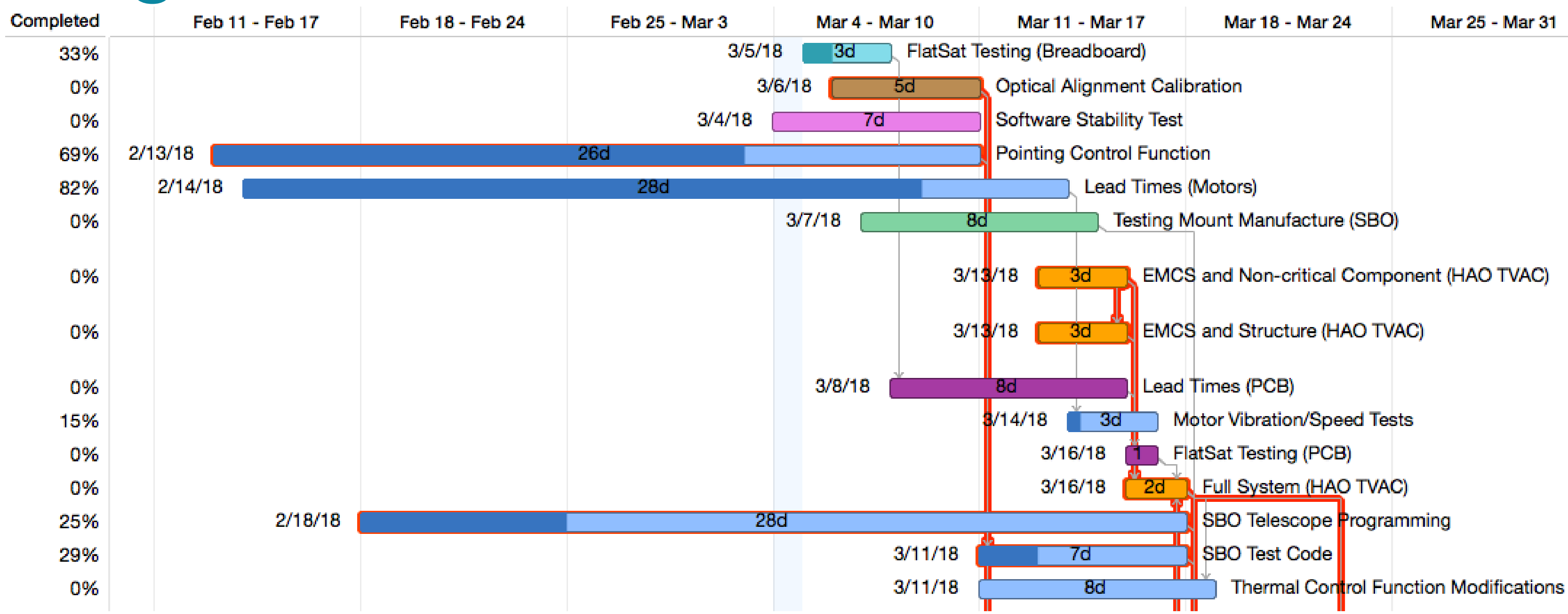
Budget

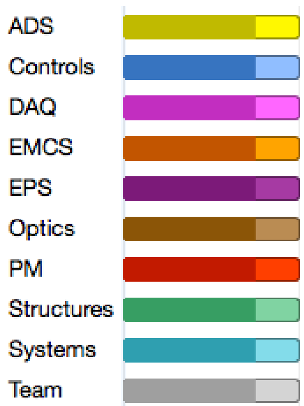
- ➢ Total Budget: $7377.00
- ➢ Expected Costs: $6680.94
- ➢ Remaining Funding: $696.06 - 10% margin in budget for remaining unexpected expenses


Allen Arnold Beavers Brock Bruski-Hyland Funk Geraghty Lux Lynch Normile Stokley
STOUT
Spectropolarimeter Telescope Observatory for UV Transmissions

Schedule

Testing Schedule

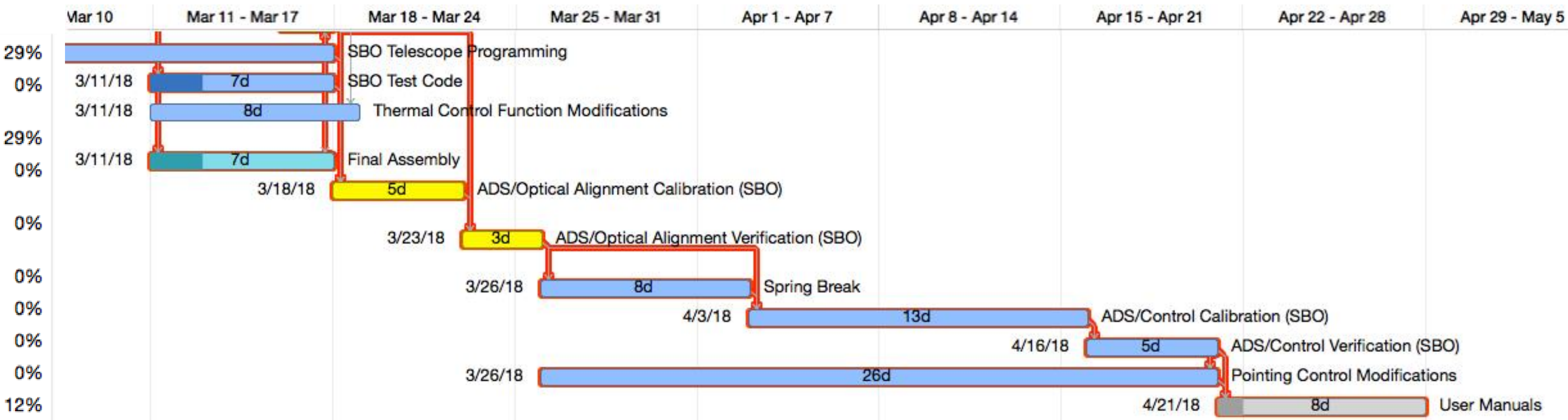


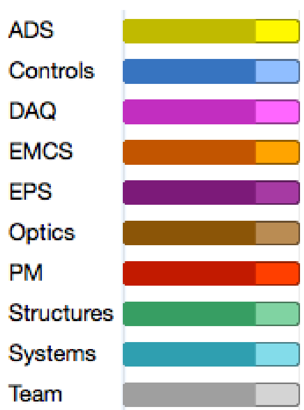


Changes from MSR:

- Pushed back stepper motor tests due to acquisition delay
- Pushed back PCB ordering due to performance issues found during FlatSat
    - Will not affect schedule due to margin built into end of schedule
    - Also pushes back PCB FlatSat
    - May require SBO tests are completed without PCB using power supplies

Testing Schedule





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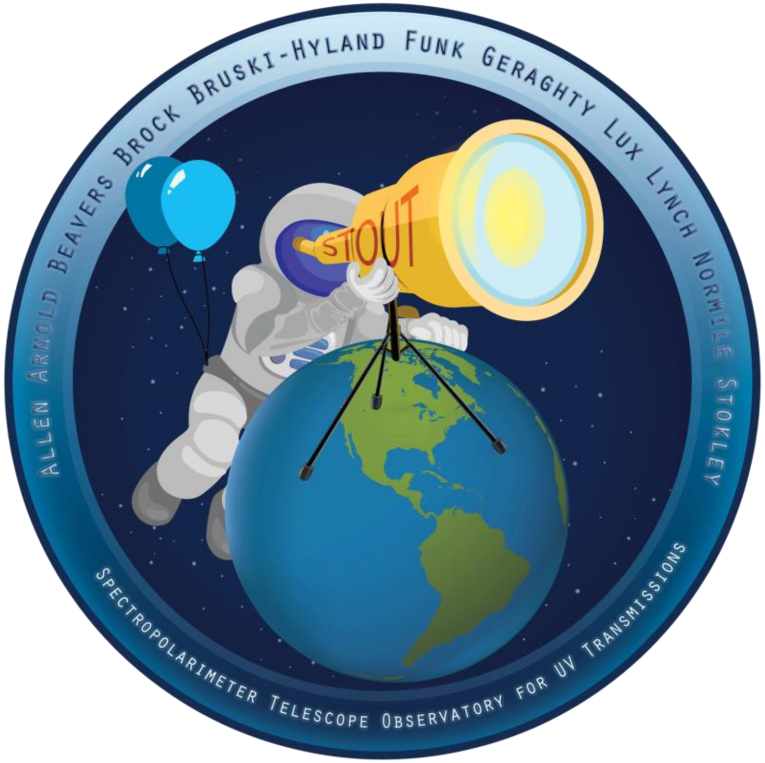


Test Readiness

Component Overview

FR6: The system shall record data

Purpose

- ➢ Verify sensor functionality
- ➢ Verify sensor software functionality

Equipment and Facilities

- ➢ UDOO x86, temperature sensors, humidity sensor, GPS, sun sensor, rotating polarizer, camera, stepper motors
- ➢ Power Supplies
- ➢ Trudy's Lab

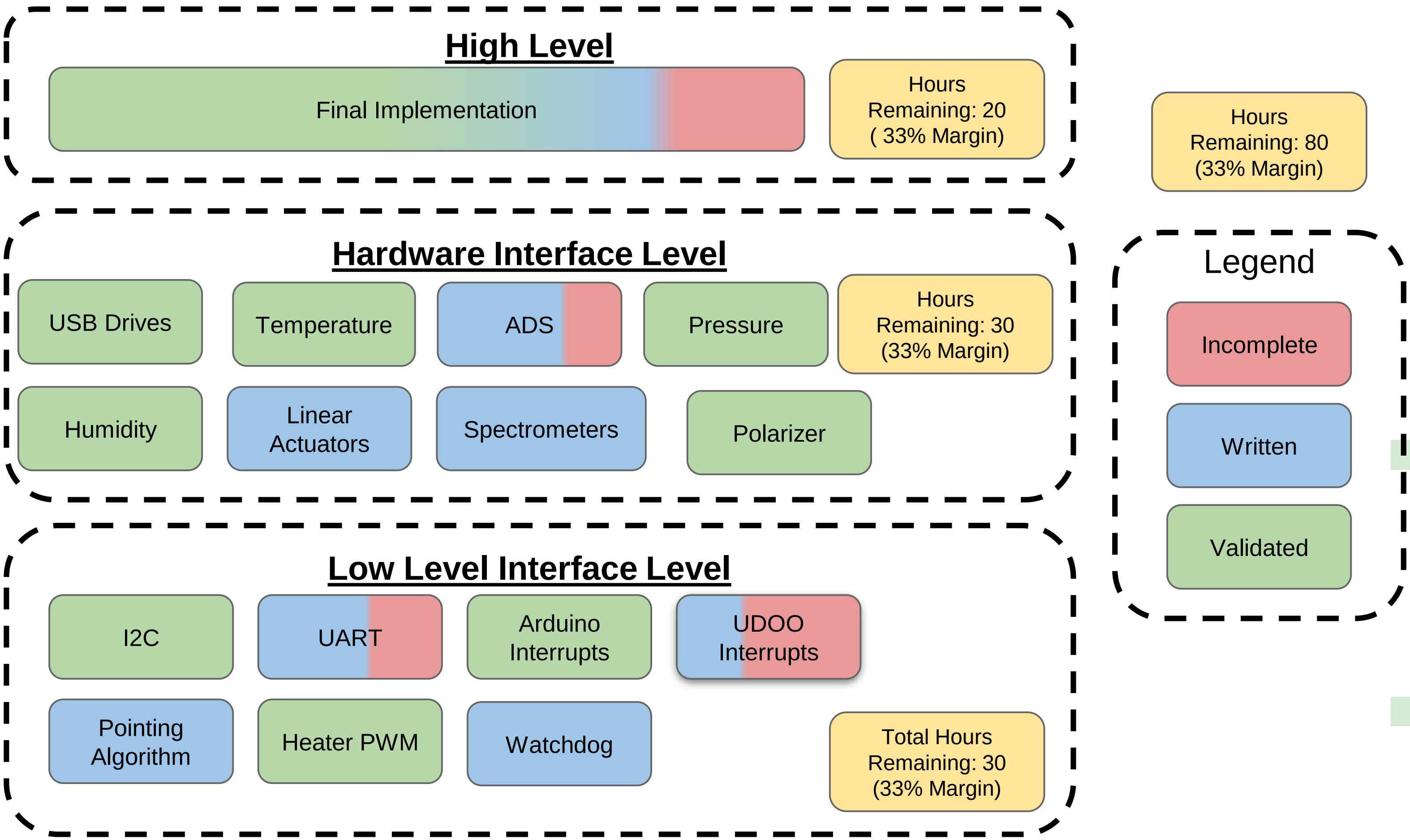
Process

- ➢ Plug sensors into microcomputer
- ➢ Environmental: Test sensors in room temperature environment
- ➢ Sun Sensor: Point sensor at Sun for data read
- ➢ Stepper Motors: Vibration, actuation speed, and fit tests
- ➢ Camera: Take picture
- ➢ GPS: Time stamp check

Risks Reduced

- ➢ Shows the STOUT module components are fully functional with written software

Component Software Status



Sommers-Bausch Test Campaign Overview

Purpose

- Verify ADS sensor accuracy
- Determine pointing angle calibration factors for optical axis and ADS sensor misalignment and offset
- Verify pointing system functionality
- Verify data collection & storage

Equipment and Facilities

- Sommers-Bausch Telescope with SkyX Pro control software
- SBO Mount
- UV photodiode with linearizing circuit
- Fully assembled STOUT module

Risks Reduced

- Shows the STOUT module can accurately locate the position of the Sun center, actuate the optical axis to the Sun center, begin a scan algorithm, and collect solar intensity data

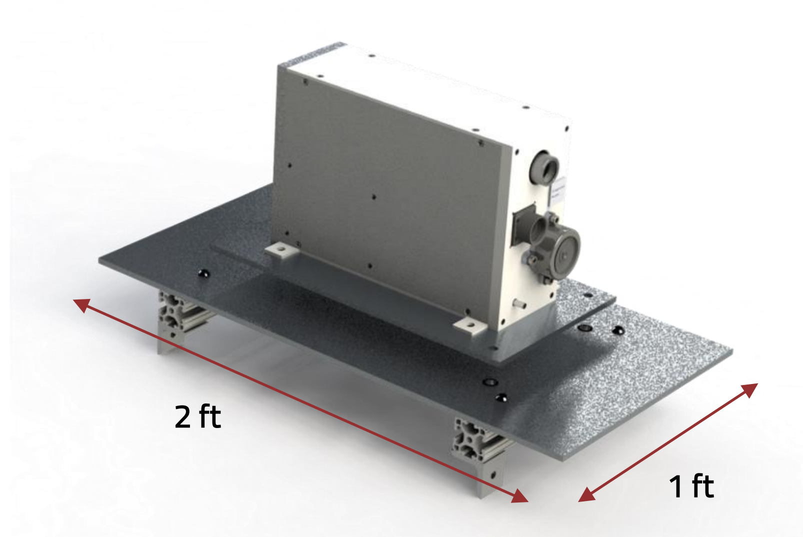
External Factors

- Sun will follow slightly different path in sky each day
- Clear skies with high UV index required
- Testing will need to be conducted at high noon with small window (~ 2 hours)

Attitude Determination System Test Set Up

Sommers-Bausch Telescope

STOUT Telescope Mount



Attitude Determination System Test

FR3: The system shall determine its attitude relative to the Sun center

Objectives

- ➢ Verify Sun sensor functionality
- ➢ Calibrate ADS Sun sensor relative to telescopic mounting
- ➢ Calibrate out sensor errors and bias

Key Requirements

- ➢ 3.1 The off-sun angle attitude shall be determined to within 0.05 degree of Sun center (3 arcminutes)
- ➢ 3.2 Attitude data shall be recorded synchronously with instrument data
- ➢ 3.3 Attitude data shall be interfaced with instrumentation pointing control

How it Reduces Risk

- ➢ Shows the system can accurately locate the position of the Sun center to be used in optical axis actuation control

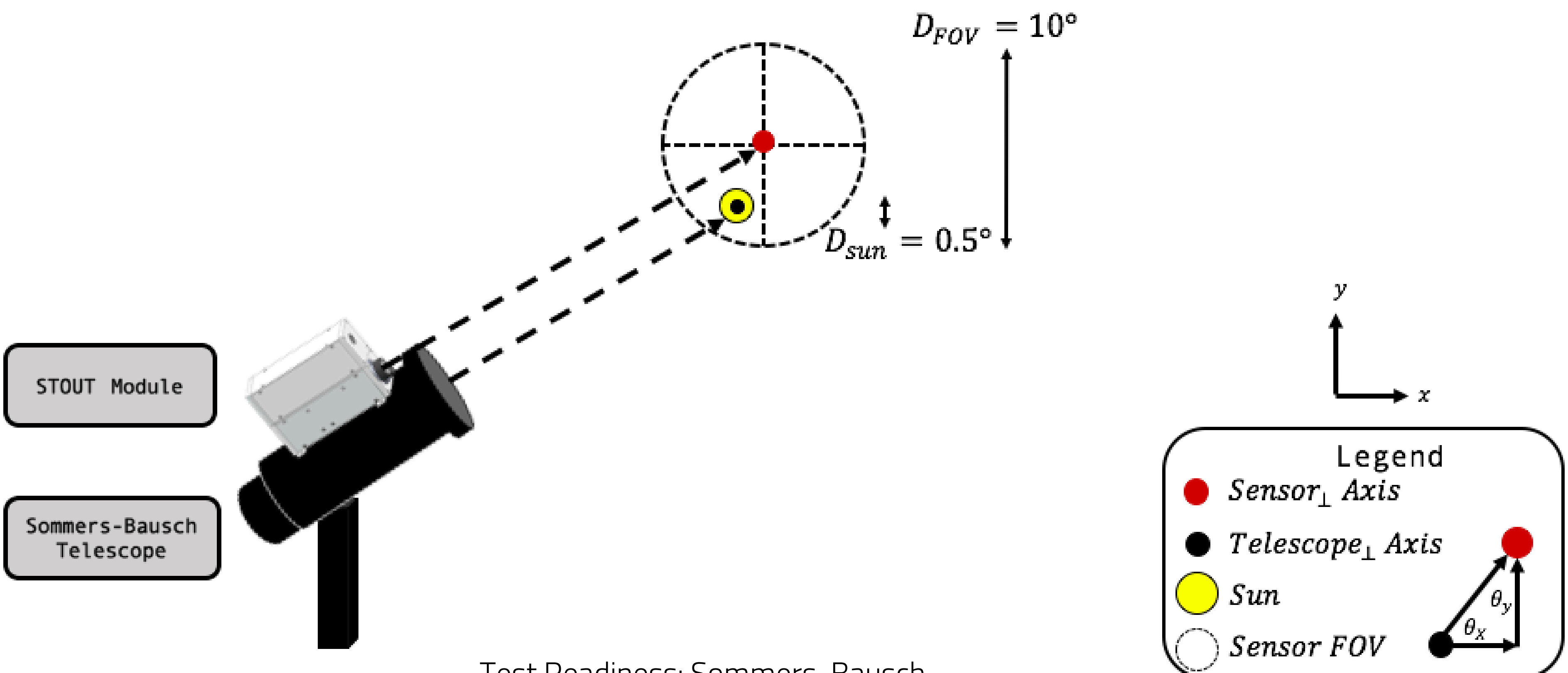
Associated Model: Sun Scanning Model

Attitude Determination System Test Set Up

Specifications

- ➢ Sommers-Bausch telescope has accuracy > 20 ″ ~ 0.0055°
- ➢ Accuracy of Sun sensor:
- ➢ 18″ ~ 0.005°
- ➢ Total accuracy: 38″ ~ 0.0105°

Data Source	Sampling Rate	Data Collected
Sun Sensor	10 Hz	Off Sun Angles α & β (deg)
Telescope Control Software	Unknown	Pointing position relative to Sun center



Test Readiness: Sommers-Bausch

Attitude Determination System Test Set Up

Specifications

- Sommers-Bausch telescope has accuracy > 20 ″ ~ 0.0055°
- Accuracy of Sun sensor:
- 18″ ~ 0.005°
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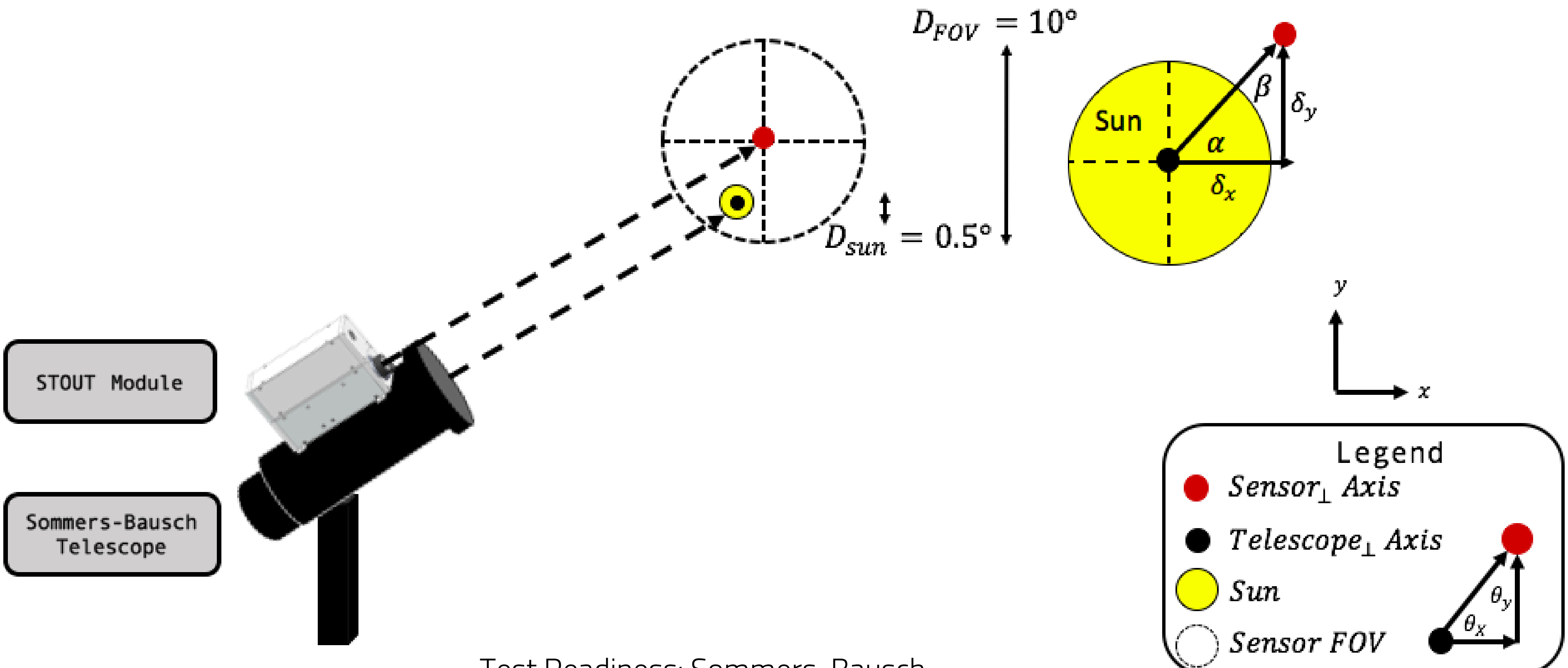
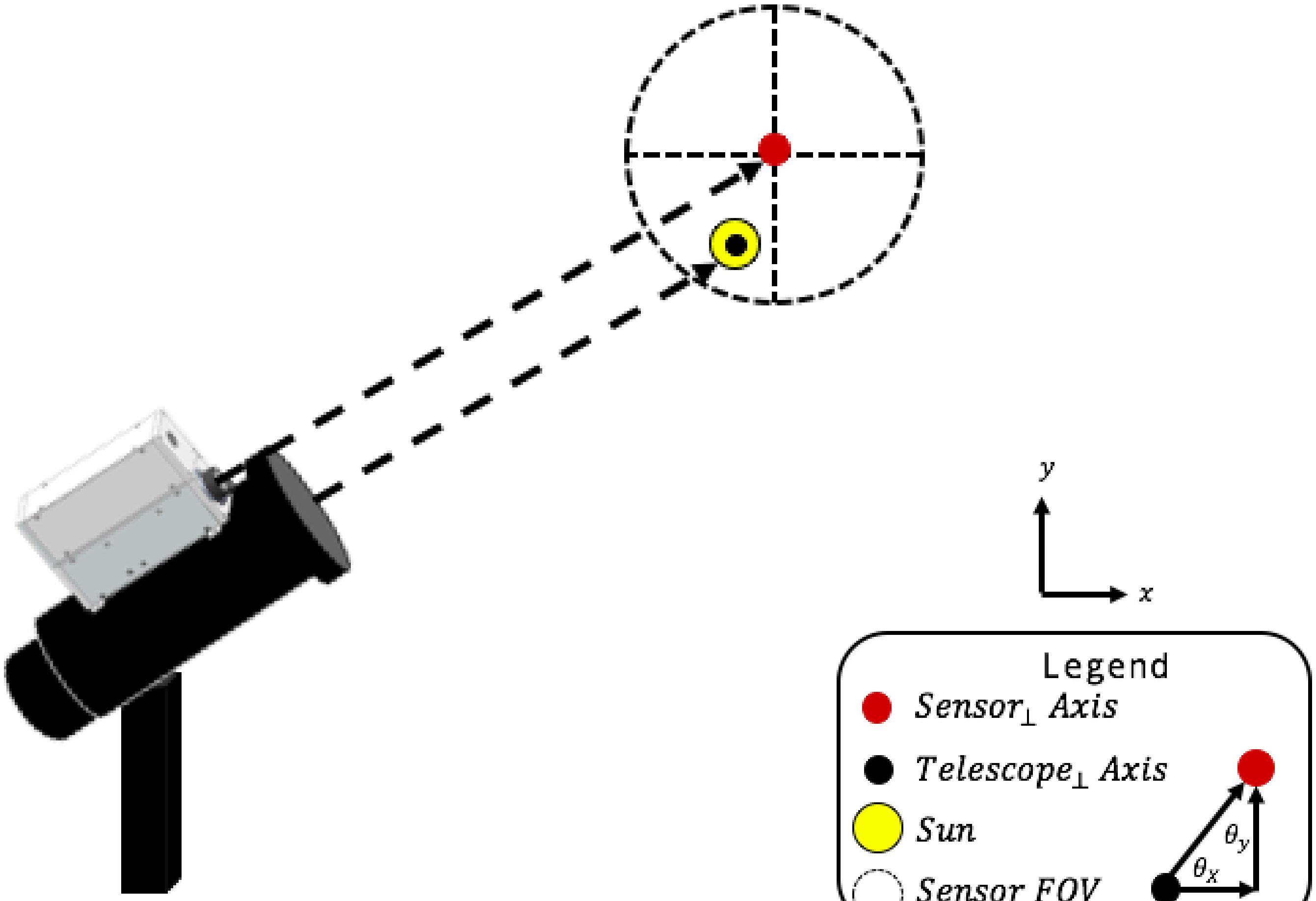
Data Source	Sampling Rate	Data Collected
Sun Sensor	10 Hz	Off Sun Angles α & β (deg)
Telescope Control Software	Unknown	Pointing position relative to Sun center



Attitude Determination System Calibration

Procedure

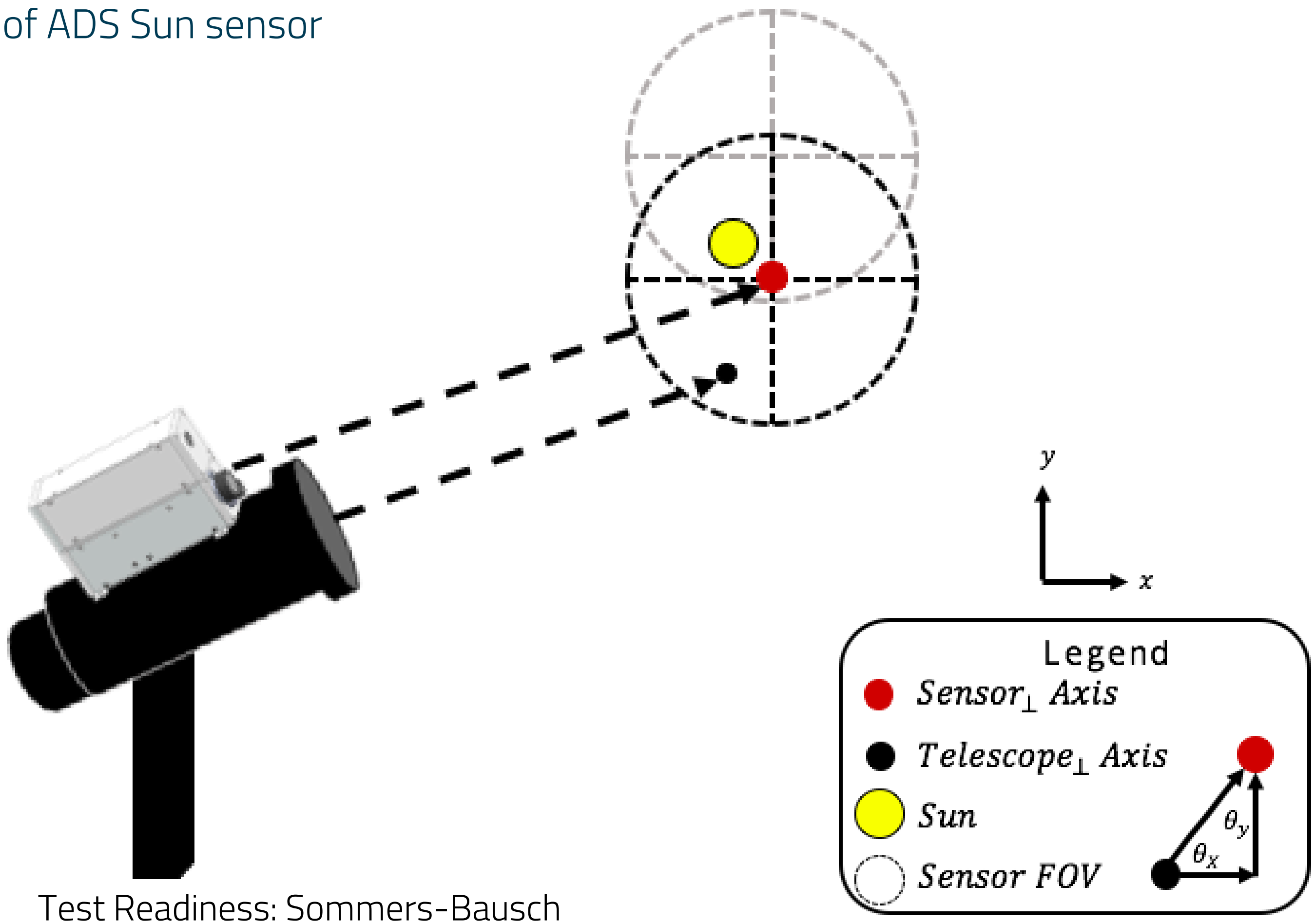
1. Point telescope at Sun center
   - Save sensor off-Sun angles



Attitude Determination System Calibration

Procedure

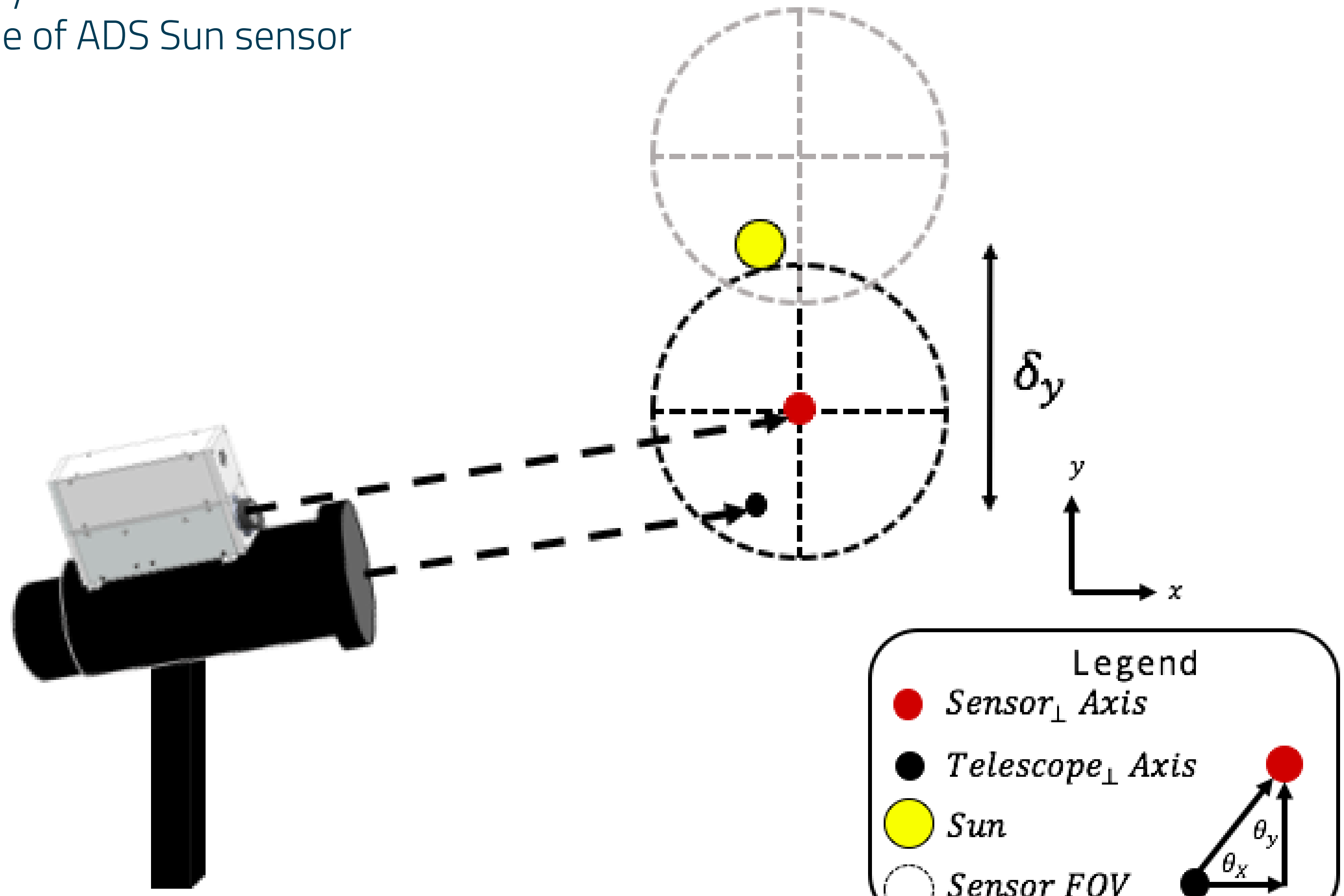
1. Point telescope at Sun center
   - Save sensor off-Sun angles
2. Slew telescope vertically until Sun circumference is outside of ADS Sun sensor FOV



Attitude Determination System Calibration

Procedure

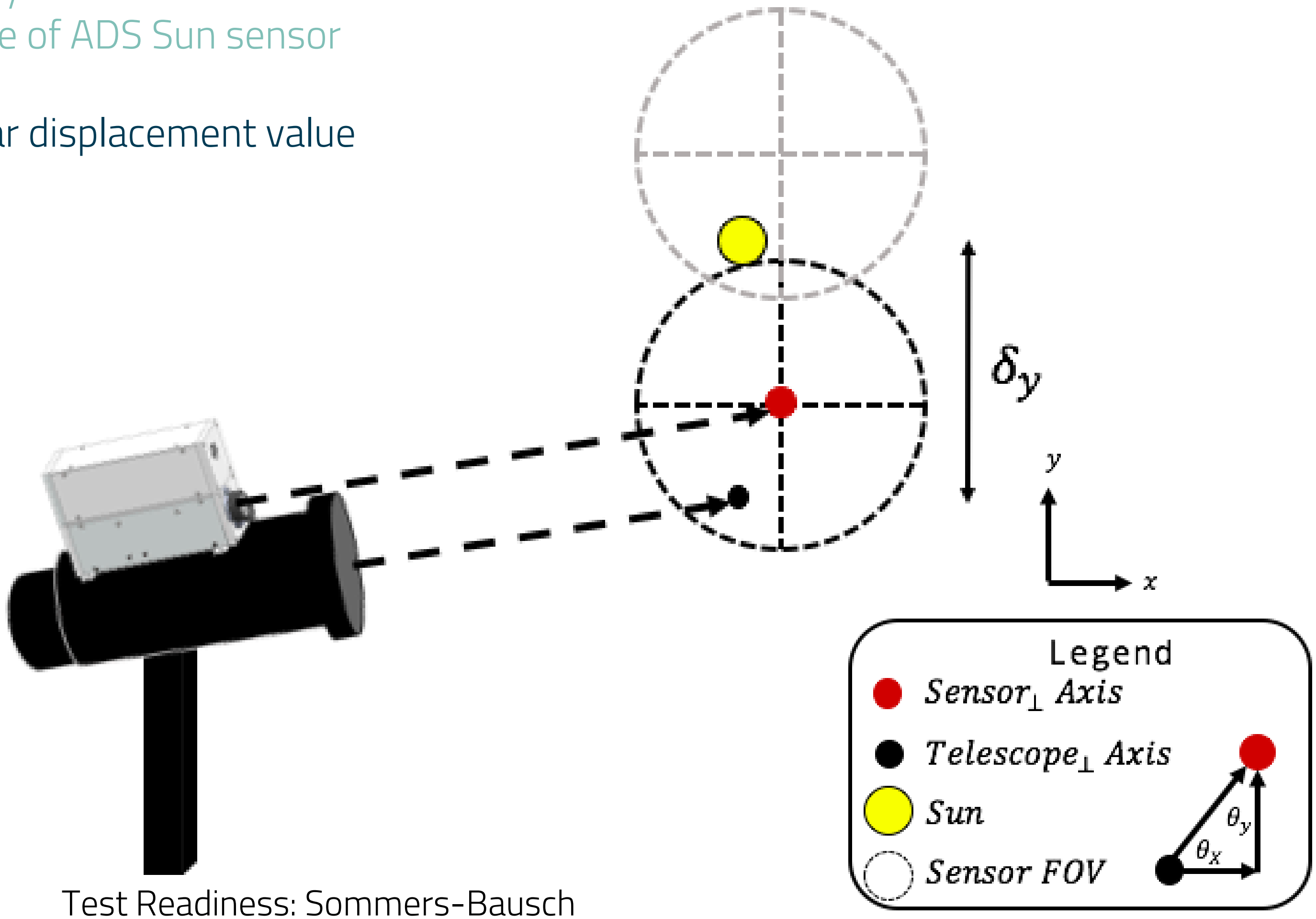
1. Point telescope at Sun center
   - Save sensor off-Sun angles
2. Slew telescope vertically until Sun circumference is outside of ADS Sun sensor FOV



Attitude Determination System Calibration

Procedure

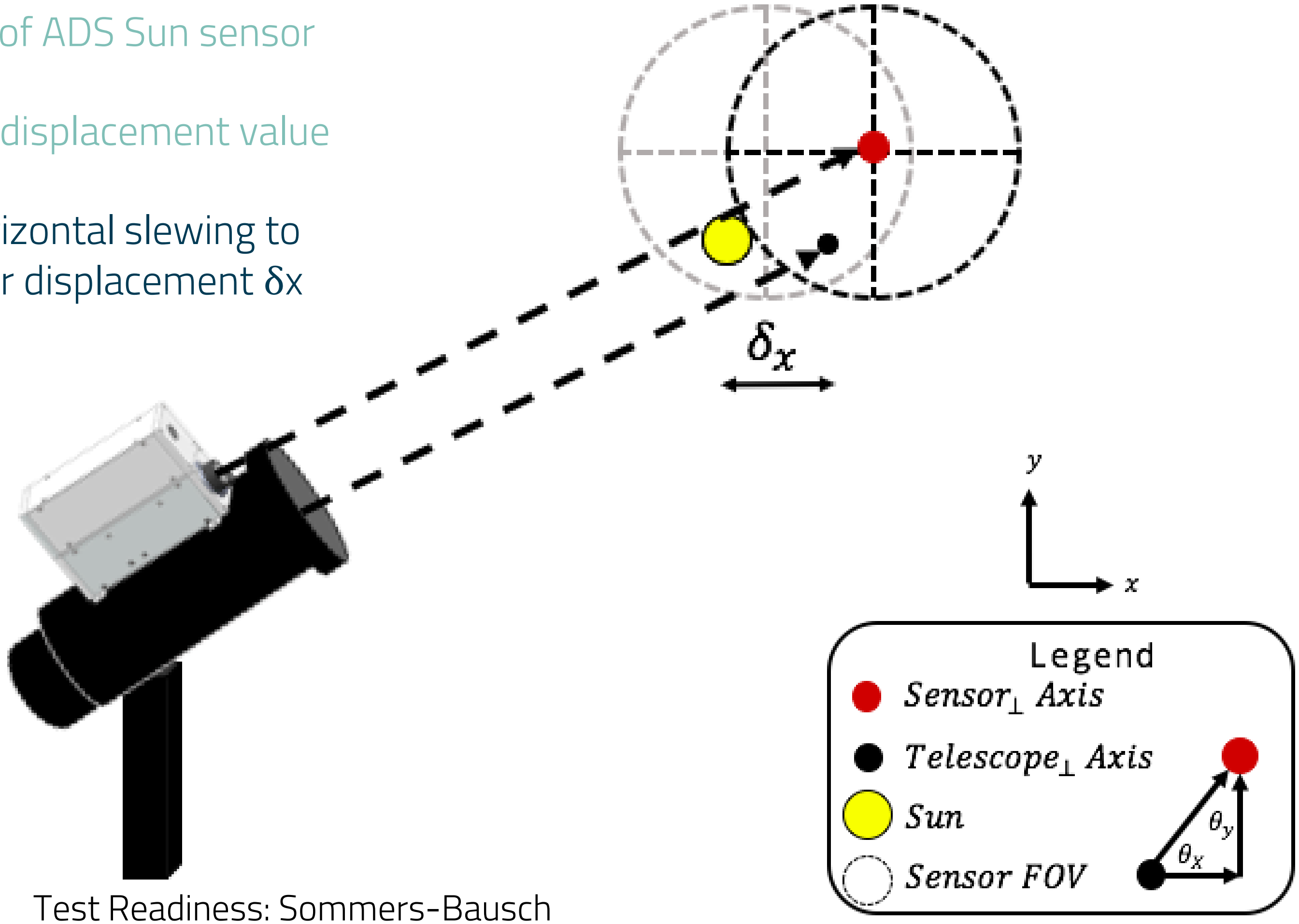
1. Point telescope at Sun center
   - Save sensor off-sun angles
2. Slew telescope vertically until Sun circumference is outside of ADS Sun sensor FOV
3. Record & program linear displacement value δy into ADS software



Attitude Determination System Calibration

Procedure

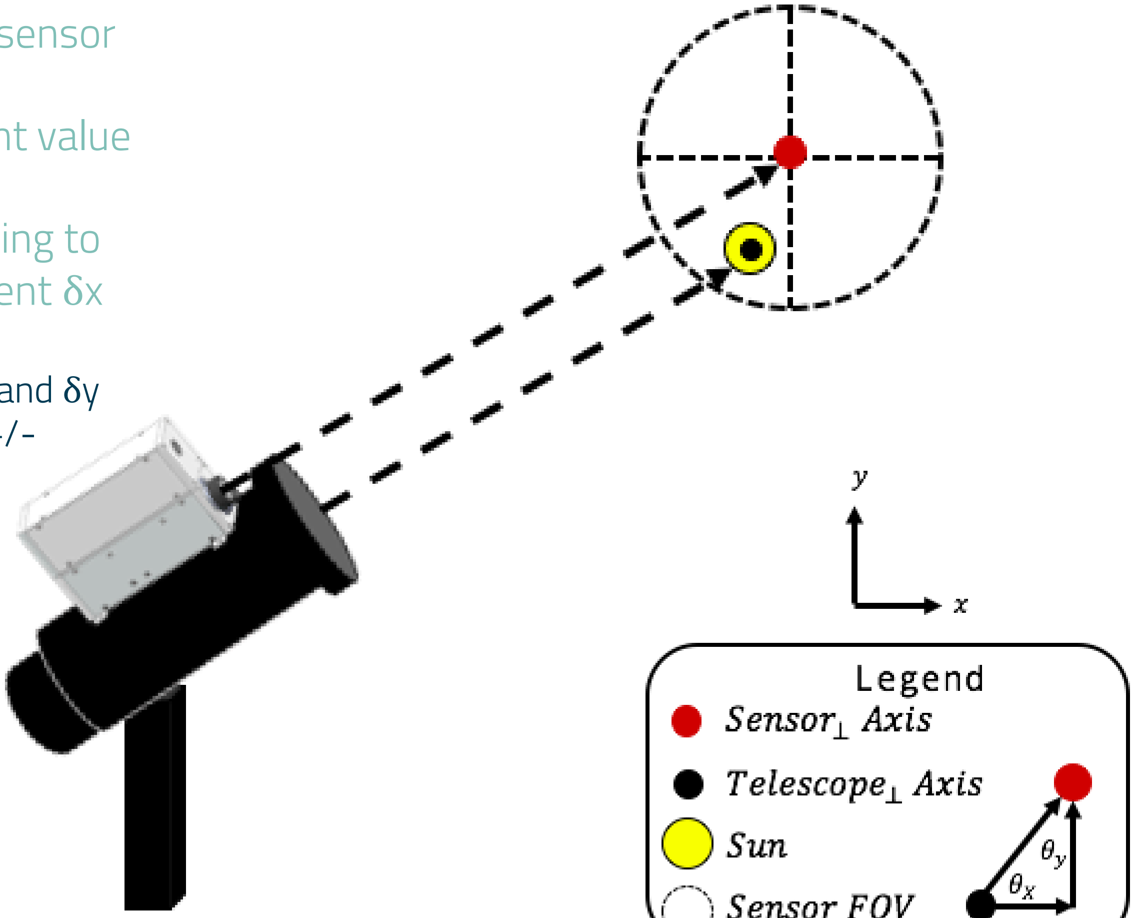
1. Point telescope at Sun center
   - Save sensor off-Sun angles
2. Slew telescope vertically until Sun circumference is outside of ADS Sun sensor FOV
3. Record & program linear displacement value δy into ADS software
4. Repeat Steps 1-3 for horizontal slewing to record and program linear displacement δx into ADS software



Attitude Determination System Calibration

Procedure

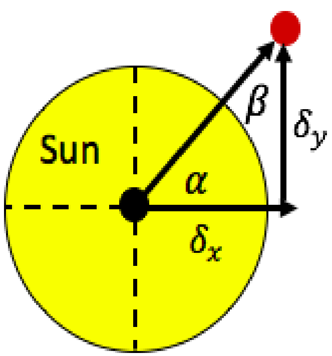
1. Point telescope at Sun center
   - Save sensor off-Sun angles
2. Slew telescope vertically until Sun circumference is outside of ADS Sun sensor FOV
3. Record & program linear displacement value δy into ADS software
4. Repeat Steps 1-3 for horizontal slewing to record and program linear displacement δx into ADS software
5. Repeat Steps 1- 4 until displacements δx and δy converge to within total ADS accuracy of +/- 0.0105°



Attitude Determination System Verification

Verification and Validation

- ➢ If sensor measured off-Sun angles are within +/-0.0105° of the experimentally determined off-sun angles the system is verified
- ➢ If measured off-sun angles are not within the error range of experimental results, explore non-linearity cases
    - ○ Redo test until verified then continue with optical calibration



$$\underbrace{\alpha}_{\text{Sensor measured off-sun angles}} \approx \underbrace{\theta_{x-Offset} = \tan^{-1}\frac{\delta_y - 5^\circ}{\delta_x - 5^\circ}}_{\text{Experimentally determined off-sun angles}}$$

$$\beta \approx \theta_{y-Offset} = \tan^{-1}\frac{\delta_x - 5^\circ}{\delta_y - 5^\circ}$$

Optics System Test

FR2: The system shall take polarized UV spectrum measurements at multiple points on the Sun

Note that the ADS sensor is assumed to be calibrated relative to SBO Telescope at this point in the testing procedure

Objectives

- ➢ Calibrate optical system pointing relative to ADS Sun sensor
- ➢ Validate pointing control response to an external pointing deviation

Key Requirements

- ➢ 2.4 Pointing capabilities of +/- 1° in azimuth and +/- 5° in elevation

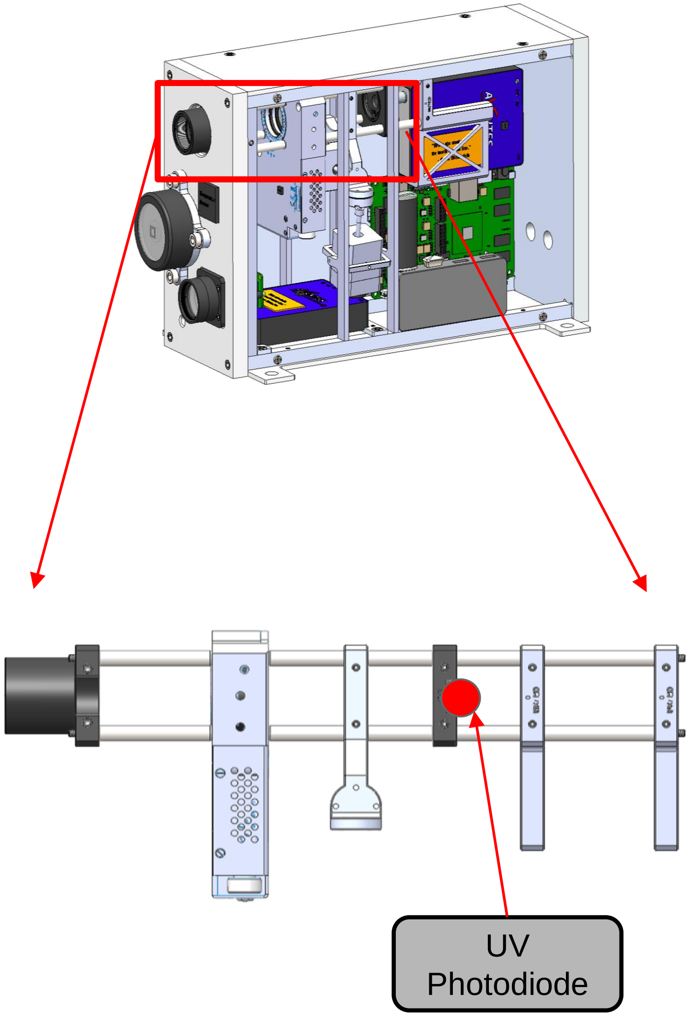
How it Reduces Risk

- ➢ Ensures that the optical system will point at the desired locations relative to ADS measurements

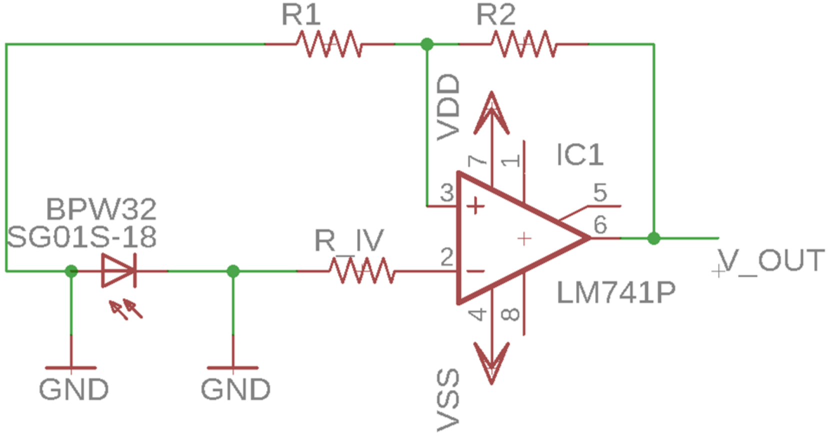
Optics System Test Set Up

Background

- Cannot use spectrometer for optics system calibration
- Replace spectrometer with UV photodiode in optics train
- Sensor outputs voltage with corresponding photocurrent generation
- Will indicate when optical axis is pointing at a location on the Sun



Linearizing Photodiode Circuit



Optics System Test Set Up

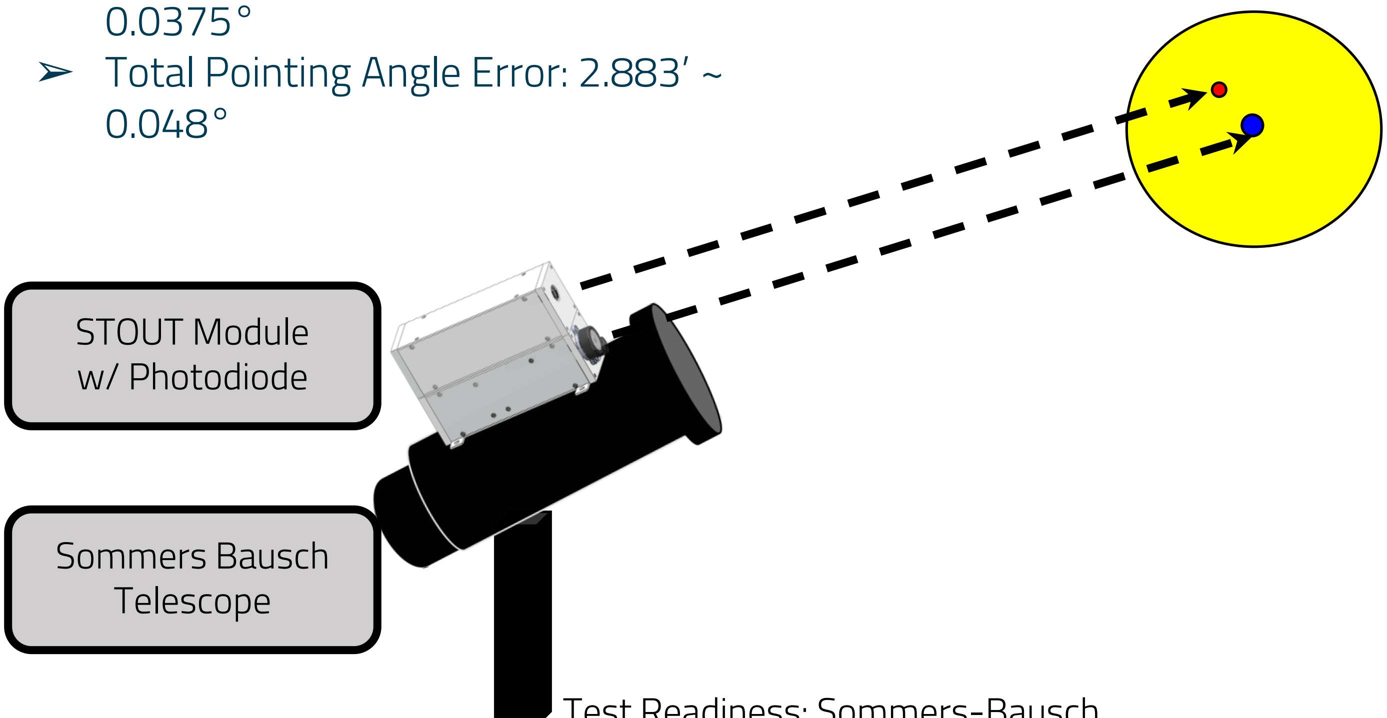
Assumptions

- Sun sensor and optical axis can be level mounted to ±0.25° so that optical axis will be on the Sun when ADS axis at the Sun center

Specifications

- Total ADS accuracy: 38″ ~ 0.0105°
- Optics Pointing Accuracy: 2.25′ ~ 0.0375°
- Total Pointing Angle Error: 2.883′ ~ 0.048°

Data Source	Sampling Rate	Data Collected
Sun Sensor	10 Hz	Off Sun Angles α & β (deg)
Telescope Control Software	Unknown	Pointing position relative to Sun center
UV Photodiode	10 Hz	Light intensity dependent voltage

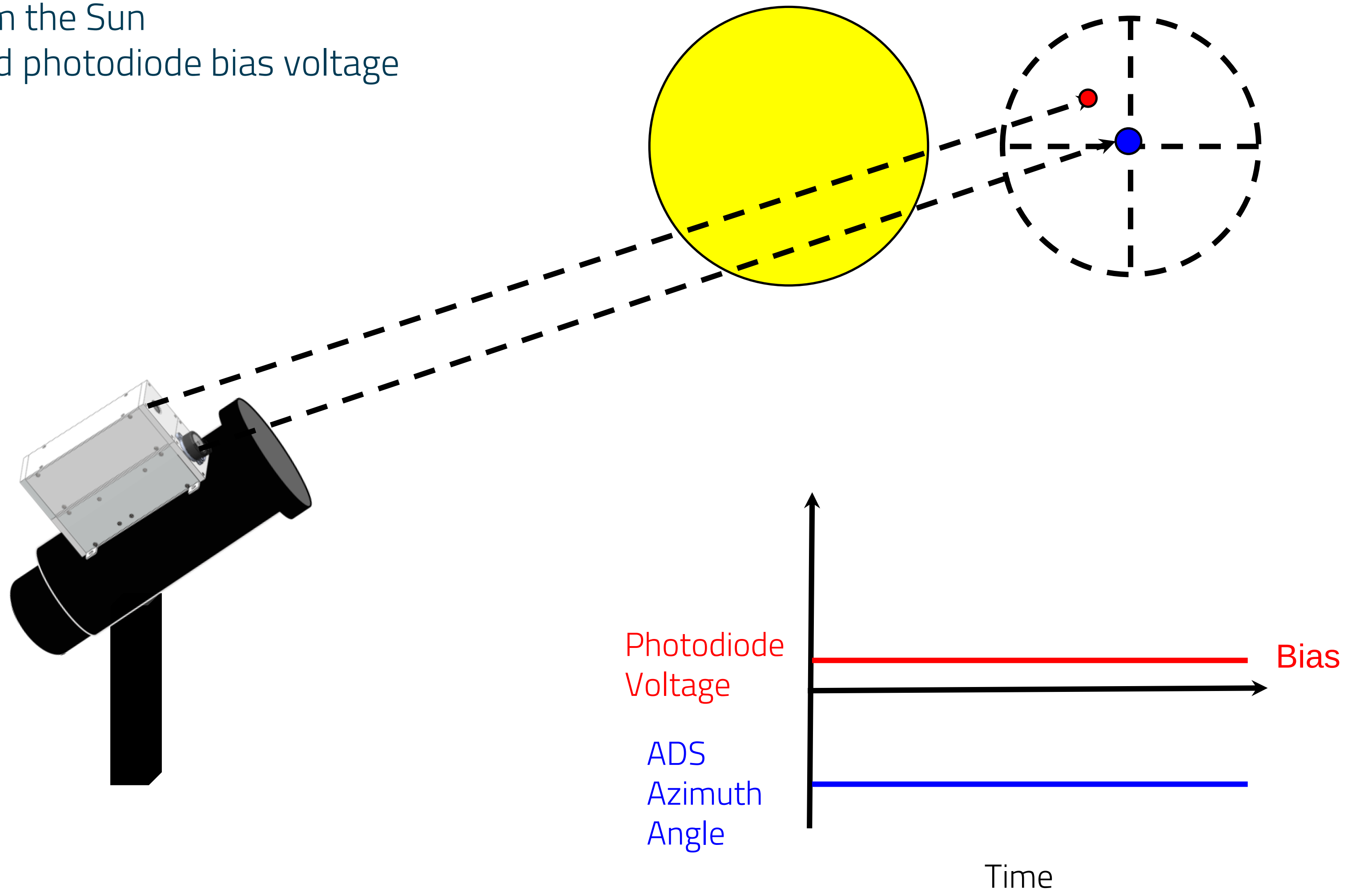


Test Readiness: Sommers-Bausch

Optics System Alignment Calibration

Procedure

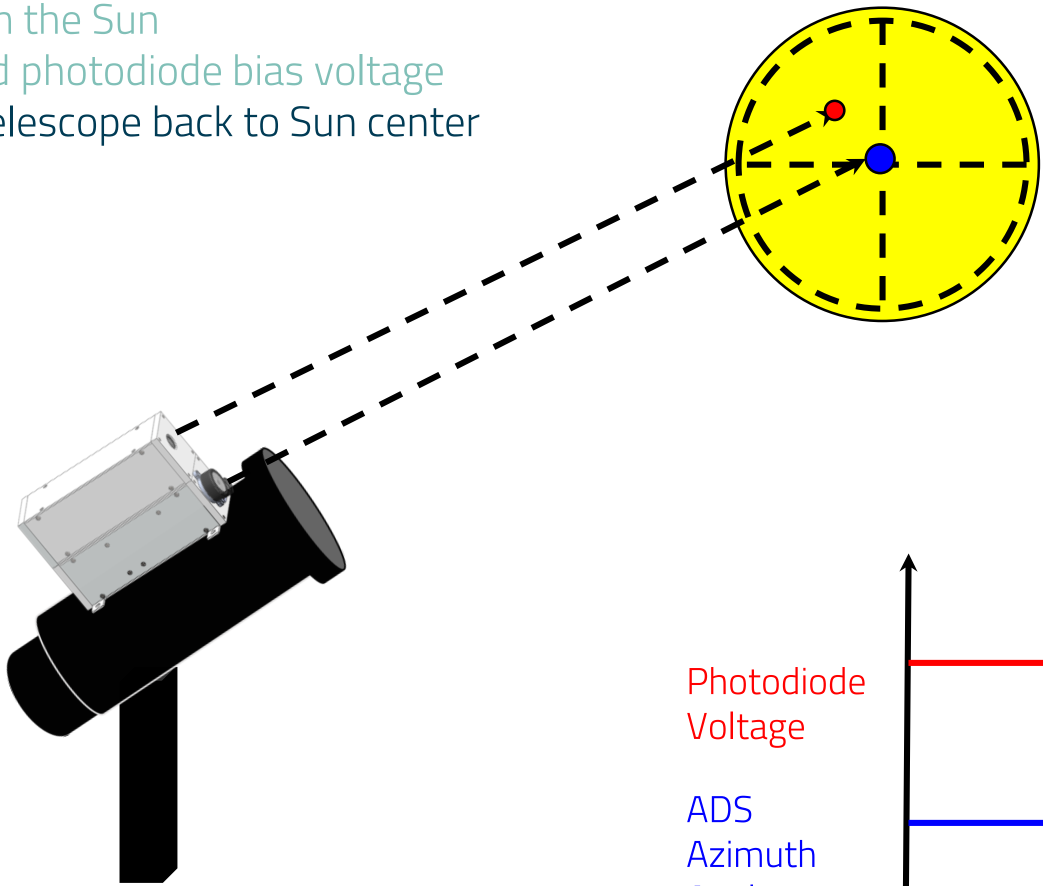
1. Point STOUT at an arbitrary point in the sky away from the Sun
   - Read photodiode bias voltage

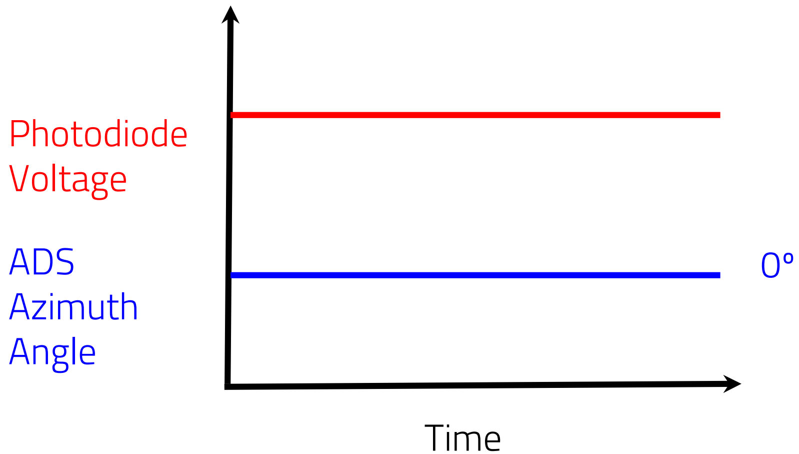


Optics System Alignment Calibration

Procedure

1. Point STOUT at an arbitrary point in the sky away from the Sun
    - Read photodiode bias voltage
2. Actuate telescope back to Sun center

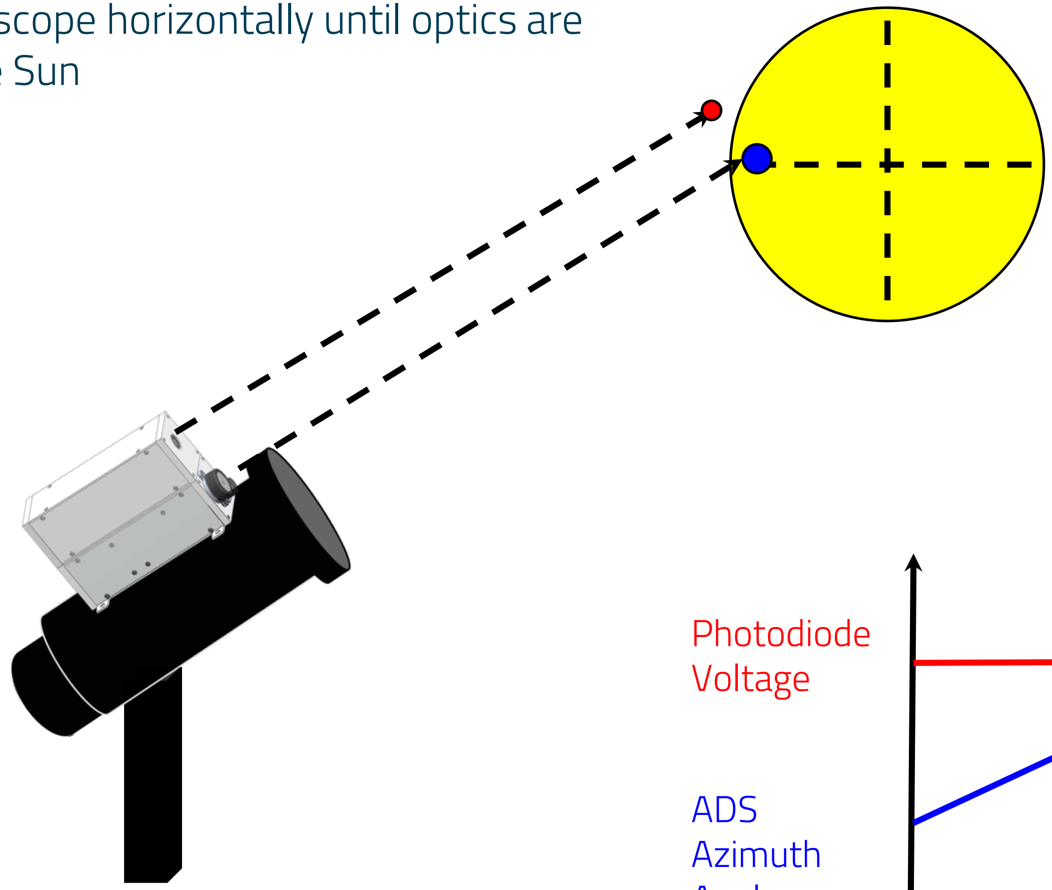


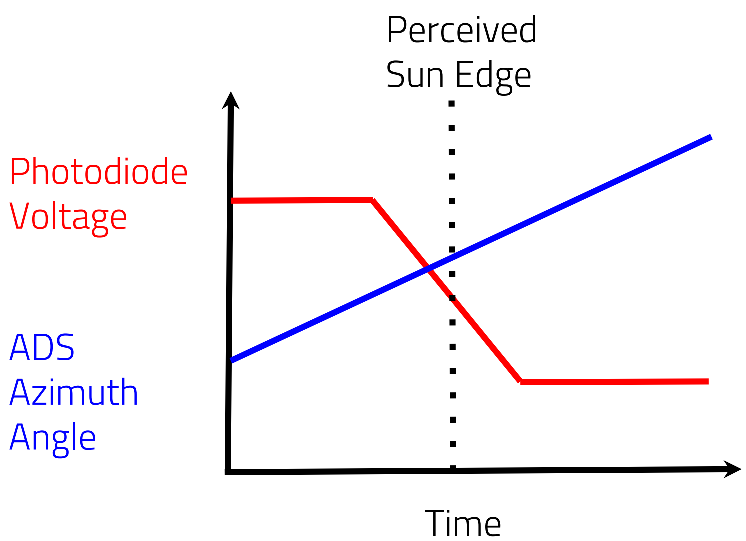


Optics System Alignment Calibration

Procedure

2. Actuate telescope back to Sun center
3. Slew telescope horizontally until optics are pointing off the Sun



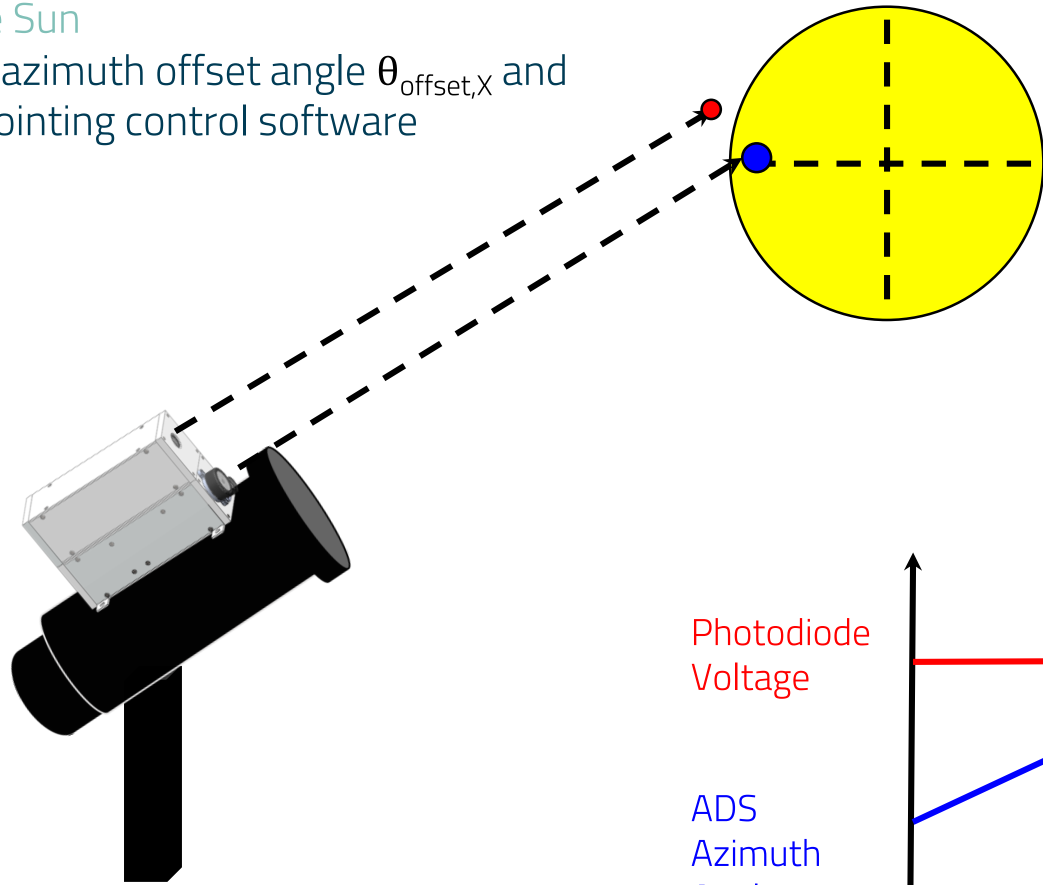


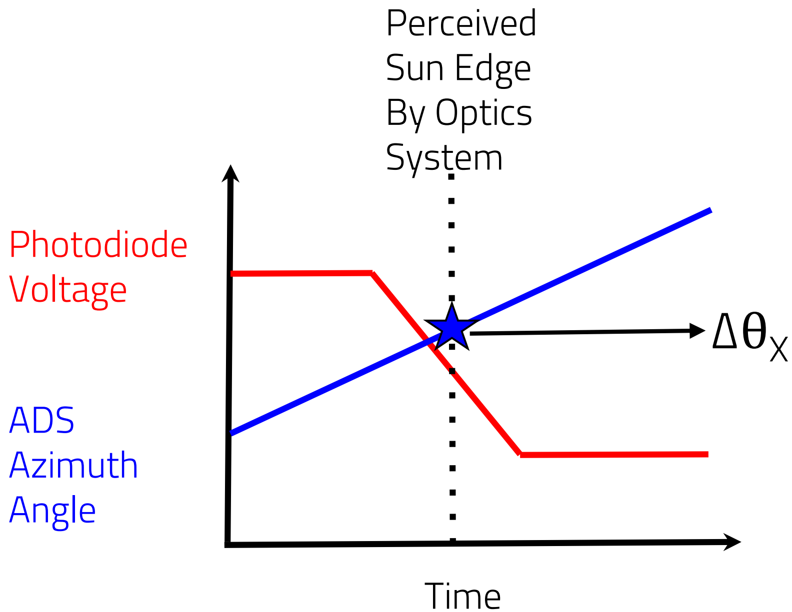
Optics System Alignment Calibration

$$\theta_{offset,X} = (\theta_{Sun}/2) - \Delta\theta_X$$

Procedure

3. Slew telescope horizontally until optics are pointing off the Sun
4. Calculate azimuth offset angle $\theta_{offset,X}$ and program into pointing control software

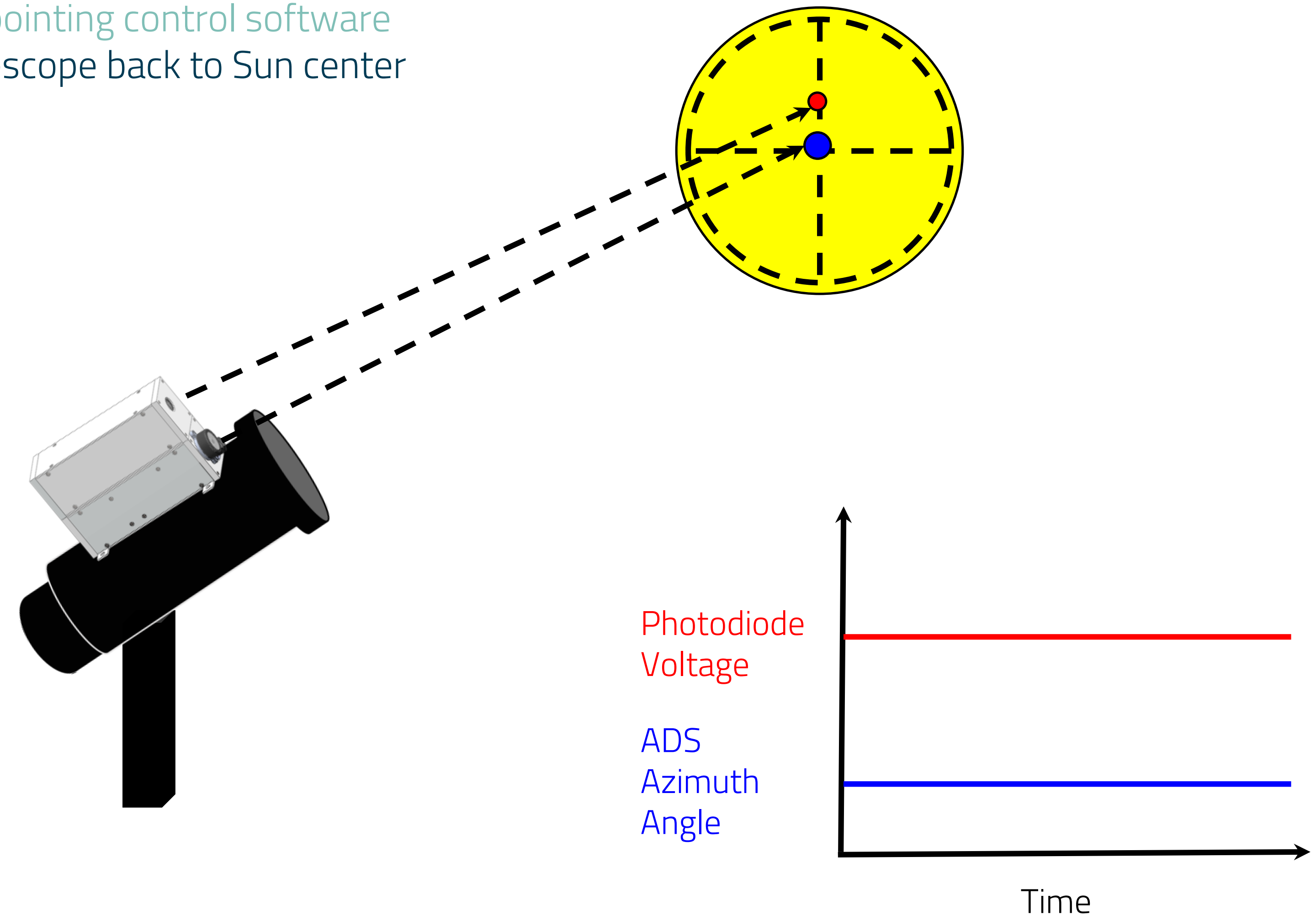




Optics System Alignment Calibration

Procedure

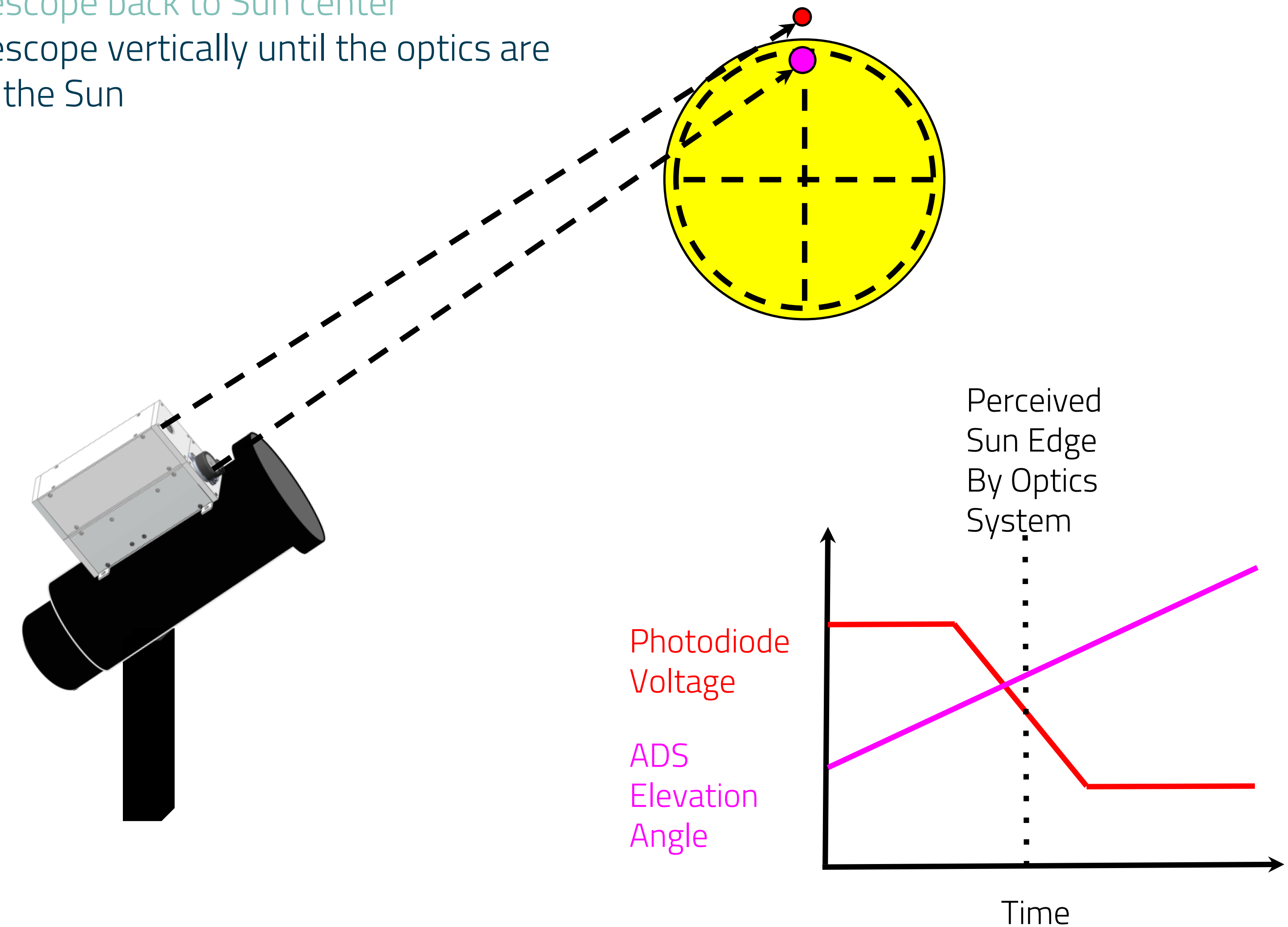
4. Calculate azimuth offset angle $\theta_{offset,X}$ and program into pointing control software
5. Slew telescope back to Sun center



Optics System Alignment Calibration

Procedure

5. Slew telescope back to Sun center
6. Slew telescope vertically until the optics are pointing off of the Sun

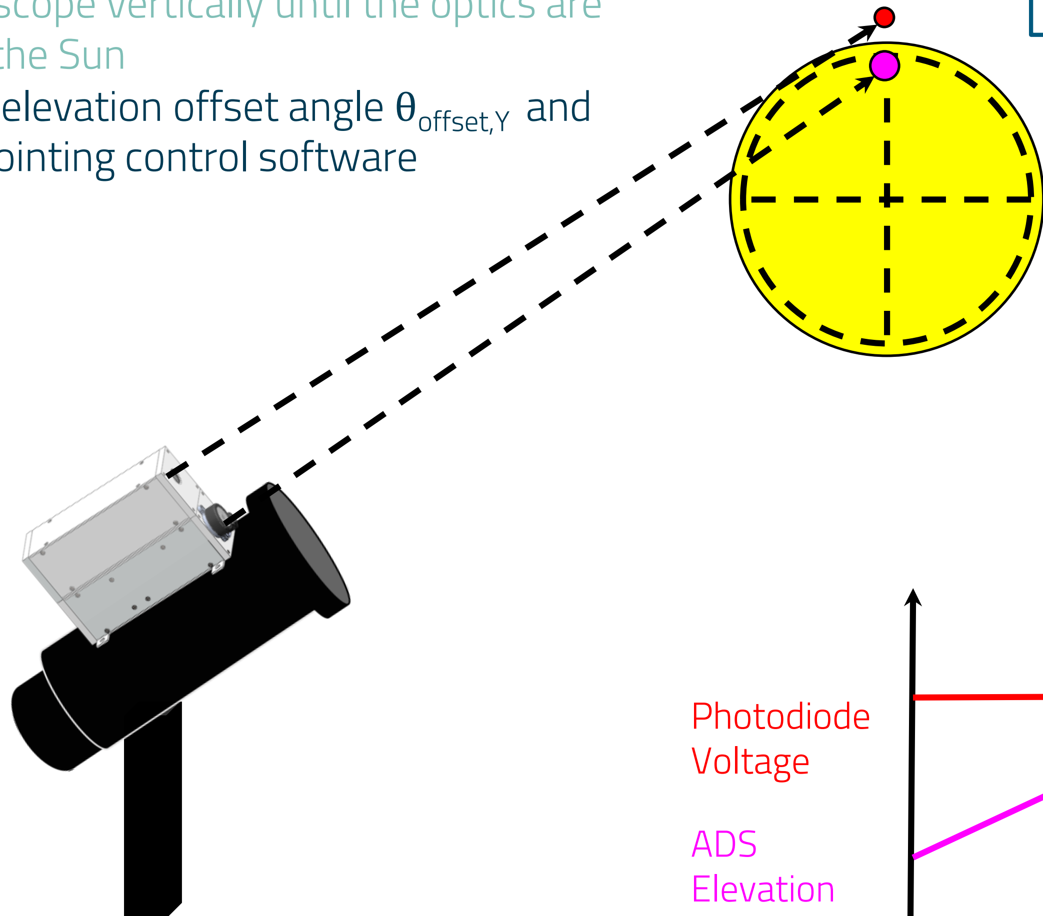


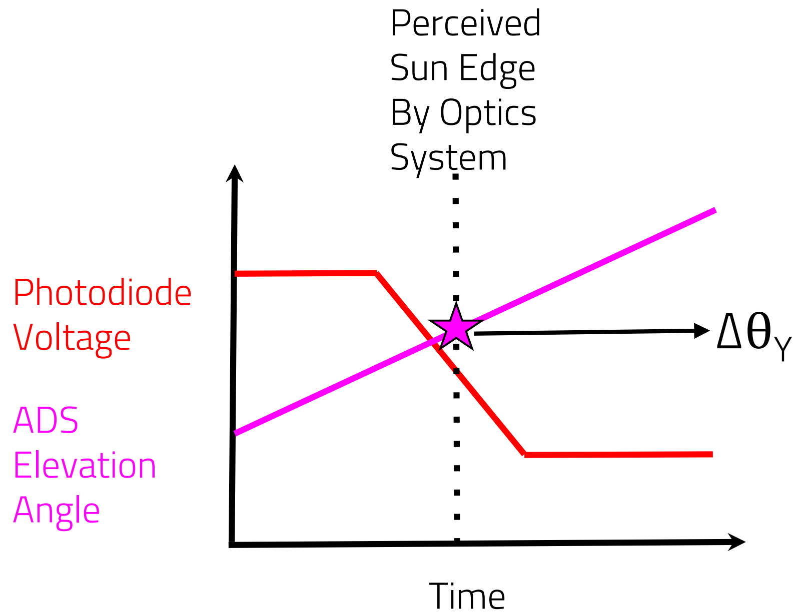
Optics System Alignment Calibration

Procedure

6. Slew telescope vertically until the optics are pointing off of the Sun
7. Calculate elevation offset angle $\theta_{offset,Y}$ and program into pointing control software

$$\theta_{offset,Y} = (\theta_{Sun}/2) - \Delta\theta_Y$$

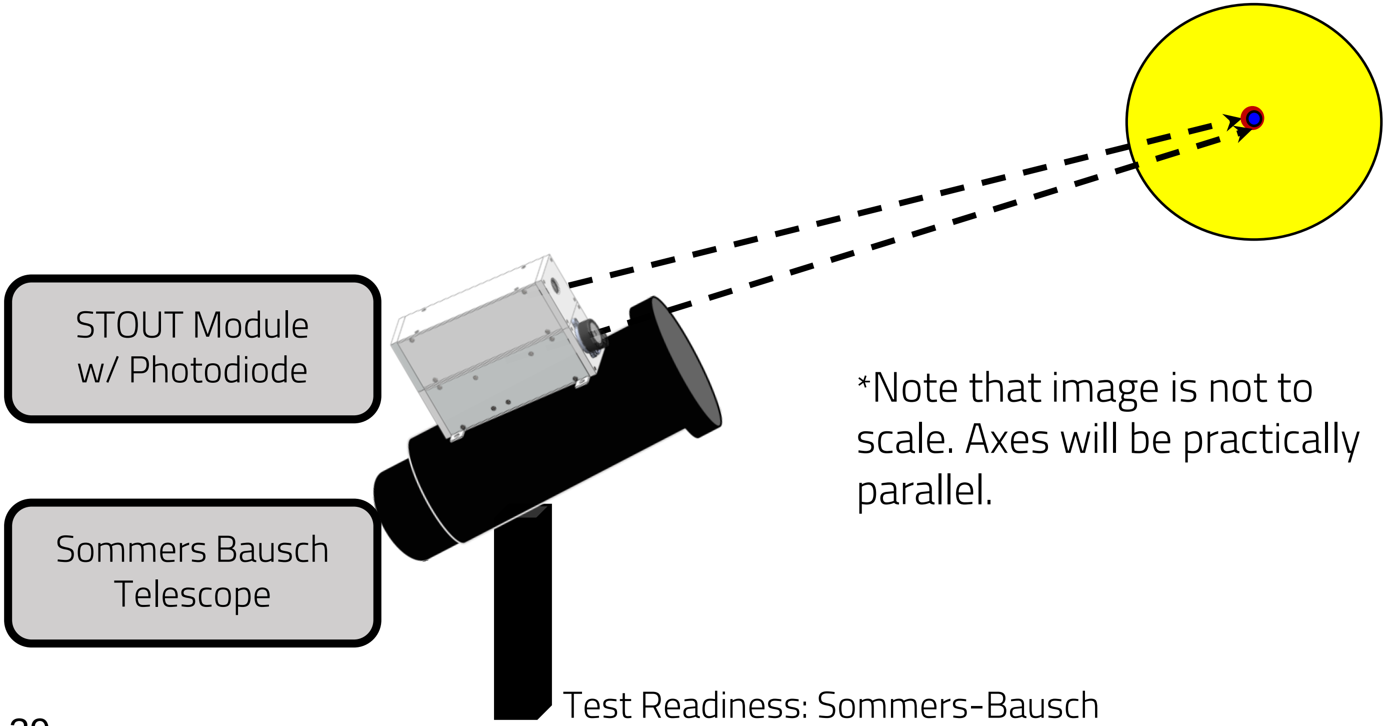




Optics System Alignment Calibration

Procedure

7. Calculate elevation offset angle $\theta_{offset,Y}$ and program into pointing control software
8. Repeat steps 1- 8 until offset angles $\theta_{offset,X}$ and $\theta_{offset,Y}$ converge to where any additional changes will be smaller than total pointing angle errors < 2.883'



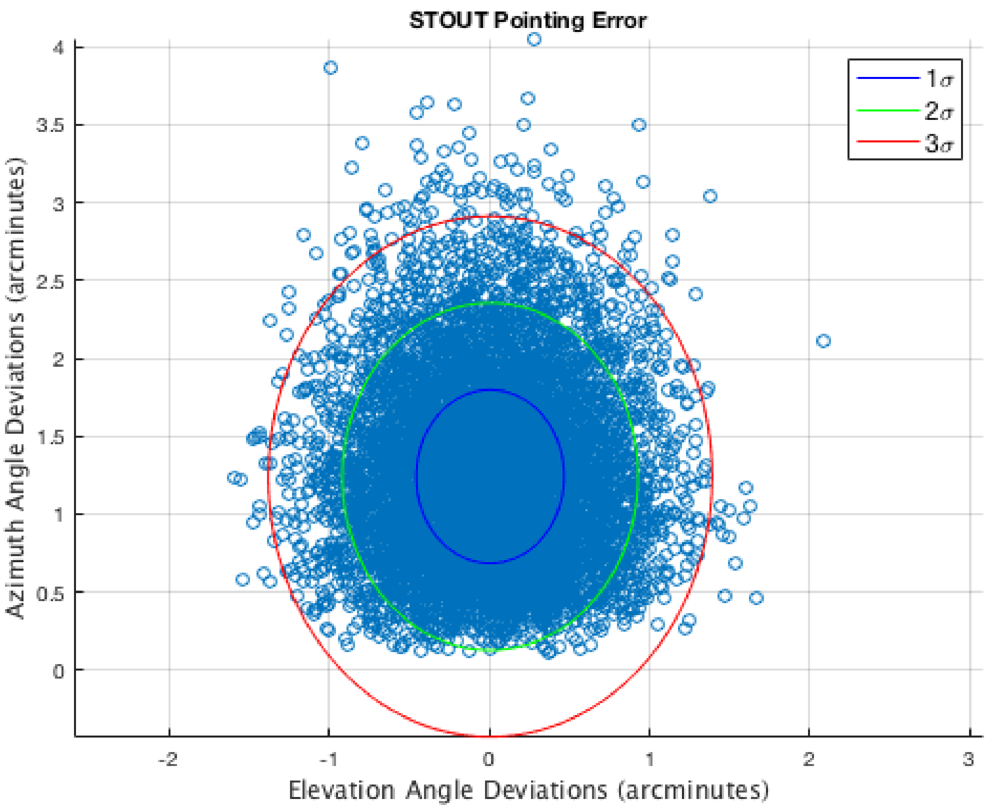
*Note that image is not to scale. Axes will be practically parallel.

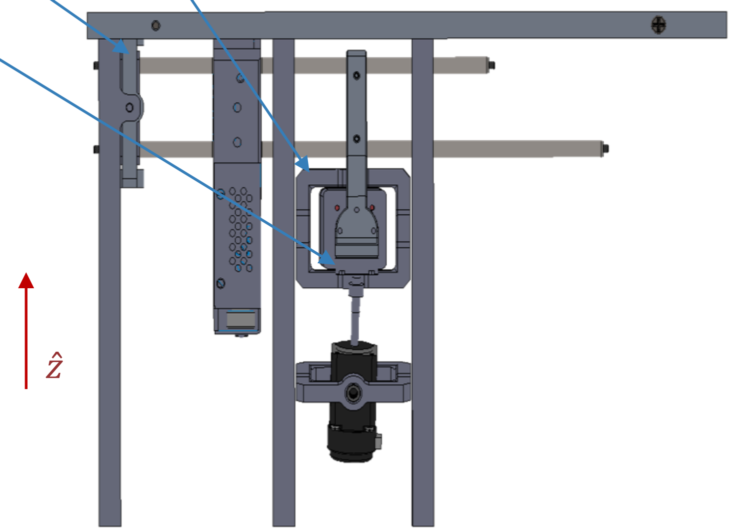
Pointing Error Monte Carlo Model

Slack Values

- Motor Gimbals: +/- 5 um horizontal and +/- 10 um vertical
- Optical Cage Gimbal: +/- 5 um horizontal and +/- 10 um vertical
- Ball Joints: +/- 1um horizontal and +/- 1um vertical
- All slack applied in cage gimbal
- Slack in $\hat{z}$ direction is negative

- Teflon washers to minimize horizontal slack
- Pointing algorithm confirmed using SolidWorks numbers





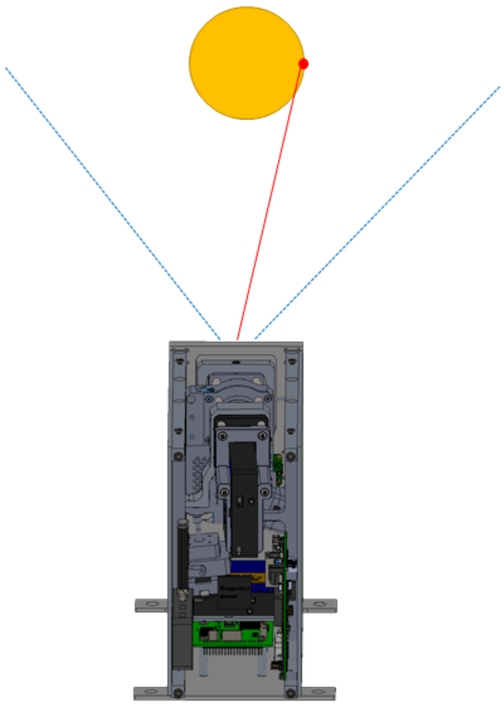
<u>3σ Pointing Error</u>
Elevation: +/- 1.4′
Azimuth: +/- 2.9′

Optical Pointing System Verification

Procedure

1. Initialized ADS on Sun's right edge
   - SBO telescope position will be locked

ADS initialization Point
ADS FOV (10º)
Optical Axis

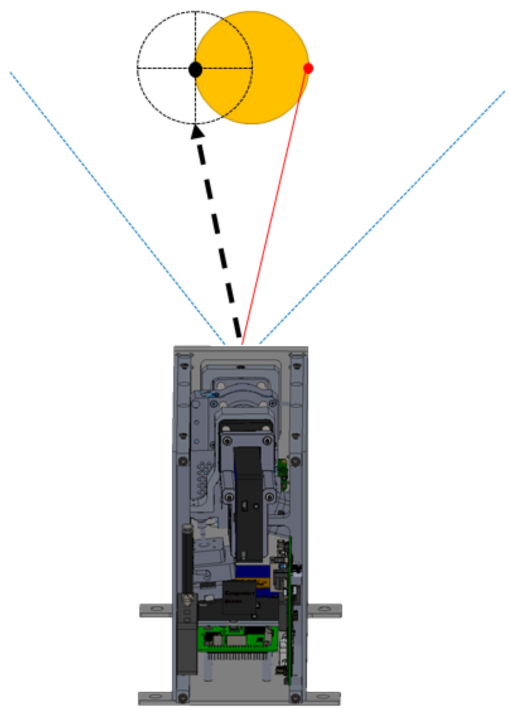


Test Readiness: Sommers-Bausch

Optical Pointing System Verification

Procedure

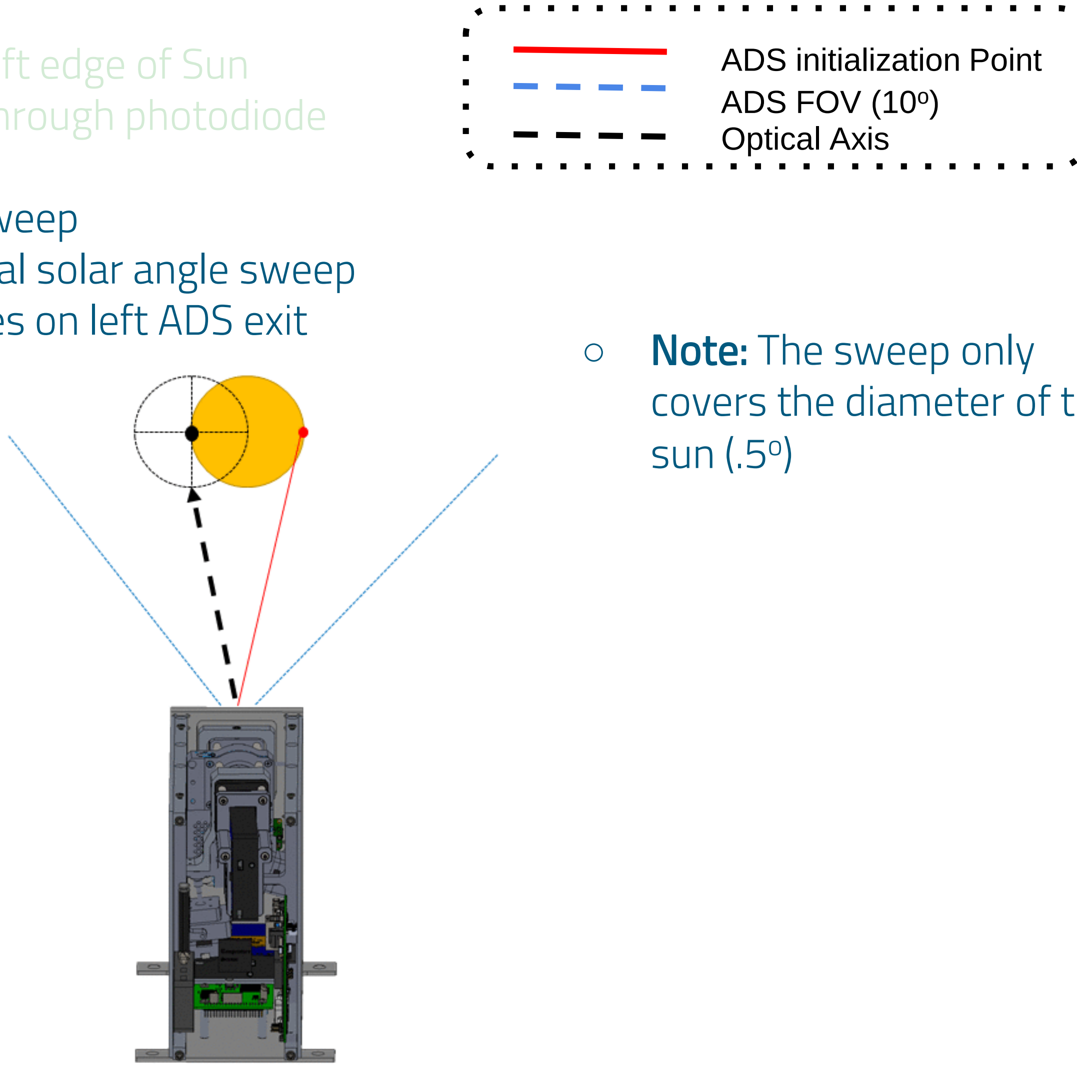
1. Initialized ADS on sun's right edge
    - SBO telescope position will be locked
2. Lock optical axis on left edge of Sun
    - Validated by constant photodiode voltage



Optical Pointing System Verification

Procedure

2. Lock optical axis on left edge of Sun
    - Accomplished through photodiode voltage
3. Initiate optics cage sweep
    - Validates internal solar angle sweep
    - Sweep concludes on left ADS exit

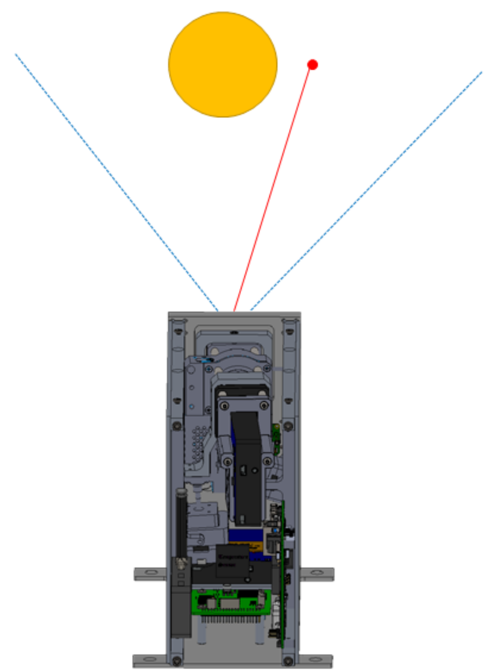


- **Note:** The sweep only covers the diameter of the sun (.5º)

Optical Pointing System Verification

Procedure

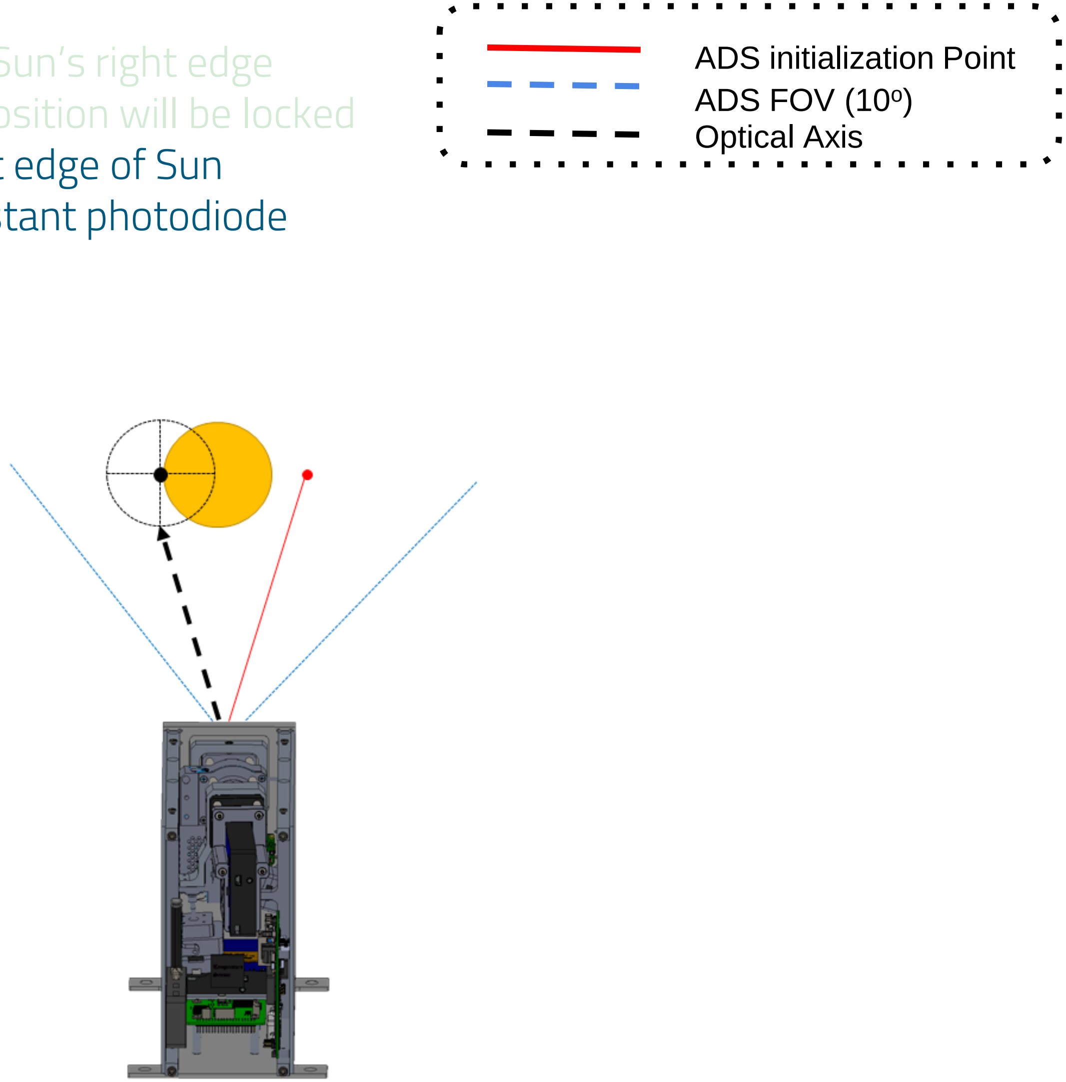
3. Initiate optics cage sweep
    - Validates internal solar angle sweep
    - **Note:** The sweep only covers the diameter of the sun (.5°)
4. Initiate ADS 3.5° from Sun's right edge
    - SBO Telescope position will be locked



Optical Pointing System Verification

Procedure

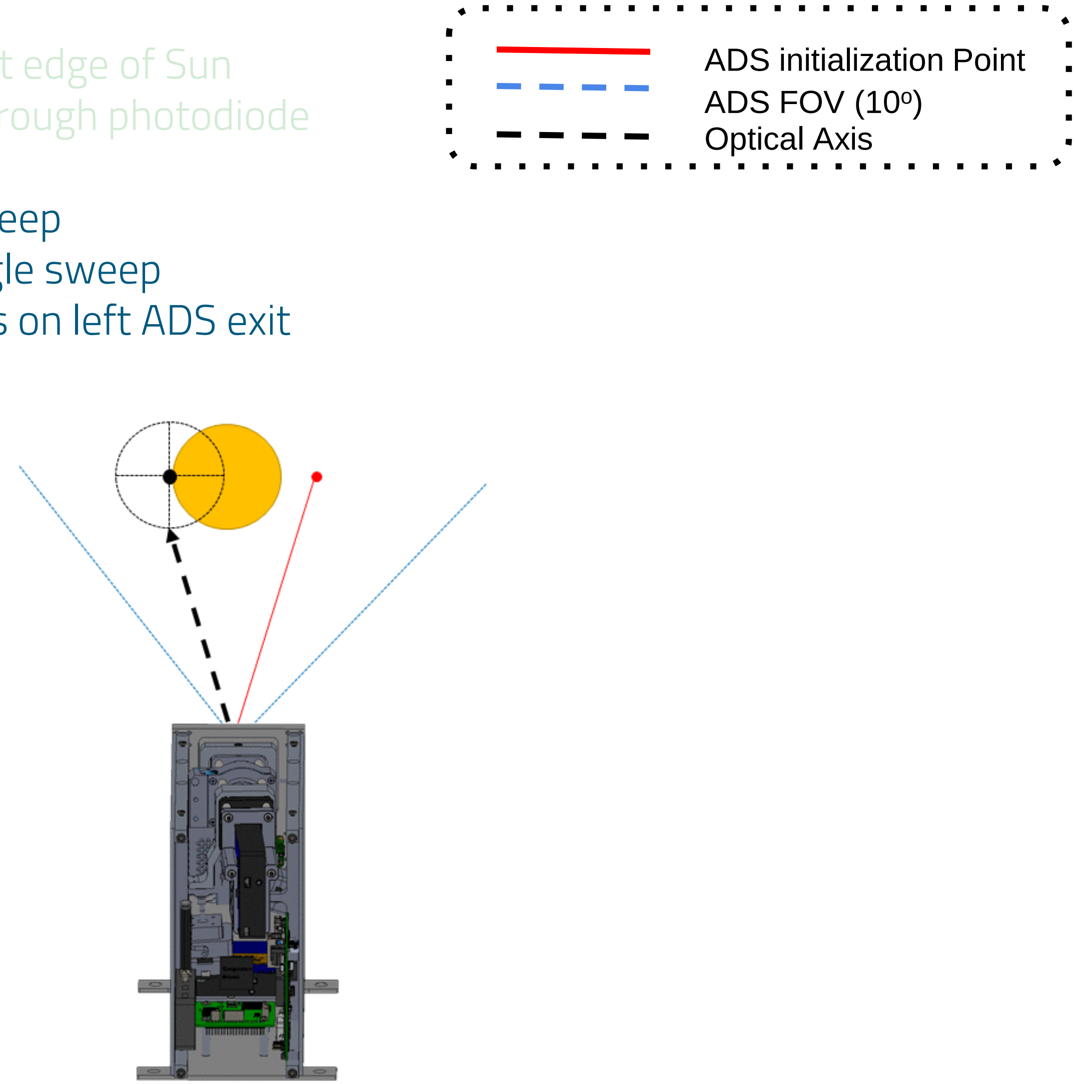
4. Initiate ADS 3.5º from Sun's right edge
   - SBO Telescope position will be locked
5. Lock optical axis on left edge of Sun
   - Validated by constant photodiode voltage



Optical Pointing System Verification

Procedure

5. Lock optical axis on left edge of Sun
    - Accomplished through photodiode voltage
6. Initiate optics cage sweep
    - Validates full angle sweep
    - Sweep concludes on left ADS exit



Environmental Testing Overview

FR5: The system shall survive the environmental conditions of a high altitude balloon flight to 40 km

Objectives

- ➢ Verify environmental sensor package
- ➢ Verify Thermal Control functionality during flight profile

Key Requirements

- ➢ 5.1 During ascent and descent the system shall survive temperatures ranging from -65°C to 20°C
- ➢ 5.2 During cruise the system shall operate at temperatures ranging from -25°C to -15°C
- ➢ 5.3 The system shall survive pressure values of ranging from 100 kPa to 100 Pa

How it Reduces Risk

- ➢ Shows the system can survive the simulated flight profile of 40 km flight, enabling mission requirements fulfillment

Associated Model: MATLAB and SolidWorks Thermal Models

Environmental Testing Overview

Purpose

- ➢ Ensure that EMCS performs as designed and supports dependent STOUT mission requirements
  - ○ Includes passive and active heating system, external and internal environment data collection, and supporting instrumentation
- ➢ Tests comprising of partial module assembly and complete module assembly will be performed through series of ascent and cruise modeling utilizing two seperate environmental chambers
- ➢ Verify previous thermal modeling by comparing them to resultant test chamber data
- ➢ Validate actual EMCS
  - ○ Prove module survivability in -65 °C environment during ascent and descent flight phases
  - ○ Prove modules ability to operate at mission capacity in cruise temperature and pressure parameters (-25 to -15 °C, less than 300 Pa)

Environmental Testing: ETC

Module Ascent Test

- CubeSat consisting of only EMCS, then all components
- EMCS validation needs to be successfully confirmed in temperature environment before full module testing, risking higher value items

ETC Specifications

- ASEN Dept
- Russells G-8-105-105
- Models temperatures between -68 °C and 177 °C.
- Will be used to validate EMCS through temperature conditions of ascent flight phase

Data Source	Sampling Rate	Data Collected
Internal Component Temperature Sensors (4)	Every 30 seconds (0.033 Hz)	Internal temperature of Spectrometers, UDOO, Sun Sensor
Internal Environment Temperature Sensors (5)	Every 30 seconds (0.033 Hz)	Temperatures at various locations inside module
External Temperature Sensors (2)	Every 30 seconds (0.033 Hz)	Atmospheric temperature during ascent
Pressure and humidity sensors	Every 30 seconds (0.033 Hz)	Atmospheric pressure, and humidity during ascent (functionality checks)

Environmental Testing: TVAC

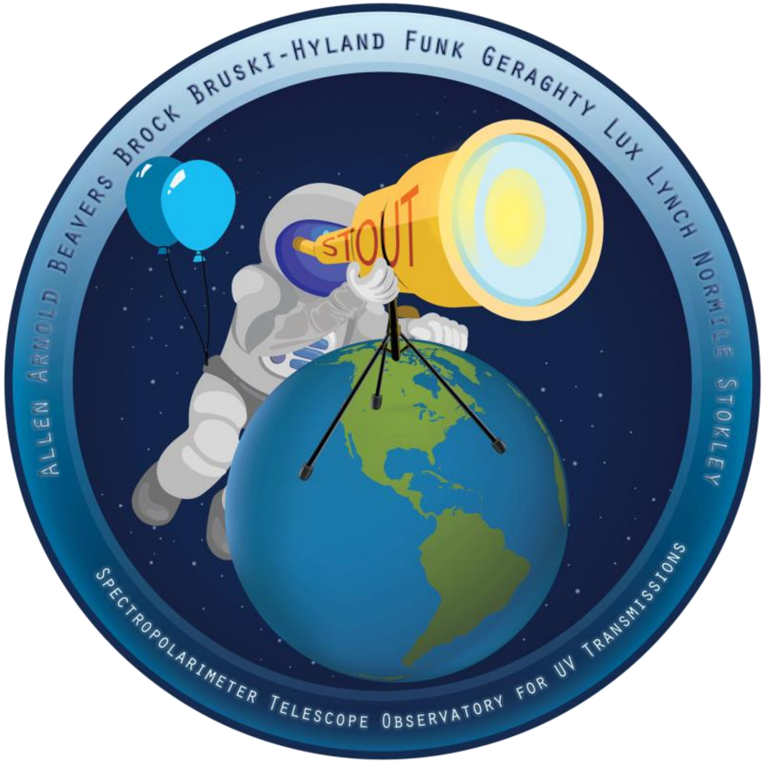
Module Cruise Test

- CubeSat consisting of only EMCS, then all components
- EMCS validation needs to be successfully confirmed in pressure environment before full module testing, risking higher value items

TVAC Specifications

- UCAR Facility
- Models temperature down to -20 C, and pressure as low as 130 Pa
- Will be used to validate EMCS through temperature and pressure conditions of cruise flight phase

Data Source	Sampling Rate	Data Collected
Internal Component Temperature Sensors (4)	Every 30 seconds (0.033 Hz)	Internal temperature of Spectrometers, UDOO, Sun Sensor
Internal Environment Temperature Sensors (5)	Every 30 seconds (0.033 Hz)	Temperatures at various locations inside module
External Temperature Sensors (2)	Every 30 seconds (0.033 Hz)	Atmospheric temperature during cruise
Pressure and humidity sensors	Every 30 seconds (0.033 Hz)	Atmospheric pressure, and humidity during cruise (functionality checks)


Allen Arnold Beavers Brock Bruski-Hyland Funk Geraghty Lux Lynch Normile Stokley
STOUT
Spectropolarimeter Telescope Observatory for UV Transmissions

Budget

Budget

Total Budget with EEF Grant	Expected Total Expenses
$7377.00	$6680.94

*This leaves us with a ~10% margin in budget for remaining unexpected expenses

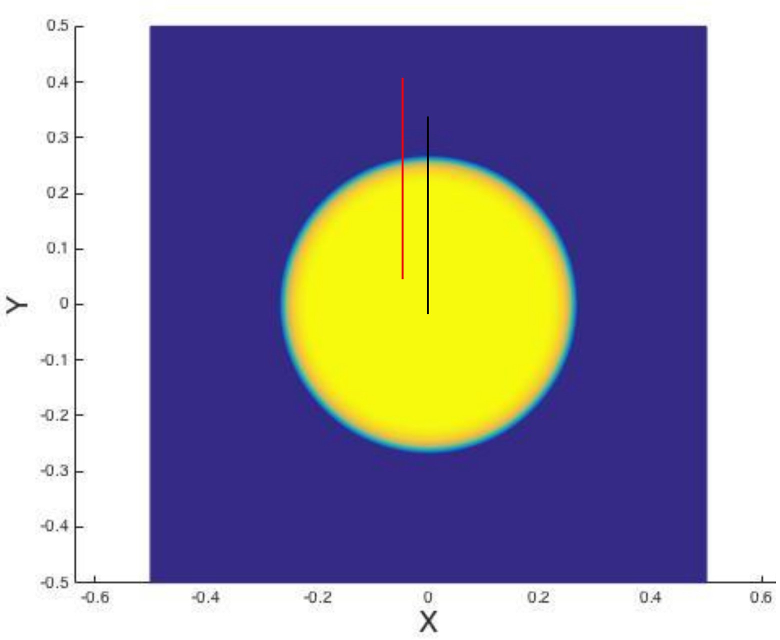
Subsystem	Part	Order Placed	Received	Cost($)	Expected Cost($)
ADS	Solar Mems Sun Sensor (x3)	Yes	Yes	900	
	UDOO RS-485 Sheild	Yes	Yes	9.95	
Optics	Main Lens	Yes	Yes	889.54	
	Polarizer Mount	Yes	Yes	1183.3	
	40um Pinhole	Yes	Yes	60.75	
	Cage Plates (x2)	Yes	Yes	38.57	
	Threaded Cage Plates (x2)	Yes	Yes	31.7	
	Cage Rods 2in (x4)	Yes	Yes	20.86	
	Cage Rods 6in (x4)	Yes	Yes	58.39	
	Lens Tubes (x2)	Yes	Yes	25.65	
	Thorlabs Shipping	NA	NA	9.02	
	Avantes COL-UV/VIS Collimating Lens	Yes	Yes	123.5	
	Thorlabs refund	NA	NA	-31.7	
	Lens Gloves/Cleaner	No	No		10
	UV Photodiode	Yes	Yes	70.39	
TCS	Temperature Sensors (x4)	Yes	Yes	15.8	
	Pressure Sensor	Yes	Yes	24.5	
	128V Pad Heaters	Yes	Yes	72.6	
	New pad heaters	Yes	Yes	164	
	Humidity Sensor	Yes	Yes	16.95	
	Thermocouples	Yes	Yes	59.36	
	Heatsinks	Yes	Yes	3.9	
	Insulation(refunded)	Yes	Yes	50.55	
	Insulation Refund	NA	NA	-45.34	
	Insulation	Yes	Yes	11.97	
	Lens Heater	No	No		50
	Thermal Tape	Yes	Yes	3.95	
Structure	Stock Aluminum 6061	Yes	Yes	401.23	
	Needle Roller Bearings	Yes	Yes	192.77	
	Screws	Yes	Yes	7.15	
	Spherical Roller Joints (x2)	Yes	Yes	783	
EPS	Converters Components	Yes	Yes	45.8	
	Wires	Yes	Yes	16.95	
	Headers	Yes	Yes	4.5	
	Jumper Wires	Yes	Yes	24.95	
	Digikey Refund	NA	NA	-8.99	
	PCB	No	No		160
Various	Gantt Chart Software	NA	NA	84.99	
	Printing	NA	NA	43.36	
Controls	Stepper Motors	Yes	No	443.51	
	GPS	Yes	Yes	49.51	
	Motor Controller	Yes	Yes	29.9	
DAQ	Camera	Yes	Yes	45	
	USB Hub	Yes	Yes	16.99	
	USB Drives	No	No		150.66
	Logic Level Converters	Yes	Yes	28	
	UDOO sensors	Yes	Yes	46.6	
	UDOO x86 Ultra	Yes	Yes	286.9	
Totals				6310.28	370.66

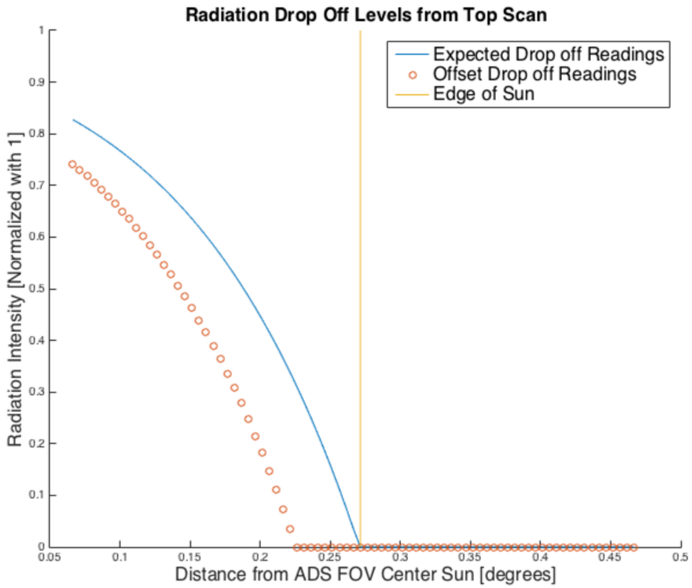
Budget

Table of Contents

ADS Calibration Model

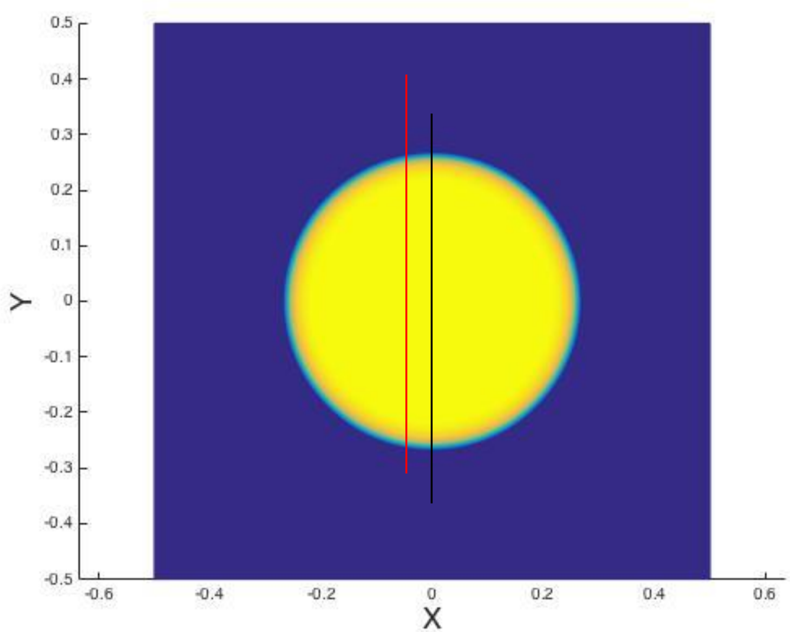
- Move ADS FOV center on center of Sun and scan along the black line.
- Optics train center will follow red path along Sun.
- The expected drop will indicate offset

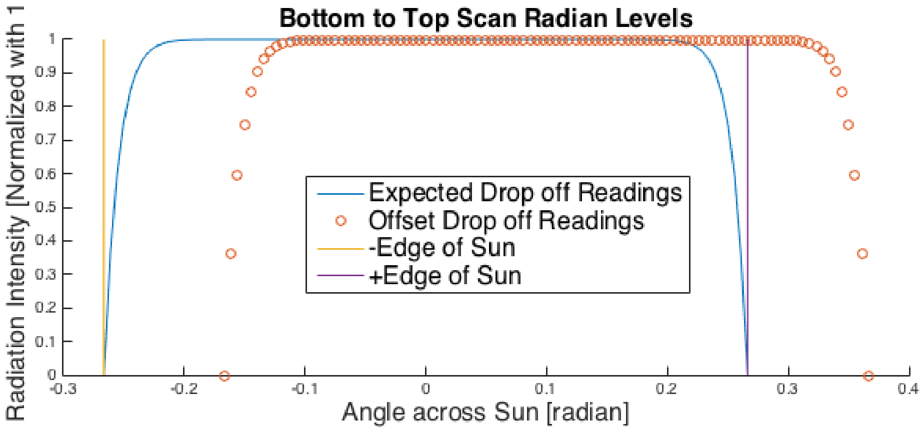




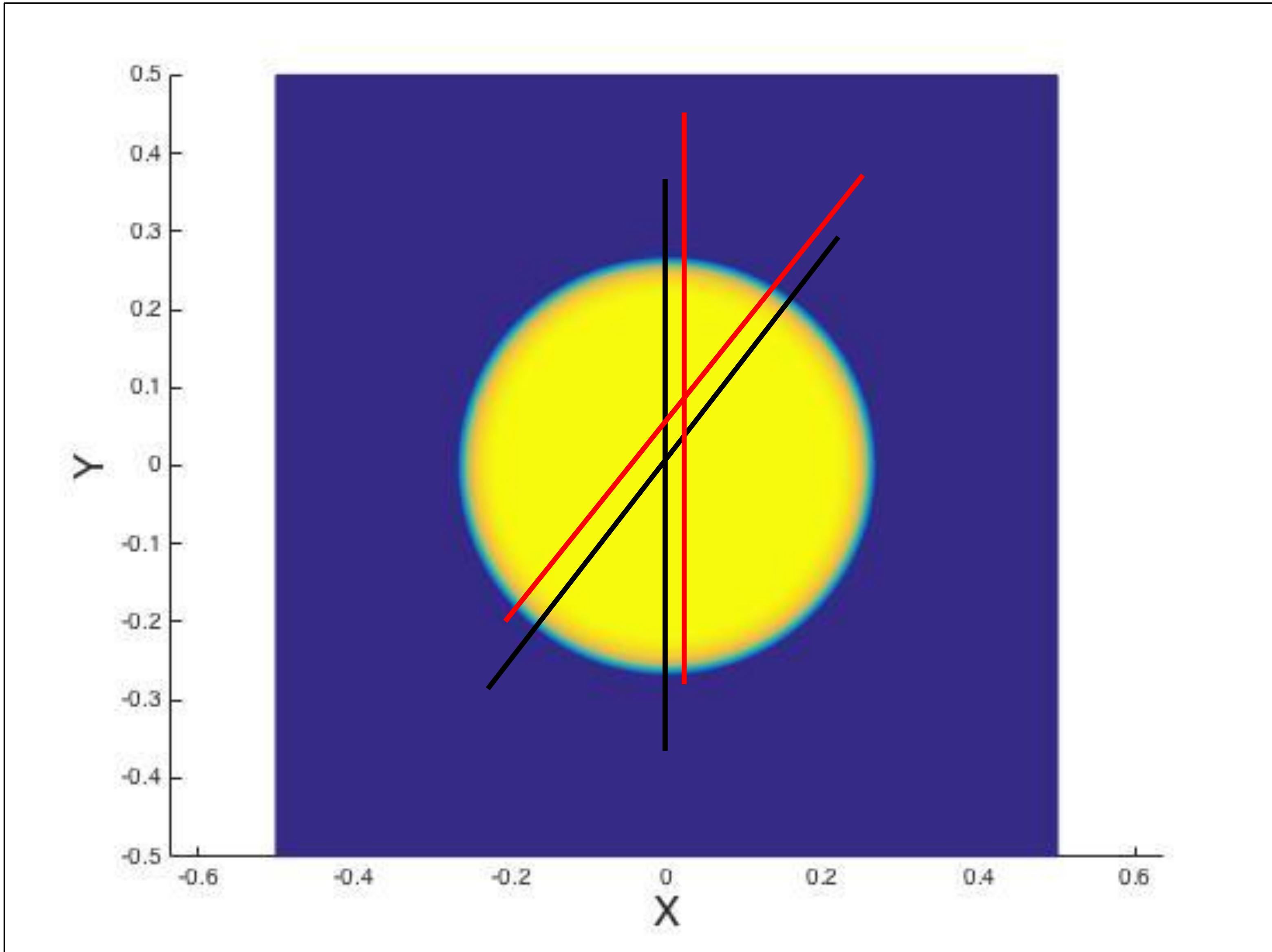
ADS Calibration Model Full Scan Check

- Move ADS FOV center on center of Sun and scan along the black doing full scan
- Verify incoming and outgoing photodiode reading slopes are the same



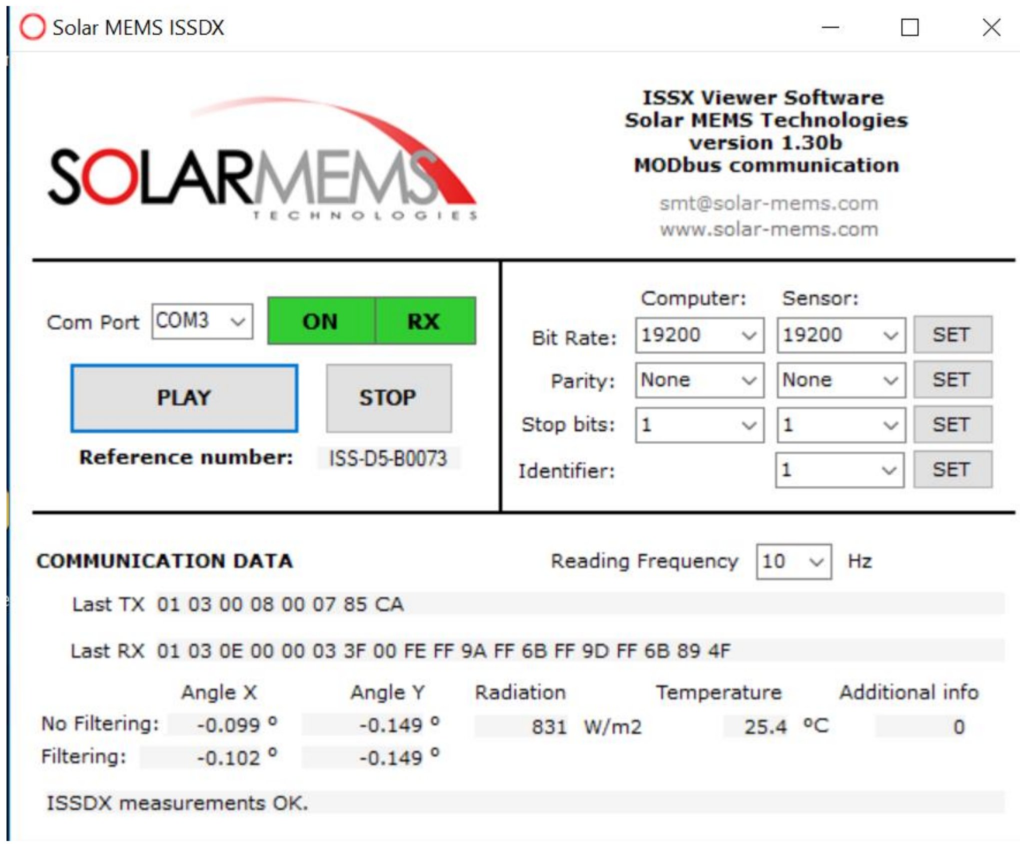


ADS Calibration Model Redundant Pattern



ADS Component Verification

- Verify that code converts Hexadecimal values from Last RX into the Angle measurements below



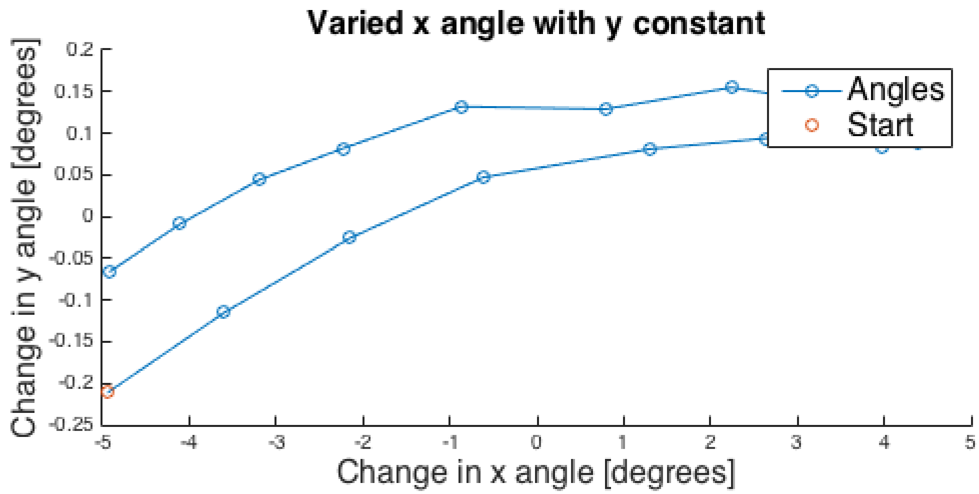
Test Readiness: Sommers-Bausch

ADS Component Verification

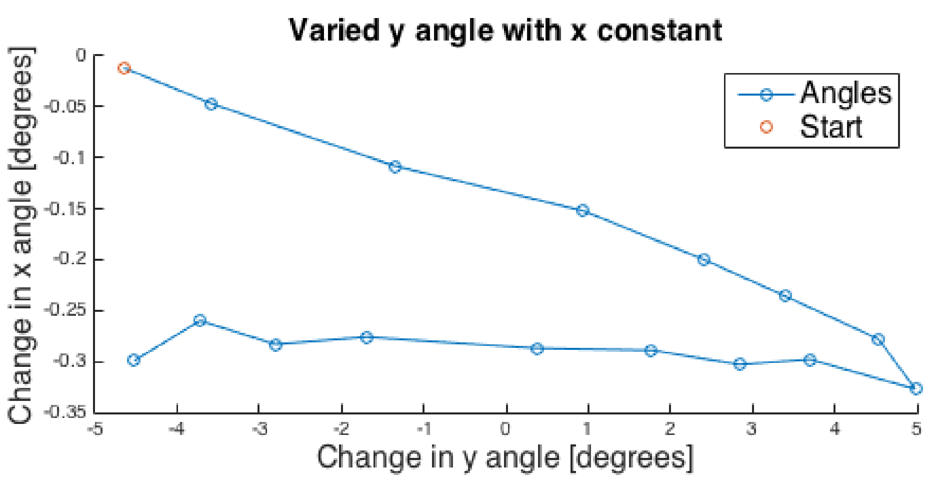
- Check for non-linearities by moving test mount in one dimension from ADS FOV end to end and recording opposite dimension

ADS Component Verification

- Move Test Frame from Right to Left then back

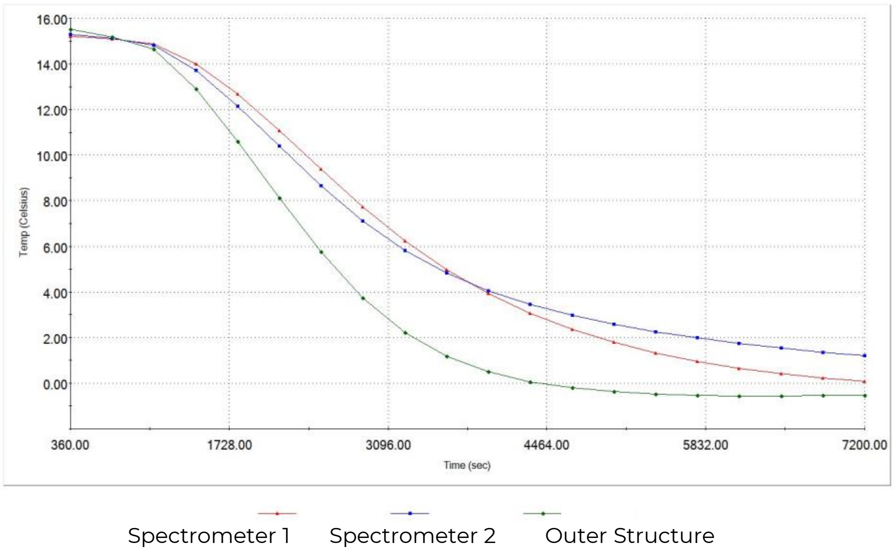


- Move Test Frame from Bottom to Top then back

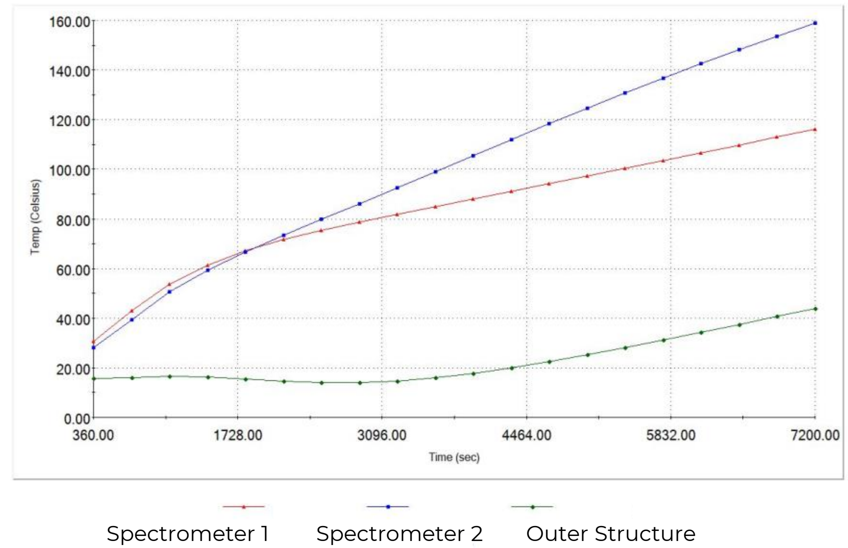


Thermal Simulations: Ascent

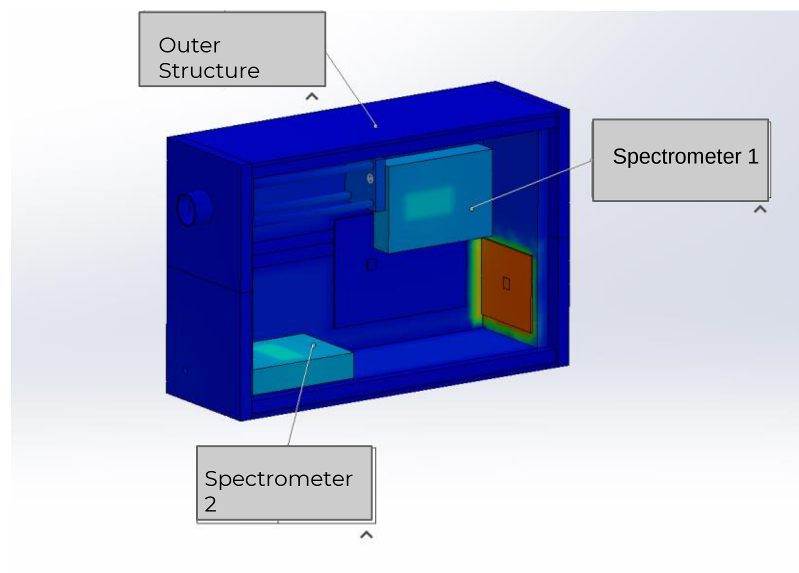
Ascent Heaters Off



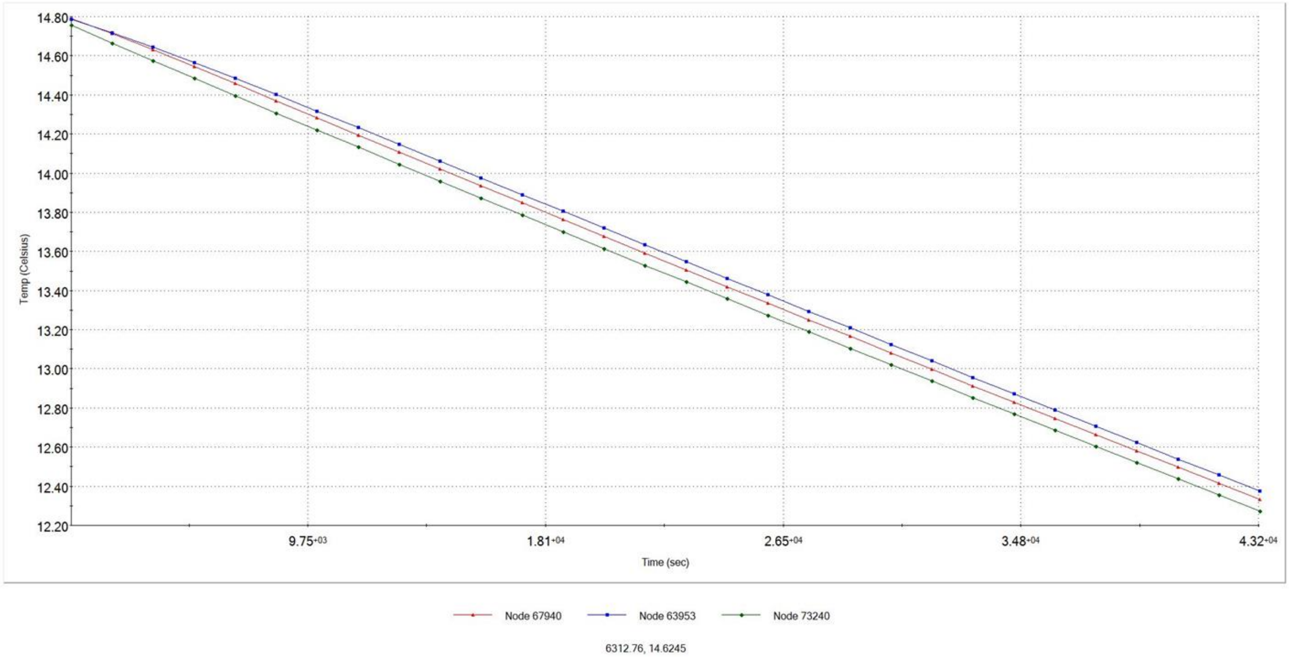
Ascent Heaters On



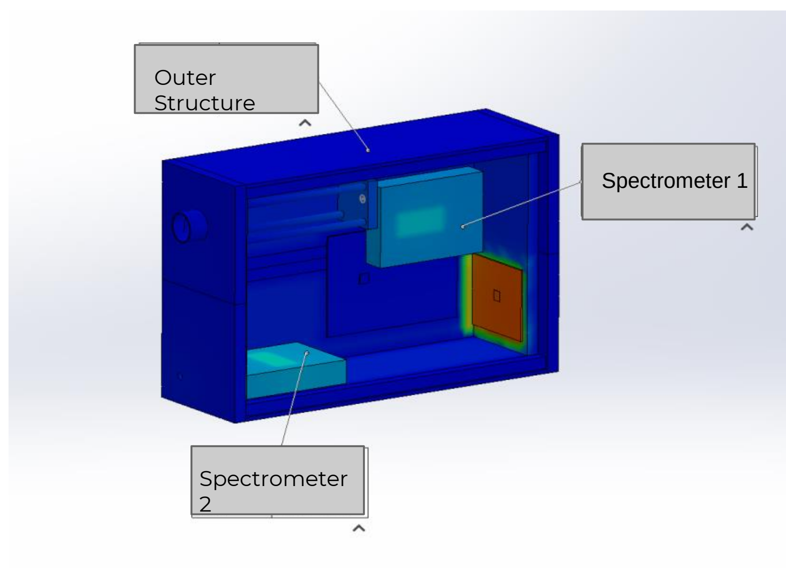
- ➢ Concerned about spectrometer survival during ascent
- ➢ Two simulations were ran simulating the environmental conditions of ascent; one with heaters on and one with heaters off
- ➢ With active heater control, we will be able to keep spectrometers at survivable temperature



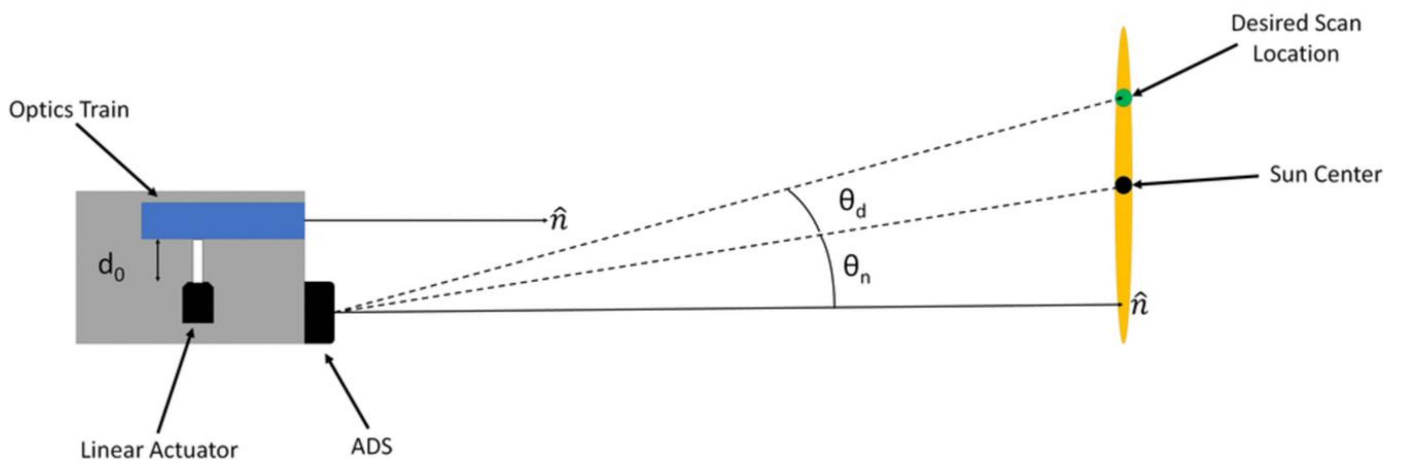
Thermal Simulations: Cruise



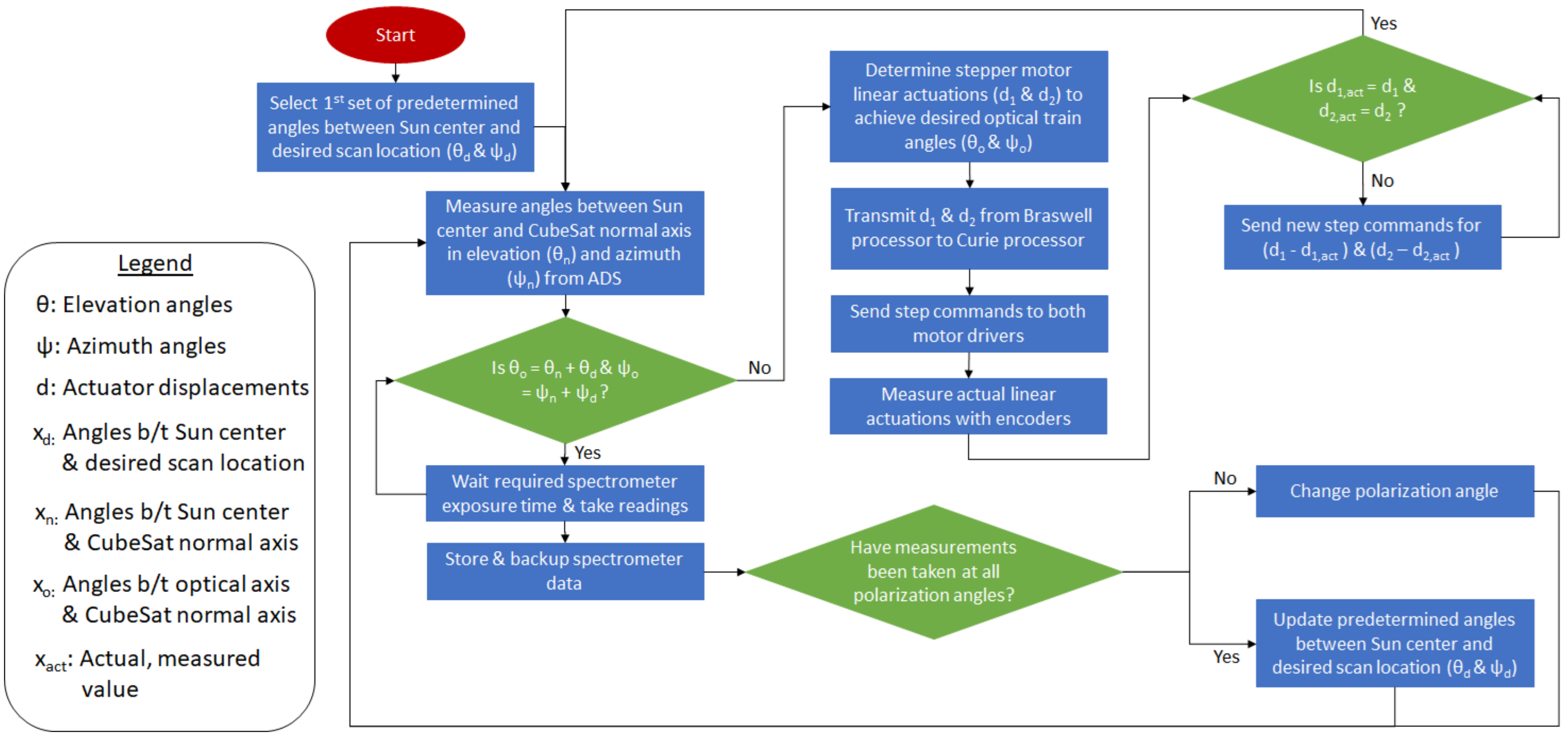
- Ran transient thermal simulation to model the environment at Cruise
- Modeled for 12 hours at 40km altitude environment
- Shows that getting too cold is not a problem.
- We will have to watch for high temperature in test chamber



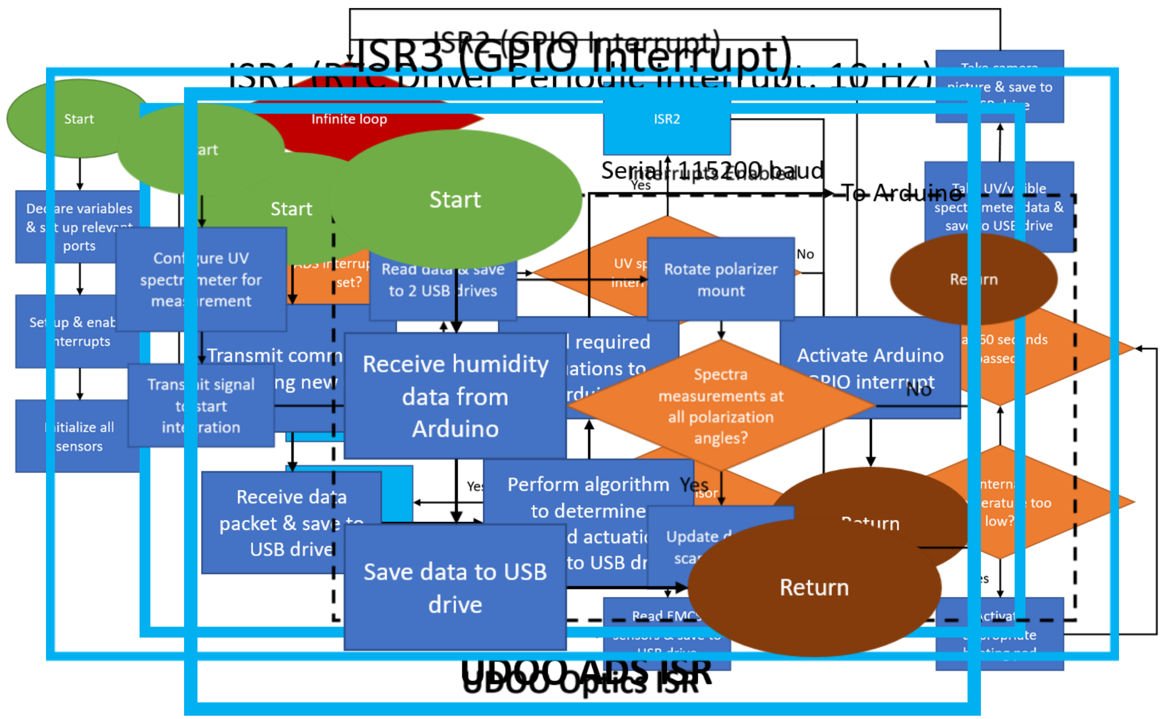
Pointing Control: Angle Explanation



Controls Software Flow

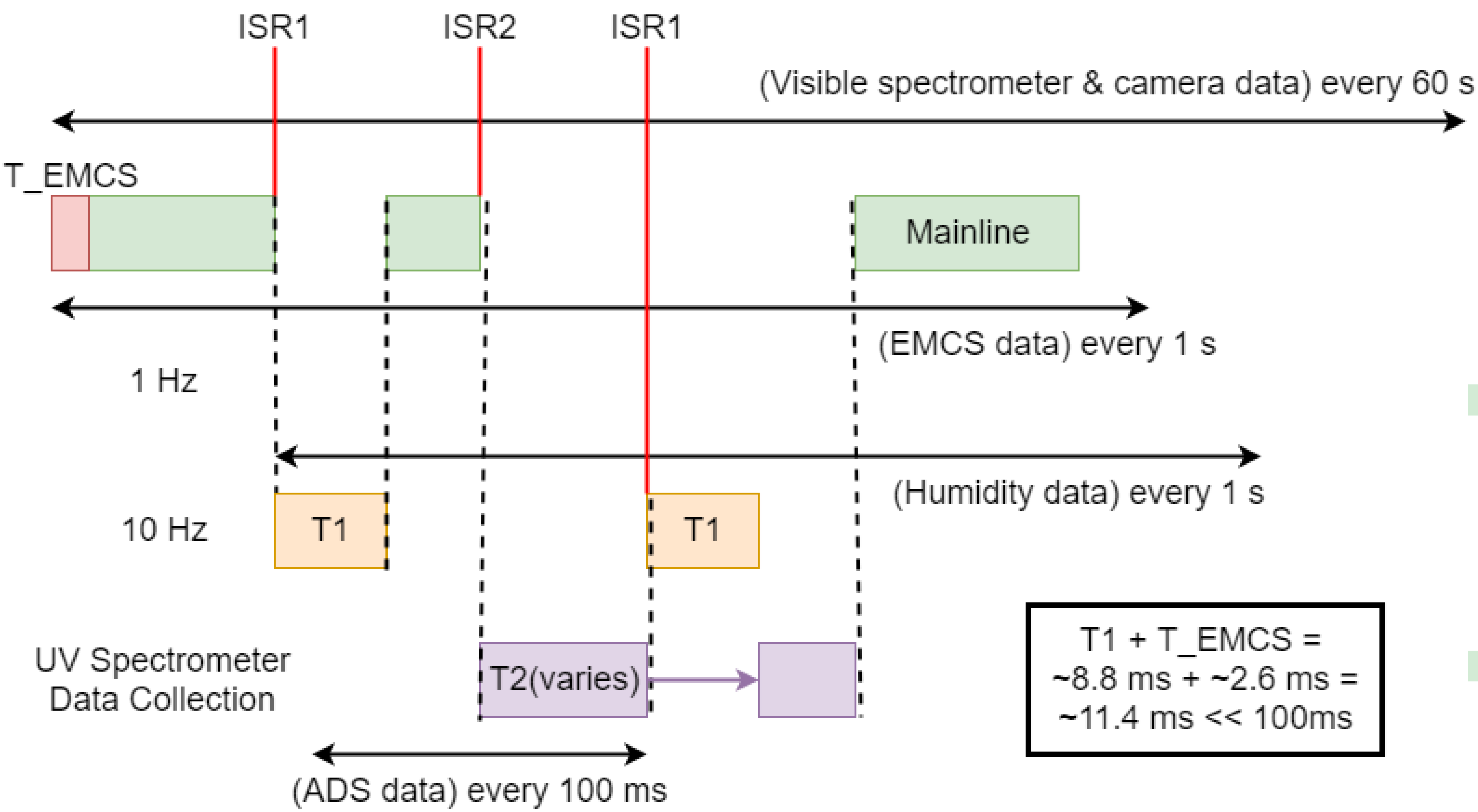


Software Flow: Single-Board Computer

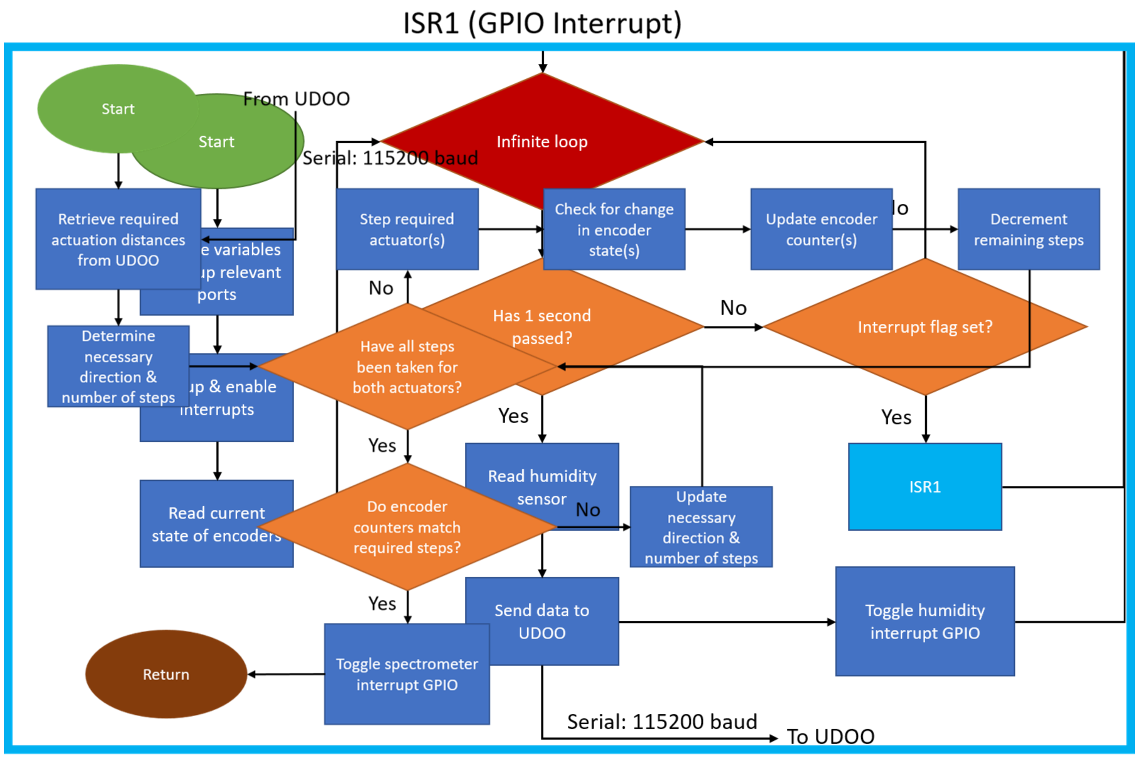


UDOO Humidity ISR

Software Timing: Single-Board Computer

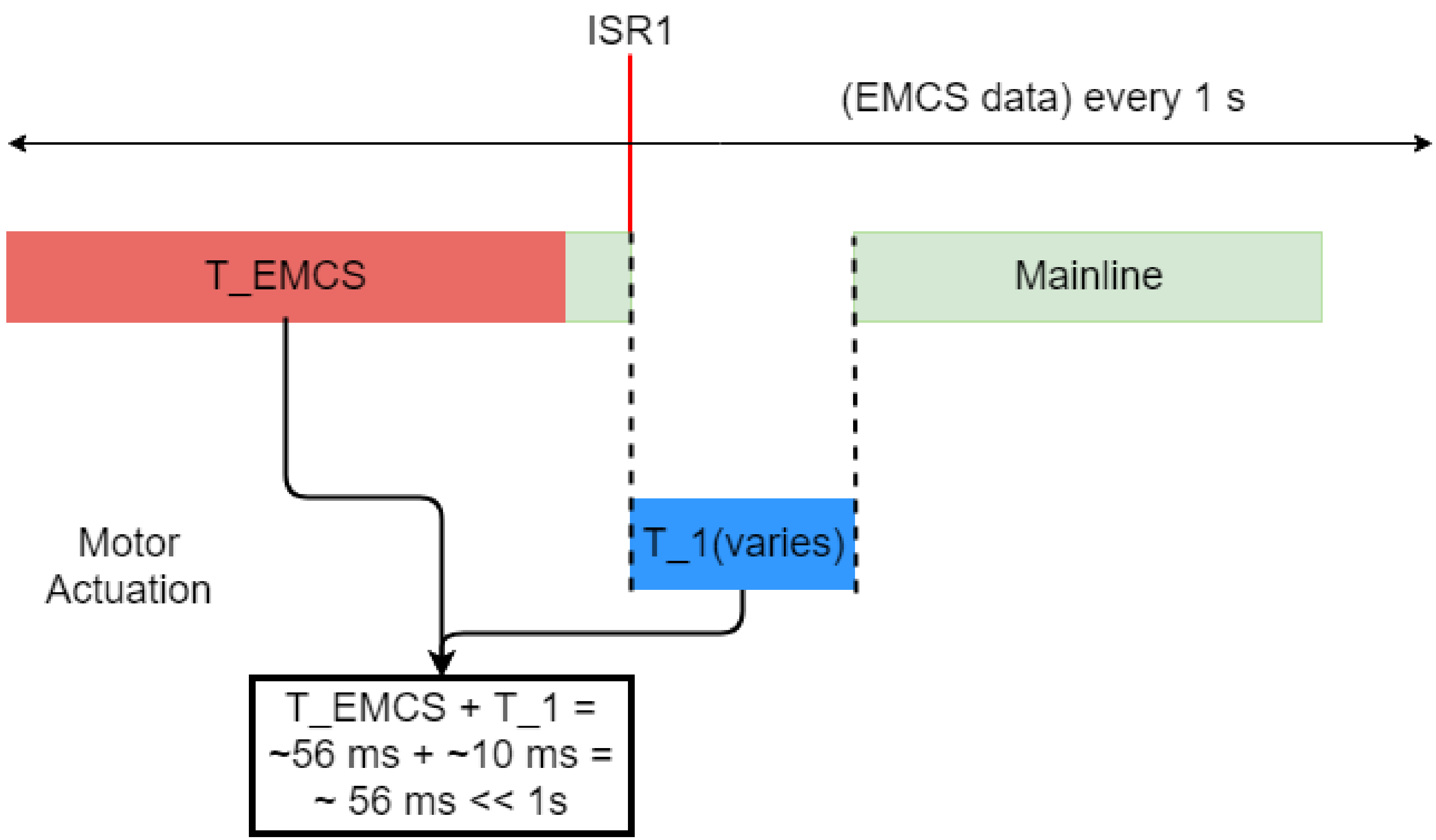


Software Flow: Microcontroller



Arduino Optics Controls ISR

Software Timing: Microcontroller



Software Path Forward

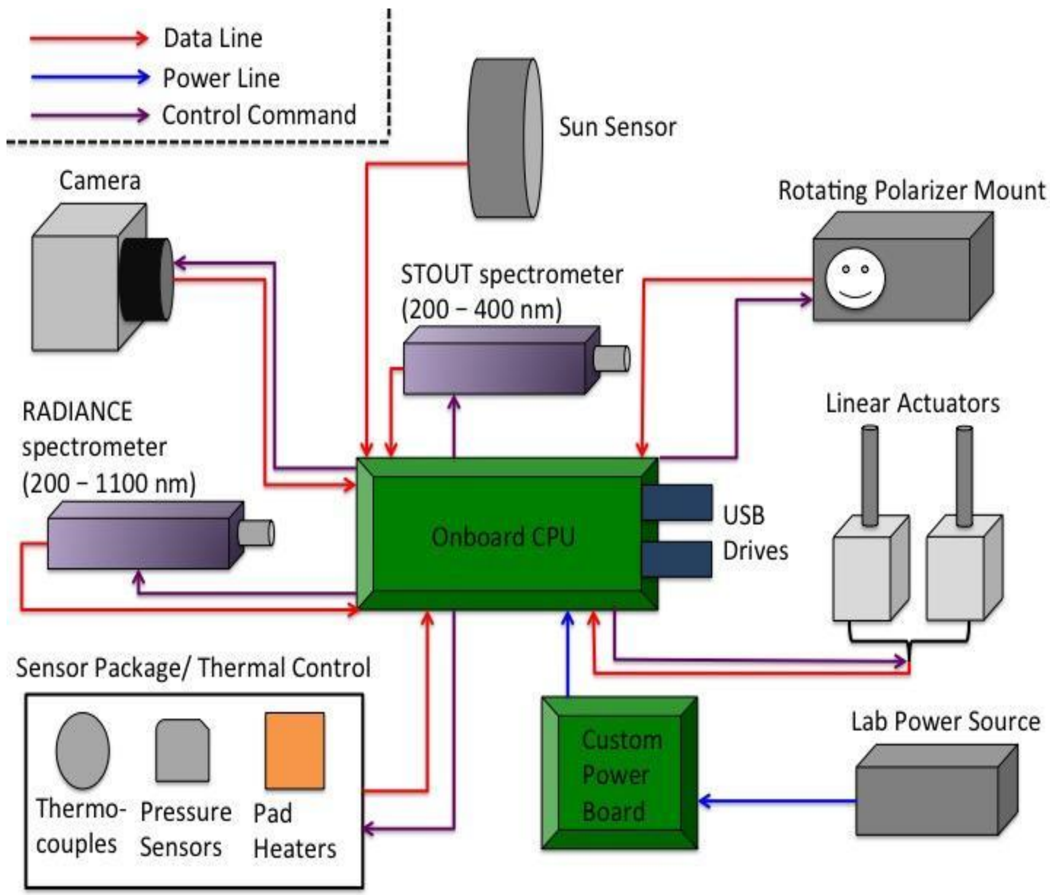
- Continue code development
  - UDOO (Linux) interrupts
  - Sensor interfaces
  - Watchdog timer
- Begin testing
  - Sensor unit tests
  - Controls tests
  - Timing evaluation
  - System tests

Most challenging to complete

FlatSat Test

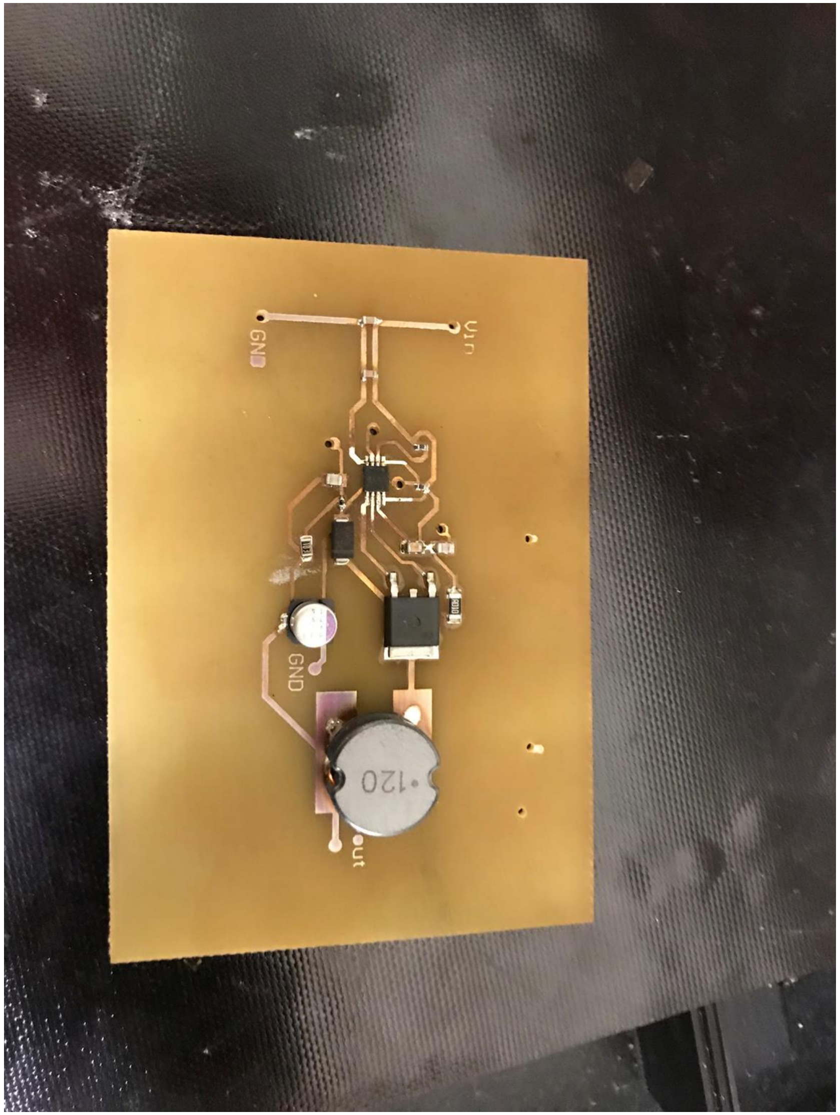
- **Purpose:** Determine that all of the components integrate and operate functionally
- **Procedure**
  - Integrate electronics outside of the CubeSat structure
  - Verify expected voltages and currents with a multimeter
  - Calculate and verify expected power draws

Simplified FlatSat Test Connections



Test Readiness: Environmental

PCB: Lessons Learned



- Surface-mount parts rather than through-hole
- Separate PCB for prototypes needed rather than simply breadboarding
- Hard to troubleshoot
- PCB size reconfiguration

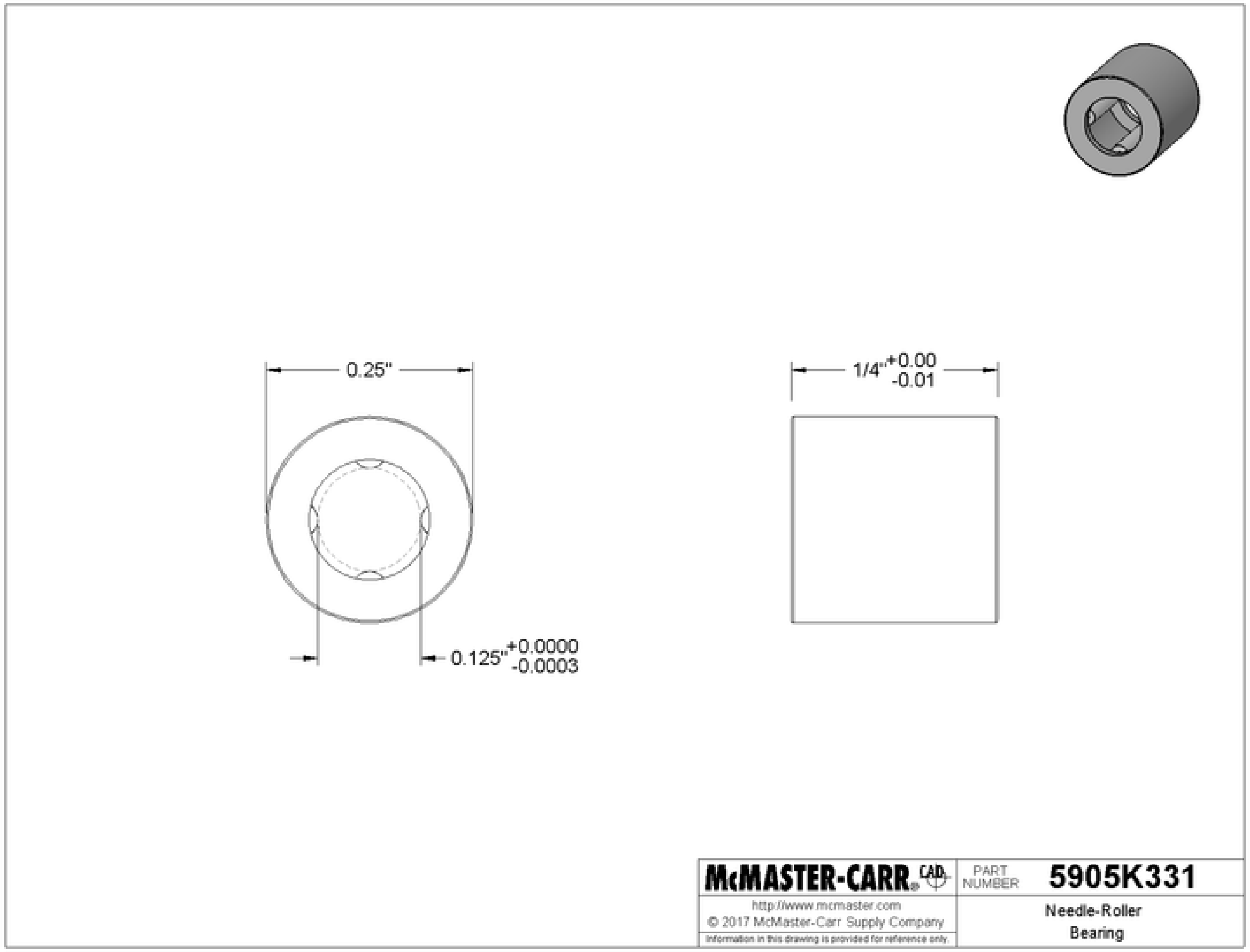
EPS Path Forward

- Converter prototype troubleshooting and testing
- PCB redesign for size (concurrent)
- Flatsat testing
- Order PCB
- PCB unit testing and troubleshooting
- Flatsat PCB

Needle Roller Bearing Specs

Parameter	Values
Shaft Diameter	⅛”
Width	¼”
Width Tolerance	-0.01-0”
Shaft Tolerance	-0.0003-0”

Needle Roller Bearing CAD



Test Readiness: Sommers-Bausch

Mainline Time Requirements							
Process	Data Size [B]	Quantity	Read Time [ms]	Write Rate [MB/s]	Interupt Time [ms]	Subtotal [ms]	
Internal Temp.	2	7	2.5	120	0	17.50011667	
External Temp.	4	2	2.5	120	0	5.000066667	
Pressure	3	1	8.22	120	0.5	8.720025	
Camera	600000	1	15	120	0	20	
Polarizer	0	1	1	120	0	1	
Spectrometer - Visible	10000	1	0.17	120	0	0.2533333333	
					Total:	52.47354167	
ISR1 (ADS)							
Operation	Data Size [B]	Comm. Rate [B/s]	Subtotal [ms]				
Request ADS Data	16	14400	1.111111111				
Wait for Data	0	0	5				
Write ADS Data to USB	16	14400	1.111111111				
Calc. Required Actuation			1				
Send Actuation (Serial)	8	14400	0.5555555556				
Arduino Interrupt			0				
		Total:	8.777777778				

ISR2 (Spectrometer)							
Operation	Data Size [B]	Comm. Rate [B/s]	Subtotal [ms]				
Config. Spectrometer			0				
Signal Measurement			0				
Spectrometer Exposure			300		Not included in total		
Spectrometer Sampling			3				
Data Transmission			4.6				
Save Data (2x)	20000	120000000	0.1666666667				
		Total:	0.1666666667				
ISR3 (Humidity)							
Operation	Data Size [B]	Comm. Rate [B/s]	Subtotal [ms]		**Main Total:**	**61.69579722**	**ms**
Grab Humidity Data	4	14400	0.2777777778		**Max Allowable Total:**	**100**	**ms**
Save Data	4	120000000	0.00003333333333				
		Total:	0.2778111111				

Structural Components

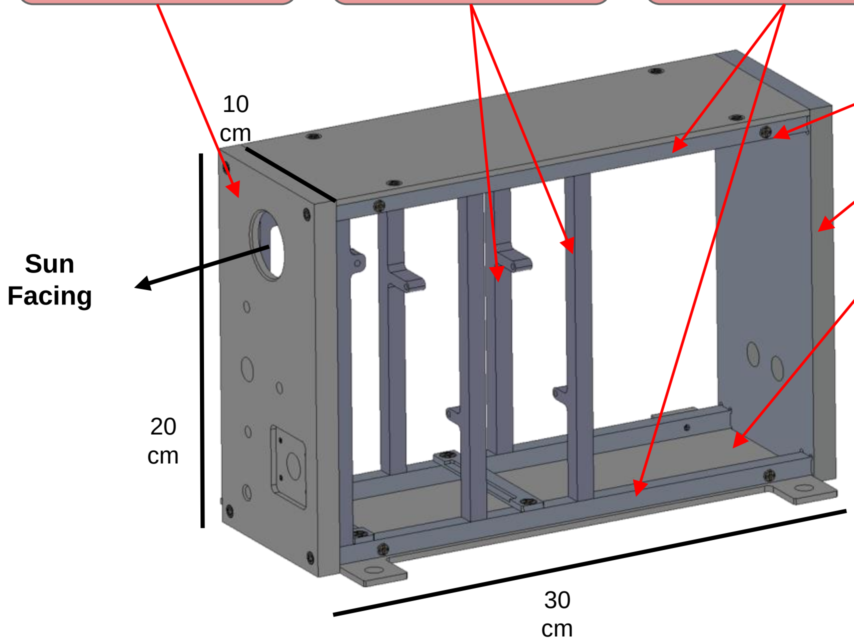
Front Plate*

Vertical Support Struts (x6)*

Horizontal Support Struts (x4)*

Back, Bottom, Top, Side Plates*

Hours Remaining: 40 (25% Margin)



Legend

Not Started

* - CAM/CNC Production

In Progress

** - 3D Print Production

Completed & Not Validated

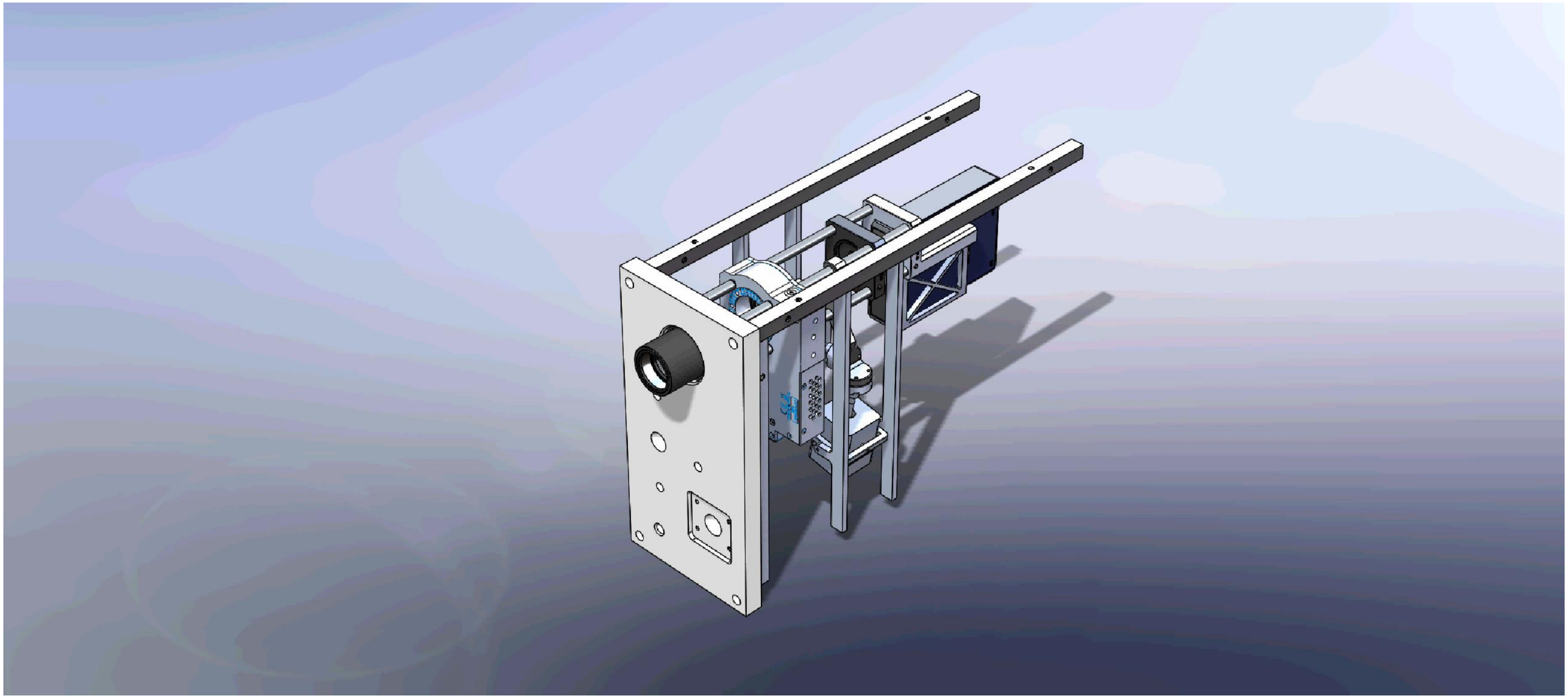
Procured

Completed & Validated

Summary

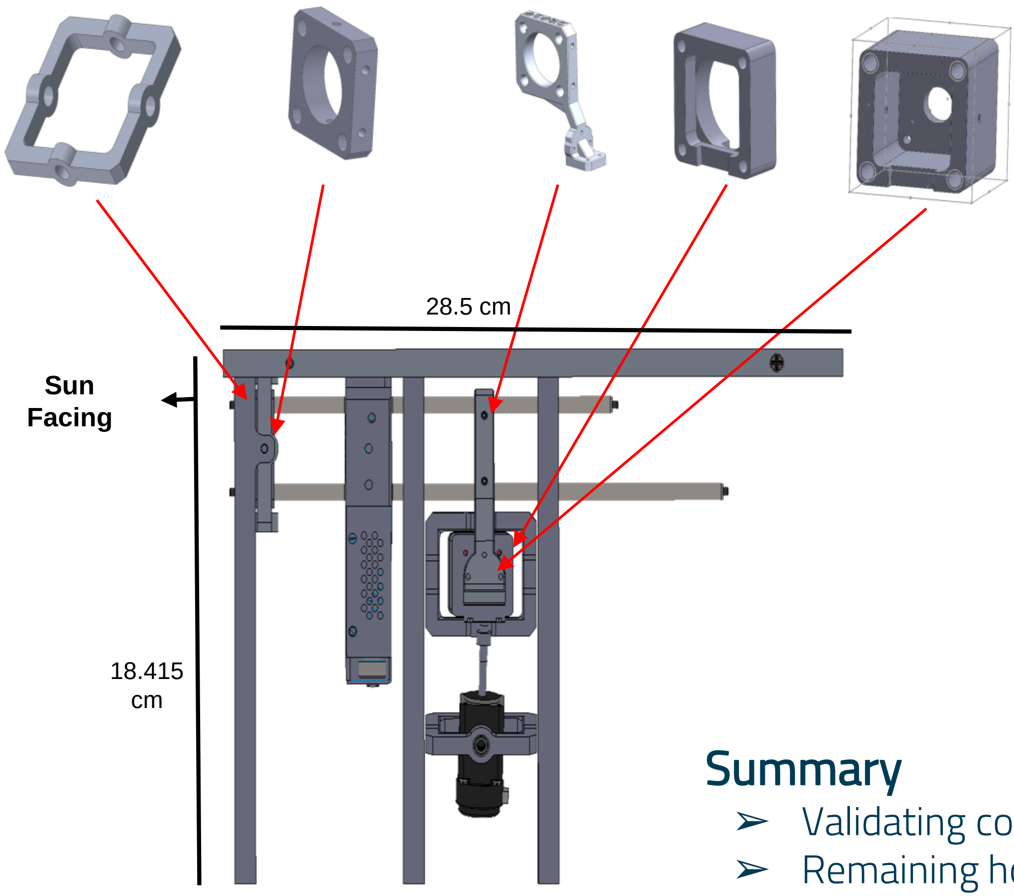
- ➢ Considerable time left but not a concern
- ➢ Simpler components for CAM/CNC manufacturing
- ➢ Approach of completing more complex components first

Pointing Control: Animation



Controls Components

Box Gimbals (x3)**	Front Inner Gimbal**	Pusher Arm**	Front Motor Mounts (x2)*	Back Motor Mounts (x2)*	Spherical Rolling Joints (x2)	Gimbal Rolling Joints (x14)	Gimbal Axles (x12)	Hours Remaining: 30 (20% Margin)



Side View

Legend

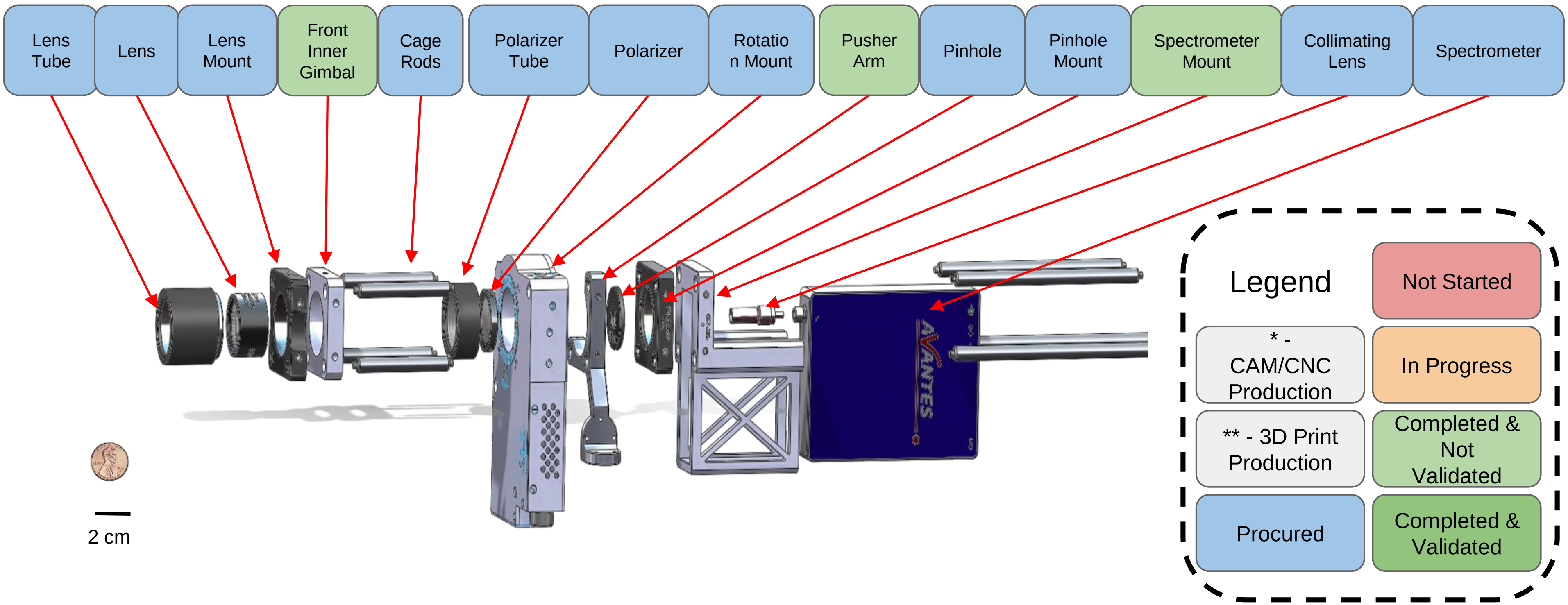
Legend	Not Started
* - CAM/CNC Production	In Progress
** - 3D Print Production	Completed & Not Validated
Procured	Completed & Validated

Summary

- ➢ Validating completed parts is a priority
- ➢ Remaining hours allocated to validating manufactured parts and finishing front motor mounts

Optics Components

Hours Remaining: 12 (20% Margin)



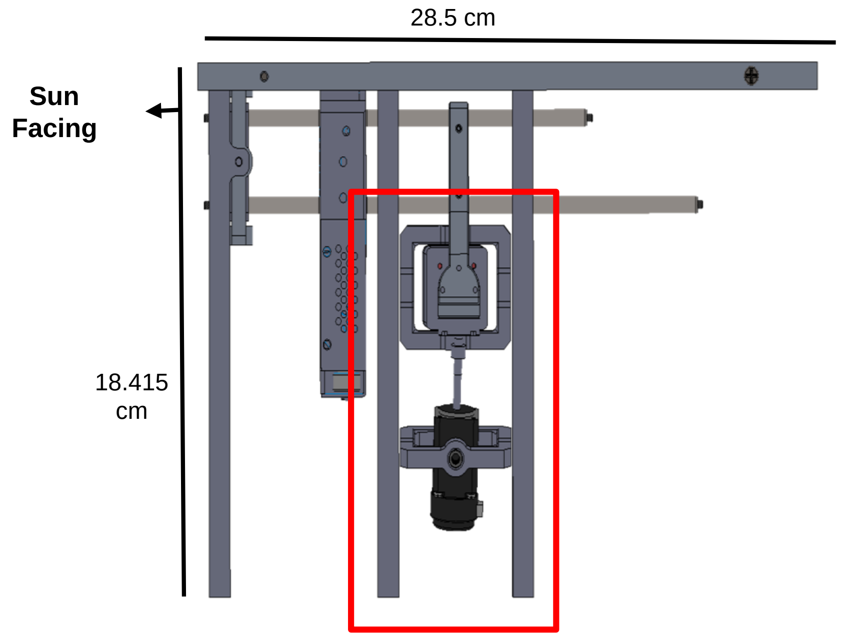
Summary

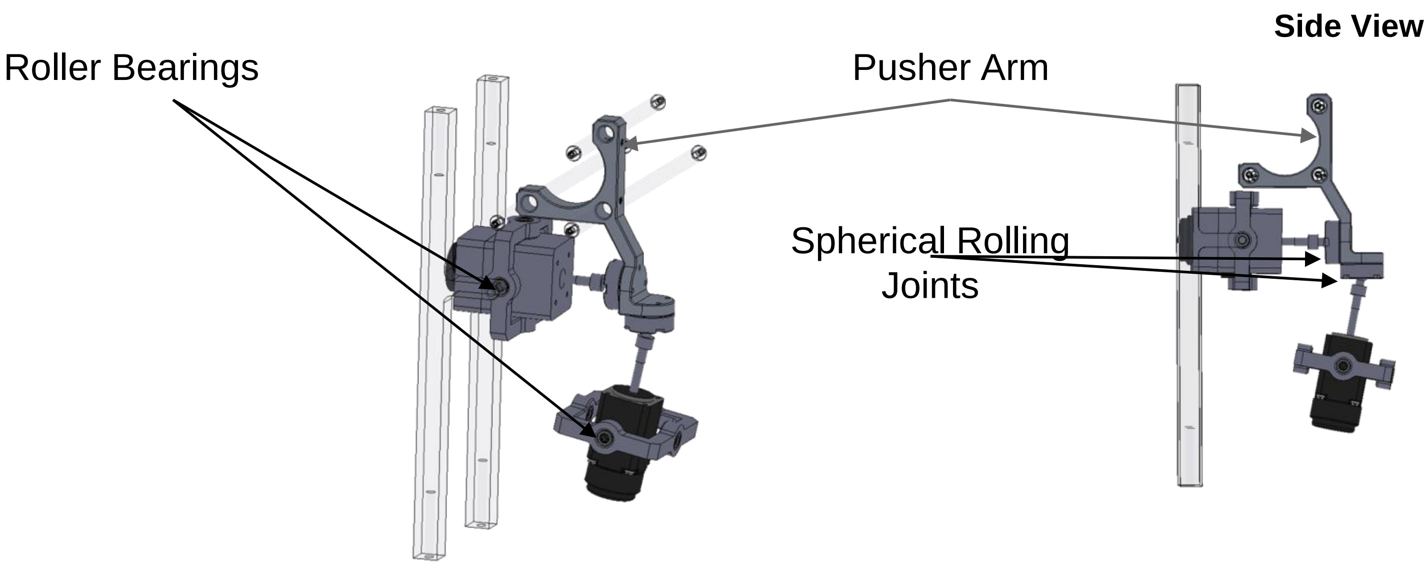
➢ Optics must still be assembled
➢ Need to validate 3D printed components to prevent breaking
➢ Remaining hours account for threading 3D printed parts and precise pinhole alignment, actual assembly will take ~3 hours

Critical Parts

Gimbal Assembly

- McMaster-Carr Needle Roller Bearings
- Pusher Arm
- Spherical rolling joints





Critical Parts

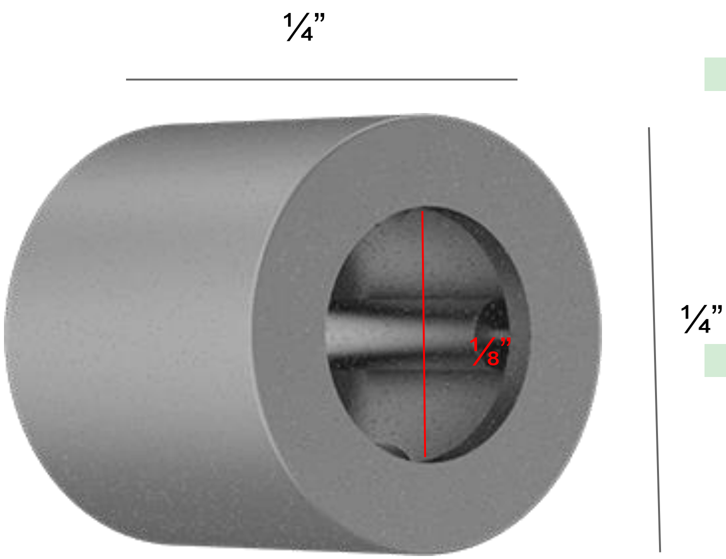
Needle Roller Bearing

Possible Issue(s):

- ➢ Bearing slack leads to inaccuracies in pointing angle

Solution(s):

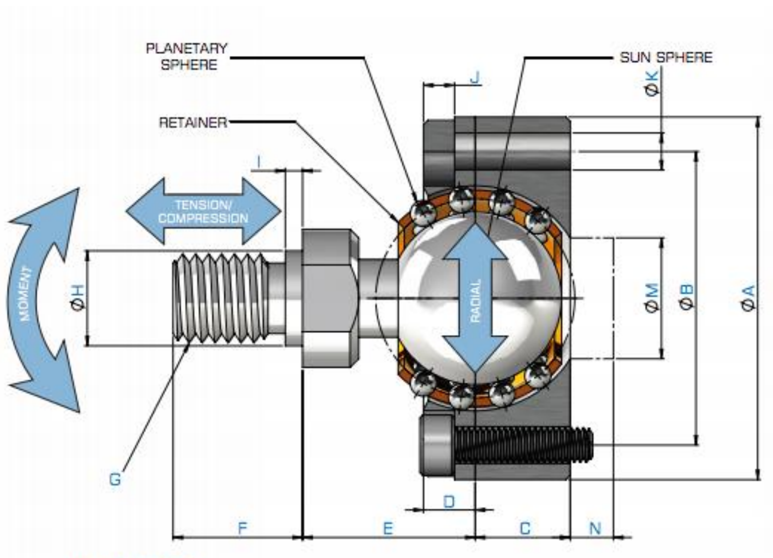
- ➢ Undersized gimbal holes
- ➢ Press fit into each gimbal
- ➢ Oversized pin press fit into bearing
- ➢ Minimizes bearing slack
- ➢ Manufacturing inaccuracies calibrated out



Critical Parts

Spherical Rolling Joint

- ➢ Skeptical to Component Conformance: “Each joint comes with a certificate of conformance indicating the actual tested accuracy” - Myostat Motion Control
- ➢ Concern: Relating error propagation in Rolling Joints, Pusher Arm, and Roller Bearings to optical pointing errors
- ➢ Monte Carlo simulation has been developed



DIMENSIONS

MODEL (units: mm)	A	B	C	D	E	F	G	H	I	J	K	M	N	WIDTH ACROSS FLATS
SRJ004C	19	15	3.8	2.5	10	6	M3x0.5	3.6	2	1.5	2	6	1.5	4

Manufacturing: Electrical

Electrical Overview

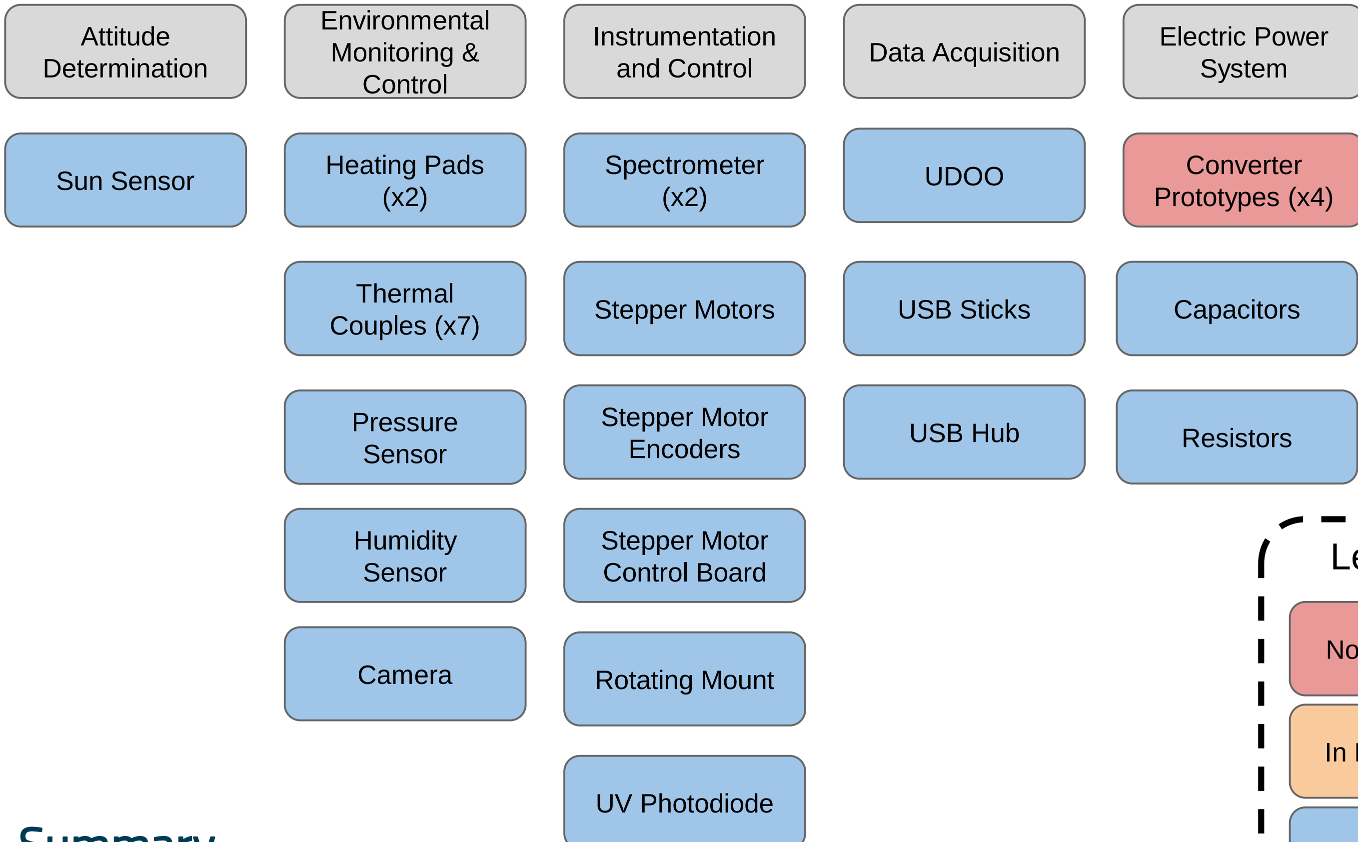
Component Overview:

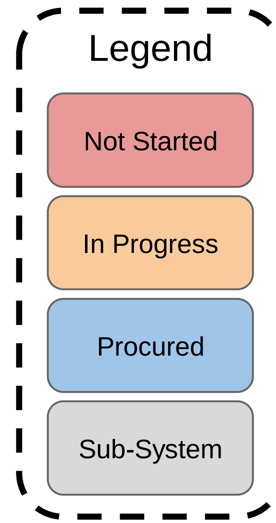
- ➢ PCB designed using Altium
- ➢ Manufactured components: converter prototypes
- ➢ Procured components: Sub-system sensors and equipment, power PCB, and circuit prototype components.
- ➢ Design and validation assistance from Dr. Erickson (EE)

Integration Plan

- ➢ Iterative process of breadboarding and FlatSat testing,
- ➢ Once PCB design is validated it will be procured from Advanced Circuits to include designed converters

Electrical Hardware Manufacturing Overview

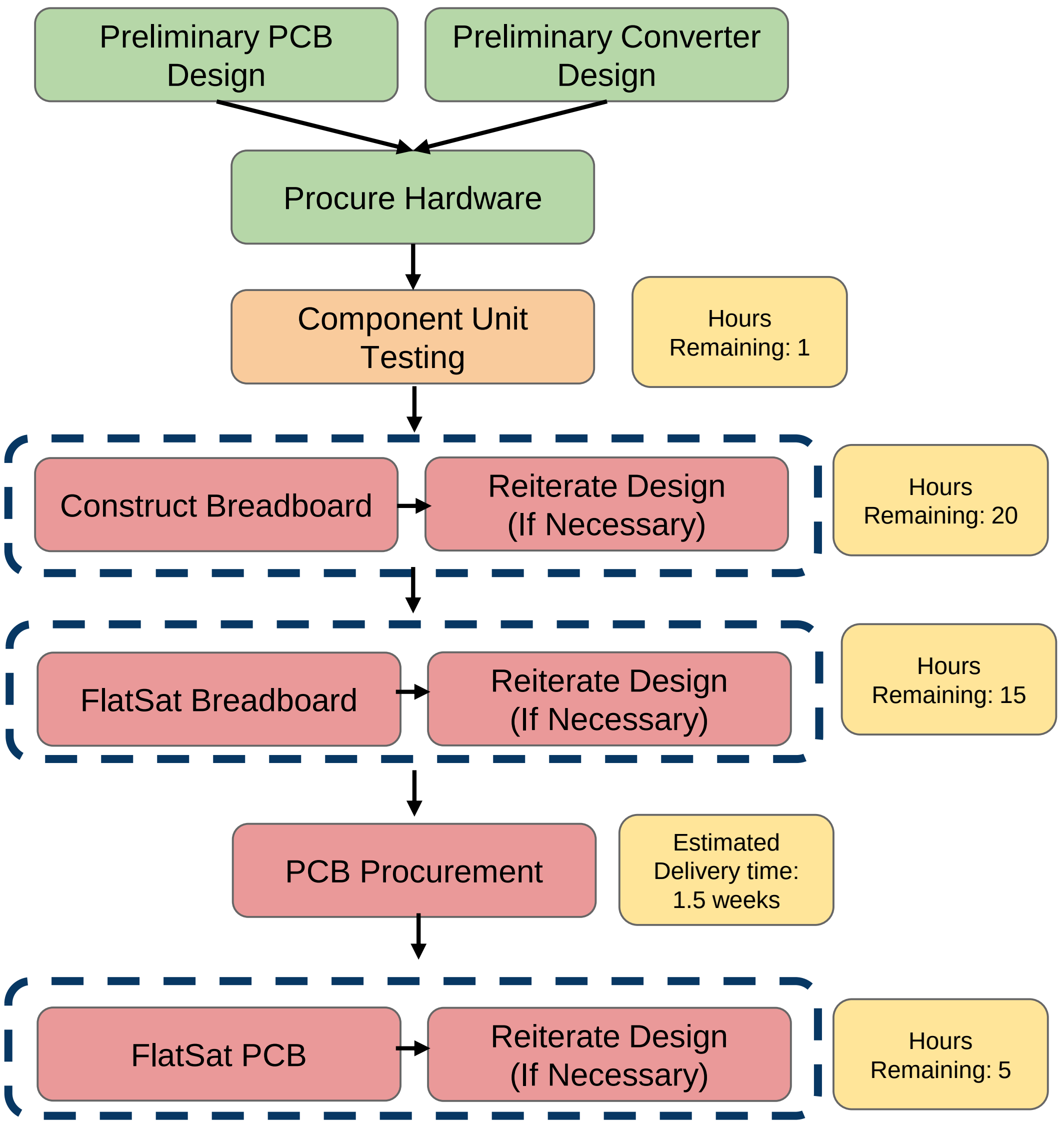


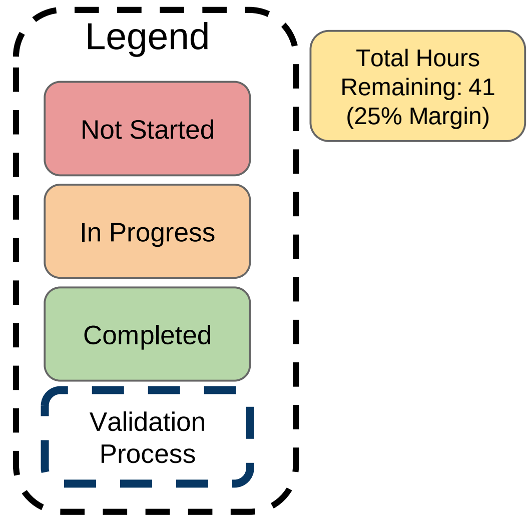


Summary

- ➢ Converters are the only component that will be manufactured
- ➢ Every other electrical component has been procured

Electrical Manufacturing Integration Plan





Summary

- ➢ This is an iterative process
- ➢ “Brunt” of effort to validating power allocation and PCB Design
- ➢ Biggest concern is validating PCB within schedule - if converter redesigns are necessary.

PCB Circuit Design