SYSTEM REQUIREMENTS REVIEW

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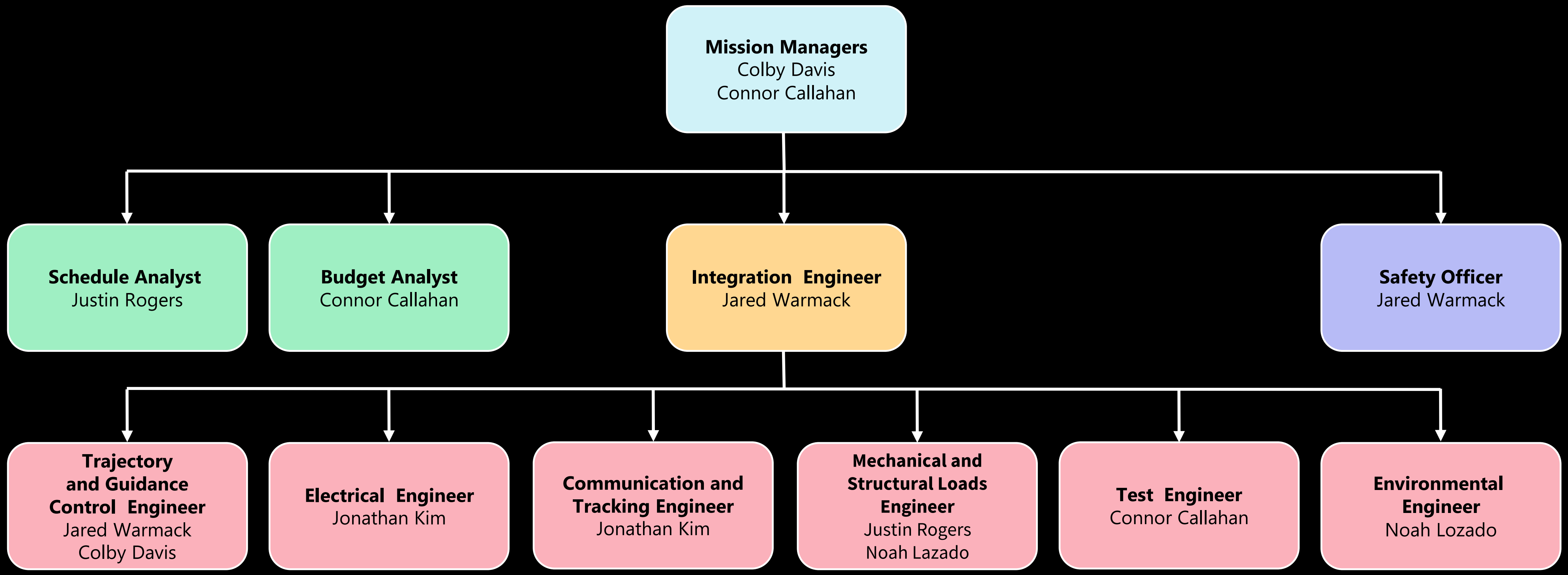
LIMESAT

Agenda

- Team Structure
- Mission Goal Statement
- Mission Objectives
- ConOps
- Integrated Schedule
- External/Internal Interfaces
- Work Breakdown Structure (WBS)
- Requirement Flow Down
- Initial Risk Assessment
- Open Items

Team Structure



Mission Goal Statement

- The CubeSat satellite "LunOSTAR" will observe the Sun's corona using occultations of the sun via the Earth - Moon system with an orbit around LaGrange Point L4.

Mission Objectives

OBJECTIVE 1: Design, test, and launch the CubeSat to the space station Gateway at L2.

OBJECTIVE 2: Once at Gateway it will deploy the CubeSat from L2 to L4 where it will establish a Short-Period Orbit (SPO) that will maximize observations of the Sun's corona.

OBJECTIVE 3: Observe, record, and transmit to earth the solar corona data in the NUV wavelengths.

ConOps

LunOSTAR Mision

LunOSTAR Mission ConOps: Pre-Launch

Manufacturing → Testing → Assembly → Transport

LunOSTAR Mission ConOps: Deployment

Deployment → **System Testing** → **Maneuver** → **Arrive at L4**

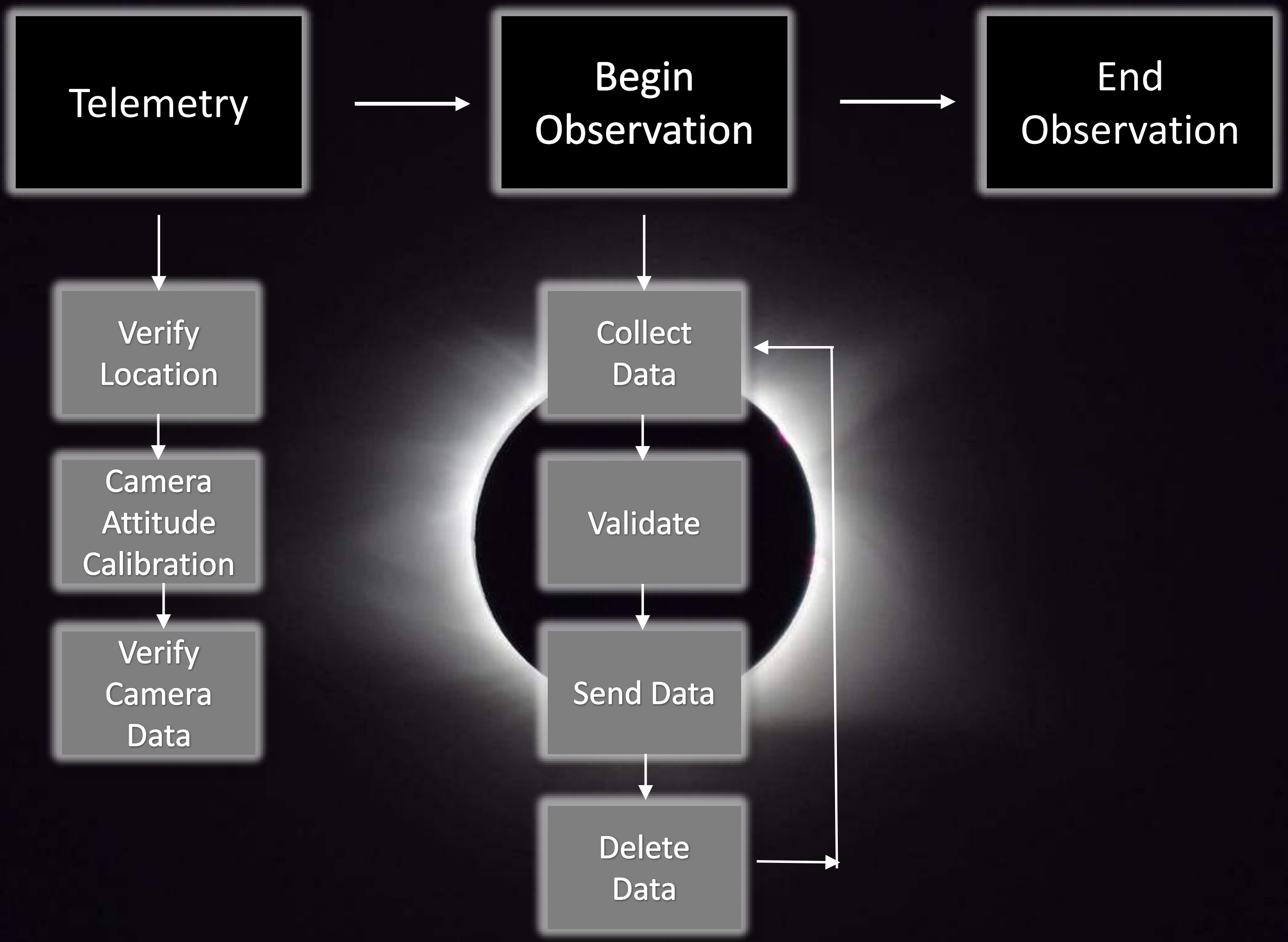
Deployment
- Avoidance Maneuver T+30sec

System Testing
- Detumble T+5min
- Solar Panel Deploy T+10min
- Extend Antenna T+15min
- Contact T+20min
- Systems Check T+30min

Maneuver
- Initial Burn T+45min
- Adjustments

Arrive at L4
- SPO Burn

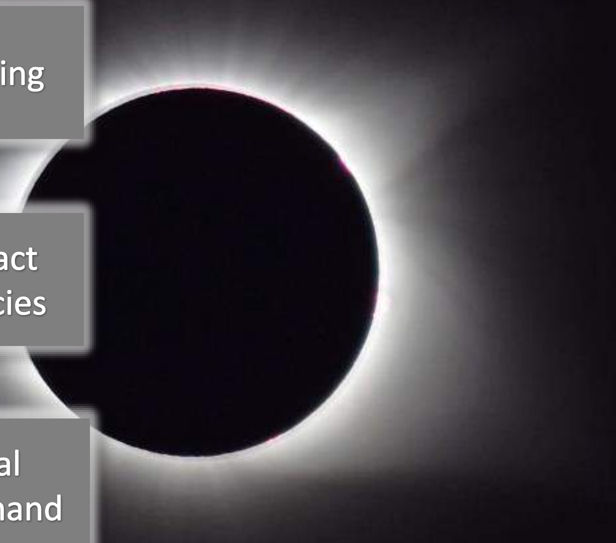
LunOSTAR Mission ConOps: Post-Deployment



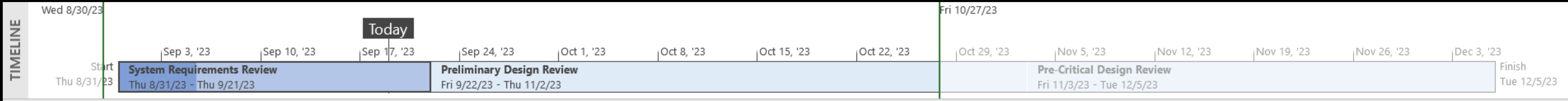
LunOSTAR Mission ConOps: Retirement

Final Check → Disposal → Post-Mission Analysis → Final Report

- Final Check
  - Data Backup ↓
  - System Check ↓
  - Passivation
- Disposal
  - Planning ↓
  - Contact Agencies ↓
  - Final Command ↓
  - Monitor

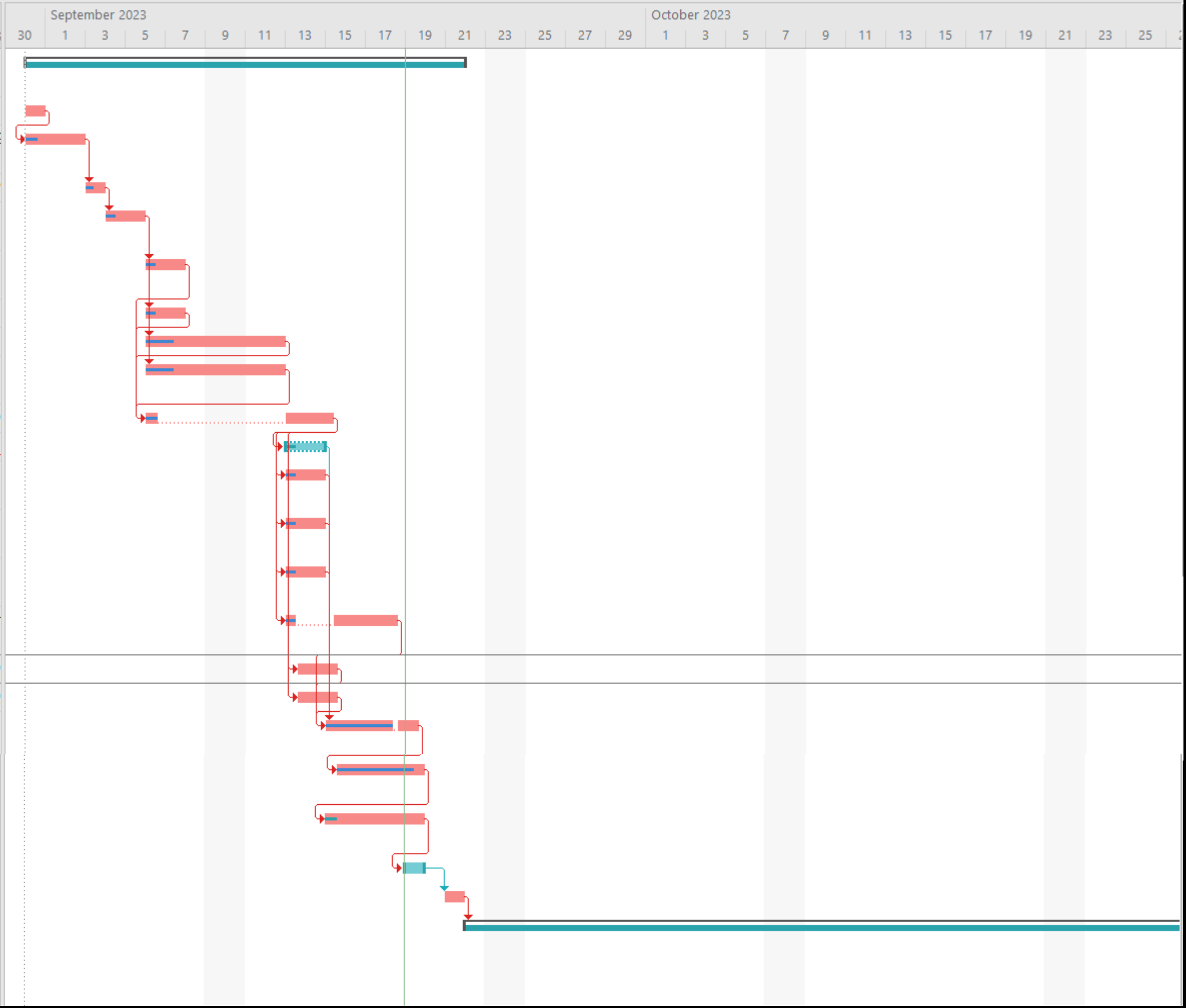


INTEGRATED SCHEDULE

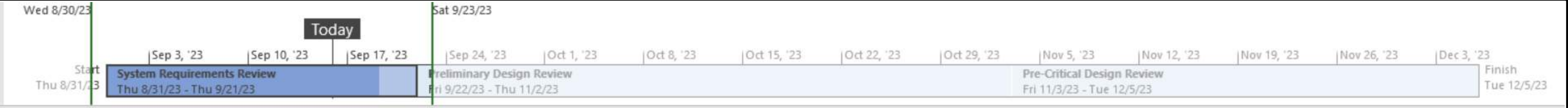


GANTT CHART

	Task Mode	Task Name	Duration	Start	Finis
1		**System Requirements Review**	**18 days?**	**Thu 8/31/23**	**Thu**
2		Team Organization	1 day	Thu 8/31/23	Thu
3		Add Requirements to Revision A	3 days	Thu 8/31/23	Sat 9
4		Review Meeting	1 day	Sun 9/3/23	Sun
5		Add Requirements to Revision B	2 days	Mon 9/4/23	Tue
6		Integrated Schedule for SRR	2 days	Wed 9/6/23	Thu
7		General ConOps	2 days	Wed 9/6/23	Thu
8		OISR #1	5 days?	Wed 9/6/23	Tue
9		Finish Requirements to Revision B	5 days?	Wed 9/6/23	Tue
10		Expand ConOps	3 days	Wed 9/6/23	Fri 9
11		Finish ConOps	2 days	Wed 9/13/23	Thu
12		Requirements Verification Matrix	2 days	Wed 9/13/23	Thu
13		Statement of Mission Goal	2 days	Wed 9/13/23	Thu
14		Objectives of Proposed Mission	2 days	Wed 9/13/23	Thu
15		Work Breakdown Structure (WBS)	2 days	Wed 9/13/23	Mor
16		Background Studies	2 days	Wed 9/13/23	Fri 9
17		Initial Risk Assessment	2 days	Wed 9/13/23	Fri 9
18		System Internal and External Interfaces	2.25 days	Fri 9/15/23	Tue
19		Verification and Validation Plans	2.25 days?	Fri 9/15/23	Tue
20		Create Slides for Presentation	3 days	Fri 9/15/23	Tue
21		Practice Presentation	1 day	Tue 9/19/23	Tue
22		SRR Presentation	1 day	Thu 9/21/23	Thu
23		**Preliminary Design Review**	**30 days**	**Fri 9/22/23**	**Thu**
25		**Pre-Critical Design Review**	**23 days**	**Fri 11/3/23**	**Tue**

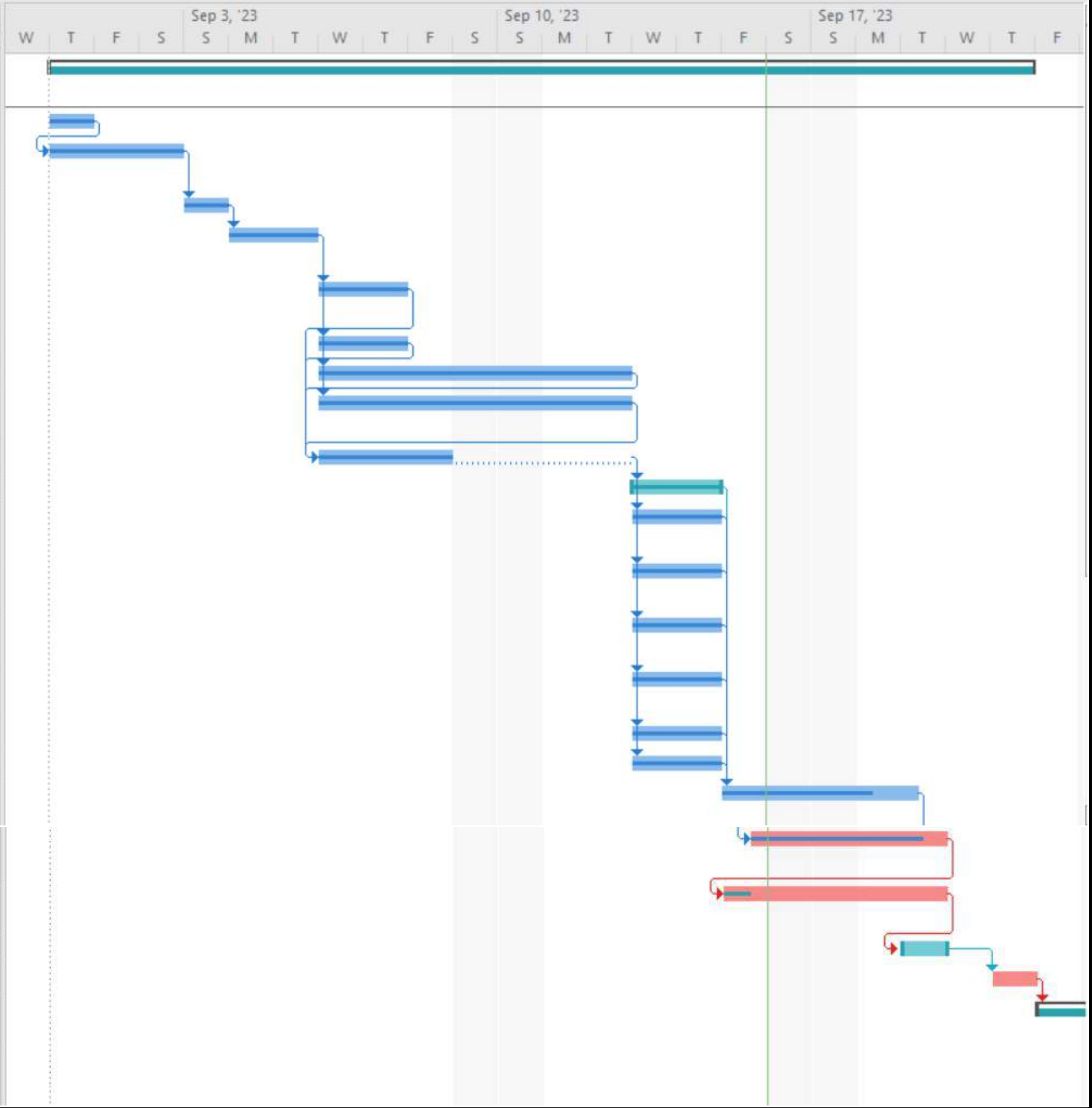


TIMELINE



GANTT CHART

		Task Mode	Task Name	Duration	Start	Finish	Predecessors	R N
1			**System Requirements Review**	**18 days?**	**Thu 8/31/23**	**Thu 9/21/23**		
2	✓		Team Organization	1 day	Thu 8/31/23	Thu 8/31/23		
3	✓		Add Requirements to Revision A	3 days	Thu 8/31/23	Sat 9/2/23	2	
4	✓		Review Meeting	1 day	Sun 9/3/23	Sun 9/3/23	3	
5	✓		Add Requirements to Revision B	2 days	Mon 9/4/23	Tue 9/5/23	4	
6	✓		Integrated Schedule for SRR	2 days	Wed 9/6/23	Thu 9/7/23	5	
7	✓		General ConOps	2 days	Wed 9/6/23	Thu 9/7/23	5	
8	✓		OISR #1	5 days?	Wed 9/6/23	Tue 9/12/23	5	
9	✓		Finish Requirements to	5 days?	Wed 9/6/23	Tue 9/12/23	5	
10	✓		Expand ConOps	3 days	Wed 9/6/23	Tue 9/12/23	7,6,9,8	
11	✓		Finish ConOps	2 days	Wed 9/13/2:	Thu 9/14/23	10	
12	✓		Requirements Verification Matrix	2 days	Wed 9/13/23	Thu 9/14/23	10	
13	✓		Statement of Mission Goal	2 days	Wed 9/13/23	Thu 9/14/23	10	
14	✓		Objectives of Proposed Mission	2 days	Wed 9/13/23	Thu 9/14/23	10	
15	✓		Work Breakdown Structure (WBS)	2 days	Wed 9/13/23	Thu 9/14/23	10	
16	✓		Background Studies	2 days	Wed 9/13/2:	Thu 9/14/23	10	
17	✓		Initial Risk Assessme	2 days	Wed 9/13/2:	Thu 9/14/23	10	
18			System Internal and External Interfaces	2.25 days	Fri 9/15/23	Tue 9/19/23	17,11,12,13,14,1!	
19			Verification and Validation Plans	2.25 days?	Fri 9/15/23	Tue 9/19/23	18	
20			Create Slides for Presentation	3 days	Fri 9/15/23	Tue 9/19/23	19	
21			Practice Presentatio	1 day	Tue 9/19/23	Tue 9/19/23	20	
22			SRR Presentation	1 day	Thu 9/21/23	Thu 9/21/23	21	
23			**Preliminary Design Review**	**30 days**	**Fri 9/22/23**	**Thu 11/2/23**	**22**	
25			**Pre-Critical Design Review**	**23 days**	**Fri 11/3/23**	**Tue 12/5/23**	**23**	



External/Internal Interfaces

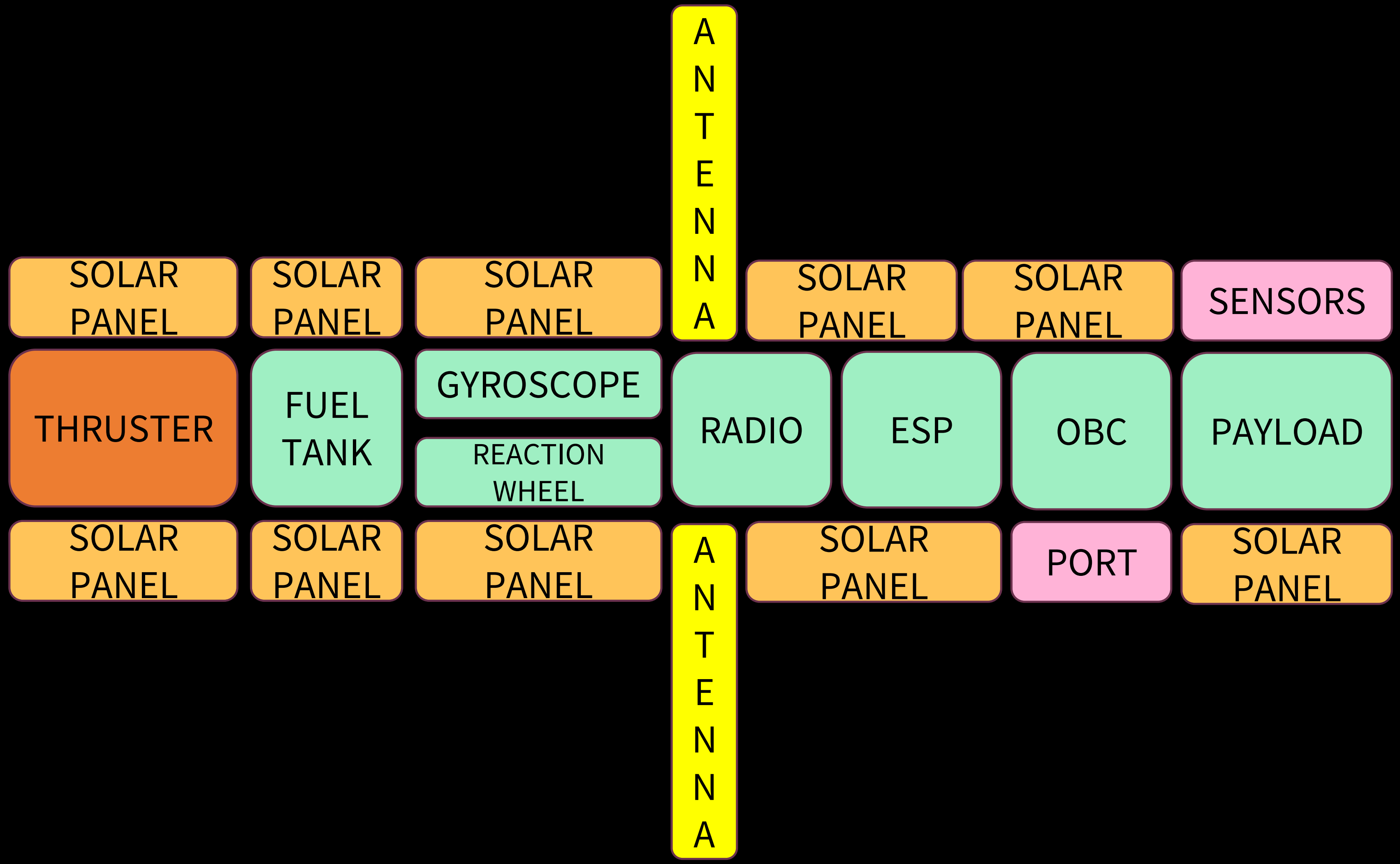
External

- Solar Panels
- Sensors
  - Sun Sensor
  - Star Tracker
  - Horizontal Sensor
- Antennas
- Data/Power Port
- Thruster
- Launch Support Rail
- Remove Before Launch Pin

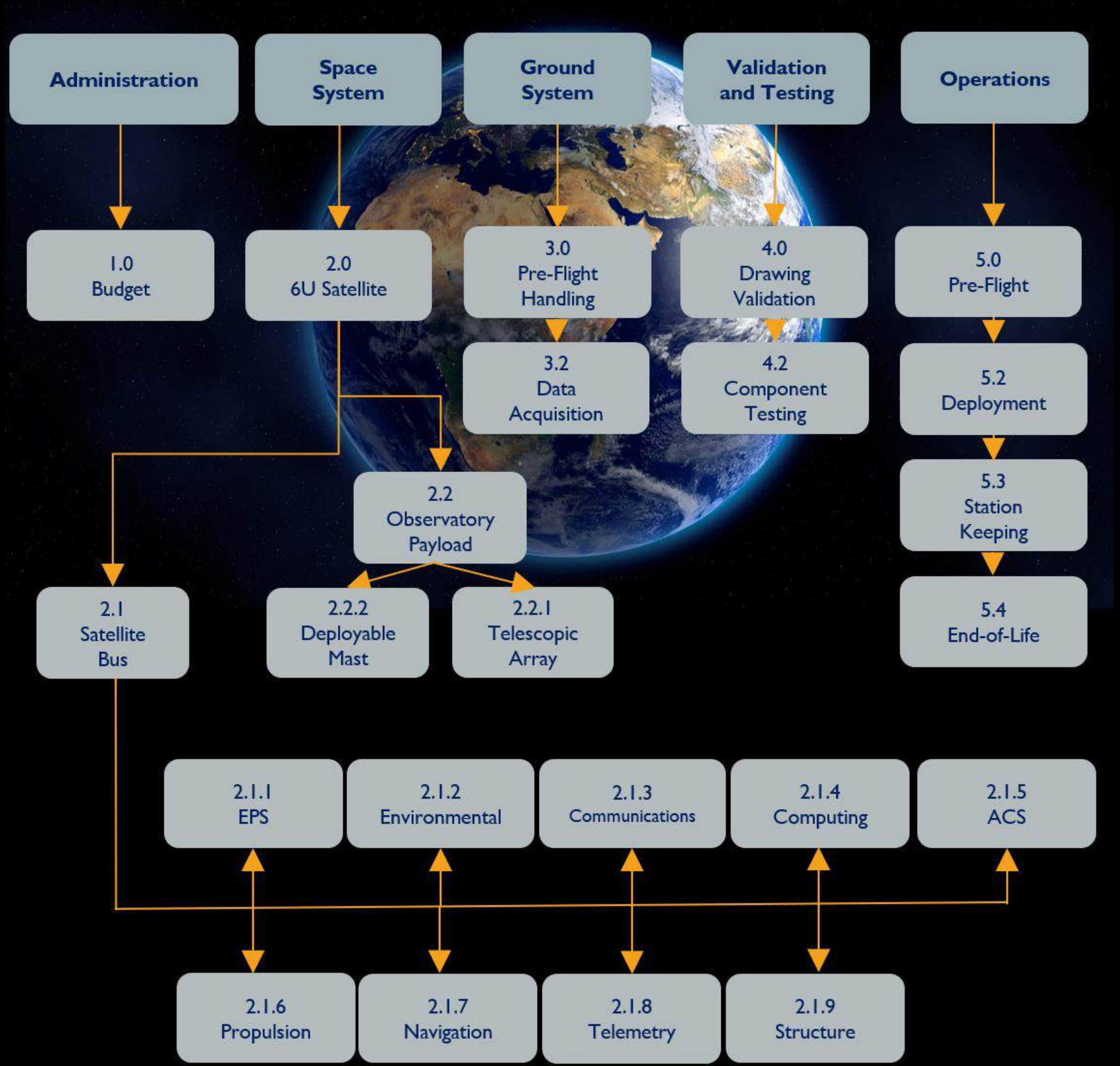
Internal

- BUS
  - OBC
  - EPS
  - Communication
  - Attitude Control
  - Fuel Tank
- PAYLOAD
  - 2 Co-Aligned Telescopes
  - Focal Plane Module

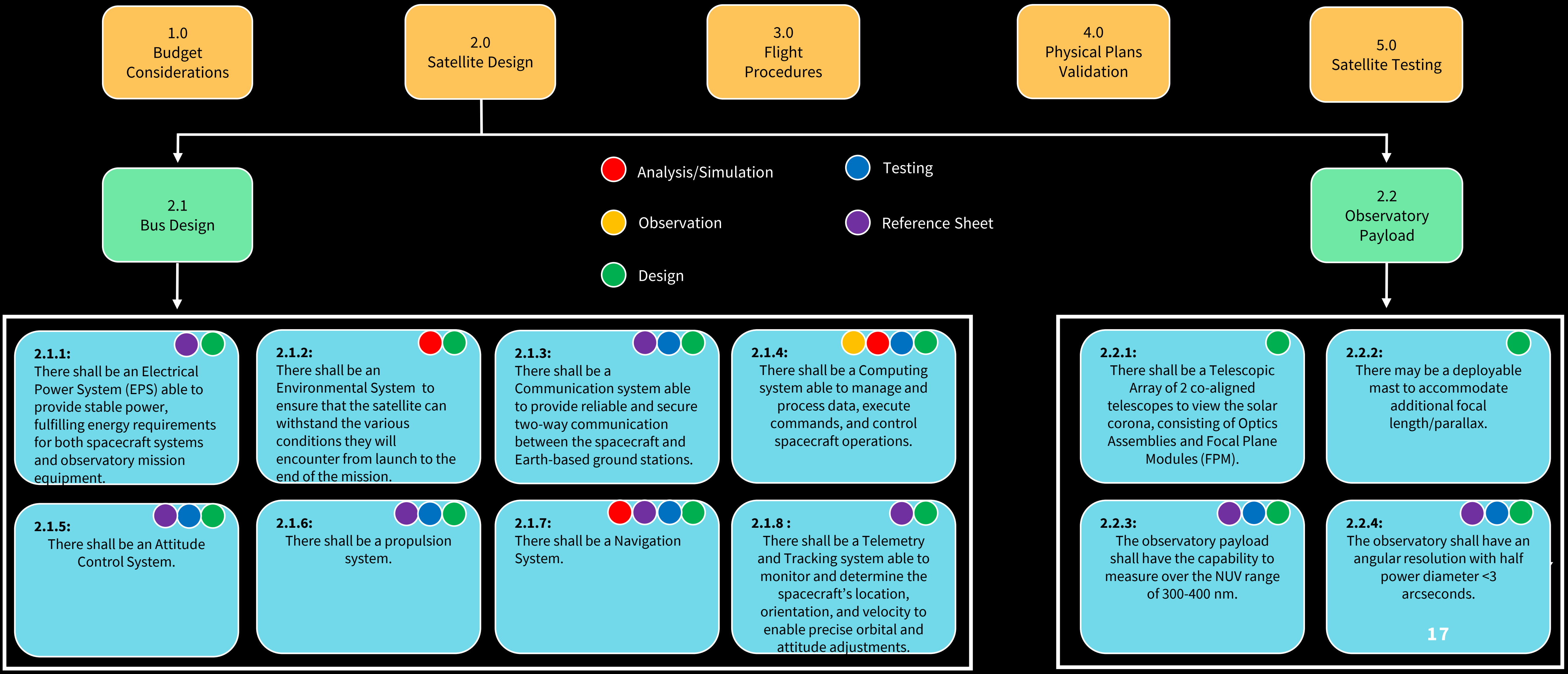
External/Internal Interfaces



Work Breakdown Structure



Requirement Flow Down Example



Mission Requirements Example

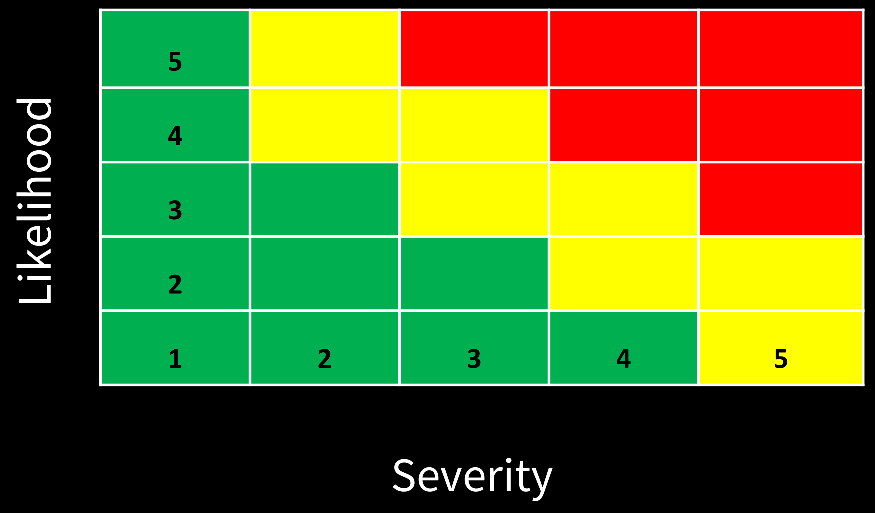
Requirement Level	Requirement Number	Requirement	Verification Model					Verification Methods
			A	O	D	T	R	
		Administration						
0	1.0	There shall be a budget of one million dollars for design, development, and mission operations.			X			Verify prices of parts with design parameters and determine, if necessary, that parts are within budget.
		Space System						
0	2.0	There shall be a 6U Satellite (30x20x10cm) which contains all necessary equipment and materials to conduct the scientific objectives and support mission operations.		X	X			Compare completed plan with physical measurements to ensure validity.
1	2.1	There shall be a Bus.			X			The bus will be designed considering structural loads during launch, and any other necessary maneuvers
2	2.1.1	There shall be an Electrical Power System (EPS) able to provide stable power, ensuring the fulfillment of energy requirements for both spacecraft systems and observatory mission equipment.			X			Calculate power requirements of each system and design or choose a preexisting system that meets those power needs

Mission Requirements Example

3	2.1.1.1	The EPS shall include a rechargeable battery capable of storing enough energy to power the operational needs of the spacecraft during periods when solar power generation is not possible.		X		X	X	Test battery capability with reference to batteries datasheet and verify battery capacity and output.	
3	2.1.1.2	The EPS shall include solar panels that can generate sufficient power to meet the operational needs of the spacecraft.			X		X	Verify with solar panel datasheet that sufficient power can be created to keep batteries charged.	
3	2.1.1.3	The EPS shall distribute power to all systems compatible with their voltage and current requirements.		X	X	X	X	Test that electrical power system can verify where power is needed and distribute power accordingly and compare to datasheet.	

Initial Risk Assessment

Failure Mode	Failure Cause	S	L	C	Failure Detection	Preventative Action
Reaction Wheel	Vibration	2	3	6	Loss of Attitude Control	Redundant wheels
Contact	Attitude Failure	5	1	5	No Contact	Testing
	Antenna Failure	5	1	5	No Contact	
	Connection Failure	5	1	5	No Contact	
RCW	Saturation	5	2	10	Loss of Control	Extra Fuel
Fuel	Over Burn	5	1	5	Trajectory	Extra Fuel
Batteries	Degradation	4	1	4	Loss of Power	Testing
Antenna	Failure to Deploy	5	1	5	No Contact	
Camera Sensors	Radiation	5	1	5	Poor Image Quality	Testing
Electronics	Radiation	5	1	5	Loss of Control	Radiation Shielding



Open Items

- Continuing Research
  - Orbit analysis
    - STK Simulations
  - Thruster/ACS requirements
  - Power/Computing requirements
  - Standard adherence
    - Identify material testing standards (vibration and shock)
  - Observatory
    - Identify optics and focusing plates
    - Determine feasibility of extendable mast
- Develop ConOps
  - Expand on the demise of the CubeSat

QUESTIONS?

Sources

- Chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://standards.nasa.gov/sites/default/files/standards/NASA/B/0/Historical/nasa-std-6016a.pdf
- https://ntrs.nasa.gov/citations/19970027853
- LunOSTAR Program Level Requirements

Appendix

Requirement Level	Requirement Number	Requirement	Verification Model A	O	D	T	R	Verification Methods	Status
		Administration							
0	1.0	There shall be a budget of one million dollars for design, development, and mission operations.			X			Verify prices of parts with design parameters and determine, if necessary, that parts are within budget.	
		Space System							
0	2.0	There shall be a 6U Satellite (30x20x10cm) which contains all necessary equipment and materials to conduct the scientific objectives and support mission operations.		X	X			Compare completed plan with physical measurements to ensure validity.	
1	2.1	There shall be a Bus.			X			The bus will be designed considering structural loads during launch, and any other necessary maneuvers	
2	2.1.1	There shall be an Electrical Power System (EPS) able to provide stable power, ensuring the fulfillment of energy requirements for both spacecraft systems and observatory mission equipment.			X		X	Calculate power requirements of each system and design or choose a preexisting system that meets those power needs	
3	2.1.1.1	The EPS shall include a rechargeable battery capable of storing enough energy to power the operational needs of the spacecraft during periods when solar power generation is not possible.		X		X	X	Test battery capability with reference to batteries datasheet and verify battery capacity and output.	
3	2.1.1.2	The EPS shall include solar panels that can generate sufficient power to meet the operational needs of the spacecraft.			X		X	Verify with solar panel datasheet that sufficient power can be created to keep batteries charged.	
3	2.1.1.3	The EPS shall distribute power to all systems compatible with their voltage and current requirements.		X	X	X	X	Test that electrical power system can verify where power is needed and distribute power accordingly and compare to datasheet.	
3	2.1.1.4	The EPS shall regulate power to stable levels that meet the requirements of all systems of the spacecraft.		X		X	X	Test that power supplied to components is steady and the amount of noise is minimal with reference to the datasheet.	

Appendix

Requirement Level	Requirement Number	Requirement	Verification Model: A	O	D	T	R	Verification Methods	Status
3	2.1.1.5	The EPS shall have a lifespan that exceeds 25-month mission duration, accounting for environmental factors.					X	Compare usage of power system to expected mission duration.	
2	2.1.2	There shall be an Environmental System designed to ensure that the satellite systems and payload can withstand the various conditions they will encounter from launch to the end of the mission.	X		X			Structural design will ensure no failure from G loads, protective material around payload will protect from vibrational loads/resonance.	
3	2.1.2.1	Materials and controls will be put into place to manage thermal pressures from the environment.	X		X		X	Thermal simulation will be done and compared to sage temperature allowances for materials used.	
3	2.1.2.2	Cosmic Radiation should be managed to mitigate damage to payload, instruments, and electronics.					X	Compare expected radiation levels to references for sensitive electronics and instruments.	
3	2.1.2.3	Solar Radiation should be managed to mitigate damage to structures, payload, instruments, and electronics.	X		X	X	X	Simulate sunlight exposure time and heating/cooling cycles, Test materials for UV resistance, payload shielded from direct sun exposure.	
3	2.1.2.4	Components of satellite will be able to operate in vacuum conditions without convective cooling.			X	X	X	Design and test cooling system that can mitigate temperatures on electronic and instruments to appropriate levels dependent on their reference sheet.	
3	2.1.2.5	The satellite shall be resistant to electro-magnetic interference.			X	X		Design satellite with protection from EMI in the form of insulation and frequency hopping techniques.	
2	2.1.3	There shall be a Communication system able to provide reliable and secure two-way communication between the spacecraft and Earth-based ground stations.			X	X	X	Choose a communication system which is capable of transmitting and receiving from cislunar space and test communication system for functionality.	

Appendix

Requirement Level	Requirement Number	Requirement	Verification Model A	O	D	T	R	Verification Methods	Status
3	2.1.3.1	The communication system shall be able to provide the essential uplink and downlink data rates for both payload data and command/control instructions.			X	X	X	Test uplink and downlink data rates and compare to reference sheet.	
3	2.1.3.2	The communication system shall have adequate antenna coverage to establish a stable signal link between the spacecraft and the ground station.			X		X	Review manufacturer documentation, datasheets, and design documents.	
3	2.1.3.3	The communication system shall be operated within VHF and UHF frequency bands, in compliance with international regulations.				X	X	Test the system under controlled environment to check both transmit and receive data within the specified VHF and UHF bands.	
3	2.1.3.4	The communication system shall have error detection and correction techniques to ensure the integrity of transmitted and received data.	X			X		Simulate transmission scenarios with injected errors to observe the system's ability to detect and correct them.	
2	2.1.4	There shall be a Computing system able to manage and process data, execute commands, and control spacecraft operations.	X	X	X	X		The computing system will be designed/chosen based off necessary possessing power for spacecraft systems	
3	2.1.4.1	The computing system shall have sufficient processing power to process all spacecraft operations.	X			X		Overload the system with tasks and data to evaluate how it performs under maximum stress.	
3	2.1.4.2	The computing system shall manage all data by collecting, storing, and transmitting it.	X		X	X		Simulate the entire process of data collection, storage, and transmission to ensure seamless integration of all steps.	
3	2.1.4.3	The computing system shall have the ability to receive and implement software updates transmitted from the ground station.			X	X		Simulate a software update and ability to rollback if update fails or causes issues.	

Appendix

Requirement Level	Requirement Number	Requirement	Verification Model					Verification Methods	Status
			A	O	D	T	R		
3	2.1.4.4	The computing system shall incorporate security measures to protect the system against unauthorized access.	X		X		X	Perform vulnerability assessment and security architecture analysis and simulate various threat scenarios to determine how system would respond.	
3	2.1.4.5	The computing system shall uphold precise timekeeping, in synchronization with a universal time standard, for all mission operations and data logging.	X			X		Test synchronization with a universal time standard source.	
3	2.1.4.6	The computing system shall promptly and accurately carry out commands received from the ground station.	X			X		Simulate by transmitting a series of commands from a ground station and observe the system's response and accuracy.	
2	2.1.5	There shall be an Attitude Control System.			X	X	X	MATLAB/Simulink	
3	2.1.5.1	The attitude of the spacecraft should be controlled within ± 10 arcseconds during each occultation opportunity.	X					The control system simulation shall be conducted in MATLAB/Simulink	
3	2.1.5.2	The ACS shall provide stable control of the spacecraft.	X		X			MATLAB/Simulink	
2	2.1.6	There shall be a Propulsion system.			X	X	X	Nozzle and system will be designed considering thrust requirements and physics of space propulsion	
3	2.1.6.1	The Propulsion system shall have adequate fuel for the duration of the prescribed mission length, and an additional 5% ΔV for unplanned/recovery maneuvers.	X		X			Maneuvers and attitude control system desaturation shall be simulated using STK/MATLAB/Simulink	
3	2.1.6.2	The Propulsion system shall enable controlled disposal at the end of the mission life.	X		X			The design should account for enough fuel for disposal.	
2	2.1.7	There shall be a Navigation system.		X	X	X	X	Star Tracker/Sun Sensor	

Appendix

3	2.1.7.1	The Navigation system should consist of an adequate selection of Star Tracker, Horizon Sensor, Gyroscope, Sun Sensor, or others, in order to accurately determine the orientation and position of the spacecraft.			X			Validate each sensor's functionality and integration in simulated conditions.	
2	2.1.8	There shall be a Telemetry and Tracking system able to monitor and determine the spacecraft's location, orientation, and velocity to enable precise orbital and attitude adjustments.			X		X	Star Tracker for location, Sun Sensor for Orientation, velocity with respect to the lunar surface	
3	2.1.8.1	The T&T system shall consistently gather telemetry data from all subsystems and payloads to monitor health and operational status.	X				X	Simulate a scenario where the system collects data from all subsystem and payload as intended.	
3	2.1.8.2	The T&T system shall provide accurate tracking data of the spacecraft's position, and velocity measurements.	X					Simulate software algorithms and methods for tracking to ensure accuracy.	
3	2.1.8.3	The T&T system shall have all telemetry data be time-tagged.	X			X		Simulate by injecting series of events or data into the system and verify that each data point has an associated time stamp.	

Requirement Level	Requirement Number	Requirement	Verification Model					Verification Methods	Status
			A	O	D	T	R		
2	2.1.9	There shall be a Structural system able to provide housing and protection for all subsystems and payloads.			X			Hand calculations will be used to test the structural design.	Complete d
3	2.1.9.1	The material of the spacecraft will be an Aluminum alloy			X		X	Material will be inspected to confirm it follows NASA-STD-6016A standards	Complete d
4	2.1.9.1.1	The aluminum alloy should be resistant to general corrosion, pitting, intergranular corrosion, and stress corrosion cracking			X	X	X	Material will be inspected to confirm it follows NASA-STD-6016A standards	

Appendix

Requirement Level	Requirement Number	Requirement	A	O	D	T	R	Verification Methods	Status
3	2.1.9.2	The structural system of the spacecraft will adhere to NASA guidelines and refrain from using any hazardous materials such as Beryllium, cadmium, mercury, silver, or any other such materials.					X	Material will be inspected to confirm it follows NASA-STD-6016A standards	
3	2.1.9.3	Any non-metallic materials used will have a Total Mass Loss (TML) and Collected Volatile Condensable Material (CVCM) equal to or lower than a maximum 1.0 percent TML and a maximum 0.10 percent CVCM.					X	Material will be inspected to confirm it follows NASA guidelines based on current outgassing data	
3	2.1.9.4	Geometry and Dimensions shall comply with the standard cube sat unit system, and will comply with the 6U specification.		X	X			20 cm x 10 cm x 34.05 cm, rectangular prism shape	Complete d
3	2.1.9.5	The payload should be able to withstand around 0.5 Gs of stress during Lunar launch				X		The payload will be vibration tested to ensure it can survive shock from ignition	Complete d
1	2.2	There shall be an Observatory Payload.			X			Observatory will use Near UV imaging techniques	
2	2.2.1	There shall be a Telescopic Array of 2 co-aligned telescopes to view the solar corona, consisting of Optics Assemblies and Focal Plane Modules (FPM).			X			The design will include two observational telescopes.	
3	2.2.1.1	The Optics Assembly shall consist of focusing lenses which transfer optical information to the FPM.			X		X	Verify type of data transfer is possible with telescope being used through reference sheet.	
3	2.2.1.2	The Focal Plane Module shall consist of a Near Ultra-Violet (NUV) sensitive CCD capable of interfacing with the data transmission hardware.			X	X	X	Verify data can be collected in NUV using reference sheet compared to test and that data can be transferred with chosen hardware.	

Verification Model: A, O, D, T, R

Appendix

Requirement Level	Requirement Number	Requirement	Verification Model A	O	D	T	R	Verification Methods	Status
2	2.2.2	There may be a deployable mast to accommodate additional focal length/parallax.			X			Mast will be designed with proper curvature for accurate imaging, design and testing at a ground facility will verify results	
2	2.2.3	The observatory payload shall have the capability to measure over the NUV range of 300-400 nm.			X	X	X	Choose telescope with given capabilities with reference to a datasheet and test for accuracy.	
2	2.2.4	The observatory shall have an angular resolution with half power diameter <3 arcseconds.			X	X	X	Choose telescope with given capabilities with reference to a datasheet and test for accuracy.	
	3.0	Ground System							
0	3.0	Pre-Flight Handling			X			A storage unit meeting the humidity, temperature, and sterilization requirements will protect the payload. Design will also consider launch loads	
1	3.1	The Satellite and components shall not be subjected to humidity greater than 70% or less than 30% during construction or storage or transportation.		X	X			Preexisting facilities with humidity and temperature requirements will be used, or one will be constructed if need be	
1	3.2	The Satellite and components shall not be subjected to a temperature greater than 23˚C or less than 13˚C during construction or storage or transportation.		X	X			Preexisting facilities with humidity and temperature requirements will be used, or one will be constructed if need be	
1	3.3	The Satellite shall be sterilized at determined intervals during construction and maintained in an ISO Class 8 clean room during all phases of the mission prior to launcher integration.		X	X			Regularly inspect and test post-sterilization to confirm the absence of contaminants.	

Appendix

1	3.4	Data Acquisition systems shall maintain compatibility with all relevant Communication Systems Requirements in 2.1.1.3	X		X	X		Simulate scenarios by injecting data into the system.	
		Validation and Testing							
0	4.0	All components of satellite shall be compared to physical plans for validation and tested for functionality.		X	X	X		Components will be measured to verify design is correct	
1	4.1	Measurement of satellite components' dimensions shall be compared to planned dimensions.		X	X		X	Use CAD model with reference to datasheets on various components.	
1	4.2	Satellite shall be tested for functionality of the electrical power system.		X		X	X	Tests will be done by running all systems simultaneously to ensure the power source can withstand the load placed on it as designed.	
2	4.2.1	Solar cells will be tested before launch to ensure adequate generation of power for satellite functions.	X				X	STK	
2	4.2.2	The EPS shall be tested to ensure distribution of power to appropriate instruments and verify the correct amount of power is being sent to specific satellite components.		X		X		Required power for every instrument/ component will be demanded and then feedback will be recorded.	
1	4.3	Optical instruments shall be tested for functionality before launching the satellite.		X		X		Telescopes and other instruments will be placed in an environment simulating mission conditions	
2	4.3.1	Main observing optical instrument shall be tested to verify an angular resolution with half-power diameter <3 arcseconds can be achieved.		X	X	X	X	Validation of physical test of optical instrument chosen with datasheet for optical instrument to ensure proper functionality.	
2	4.3.2	Main observing optical instrument shall be tested to verify solar radiation measurements can be made in Near UV range of 300-400nm.			X		X	Measurements will be conducted and analyzed in a test to confirm near UV capabilities	

Appendix

Requirement Level	Requirement Number	Requirement	Verification Model			Verification Methods			Status
			A	O	D	T	R		
1	4.4	All elements of satellite will be tested to comply with environmental standards.	X	X		X		Satellite will be tested to withstand thermal stresses, radiation, attitude control, tracking, and observation of solar corona	
2	4.4.1	The satellite's thermal protection and all components of exterior faces shall be able to withstand a temperature range of –250 to 250 degrees Fahrenheit.	X		X		X	Using thermal simulation along with a prepared CAD model of the satellite along with datasheets of components.	
2	4.4.2	The satellite shall be able to withstand material stresses due to thermal shock between lit and shaded regions.	X		X		X	Using thermal simulation along with a prepared CAD model of the satellite along with datasheets of components.	
1	4.5	The propulsion system shall be tested to ensure accuracy of commanded thrust and impulse.	X		X	X	X	MATLAB Simulink along with reference to propulsion system datasheet through tests shall be used.	
1	4.6	The attitude system shall be tested for functionality and accuracy of controls within ± 10 arcseconds.	X		X		X	MATLAB Simulink along with reference to propulsion system datasheet shall be used.	
		Operations							
0	5.0	There shall be procedures and timelines for every section of the operation			X				
1	5.1	There shall be pre-flight procedures and timelines.							
2	5.1.1	The Satellite shall undergo a charging cycle to optimize capacity upon deployment and lifetime cyclability before delivery.		X		X	X	Battery cycle testing shall be conducted, and data sheet referenced.	

Appendix

Requirement Level	Requirement Number	Requirement	Verification Model					Verification Methods	Status
			A	O	D	T	R		
2	5.1.2	The Satellite shall be stored in an ISO Class 8 clean room before delivery.					X	ISO Class 8 clean room will ensure sterilization, observation of components will check for unwanted contamination	
2	5.1.3	The Satellite shall be made 'safe' and flight-ready by means of "Remove Before Flight" safety features before delivery.		X	X		X	Inspectors shall verify that RBF implements are in place.	
2	5.1.4	The Satellite shall undergo a final flight readiness inspection to be signed by the Project Manager(s), Principal Investigator(s), and Technical Authority.		X			X	Inspectors shall validate dimensions, the engagement of any single use deployment mechanisms, power systems, state of charge, etc.	
1	5.2	Deployment			X				
2	5.2.1	The satellite shall be deployed from Gateway orbital science station at the cislunar L2 LaGrange point.			X			The design shall comply with the Nanoracks dimension specifications and launch requirements.	
3	5.2.1.1	The deployment readiness date shall be NLT 31 December 2026			X		X	Frequent progress checks and effective planning will ensure the deadline is made	
3	5.2.1.2	The Mission Elapsed Time (MET) shall begin when spacecraft is deployed from Gateway.			X			The release of a depression switch shall initiate the MET Timer	
3	5.2.1.3	The Satellite shall enable primary power to the Bus NET T+ 00:30:00 from the MET.				X		The Boot-On command shall be sent 30 minutes after the MET begins	
1	5.3	Station Keeping	X		X			Regularly scheduled maintenance checks will be conducted to ensure station is performing as planned	

Appendix

2	5.3.1	The Satellite's orbital period around L4 shall be near the orbital period of the Moon around the Earth, within a tolerance TBD.	X		X			The orbit shall be validated with STK simulation/MATLAB/Simulink	
1	5.4	End-of-Life			X			Deorbiting the satellite into a graveyard orbit will ensure safe End-of-Life is responsible	
2	5.4.1	The Satellite should be decommissioned in a responsible and timely manner at the mission conclusion.	X		X			TBR in accordance with NASA NID 8715.129	

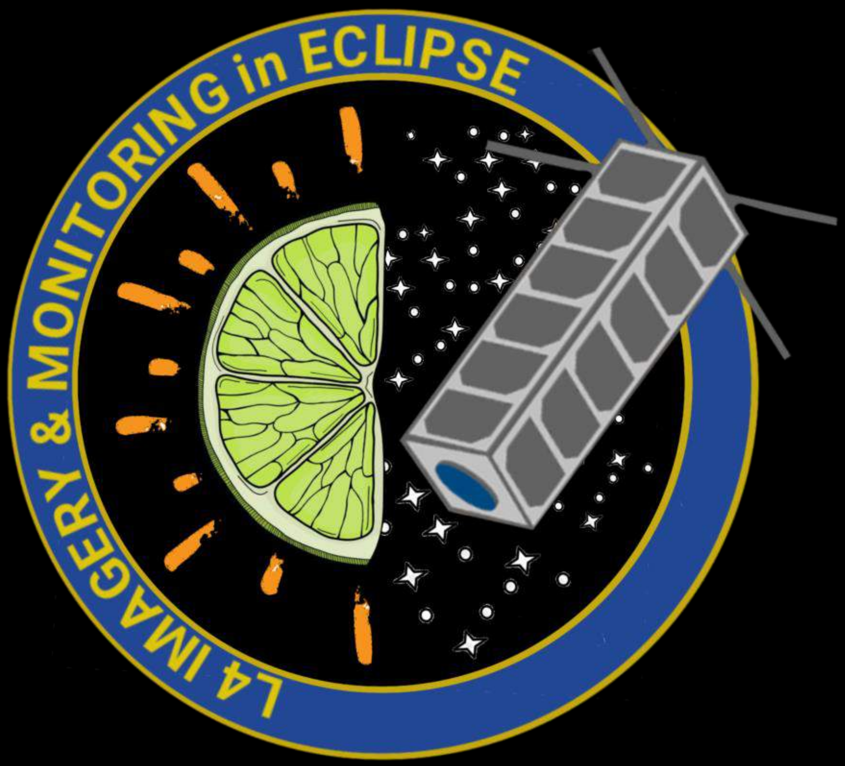
PRELIMINARY DESIGN REVIEW

COLBY DAVIS, CONNOR CALLAHAN, JUSTIN ROGERS, NOAH LOZADO, JARED WARMACK, JONATHAN KIM

LIMESAT

ACRONYMS

Acronym	Description
ACS	Attitude Control System
CAD	Computer-Aided Design
CCD	Charge-Coupled Device
CDH	Command & Data Handling
ConOps	Concept of Operations
DAQ	Data Acquisition
EPS	Electronic Power System
GNC	Guidance, Navigation, & Control
OBC	On-Board Computer
SPO	Short Period Orbit
SRR	System Requirements Review
UHF	Ultra High Frequency
VHF	Very High Frequency
CR3BP	Circular Restricted 3 Body Problem



Agenda

- SRR Open
  - Requirements Action
- Integrated Schedule
- ConOps
- CAD Model
- System Schematic
- GNC
- Trade Studies
- Components
  - Observatory Design
- Data Transmission Design
- Power & Mass
- Cost
- Risk Assessment
- Analysis & Conclusion
- Open Items

SRR Open Action

SRR Open Action	Status	Action Taken
Requirements need to include customer requirements	Complete	Requirements updated
ConOps sooner in the presentation	Complete	ConOps was moved toward the beginning, after the mission objectives
More specific open item's section	Complete	Open Actions was expanded on with more detail
Risk Assessment needs to be more thorough	Complete	Risk Assessment was made to be more specific

No Action Items:

- Team Structure
- Mission Statement
- Mission Objectives
- Integrated Schedule
- External/Internal Interfaces
- Work Breakdown Structure (WBS)
- Requirement Flow Down

Requirements Additions

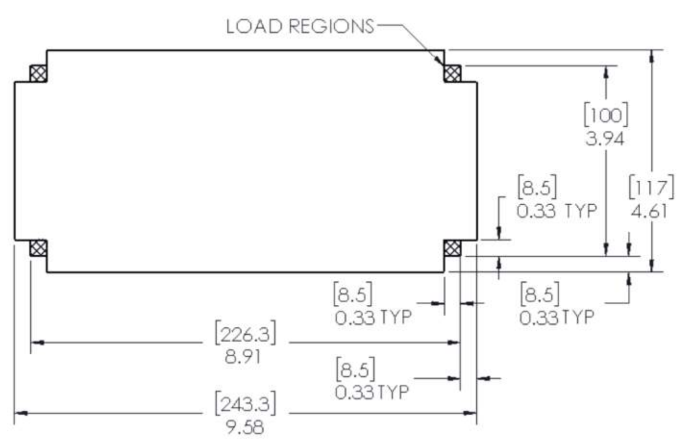
Requirement Level	Requirement Number	Requirement	Verification Model					Verification Methods	Status
			A	O	D	T	R		
		Space System							
3	2.1.1.6	The EPS shall have three independent electrical inhibitor deployment switches.			X		X	Procure switches and validate capability of switches with design and reference sheet,	
4	2.1.1.6.1	Rail deployment switches shall have a minimum actuation travel of 1 mm.				X	X	Validate switches travel with reference sheet and physical testing.	
4	2.1.1.6.2	Deployment switches shall reset the payload to pre-launch if cycled within 30 minutes of switches closing.			X	X		Design EPS with disable condition, validate design through testing.	
4	2.1.1.6.3	Deployment switches shall be captive.			X			Design switches to be retained in the CubeSat after launch.	
4	2.1.1.6.4	Force of deployment switches shall not exceed 18N.				X	X	Test switch applied force and validate with reference sheet.	
4	2.1.1.6.5	Deployment switches shall have a contact width of at least 75%.			X		X	Design and choose switches, validate with reference sheet.	
3	2.1.1.7	EPS shall not be energized for a minimum of 30 minutes where hazards existed.			X		X	Design electrical system and validate with EPS reference sheet.	

Requirements Additions

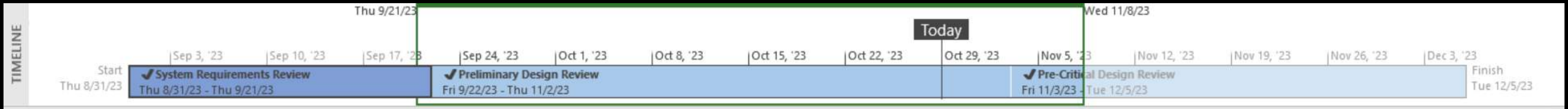
Requirement Level	Requirement Number	Requirement	Verification Model					Verification Methods	Status
			A	O	D	T	R		
		Space System							
3	2.1.9.5	The payload should be able to withstand stresses as outlined on the NRDD IDD reference section 4.3.4.					X	The payload will be vibration tested to ensure it can survive shock from ignition	Completed
3	2.1.10	The structural system shall be compatible with NanoRacks requirements.			X		X	Structure will be designed to meet Nanoracks requirements and will be validated with individual part reference sheets.	
4	2.1.10.1	There shall be four rails along the z-axis to interface with slots dimensioned in *Figure 4.1.2-1* in the NRSC IDD.			X		X	Rails will be designed and validated with existing dimensioned diagrams from Nanoracks.	
5	2.1.10.1.1	Edge of rails shall have a radius of .5mm (+/-0.1mm)			X		X	Purchased rails should have dimensions validated through their provided reference sheets.	
5	2.1.10.1.2	Interface rails shall have a length of 366mm (+0.0/ -65.0).			X		X	Purchased rails should have dimensions validated through their provided reference sheets.	
5	2.1.10.1.3	Interface rails shall be contiguous and have no interruption across their length.		X			X	Rails should be purchased containing no interruptions and should be validated by observing the purchased part.	
5	2.1.10.1.4	Interface rails shall be the only mechanical interface between the NRDD and the CubeSat in the lateral axes.			X		X	Design shall be made with reference to Nanoracks deployer reference sheet,	
5	2.1.10.1.5	Interface rails shall extend beyond the +/- z faces of the payload with the exception of load points.			X			Rails should be designed to extend past Z faces.	

Requirements Additions

Requirement Level	Requirement Number	Requirement	Verification Model A	O	D	T	R	Verification Methods	Status
		Space System							
5	2.1.10.1.6	Interface rails shall have a hardness equal to or greater than hard-anodized aluminum (Rockwell C65-70).				X	X	Rail hardness should be chosen for hardness with respect to their reference sheet and validated for hardness through testing.	
5	2.1.10.1.7	Interface rails shall have a surface roughness of less than or equal to 1.6 µm.					X	Rail surface roughness shall be validated through the rail reference sheet.	
4	2.1.10.2	The structural system shall be dimensioned to comply with *Figure 4.1.2-2* in the NRSC IDD.					X	Ensure compliance with NRSC IDD reference sheet.	
4	2.1.10.3	There shall be load points on the +/- z-faces.			X			Load point existence shall be validated through design of satellite.	
5	2.1.10.3.1	Load points shall be coplanar with end of tabs.			X			Load point location shall be validated through design of satellite.	
5	2.1.10.3.2	Load points shall envelop areas designated in *Figure 4.1.2-1* of NRDD IDD.			X		X	Load point design shall be validated with NRDD IDD reference sheet.	
5	2.1.10.3.3	Load points shall have a hardness equal to or greater than hard-anodized aluminum (Rockwell C65-70).				X	X	Load point hardness should be chosen with respect to their reference sheet and validated for hardness through testing.	
5	2.1.10.3.4	Load points shall have a surface roughness of less than or equal to 1.6 µm.					X	Load point roughness shall be validated through the load point reference sheet.	
2	2.1.11	The CubeSat shall have mass requirements complying with the NRDD IDD document.			X	X	X	Satellite will be designed and validated through testing and compliance with the NRDD IDD reference sheet.	
3	2.1.11.1	The center of mass shall be located within the geometric center within tolerances: X: (+/- 5cm) Y: (+/- 3cm) Z: (+/- 8cm).			X	X	X	Satellite will be designed to be within center of mass requirements and validated through testing and compliance with Nanoracks reference sheet.	

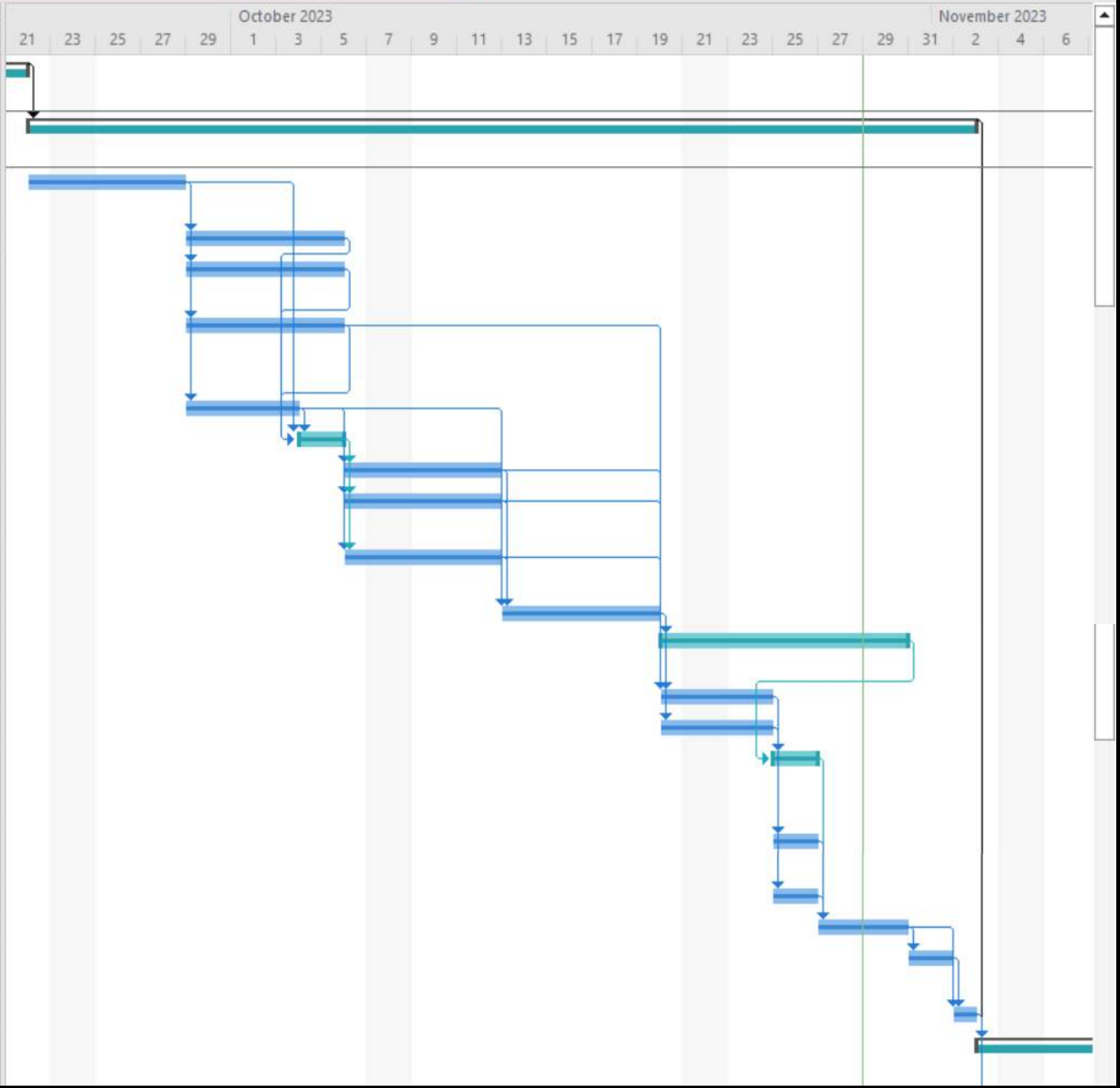


INTEGRATED SCHEDULE



GANTT CHART

	Task Name	Duration	Start	Finish	Predecessors
1	**System Requirements Review**	**18 days?**	**Thu 8/31/23**	**Thu 9/21/23**	
23	**Preliminary Design Review**	**30 days?**	**Fri 9/22/23**	**Thu 11/2/:**	**22,1**
24	Schedule (PDR-CDR)	5 days?	Fri 9/22/23	Thu 9/28/23	
25	Post-SRR Revision	5 days	Fri 9/29/23	Thu 10/5/23	24
26	STK Orbit Simulations	5 days	Fri 9/29/23	Thu 10/5/23	24
27	Trade Studies for Telemetry & Guidence	5 days?	Fri 9/29/23	Thu 10/5/23	24
28	CAD Model	3 days	Fri 9/29/23	Tue 10/3/23	24
29	OSIR #2	2 days	Wed 10/4/2:	Thu 10/5/23	25,24,27,26,28
30	Guidance & Control	5 days?	Fri 10/6/23	Thu 10/12/2:	29,28
31	Telemetry (data transmission)	5 days?	Fri 10/6/23	Thu 10/12/23	29,28
32	Trade Studies for Other Systems	5 days?	Fri 10/6/23	Thu 10/12/23	29,28
33	System Schematic	5 days	Fri 10/13/23	Thu 10/19/2:	30,31,32,28
34	Requirements Revision C	7 days	Fri 10/20/23	Mon 10/30/23	33
35	Budgets	3 days	Fri 10/20/23	Tue 10/24/2:	30,27,31,33,32
36	Risk Chart	3 days	Fri 10/20/23	Tue 10/24/2:	33
37	ConOps (Deployment to Demise)	2 days	Wed 10/25/23	Thu 10/26/23	35,36,34
38	Requirements Violations	2 days?	Wed 10/25/23	Thu 10/26/23	35,36
39	Results/Analysis	2 days?	Wed 10/25/:	Thu 10/26/2:	35,36
40	Create Presentation	2 days?	Fri 10/27/23	Mon 10/30/2	37,38,39
41	Practice Presentation	2 days	Tue 10/31/23	Wed 11/1/23	40
42	PDR Presentation	1 day	Thu 11/2/23	Thu 11/2/23	41,40
43	**Pre-Critical Design Review**	**23 days?**	**Fri 11/3/23**	**Tue 12/5/23**	**23,42**



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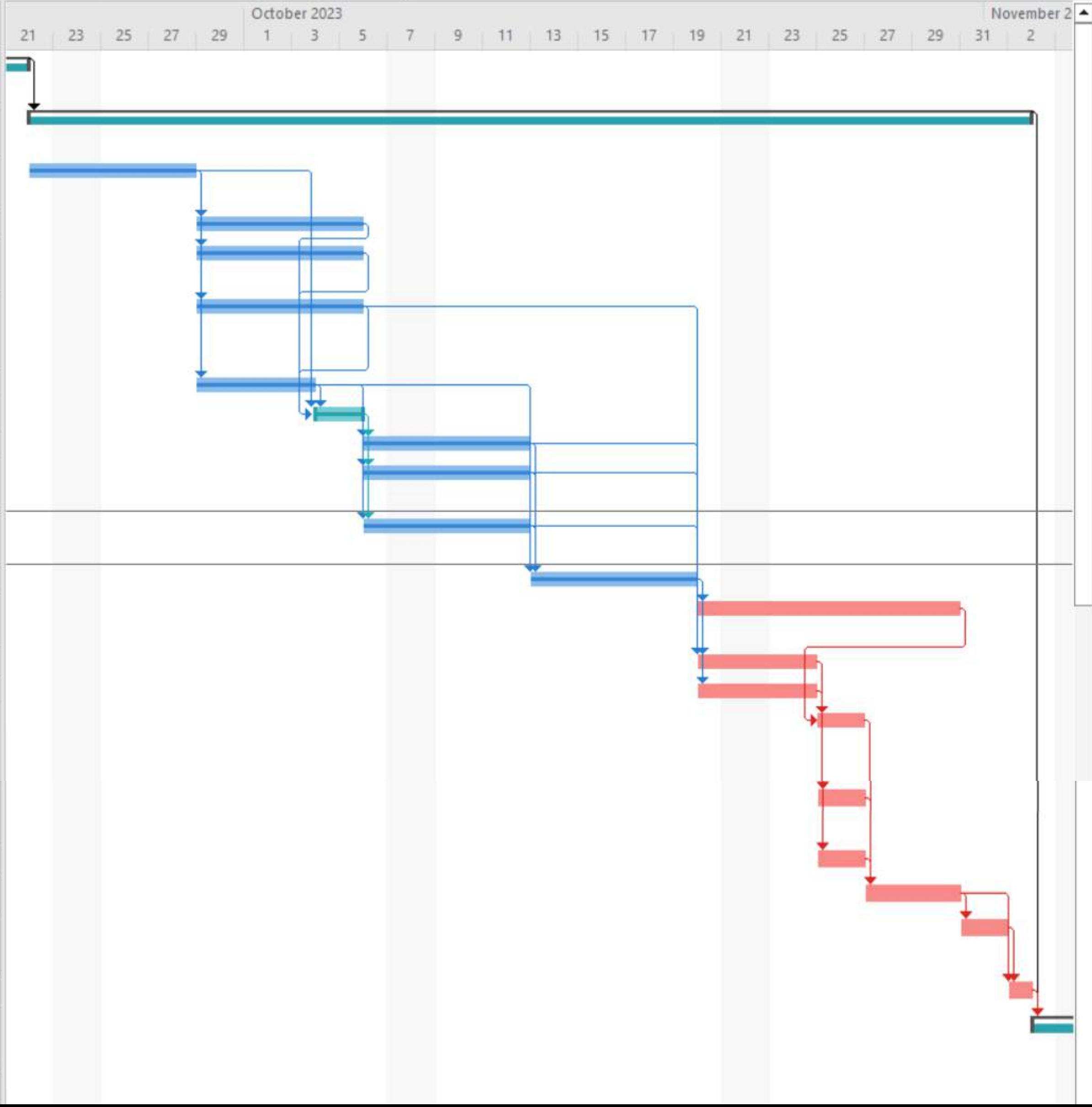

TIMELINE

Sun 10/29/23

Today

| Sep 3, '23 | Sep 10, '23 | Sep 17, '23 | Sep 24, '23 | Oct 1, '23 | Oct 8, '23 | Oct 15, '23 | Oct 22, '23 | Oct 29, '23 | Nov 5, '23 | Nov 12, '23 | Nov 19, '23 | Nov 26, '23 | Dec 3, '23 |

Start Thu 8/31/23

System Requirements Review Thu 8/31/23 - Thu 9/21/23

Preliminary Design Review Fri 9/22/23 - Thu 11/2/23

Pre-Critical Design Review Fri 11/3/23 - Tue 12/5/23

Finish Tue 12/5/23

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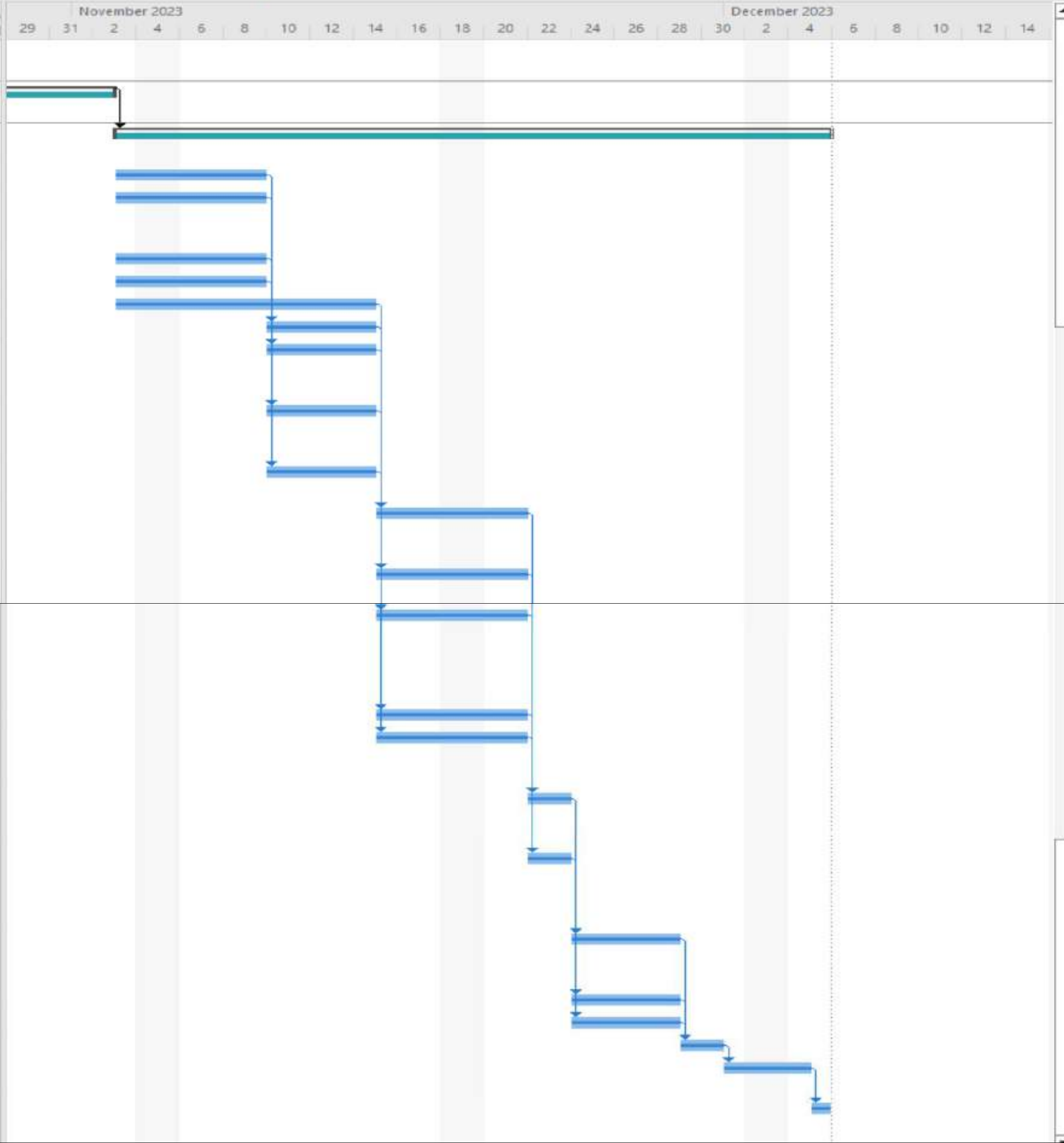
44	Schedule	5 days	Fri 11/3/23	Thu 11/9/23	42
45	Initial draft of wire routing/CubeSat build-up process	5 days?	Fri 11/3/23	Thu 11/9/23	
46	Electrical Schematic	5 days?	Fri 11/3/23	Thu 11/9/23	
47	Drawing Template	5 days?	Fri 11/3/23	Thu 11/9/23	
48	Improve CAD Model	8 days	Fri 11/3/23	Tue 11/14/2:	
49	FEM Stress Strain	3 days?	Fri 11/10/23	Tue 11/14/2:	46,47,44,45
50	Thermal analysis-proposed method	3 days	Fri 11/10/23	Tue 11/14/23	46,47,44,45
51	Vibration analysis-proposed method	3 days?	Fri 11/10/23	Tue 11/14/23	46,47,44,45
52	Linear controls analysis	3 days?	Fri 11/10/23	Tue 11/14/23	46,47,44,45
53	Developed detailed process to measure drag force	5 days?	Wed 11/15/23	Tue 11/21/23	52,48,49,50,51
54	Initial estimate of orbital lifetime	5 days?	Wed 11/15/23	Tue 11/21/23	52,48,49,50,51
55	Power budget by mission phase showing wost case and average scenarios	5 days?	Wed 11/15/23	Tue 11/21/23	52,48,49,50,51
56	Cost Budget	5 days?	Wed 11/15/:	Tue 11/21/2:	52,48,49,50,51
57	Data download and upload rates and associated costs	5 days?	Wed 11/15/23	Tue 11/21/23	52,48,49,50,51
58	Overall CubeSat mass and component-by-com	2 days?	Wed 11/22/23	Thu 11/23/23	57,53,54,55,56
59	Identify Communication methodology from CubeSat to the PI	2 days?	Wed 11/22/23	Thu 11/23/23	57,53,54,55,56
60	ConOps for Mission Science and Demise phase	3 days?	Fri 11/24/23	Tue 11/28/23	59,58
61	Center of Gravity	3 days?	Fri 11/24/23	Tue 11/28/2:	59,58
62	Moments of Inertia	3 days?	Fri 11/24/23	Tue 11/28/2:	59,58
63	Create Presentation	2 days	Wed 11/29/:	Thu 11/30/2:	62,61,60
64	Practice Presentation	2 days	Fri 12/1/23	Mon 12/4/23	63
65	PCDR Presentation	1 day	Tue 12/5/23	Tue 12/5/23	64



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Tue 10/31/23 — Today

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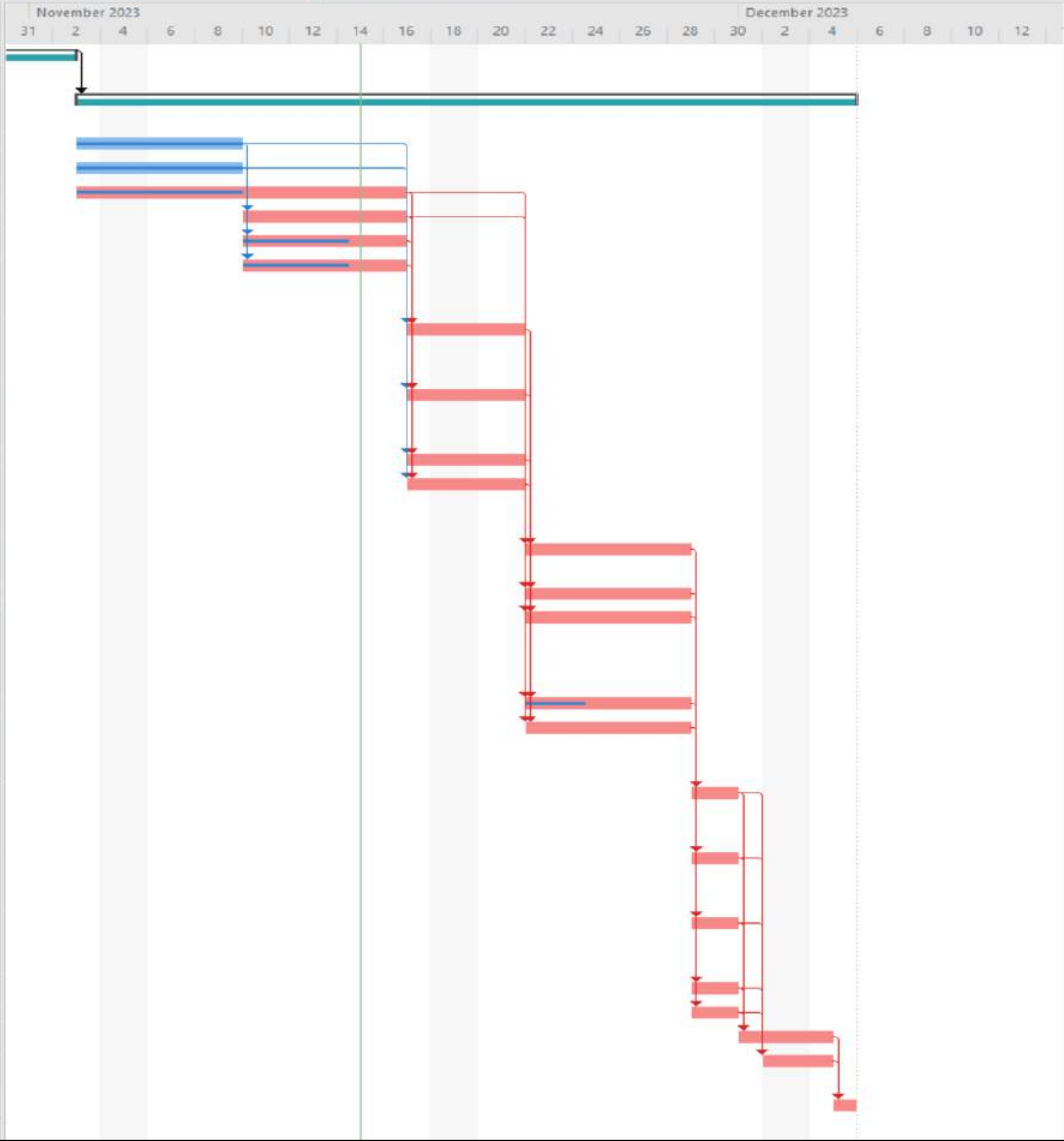


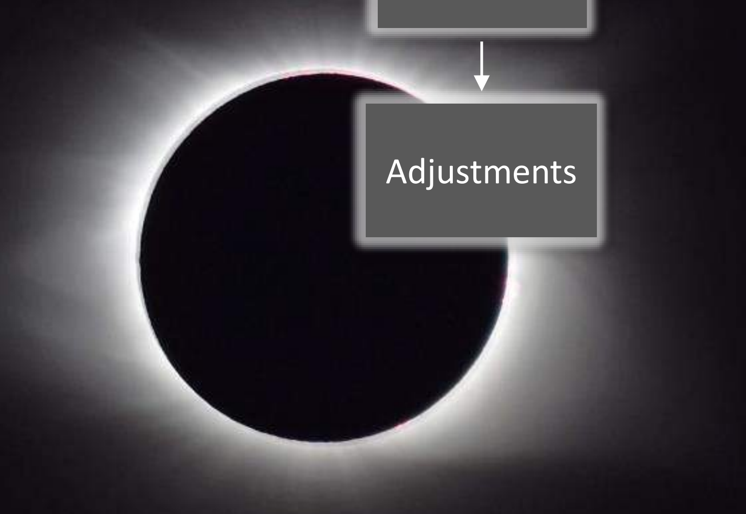
CONOPS

LUNOSTAR MISION

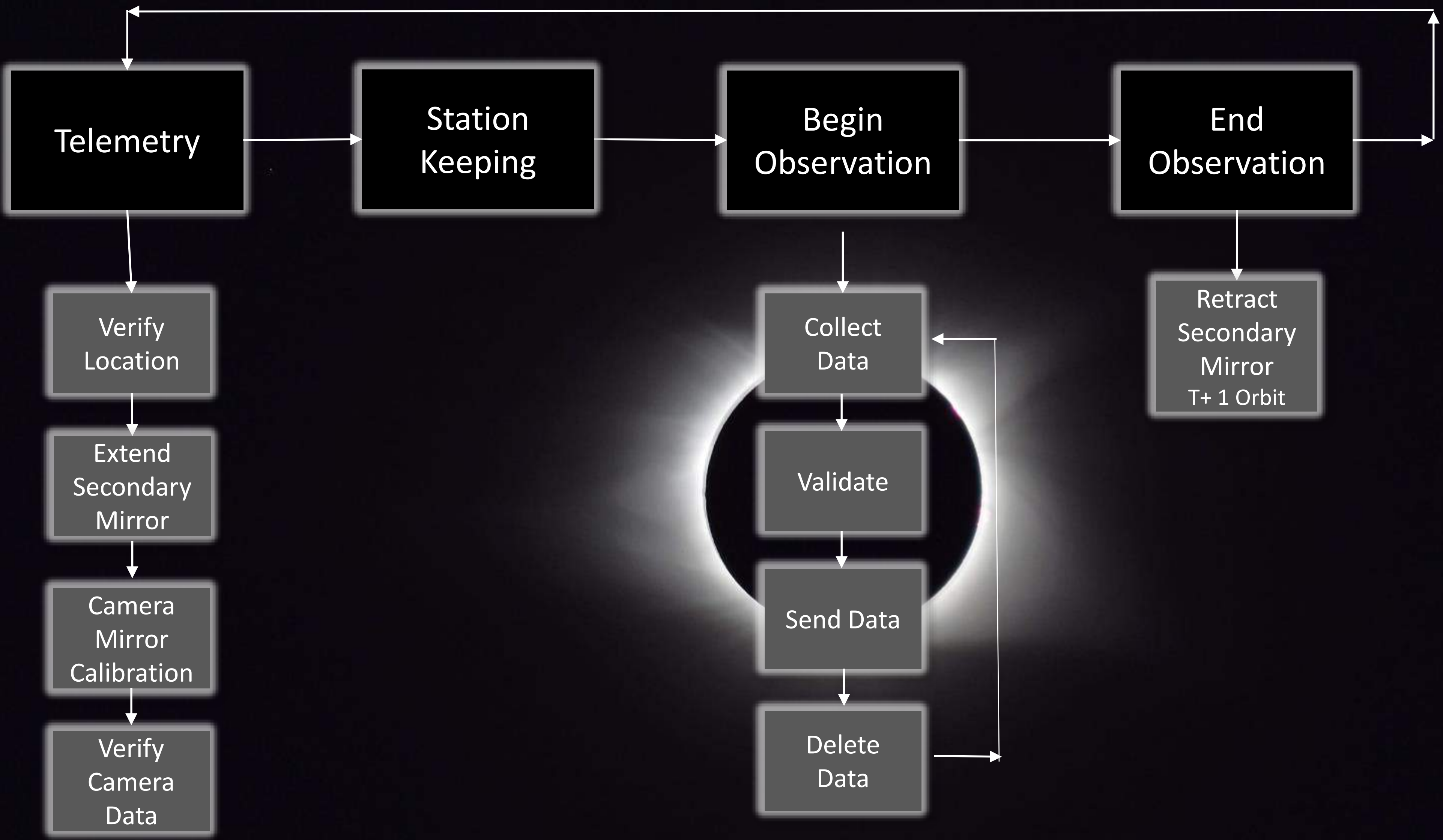
LunOSTAR Mission ConOps: Deployment

Deployment → **System Testing** → **Maneuver** → **Arrive at L4**

- **Deployment**
  - Avoidance Maneuver T+30sec
- **System Testing**
  - Extend Antenna T+15min
  - Contact T+20min
  - Solar Panel Deploy T+30min
  - Detumble T+5hours
  - Systems Check T+10hours
- **Maneuver**
  - Initial Burn T+15 hours
  - Adjustments
- **Arrive at L4**
  - SPO Burn T+15 days



LunOSTAR Mission ConOps: Post-Deployment



LunOSTAR Mission ConOps: Demise

Final Check
TD+760 days

Data Backup
T+5 days

System Check
T+1 day

Passivation
T+1 hr

Disposal

Planning
T+7 days

Contact Agencies
T+3 days

Final Command
T+1 days

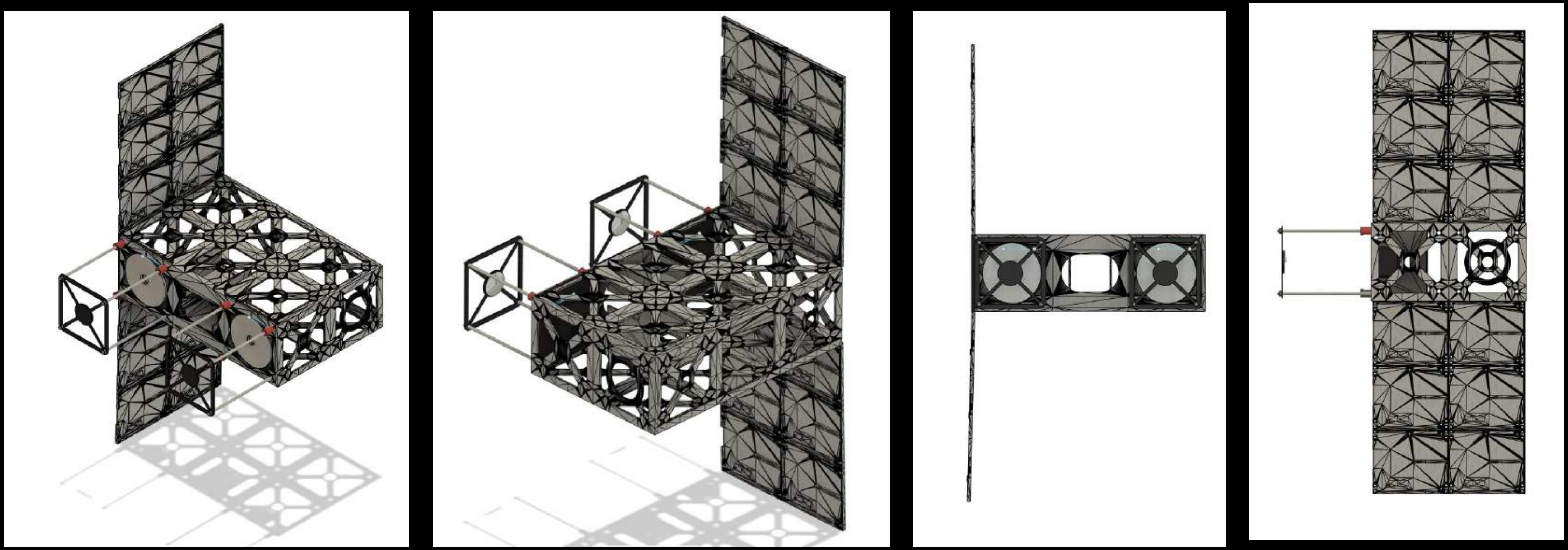
Monitor
T+21 days

Post-Mission Analysis

Final Report
TD+800 days

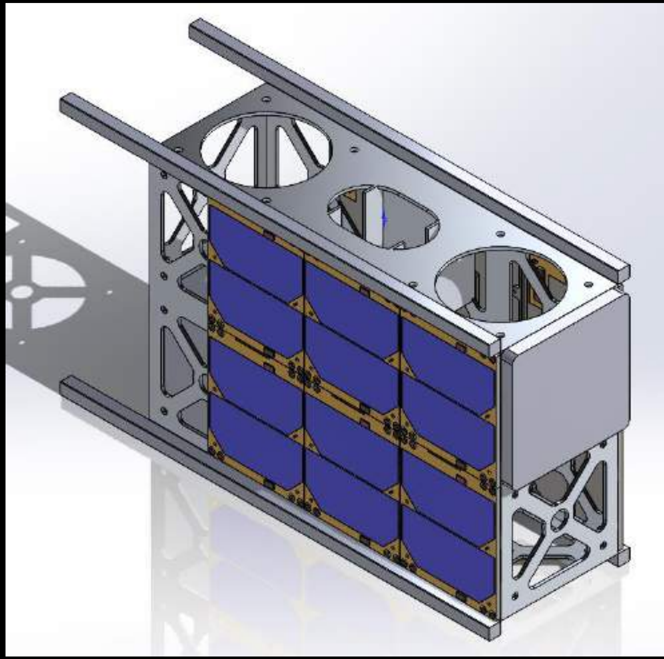
CAD Model

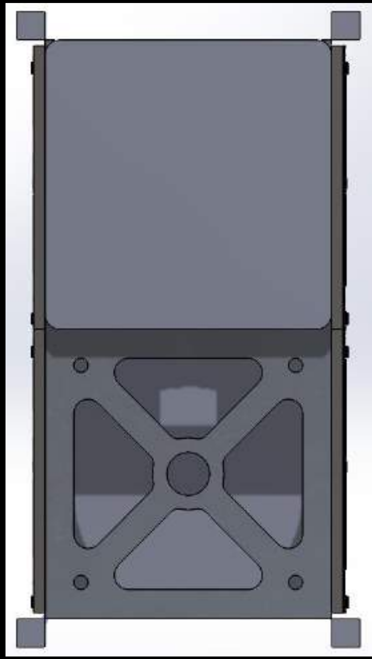
Deployed:

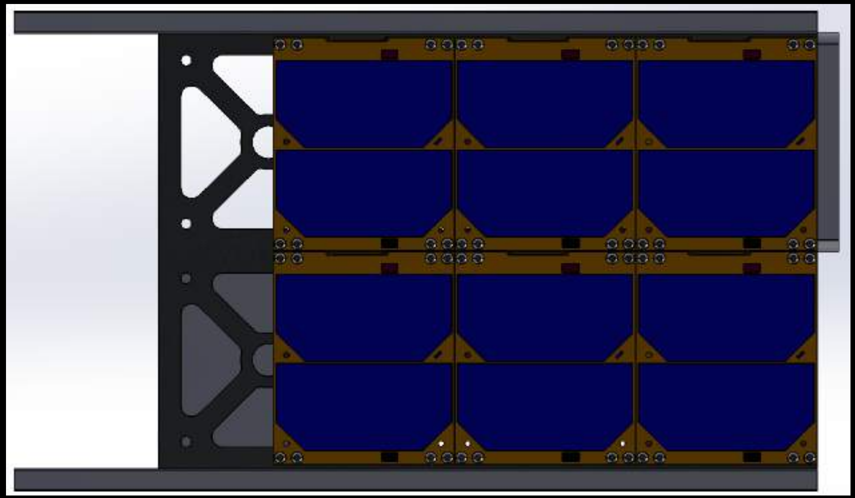


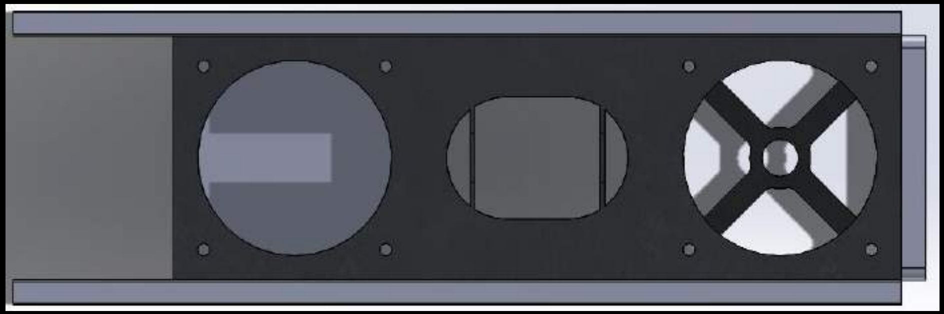
CAD Model

Stowed:

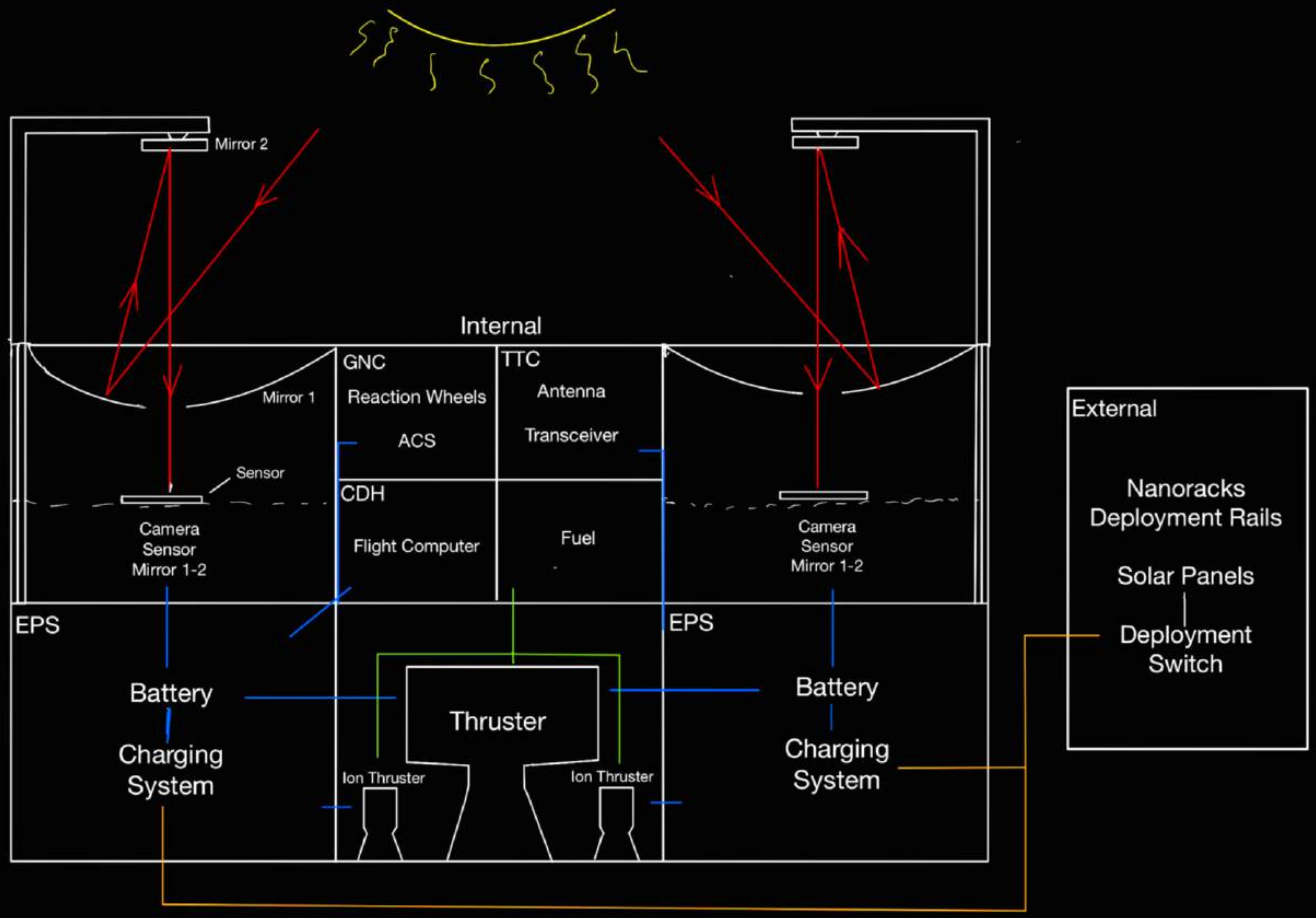


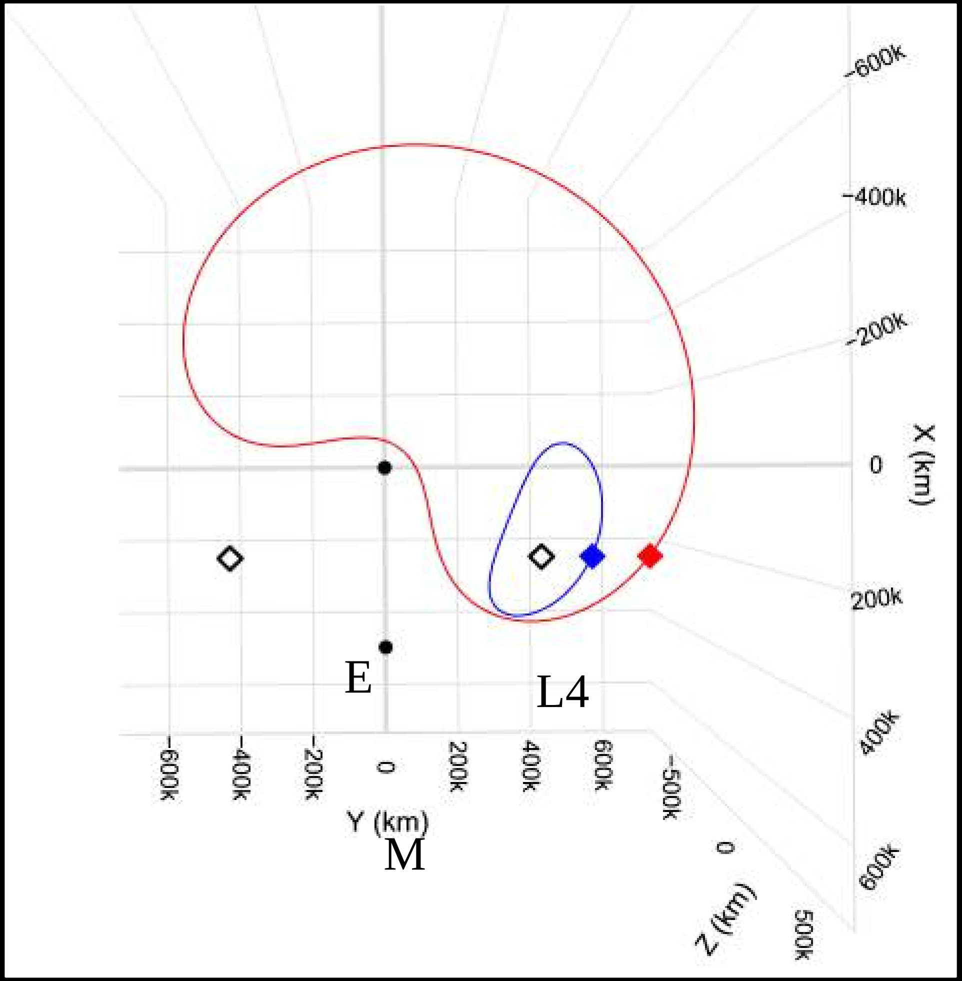






System Schematic



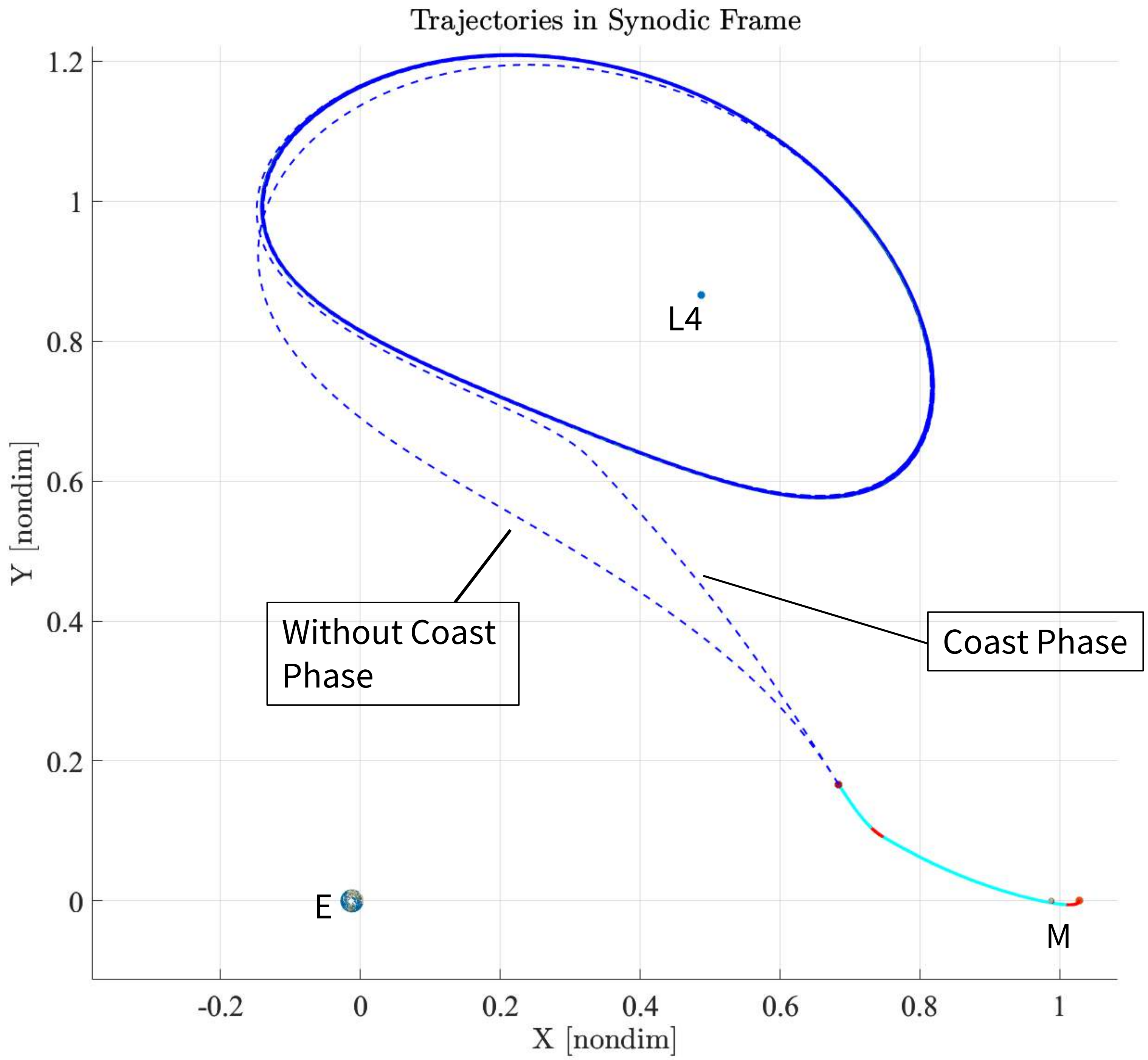


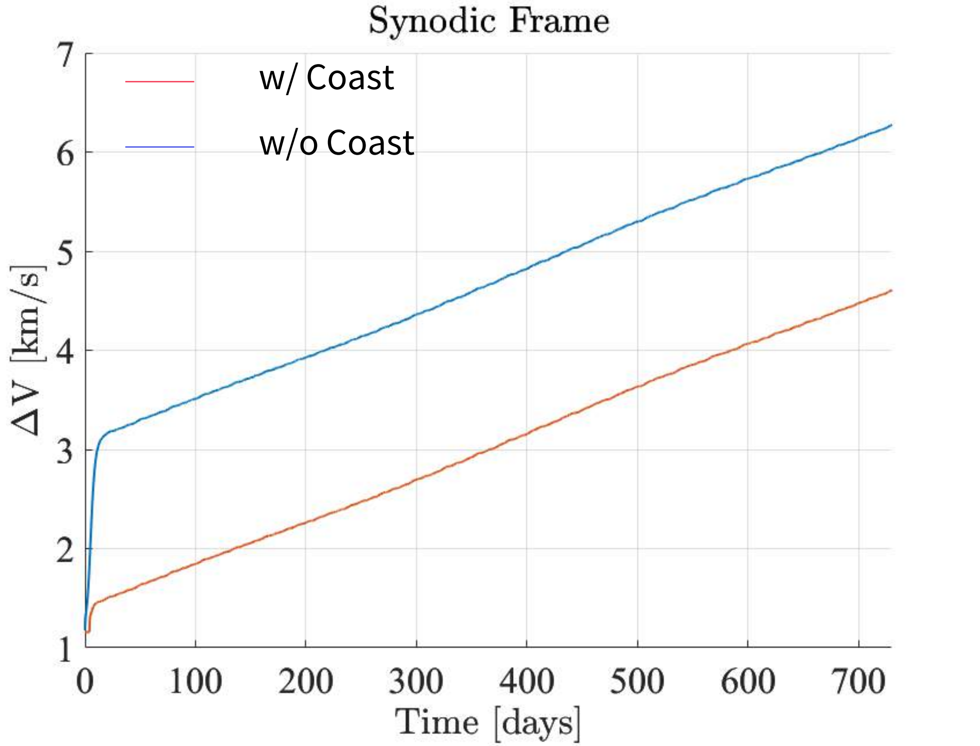
Orbital Period ~27.9 Days	
Orbital Period ~29 Days	

Earth-Moon Short Period Orbits

Discussing Maneuver Optimizations, and Controller Tuning

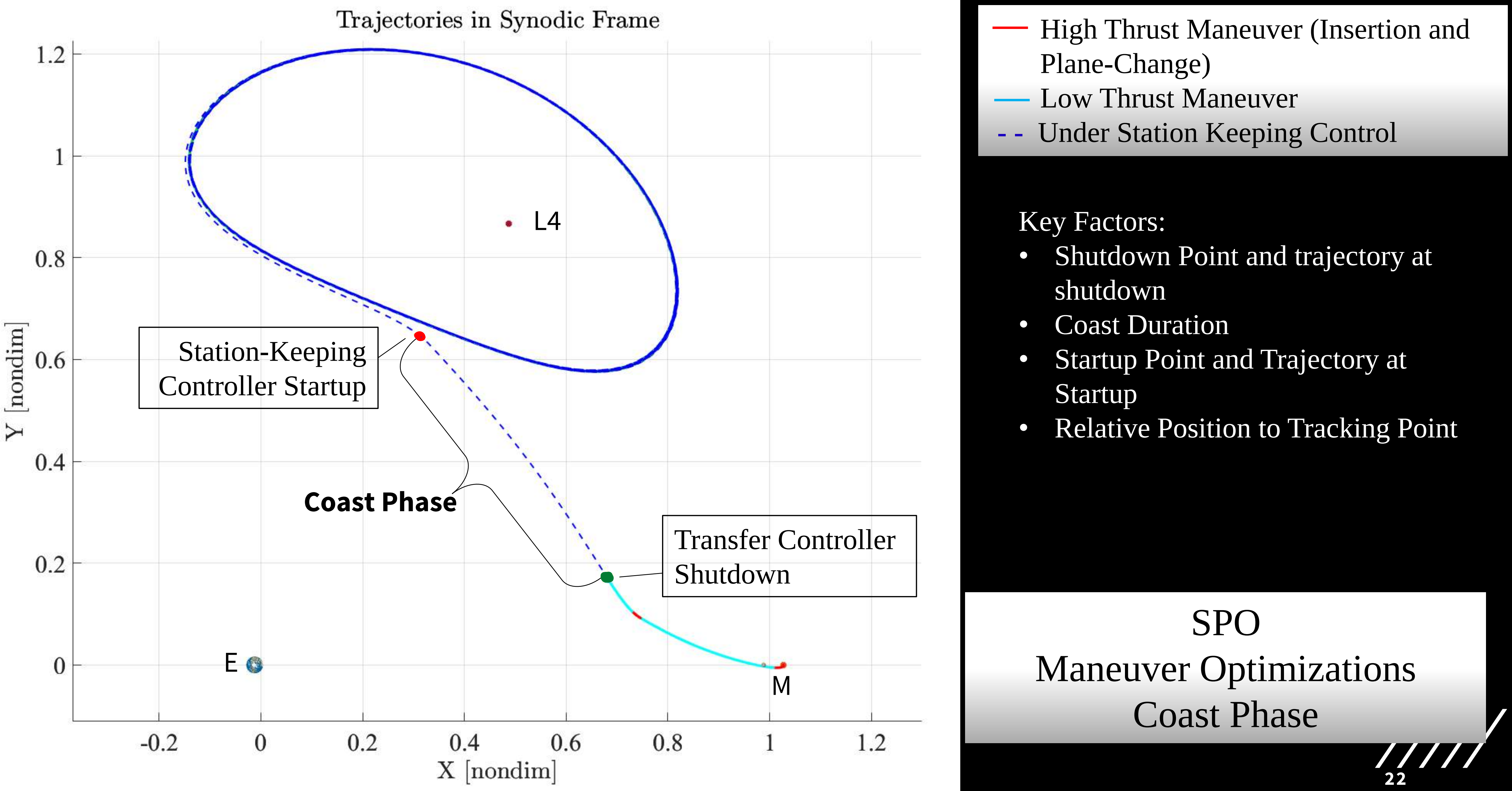
- Coasting Phases
- Departure Location from NHRO
- Tracking Point
- Creative Maneuvers
- Challenges





The Coast Phase during transfer may allow for significant ΔV savings (>36%)

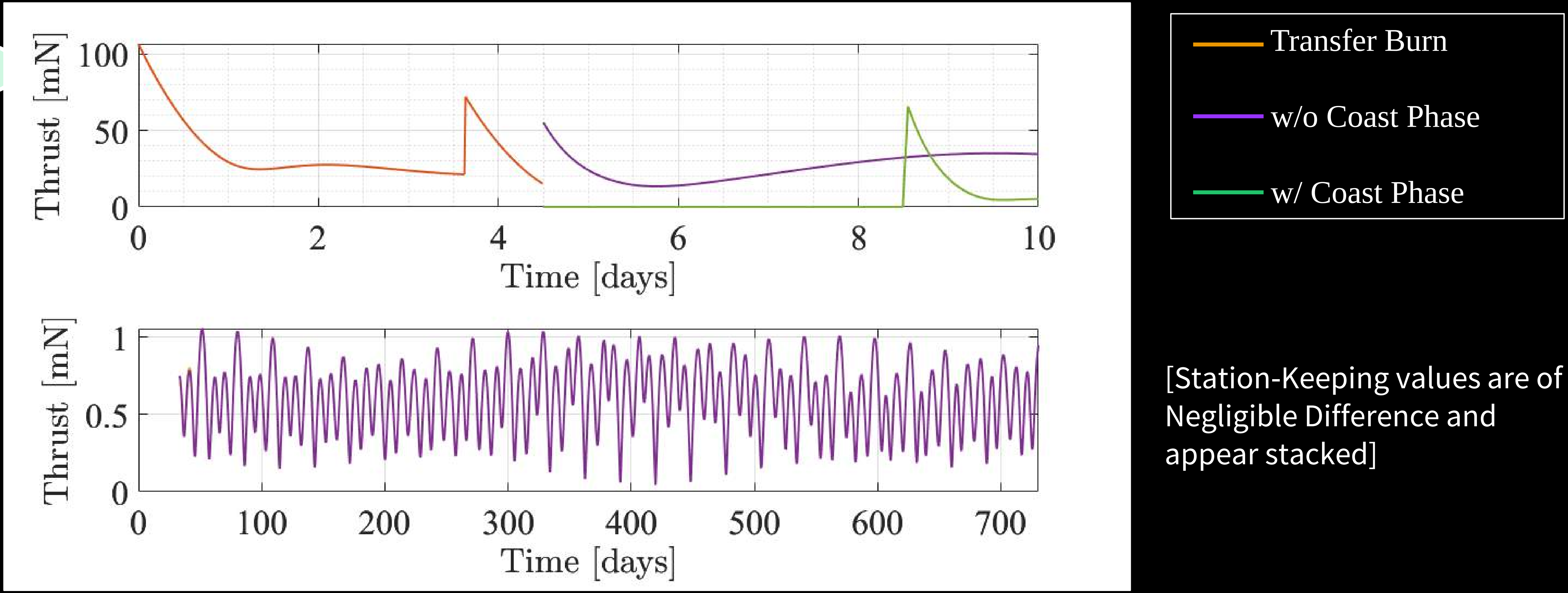
SPO
Maneuver Optimizations
Coast Phase



Key Factors:

- Shutdown Point and trajectory at shutdown
- Coast Duration
- Startup Point and Trajectory at Startup
- Relative Position to Tracking Point

SPO
Maneuver Optimizations
Coast Phase



[Station-Keeping values are of Negligible Difference and appear stacked]

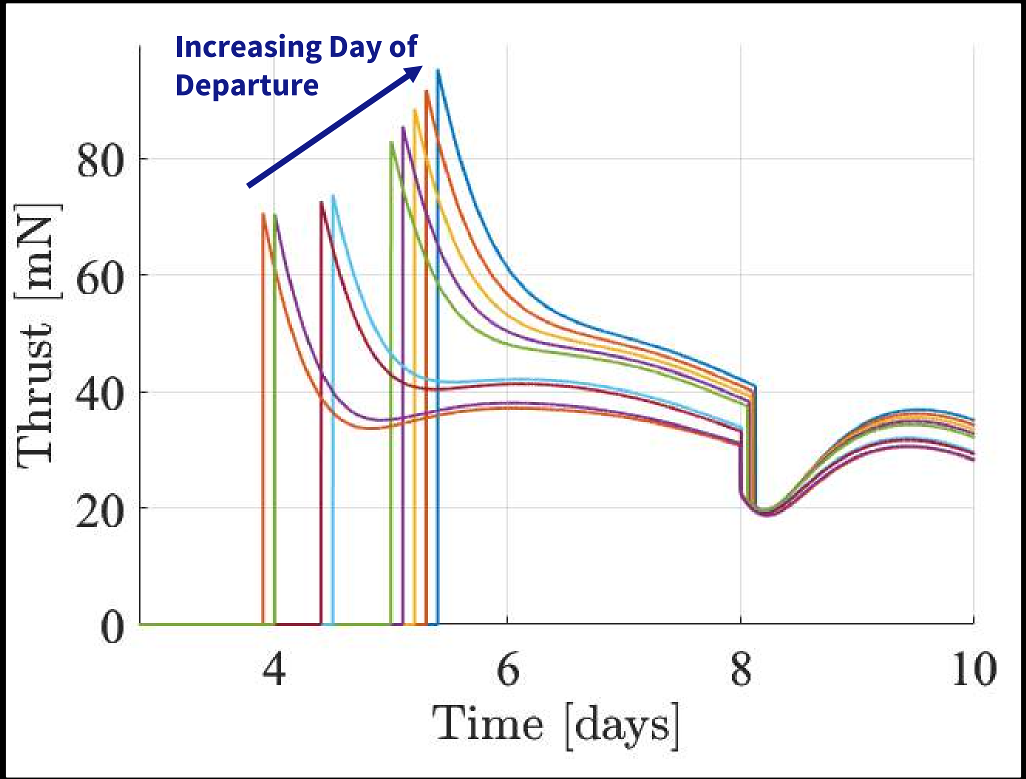
Tradeoffs between Delta-V savings and maximum thrust requirements.

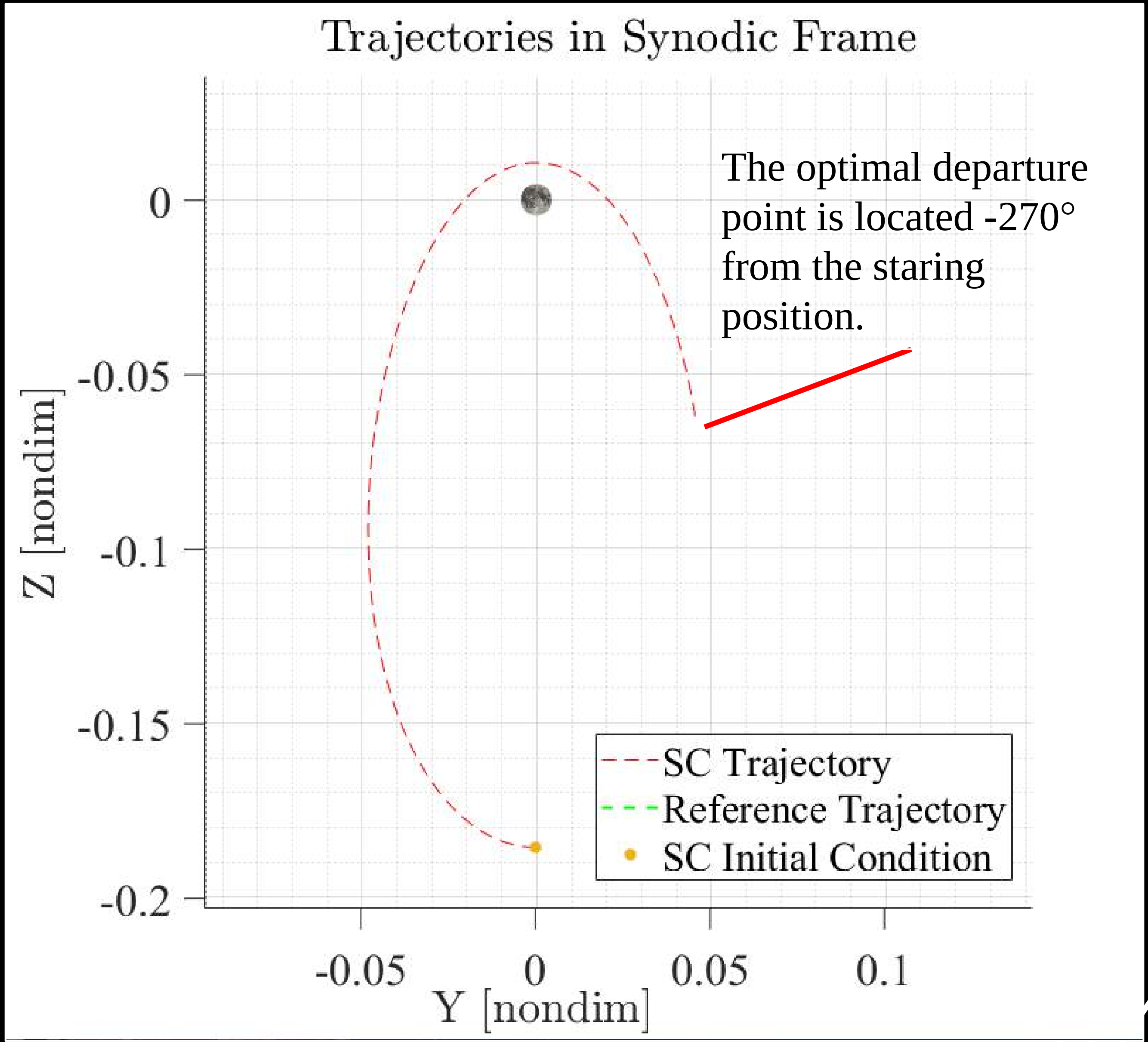
SPO
Maneuver Optimizations
Coast Phase

*Maneuvers Not Final, for Example Only

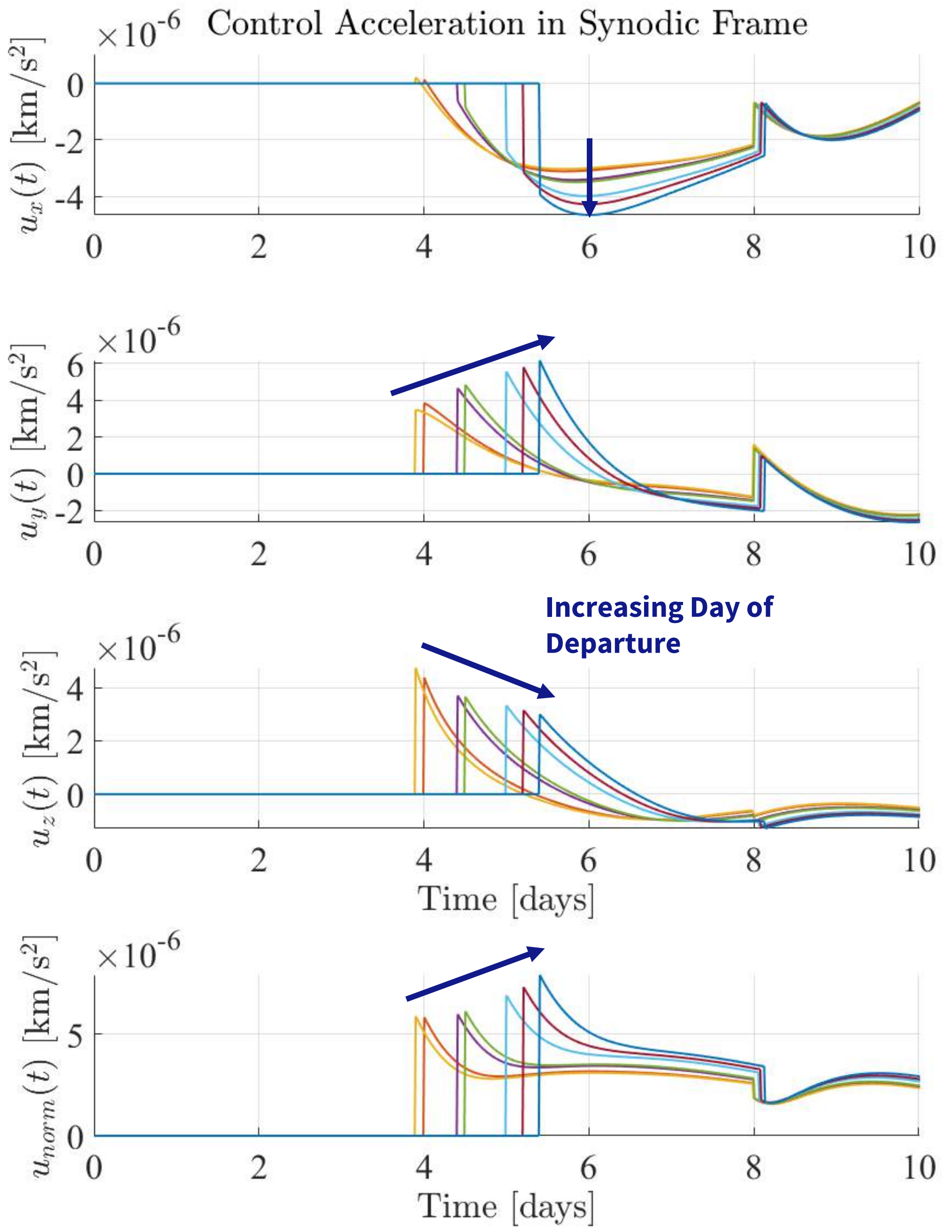
SPO
Maneuver Optimizations
- Departure Location -

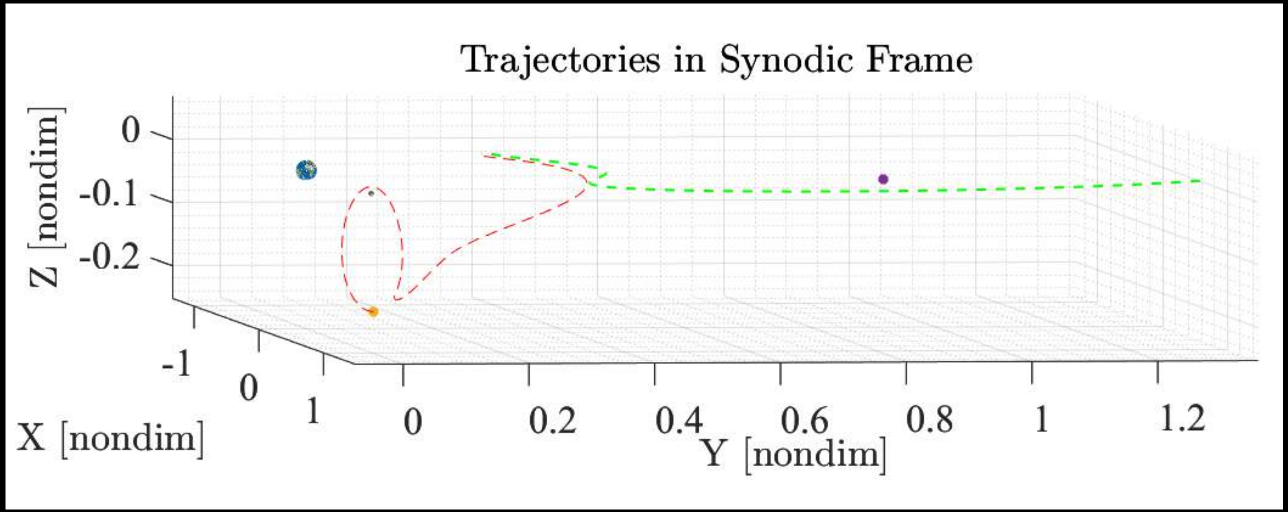
By iterating the day of departure, a local minimum is found in the thrust profiles.





*Maneuvers Not Final, for Example Only





Tradeoffs:

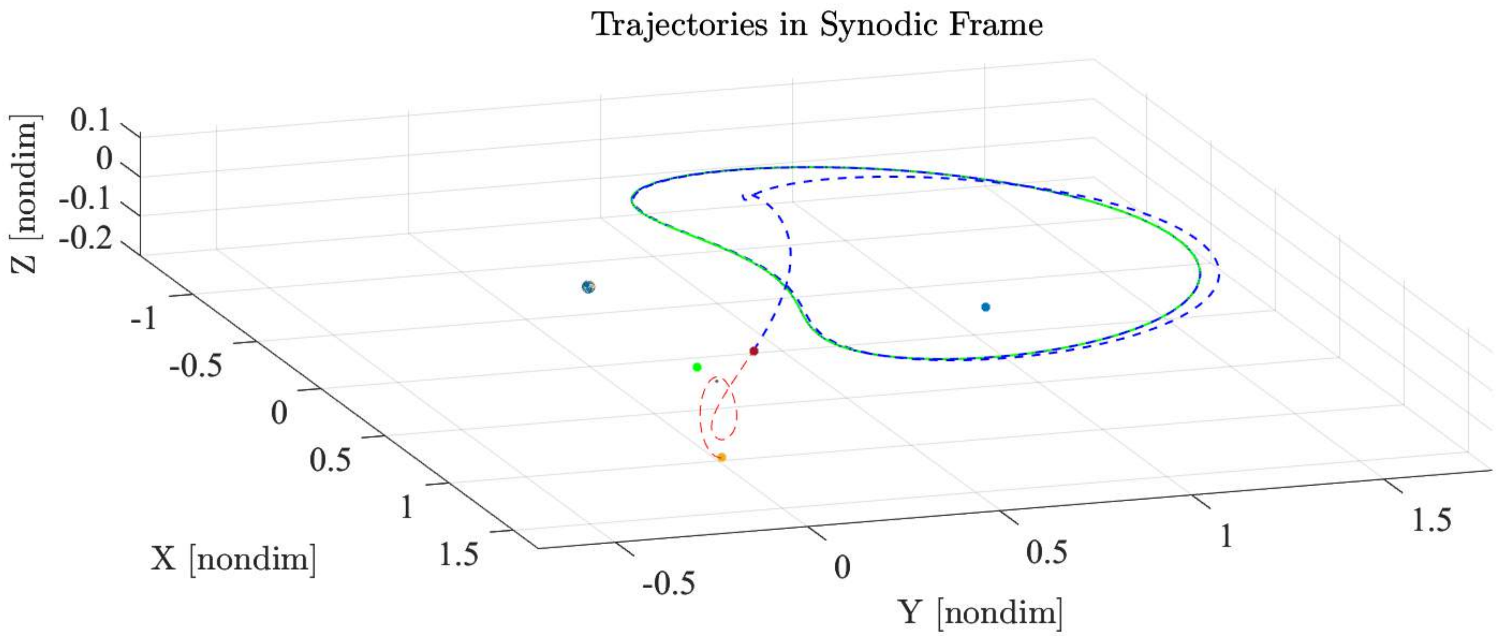
- Lowering max acceleration in one dimension may raise it in another.
- Lower thrust maneuvers often increase total Delta-V required.

Finding a Solution:

A combination of techniques are used, and still being explored.

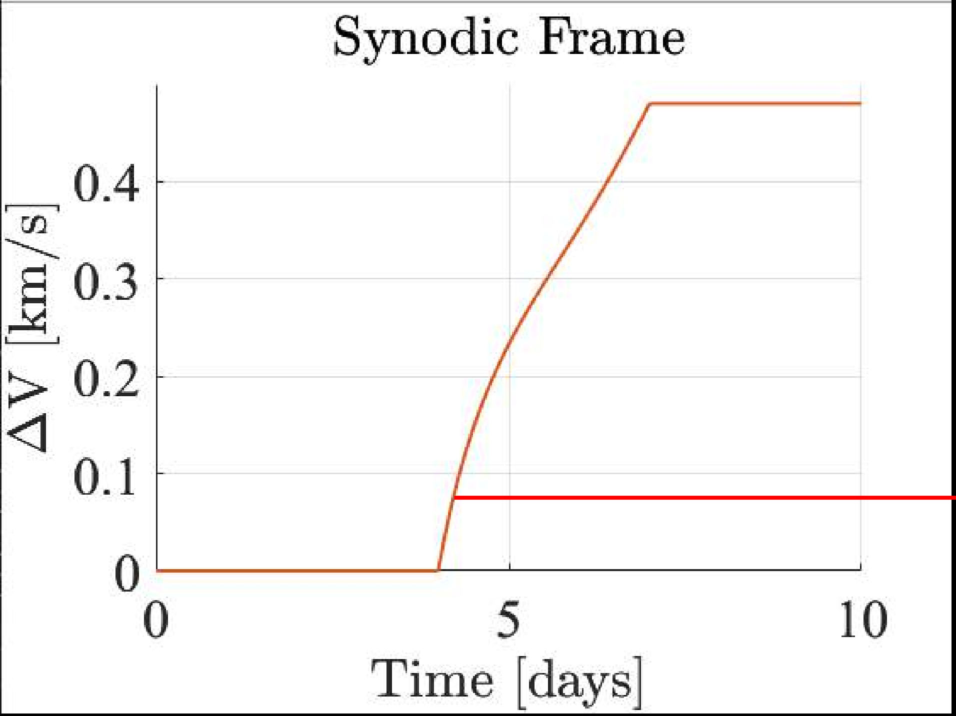
The current iteration uses the following:

- Departure point adjustments
- Coasting phases
- Tracking point adjustments (adjustments are made after coasting phases to mitigate unwanted acceleration)
- Pole placement tuning (independently tuned for transfer and station-keeping)
- Special maneuvering

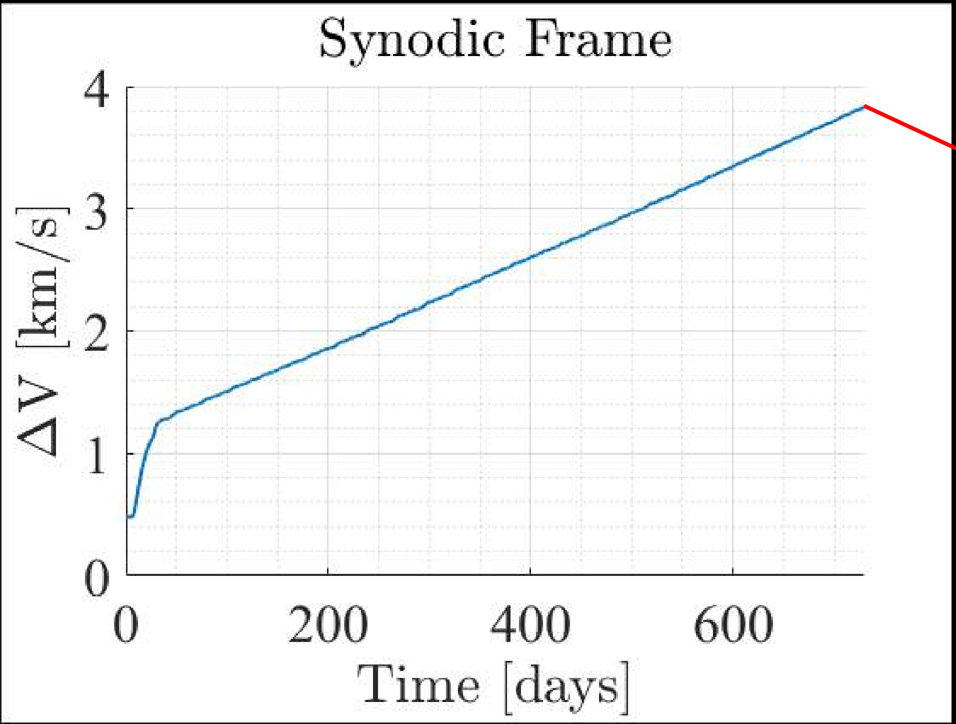


Per a suggestion from Luis, we found that allowing the spacecraft to drift near L1, we gained significant ΔV savings in the transfer stage.

ΔV and Thrust Profiles

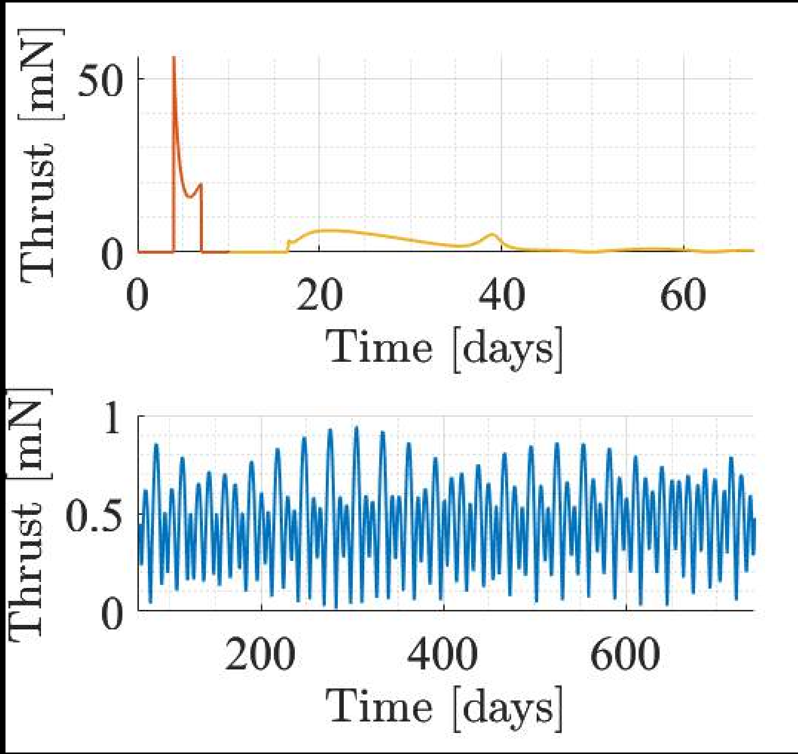


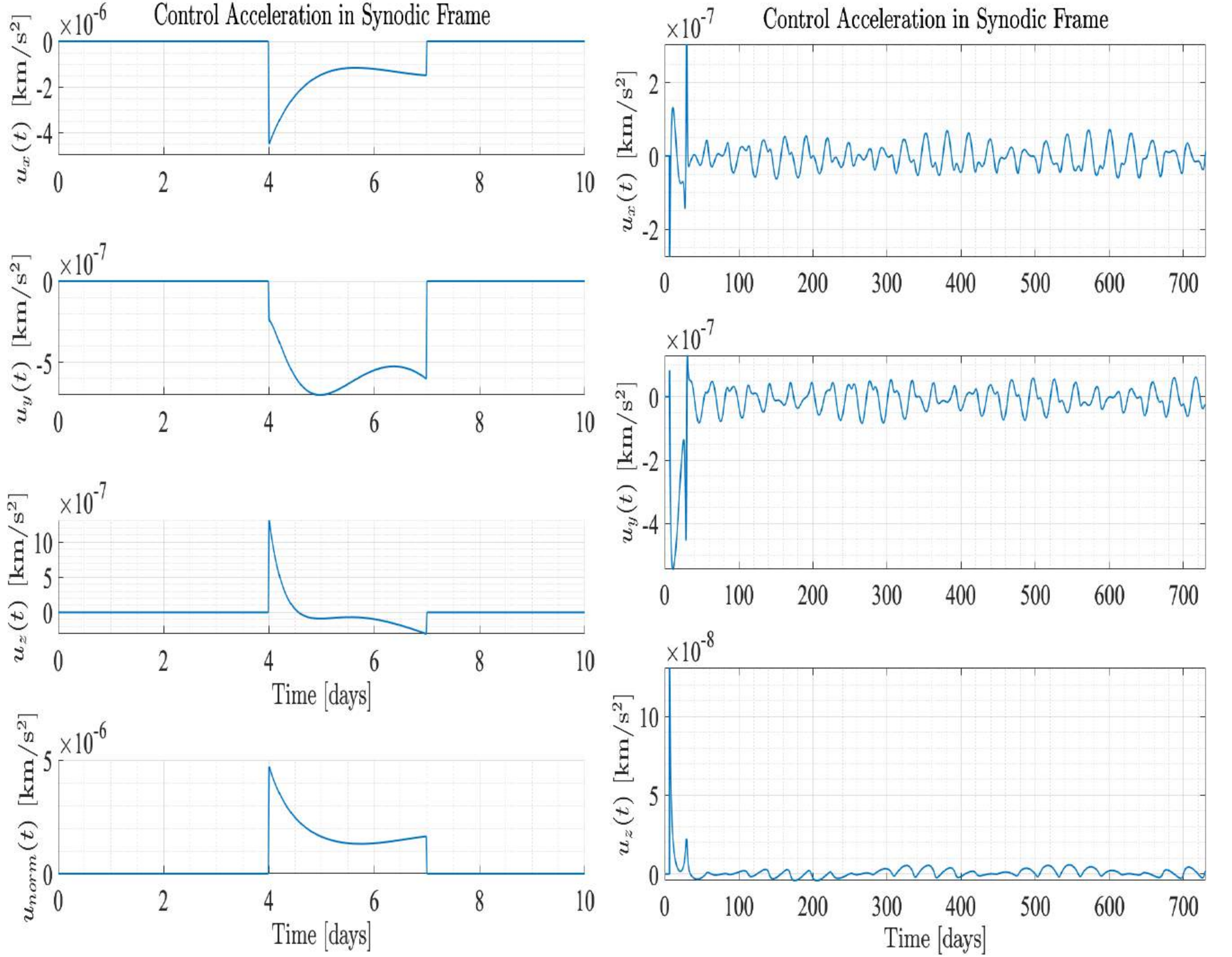
A 1U chemical propulsion system is capable of about 75m/s ΔV



3.8km/s at an ISP of 1100s equates to 3.6kg of xenon, or about 1 liter of liquid Xenon. This is exactly 1U of propellant

Thrust is peaking around 56mN, just outside the range of the best Hall Effect Thrusters.



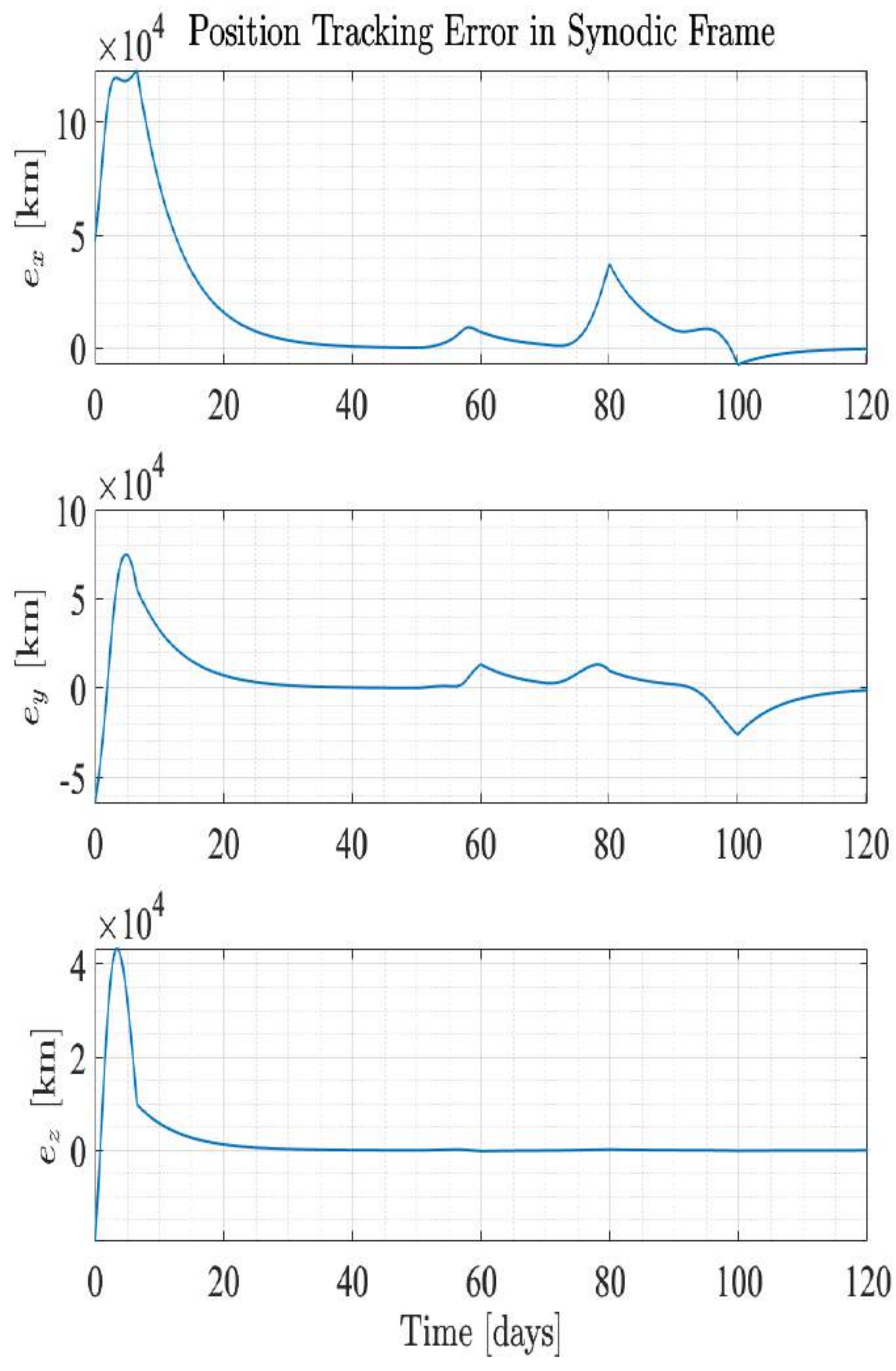


Acceleration Profiles

Transfer Phase – 10^-6 km/s^2

Station Keeping – 10^-8 km/s^2

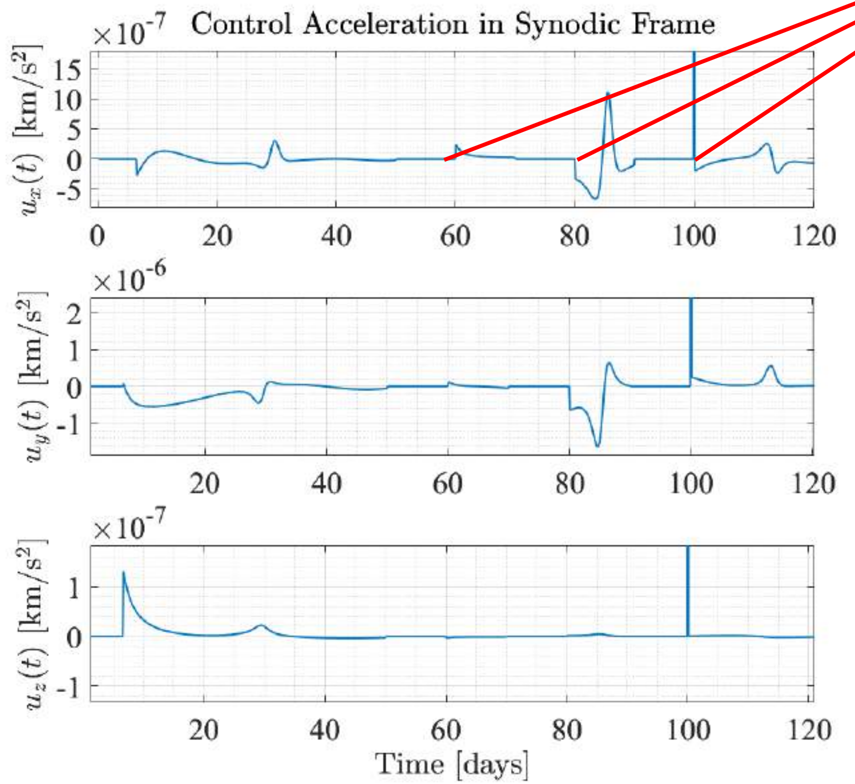
NOTE: With the current size and weight limitations the spacecraft cannot produce enough power to control itself continuously. There are significant acceleration penalties for having to coast for long periods. This graph represents the ideal case, not a realistic one.

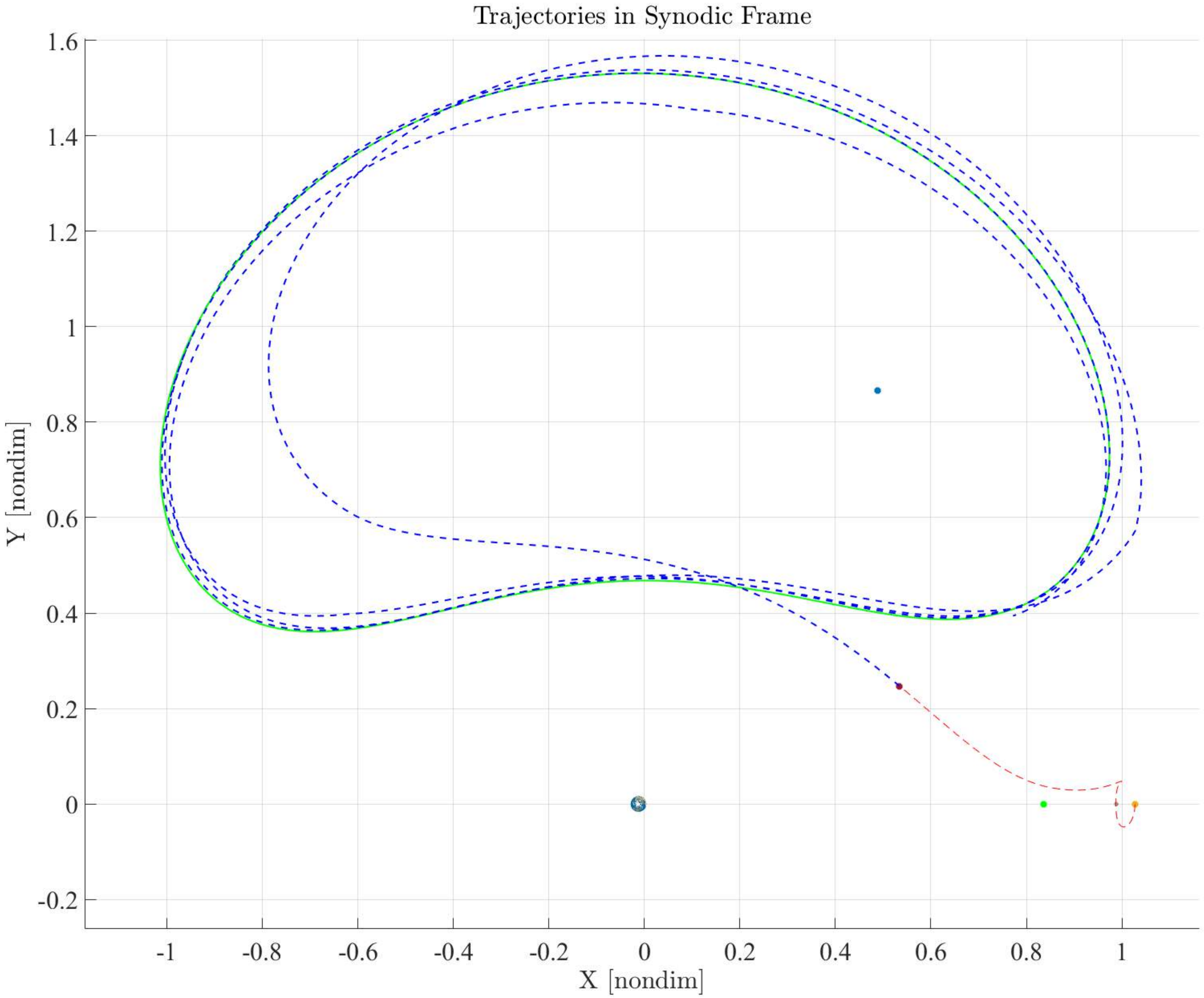


Tracking Error Profiles

10 Day coast periods at
- 50-60 days,
- 70-80 days
- 90-100 days

Depending on where in the orbit the coast period takes place, the correction acceleration needs can significantly change





- 100 Day simulation

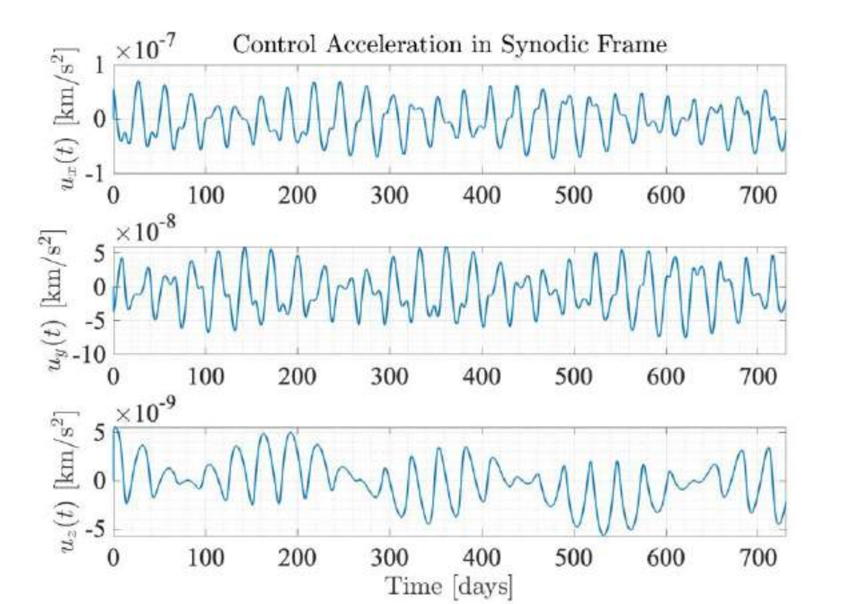
- Three 10-day periods of coasting whilst on-station

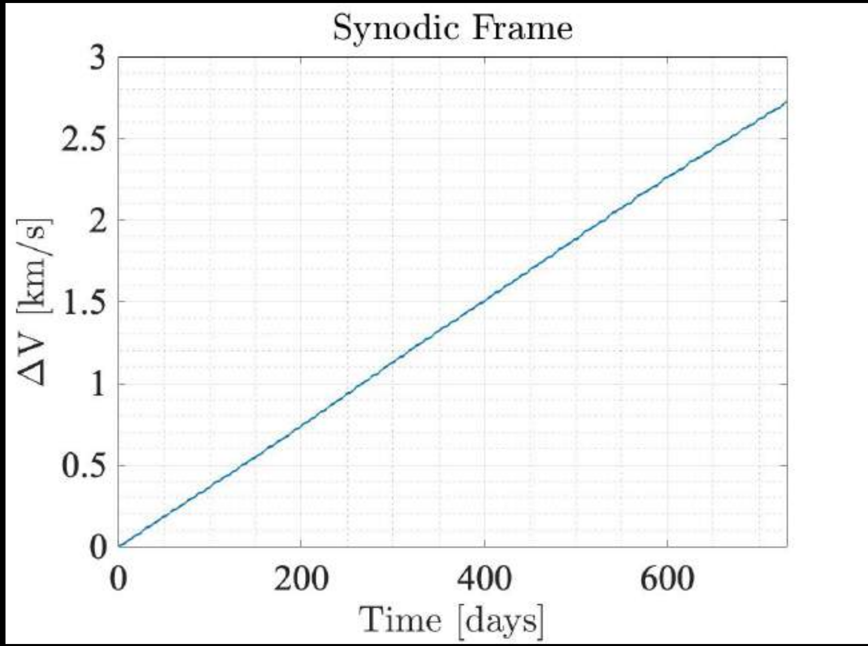
It may be that there is an optimal position along the orbit for coasting without drifting too far off course.

Still To-Do:

- SPO Trials
- Optimizing L1 Maneuver
- Develop Coasting Period Algorithm

Station Keeping in SPO





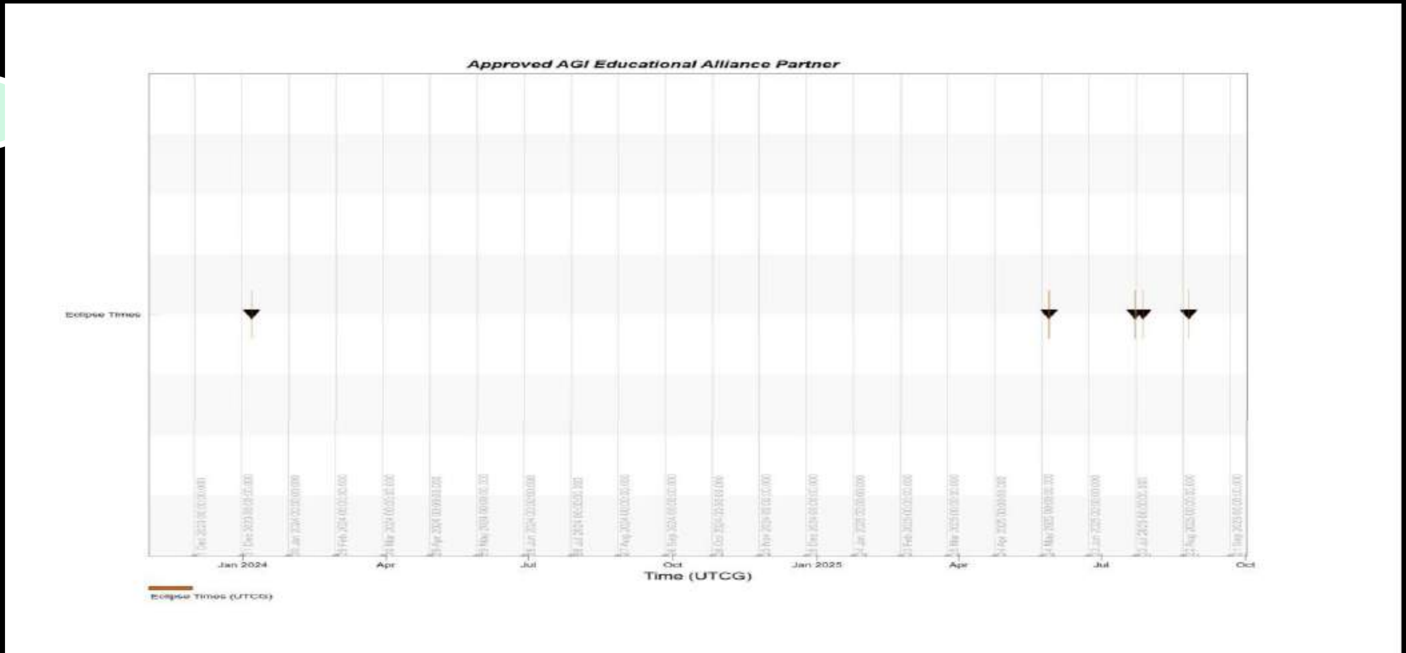
- 700 Day simulation in Matlab
- Required acceleration to maintain orbit
- Total Delta V for duration of mission

Station Keeping in SPO

- 100 Day simulation in STK
- CR3BP
- Earth-Luna System
- Without maneuvers

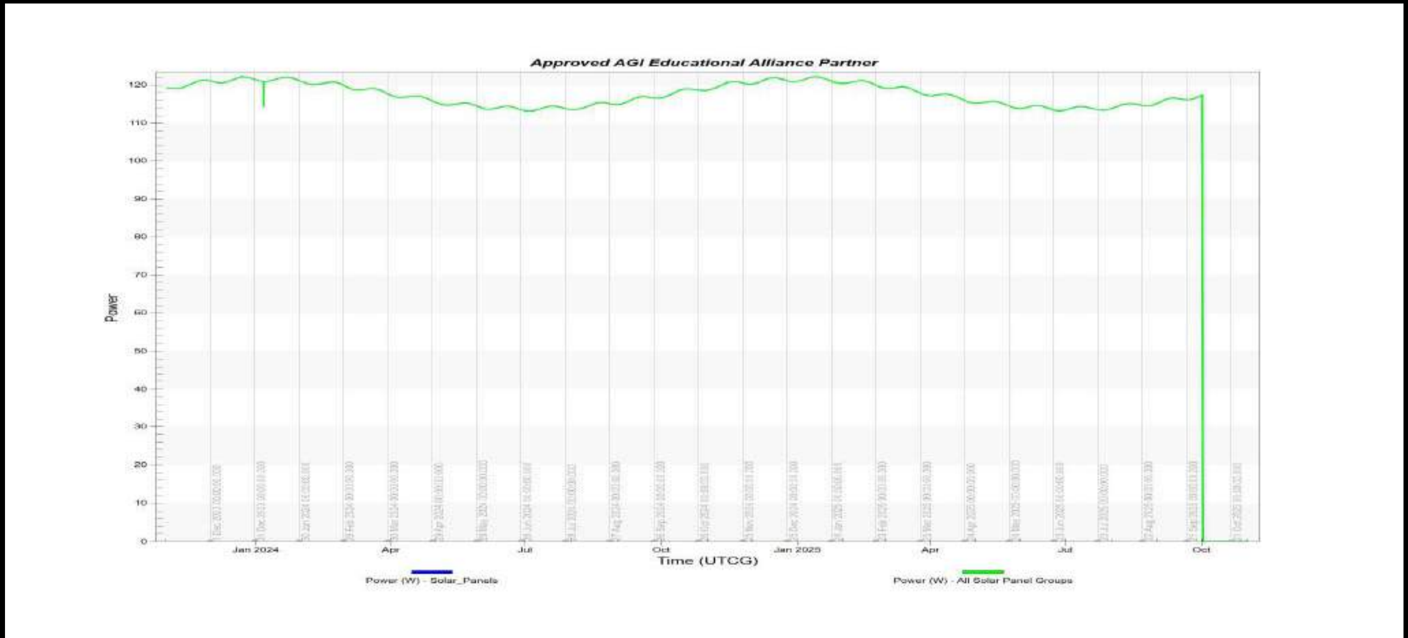
Still To-Do:

- Corrections Burns
- Optimizing: Time in penumbra, number of eclipses



- Eclipse with moon
- 5 penumbras
- Time Step: 0.25 Days

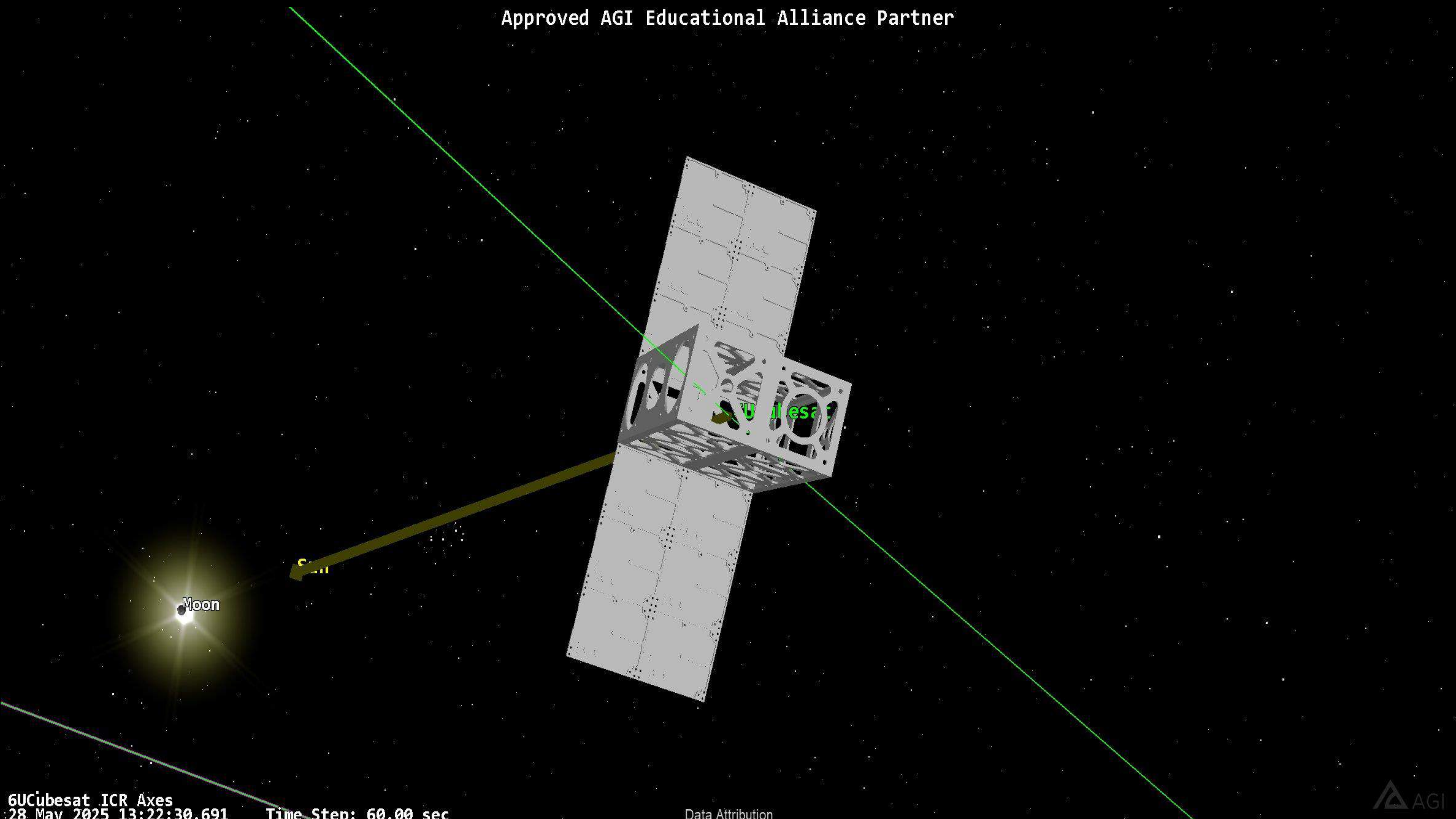
Note: Power generation is not accounting for attitude adjustment to align camera




```
Page 1
                                  2 Nov 2023 00:58:08
Approved AGI Educational Alliance Partner
Satellite-6UCubesat:   Penumbra Start

    Start Time (UTCG)
------------------------
 6 Jan 2024 03:47:13.924
28 May 2025 12:27:23.686
22 Jul 2025 10:34:31.019
27 Jul 2025 06:08:35.979
25 Aug 2025 10:29:35.226
```

```
    Stop Time (UTCG)
------------------------
 6 Jan 2024 06:51:33.593
28 May 2025 13:54:28.184
22 Jul 2025 12:01:12.369
27 Jul 2025 09:54:02.921
25 Aug 2025 12:02:08.916
```

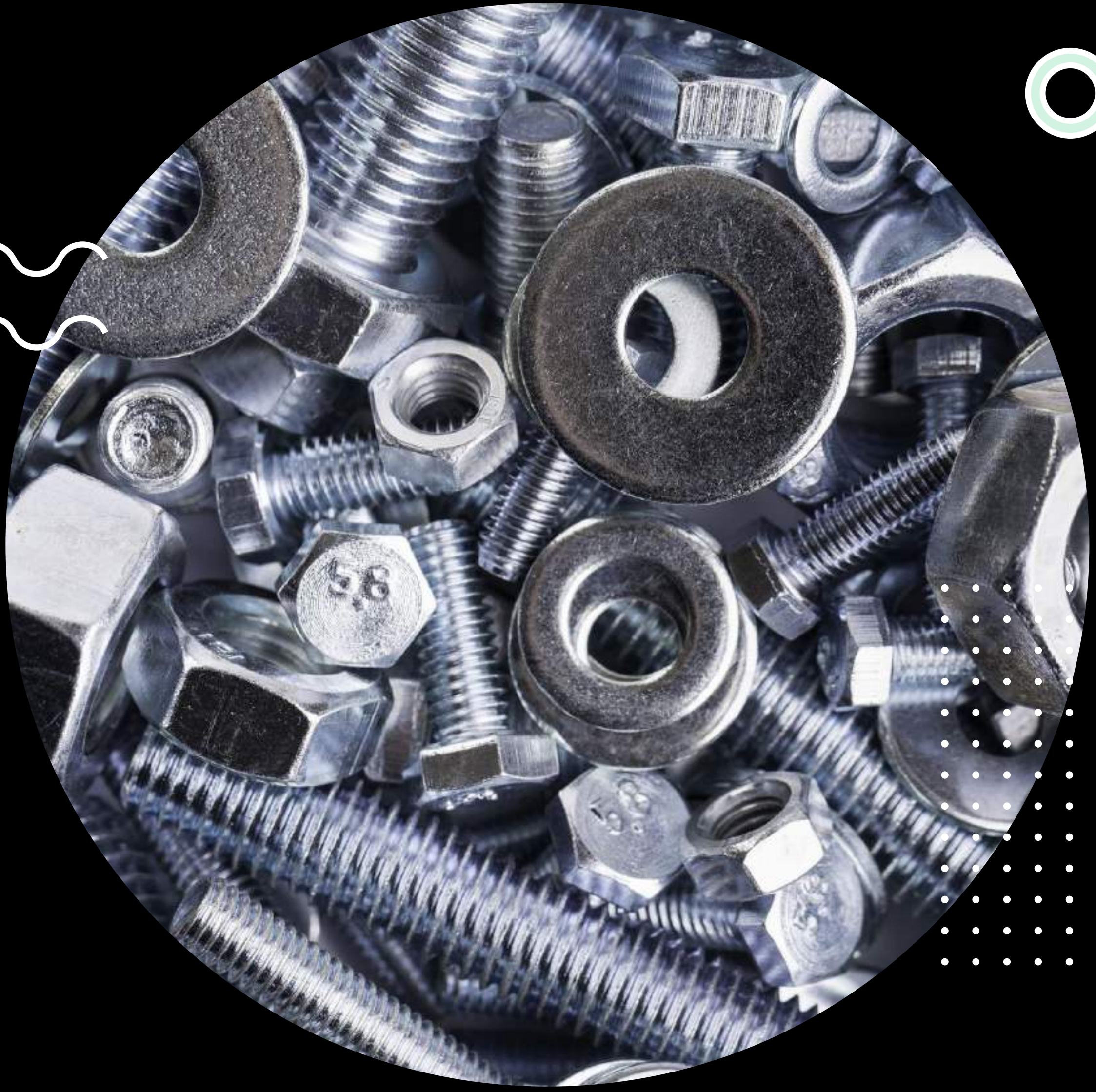


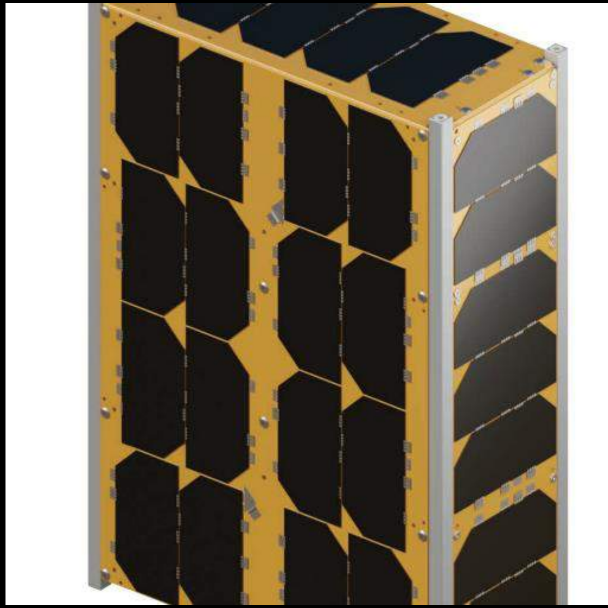
Approved AGI Educational Alliance Partner
Moon
6UCubesat ICR Axes
28 May 2025 13:22:30.691
Time Step: 60.00 sec
Data Attribution
AGI

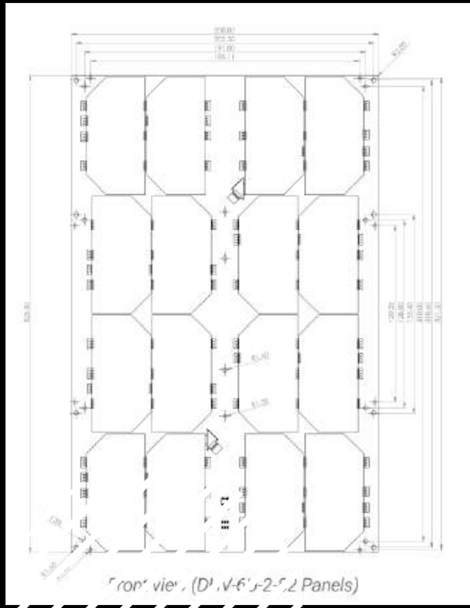
Trade Studies

Reaction Wheel			**SatBus 4RWO**			**RL-RW-0.03**			**Gen 1: Cube Wheel Med**		
Parameter	Weight	Units	Mag.	Score	Value	Mag.	Score	Value	Mag.	Score	Value
Max Power Draw	0.25	W	3.25	1	0.25	1.8	3	0.75	2.3	2	0.50
Max Momentum	0.20	Nms	0.02	2	0.40	0.04	3	0.60	0.011	1	0.20
Torque	0.20	mNm	3.2	3	0.60	±2	2	0.40	1	1	0.20
Cost per wheel	0.15	USD	29,000	2	0.30	20,000	3	0.45	30,160	2	0.30
Mass	0.10	g	137	3	0.30	185	1	0.10	150	2	0.20
Dimensions	0.10	mm	43.5x43.5x24	3	0.30	50x50x40	1	0.10	46x46x31.5	2	0.20
Overall Value:					2.15			2.4			1.6

COMPONENTS







Solar Panels

DHV Tech 6U 8S2P

<u>Parameters:</u>

Max Power:	**19.3 W**
Max Voltage:	**19.3 V**
Max Amperage:	**1 A**
Mass:	**.3 Kg**

<u>Sensors:</u>

Temperature, Sun

<u>Cost:</u>

$75,000.00 (estimated)

Solar Array Losses

Parameters	BOL			EOL		
Temperature (°C)	-50 °C	28 °C	125 °C	-50 °C	28 °C	125 °C
V_{oc} (V)	25.39	21.52	16.71	24.90	20.85	15.80
I_{sc} (A)	0.98	1.04	1.11	0.98	1.04	1.10
V_{mp} (V)	22.99	18.81	13.61	22.54	18.30	13.02
I_{mp} (A)	0.95	0.99	1.03	0.94	0.97	1.01
P_{mp} (W)	21.80	18.54	14.05	21.10	17.70	13.10

Max Onboard Power Per Panel:

19.3 W

Considerations:

1. ***Temperature***

   Temperature Tested at 25C

   14.05 W

2. ***Degradation (2 yrs)***

   3 Year Lifespan

   13.42 W

3. ***Distance to Sun***

   Inverse Square Law (97%)

   BOL: 13.6 W EOL: 13 W

4. ***Incidence Angle***

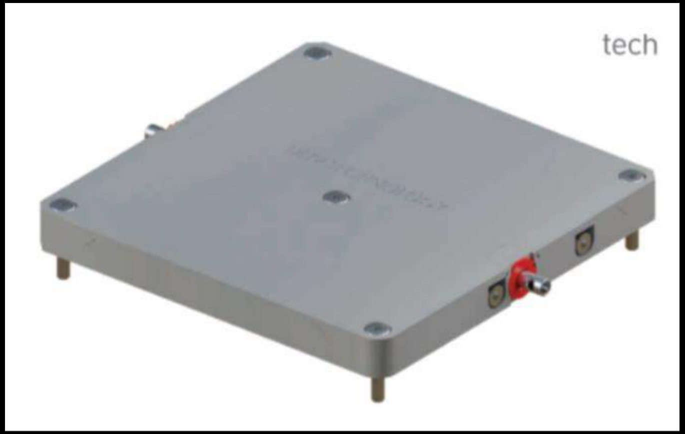
Solar Array Drive

DHV MicroSADA-10

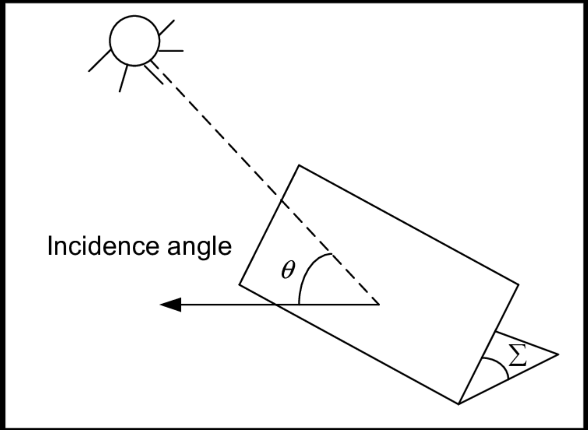
Purpose
- **Eliminate/ Reduce Losses due to incidence angle.**
- **Allows Pointing of solar panels in three axes.**
- **Allows Thrust Pointing without Power Sacrifice.**

Specifications:
Intended for use with DHV panels

Mass:	**< .25 g**
Max Power:	**< 5 W**
Range of Motion:	**+/- 180 deg**
Max Rotation:	**.9 deg/s**
TID:	**< 28 kRad**



Solar Array Drive



Smaller Incidence Angle = More Absorption

Justification:

1. **Less Mass**

    Endurosat 6U Folding: 757 g 19.2 W

    DHV 6U w/Solar Drive: 425 g 19.3 W

2. **Power Cost**

    MicroSADA-10 Max Power = 5 W

    (This assumes max rotation of .9 deg/s)

    <u>**Sun Revolution Every 6.7mins**</u>

    Conservative estimate of .5 W for operation

Solar Panel			**Endurosat 6U Foldable**			**ISIS Space 6U**			**DHV Tech 6U 8S2P**		
Parameter	Weight	Units	Mag.	Score	Value	Mag.	Score	Value	Mag.	Score	Value
Max Power	2	W	19.2	10	20	17	0	0	19.3	10	20
Max Voltage	1	V	19.2	8	8	3, 5, 8	10	10	19.2	8	8
Max Current	1	A	1	8	8	variant	10	10	1	8	8
Mass	2	Kg	.757	0	0	.3	10	20	.55	4.5	9.1
Price	2	$	48,000	10	20	60,000	5.6	11.2	75,000	0	0
Power/Mass	3	W/Kg	25.4	0	0	56.7	10	30	35.1	3.1	9.3
Pointable?	3	unitless	Limited	5	15	No	0	0	Unlimited	10	30
Overall Value:					71			81			84

E P S

ENDUROSAT EPS I PLUS

Input Voltage: 5.5 V per Channel
Input Current: 1.8 A per Channel
Output: 3.3 V, 5 V
BCR Regulator

Internal Battery Pack: 20 Wh
Interfaces: RS-485, USB-C

Remove before flight switch

Cost: $5,800.00

BATTERY

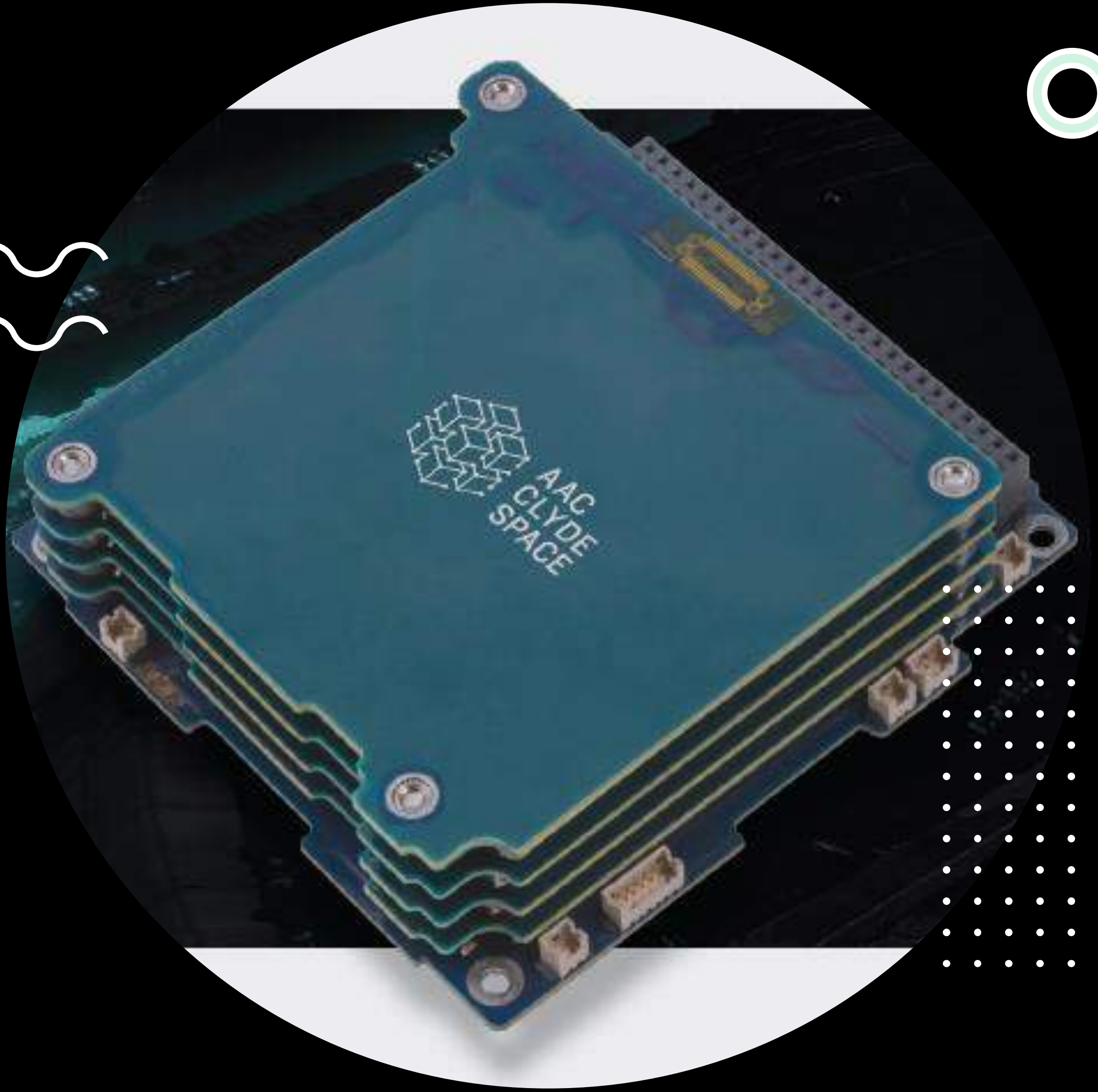
AAC CLYDE SPACE OPTIMUS-30

Capacity: 30 Wh
Charge/Discharge: 1.95 A
Max Voltage: 8.4 V
Output: 3V, 5V

NASA Standards
Vacuum, Radiation, Vibration Tested

300~500 Life Cycle

Cost: $10,000.00



OBC

ENDUROSAT OBC

- ARM Cortex M7 Processor
- 8Gb secure onboard memory
- SD Card Slot
- Time Clock

- Interfaces:
  USB-SCIC, USB-C
  RS-485, RS-422
  UART, 12C, SPI, CAN

Cost: $7,500.00

Communication

ISISPACE VHF/UHF DUPLEX

- VHF+UHF Transceiver

- Frequency
  - 145.80 - 150.05 MHz
  - 400.15 - 438.00 MHz
  - Other ranges available on request

- Can operate in both commercial and amateur bands
- Highly customizable
- Flight proven since 2016

Sensors

Star Tracker

CubeSpace Gen2: CubeStar

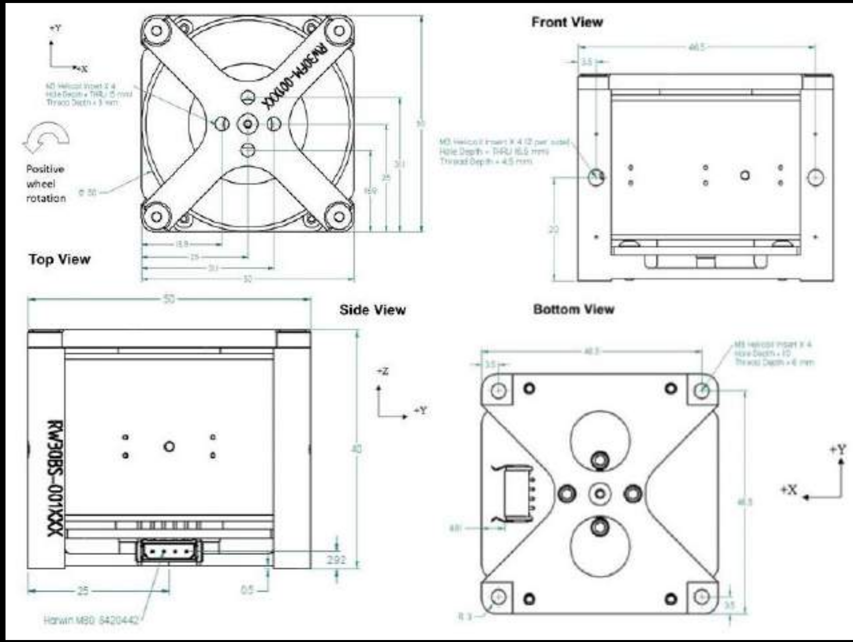
- **Medium to high accuracy**
- **Flight-proven**
- **Aluminum case with EMI filters**

Cost: $17,600.00

Sun Sensor

Solar MEMS Tech. NanoSSOC-D60

- **Space-grade components**
  - **Proven with hundreds of units in orbit**
- **Compatible with most structures**
- **Compatible with most OBCs**



Reaction Wheel

3-axis attitude control

Brand: RocketLab

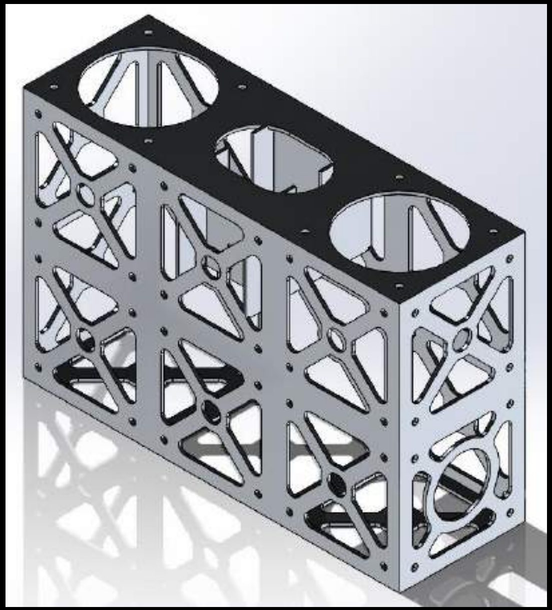
Momentum: 0.03 Nms

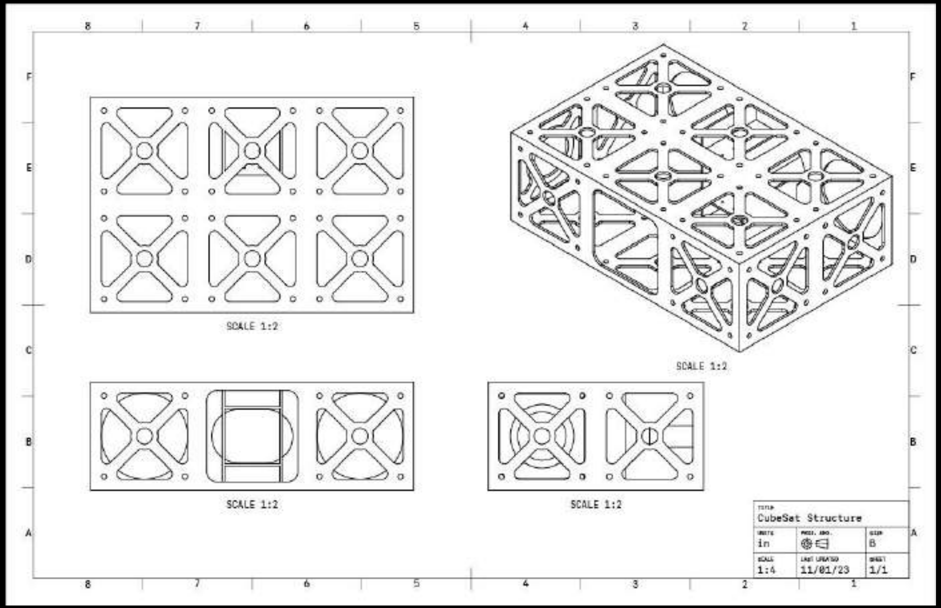
Torque: 2 mNm

Mass: 185 g

Supply Voltage: Nominal 3.4-6 V

Price: $20,000





Structure

Housing for payload and bus

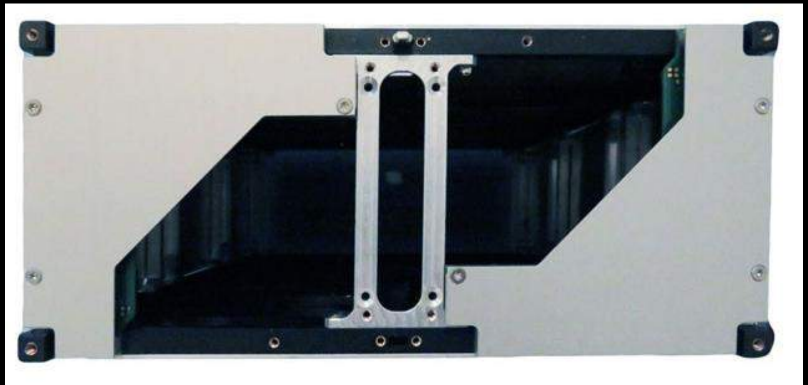
Brand: EnduroSat

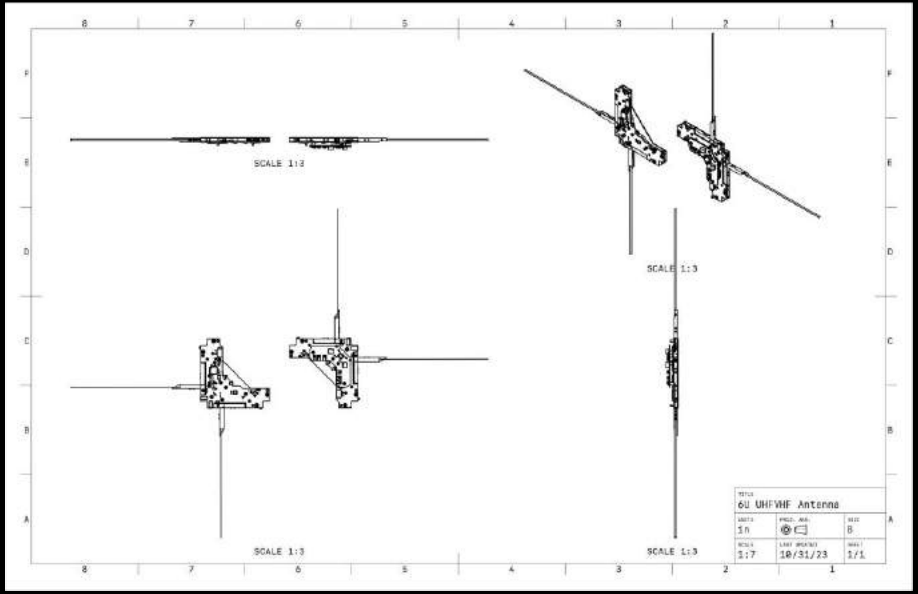
Material: Al 6082

Dimensions: 100 x 226.3 x 366 mm

Mass: 850 g

Cost: $7,600





Antenna

For transmitting and receiving data

Brand: ISISPACE

Bandwidth: UHF > 50 Mhz

VHF > 10 Mhz

Power Draw: Nominal < 30 mW

Electrical: Miniature 9 pin OMNETICS connector

RF input/output: MMCX female 50 ohm

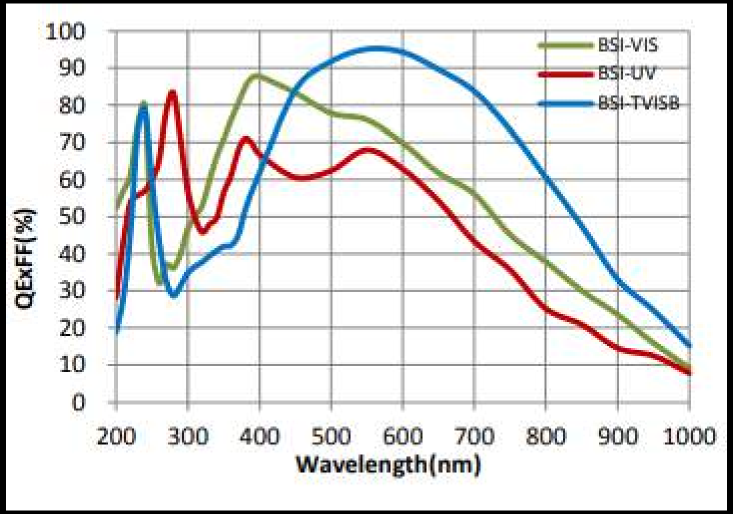
Mass: 90 g

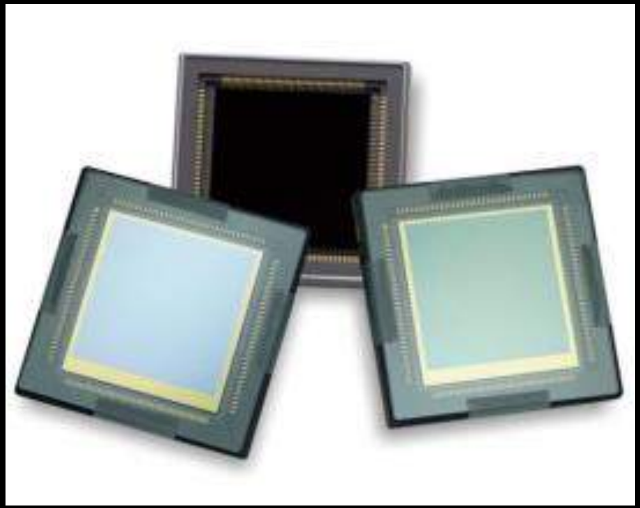
Cost: $4,500

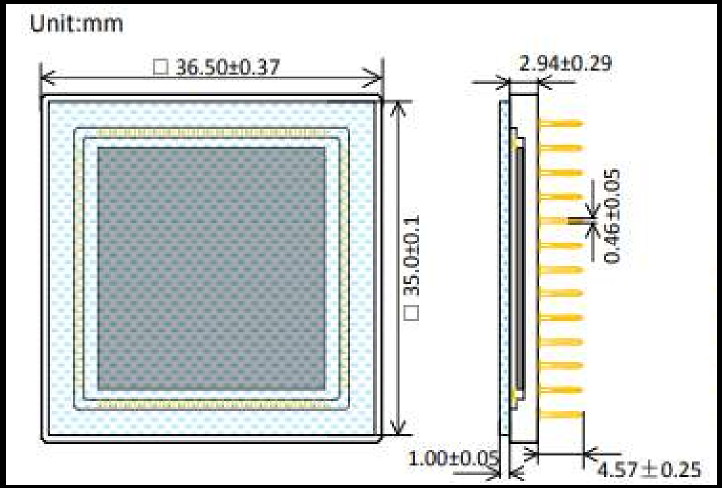
OBSERVATION CHIP

GPIXEL GSENSE400BSI-UV

- Imaging Area: 22.5x22.5mm
- Pixel Size: 11μm
- Max Power Drain: 600mW
- 48 FPS 4K (STD) 24FPS 4K (HDR)







Observatory Design: A Pair of Cassegrain Telescopes

- JWST, Hubble: both Cassegrain
- What is a Cassegrain
- Why it matters
- How we will make it work

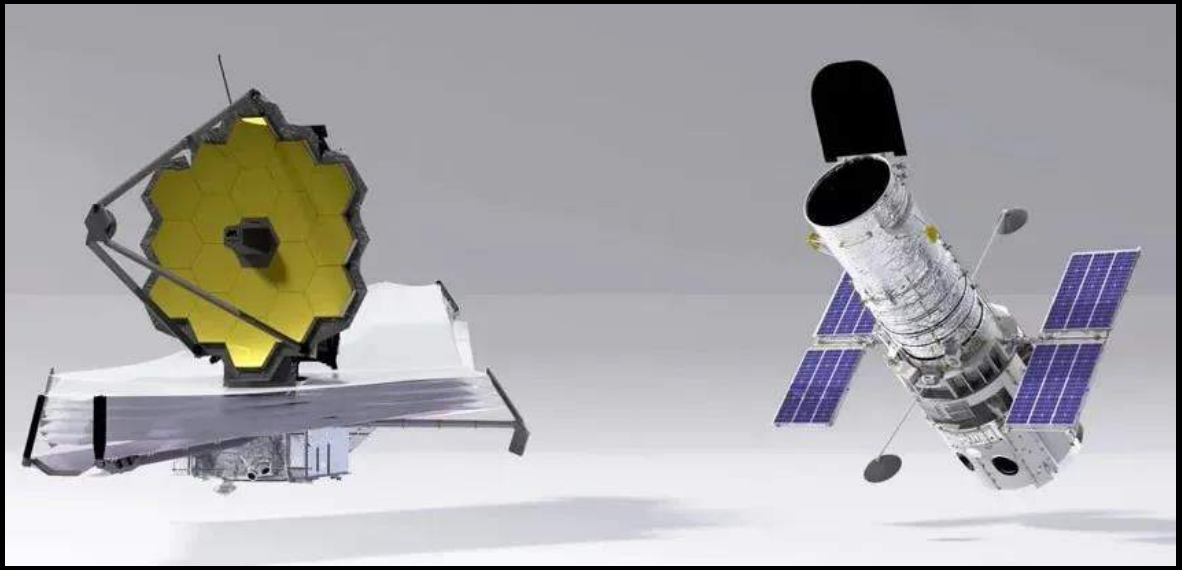
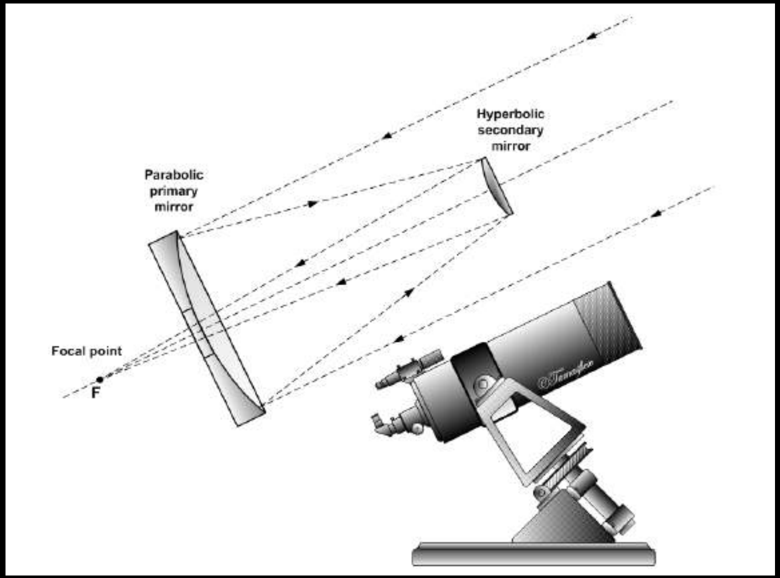


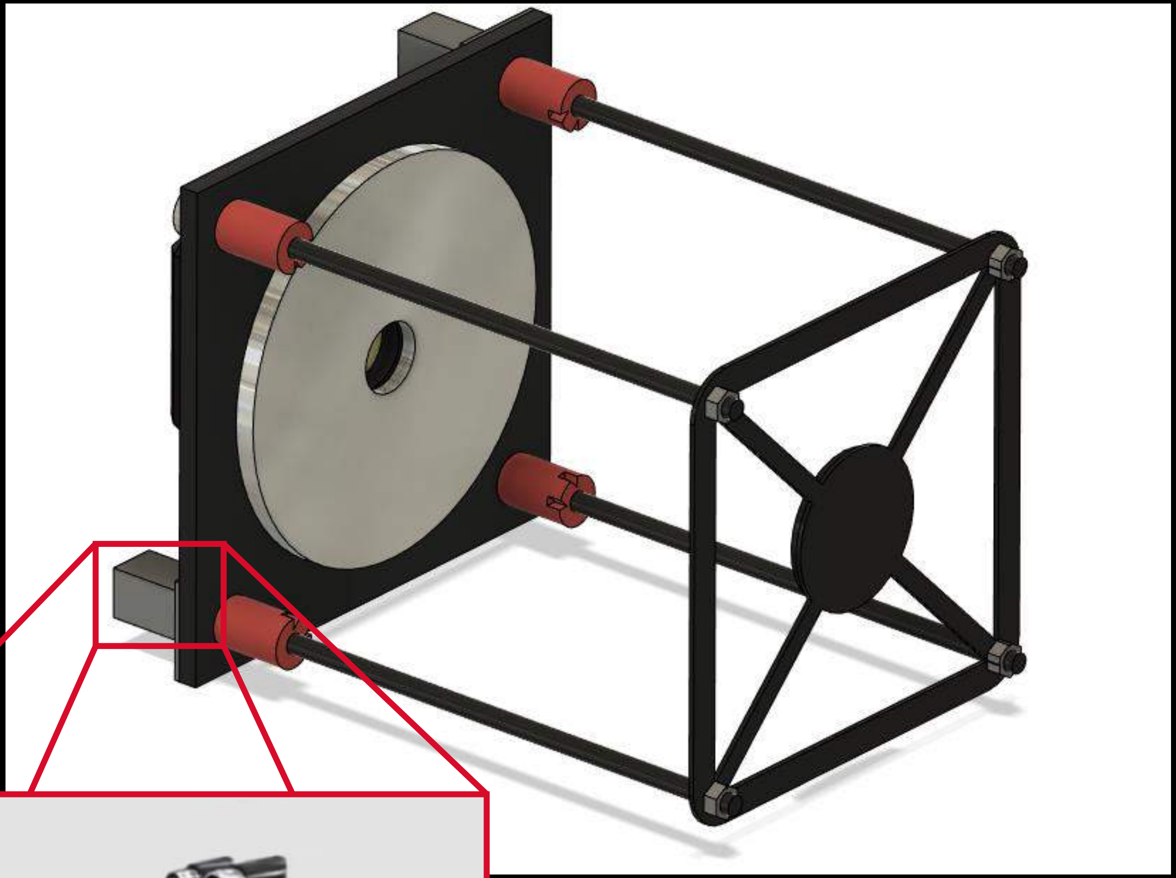
Image courtesy: NASA



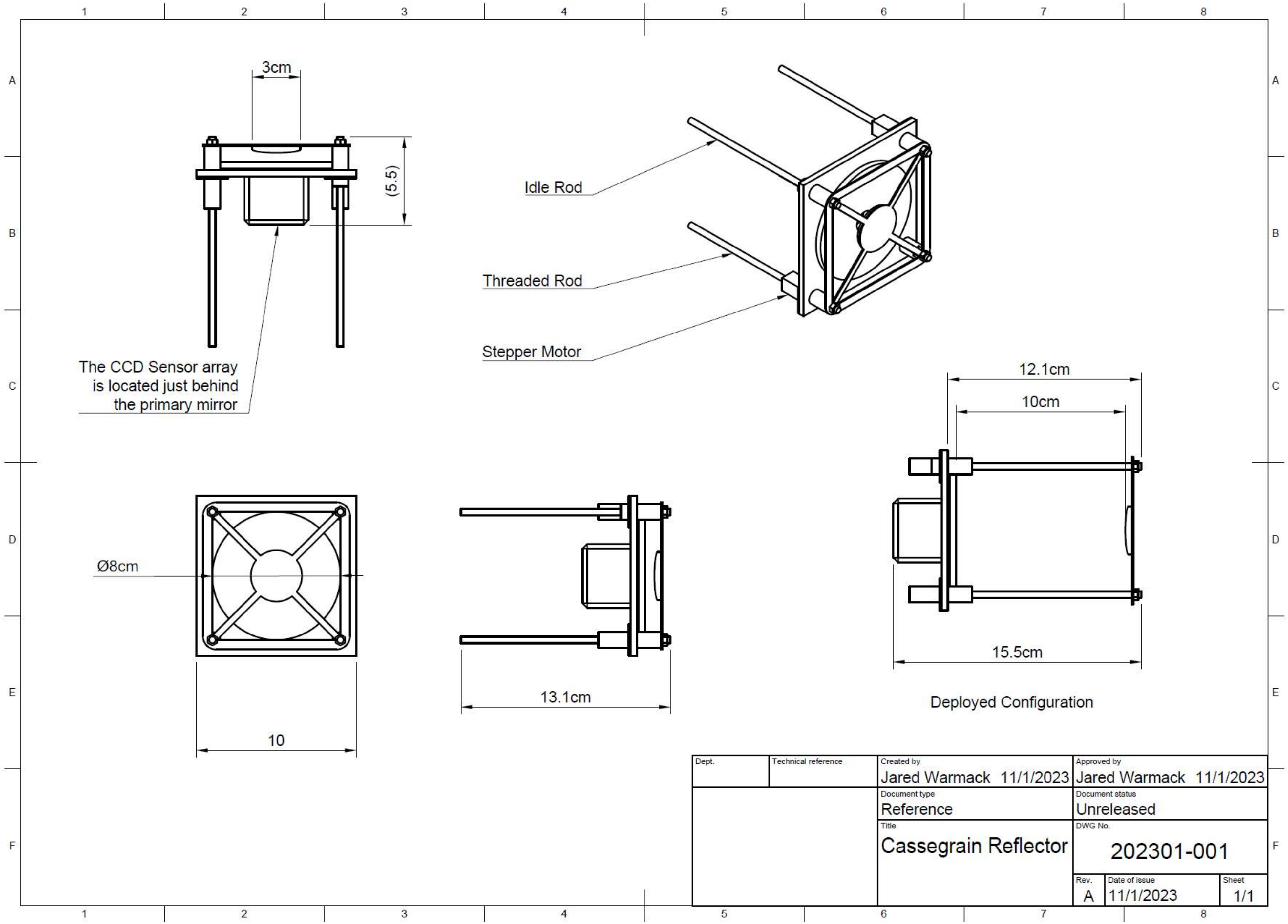
- Two mirrors, a primary parabolic with a ‘donut hole’ and a secondary hyperbolic.
- Shortens overall length dramatically while maintaining high effective focal length.
- Massive weight savings over refractors and other reflectors
- Collapsibility for compact stowage.
- Focus adjustment on station (remember Hubble)

Observatory Design

- Pusher Rod/Step Motor deployment
  - 2 idle rods, 2 threaded rods
  - Extremely precise focus tuning (motor capable of 1.4° steps.)
  - Adjustments can be made to scatter light to protect CCD from direct sun exposure during orbit
- Allows for 70% volume savings
- Lightweight frame saves mass over reflector designs



STOBER Ball Screw & Hollow Bore Stepper Motor



Overall Size:
Stowed 1x1x0.5 (U)
Not including the pushrods.

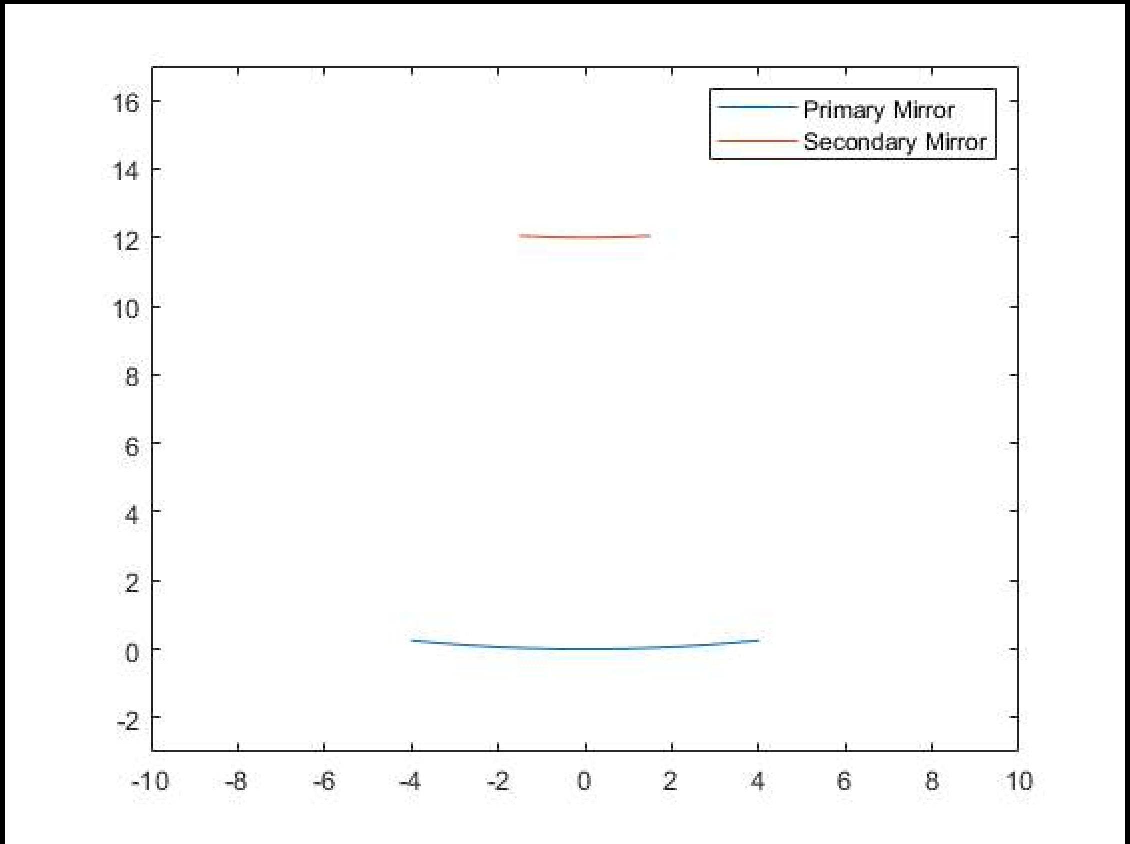
Stepper motors are fixed to the assembly frame and rotate a threaded hollow core which extends the rods.

Telescope Parameters:

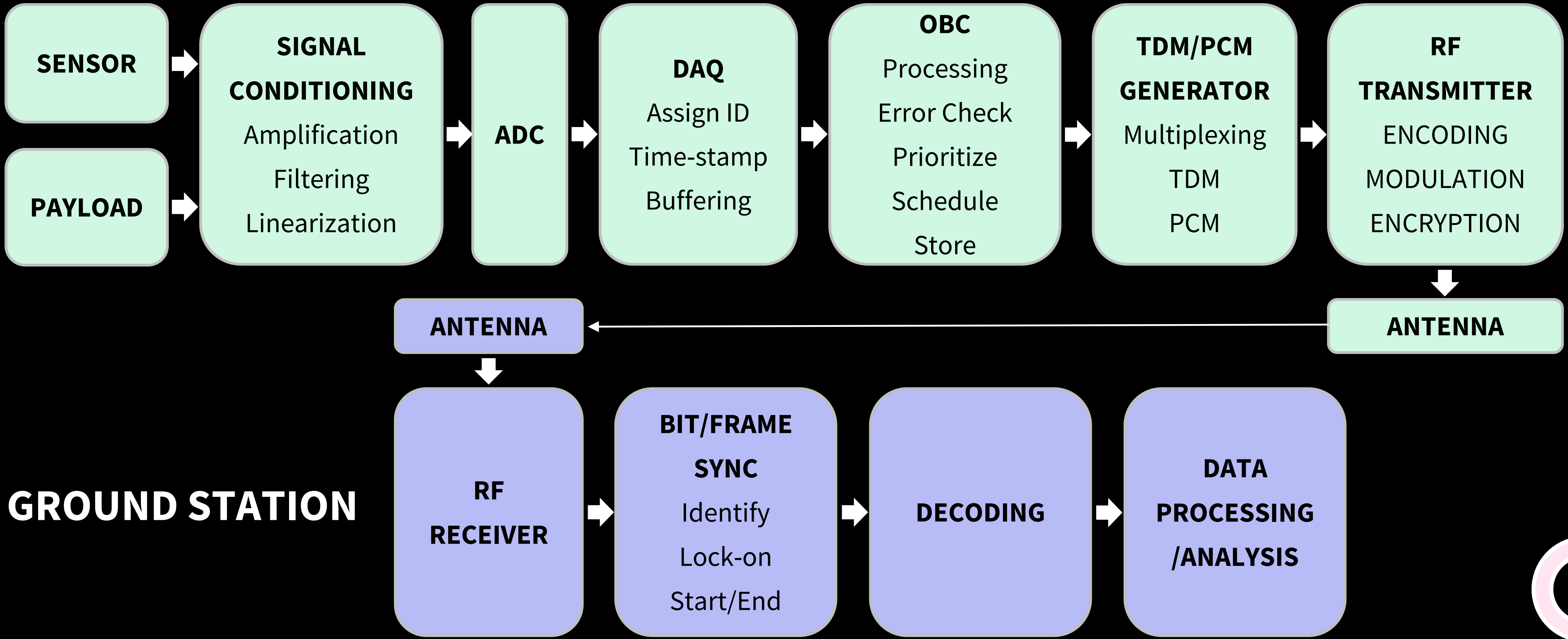
- Primary Mirror Diameter: 8 (cm)
- Secondary Mirror Diameter: 3 (cm)
- Effective Focal Length: 37.33 (cm)
  [Requirements suggest at least 20cm]
- Magnification: 2.33x
- F/stop: 4.667
- Angular Resolution 1.25822 (arcsec)
  [Requirement BTR2.0 states <3 arcsec]
- Light Gathering Reduction: -14.0625%
- Obstruction Ratio: 37.5%

Using this, the exact curvature of the mirrors is plotted in MATLAB. We have also confirmed that the angular resolution requirement BTR2.0 is met.

Even greater magnification and effective focal length are achievable if space allows for longer threaded rod assemblies to extend into the spacecraft body.



Data Transmission Design



Data Transmission

- NUV Image Data Size
  - Image resolution 2048 x 2048 pixels
  - 16-bits per pixel
  - 8.4 MB (~4.2 MB Compressed)

- Frequency
  - VHF – 144 MHz
  - UHF – 430 MHz
- Data Rate
  - Moderate: up to 38.4 kbps
  - High end: up to 256 kbps

- Regulatory Requirements
  - International Telecommunication Union (ITU)
    - Frequency Allocation
  - Federal Communications Commission (FCC)
    - License for satellite communication

- Other Options
  - S-Band: 2.0~2.3 GHz, up to 10Mbps

Power & Mass

Part	Mass (kg)	Max Wattage (W)	Nominal Wattage (W)
Reaction Wheel	0.19	-1.80	-0.30
Anntena	0.09	-2.30	-0.03
EPS	0.33	-1.50	-0.50
Battery	0.27	0.00	0.00
Telemetry Software	0.00	0.00	0.00
Structure	0.85	0.00	0.00
Thruster L2 to L4	1.10	-12.00	-6.00
Thruster L4 Station	1.20	~	~
OBC	0.13	-2.50	-0.50
Comm	0.09	-1.40	-0.50
Star Tracker	0.06	-0.14	0.00
Solar Panels	0.60	28.60	27.17
Solar Array Drive	0.25	-5.00	-0.50
Mirrors	0.25	0.00	0.00
Observation Chip	0.03	-0.60	-0.60
Telescope Misc. Parts	0.09	-2.00	-0.50
Wiring+Hardware	0.56	0.00	0.00
Fuel Tank	~	0.00	0.00
Ion Fuel	1.78	0.00	0.00
Chemical Fuel	0.31	0.00	0.00
Total	8.17	-0.64	17.74

Green	Known Values
Orange	Thruster (Will Not Result in Appropriate dV)
Blue	Cost Estimates

Cost

Part	Price ($)
Reaction Wheel	$ 100,000.00
Anntena	$ 16,005.00
EPS	$ 5,800.00
Battery	$ 6,200.00
Telemetry Software	$ 30,000.00
Structure	$ 7,600.00
Thruster L2 to L4	$ 400,000.00
Thruster L4 Station	$ 210,000.00
OBC	$ 7,500.00
Comm	$ 5,900.00
Star Tracker	$ 17,600.00
Solar Panels	$ 150,000.00
Solar Array Drive	$ 46,000.00
Mirrors	$ 10,000.00
Observation Chip	$ 10,000.00
Telescope Misc. Parts	$ 1,000.00
Wiring+Hardware	$ 200.00
Fuel Tank	$ 200.00
Ion Fuel	$ 6,000.00
Chemical Fuel	$ 500.00
Total	$1,030,505.00

	Known Values
	Thruster
	Cost Estimates

- Thruster:

  L2-L4 Thruster:
  - Estimates ranged up to 500k.

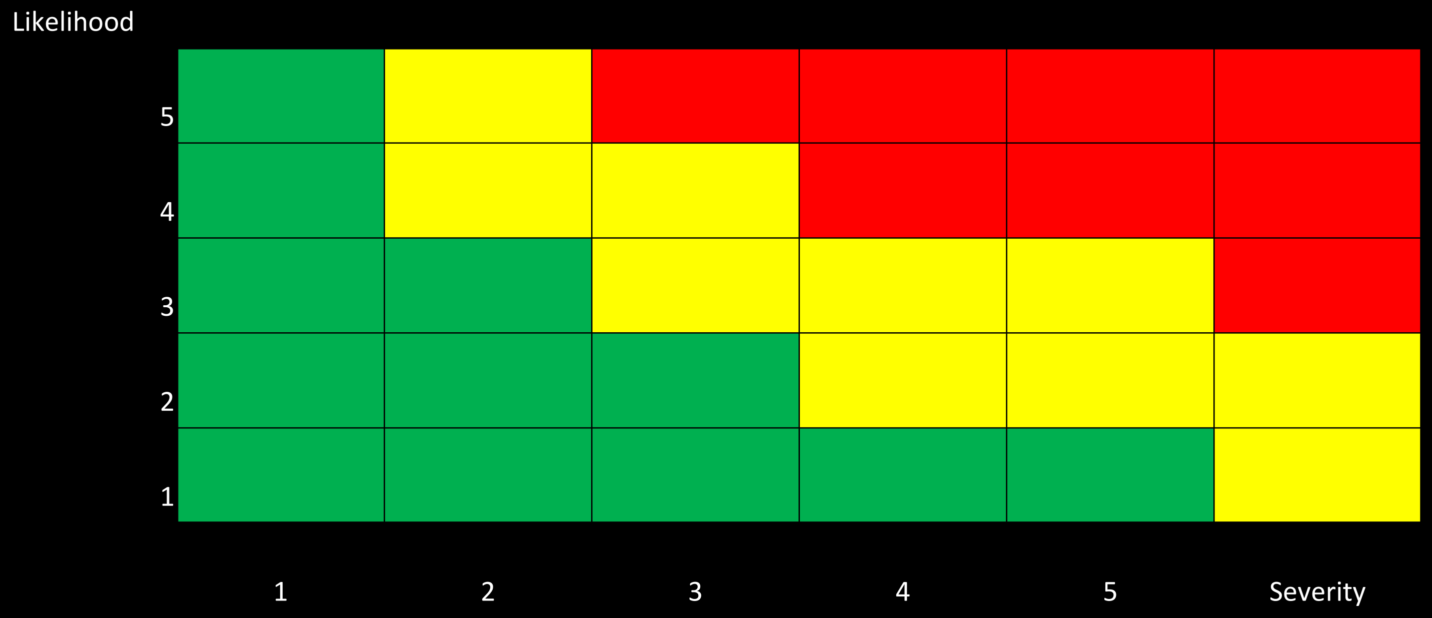
  L4 Station
  - Estimate could not be found for HE.
  - Found for Ion.

  Fuel Tanks:
  - Chem fuel built in .
  - Ion fuel tank estimated.

- Cost Estimates:

  Based on adjacent parts and rough market price adjusted for complexity of chosen part.

Risk Assessment



High Risk	Significant Impact
Moderate Risk	Some Impact
Risk	Minimum Impact

Risk Assessment

Failure Mode	Failure Cause	S	L	C	Failure Detection	Preventative Action
Transfer Orbit Failure	No Detumble	5	1	5	Inconsistent Data	Redundant Systems
	Antenna Deployment	5	1	5	No Data	Testing
	Solar Panel Deployment	5	1	5	Loss of Contact	Testing
	Propulsion Failure	5	1	5	Wrong Trajectory	Simulations/Test Fires
	ACS Failure	5	1	5	Inconsistent Data	Testing
SPO Orbit Failure	Propulsion Failure	5	1	5	Telemetry	Simulations/Test Fires
Imagery	Gimble	5	1	5	Blurry Image	Testing
	Rods	5	1	5	No Image	Testing
	Focus	3	2	6	Blurry Image	Auto Focus Software
Electronics	Radiation Damage	3	1	3	Loss of Contact	Radiation Protection
	Temperature Damage	3	1	3	Loss of Contact	Radiator/Testing
Ground Station	Upkeep	4	1	4	On the Ground	Regular Visits to Ground
	Line of Sight (LOS)	1	3	3	No Contact	Simulations

Analysis & Conclusion

Areas for Improvement:

- Orbits refined endlessly, no feasible solution found, L1 boost may help.
- No transfer orbit and station keeping combination has yielded values which would allow for thrusters that could feasibly fit the size, weight, or power requirements for this Cubesat.

Positives:

- Space saving telescope designed which exceeds requirements
- Vast majority of parts for the satellite have been chosen excluding thruster components.

Open Items

- Find orbit with sufficiently low ΔV and acceleration for feasible thruster size and weight constraints.
- Nail down more accurate cost estimates for parts.
- Refine orbit parameters.
- Find thrusters that will meet orbital, power, and price requirements.
- Refine CAD model to be more specific.

QUESTIONS?

Sources

- Chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://standards.nasa.gov/sites/default/files/standards/NASA/B/0/Historical/nasa-std-6016a.pdf
- https://ntrs.nasa.gov/citations/19970027853
- LunOSTAR Program Level Requirements
- https://www.rocketlabusa.com/space-systems/satellite-components/reaction-wheels/
- https://www.isispace.nl/product/antenna-system-for-6u-12u-cubesats/
- https://www.endurosat.com/cubesat-store/cubesat-structures/6u-cubesat-structure/
- https://www.satcatalog.com/component/nanossoc-d60/

Trade Studies Extended

Antenna			**ISIS VHF/UHF**			**UHF Antenna III**			**ISIS GNSS Patch Antenna**		
Parameter	Weight	Units	Mag.	Score	Value	Mag.	Score	Value	Mag.	Score	Value
Max Transmit Power	0.25	W	2	3	0.75	3.5	1	0.25	3-5	1	0.25
Max Power Draw	0.25	W	2.3	2	0.50	1.25	3	0.75	3.5	1	0.25
Frequency	0.15	MHz	300-3000	3	0.45	435-438	2	0.30	1575	2	0.30
Gain	0.05	dBi	0 / 0	1	0.05	> 0	2	0.10	5.5	3	0.15
Cost	0.15	USD	4,500	2	0.30	4,700	2	0.30	3,800	3	0.45
Mass	0.15	g	90	1	0.15	85	2	0.30	16	3	0.45
		Overall Value:			2.2			2.0			1.85

Trade Studies Extended

CubeSat Structure			Endurosat 6U XL			Pumpkin, Ink 6U Supernova			GOMspace 6U Nanosatellite		
Parameter	Weight	Units	Mag.	Score	Value	Mag.	Score	Value	Mag.	Score	Value
Material	0.25	N/A	Al 6082	3	0.75	Al 6061-T6	2	0.50	Al 7075	1	0.25
Cost	0.25	USD	7,600	2	0.50	7,350	3	0.75	8,100	1	0.25
Mass	0.25	g	850	2	0.50	1650	1	0.25	731	3	0.75
Flight Heritage	0.10	N/A	Yes	3	0.10	Yes	3	0.10	Yes	3	0.10
Dimensions	0.15	mm	100x226.3x366	3	0.45	104x222x348	2	0.30	100x226.3x340.5	3	0.45
		Overall Value:			2.3			1.9			1.8

Trade Studies Extended

Solar Panel			Endurosat 6U Foldable			ISIS Space 6U			DHV Tech 6U 8S2P		
Parameter	Weight	Units	Mag.	Score	Value	Mag.	Score	Value	Mag.	Score	Value
Max Power	2	W	19.2	10	20	17	0	0	19.3	10	20
Max Voltage	1	V	19.2	8	8	3, 5, 8	10	10	19.2	8	8
Max Current	1	A	1	8	8	variant	10	10	1	8	8
Mass	2	Kg	.757	0	0	.3	10	20	.55	4.5	9.1
Price	2	$	48,000	10	20	60,000	5.6	11.2	75,000	0	0
Power/Mass	3	W/Kg	25.4	0	0	56.7	10	30	35.1	3.1	9.3
Pointable?	3	unitless	Limited	5	15	No	0	0	Unlimited	10	30
Overall Value:					71			81			84

Trade Studies Extended

Thrusters			Spaceware Nano L			AAC Clyde Space PM 200			SETS ST40		
Parameter	Weight	Units	Mag.	Score	Value	Mag.	Score	Value	Mag.	Score	Value
Discharge Power	0.15	W	60	2	0.30	12	3	0.45	650	1	0.15
Thrust	0.15	mN	2.5	1	0.15	500	3	0.45	28	2	0.30
Specific Impulse	0.10	s	90	1	0.10	285	2	0.20	1850	3	0.30
Impulse	0.10	Ns	5400	3	0.30	850	2	0.20	1.2E6	3	0.30
Max ΔV of System	0.10	m/s	TBA	1	0.10	230	3	0.30	TBA	1	0.10
Cost	0.05	USD	TBA	1	0.05	TBA	1	0.05	TBA	1	0.05
Mass	0.15	kg	3.4	3	0.45	1.1 (PU)	3	0.30	1.1 (13.6 system)	1	0.15
Fuel Mass (3.8 km/s)	0.15	kg	11.6	1	0.15	0.47	3	0.45	3.6	2	0.30
Dimensions (Thruster Only)	0.05	cm	10.5x11x22.6	2	0.10	10x10x10	3	0.15	14x11.7x12.2	2	0.10
Overall Value:					1.7			2.55			1.75

Trade Studies Extended

EPS			EnduroSat EPS I			ICEPS Core			ISIS iEPS		
Parameter	Weight	Units	Mag.	Score	Value	Mag.	Score	Value	Mag.	Score	Value
Voltage	0.15	V	~5.5	3	0.45	33.3, 5	2	0.30	3.3, 5	2	0.30
Current	0.15	A	~3.0	3	0.45	2.75	2	0.30	~1.8	1	0.15
Features	0.10	N/A	RBF	1	0.10	X	X	X	X	X	X
Interfaces	0.10	N/A	RS, USB	1	0.10	X	X	X	X	X	X
Size	0.20	Scaled	2	2	0.40	X	X	X	2	2	0.40
Price	0.10	USD	5,800	3	0.30	27,000	1	0.10	X	X	X
		Overall Value:			1.80	Many info about the model not available		0.70	Many info about the model not available		0.85

Trade Studies Extended

Battery			EnduroSat Battery Pack			AAC Optimus-30			NanoAvionics EPS 1.0		
Parameter	Weight	Units	Mag.	Score	Value	Mag.	Score	Value	Mag.	Score	Value
Capacity	0.15	Wh	84	3	0.45	30	1	0.15	~161	3	0.45
Current	0.10	A	4	3	0.30	1.95	2	0.20	2.6~1.5	3	0.30
Voltage	0.10	V	10~36	3	0.30	8.4	2	0.20	2.6~18	3	0.30
Interfaces	0.15	N/A	RS-485	1	0.15	PC104	3	0.45	PC104	3	0.45
Mass	0.25	g	1,072	1	0.25	268	3	0.75	X	1	0.25
Size	0.25	Scaled	3	1	0.25	1	3	0.75	3	1	0.25
Overall Value:					1.70			2.50			2.00

Appendix

Requirement Level	Requirement Number	Requirement	Verification Model					Verification Methods	Status
			A	O	D	T	R		
		Administration							
0	1.0	There shall be a budget of one million dollars for design, development, and mission operations.			X			Verify prices of parts with design parameters and determine, if necessary, that parts are within budget.	
		Space System							
0	2.0	There shall be a 6U Satellite (30x20x10cm) which contains all necessary equipment and materials to conduct the scientific objectives and support mission operations.		X	X			Compare completed plan with physical measurements to ensure validity.	
1	2.1	There shall be a Bus.			X			The bus will be designed considering structural loads during launch, and any other necessary maneuvers	
2	2.1.1	There shall be an Electrical Power System (EPS) able to provide stable power, ensuring the fulfillment of energy requirements for both spacecraft systems and observatory mission equipment.			X		X	Calculate power requirements of each system and design or choose a preexisting system that meets those power needs	
3	2.1.1.1	The EPS shall include a rechargeable battery capable of storing enough energy to power the operational needs of the spacecraft during periods when solar power generation is not possible.		X		X	X	Test battery capability with reference to batteries datasheet and verify battery capacity and output.	
3	2.1.1.2	The EPS shall include solar panels that can generate sufficient power to meet the operational needs of the spacecraft.			X		X	Verify with solar panel datasheet that sufficient power can be created to keep batteries charged.	
4	2.1.1.2.1	Deployable solar panels shall have independent restraint mechanisms.			X	X		Verify that procured solar panel restraints have the ability to restrain solar panel design and test the restraint mechanism.	
3	2.1.1.3	The EPS shall distribute power to all systems compatible with their voltage and current requirements.		X	X	X	X	Test that electrical power system can verify where power is needed and distribute power accordingly and compare to datasheet.	

Appendix

3	2.1.1.4	The EPS shall regulate power to stable levels that meet the requirements of all systems of the spacecraft.		X		X	X	Test that power supplied to components is steady and the amount of noise is minimal with reference to the datasheet.	
3	2.1.1.5	The EPS shall have a lifespan that exceeds 25-month mission duration, accounting for environmental factors.					X	Compare usage of power system to expected mission duration.	
3	2.1.1.6	The EPS shall have three independent electrical inhibitor deployment switches.			X		X	Procure switches and validate capability of switches with design and reference sheet,	
4	2.1.1.6.1	Rail deployment switches shall have a minimum actuation travel of 1 mm.				X	X	Validate switches travel with reference sheet and physical testing.	
4	2.1.1.6.2	Deployment switches shall reset the payload to pre-launch if cycled within 30 minutes of switches closing.			X	X		Design EPS with disable condition, validate design through testing.	
4	2.1.1.6.3	Deployment switches shall be captive.			X			Design switches to be retained in the CubeSat after launch.	
4	2.1.1.6.4	Force of deployment switches shall not exceed 18N.				X	X	Test switch applied force and validate with reference sheet.	
4	2.1.1.6.5	Deployment switches shall have a contact width of at least 75%.			X		X	Design and choose switches, validate with reference sheet.	
3	2.1.1.7	EPS shall not be energized for a minimum of 30 minutes where hazards existed.			X		X	Design electrical system and validate with EPS reference sheet.	

Appendix

Requirement Level	Requirement Number	Requirement	Verification Model					Verification Methods	Status
			A	O	D	T	R		
2	2.1.2	There shall be an Environmental System designed to ensure that the satellite systems and payload can withstand the various conditions they will encounter from launch to the end of the mission.	X		X			Structural design will ensure no failure from G loads, protective material around payload will protect from vibrational loads/resonance.	
3	2.1.2.1	Materials and controls will be put into place to manage thermal pressures from the environment.	X		X		X	Thermal simulation will be done and compared to sage temperature allowances for materials used.	
3	2.1.2.2	Cosmic Radiation should be managed to mitigate damage to payload, instruments, and electronics.					X	Compare expected radiation levels to references for sensitive electronics and instruments.	
3	2.1.2.3	Solar Radiation should be managed to mitigate damage to structures, payload, instruments, and electronics.	X		X	X	X	Simulate sunlight exposure time and heating/cooling cycles, Test materials for UV resistance, payload shielded from direct sun exposure.	
3	2.1.2.4	Components of satellite will be able to operate in vacuum conditions without convective cooling.			X	X	X	Design and test cooling system that can mitigate temperatures on electronic and instruments to appropriate levels dependent on their reference sheet.	
3	2.1.2.5	The satellite shall be resistant to electro-magnetic interference.			X	X		Design satellite with protection from EMI in the form of insulation and frequency hopping techniques.	
2	2.1.3	There shall be a Communication system able to provide reliable and secure two-way communication between the spacecraft and Earth-based ground stations.			X	X	X	Choose a communication system which is capable of transmitting and receiving from cislunar space and test communication system for functionality.	
3	2.1.3.1	The communication system shall be able to provide the essential uplink and downlink data rates for both payload data and command/control instructions.			X	X	X	Test uplink and downlink data rates and compare to reference sheet.	

Appendix

Requirement Level	Requirement Number	Requirement	Verification Model					Verification Methods	Status
			A	O	D	T	R		
3	2.1.3.2	The communication system shall have adequate antenna coverage to establish a stable signal link between the spacecraft and the ground station.			X		X	Review manufacturer documentation, datasheets, and design documents.	
3	2.1.3.3	The communication system shall be operated within VHF 136-174 MHz and UHF 400-520 MHz in compliance with international regulations.				X	X	Test the system under controlled environment to check both transmit and receive data within the specified VHF and UHF bands.	
3	2.1.3.4	The communication system shall have error detection and correction techniques to ensure the integrity of transmitted and received data.	X			X		Simulate transmission scenarios with injected errors to observe the system's ability to detect and correct them.	
2	2.1.4	There shall be a Computing system able to manage and process data, execute commands, and control spacecraft operations.	X	X	X	X		The computing system will be designed/chosen based off necessary possessing power for spacecraft systems	
3	2.1.4.1	The computing system shall have sufficient processing power to process all spacecraft operations.	X			X		Overload the system with tasks and data to evaluate how it performs under maximum stress.	
3	2.1.4.2	The computing system shall manage all data by collecting, storing, and transmitting it.	X		X	X		Simulate the entire process of data collection, storage, and transmission to ensure seamless integration of all steps.	
3	2.1.4.3	The computing system shall have the ability to receive and implement software updates transmitted from the ground station.			X	X		Simulate a software update and ability to rollback if update fails or causes issues.	
3	2.1.4.4	The computing system shall incorporate security measures to protect the system against unauthorized access.	X		X		X	Perform vulnerability assessment and security architecture analysis and simulate various threat scenarios to determine how system would respond.	

Appendix

Requirement Level	Requirement Number	Requirement	Verification Model					Verification Methods	Status
			A	O	D	T	R		
3	2.1.4.5	The computing system shall uphold precise timekeeping, in synchronization with a universal time standard, for all mission operations and data logging.	X			X		Test synchronization with a universal time standard source.	
3	2.1.4.6	The computing system shall promptly and accurately carry out commands received from the ground station.	X			X		Simulate by transmitting a series of commands from a ground station and observe the system's response and accuracy.	
2	2.1.5	There shall be an Attitude Control System.			X	X	X	MATLAB/Simulink	
3	2.1.5.1	The attitude of the spacecraft should be controlled within ± 10 arcseconds during each occultation opportunity.	X					The control system simulation shall be conducted in MATLAB/Simulink	
3	2.1.5.2	The ACS shall provide stable control of the spacecraft.	X		X			MATLAB/Simulink	
2	2.1.6	There shall be a Propulsion system.			X	X	X	Nozzle and system will be designed considering thrust requirements and physics of space propulsion	
3	2.1.6.1	The Propulsion system shall have adequate fuel for the duration of the prescribed mission length, and an additional 5% ΔV for unplanned/recovery maneuvers.	X		X			Maneuvers and attitude control system desaturation shall be simulated using STK/MATLAB/Simulink	
3	2.1.6.2	The Propulsion system shall enable controlled disposal at the end of the mission life.	X		X			The design should account for enough fuel for disposal.	
2	2.1.7	There shall be a Navigation system.		X	X	X	X	Star Tracker/Sun Sensor	
3	2.1.7.1	The Navigation system should consist of an adequate selection of Star Tracker, Horizon Sensor, Gyroscope, Sun Sensor, or others, in order to accurately determine the orientation and position of the spacecraft.			X			Validate each sensor's functionality and integration in simulated conditions.	

Appendix

2	2.1.8	There shall be a Telemetry and Tracking system able to monitor and determine the spacecraft's location, orientation, and velocity to enable precise orbital and attitude adjustments.			X		X	Star Tracker for location, Sun Sensor for Orientation, velocity with respect to the lunar surface	
3	2.1.8.1	The T&T system shall consistently gather telemetry data from all subsystems and payloads to monitor health and operational status.	X				X	Simulate a scenario where the system collects data from all subsystem and payload as intended.	
3	2.1.8.2	The T&T system shall provide accurate tracking data of the spacecraft's position, and velocity measurements.	X					Simulate software algorithms and methods for tracking to ensure accuracy.	
3	2.1.8.3	The T&T system shall have all telemetry data be time-tagged.	X			X		Simulate by injecting series of events or data into the system and verify that each data point has an associated time stamp.	

Requirement Level	Requirement Number	Requirement	Verification Model					Verification Methods	Status
			A	O	D	T	R		
2	2.1.9	There shall be a Structural system able to provide housing and protection for all subsystems and payloads.			X			Hand calculations will be used to test the structural design.	Completed
3	2.1.9.1	The material of the spacecraft will be an Aluminum alloy			X		X	Material will be inspected to confirm it follows NASA-STD-6016A standards	Completed
4	2.1.9.1.1	The aluminum alloy should be resistant to general corrosion, pitting, intergranular corrosion, and stress corrosion cracking			X	X	X	Material will be inspected to confirm it follows NASA-STD-6016A standards	
3	2.1.9.2	The structural system of the spacecraft will adhere to NASA guidelines and refrain from using any hazardous materials such as Beryllium, cadmium, mercury, silver, or any other such materials.					X	Material will be inspected to confirm it follows NASA-STD-6016A standards	

Appendix

3	2.1.9.3	Any non-metallic materials used will have a Total Mass Loss (TML) and Collected Volatile Condensable Material (CVCM) equal to or lower than a maximum1.0 percent TML and a maximum 0.10 percent CVCM.					X	Material will be inspected to confirm it follows NASA guidelines based on current outgassing data	
3	2.1.9.4	Geometry and Dimensions shall comply with the standard cube sat unit system and will comply with the 6U specification.		X	X			20 cm x 10 cm x 34.05 cm, rectangular prism shape	Completed
3	2.1.9.5	The payload should be able to withstand stresses as outlined on the NRDD IDD reference section 4.3.4.					X	The payload will be vibration tested to ensure it can survive shock from ignition	Completed
3	2.1.10	The structural system shall be compatible with NanoRacks requirements.			X		X	Structure will be designed to meet Nanoracks requirements and will be validated with individual part reference sheets.	
4	2.1.10.1	There shall be four rails along the z-axis to interface with slots dimensioned in *Figure 4.1.2-1* in the NRSC IDD.			X		X	Rails will be designed and validated with existing dimensioned diagrams from Nanoracks.	
5	2.1.10.1.1	Edge of rails shall have a radius of .5mm (+/-0.1mm)			X		X	Purchased rails should have dimensions validated through their provided reference sheets.	
5	2.1.10.1.2	Interface rails shall have a length of 366mm (+0.0/ -65.0).			X		X	Purchased rails should have dimensions validated through their provided reference sheets.	
5	2.1.10.1.3	Interface rails shall be contiguous and have no interruption across their length.		X			X	Rails should be purchased containing no interruptions and should be validated by observing the purchased part.	
5	2.1.10.1.4	Interface rails shall be the only mechanical interface between the NRDD and the CubeSat in the lateral axes.			X		X	Design shall be made with reference to Nanoracks deployer reference sheet,	
5	2.1.10.1.5	Interface rails shall extend beyond the +/- z faces of the payload with the exception of load points.			X			Rails should be designed to extend past Z faces.	

Appendix

5	2.1.10.1.6	Interface rails shall have a hardness equal to or greater than hard-anodized aluminum (Rockwell C65-70).				X	X	Rail hardness should be chosen for hardness with respect to their reference sheet and validated for hardness through testing.	
5	2.1.10.1.7	Interface rails shall have a surface roughness of less than or equal to 1.6 µm.					X	Rail surface roughness shall be validated through the rail reference sheet.	
4	2.1.10.2	The structural system shall be dimensioned to comply with *Figure 4.1.2-2* in the NRSC IDD.					X	Ensure compliance with NRSC IDD reference sheet.	
4	2.1.10.3	There shall be load points on the +/- z-faces.			X			Load point existence shall be validated through design of satellite.	
5	2.1.10.3.1	Load points shall be coplanar with end of tabs.			X			Load point location shall be validated through design of satellite.	
5	2.1.10.3.2	Load points shall envelop areas designated in *Figure 4.1.2-1* of NRDD IDD.			X		X	Load point design shall be validated with NRDD IDD reference sheet.	
5	2.1.10.3.3	Load points shall have a hardness equal to or greater than hard-anodized aluminum (Rockwell C65-70).				X	X	Load point hardness should be chosen with respect to their reference sheet and validated for hardness through testing.	
5	2.1.10.3.4	Load points shall have a surface roughness of less than or equal to 1.6 µm.					X	Load point roughness shall be validated through the load point reference sheet.	
2	2.1.11	The CubeSat shall have mass requirements complying with the NRDD IDD document.			X	X	X	Satellite will be designed and validated through testing and compliance with the NRDD IDD reference sheet.	
3	2.1.11.1	The center of mass shall be located within the geometric center within tolerances: X: (+/- 5cm) Y: (+/- 3cm) Z: (+/- 8cm).			X	X	X	Satellite will be designed to be within center of mass requirements and validated through testing and compliance with Nanoracks reference sheet.	

Appendix

Requirement Level	Requirement Number	Requirement	Verification Model					Verification Methods	Status
			A	O	D	T	R		
3	2.1.11.2	The maximum mass of the satellite shall be 12 kg.			X	X	X	Satellite will be designed to be below weight limit and validated through testing and compliance with the NRDD IDD reference sheet.	
1	2.2	There shall be an Observatory Payload.			X			Observatory will use Near UV imaging techniques	
2	2.2.1	There shall be a Telescopic Array of 2 co-aligned telescopes to view the solar corona, consisting of Optics Assemblies and Focal Plane Modules (FPM).			X			The design will include two observational telescopes.	
3	2.2.1.1	The Optics Assembly shall consist of focusing lenses which transfer optical information to the FPM.			X		X	Verify type of data transfer is possible with telescope being used through reference sheet.	
3	2.2.1.2	The Focal Plane Module shall consist of a Near Ultra-Violet (NUV) sensitive CCD capable of interfacing with the data transmission hardware.			X	X	X	Verify data can be collected in NUV using reference sheet compared to test and that data can be transferred with chosen hardware.	
2	2.2.2	There may be a deployable mast to accommodate additional focal length/parallax.			X			Mast will be designed with proper curvature for accurate imaging, design and testing at a ground facility will verify results	
2	2.2.3	The observatory payload shall have the capability to measure over the NUV range of 300-400 nm.			X	X	X	Choose telescope with given capabilities with reference to a datasheet and test for accuracy.	
2	2.2.4	The observatory shall have an angular resolution with half power diameter <3 arcseconds.			X	X	X	Choose telescope with given capabilities with reference to a datasheet and test for accuracy.	
	3.0	Ground System							

Appendix

Requirement Level	Requirement Number	Requirement	Verification Model A	O	D	T	R	Verification Methods	Status
0	3.0	Pre-Flight Handling			X			A storage unit meeting the humidity, temperature, and sterilization requirements will protect the payload. Design will also consider launch loads	
1	3.1	The Satellite and components shall not be subjected to humidity greater than 70% or less than 30% during construction or storage or transportation.		X	X			Preexisting facilities with humidity and temperature requirements will be used, or one will be constructed if need be	
1	3.2	The Satellite and components shall be able to withstand temperatures as outline by the ranges seen in the NRDD IDD reference, Table 4.3.6-1.		X	X			Preexisting facilities with humidity and temperature requirements will be used, or one will be constructed if need be	
1	3.3	The Satellite shall be sterilized at determined intervals during construction and maintained in an ISO Class 8 clean room during all phases of the mission prior to launcher integration.		X	X			Regularly inspect and test post-sterilization to confirm the absence of contaminants.	
1	3.4	Data Acquisition systems shall maintain compatibility with all relevant Communication Systems Requirements in 2.1.1.3	X		X	X		Simulate scenarios by injecting data into the system.	
		Validation and Testing							
0	4.0	All components of satellite shall be compared to physical plans for validation and tested for functionality.		X	X	X		Components will be measured to verify design is correct	
1	4.1	Measurement of satellite components' dimensions shall be compared to planned dimensions.		X	X		X	Use CAD model with reference to datasheets on various components.	

Appendix

1	4.2	Satellite shall be tested for functionality of the electrical power system.		X		X	X	Tests will be done by running all systems simultaneously to ensure the power source can withstand the load placed on it as designed.	
2	4.2.1	Solar cells will be tested before launch to ensure adequate generation of power for satellite functions.	X				X	STK	
2	4.2.2	The EPS shall be tested to ensure distribution of power to appropriate instruments and verify the correct amount of power is being sent to specific satellite components.		X		X		Required power for every instrument/ component will be demanded and then feedback will be recorded.	
1	4.3	Optical instruments shall be tested for functionality before launching the satellite.		X		X		Telescopes and other instruments will be placed in an environment simulating mission conditions	
2	4.3.1	Main observing optical instrument shall be tested to verify an angular resolution with half-power diameter <3 arcseconds can be achieved.		X	X	X	X	Validation of physical test of optical instrument chosen with datasheet for optical instrument to ensure proper functionality.	
2	4.3.2	Main observing optical instrument shall be tested to verify solar radiation measurements can be made in Near UV range of 300-400nm.			X		X	Measurements will be conducted and analyzed in a test to confirm near UV capabilities	

Requirement Level	Requirement Number	Requirement	Verification Model			Verification Methods			Status
			A	O	D	T	R		
1	4.4	All elements of satellite will be tested to comply with environmental standards.	X	X		X		Satellite will be tested to withstand thermal stresses, radiation, attitude control, tracking, and observation of solar corona	

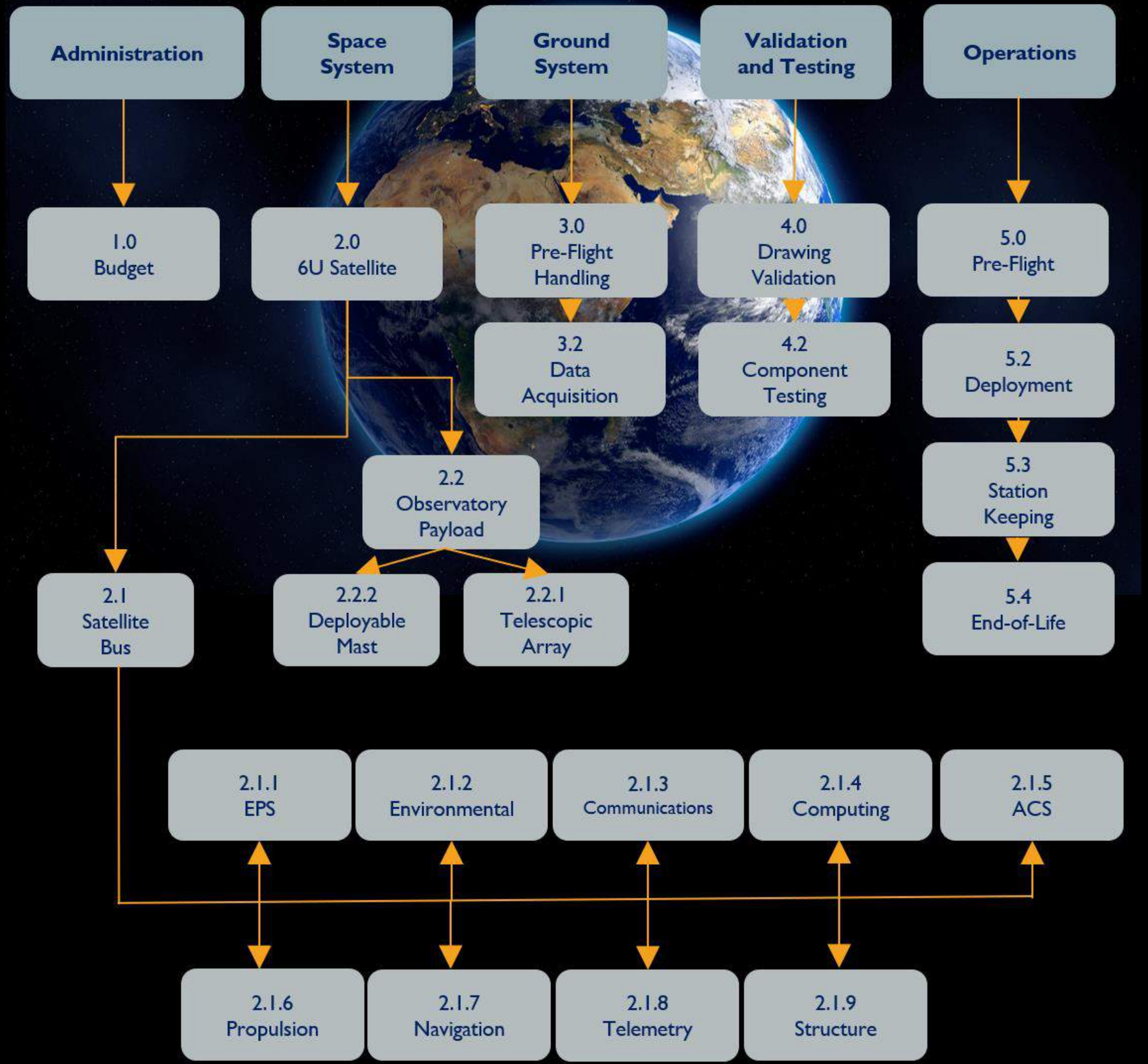
Appendix

2	4.4.1	The satellite's thermal protection and all components of exterior faces shall be able to withstand a temperature range of –250 to 250 degrees Fahrenheit.	X		X		X	Using thermal simulation along with a prepared CAD model of the satellite along with datasheets of components.	
2	4.4.2	The satellite shall be able to withstand material stresses due to thermal shock between lit and shaded regions.	X		X		X	Using thermal simulation along with a prepared CAD model of the satellite along with datasheets of components.	
1	4.5	The propulsion system shall be tested to ensure accuracy of commanded thrust and impulse.	X		X	X	X	MATLAB Simulink along with reference to propulsion system datasheet through tests shall be used.	
1	4.6	The attitude system shall be tested for functionality and accuracy of controls within ± 10 arcseconds.	X		X		X	MATLAB Simulink along with reference to propulsion system datasheet shall be used.	
		Operations							
0	5.0	There shall be procedures and timelines for every section of the operation			X				
1	5.1	There shall be pre-flight procedures and timelines.							
2	5.1.1	The Satellite shall undergo a charging cycle to optimize capacity upon deployment and lifetime cyclability before delivery.		X		X	X	Battery cycle testing shall be conducted, and data sheet referenced.	
2	5.1.2	The Satellite shall be stored in an ISO Class 8 clean room before delivery.					X	ISO Class 8 clean room will ensure sterilization, observation of components will check for unwanted contamination	
2	5.1.3	The Satellite shall be made 'safe' and flight-ready by means of "Remove Before Flight" safety features before delivery.		X	X		X	Inspectors shall verify that RBF implements are in place.	

Appendix

Requirement Level	Requirement Number	Requirement	Verification Model					Verification Methods	Status
			A	O	D	T	R		
2	5.1.4	The Satellite shall undergo a final flight readiness inspection to be signed by the Project Manager(s), Principal Investigator(s), and Technical Authority.		X			X	Inspectors shall validate dimensions, the engagement of any single use deployment mechanisms, power systems, state of charge, etc.	
1	5.2	Deployment			X				
2	5.2.1	The satellite shall be deployed from Gateway orbital science station at the cislunar L2 LaGrange point.			X			The design shall comply with the Nanoracks dimension specifications and launch requirements.	
3	5.2.1.1	The deployment readiness date shall be NLT 31 December 2026			X		X	Frequent progress checks and effective planning will ensure the deadline is made	
3	5.2.1.2	The Mission Elapsed Time (MET) shall begin when spacecraft is deployed from Gateway.			X			The release of a depression switch shall initiate the MET Timer	
3	5.2.1.3	The Satellite shall enable primary power to the Bus NET T+ 00:30:00 from the MET.				X		The Boot-On command shall be sent 30 minutes after the MET begins	
1	5.3	Station Keeping	X		X			Regularly scheduled maintenance checks will be conducted to ensure station is performing as planned	
2	5.3.1	The Satellite's orbital period around L4 shall be near the orbital period of the Moon around the Earth, within a tolerance TBD.	X		X			The orbit shall be validated with STK simulation/MATLAB/Simulink	
1	5.4	End-of-Life			X			Deorbiting the satellite into a graveyard orbit will ensure safe End-of-Life is responsible	
2	5.4.1	The Satellite should be decommissioned in a responsible and timely manner at the mission conclusion.	X		X			TBR in accordance with NASA NID 8715.129	

Work Breakdown Structure



PRELIMINARY CRITICAL DESIGN REVIEW

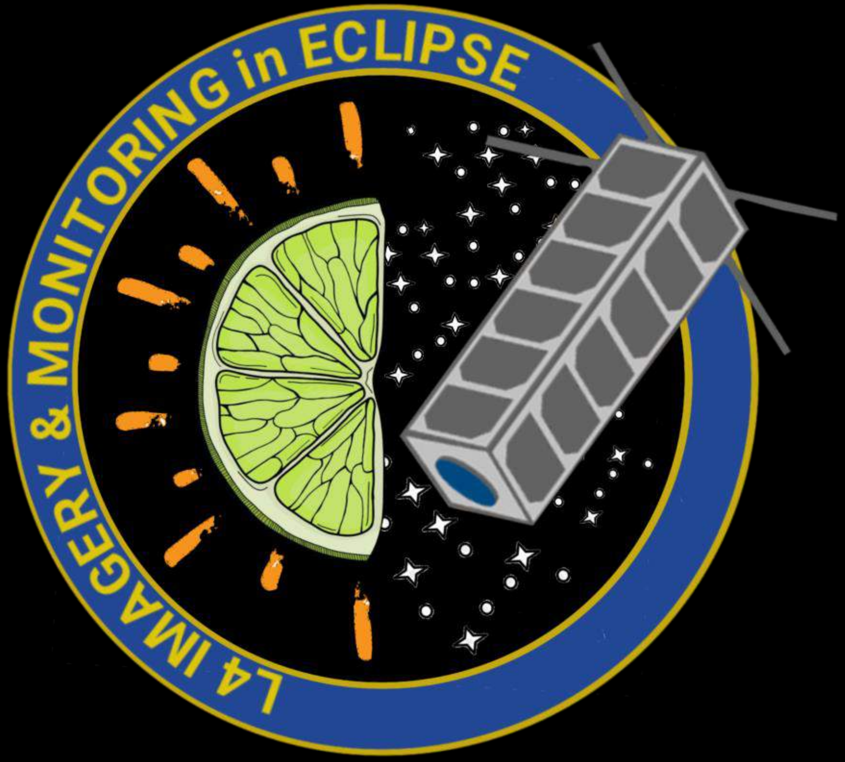
COLBY DAVIS, CONNOR CALLAHAN, JUSTIN ROGERS, NOAH LOZADO, JARED WARMACK, JONATHAN KIM

L4 IMAGERY & MONITORING in ECLIPSE

LIMESAT

ACRONYMS

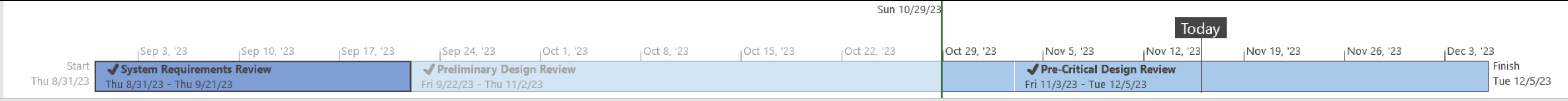
Acronym	Description
ACS	Attitude Control System
CAD	Computer-Aided Design
CCD	Charge-Coupled Device
CDH	Command & Data Handling
ConOps	Concept of Operations
DAQ	Data Acquisition
EPS	Electronic Power System
GNC	Guidance, Navigation, & Control
OBC	On-Board Computer
SPO	Short Period Orbit
UHF	Ultra High Frequency
VHF	Very High Frequency
CR3BP	Circular Restricted 3 Body Problem



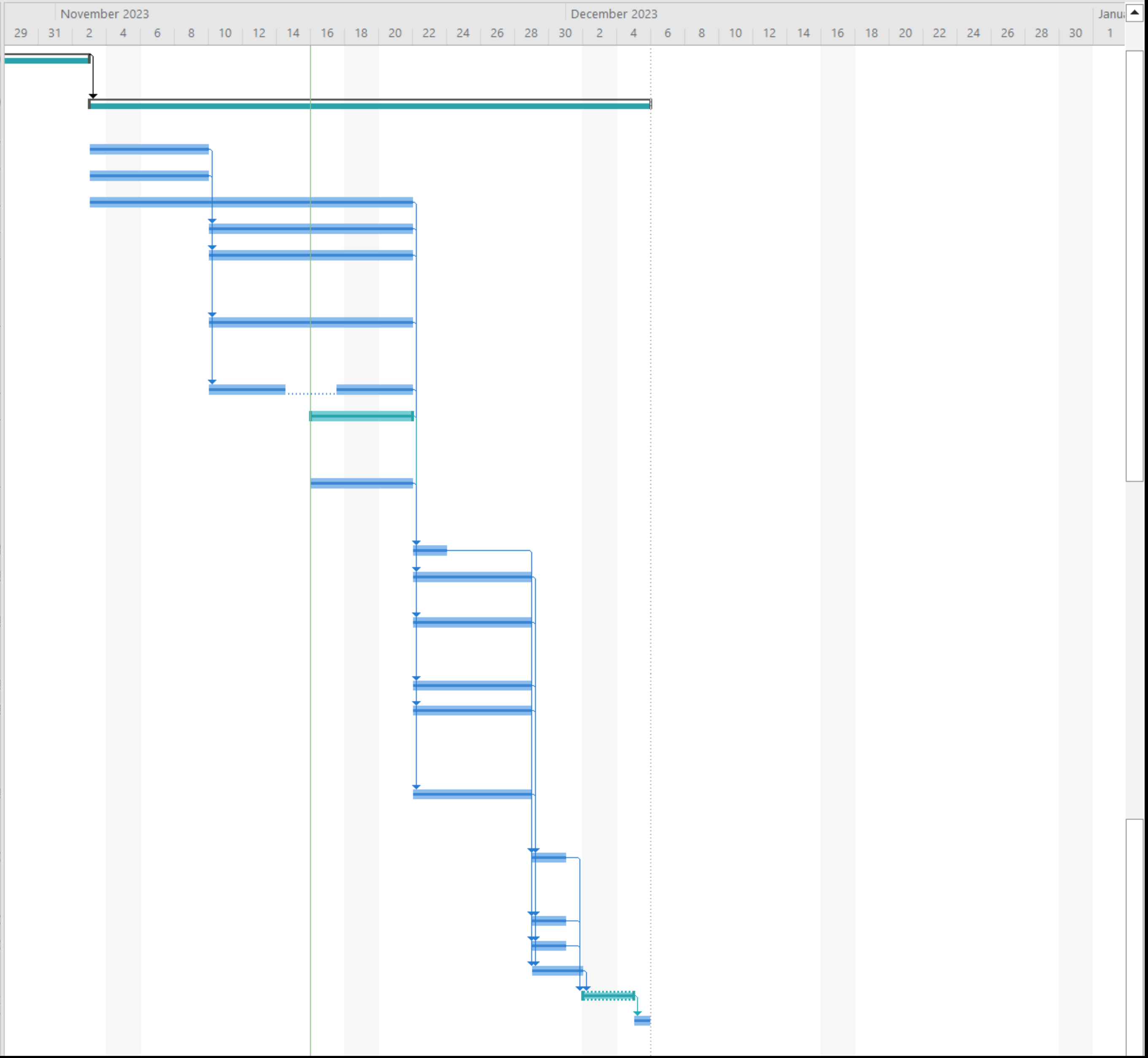
Agenda

- Integrated Schedule
- Financial Budget
- Power Budget
- Mass Budget
- ConOps
- Data Management
- Communication Method
- Attitude Navigation
- CAD Model
- Initial Draft Wiring
- Electrical Schematic
- Engineering Drawings
- Stress-Strain Analysis
- Thermal Analysis Method
- Vibration Analysis Method
- Moments of Inertia
- Center of Gravity

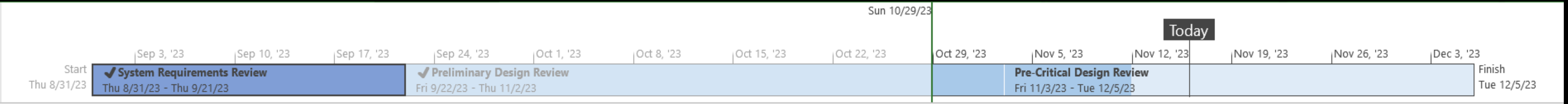
INTEGRATED SCHEDULE



	Task Mode	Task Name	Duration	Start	Finish
23		**Preliminary Design Review**	**30 days?**	**Fri 9/22/23**	**Thu 11/2/**
43		**Pre-Critical Design Review**	**23 days?**	**Fri 11/3/23**	**Tue 12/5/**
44		Schedule	5 days	Fri 11/3/23	Thu 11/9/
45		OSIR #3	5 days	Fri 11/3/23	Thu 11/9/
46		Improve CAD Model	13 days	Fri 11/3/23	Tue 11/21
47		Electrical Schematic	8 days?	Fri 11/10/23	Tue 11/21
48		Initial draft of wire routing/CubeSat build-up process	8 days?	Fri 11/10/23	Tue 11/21
49		ConOps for Mission Science and Demise phase	8 days?	Fri 11/10/23	Tue 11/21
50		Cost Budget	5 days?	Fri 11/10/23	Tue 11/21
51		Thermal analysis-proposed method	4 days	Thu 11/16/23	Tue 11/21
52		Vibration analysis-proposed method	4 days	Thu 11/16/23	Tue 11/21
53		FEM Stress Strain	2 days	Wed 11/22/2:	Thu 11/23
54		Preliminary attitude & controls analysis	5 days?	Wed 11/22/23	Tue 11/28
55		Identify Communication methodology from CubeSat to the PI	5 days?	Wed 11/22/23	Tue 11/28
56		Drawing Template	5 days?	Wed 11/22/2:	Tue 11/28
57		Power budget by mission phase showing wost case and average scenarios	5 days?	Wed 11/22/23	Tue 11/28
58		Data download and upload rates and associated costs	5 days?	Wed 11/22/23	Tue 11/28
59		Overall CubeSat mass and component-by-compon	2 days?	Wed 11/29/23	Thu 11/30
60		Center of Gravity	2 days?	Wed 11/29/2:	Thu 11/30
61		Moments of Inertia	2 days?	Wed 11/29/2:	Thu 11/30
62		Create Presentation	3 days	Wed 11/29/2:	Fri 12/1/2
63		Practice Presentation	2 days	Sat 12/2/23	Mon 12/4
64		PCDR Presentation	1 day	Tue 12/5/23	Tue 12/5/



TIMELINE



GANTT CHART

	Task Name	Duration	Start	Finish	Prede
23	**Preliminary Design Review**	**30 days?**	**Fri 9/22/23**	**Thu 11/2/23**	**22,1**
43	**Pre-Critical Design Review**	**23 days?**	**Fri 11/3/23**	**Tue 12/5/23**	**23,42**
44	Schedule	5 days	Fri 11/3/23	Thu 11/9/23	42
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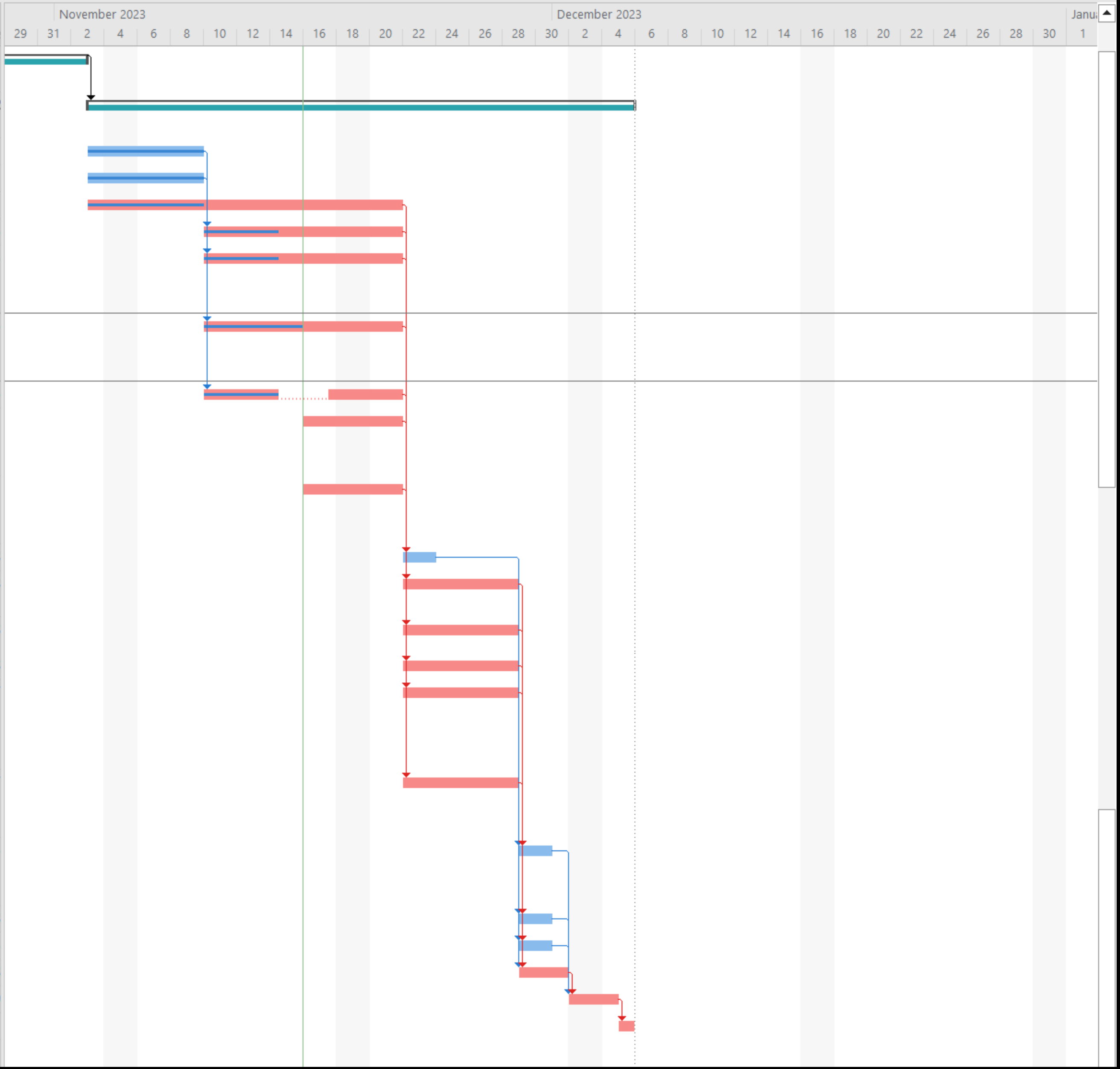
46	Improve CAD Model	13 days	Fri 11/3/23	Tue 11/21/23	42
47	Electrical Schematic	8 days?	Fri 11/10/23	Tue 11/21/23	44,45
48	Initial draft of wire routing/CubeSat build-up process	8 days?	Fri 11/10/23	Tue 11/21/23	44,45
49	ConOps for Mission Science and Demise phase	8 days?	Fri 11/10/23	Tue 11/21/23	44,45
50	Cost Budget	5 days?	Fri 11/10/23	Tue 11/21/23	44,45
51	Thermal analysis-proposed method	4 days	Thu 11/16/23	Tue 11/21/23	
52	Vibration analysis-proposed method	4 days	Thu 11/16/23	Tue 11/21/23	
53	FEM Stress Strain	2 days	Wed 11/22/2:	Thu 11/23/23	47,48
54	Preliminary attitude & controls analysis	5 days?	Wed 11/22/23	Tue 11/28/23	47,48
55	Identify Communication methodology, from	5 days?	Wed 11/22/23	Tue 11/28/23	47,48
56	Drawing Template	5 days?	Wed 11/22/2:	Tue 11/28/23	47,48
57	Power budget by mission phase showing wost case and average scenarios	5 days?	Wed 11/22/23	Tue 11/28/23	52,47
58	Data download and upload rates and associated costs	5 days?	Wed 11/22/23	Tue 11/28/23	51,47
59	Overall CubeSat mass and component-by-compon	2 days?	Wed 11/29/23	Thu 11/30/23	58,53
60	Center of Gravity	2 days?	Wed 11/29/2:	Thu 11/30/23	55,58
61	Moments of Inertia	2 days?	Wed 11/29/2:	Thu 11/30/23	58,53
62	Create Presentation	3 days	Wed 11/29/2:	Fri 12/1/23	57,58
63	Practice Presentation	2 days	Sat 12/2/23	Mon 12/4/23	62,60
64	PCDR Presentation	1 day	Tue 12/5/23	Tue 12/5/23	63



GANTT CHART

Financial Budget

Part	Price ($)
Reaction Wheel	$100,000.00
Anntena	$4,600.00
EPS	$5,800.00
Battery	$10,800.00
Telemetry Software	$48,000.00
Structure	$7,600.00
OBC	$7,500.00
Comm	$5,900.00
Star Tracker	$17,600.00
Gyroscope	$10,000.00
Solar Panels	$150,000.00
Solar Array Drive	$46,000.00
Mirrors	$10,000.00
Observation Chip	$5,000.00
Motor	$64.00
Wiring + Hardware	$200.00
Total	$429,064.00

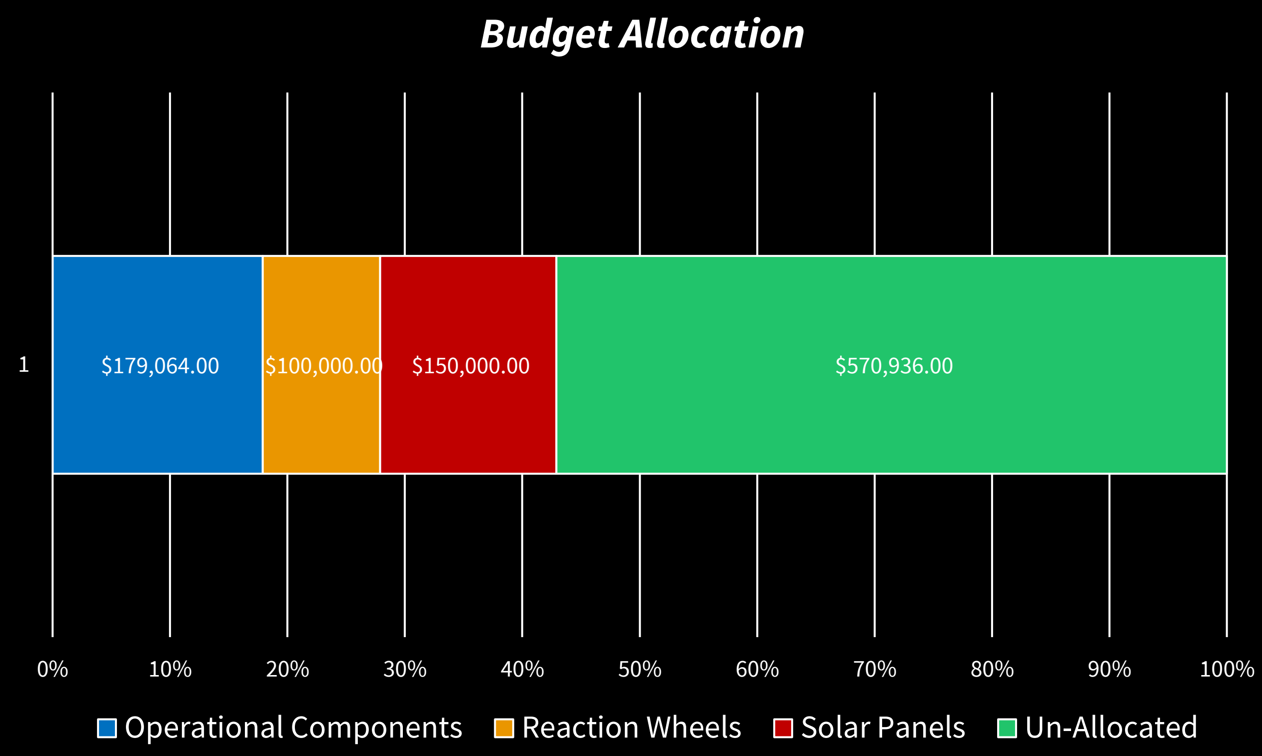
	Known Values
	In Contact
	Cost Estimates

- **Cost Estimates:**
  - Mirror:
    - Companies require substantial orders for pricing info. However, mirror polishing, and creation is a common process for even amateur astronomers, a price of $10,000 is considered reasonable.

- **In Contact:**
  - Solar Panels and MicroSADA: Awaiting custom solution pricing for combining of 2 6U solar panels and the MicroSADA drive.
  - Gyroscope: Awaiting Reply

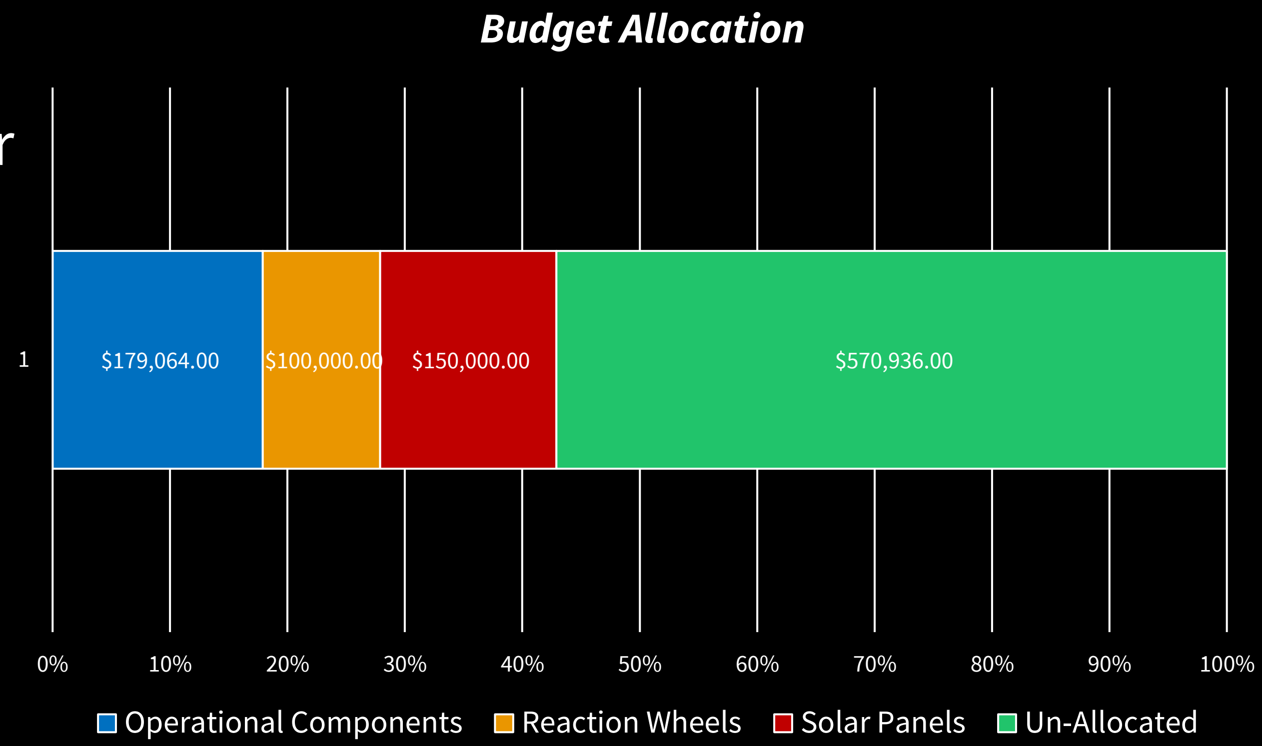
Financial Budget

- 3 General Categories Present:
  - Operational Parts: Every part on satellite excluding reaction wheels and solar panels.
  - Solar Panels, Reaction Wheels comprise most of the budget. Therefore, these two categories will be focused on if budget cuts are needed in the future.
  - Un-Allocated funds represent over 50% of the total budget



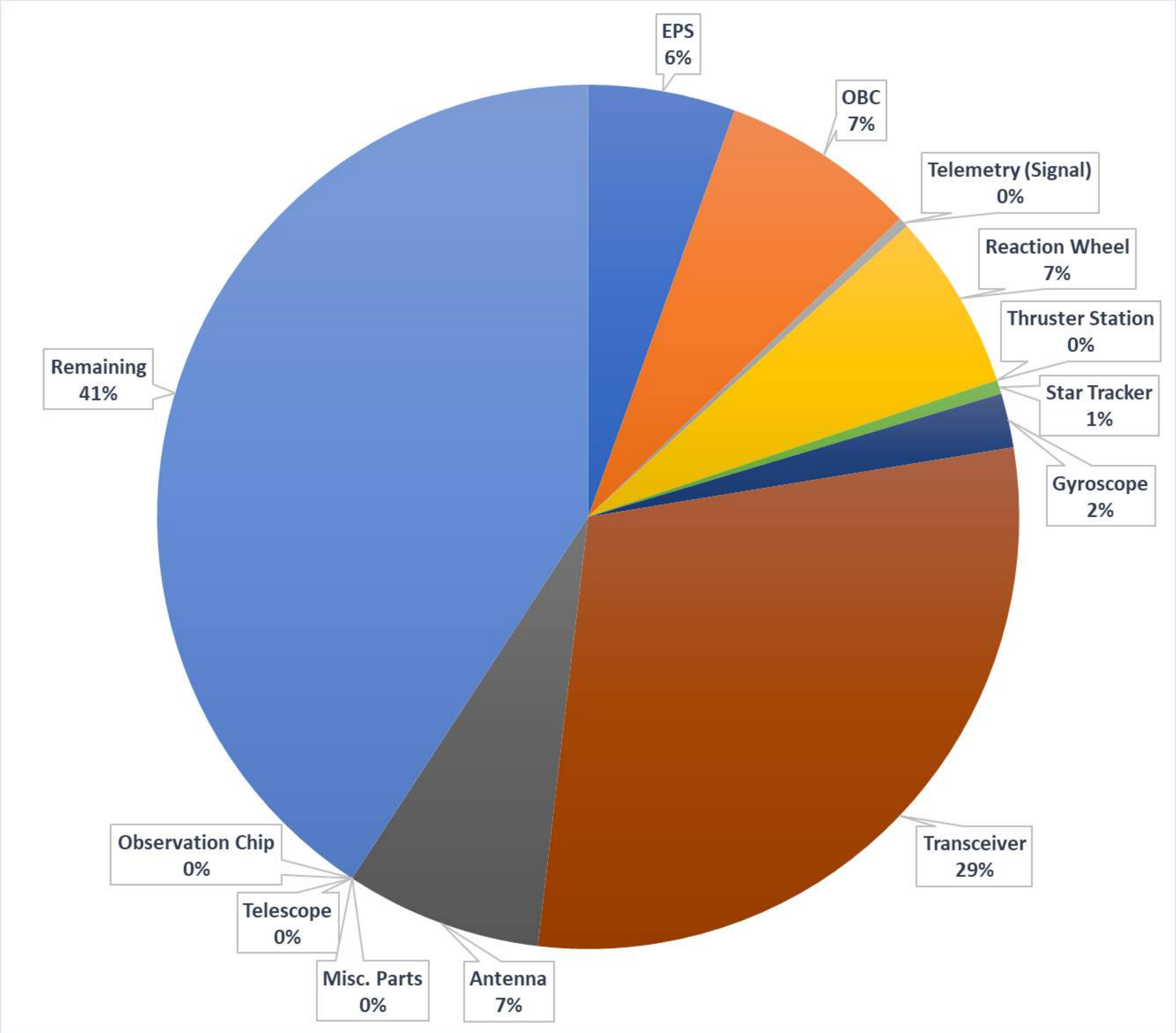
Financial Budget

- Un-Allocated Budget:
  - $570,000 excess budget intended for use with future thruster system. Large amounts of un-allocated budget leaves space to pursue a wide variety of thruster solutions.
  - Un-Allocated will also be used for fuel and any unforeseen expenses (ie. Further testing or proofing not yet considered).



Power Budget: Nominal

Initial Start / Detumble / Systems Check

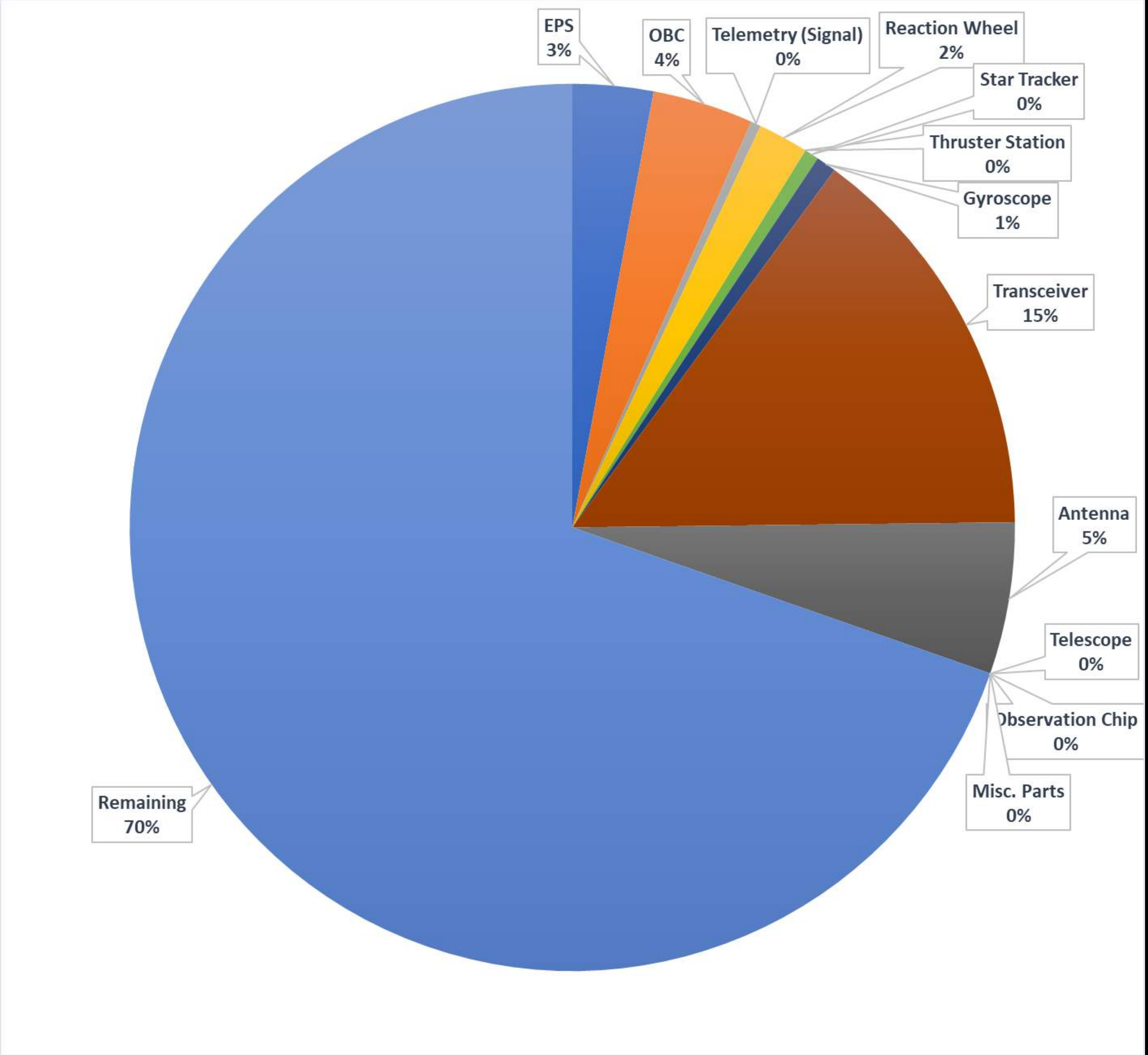


Power Available: 27.17 W

Components	**Consumption (W)**	**Status**
EPS	1.5	Active
OBC	2.0	Active
Telemetry	0.1	Active
Reaction Wheel	1.8	Active
Thruster (Station)	0.0	Idle
Star Tracker	0.142	Active
Gyroscope	0.55	Active
Transceiver	8.0	Active
Antenna	2.0	Active
Telescope	0.0	Idle
Observation Chip	0.0	Idle
Misc. Parts	0.0	Idle
Remaining	**11.078 (41%)**	

Power Budget: Nom
Maneuver from L2 to L4

*Dedicated battery capable of discharging 630W is used for the thruster and is not listed on the table since it doesn't use main system power



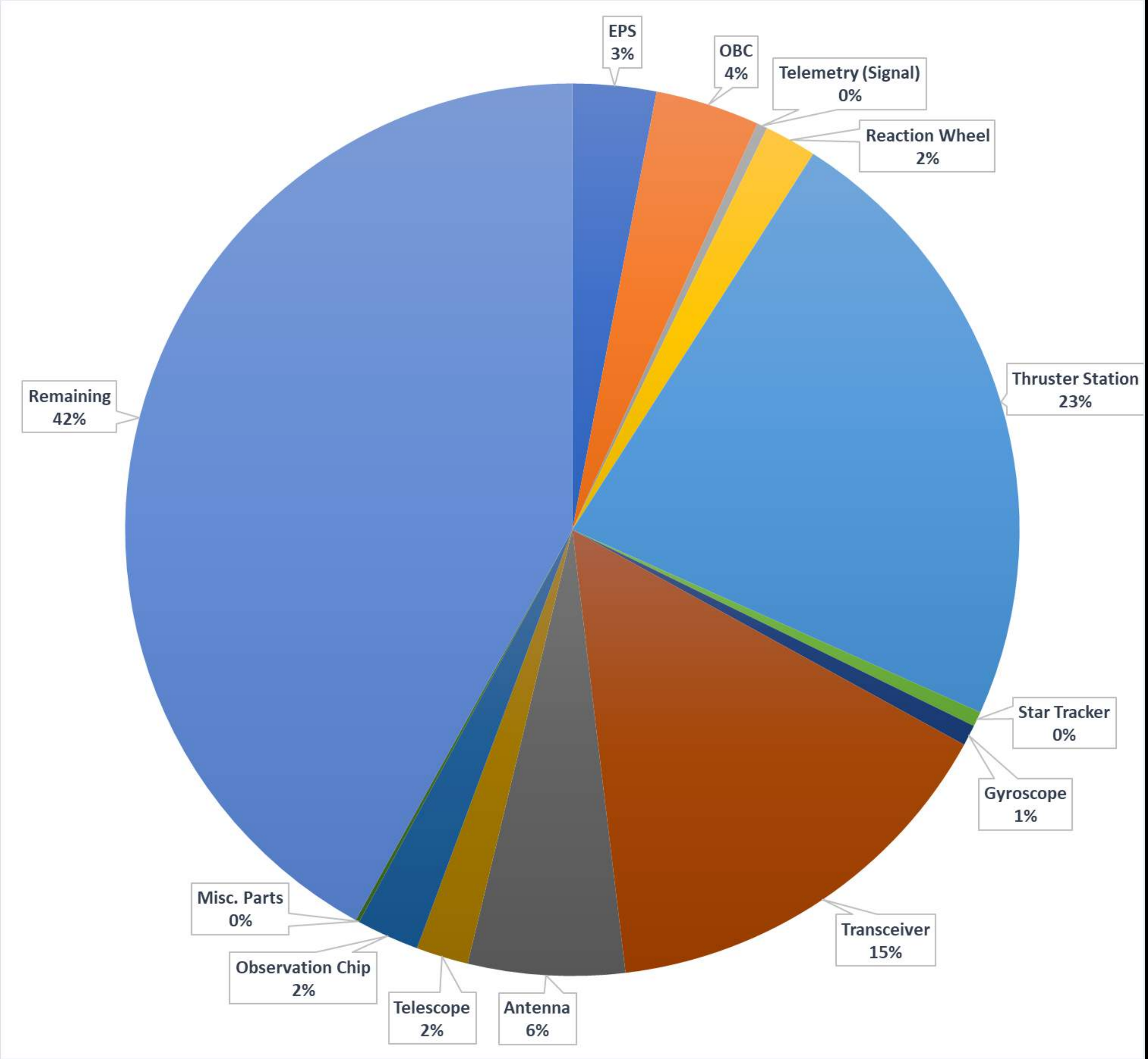
Power Available: 27.17 W

Components	**Consumption (W)**	**Status**
EPS	0.8	Active
OBC	1.0	Active
Telemetry	0.1	Active
Reaction Wheel	0.5	Active
Thruster (Station)	0.0	Idle
Star Tracker	0.142	Active
Gyroscope	0.2	Active
Transceiver	4.0	Active
Antenna	1.5	Active
Telescope	0.0	Idle
Observation Chip	0.0	Idle
Misc. Parts	0.0	Idle
Remaining	**18.928 (70%)**	

Power Budget: Nom

Telescope Operation / L4 Station

*A solar panel performance degradation rate of –2.5% for the first year and –0.5% per year after has been applied to the available power

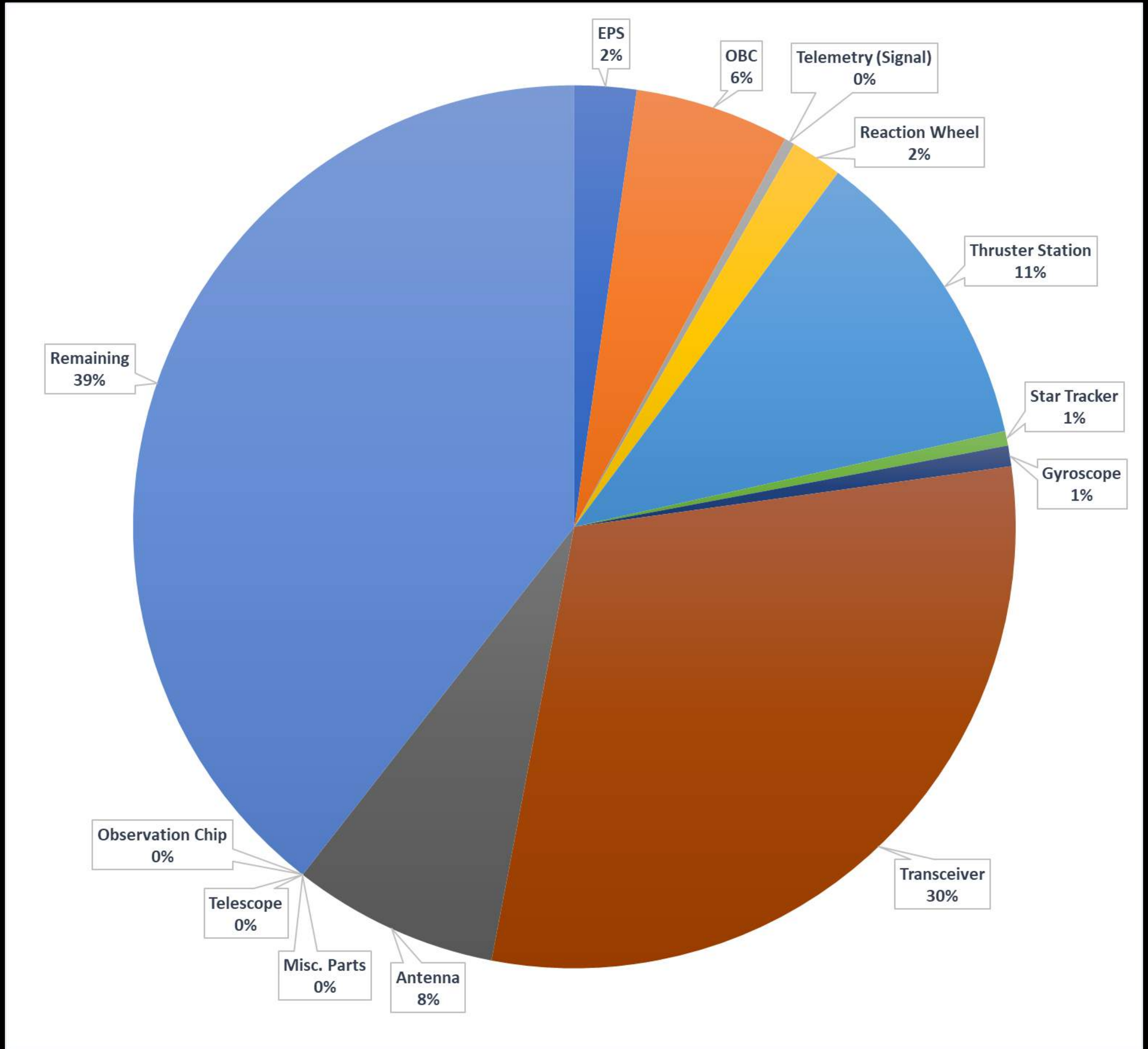


Power Available: 26.49 W

Components	**Consumption (W)**	**Status**
EPS	0.8	Active
OBC	1	Active
Telemetry	0.1	Active
Reaction Wheel	0.5	Active
Thruster (Station)	6	Active
Star Tracker	0.142	Active
Gyroscope	0.2	Active
Transceiver	4	Active
Antenna	1.5	Active
Telescope	0.5	Active
Observation Chip	0.6	Active
Misc. Parts	0.036	Active
Remaining	**11.113 (42%)**	

Power Budget: Nom
Data Transmission / System Updates

*A solar panel performance degradation rate of –2.5% for the first year and –0.5% per year after has been applied to the available power



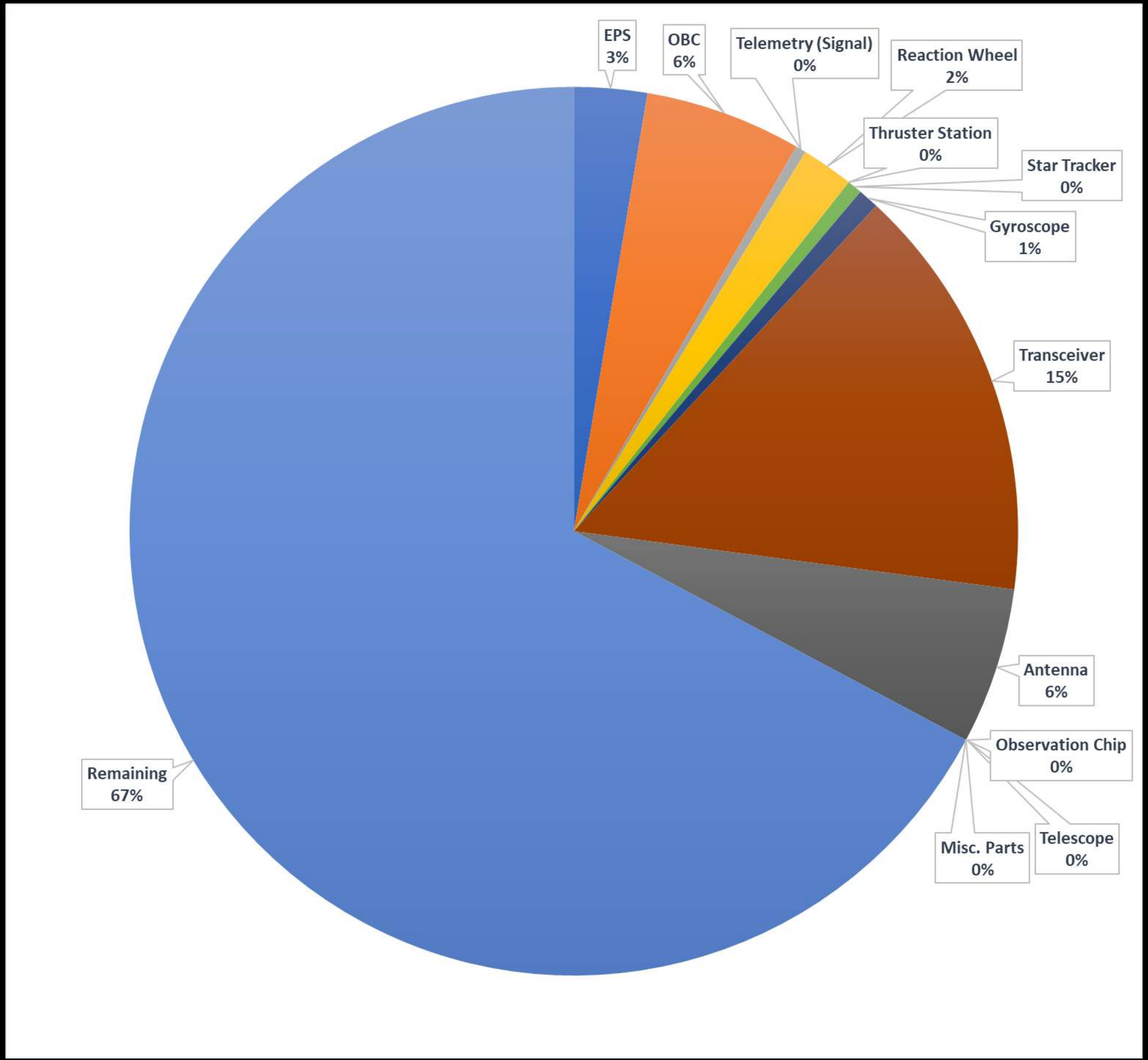
Power Available: 26.49 W

Components	**Consumption (W)**	**Status**
EPS	0.6	Active
OBC	1.5	Active
Telemetry	0.1	Active
Reaction Wheel	0.5	Active
Thruster (Station)	3.0	Active
Star Tracker	0.142	Active
Gyroscope	0.2	Active
Transceiver	8.0	Active
Antenna	2.0	Active
Telescope	0	Idle
Observation Chip	0	Idle
Misc. Parts	0	Idle
Remaining	**10.449 (39%)**	

Power Budget: Nom

Retire / Demise

*A solar panel performance degradation rate of –2.5% for the first year and –0.5% per year after has been applied to the available power



Power Available: 26.35 W

Components	Consumption (W)	Status
EPS	0.7	Active
OBC	1.5	Active
Telemetry	0.1	Active
Reaction Wheel	0.5	Active
Thruster (Station)	0.0	Idle
Star Tracker	0.142	Active
Gyroscope	0.2	Active
Transceiver	4.0	Active
Antenna	1.5	Active
Telescope	0.0	Idle
Observation Chip	0.0	Idle
Misc. Parts	0.0	Idle
Remaining	**17.72 (67%)**	

Power Budget: Max Usage

- 4 Cases Outlined:
  - Tumble
  - Transfer
  - Transition
  - Eclipse

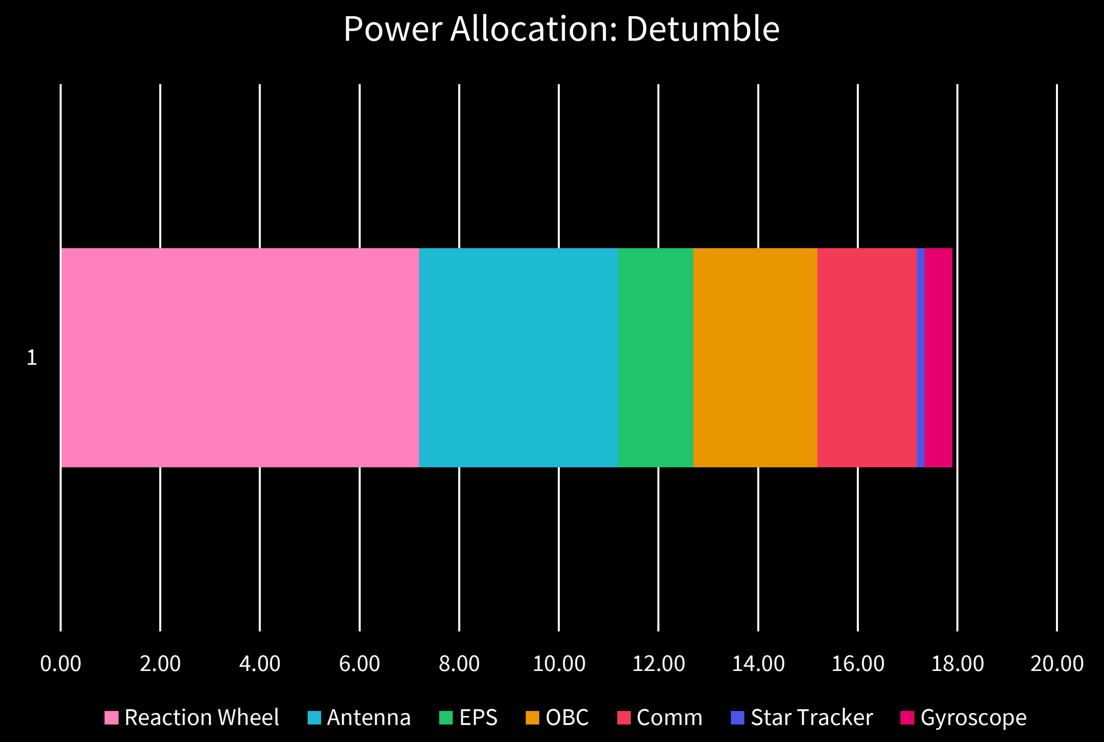
  - Max Power estimates for components determined by manufacturer data. Values represent an ABSOLUTE worst-case scenario for power consumption.
  - Power production estimated dependent on case, most conservative estimates for solar panel production are used for every case.

Power Budget: Max Usage

- Case: *Detumble*
  - Post LIMESAT deployment, before solar array deployment.

  - Solar Available: Assume 0 (This value will be positive in actuality)
  - Battery Capacity: 30 Wh
  - Total Usage: 17.89 W

  - Time Till Dead: 100 mins

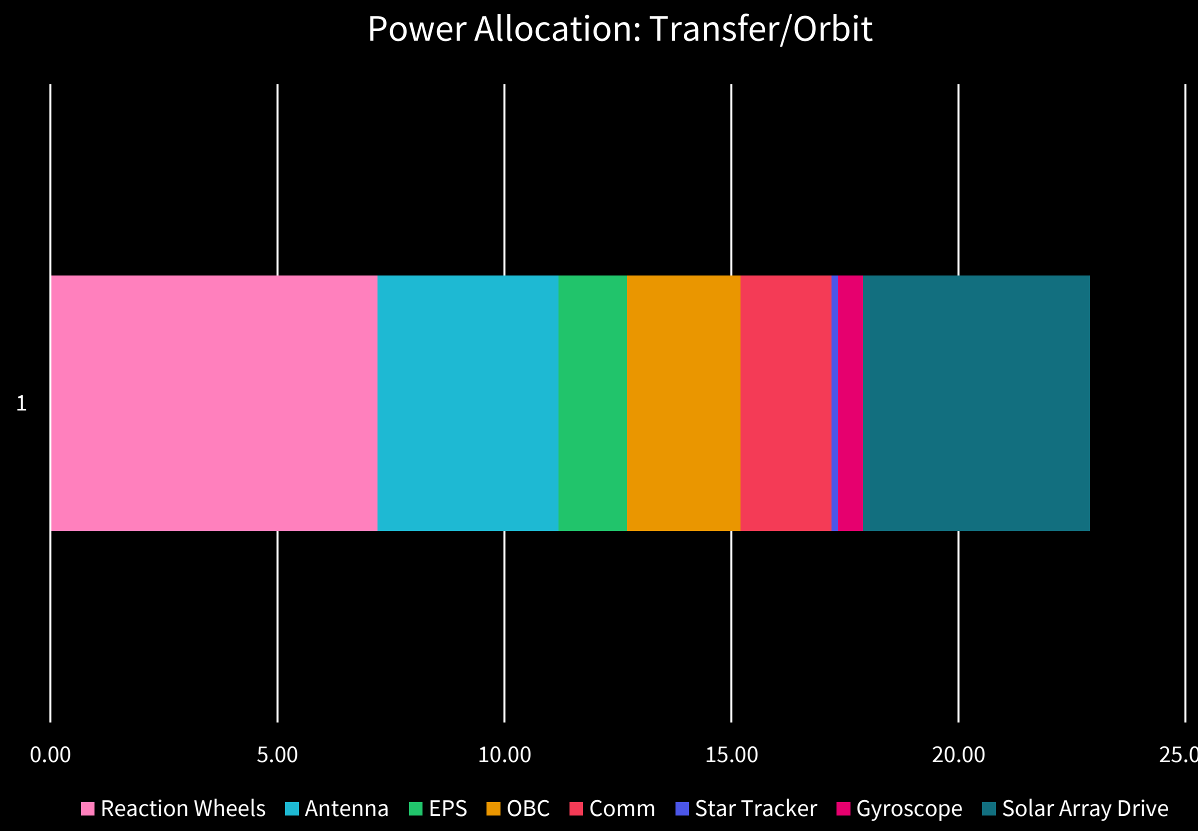


Power Budget: Max Usage

- Case: *Transfer/Orbit*
  - Post Deployment, post solar array deployment. Case applies in L2-L4 Transfer or during station keeping.

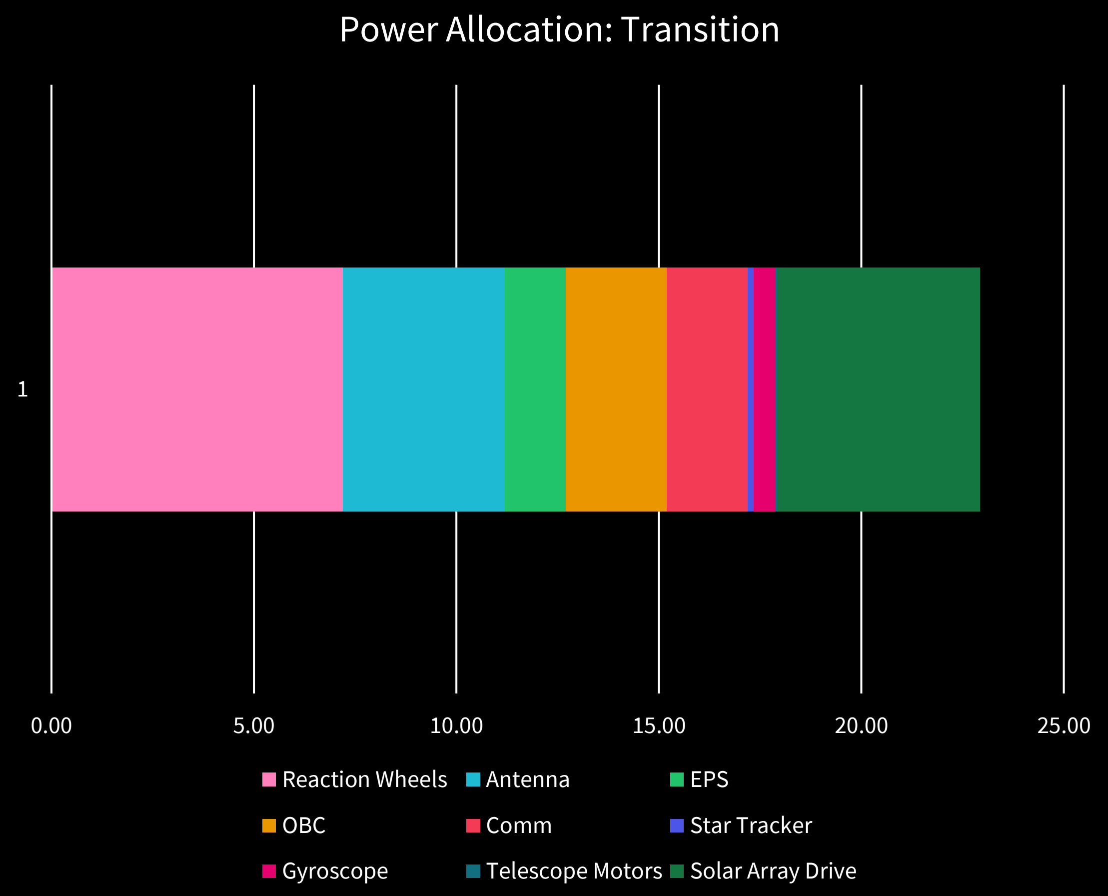
  - *Solar Available:* 26 W
  (Worst Case from PDR for 2 Panels)
  - *Total Usage:* 22.89 W

  - Net Power Production:
  +3.11 W



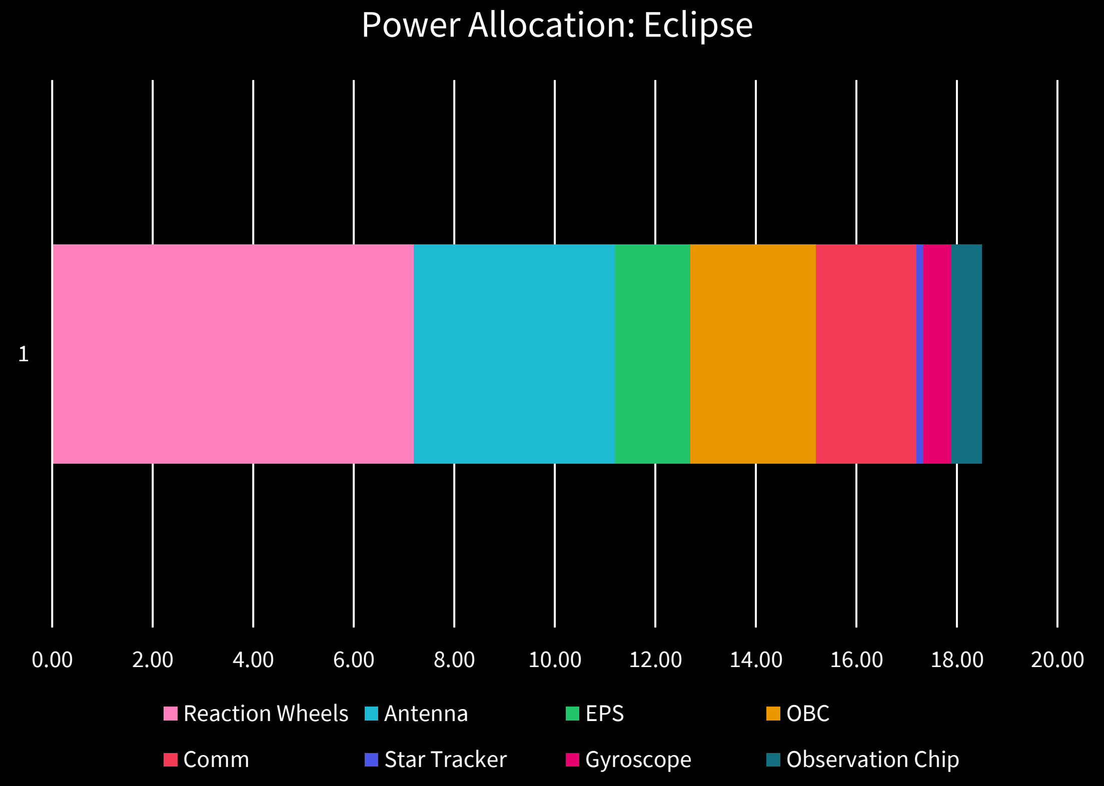
Power Budget: Max Usage

- Case: *Transition*
  - Transient time while entering or leaving lunar eclipse from L4 orbit.
  - Solar Available: 0W (Assume Eclipse worst case) in reality, will be greater than 0 even during eclipse.
  - Total Usage: 22.93 W
  - Battery Capacity: 30 Wh
  - Time Till Dead: 78 mins



Power Budget: Max Usage

- Case: *Eclipse*
  - Time during observation in eclipse of moon.
  - Solar Available: 0W (Assume Eclipse worst case) in reality, will be greater than 0 even in eclipse.
  - Total Usage: 18.49 W
  - Battery Capacity: 30 Wh
  - Time Till Dead: 97 mins



Mass Budget

Part	Mass (kg)
Reaction Wheel	0.74
Anntena	0.03
EPS	0.33
Battery	0.27
Telemetry Software	0.00
Structure	0.85
Thruster L2 to L4	1.10
Thruster L4 Station	1.20
OBC	0.13
Comm	0.09
Star Tracker	0.05
Solar Panels	0.60
Solar Array Drive	0.25
Mirrors	0.25
Observation Chip	0.03
Telescope Misc. Parts	0.09
Motor	0.2
Wiring+Hardware	0.56
Fuel Tank	~
Ion Fuel	1.78
Chemical Fuel	0.31
Total	8.85

	Known Values
	Preliminary
	Cost Estimates

$$\underline{\boldsymbol{M = 8.85\ Kg}}$$

- *Stand-In Mass Budget*
  - Values found for most components as denoted in green.
  - Red Values represent estimates from existing propulsion devices. (NOTE: Since no appropriate thrusters could be found, these are solely existing propulsion systems in the market and do not represent final design masses).
  - L2-L4 Thruster Stand In: *PM2000*
  - L4 Station Thruster Stand In: *Cluster of IFM Nano Thruster for Small Sats*

Mass Budget

Part	Mass (kg)
Reaction Wheel	0.74
Anntena	0.03
EPS	0.33
Battery	0.27
Telemetry Software	0.00
Structure	0.85
Thruster L2 to L4	~
Thruster L4 Station	~
OBC	0.13
Comm	0.09
Star Tracker	0.05
Solar Panels	0.60
Solar Array Drive	0.25
Mirrors	0.25
Observation Chip	0.03
Telescope Misc. Parts	0.09
Motor	0.2
Wiring+Hardware	0.56
Fuel Tank	~
Ion Fuel	~
Chemical Fuel	~
Total	4.46

	Known Values
	Preliminary
	Cost Estimates

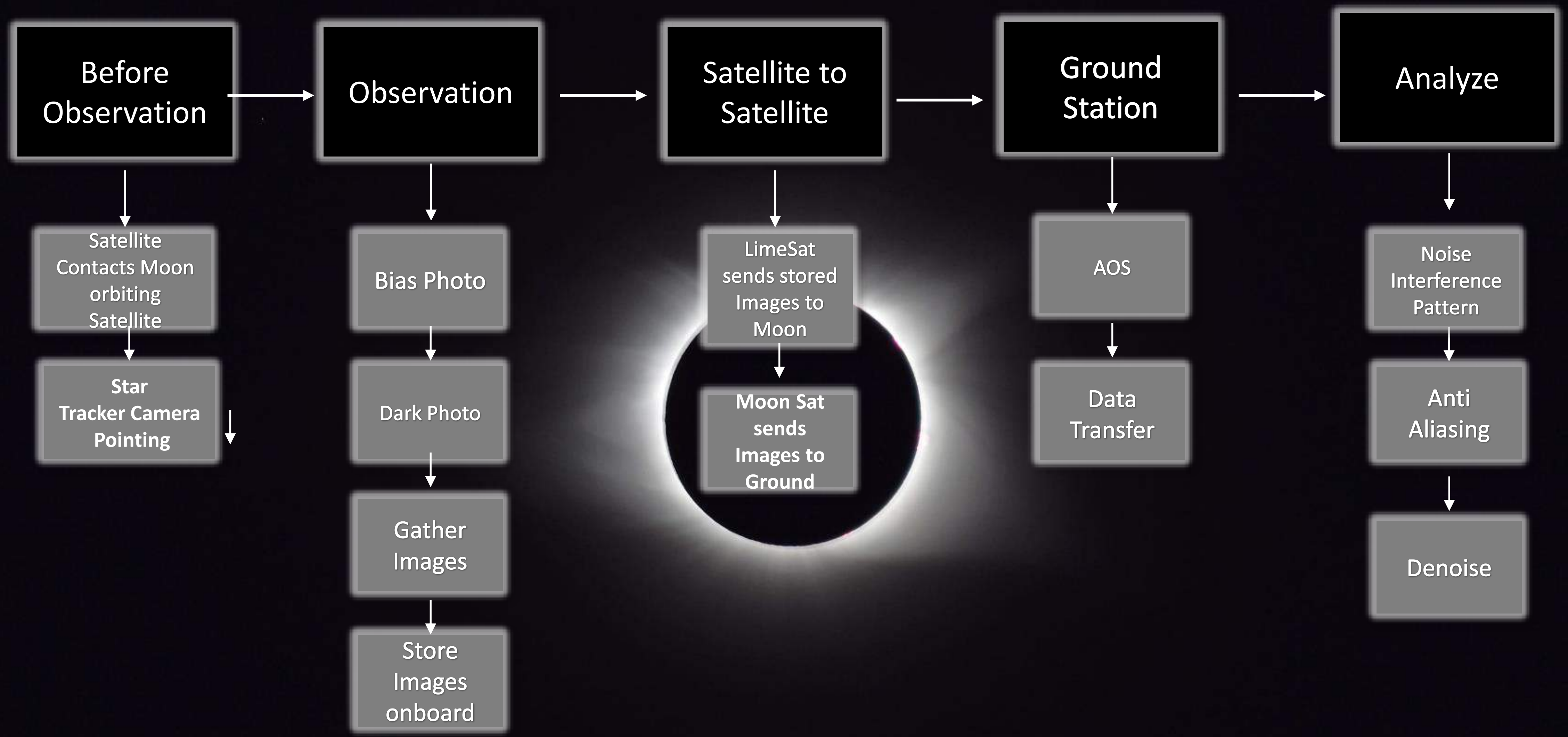
$$\underline{\boldsymbol{M = 4.46\ Kg}}$$

- *Actual Mass Budget*
  - Not adjusted for hypothetical thruster values, actual weight of *LIMESAT* with current design.
  - Design allows for a little over 7.5 Kg of thrusters and fuel assuming current total weight restriction of 12 Kg.

CONOPS

LUNOSTAR MISION

LunOSTAR Mission ConOps: Mission Science



LunOSTAR Mission ConOps: Demise

Final Check T+700days → Disposal → Post-Mission Analysis → Final Report

- Final Check
  - T+700days
  - Data Backup T+5 days
  - System Check T+1 day
- Disposal
  - Planning T+7 days
  - Contact Agencies T+3 days
  - Graveyard Orbit Transfer +15 days
  - Monitor T+21 days → Passivation T+ 30 days
- Post-Mission Analysis
- Final Report

Data Size & Storage

NUV Image: 4MB per Image

	# of Images	File Size (MB)	File Size (GB)
Low Estimate	180	720	0.72
High Estimate	360	1,440	1.44

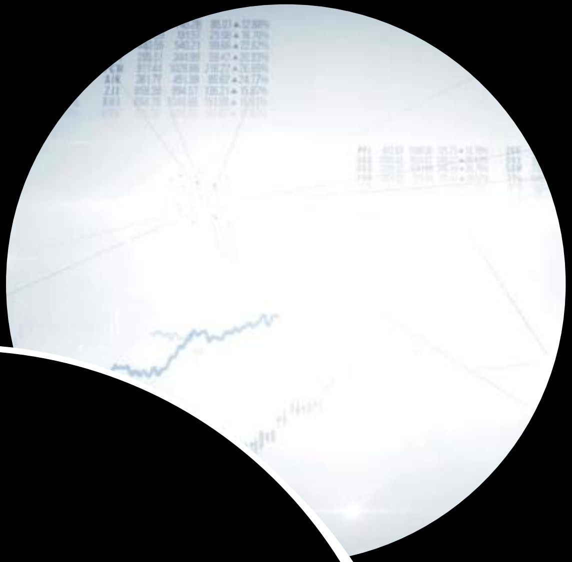
Telemetry Data Size

Less than 200 bytes per each data packet

- **Battery Status**
- **Attitude & Position**
- **System Status**
- **Etc.**

OBC

- **8GB Secured Onboard Memory**
- **SD Card Memory Expansion Ready**



Data Transmission

Type: X-Band

Frequency: 8.375 GHz

Data Rate

- **Downlink: 50Mbps**
- **Uplink: 56Kbps**

Can transmit 1.56 images per second
93.75 images per minute

Takes 1.92 mins to send 180 images
3.84 mins to send 360 images

Communication Network (Ground Station)

Crescent Space by Lockheed Martin

Parsec Network: Operational in 2026
End-to-End Communication Service

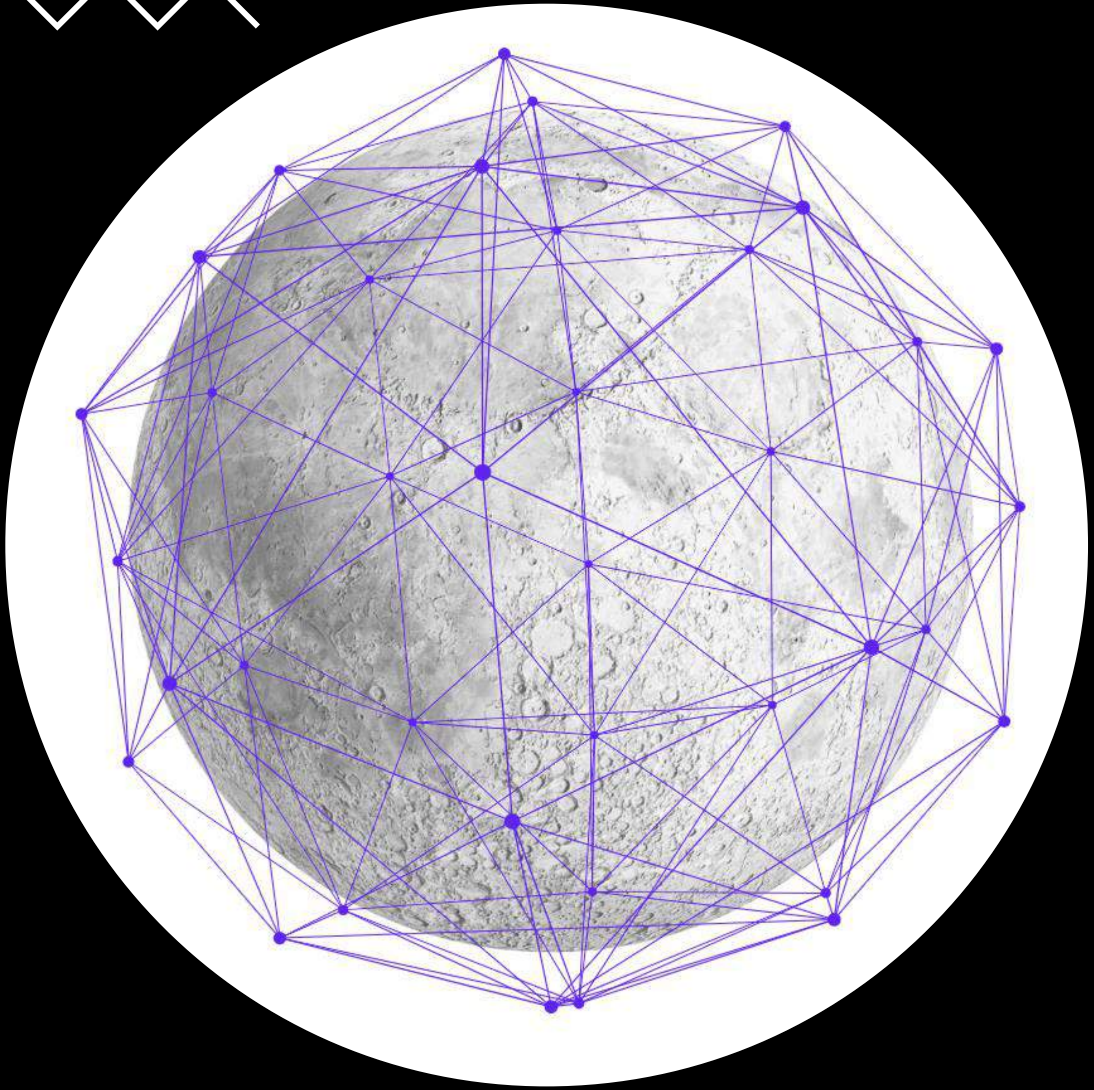
Reserved: Approx. $10.00 per min
On-Demand: Approx. $22.00 per min

Telemetry & Position Data

- Once every 6 hours (1 min each)
- Reserved: 4 mins per day ($1,200 per month)

Nuv Image Data

- On-Demand: 5 mins ($110 per transmission)

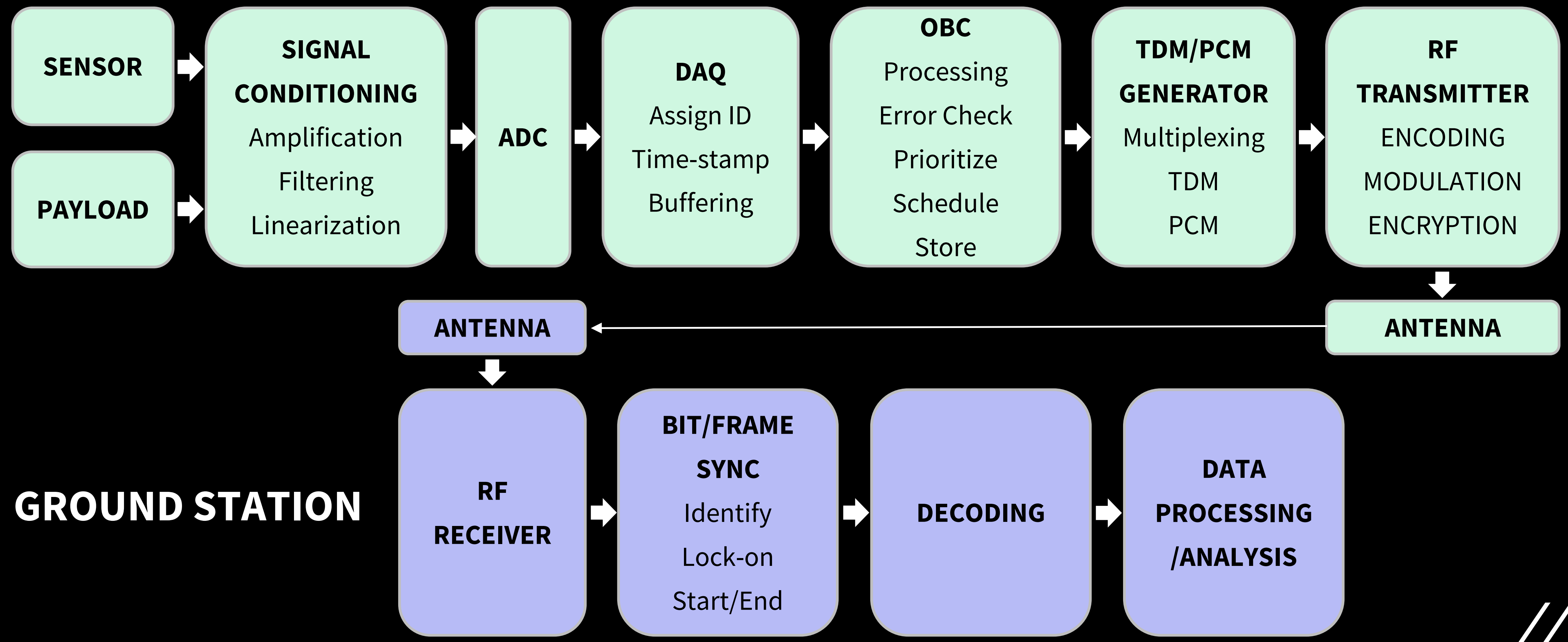


Communication Network

Parsec Lunar Network

- System of small satellites working in unison to allow for seamless connection to the Earth
- Satellite network create an orbiting relay network that provides complete communication and navigation coverage
- End-to-end communication services that deliver data back to Earth securely and efficiently

Communication Methodology



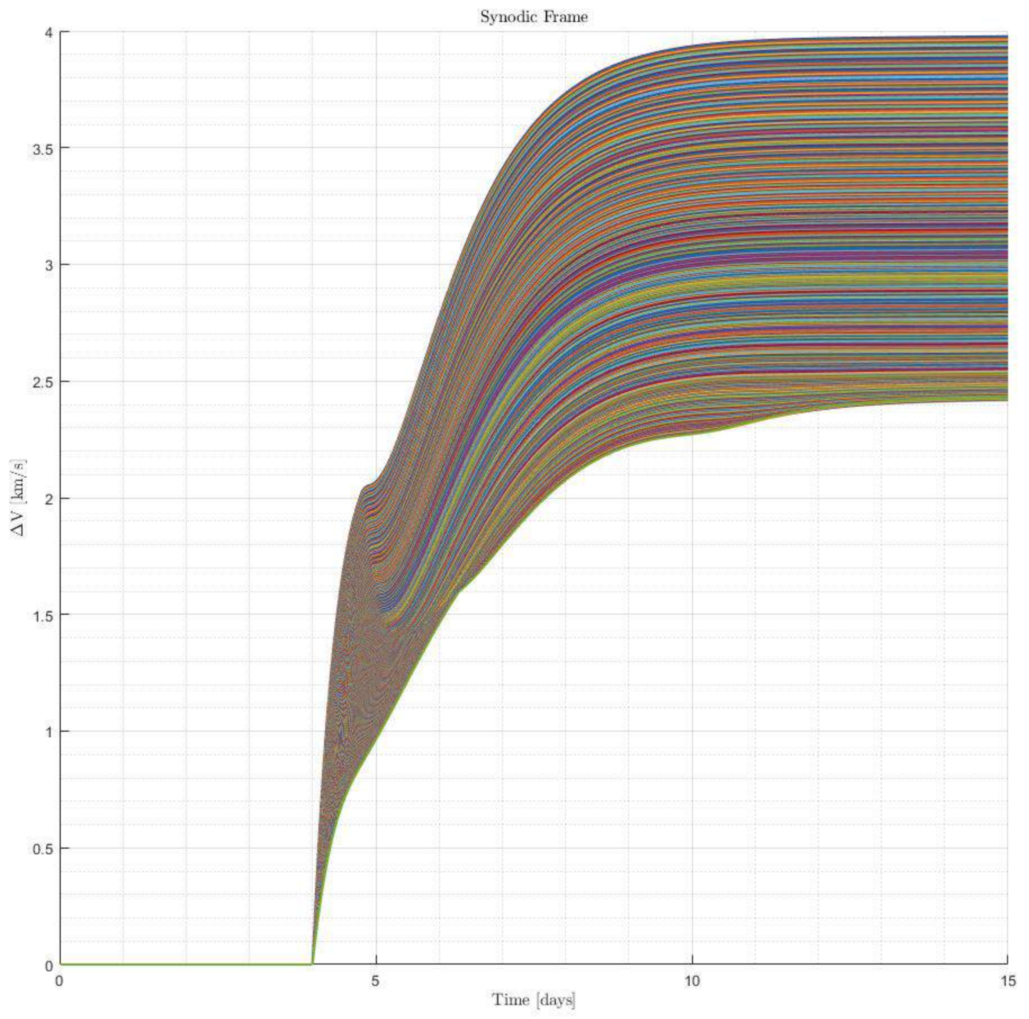
GNC – Ongoing Strategies

TRANSFER

- Tabulated every possible reference SPO, allowing the calculation of multiple transfer orbit solutions at once.

STATION KEEPING

- “Find Nearest” Method – Using a database of every position and velocity vector along every point of every reference SPO, we can guide the spacecraft to an orbit, turn it off, and allow it to select the nearest orbit solution when it turns back on for its station-keeping burn period.
  - This is an enhancement of the “Spiral Out” method proposed by Luis at the last review.
  - Minimizes the “correction burns” while still allowing the spacecraft to stay in orbit longer.

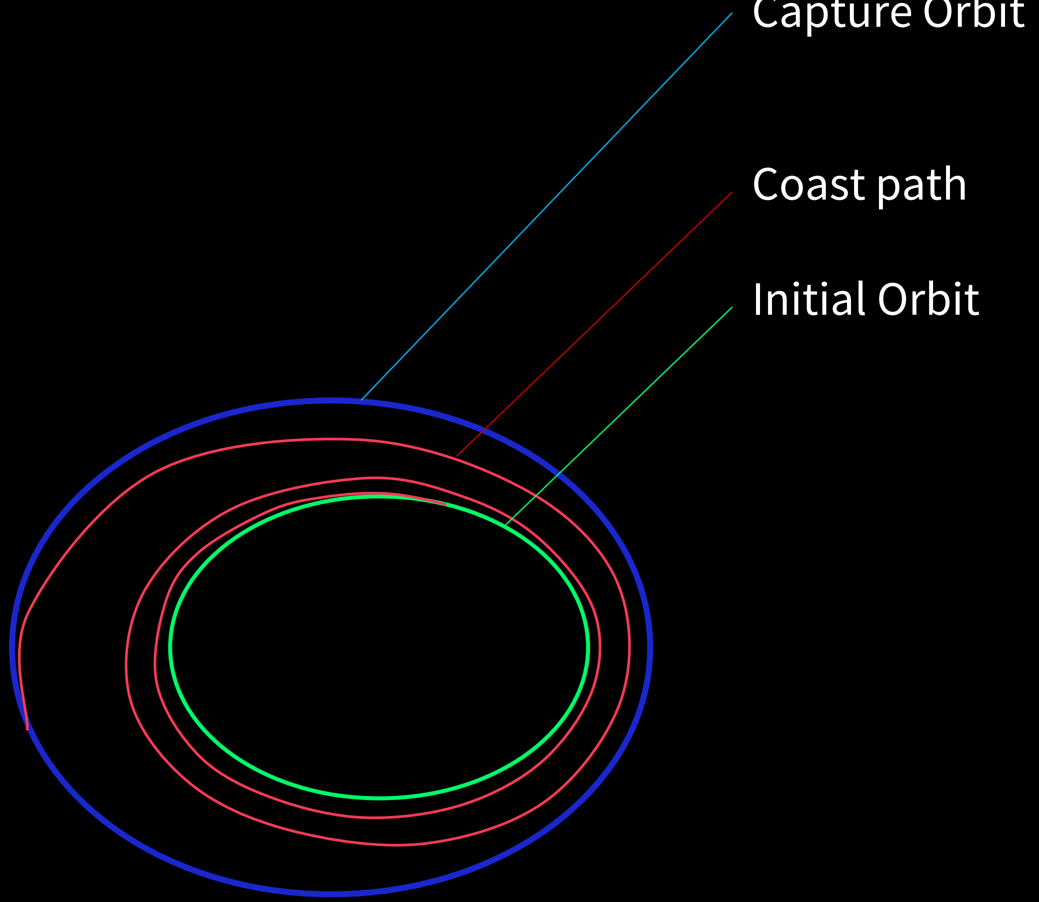


Delta V of the transfer burn plotted with a shifting reference SPO.

An overall minimum Delta V can be found, but other considerations include the nature of an impulse burn. It may be better to optimize Delta V for only the first day of the transfer orbit maneuver if the spacecraft is going to coast for the majority of the ride.

GNC – Ongoing Strategies

GNC – Ongoing Strategies



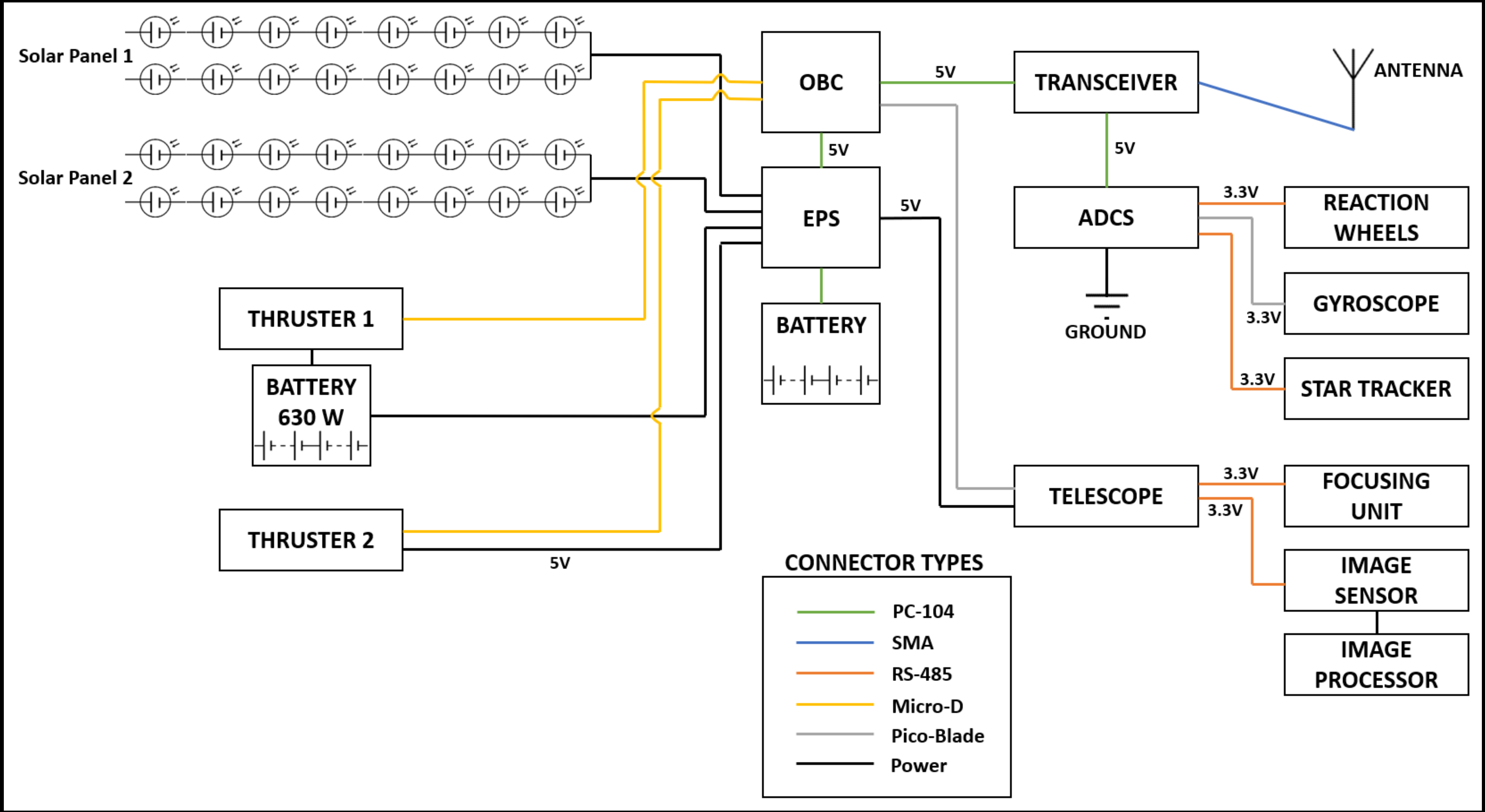
"Find Nearest" Method

Starting from the inner Green orbit, the spacecraft will naturally be perturbed towards the blue orbit.

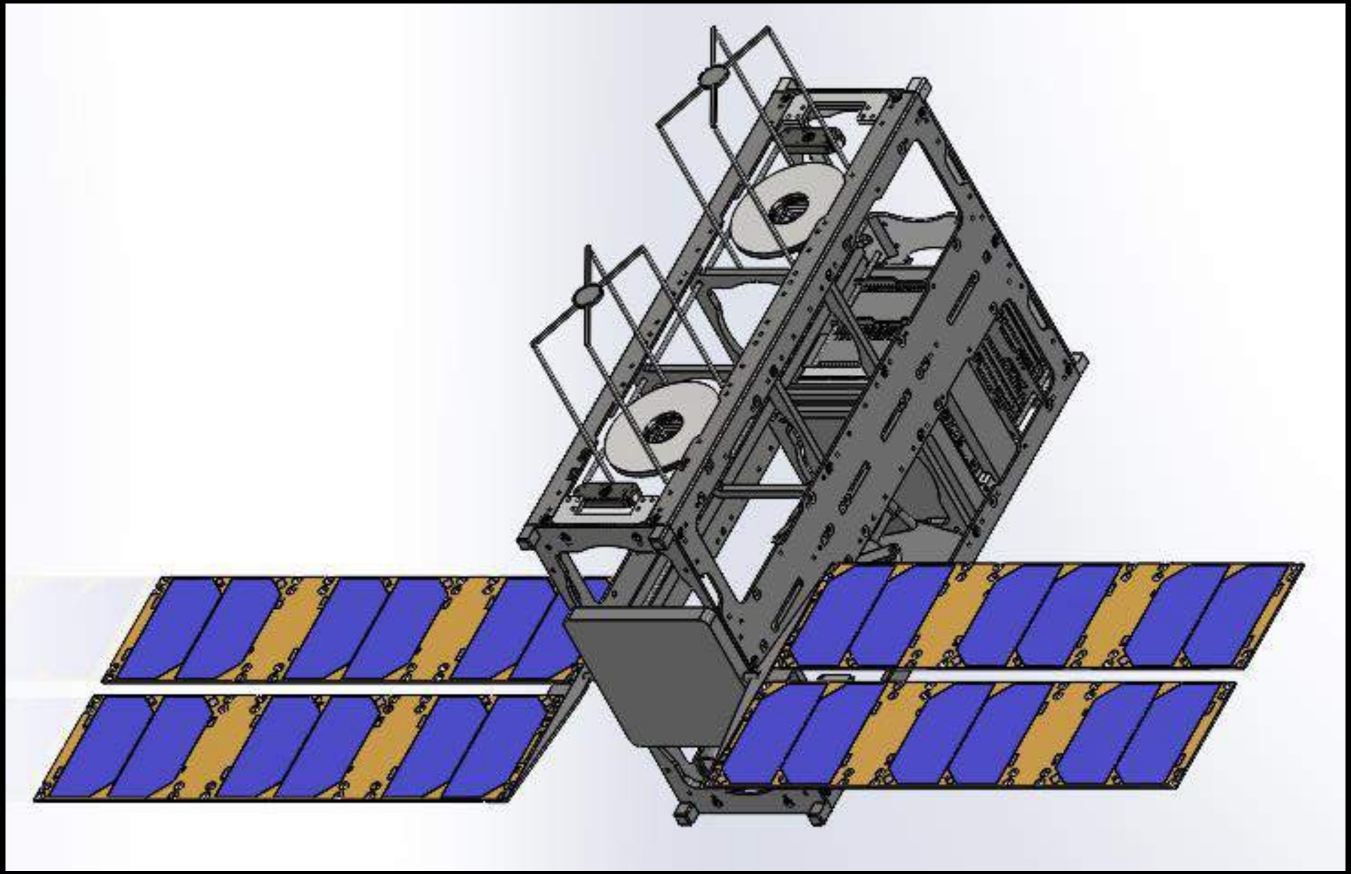
We allow the spacecraft to coast along the red path, saving fuel, and then a small correction burn aligns the spacecraft with the blue orbit, increasing the operational lifetime of the spacecraft without consuming as much fuel as a full correction back to the green orbit.

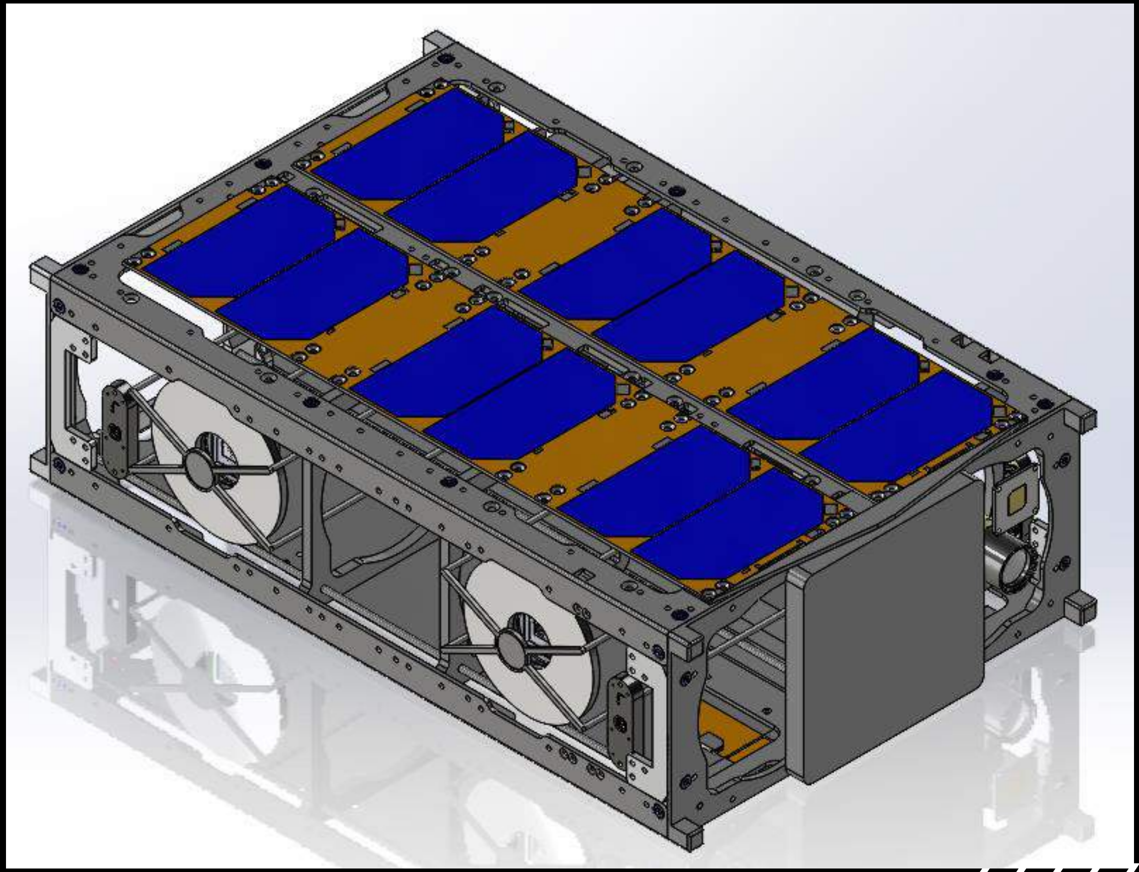
This process can be repeated many times; it could possibly be implemented in the transfer maneuver as well.

Electrical Schematic

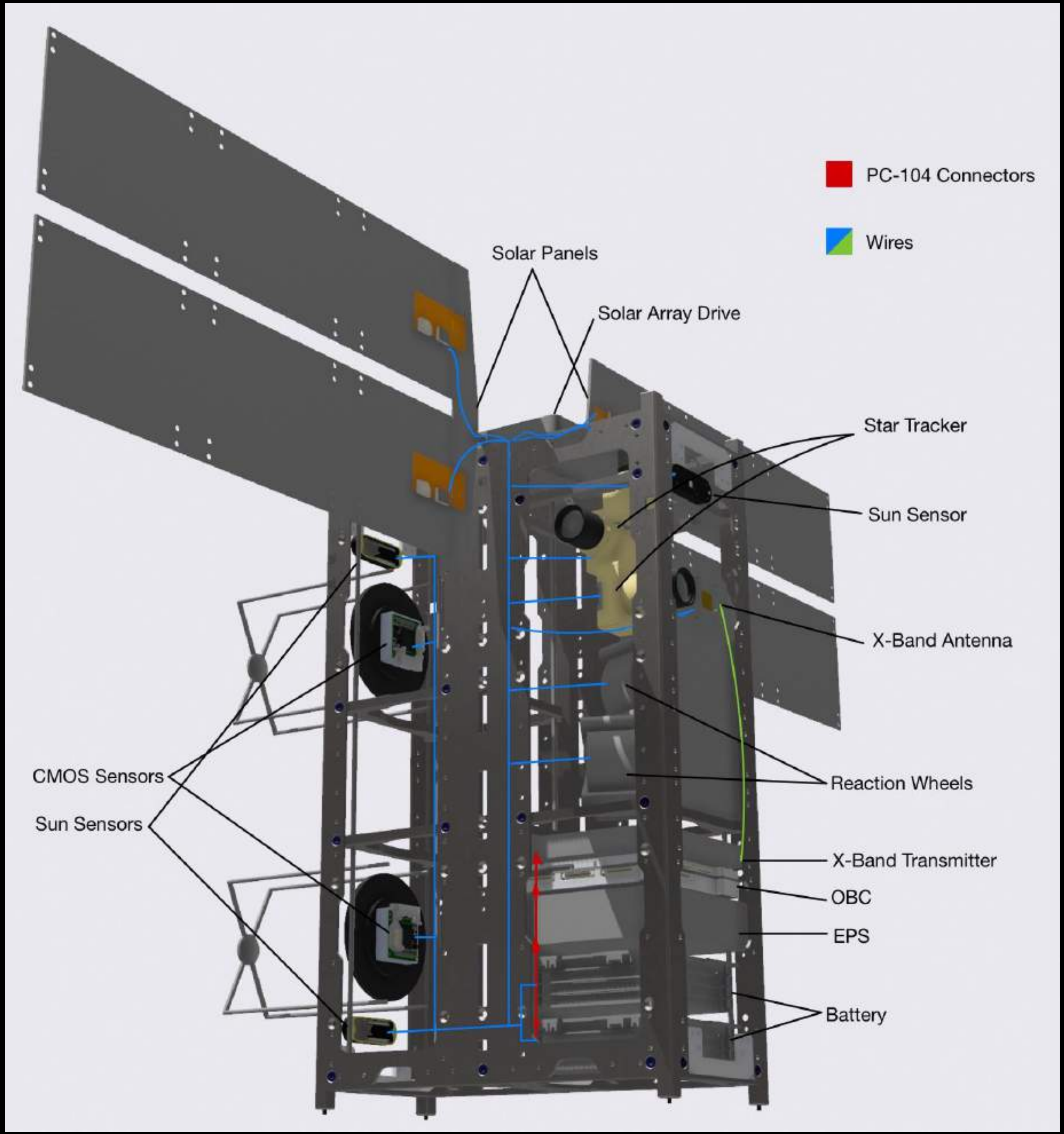


CAD Model





WIRE ROUTING



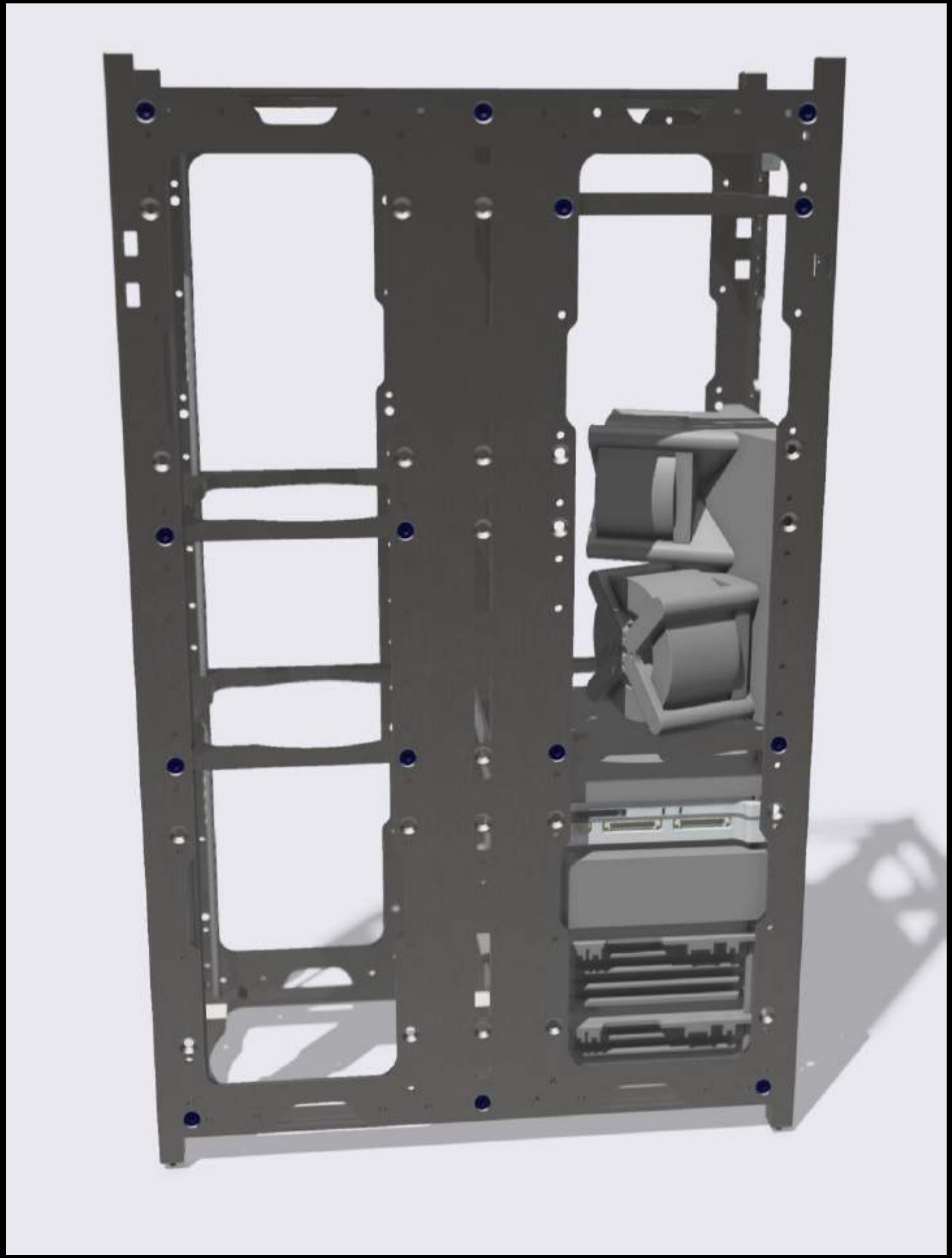
Build-Up Process

1. Batteries x2
2. EPS
3. OBC
4. X-Band Transmitter

Build-Up Process

5. Reaction Wheels Mount

6. Reaction Wheels x2

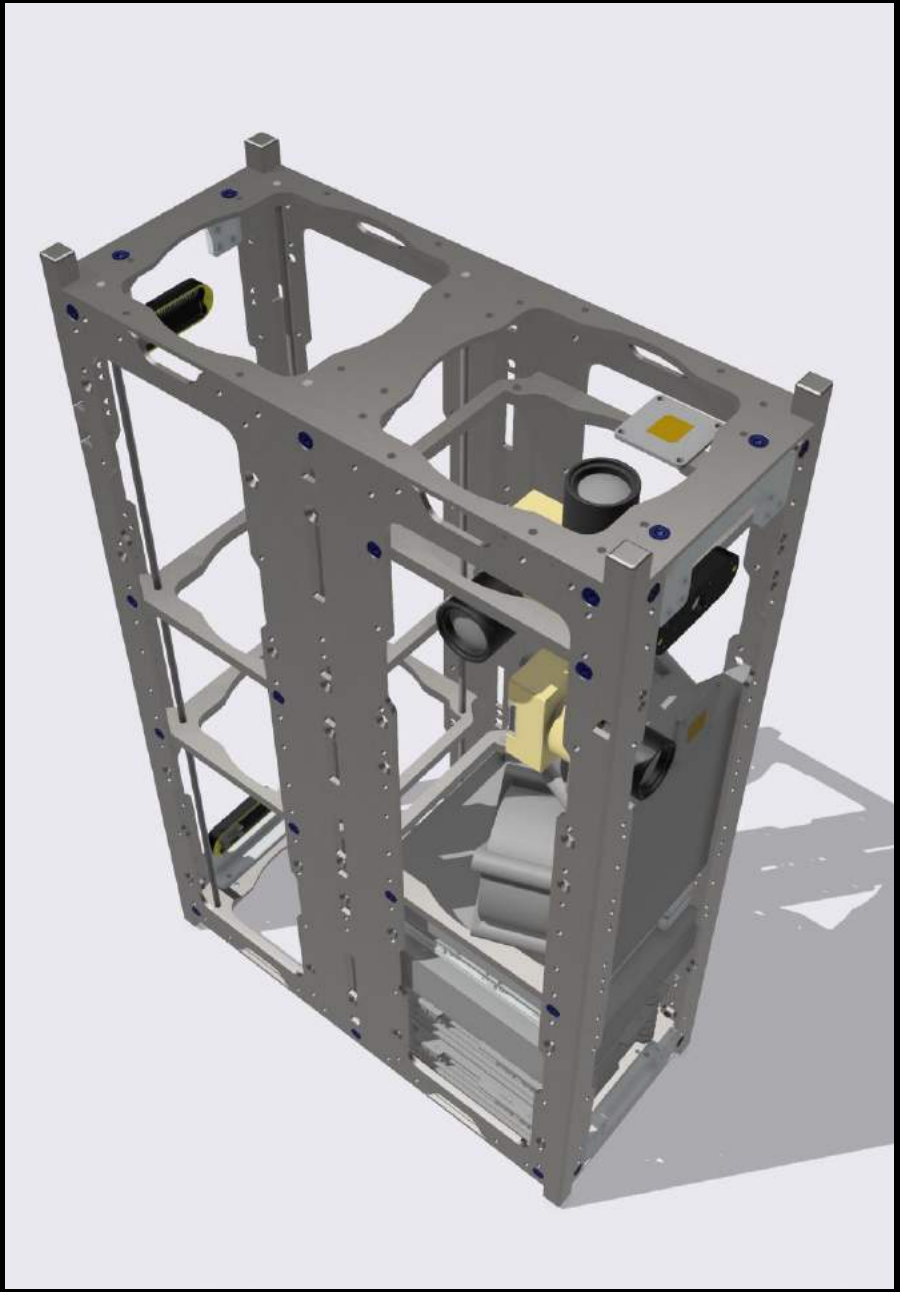


Build-Up Process

7. Star Trackers x3

8. Sun Sensors x3

9. X-Band Antennas x2



Build-Up Process

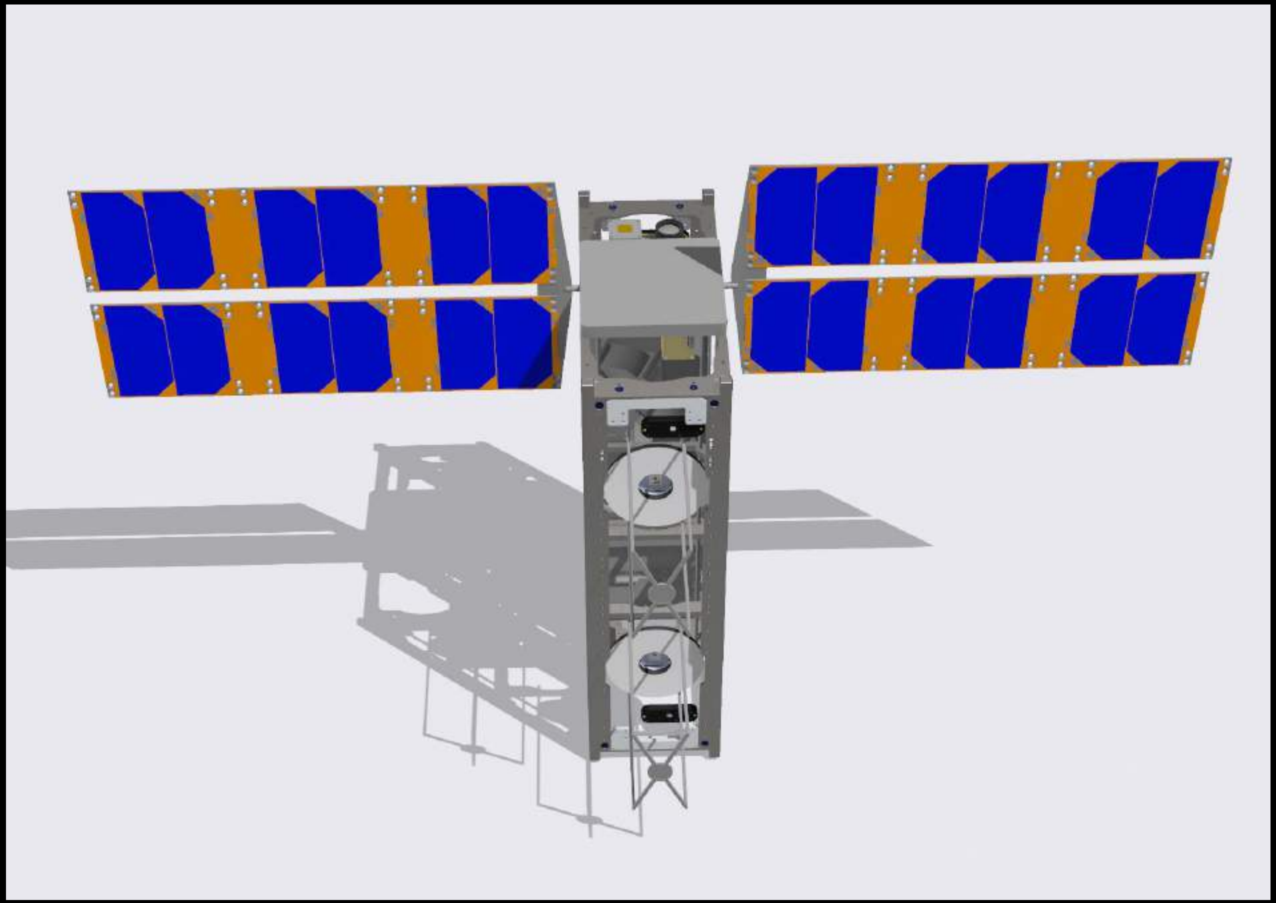
10. Alvium Frames x2
11. CMOS Sensors x2
12. Primary Mirrors x2
13. Motors x4
14. Threaded rods x8
15. Secondary Mirrors x2

Build-Up Process

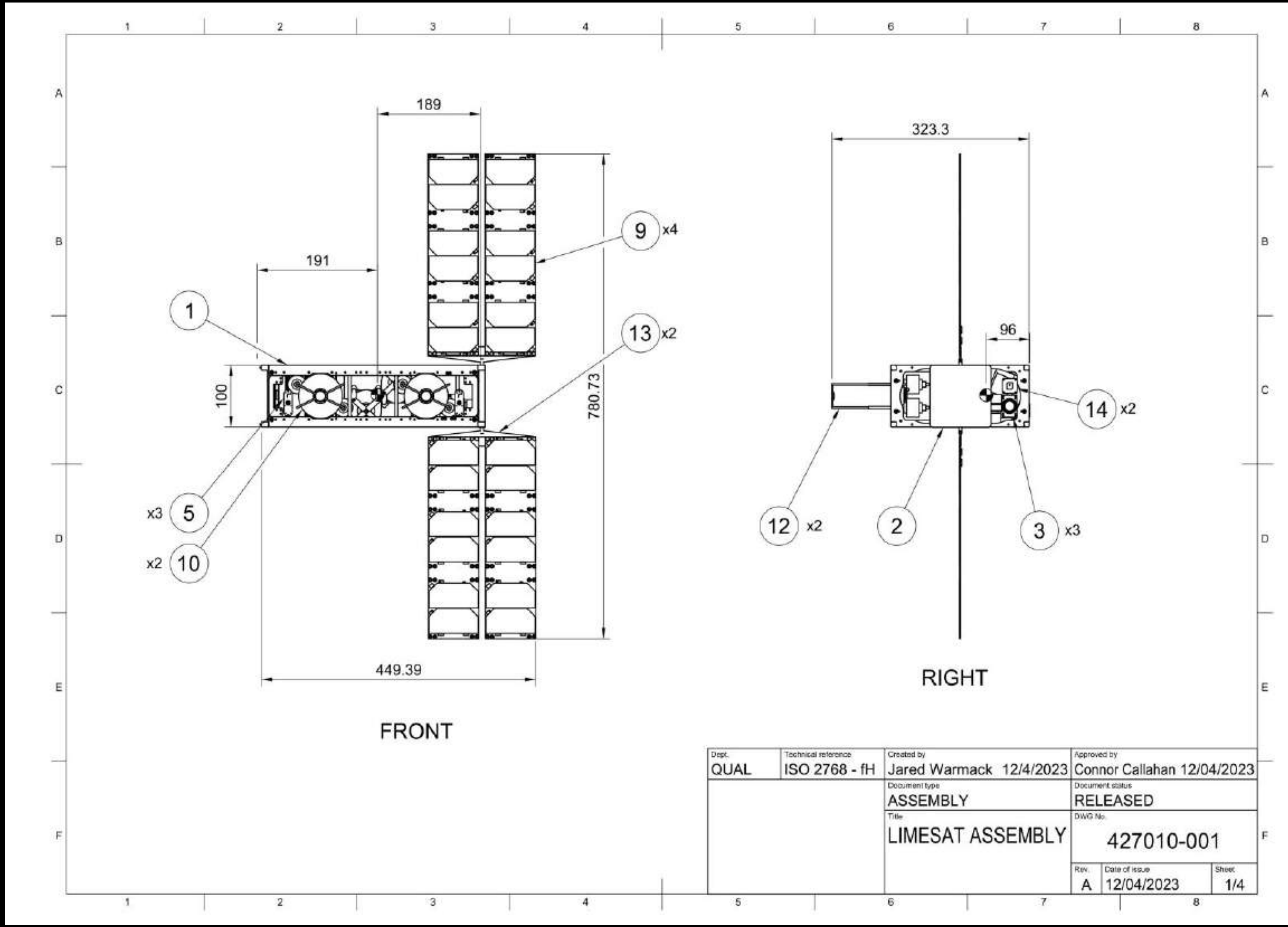
16. Solar Array Drive

17. Solar Array Arms x2

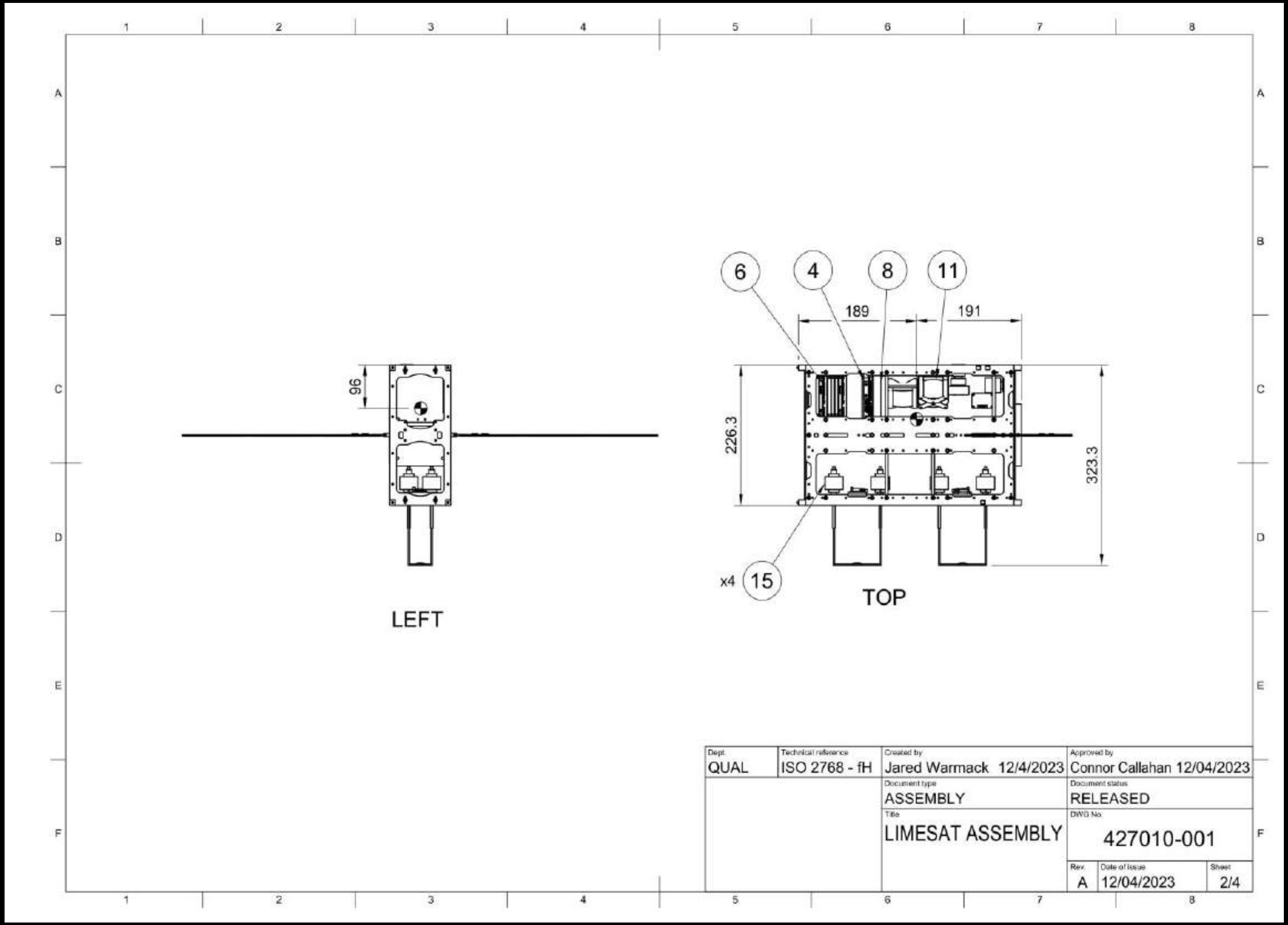
18. Solar Panels x4



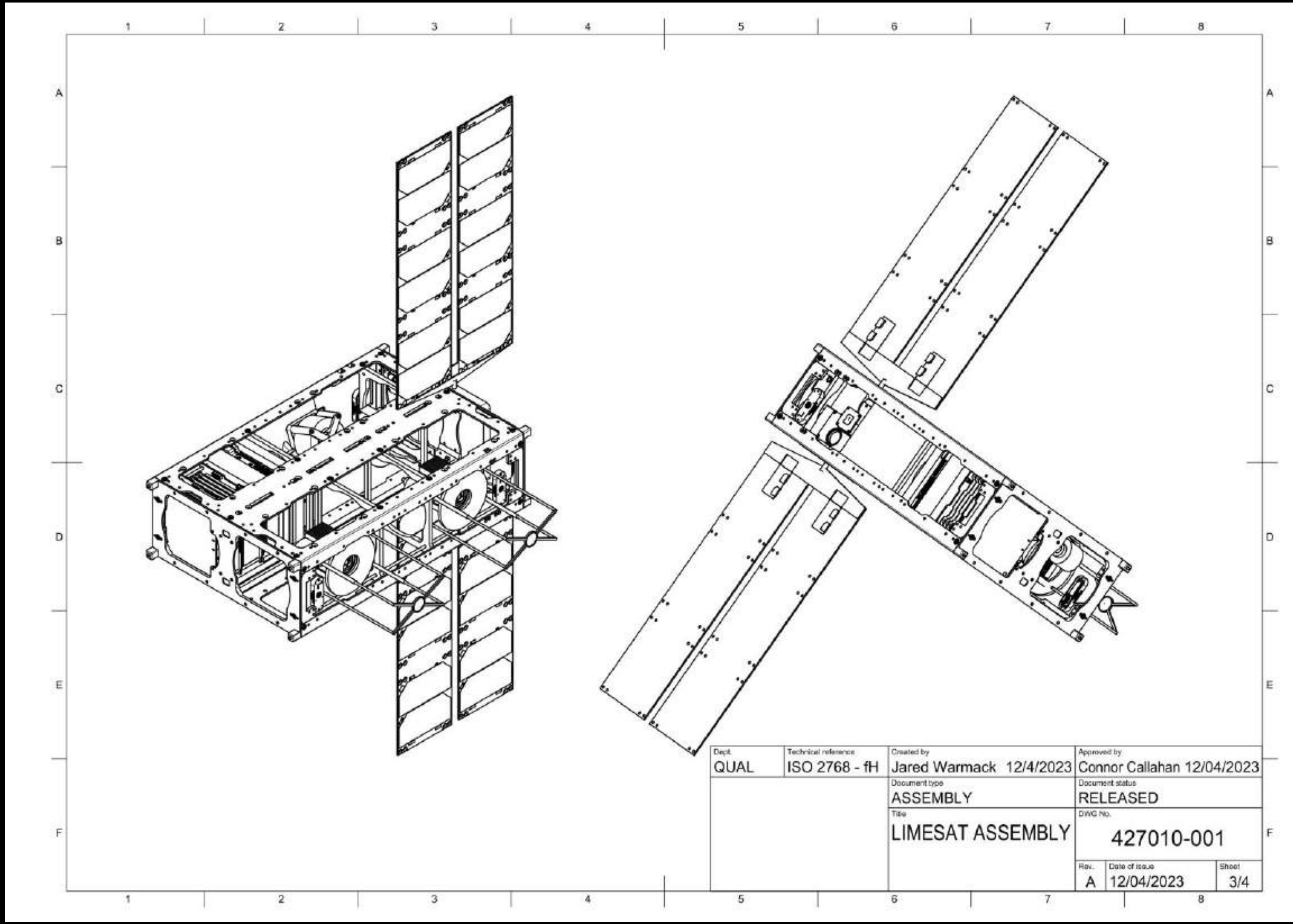
Engineering Drawings



Engineering Drawings



Engineering Drawings

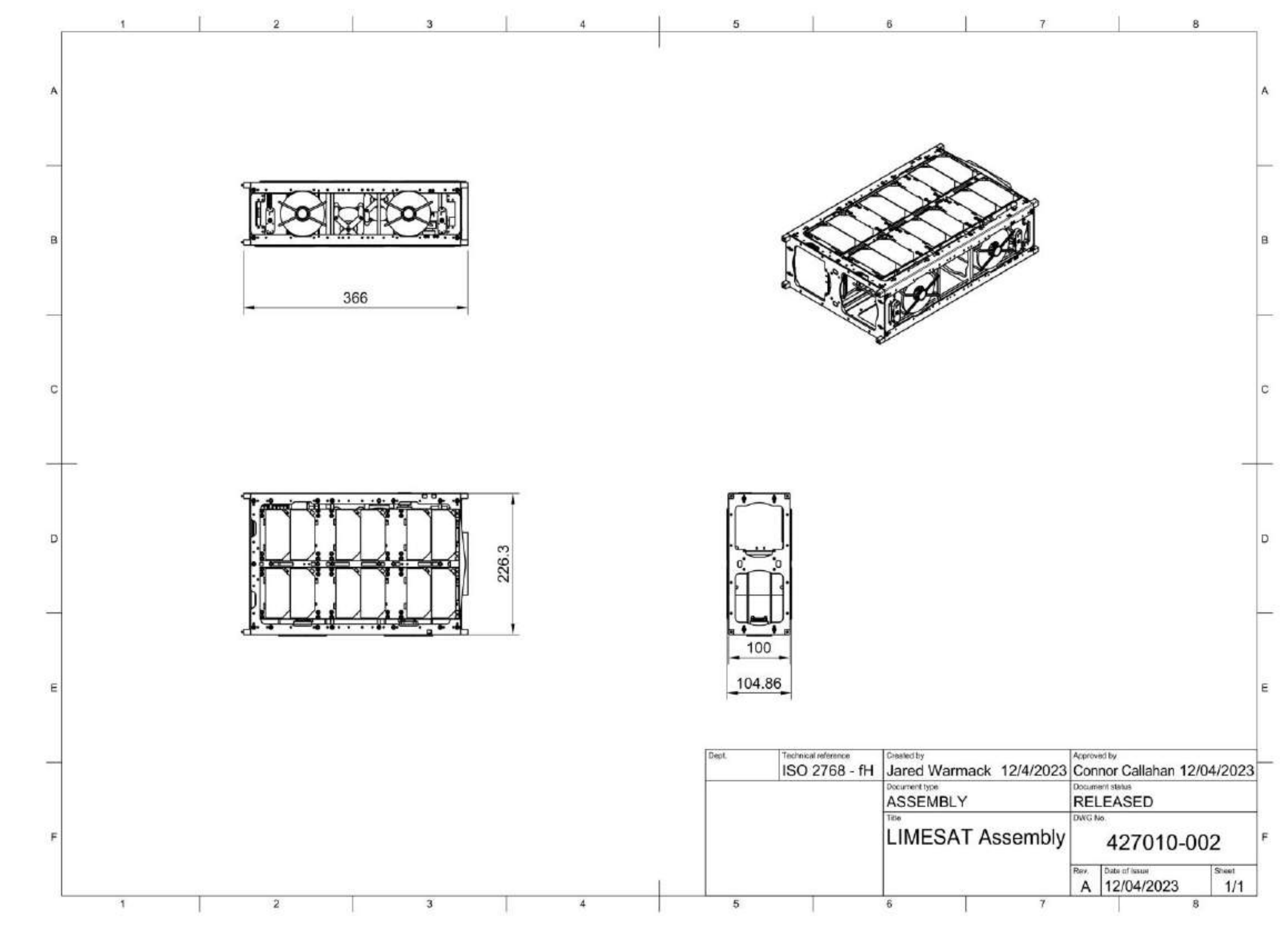


Engineering Drawings

Parts List			
Item	Qty	Part Number	Description
1	1	427011-001	ENDUROSAT - 6U Structure
2	1	427004-001	Solar Array Drive
3	3	427007-001	CubeStar - Star Tracker
4	1	427005-001	Onboard Computing System
5	3	427002-001	Sun Sensor
6	1	427012-001	Optimus Battery
7	1	427006-001	EPS
8	1	427013-001	X-Band Transmitter
9	4	427009-001	ISIS Space 3U Solar Panel
10	2	427003-001	Observatory Primary Assembly
11	1	427015-001	Reaction Wheel Assembly
12	2	427003-001	Observatory Secondary Assembly
13	2	427014-001	Solar Array Arm
14	2	427008-001	X-Band Antenna Patch
15	4	427016-001	Ball Screw Motor, Hollow Bore

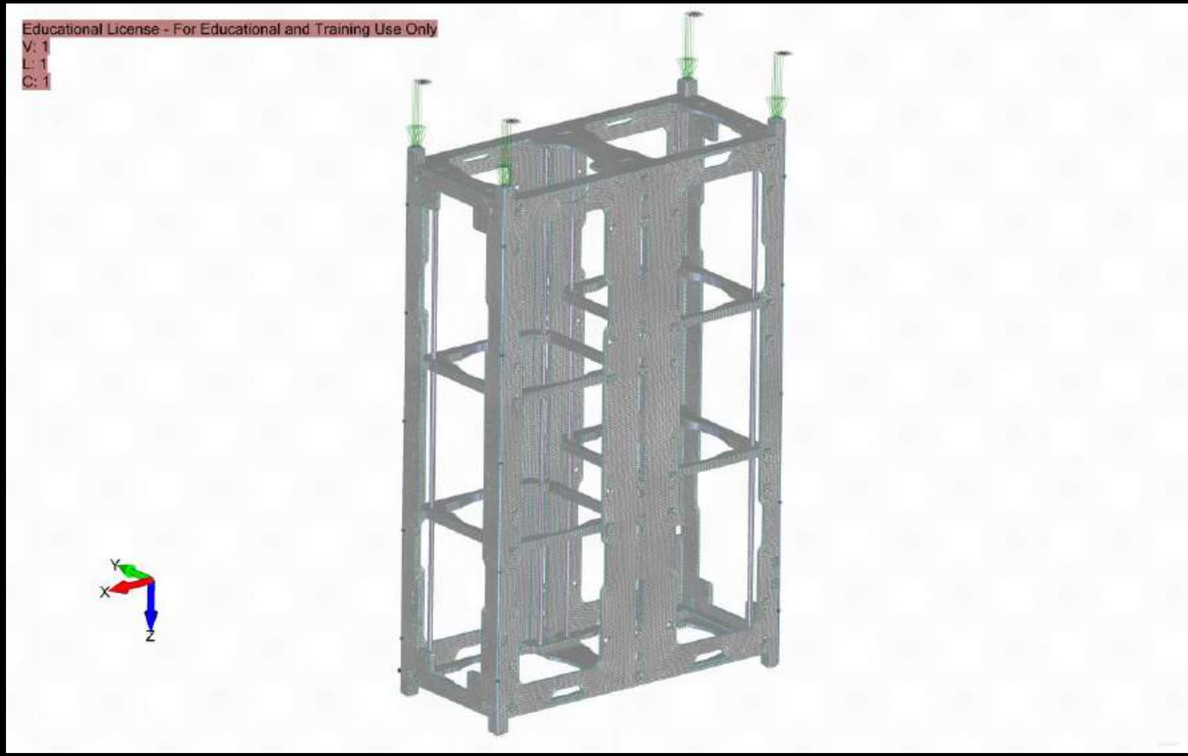
Dept.	Technical reference	Created by	Approved by
QUAL	ISO 2768 - fH	Jared Warmack 12/4/2023	Connor Callahan 12/04/2023
		Document type: ASSEMBLY	Document status: RELEASED
		Title: LIMESAT ASSEMBLY	DWG No.: 427010-001
			Rev.: A · Date of issue: 12/04/2023 · Sheet: 4/4

Engineering Drawings



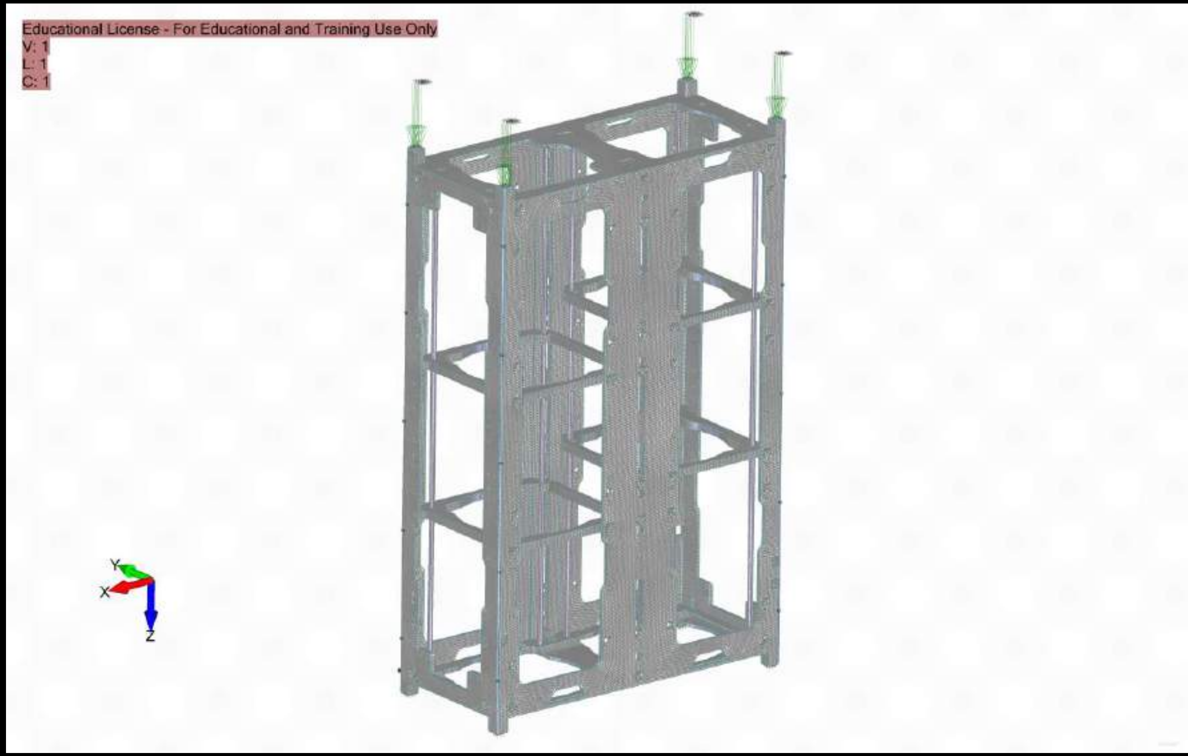
Stress-Strain Analysis

- *Loads:*
  - Loads prescribed by *NanoRacks External CubeSat Deployer (NRCSD-E) Interface Definition Document (IDD).*
    - Although there are different *NanoRacks* deployers, this one can launch 6U satellites and requires the greatest force resistance resulting in a conservative estimate.
  - *NRCSD-E IDD* requires a force of 1320 N across load points equally.
  - 1320N surface force applied across rail ends which are the load bearing point according to the *NRCSD-E IDD*.



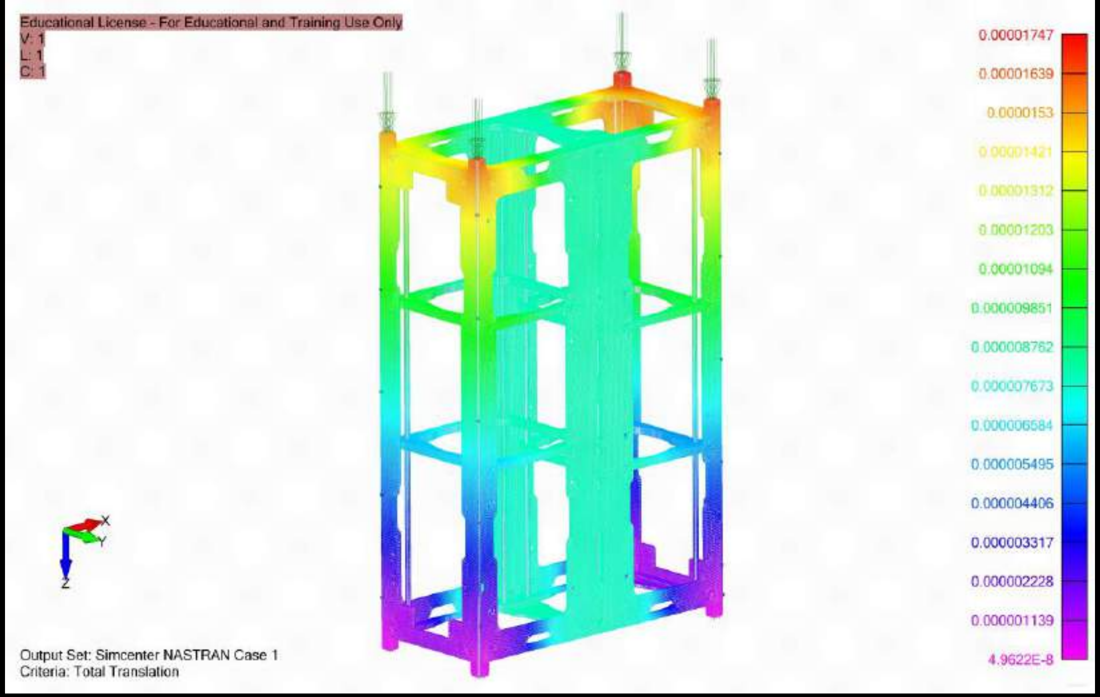
Stress-Strain Analysis

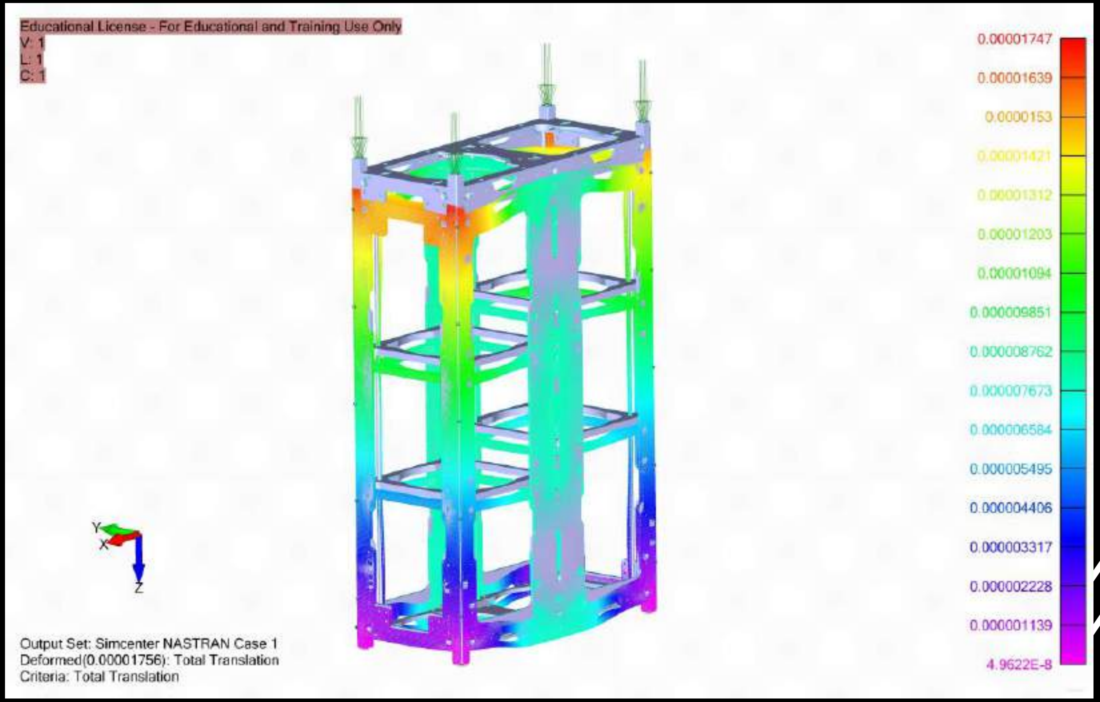
- *Constraints:*
  - End of rails (+Z Direction) constrained in the Z direction.
  - XZ and YZ faces of rails constrained in the X and Y directions.
  - Constraints meant to mimic conditions inside of deployer.
- *Mesh:*
  - Mesh sized automatically by *FEMAP*, four sided on the scale of 1E-4m.



Stress-Strain Analysis

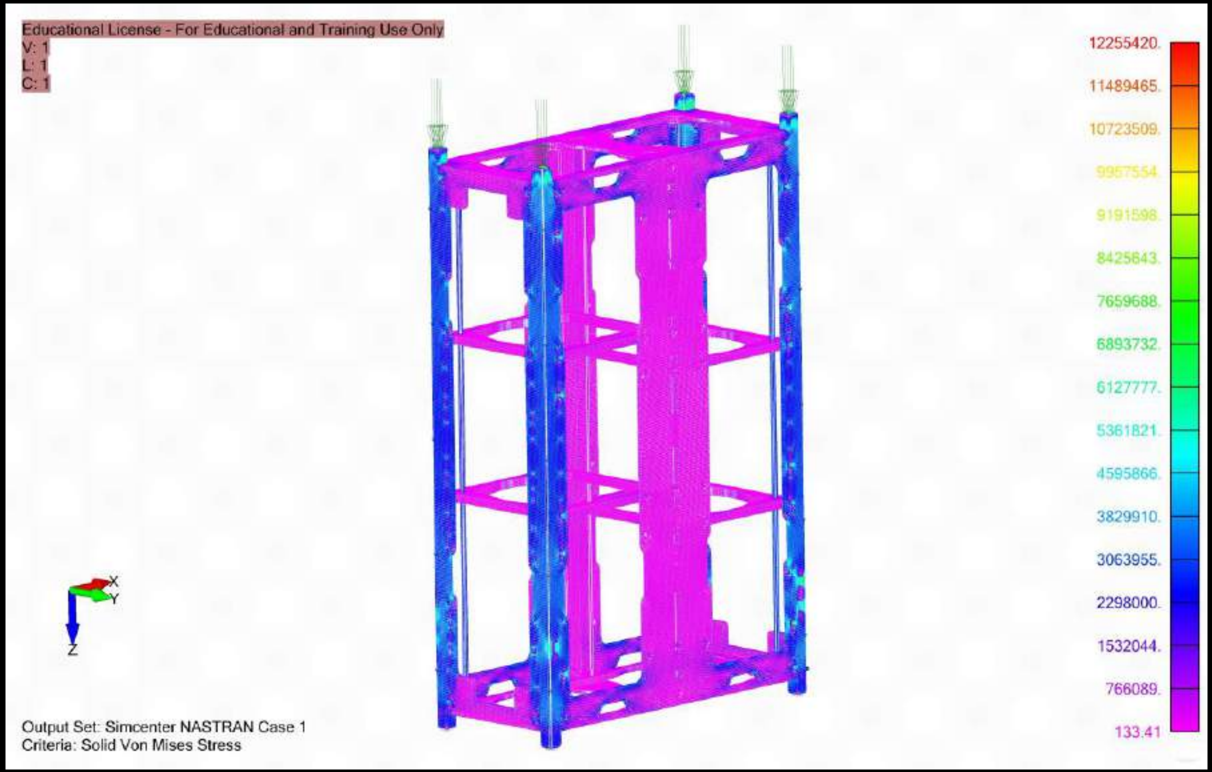
- *Translation Analysis:*
  - First analysis done is total translation of features.
  - Z-axis columns experience the greatest translation.
  - Translation is at a maximum 17 Micro-Meters.
  - Deformation case shown is exaggerated for visualization of bending mode (not representative of actual translation magnitudes).





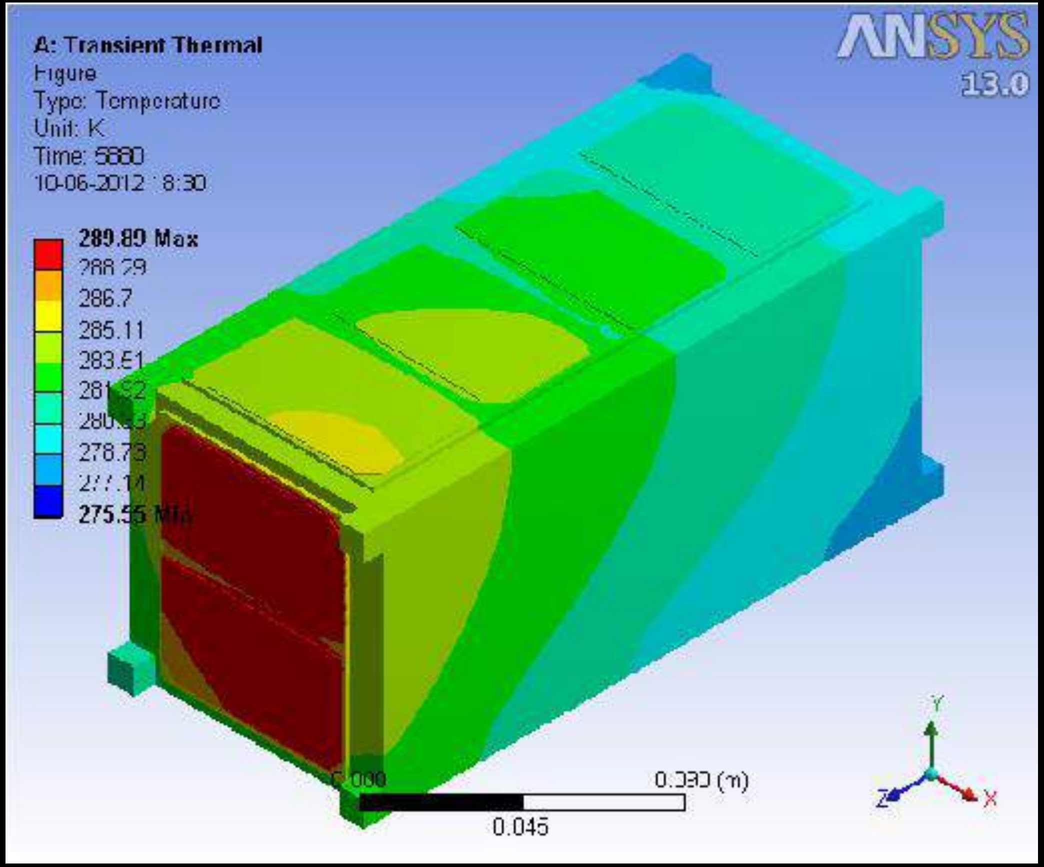
Stress-Strain Analysis

- *Von-Mises Stress Analysis*
  - Max FEMAP Von-Mises Stress:
    12.2 MPa
    - Failure Check:
      - *Al 6082* Tensile Strength, Yield: 250MPa
      - Von-Mises stress falls well below yield strength of *Al 6082*
    - Stress concentrations:
      - Stress currently concentrated around screw holes and would likely be reduced dramatically once fully assembled with screws taking up empty space.



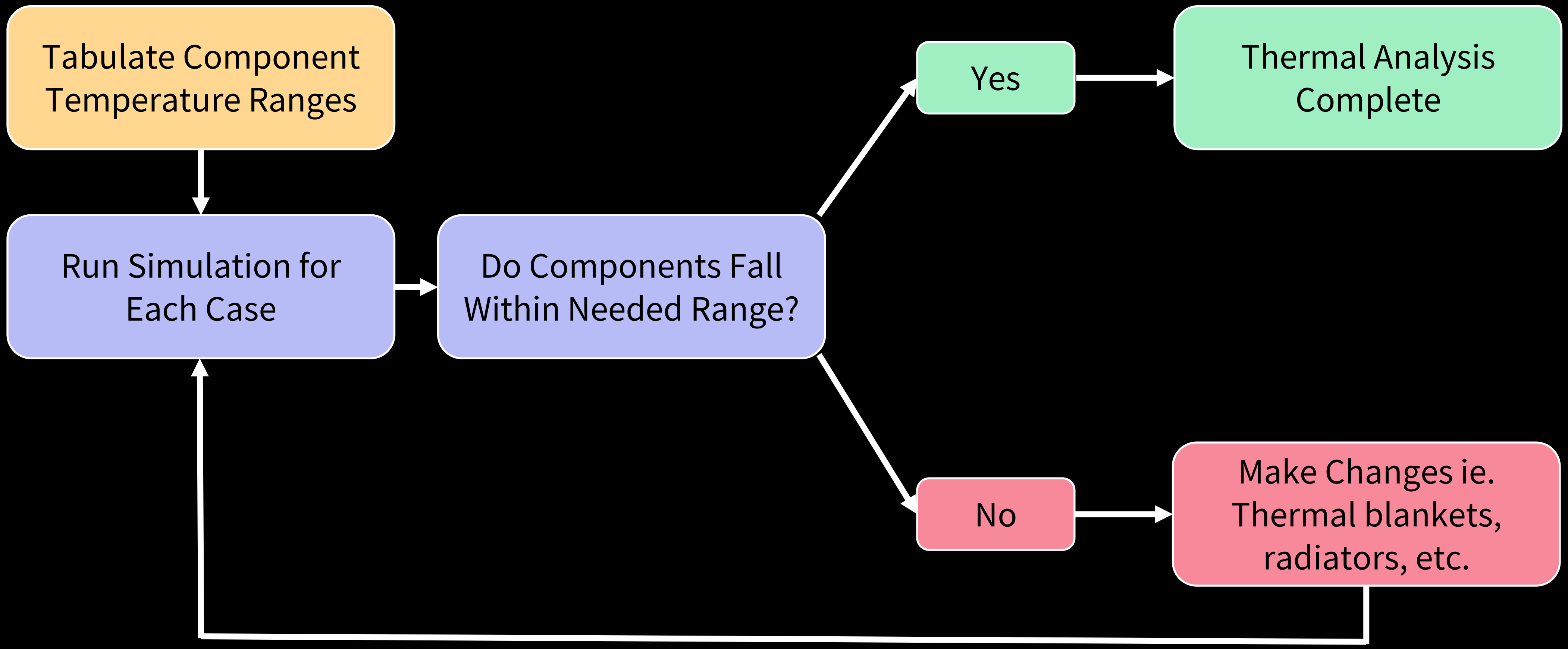
Thermal Analysis Method

- *ANSYS* can be used to determine temperatures of components by importing CAD model and modeling different cases using solar radiation determined at location in orbit.
- <u>Cases to be analyzed:</u>
  - In eclipse
  - In Sun- Close end of orbit
  - In Sun- Far end of orbit



<u>Note:</u> Figure for viewing purposes, not representative of any thermal analysis executed for this project.

Thermal Analysis Method



Vibration Analysis Method

- Will be sent to Experior Laboratories for testing
  - Sine sweep Vibration Testing: >220 G pk
  - Random Vibration Testing: >175 G rms
  - Cleanroom Option Available
  - Combined Environments: Vibration at ho t and cold Temperatures
  - Up to > 300 Channels of Vibration   Testing Data R ecording
  - Time history data recording up to 200kHz
- Adheres to NASA-HDBK-7004C Requirements
- FEM Analysis on CAD model for this project

Moments of Inertia

Principal axes of inertia and principal moments of inertia: (kilograms * square meters)
Taken at the center of mass.

Ix = (-0.15, -0.02, 0.99)	Px = 0.04
Iy = (0.01, -1.00, -0.02)	Py = 0.06
Iz = (0.99, 0.01, 0.15)	Pz = 0.08

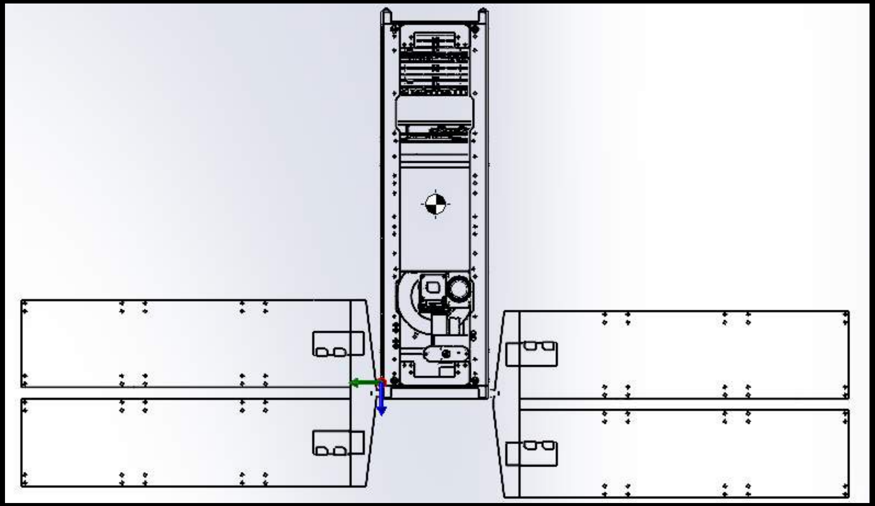
Moments of inertia: (kilograms * square meters)
Taken at the center of mass and aligned with the output coordinate system. (Using positive tensor notation.)

Lxx = 0.08	Lxy = 0.00	Lxz = -0.01
Lyx = 0.00	Lyy = 0.06	Lyz = 0.00
Lzx = -0.01	Lzy = 0.00	Lzz = 0.04

Moments of inertia: (kilograms * square meters)
Taken at the output coordinate system. (Using positive tensor notation.)

Ixx = 0.19	Ixy = 0.01	Ixz = 0.04
Iyx = 0.01	Iyy = 0.19	Iyz = 0.03
Izx = 0.04	Izy = 0.03	Izz = 0.07

Center of Gravity

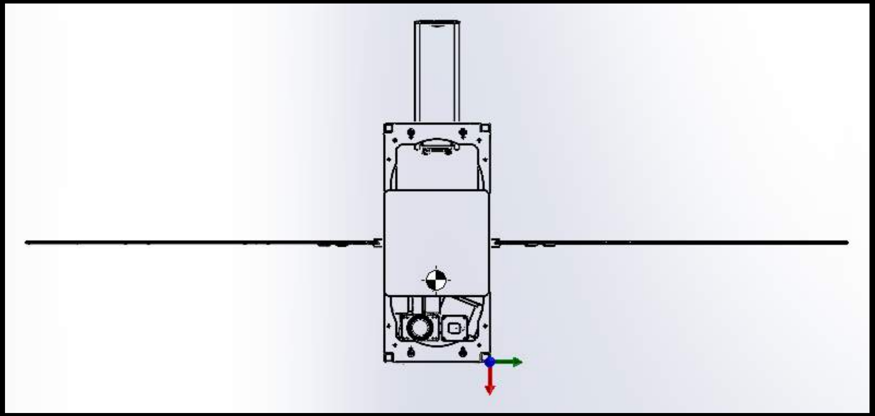


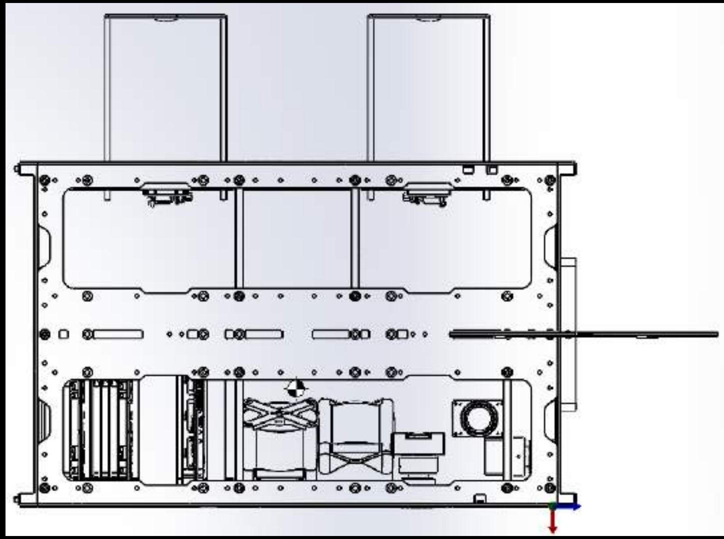
Center of mass: (meters)

X = -0.08

Y = -0.05

Z = -0.17





Open Items

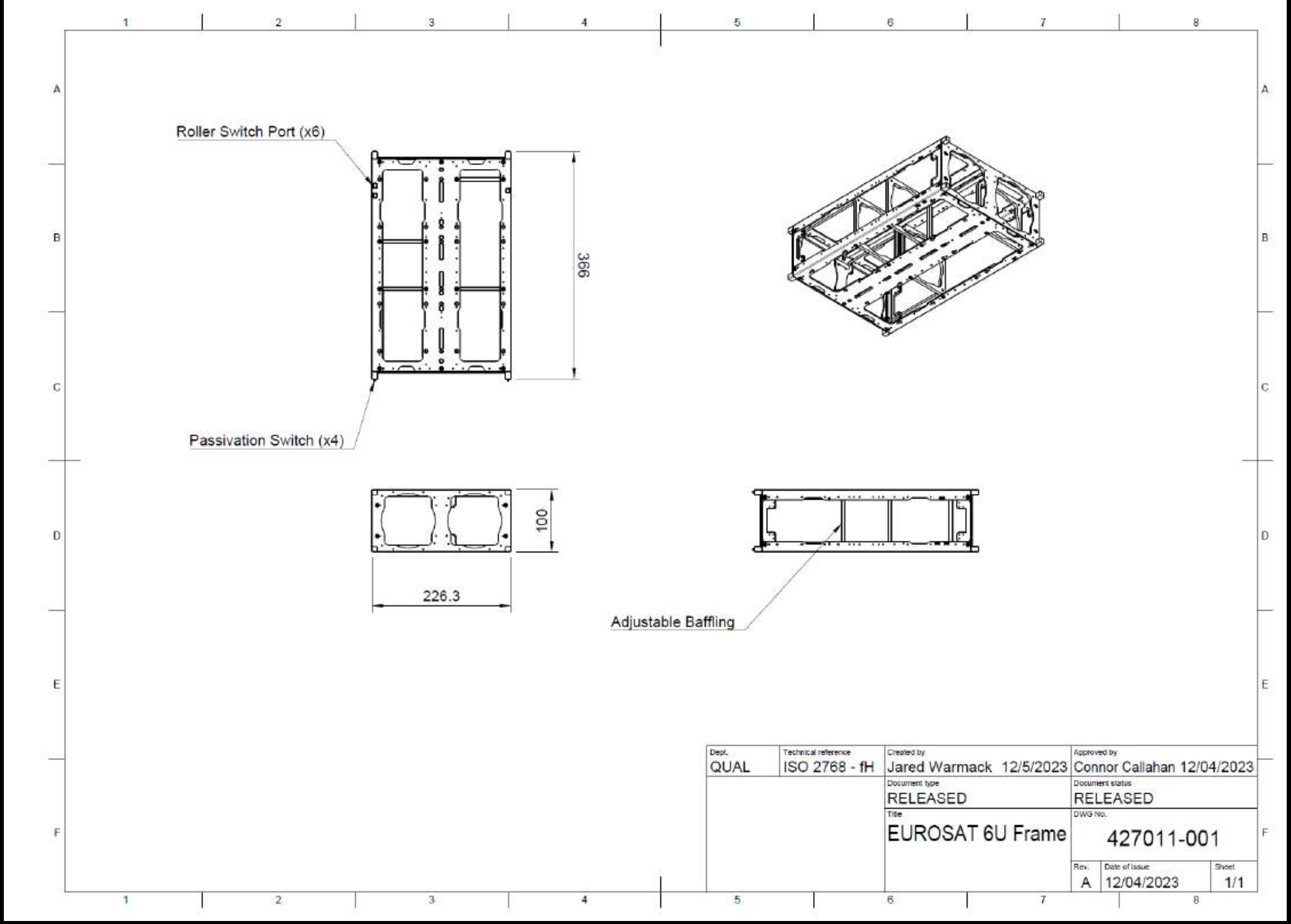
- GNC Ongoing Strategies
  - Transfer Maneuvers
    - Bulk Analysis
  - Station Keeping
    - “Find Nearest”
- Observatory Cleanup
  - Finalize stepper-motor/ball screw assembly
  - Design scaffolding
- Propulsion Power Unit
  - Battery design and EPS integration
- Propulsion
  - DeltaV and Propellant Volume solutions continue to evade us
- RCW Sizing/orientation/multiplicity adjustments

QUESTIONS?

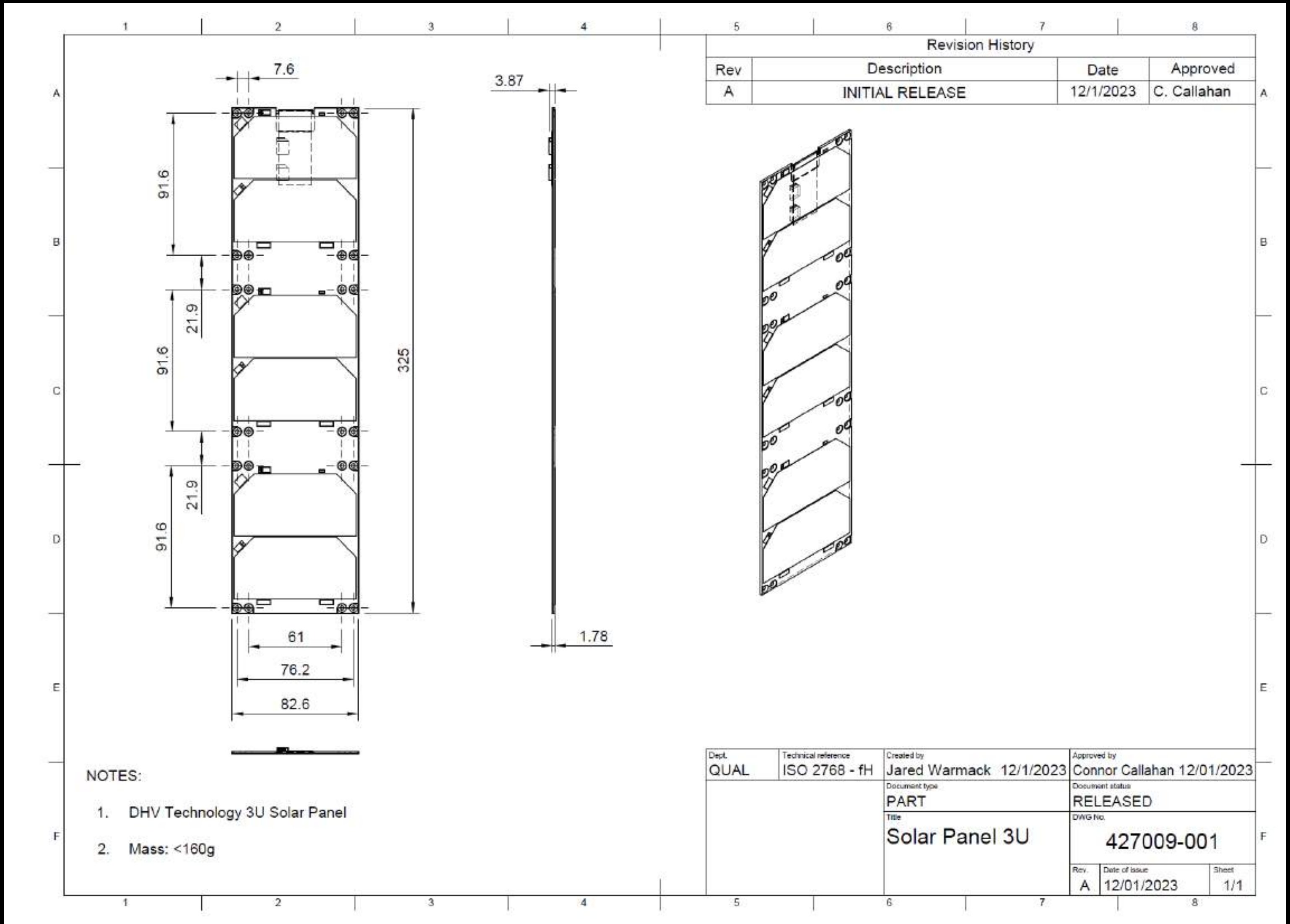
Sources

- Chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://standards.nasa.gov/sites/default/files/standards/NASA/B/0/Historical/nasa-std-6016a.pdf
- https://ntrs.nasa.gov/citations/19970027853
- LunOSTAR Program Level Requirements
- https://www.rocketlabusa.com/space-systems/satellite-components/reaction-wheels/
- https://www.isispace.nl/product/antenna-system-for-6u-12u-cubesats/
- https://www.endurosat.com/cubesat-store/cubesat-structures/6u-cubesat-structure/
- https://www.satcatalog.com/component/nanossoc-d60/
- https://experiorlabs.com/cubesat-testing/
- chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://22131a.a2cdn1.secureserver.net/wp-content/uploads/2019/10/NASA-HDBK-7004C-Force-Limited-Vibration-Testing.pdf

Appendix

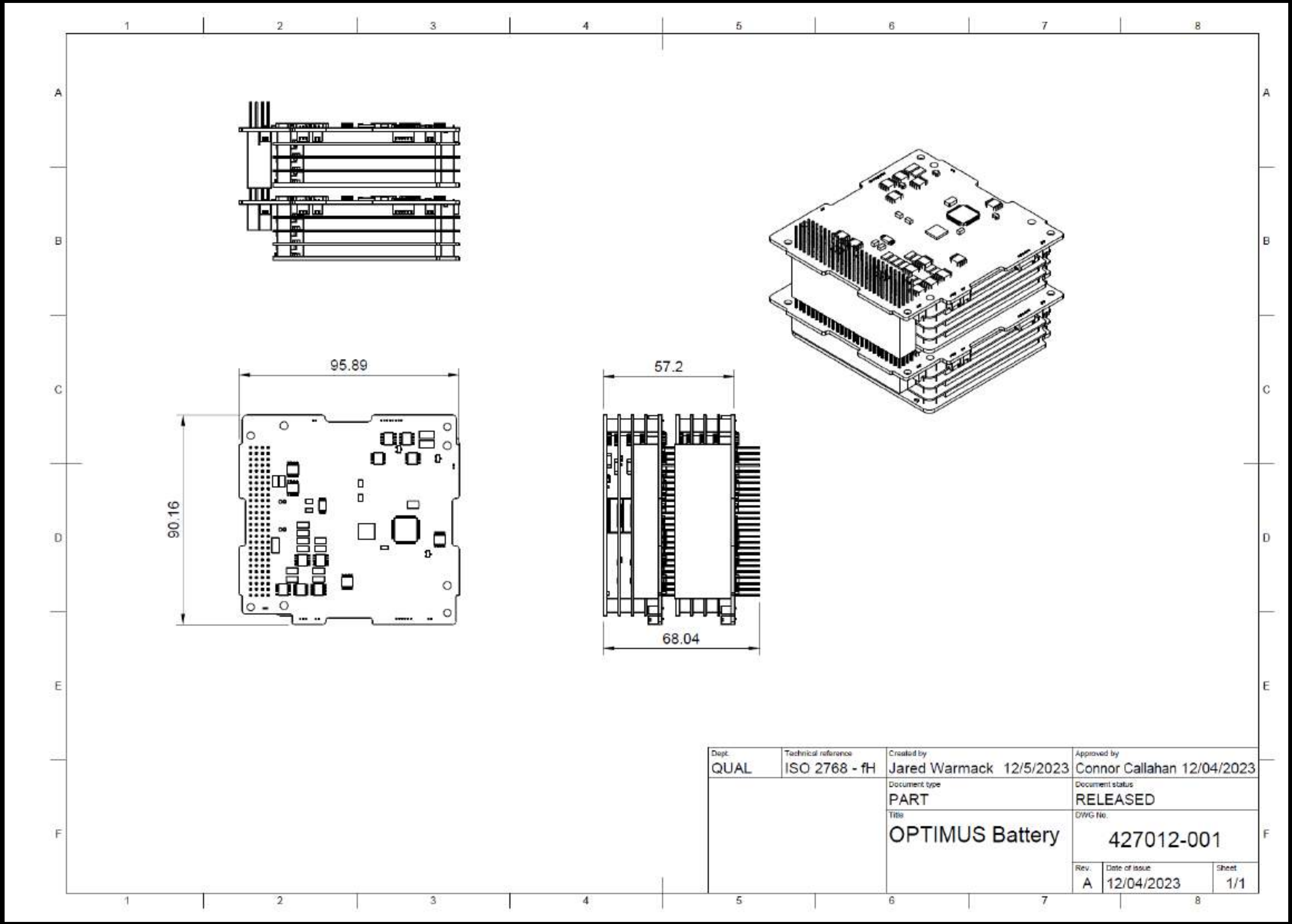

Roller Switch Port (x6)
366
Passivation Switch (x4)
100
226.3
Adjustable Baffling
Dept.
QUAL
Technical reference
ISO 2768 - fH
Created by
Jared Warmack 12/5/2023
Approved by
Connor Callahan 12/04/2023
Document type
RELEASED
Document status
RELEASED
Title
EUROSAT 6U Frame
DWG No.
427011-001
Rev.
A
Date of issue
12/04/2023
Sheet
1/1

Appendix



Revision History
Rev | Description | Date | Approved
A | INITIAL RELEASE | 12/1/2023 | C. Callahan
7.6
3.87
91.6
21.9
91.6
21.9
91.6
325
1.78
61
76.2
82.6
NOTES:
1. DHV Technology 3U Solar Panel
2. Mass: <160g
Dept. QUAL
Technical reference ISO 2768 - fH
Created by Jared Warmack 12/1/2023
Approved by Connor Callahan 12/01/2023
Document type PART
Document status RELEASED
Title Solar Panel 3U
DWG No. 427009-001
Rev. A
Date of issue 12/01/2023
Sheet 1/1

Appendix


95.89
90.16
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68.04
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ISO 2768 - fH
Created by
Jared Warmack 12/5/2023
Approved by
Connor Callahan 12/04/2023
Document type
PART
Document status
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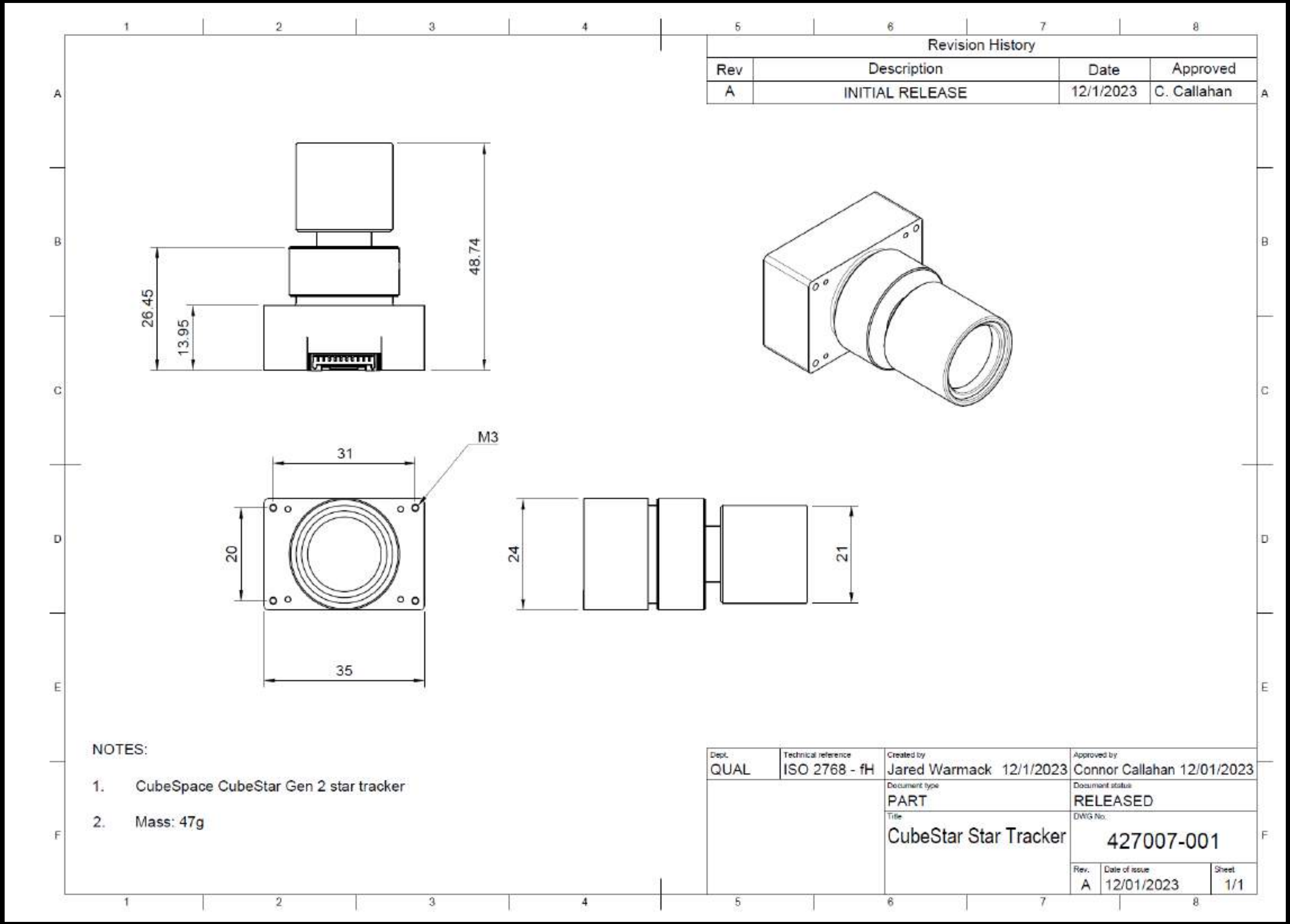
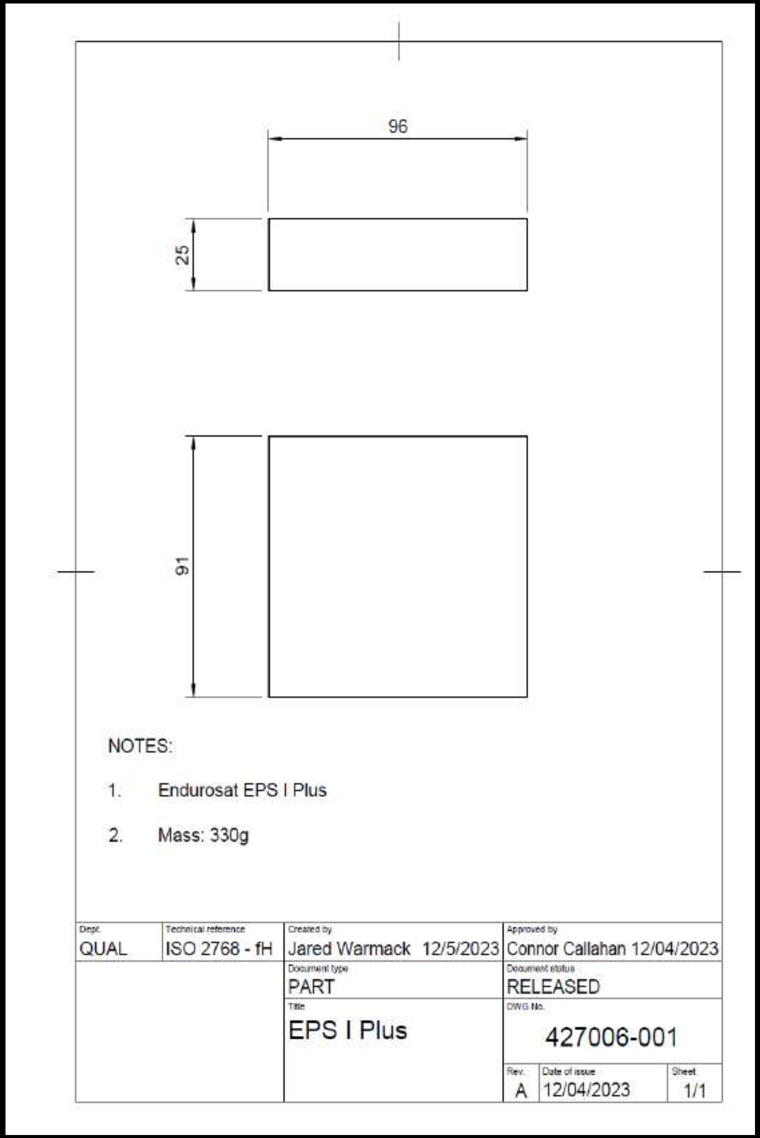
Title
OPTIMUS Battery
DWG No.
427012-001
Rev.
A
Date of issue
12/04/2023
Sheet
1/1

Appendix



Revision History
Rev | Description | Date | Approved
A | INITIAL RELEASE | 12/1/2023 | C. Callahan
48.74
26.45
13.95
M3
31
20
35
24
21
NOTES:
1. CubeSpace CubeStar Gen 2 star tracker
2. Mass: 47g
Dept. QUAL
Technical reference ISO 2768 - fH
Created by Jared Warmack 12/1/2023
Approved by Connor Callahan 12/01/2023
Document type PART
Document status RELEASED
Title CubeStar Star Tracker
DWG No. 427007-001
Rev. A
Date of issue 12/01/2023
Sheet 1/1

Appendix



96
25
91
NOTES:
1. Endurosat EPS I Plus
2. Mass: 330g
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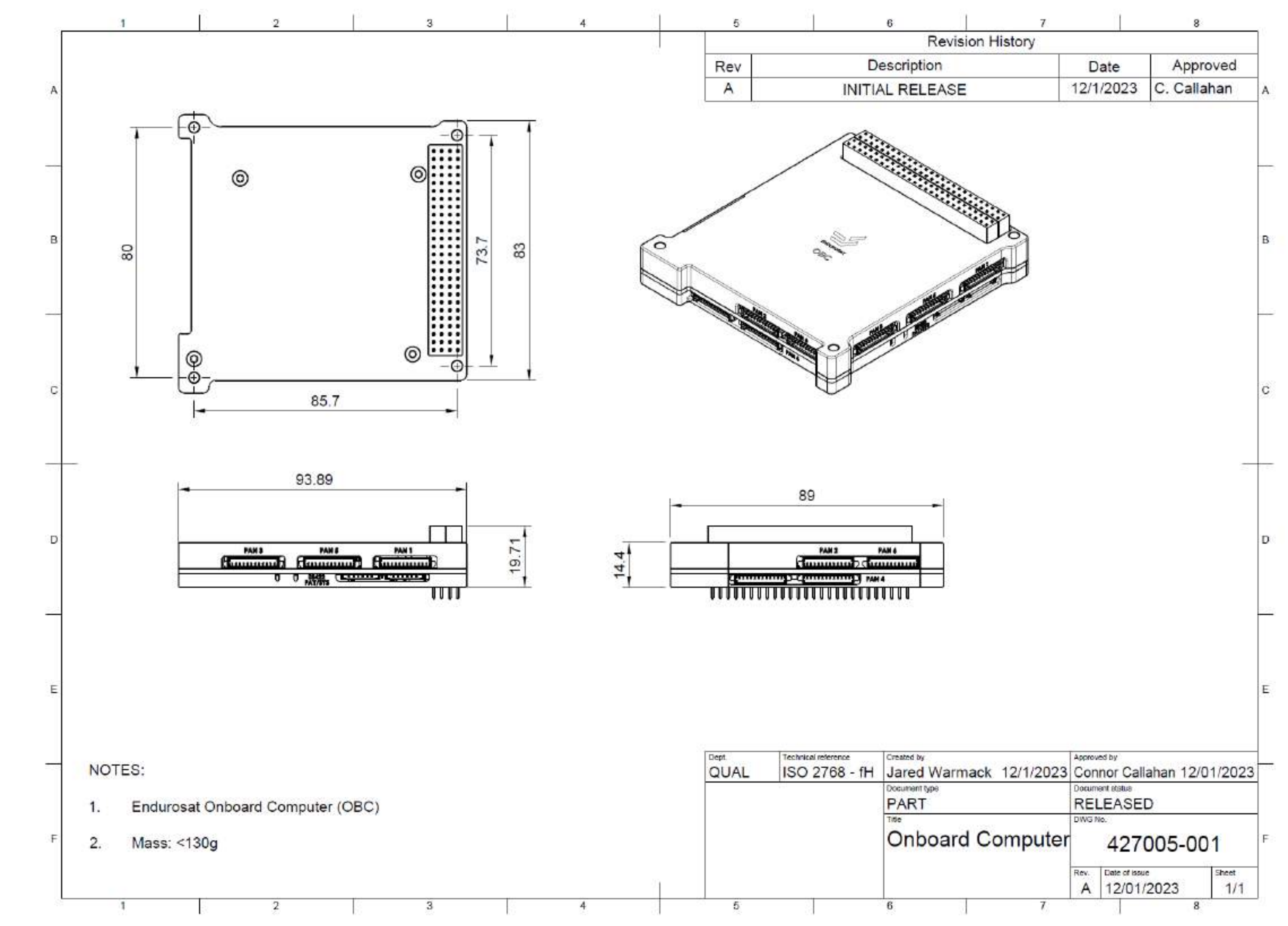
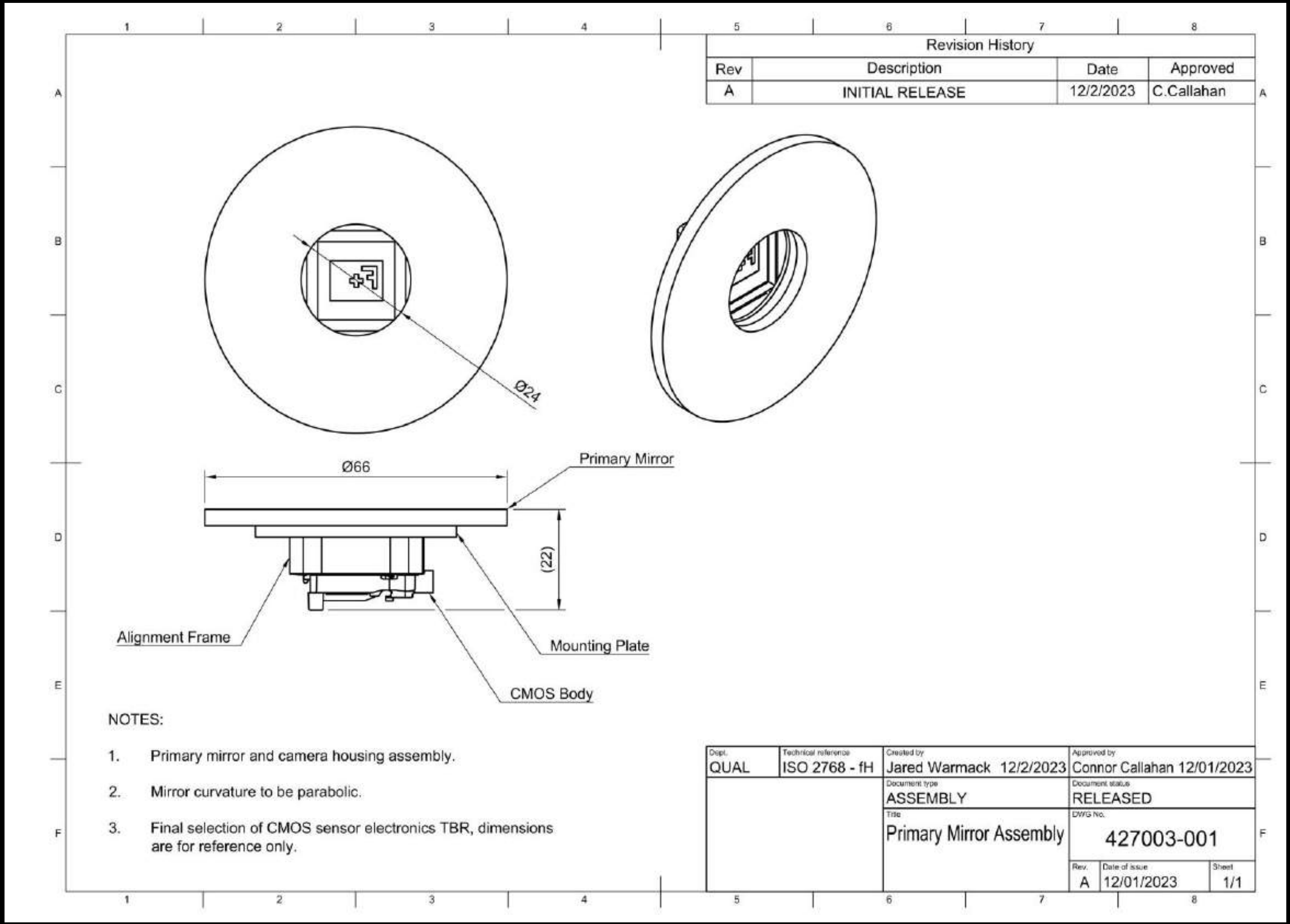
Technical reference
ISO 2768 - fH
Created by
Jared Warmack 12/5/2023
Approved by
Connor Callahan 12/04/2023
Document type
PART
Document status
RELEASED
Title
EPS I Plus
DWG No.
427006-001
Rev.
A
Date of issue
12/04/2023
Sheet
1/1

Appendix

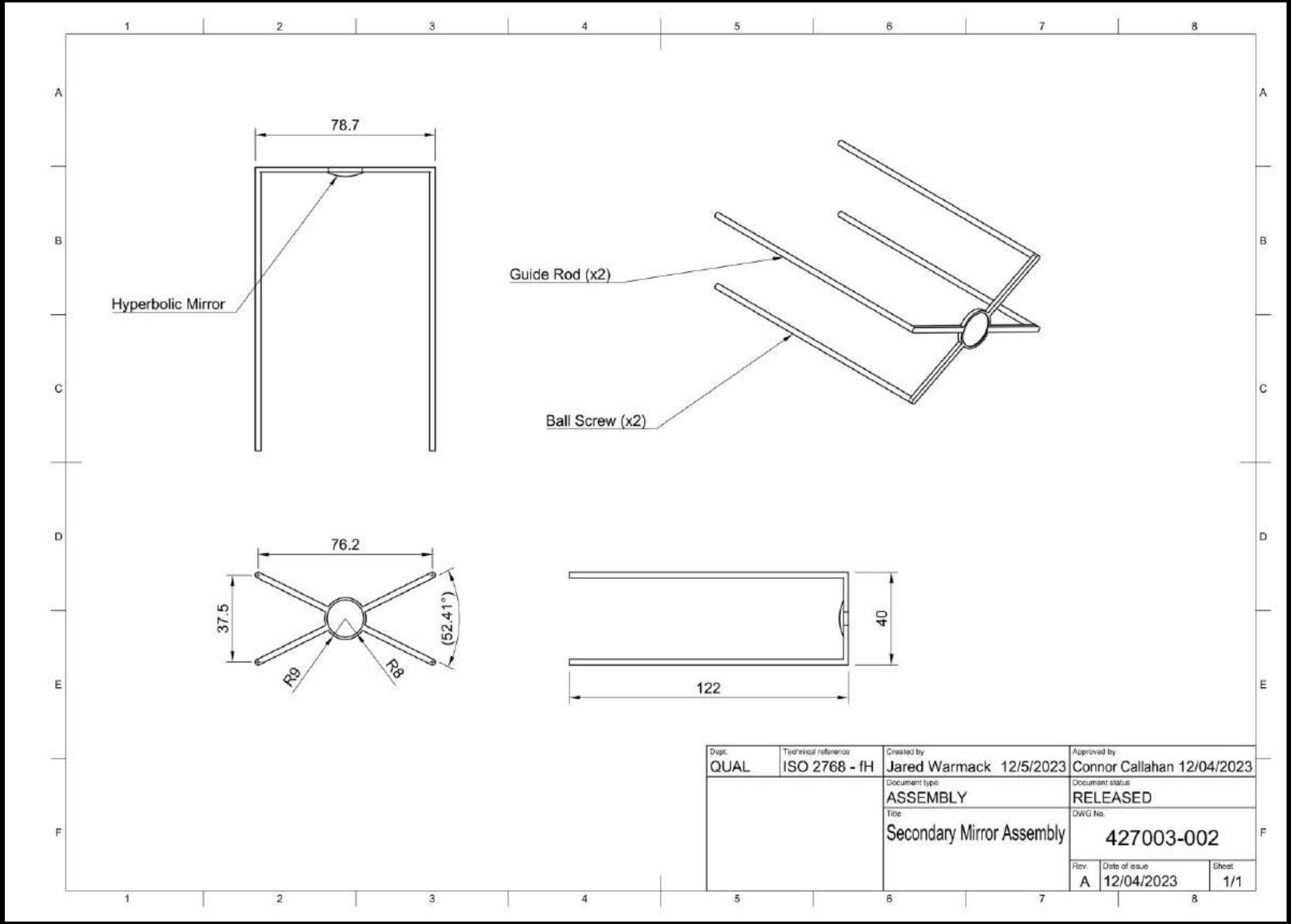

Revision History
Rev
Description
Date
Approved
A
INITIAL RELEASE
12/1/2023
C. Callahan
80
73.7
83
85.7
93.89
19.71
89
14.4
NOTES:
1. Endurosat Onboard Computer (OBC)
2. Mass: <130g
Dept.
QUAL
Technical reference
ISO 2768 - fH
Created by
Jared Warmack 12/1/2023
Approved by
Connor Callahan 12/01/2023
Document type
PART
Document status
RELEASED
Title
Onboard Computer
DWG No.
427005-001
Rev.
A
Date of issue
12/01/2023
Sheet
1/1

Appendix



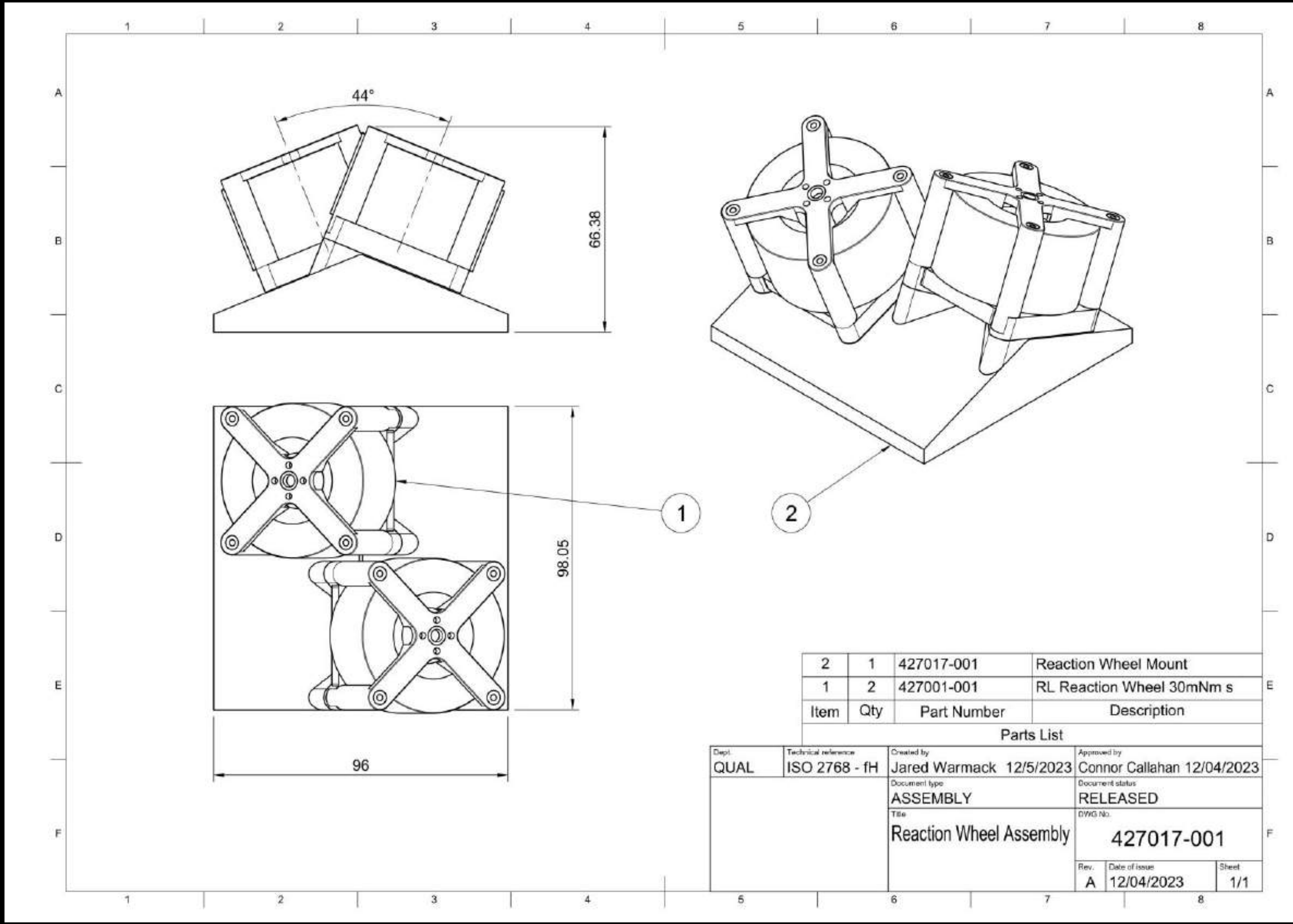
Revision History
Rev
Description
Date
Approved
A
INITIAL RELEASE
12/2/2023
C.Callahan
Ø24
Ø66
Primary Mirror
(22)
Alignment Frame
Mounting Plate
CMOS Body
NOTES:
1. Primary mirror and camera housing assembly.
2. Mirror curvature to be parabolic.
3. Final selection of CMOS sensor electronics TBR, dimensions are for reference only.
QUAL
ISO 2768 - fH
Jared Warmack 12/2/2023
Connor Callahan 12/01/2023
ASSEMBLY
RELEASED
Primary Mirror Assembly
427003-001
A
12/01/2023
1/1

Appendix

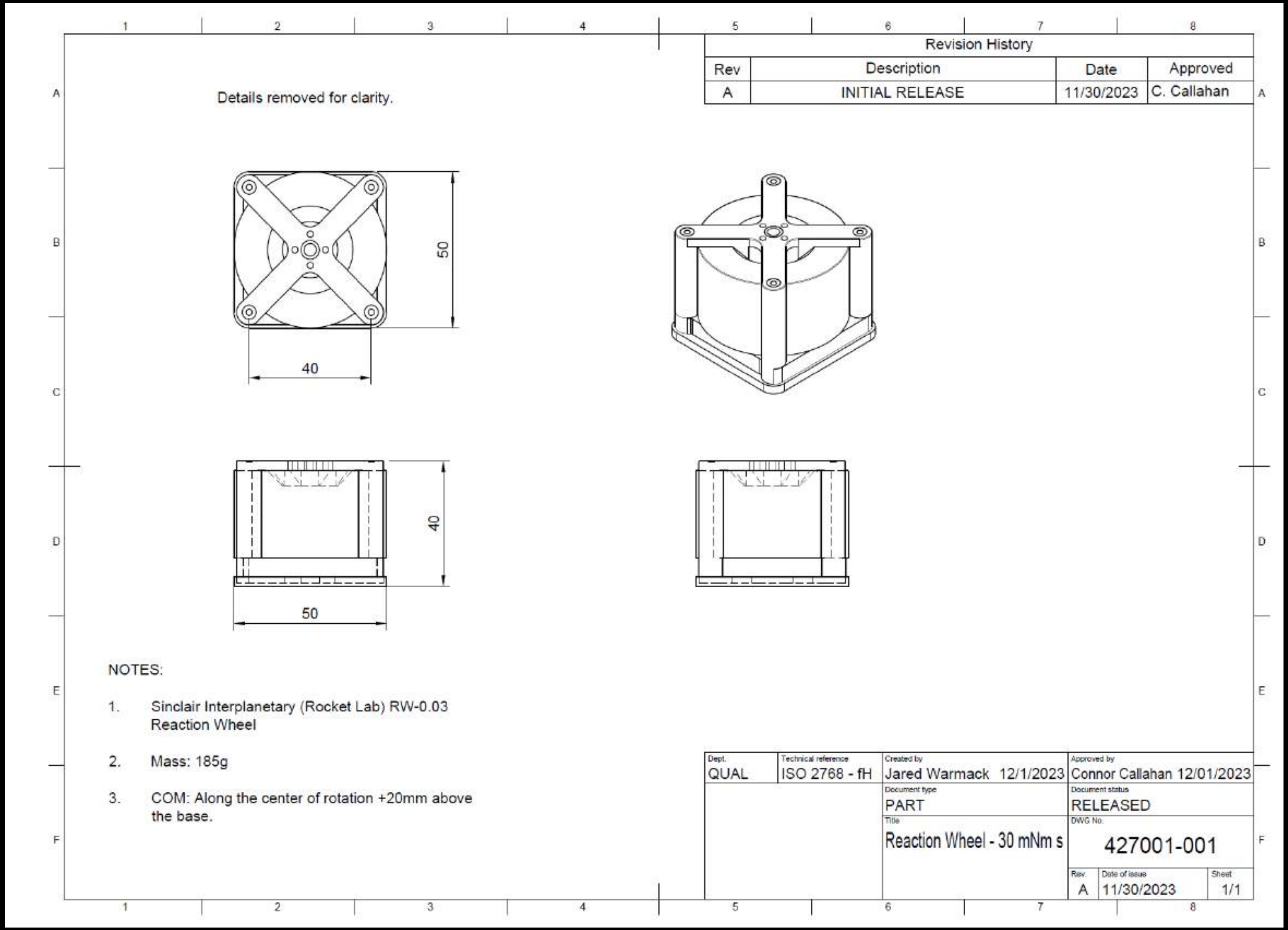


78.7
Hyperbolic Mirror
Guide Rod (x2)
Ball Screw (x2)
76.2
37.5
(52.41°)
R9
R8
40
122
Dept.
QUAL
Technical reference
ISO 2768 - fH
Created by
Jared Warmack 12/5/2023
Approved by
Connor Callahan 12/04/2023
Document type
ASSEMBLY
Document status
RELEASED
Title
Secondary Mirror Assembly
DWG No.
427003-002
Rev.
A
Date of issue
12/04/2023
Sheet
1/1

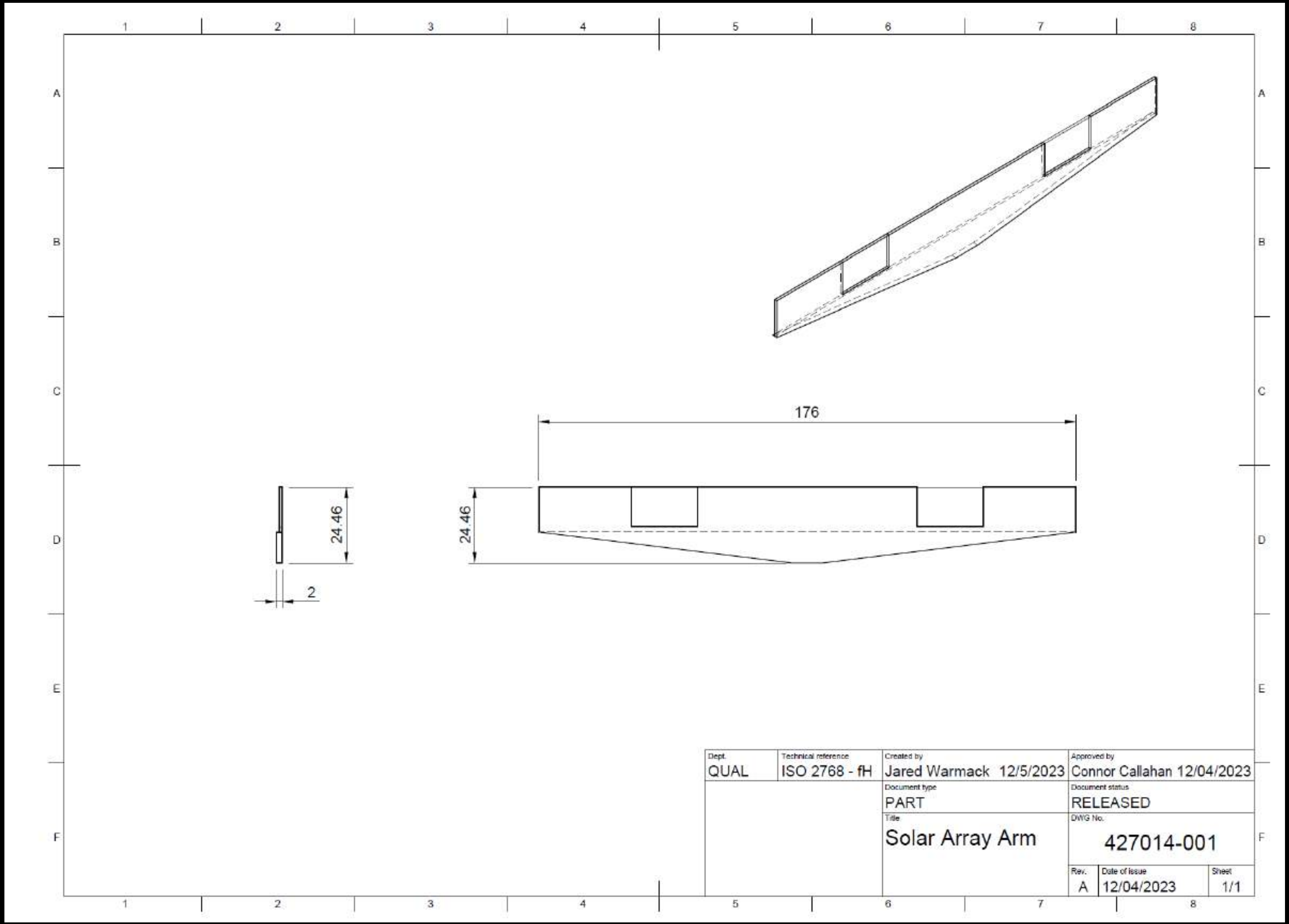
Appendix


44°
66.38
98.05
96
1
2
Item	Qty	Part Number	Description
2	1	427017-001	Reaction Wheel Mount
1	2	427001-001	RL Reaction Wheel 30mNm s
Parts List
Dept. QUAL
Technical reference ISO 2768 - fH
Created by Jared Warmack 12/5/2023
Approved by Connor Callahan 12/04/2023
Document type ASSEMBLY
Document status RELEASED
Title Reaction Wheel Assembly
DWG No. 427017-001
Rev. A
Date of issue 12/04/2023
Sheet 1/1

Appendix

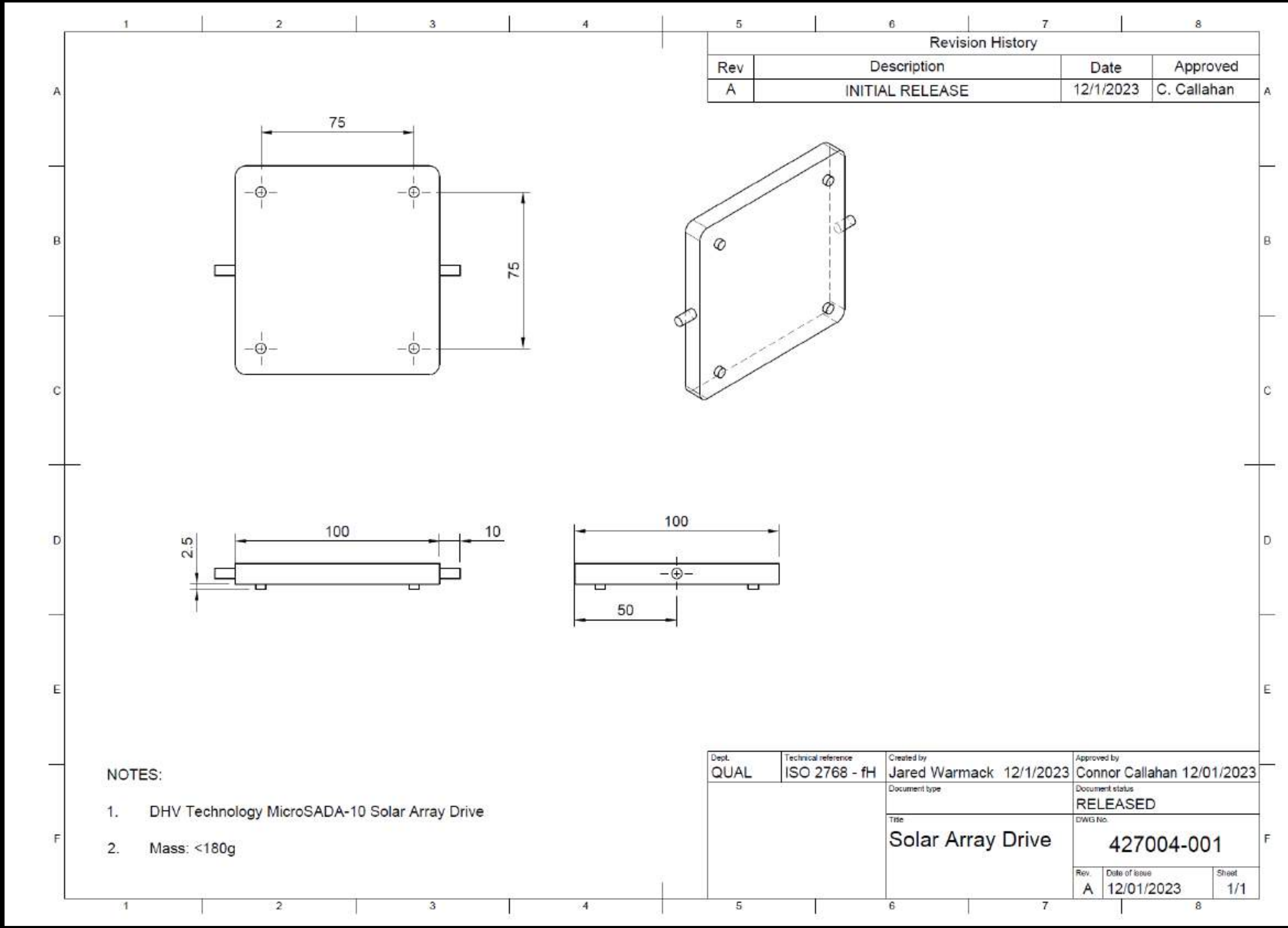

Revision History
Rev | Description | Date | Approved
A | INITIAL RELEASE | 11/30/2023 | C. Callahan
Details removed for clarity.
50
40
40
50
NOTES:
1. Sinclair Interplanetary (Rocket Lab) RW-0.03 Reaction Wheel
2. Mass: 185g
3. COM: Along the center of rotation +20mm above the base.
Dept. QUAL
Technical reference ISO 2768 - fH
Created by Jared Warmack 12/1/2023
Approved by Connor Callahan 12/01/2023
Document type PART
Document status RELEASED
Title Reaction Wheel - 30 mNm s
DWG No. 427001-001
Rev. A
Date of issue 11/30/2023
Sheet 1/1

Appendix



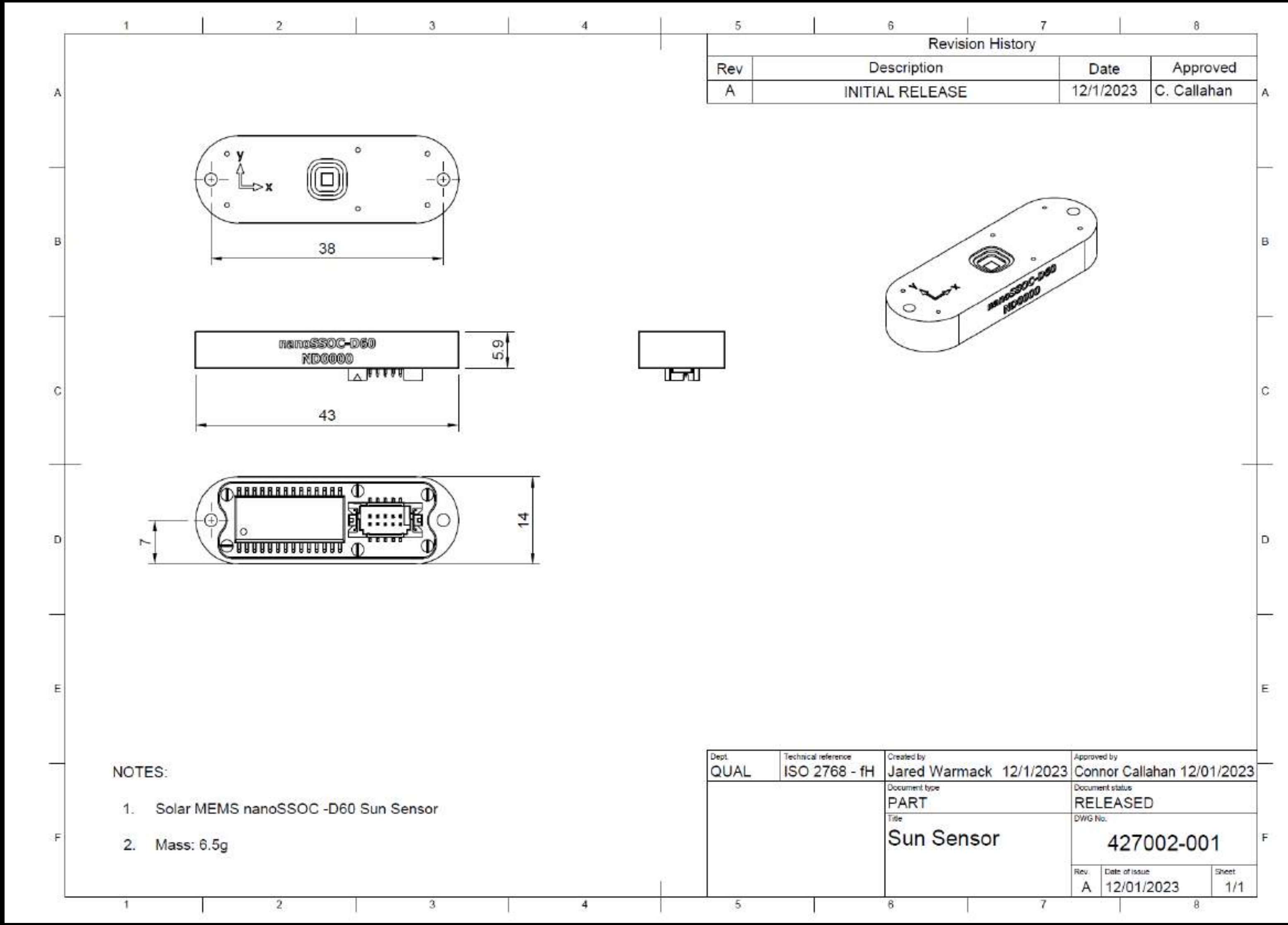
176
24.46
24.46
2
Dept.
QUAL
Technical reference
ISO 2768 - fH
Created by
Jared Warmack 12/5/2023
Approved by
Connor Callahan 12/04/2023
Document type
PART
Document status
RELEASED
Title
Solar Array Arm
DWG No.
427014-001
Rev.
A
Date of issue
12/04/2023
Sheet
1/1

Appendix



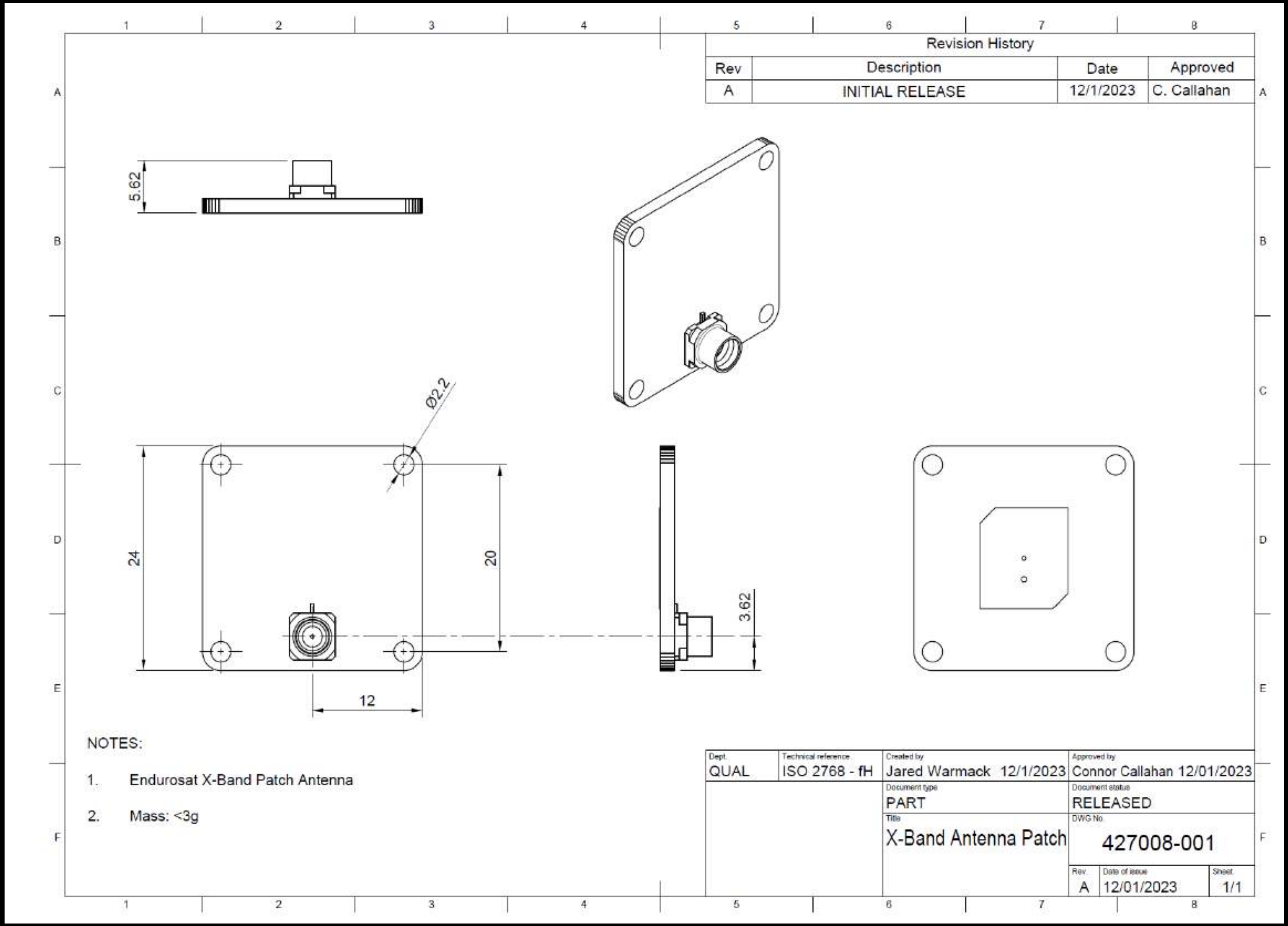
Revision History
Rev | Description | Date | Approved
A | INITIAL RELEASE | 12/1/2023 | C. Callahan
75
75
100
10
2.5
100
50
NOTES:
1. DHV Technology MicroSADA-10 Solar Array Drive
2. Mass: <180g
Dept. QUAL
Technical reference ISO 2768 - fH
Created by Jared Warmack 12/1/2023
Approved by Connor Callahan 12/01/2023
Document type
Document status RELEASED
Title Solar Array Drive
DWG No. 427004-001
Rev. A
Date of issue 12/01/2023
Sheet 1/1

Appendix



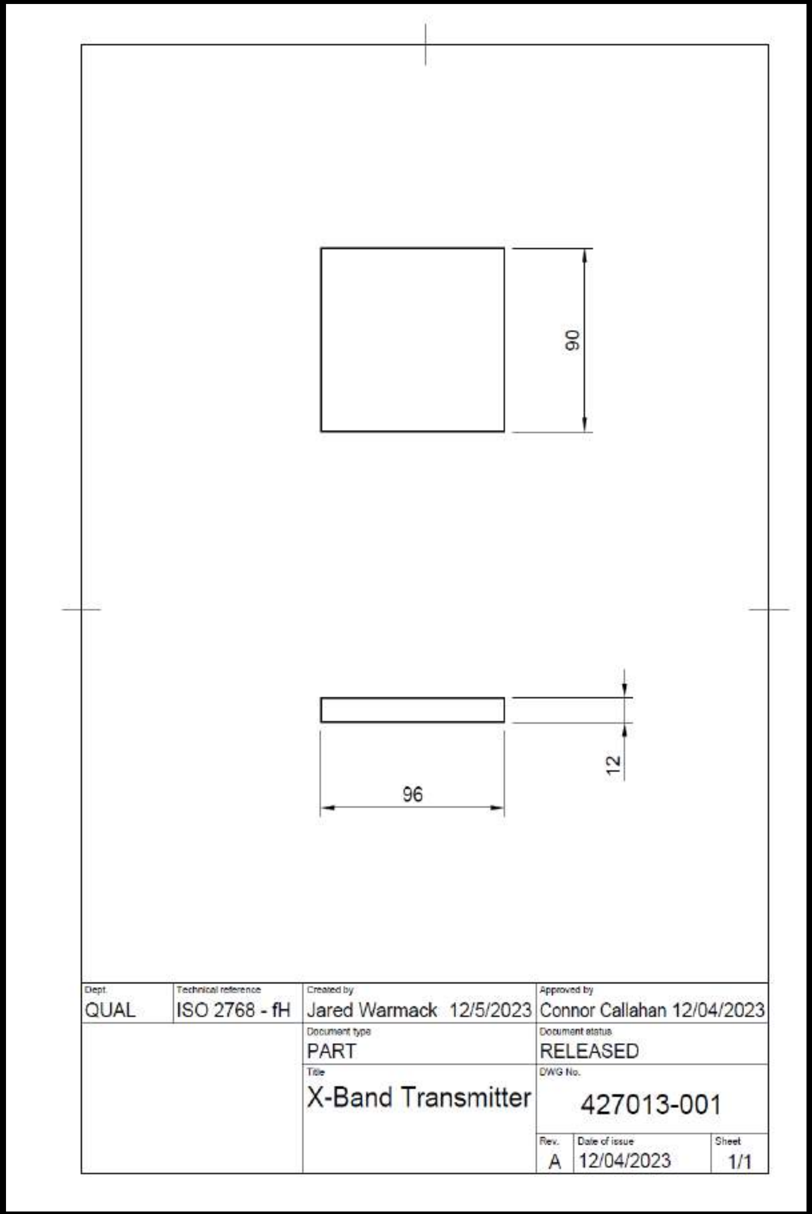
Revision History
Rev
Description
Date
Approved
A
INITIAL RELEASE
12/1/2023
C. Callahan
38
nanoSSOC-D60
ND0000
5.9
43
14
7
NOTES:
1. Solar MEMS nanoSSOC -D60 Sun Sensor
2. Mass: 6.5g
Dept.
QUAL
Technical reference
ISO 2768 - fH
Created by
Jared Warmack 12/1/2023
Approved by
Connor Callahan 12/01/2023
Document type
PART
Document status
RELEASED
Title
Sun Sensor
DWG No.
427002-001
Rev.
A
Date of issue
12/01/2023
Sheet
1/1

Appendix



Revision History
Rev | Description | Date | Approved
A | INITIAL RELEASE | 12/1/2023 | C. Callahan
5.62
Ø2.2
24
20
12
3.62
NOTES:
1. Endurosat X-Band Patch Antenna
2. Mass: <3g
Dept. QUAL
Technical reference ISO 2768 - fH
Created by Jared Warmack 12/1/2023
Approved by Connor Callahan 12/01/2023
Document type PART
Document status RELEASED
Title X-Band Antenna Patch
DWG No 427008-001
Rev. A
Date of issue 12/01/2023
Sheet 1/1

Appendix



90
12
96
Dept.
QUAL
Technical reference
ISO 2768 - fH
Created by
Jared Warmack 12/5/2023
Approved by
Connor Callahan 12/04/2023
Document type
PART
Document status
RELEASED
Title
X-Band Transmitter
DWG No.
427013-001
Rev.
A
Date of issue
12/04/2023
Sheet
1/1

CRITICAL DESIGN REVIEW

COLBY DAVIS, CONNOR CALLAHAN, JUSTIN ROGERS, JARED WARMACK, JONATHAN KIM, MATT WOLFF

LIMESAT

Mission Logo & Pantone Colors

- Congress Blue – #004980
- St Tropaz – #224795
- Sahara – #c5a90e
- Galliano – #ddc50a
- Tree Poppy – #f7941d
- Dingley – #76894c
- Yellow Green – #c2e26b
- Beryl Green – #dee8c3
- Silver – #c3c3c3
- Storm Dust – #626261
- Black – #000000
- White – #ffffff

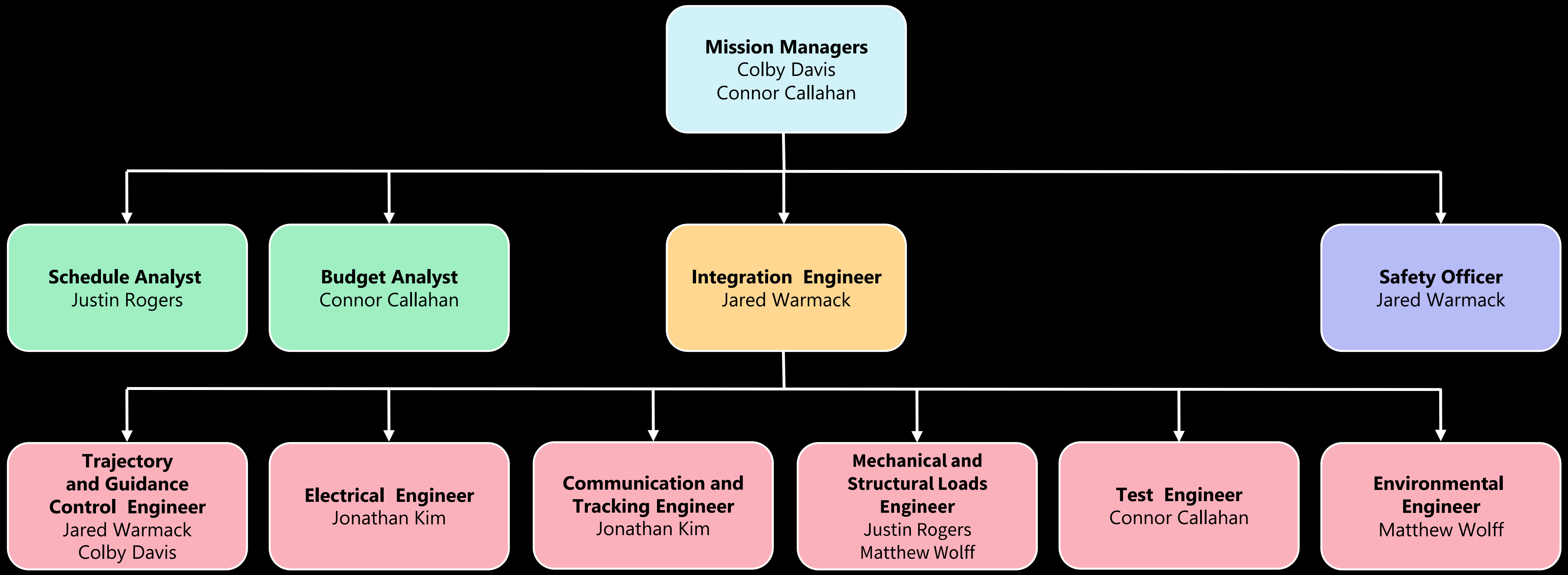
ACRONYMS

Acronym	Description
ACS	Attitude Control System
AOS	Acquisition of Signal
CAD	Computer-Aided Design
CCD	Charge-Coupled Device
CDH	Command & Data Handling
ConOps	Concept of Operations
DAQ	Data Acquisition
EPS	Electronic Power System
GNC	Guidance, Navigation, & Control
OBC	On-Board Computer
SPO	Short Period Orbit
UHF	Ultra High Frequency
VHF	Very High Frequency
CR3BP	Circular Restricted 3 Body Problem

Agenda

Team Structure → Mission Goal & Objectives → Integrated Schedule → Telescope Operations → ConOps → Mission Requirements → Financial Budget → Power Budget → Mass Budget → CAD Model → Engineering Drawings → Center of Mass → Moments of Inertia → Assembly Procedures → Vibration Analysis → Stress-Strain Analysis → Thermal Analysis → GNC → Environmental Test Plan → Electrical Schematic → Data Management → Communication Method → Resolved Issues

Team Structure



Mission Goal Statement

- The CubeSat satellite "LunOSTAR" will observe the Sun's corona using occultations of the sun via the Earth - Moon system with an orbit around LaGrange Point L4.

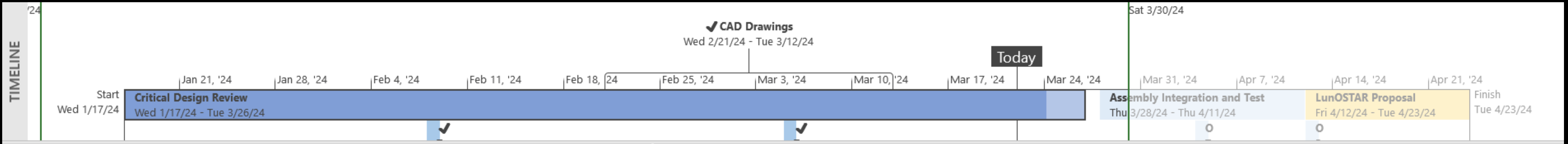
Mission Objectives

OBJECTIVE 1: Design, test, and launch the CubeSat to the space station Gateway at L2.

OBJECTIVE 2: Once at Gateway it will deploy the CubeSat from L2 to L4 where it will establish a Short-Period Orbit (SPO) that will maximize observations of the Sun’s corona.

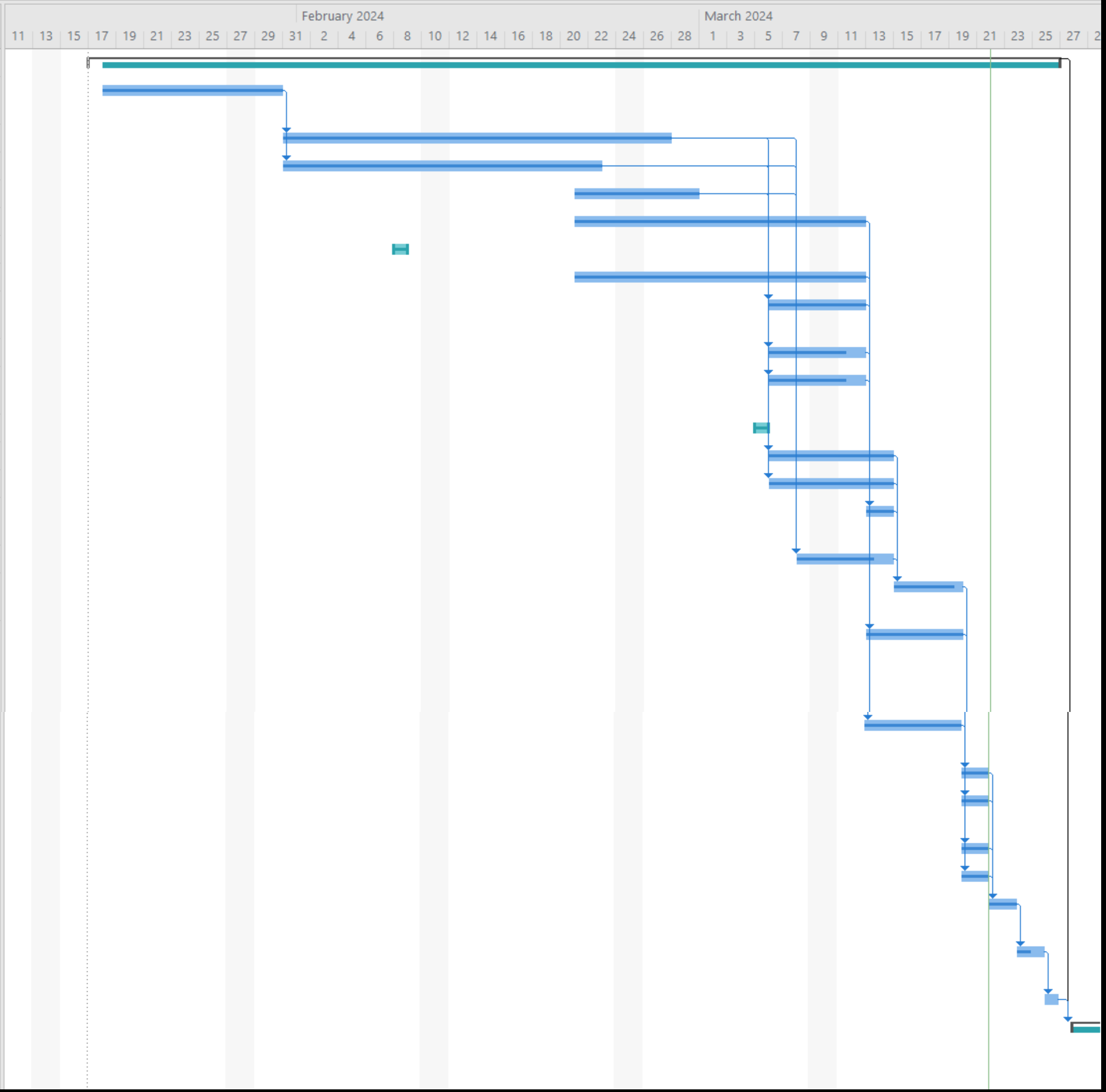
OBJECTIVE 3: Observe, record, and transmit to earth the solar corona data in the NUV wavelengths.

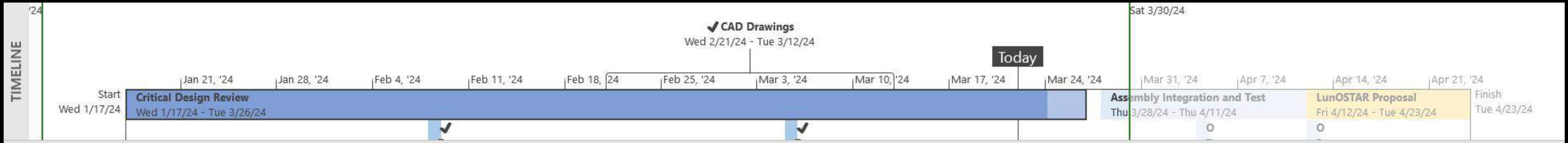
INTEGRATED SCHEDULE



GANTT CHART

		Task Mode	Task Name	Duration	Start	Finish
1			**Critical Design Review**	**52 days?**	**Wed 1/17/24**	**Tue 3/26/24**
2			Find Thruster & 12U Structure	9 days	Thu 1/18/24	Tue 1/30/24
3			CAD	20 days	Wed 1/31/24	Tue 2/27/24
4			Electrical Schmatic	17 days	Wed 1/31/24	Thu 2/22/24
5			Simplified CAD	7 days	Wed 2/21/24	Thu 2/29/24
6			CAD Drawings	15 days?	Wed 2/21/24	Tue 3/12/24
7			OISR #1	1 day?	Thu 2/8/24	Thu 2/8/24
8			GNC Analysis	15 days	Wed 2/21/24	Tue 3/12/24
9			CONOPS for Telemetry	5 days	Wed 3/6/24	Tue 3/12/24
10			BOM	5 days	Wed 3/6/24	Tue 3/12/24
11			Assembly Procedure	5 days	Wed 3/6/24	Tue 3/12/24
12			OISR #2	1 day	Tue 3/5/24	Tue 3/5/24
13			FEM Stress-Strain	7 days?	Wed 3/6/24	Thu 3/14/24
14			Vibration Analysis	7 days	Wed 3/6/24	Thu 3/14/24
15			Specific areas of interest	2 days	Wed 3/13/24	Thu 3/14/24
16			Thermal Analysis	5 days	Fri 3/8/24	Thu 3/14/24
17			Environmental Test Plan	3 days	Fri 3/15/24	Tue 3/19/24
18			Telemetry coverage areas with Data delivery and data rates	5 days?	Wed 3/13/24	Tue 3/19/24
19			Time in each coverage area	5 days?	Wed 3/13/24	Tue 3/19/24
20			Power Budget	2 days	Wed 3/20/24	Thu 3/21/24
21			Mass Budget and Properties	2 days	Wed 3/20/24	Thu 3/21/24
22			Other Budget	2 days?	Wed 3/20/24	Thu 3/21/24
23			Resolved Issues	2 days?	Wed 3/20/24	Thu 3/21/24
24			Add slides to Presentation	2 days?	Fri 3/22/24	Sat 3/23/24
25			Practice Presentation	2 days?	Sun 3/24/24	Mon 3/25/24
26			CDR Presentation	1 day?	Tue 3/26/24	Tue 3/26/24
27			**Assembly Integration and Test Procedures**	**11 days?**	**Thu 3/28/24**	**Thu 4/11/24**
37			**LunOSTAR Proposal**	**8 days?**	**Fri 4/12/24**	**Tue 4/23/24**





GANTT CHART

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13		FEM Stress-Strain	7 days?	Wed 3/6/24	Thu 3/14/24
14		Vibration Analysis	7 days	Wed 3/6/24	Thu 3/14/24
15		Specific areas of interest	2 days	Wed 3/13/24	Thu 3/14/24
16		Thermal Analysis	5 days	Fri 3/8/24	Thu 3/14/24
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18		Telemetry coverage areas with Data delivery and data rates	5 days?	Wed 3/13/24	Tue 3/19/24
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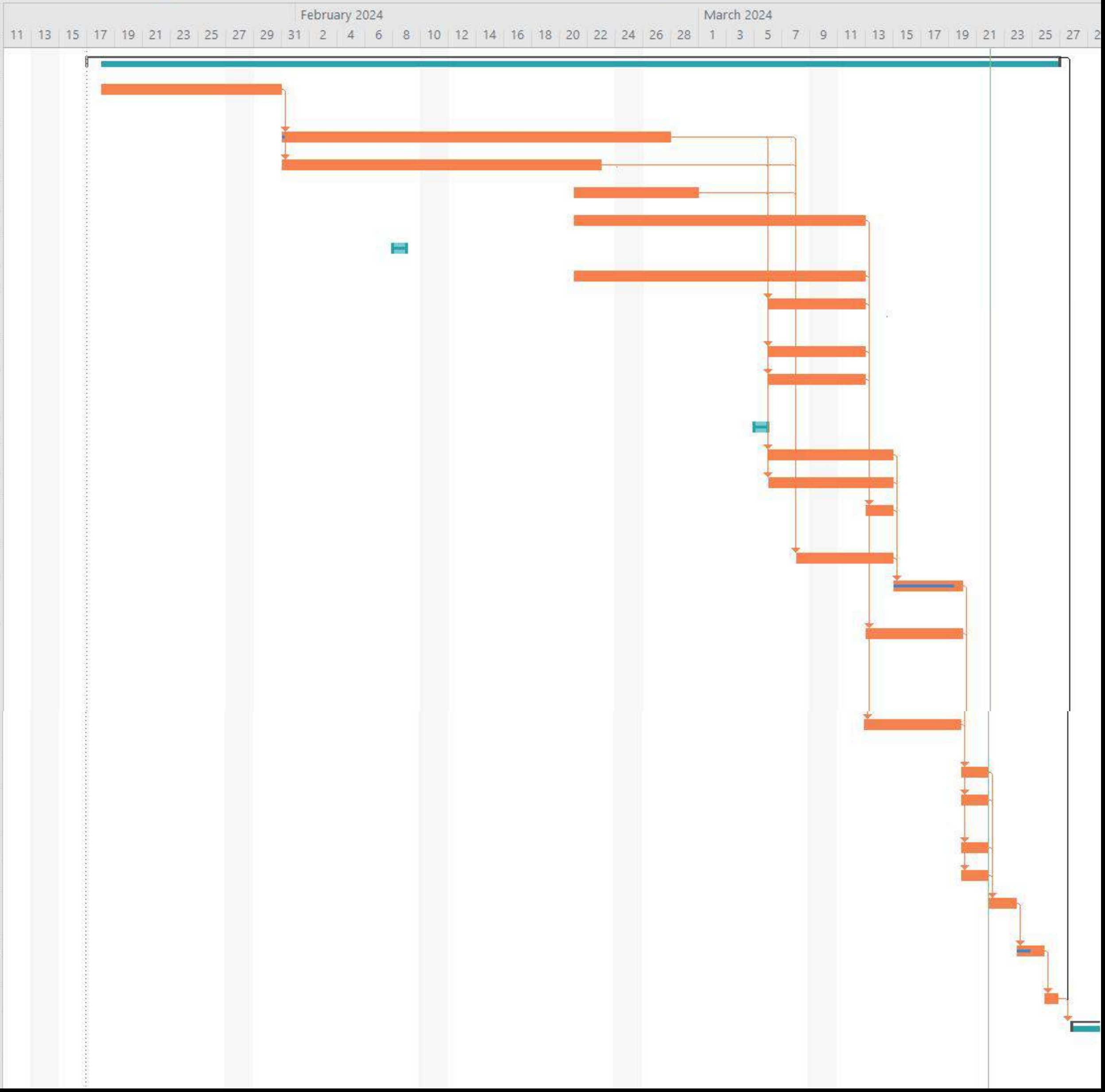
23		Resolved Issues	2 days?	Wed 3/20/24	Thu 3/21/24
24		Add slides to Presentation	2 days?	Fri 3/22/24	Sat 3/23/24
25		Practice Presentation	2 days?	Sun 3/24/24	Mon 3/25/24
26		CDR Presentation	1 day?	Tue 3/26/24	Tue 3/26/24
27		**Assembly Integration and Test Procedures**	**11 days?**	**Thu 3/28/24**	**Thu 4/11/24**
37		**LunOSTAR Proposal**	**8 days?**	**Fri 4/12/24**	**Tue 4/23/24**



CONOPS

LUNOSTAR MISION

LunOSTAR Mission ConOps: Mission Science

Before Observation
- Satellite Contacts Moon orbiting Satellite
- **Star Tracker Camera Pointing**

Observation
- Bias Photo
- Dark Photo
- Gather Images
- Compress Images
- Delete Old Images
- Store Images onboard

Satellite to Satellite
- LimeSat sends stored Images to Moon
- **Moon Sat sends Images to Ground**

Ground Station
- AOS
- Data Transfer

Analyze
- Noise Interference Pattern
- Anti Aliasing
- Denoise

LunOSTAR Mission ConOps: Telemetry

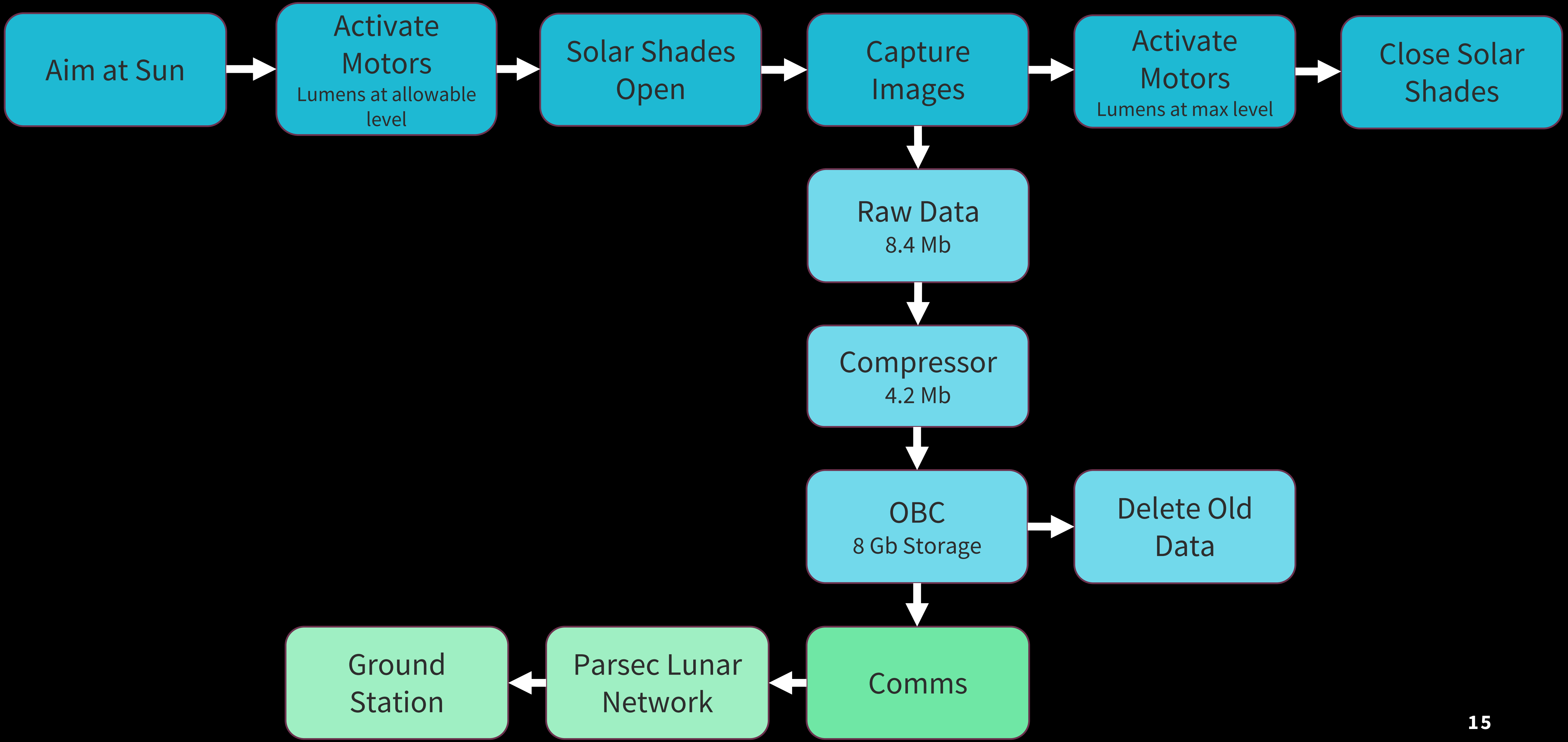
- **Data Collection**
  - System Status
  - Position & Attitude
  - PAYLOAD Status
- **Storage**
  - Time Stamp
  - Error Checking
  - Prioritize
  - Transmission Schedule
- **Data Transmission**
  - Combine
  - Encrypt
  - Assign ID
- **Data Processing**
  - Signal to Data
  - Decrypt
  - Error Checking
- **Data Analysis**
  - Analyzing
  - Interpret
  - Adjustments

LunOSTAR Mission ConOps: Demise

Final Check T+700days → Disposal → Post-Mission Analysis → Final Report

- Final Check T+700days
  - Data Backup T+5 days
  - System Check T+1 day
- Disposal
  - Planning T+7 days
  - Contact Agencies T+3 days
  - Graveyard Orbit Transfer +15 days
  - Monitor T+21 days → Passivation T+ 30 days
- Post-Mission Analysis
- Final Report

Telescope Operation



Requirement Flow Down Example

1.0
Budget Considerations

2.0
Satellite Design

3.0
Flight Procedures

4.0
Physical Plans Validation

5.0
Satellite Testing

Analysis/Simulation

Testing

Observation

Reference Sheet

Design

2.1
Bus Design

2.1.1:
There shall be an Electrical Power System (EPS) able to provide stable power, fulfilling energy requirements for both spacecraft systems and observatory mission equipment.

2.1.2:
There shall be an Environmental System to ensure that the satellite can withstand the various conditions they will encounter from launch to the end of the mission.

2.1.3:
There shall be a Communication system able to provide reliable and secure two-way communication between the spacecraft and Earth-based ground stations.

2.1.4:
There shall be a Computing system able to manage and process data, execute commands, and control spacecraft operations.

2.1.5:
There shall be an Attitude Control System.

2.1.6:
There shall be a propulsion system.

2.1.7:
There shall be a Navigation System.

2.1.8 :
There shall be a Telemetry and Tracking system able to monitor and determine the spacecraft’s location, orientation, and velocity to enable precise orbital and attitude adjustments.

2.2
Observatory Payload

2.2.1:
There shall be a Telescopic Array of 2 co-aligned telescopes to view the solar corona, consisting of Optics Assemblies and Focal Plane Modules (FPM).

2.2.2:
There may be a deployable mast to accommodate additional focal length/parallax.

2.2.3:
The observatory payload shall have the capability to measure over the NUV range of 300-400 nm.

2.2.4:
The observatory shall have an angular resolution with half power diameter <3 arcseconds.

Mission Requirements Example

Requirement Level	Requirement Number	Requirement	Verification Model					Verification Methods	Status
			A	O	D	T	R		
		Administration							
0	1.0	There shall be a budget of one million dollars for design, development, and mission operations.			X			Verify prices of parts with design parameters and determine, if necessary, that parts are within budget.	
		Space System							
0	2.0	There shall be a 12U Satellite (20x20x34.05cm) which contains all necessary equipment and materials to conduct the scientific objectives and support mission operations.		X	X			Compare completed plan with physical measurements to ensure validity.	
1	2.1	There shall be a Bus.			X			The bus will be designed considering structural loads during launch, and any other necessary maneuvers	
2	2.1.1	There shall be an Electrical Power System (EPS) able to provide stable power, ensuring the fulfillment of energy requirements for both spacecraft systems and observatory mission equipment.			X		X	Calculate power requirements of each system and design or choose a preexisting system that meets those power needs	

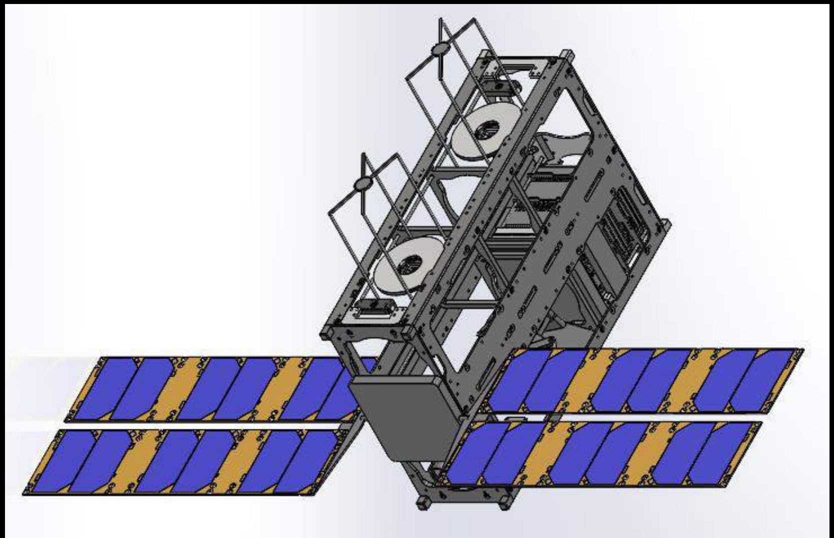
Mission Requirements Example

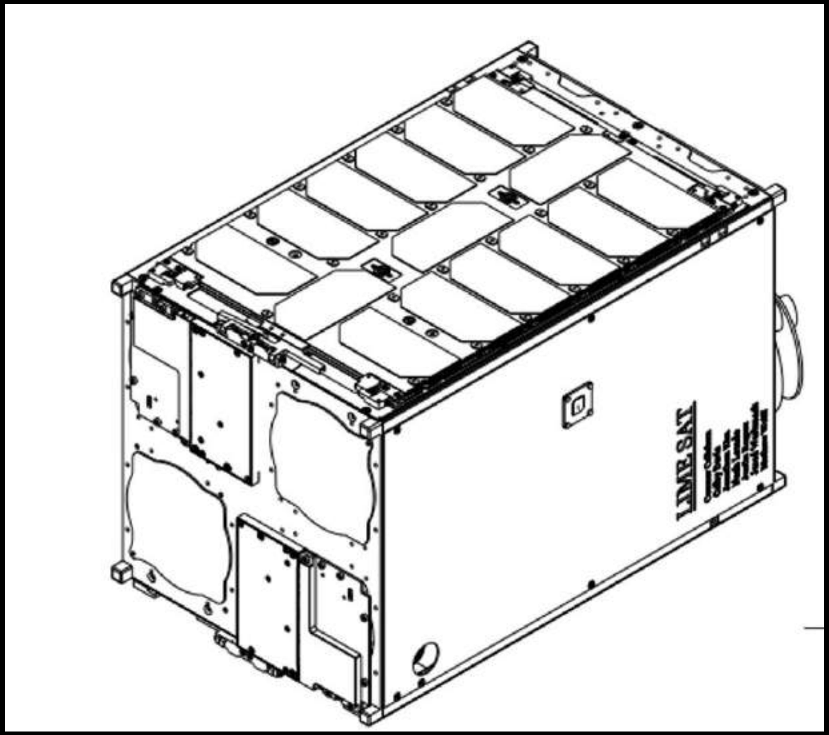
3	2.1.1.1	The EPS shall include a rechargeable battery capable of storing enough energy to power the operational needs of the spacecraft during periods when solar power generation is not possible.		X		X	X	Test battery capability with reference to batteries datasheet and verify battery capacity and output.	
3	2.1.1.2	The EPS shall include solar panels that can generate sufficient power to meet the operational needs of the spacecraft.			X		X	Verify with solar panel datasheet that sufficient power can be created to keep batteries charged.	
3	2.1.1.3	The EPS shall distribute power to all systems compatible with their voltage and current requirements.		X	X	X	X	Test that electrical power system can verify where power is needed and distribute power accordingly and compare to datasheet.	

Revisions

<u>Switched to 12U Structure</u>

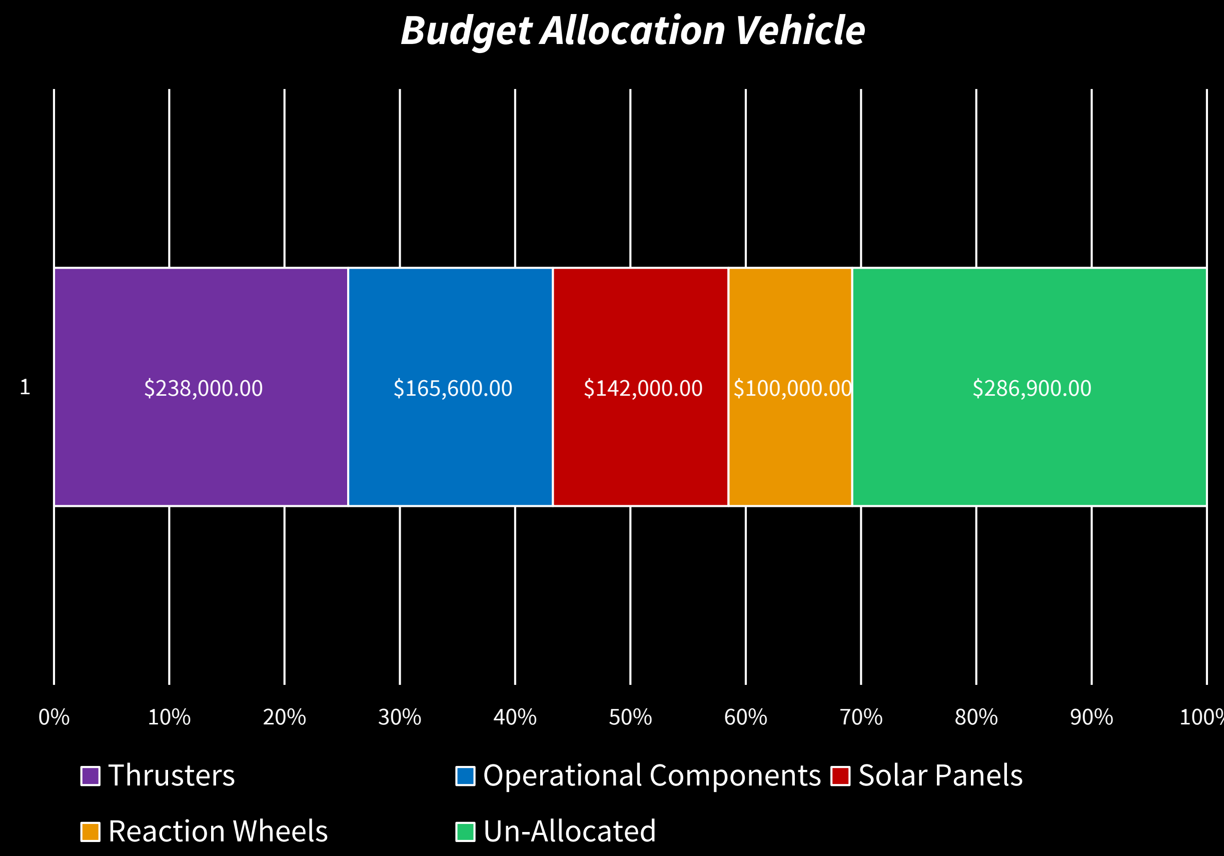
1. Larger thruster for station keeping
2. Additional thruster for transfer orbit
3. Larger solar panels
4. Stationary secondary mirror
5. Increased battery capacity
6. Mirror solar shades





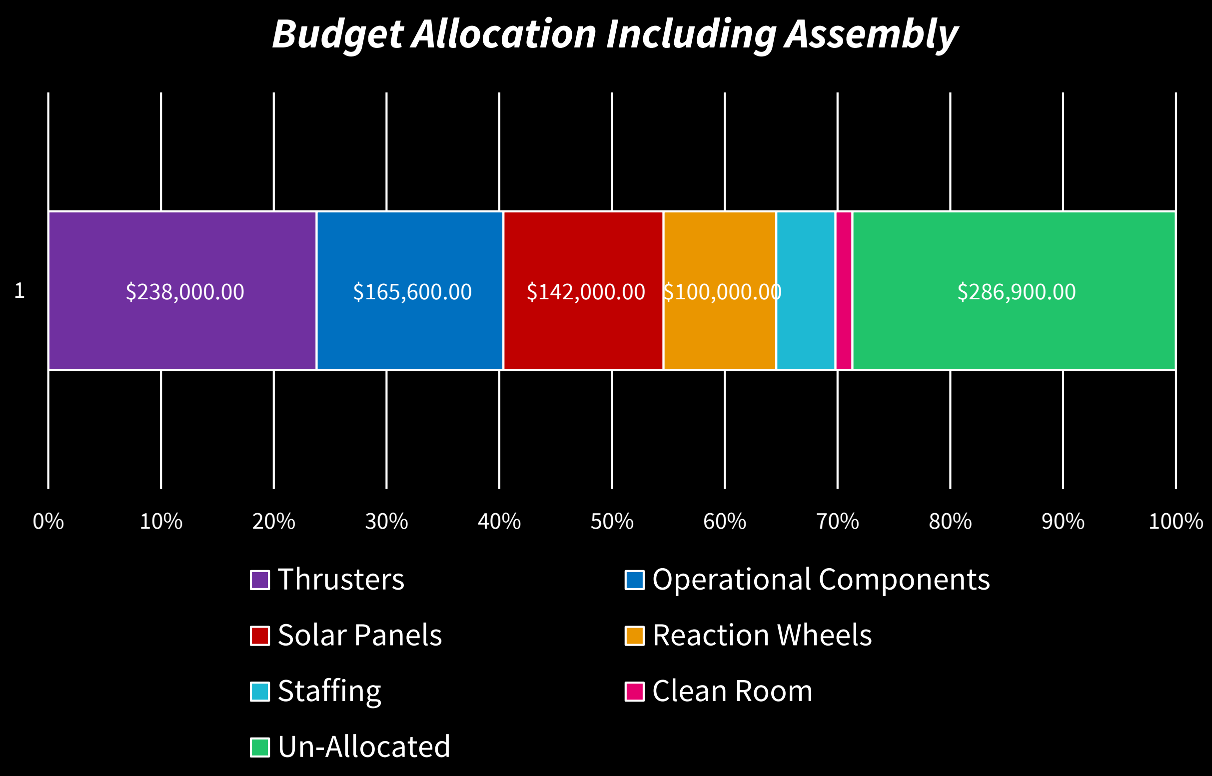
Financial Budget

- 3 General Categories Present:
  - Operational Parts: Every part on satellite excluding reaction wheels and solar panels.
  - Thrusters, Solar Panels, and Reaction Wheels comprise most of the budget.
  - Un-Allocated funds represent over 30% of the total budget



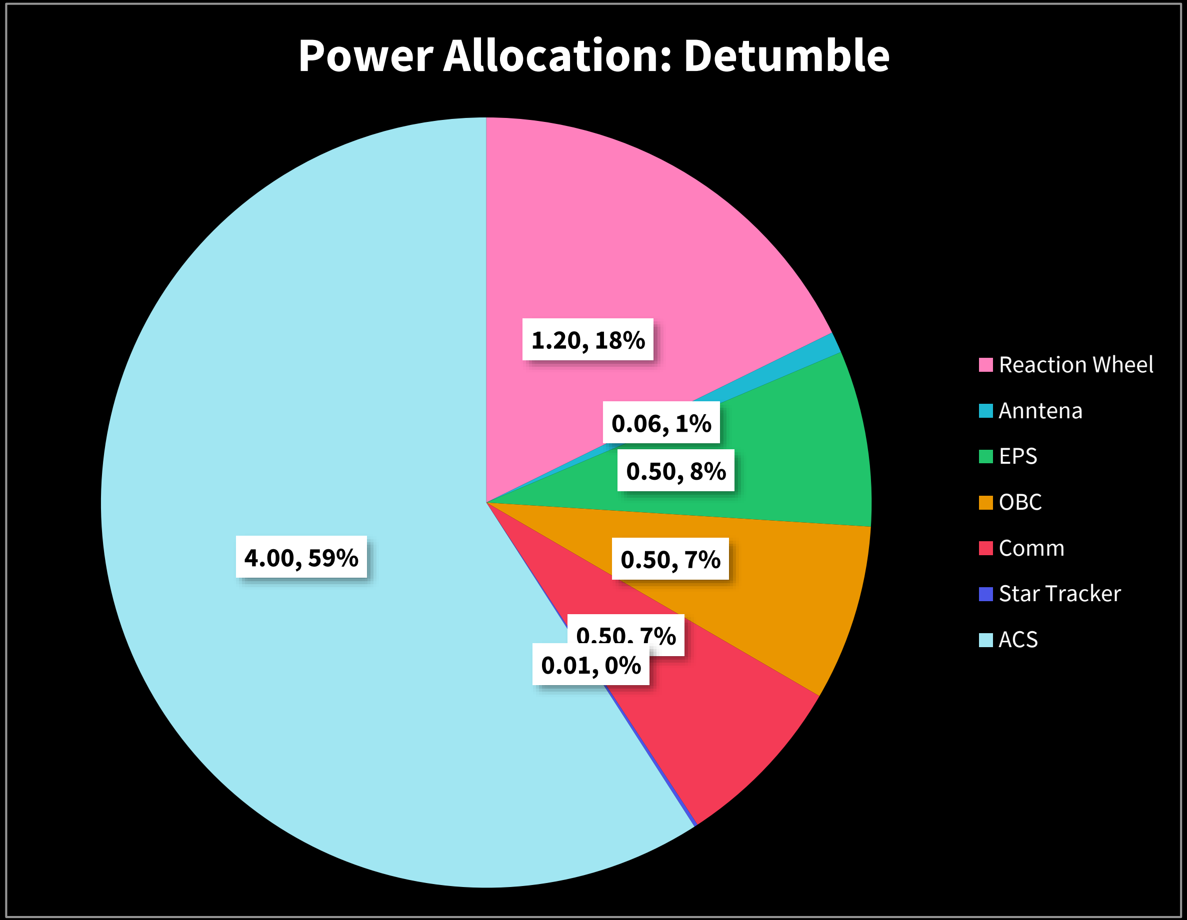
Financial Budget

- Un-Allocated Budget:
  - $360,000 excess budget intended for facilities and staff for assembly
  - Budgeting for three entry-level staff members for 3 months: $52,500
  - Additional Budgeting for clean room renting based on rough estimates: $15,000.
  - Remaining budget of $290,000 for delays or extenuating circumstances



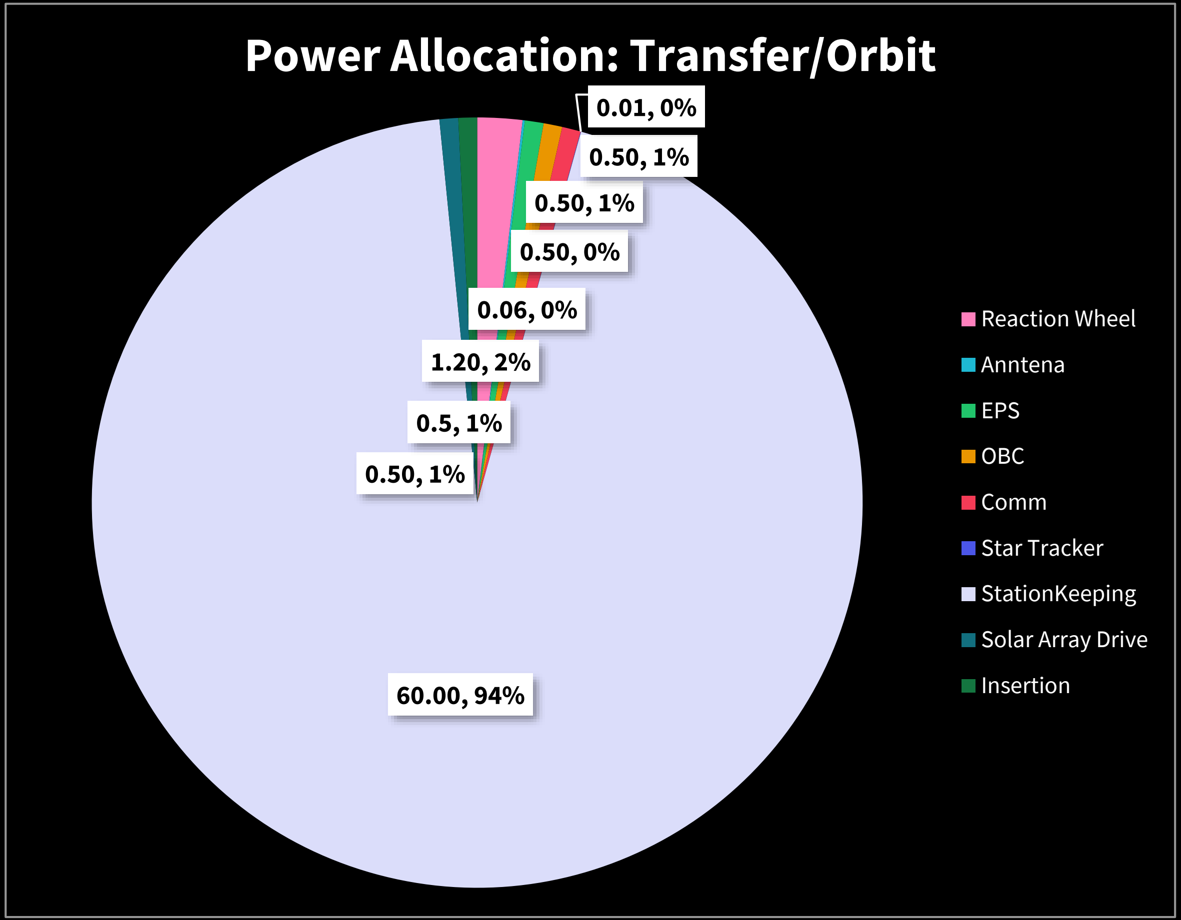
Power Budget: Nominal Usage

- Case: Detumble
  - <u>Major consumption:</u>
    ACS and Reaction Wheels
  - Solar Available:
    - Conservative Assumption:
      0 W
  - Total Consumption:
    6.77 W
  - Margin
    -6.77 W



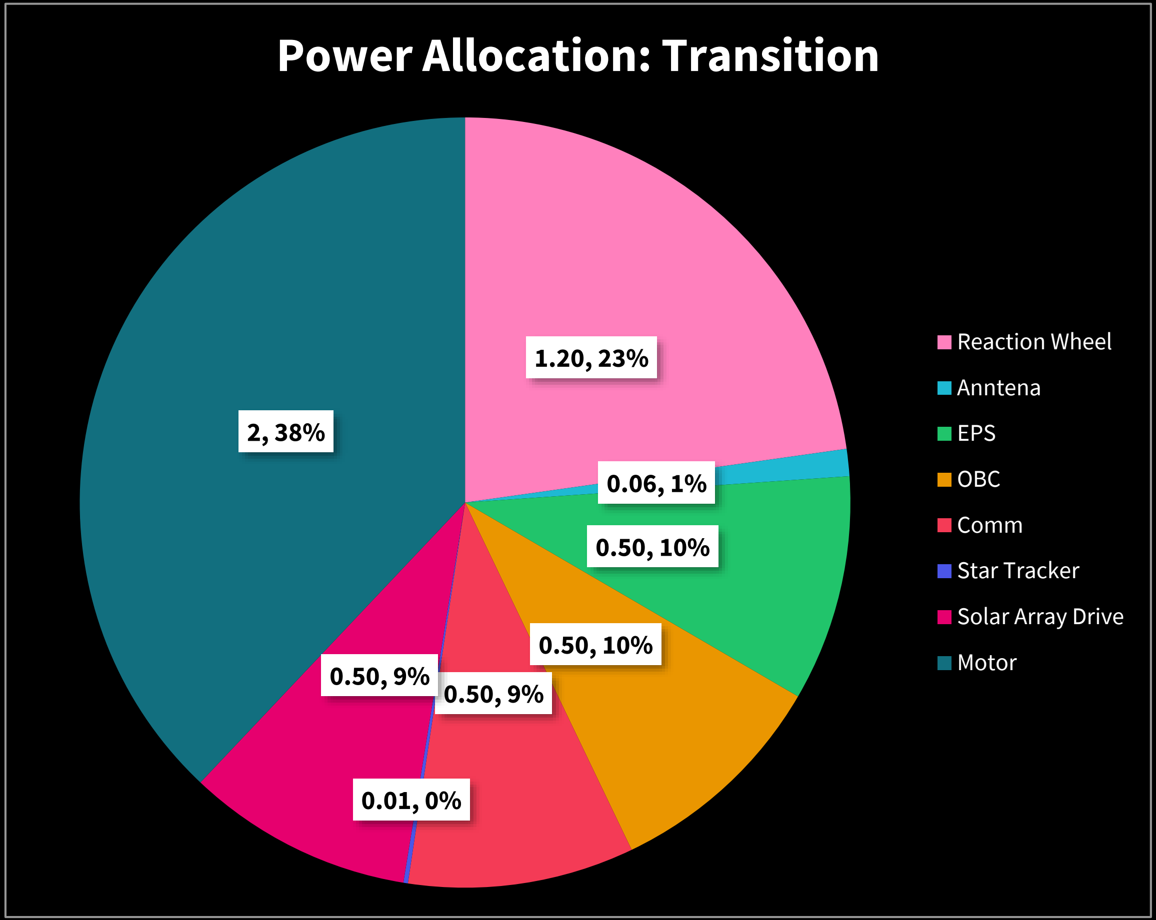
Power Budget: Nominal Usage

- Case: Transfer/Orbit
  - <u>Major consumption:</u>
    Station Keeping Thruster
  - Solar Available:
    90 W
  - Total Consumption:
    63.77 W
  - Margin:
    26.23 W



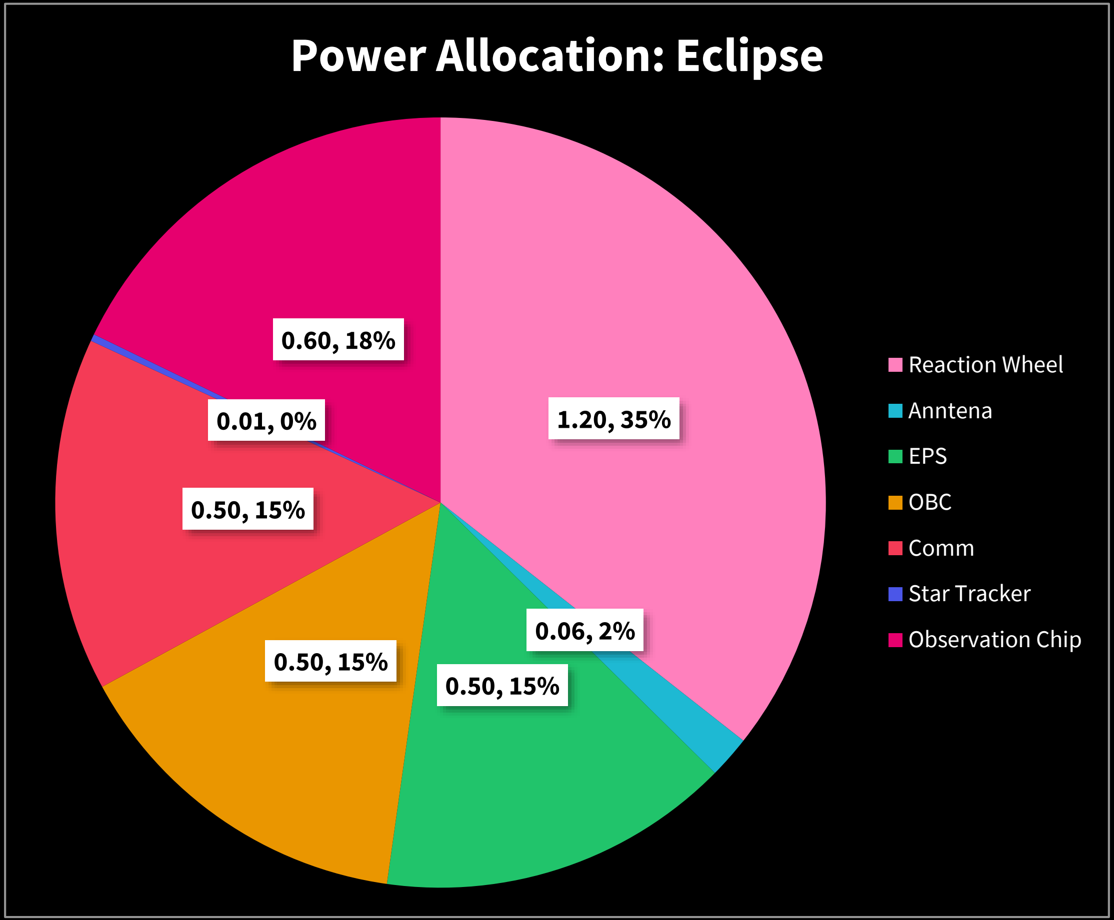
Power Budget: Nominal Usage

- Case: Transition
  - Major consumption:
    Motor and Reaction Wheels
  - Solar Available:
    90 W
  - Total Consumption:
    5.27 W
  - Margin:
    84.73 W



Power Budget: Nominal Usage

- Case: Eclipse
  - <u>Major consumption:</u>
    Observation Chip and Reaction Wheels
  - Solar Available:
    90 W
  - Total Consumption:
    3.37 W
  - Margin:
    86.63 W

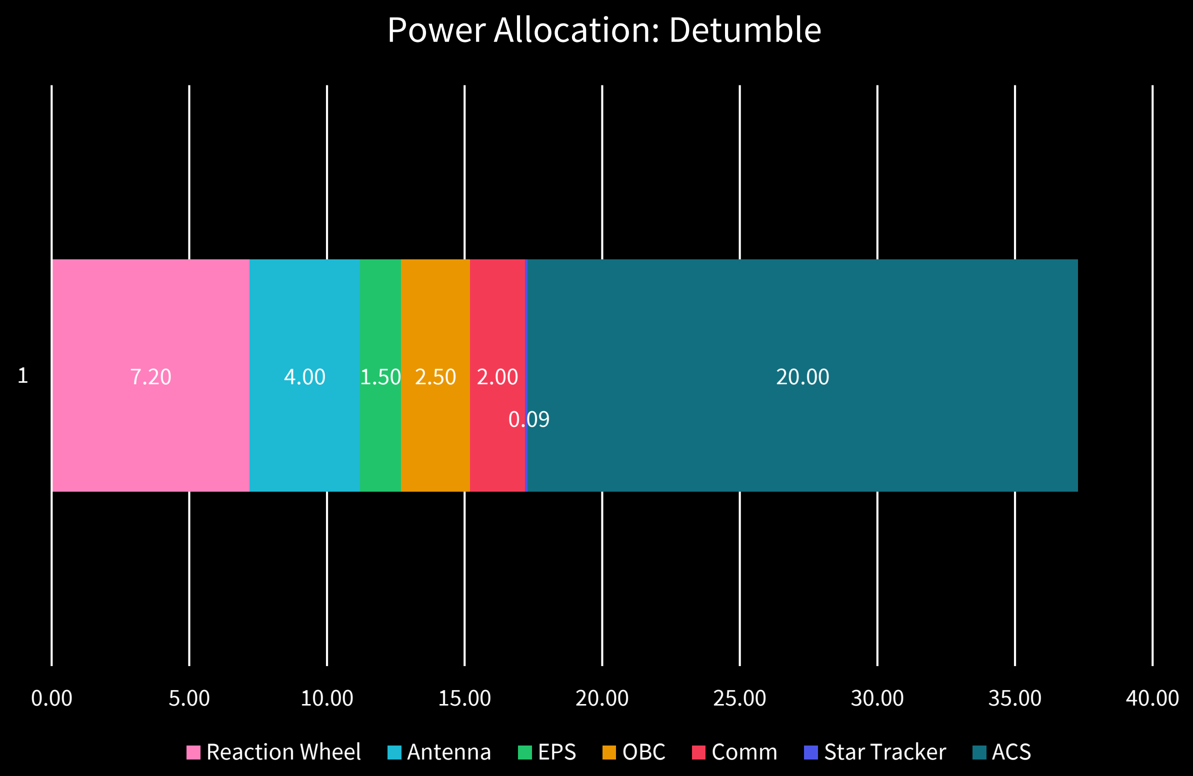


Power Budget: Max Usage

- Case: *Detumble*
  - Post LIMESAT deployment, before solar array deployment.

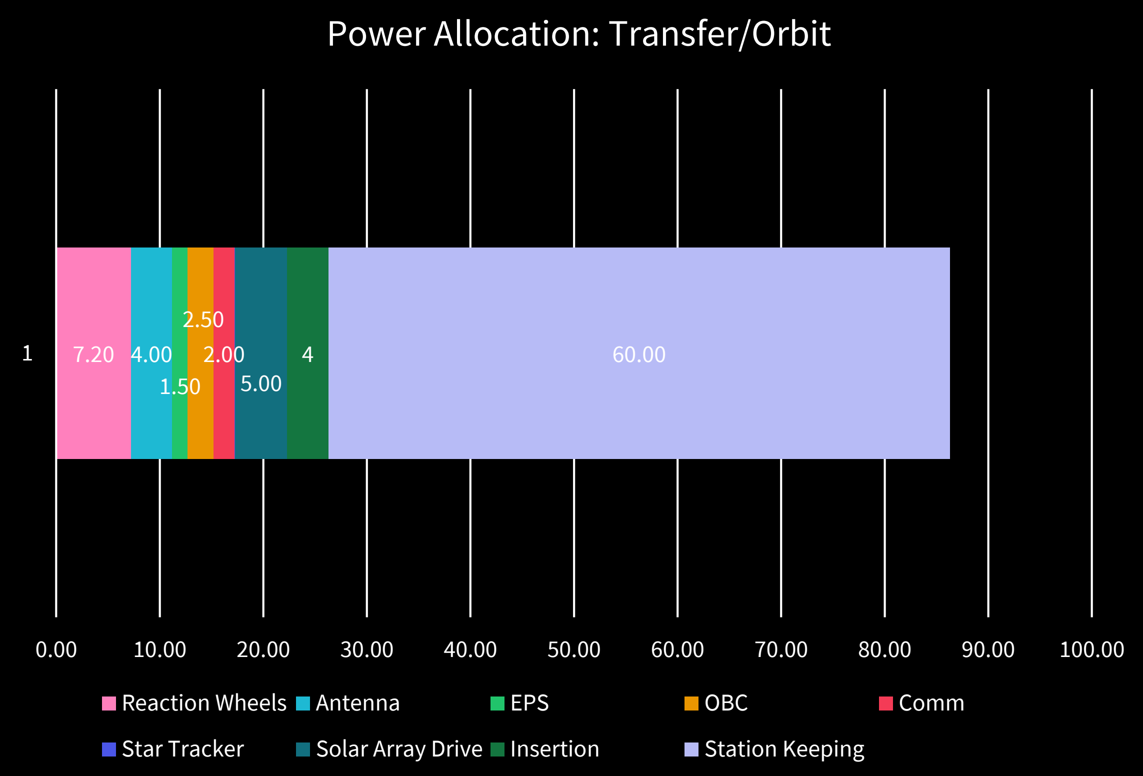
  - Solar Available: Assume 0 (This value will be positive in actuality)
  - Battery Capacity: 160 Wh
  - Total Usage: 37.29 W

  - Time Till Dead: 257 mins



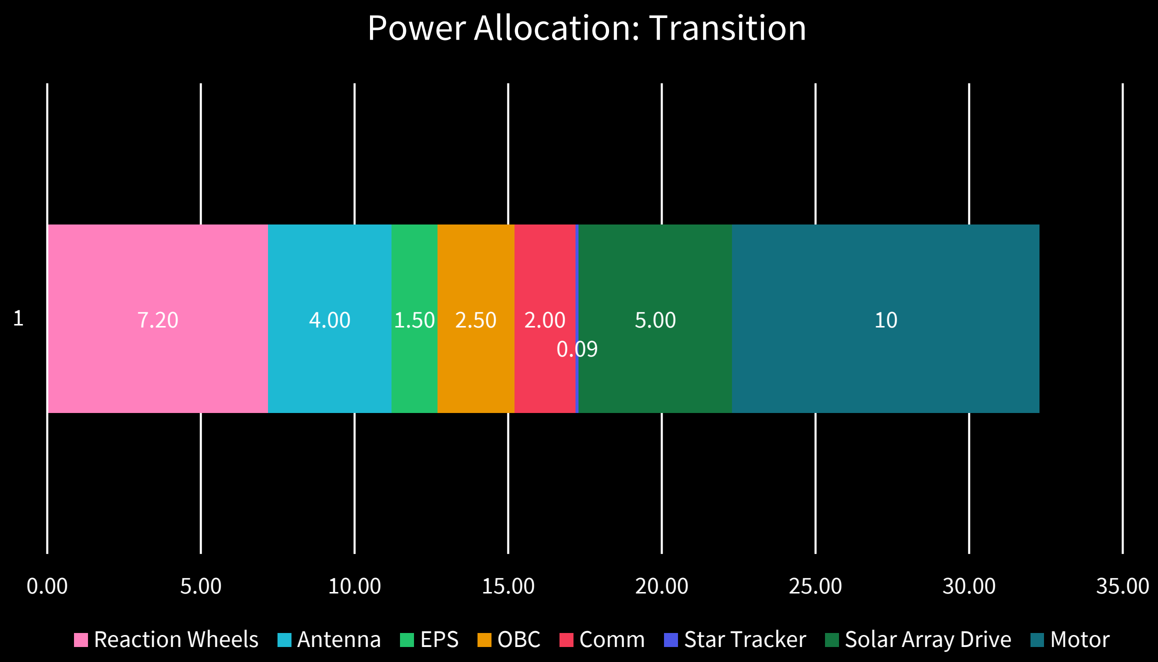
Power Budget: Max Usage

- Case: *Transfer/Orbit*
  - Post Deployment, post solar array deployment. Case applies in L2-L4 Transfer or during station keeping.
  - *Solar Available:* 90 W
  - *Total Usage:* 86.29 W
  - Net Power Production: +3.71 W



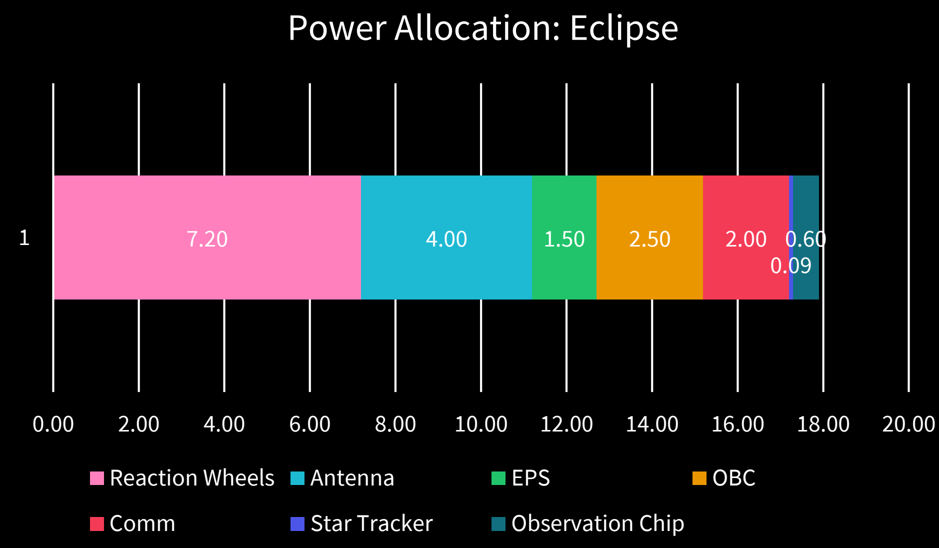
Power Budget: Max Usage

- Case: *Transition*
  - Transient time while entering or leaving lunar eclipse from L4 orbit.
  - Solar Available: 0W (Assume Eclipse worst case) in reality, will be greater than 0 even during eclipse.
  - Total Usage: 32.29 W
  - Battery Capacity: 160 Wh
  - Time Till Dead: 297 mins



Power Budget: Max Usage

- Case: *Eclipse*
  - Time during observation in eclipse of moon.
  - Solar Available: 0W (Assume Eclipse worst case) in reality, will be greater than 0 even in eclipse.
  - Total Usage: 17.89 W
  - Battery Capacity: 160 Wh
  - Time Till Dead: 537 mins



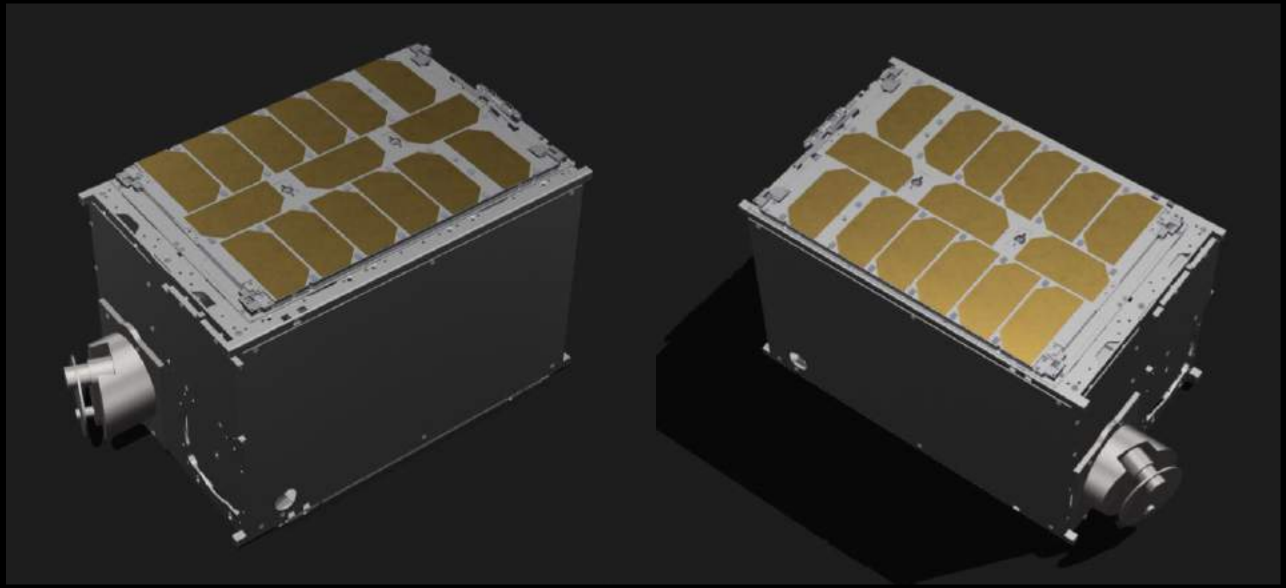
Mass Budget

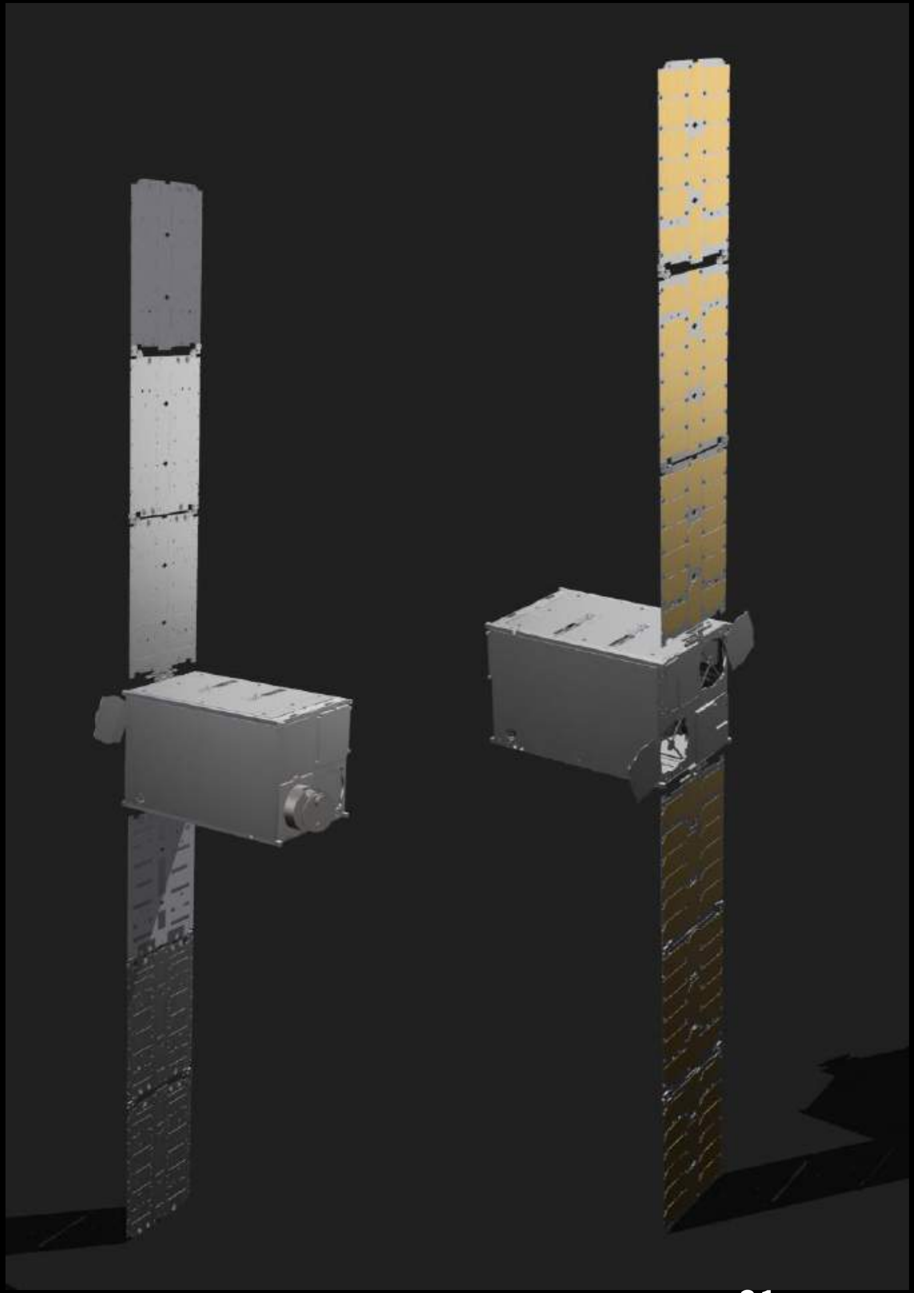
- Overall mass of components: 10.36 kg
- Design falls within current total

Weight restriction of 20kg

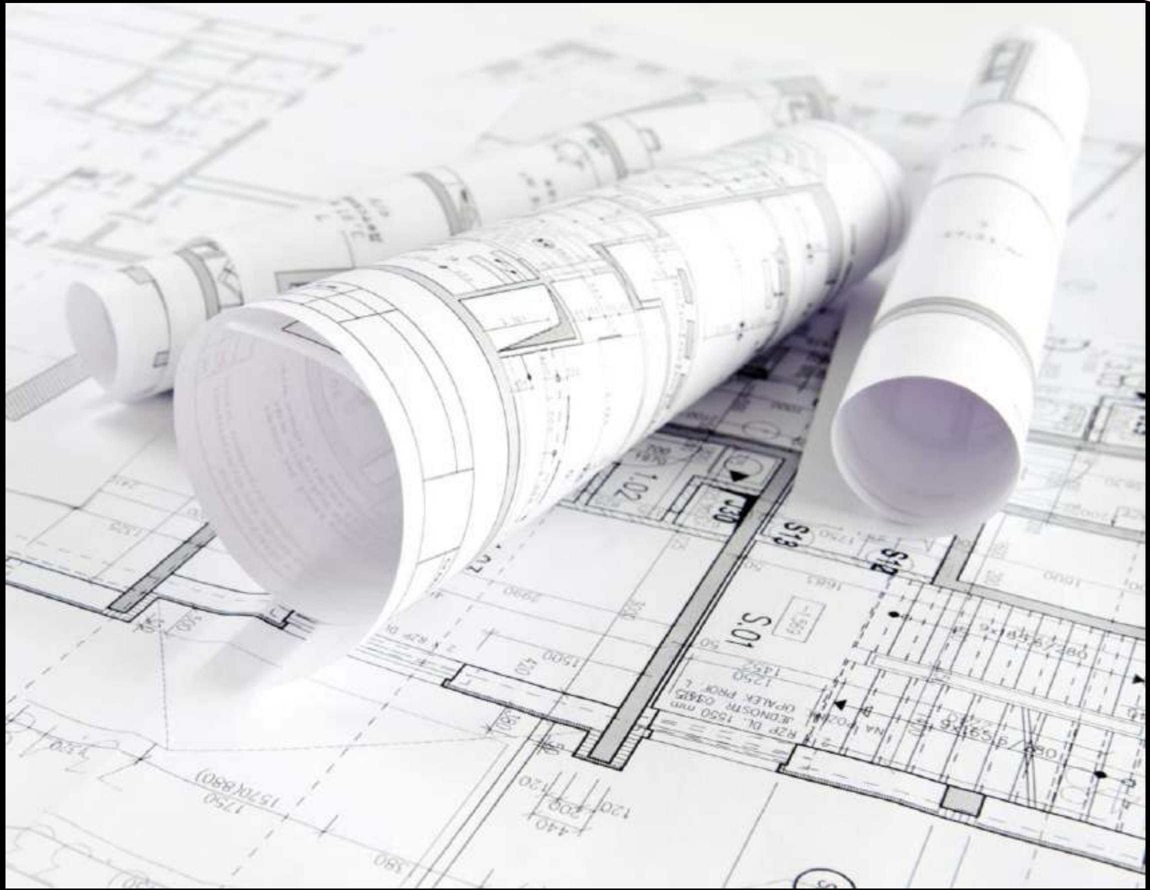
Part	Mass (kg)
Reaction Wheel	0.74
Anntena	0.03
EPS	0.33
Battery	0.27
Telemetry Software	0.00
Structure	2.44
Thruster L2 to L4	0.46
Thruster L4 Station	3.40
OBC	0.13
Comm	0.09
Star Tracker	0.05
Solar Panels	0.60
Solar Array Drive	0.70
Mirrors	0.25
Observation Chip	0.03
Telescope Misc. Parts	0.09
Motor	0.2
Wiring+Hardware	0.56
Total	10.36

CAD Model

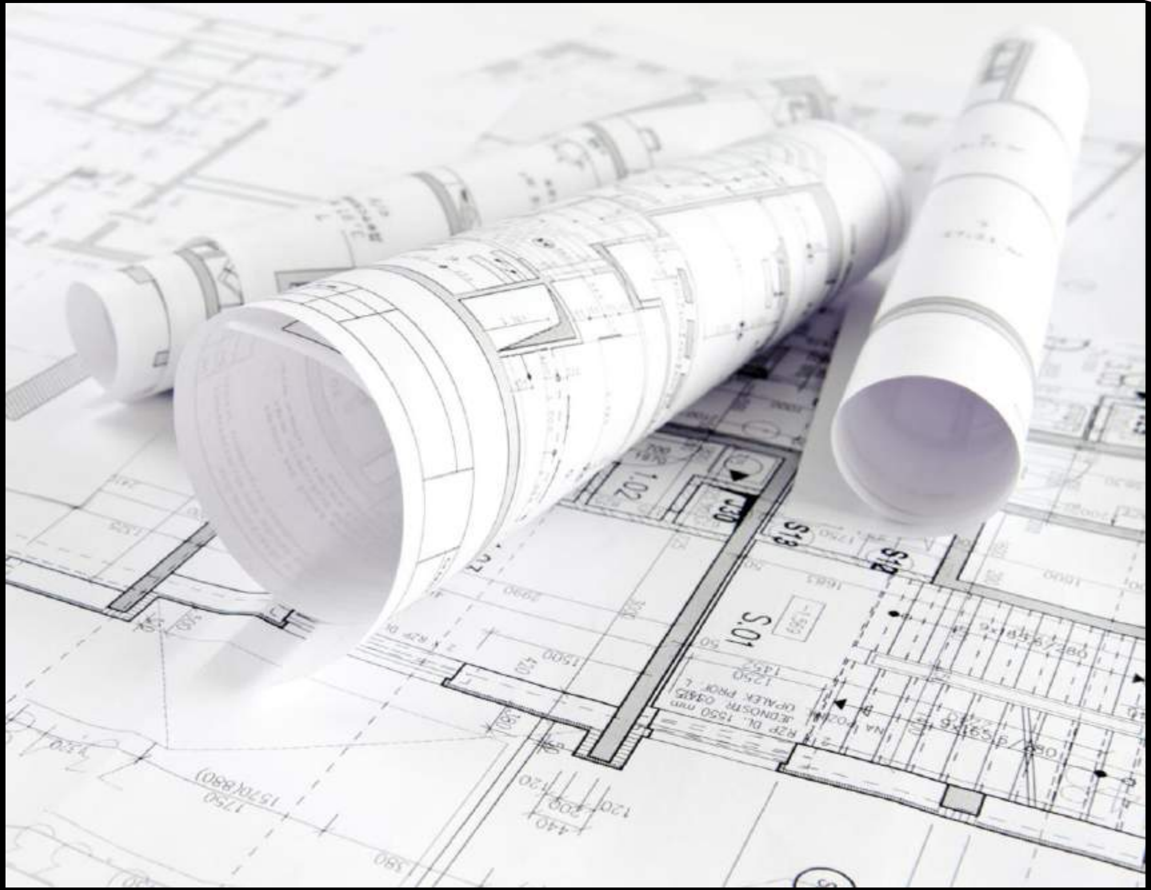




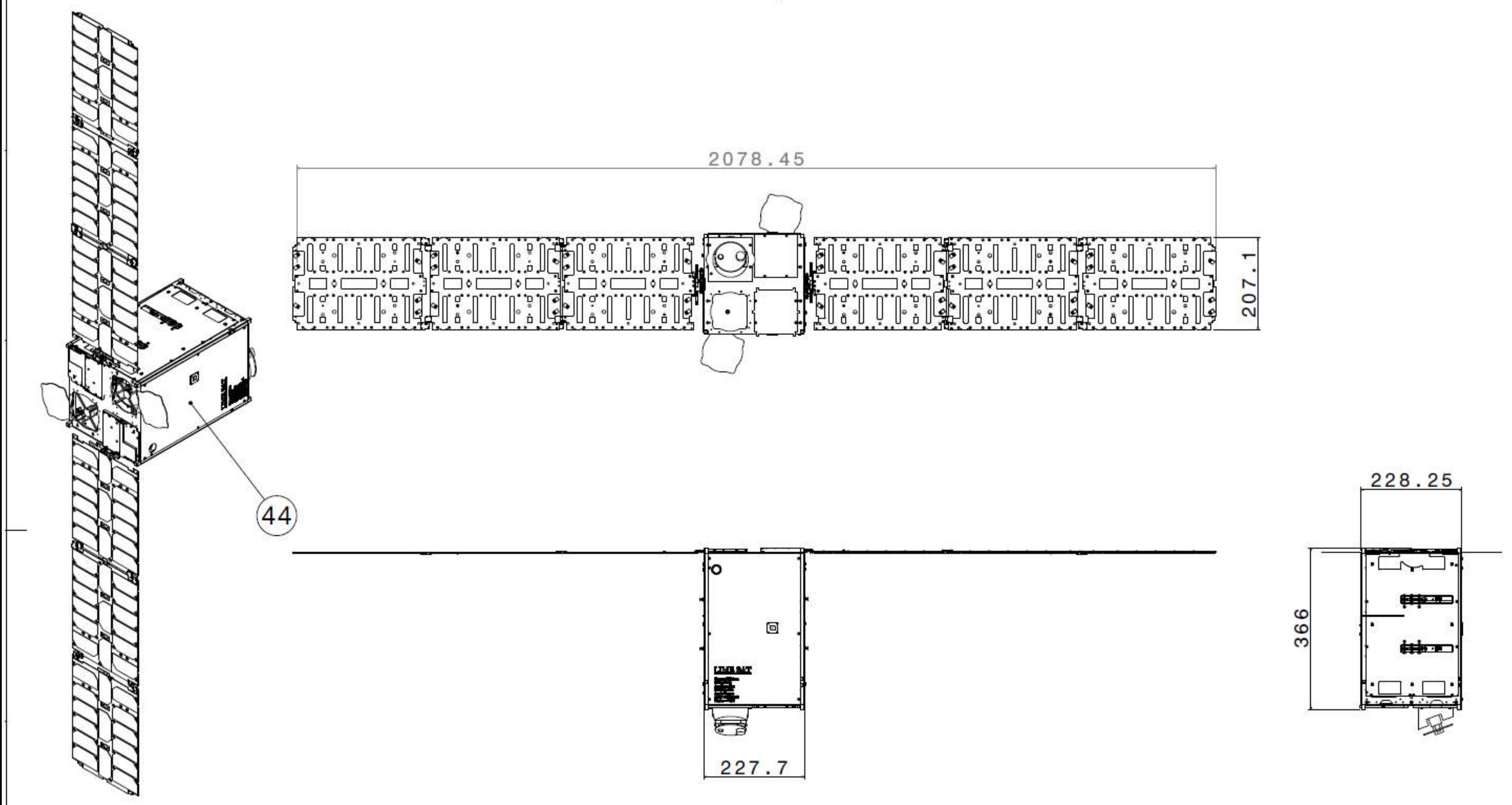
ENGINEERING DRAWINGS



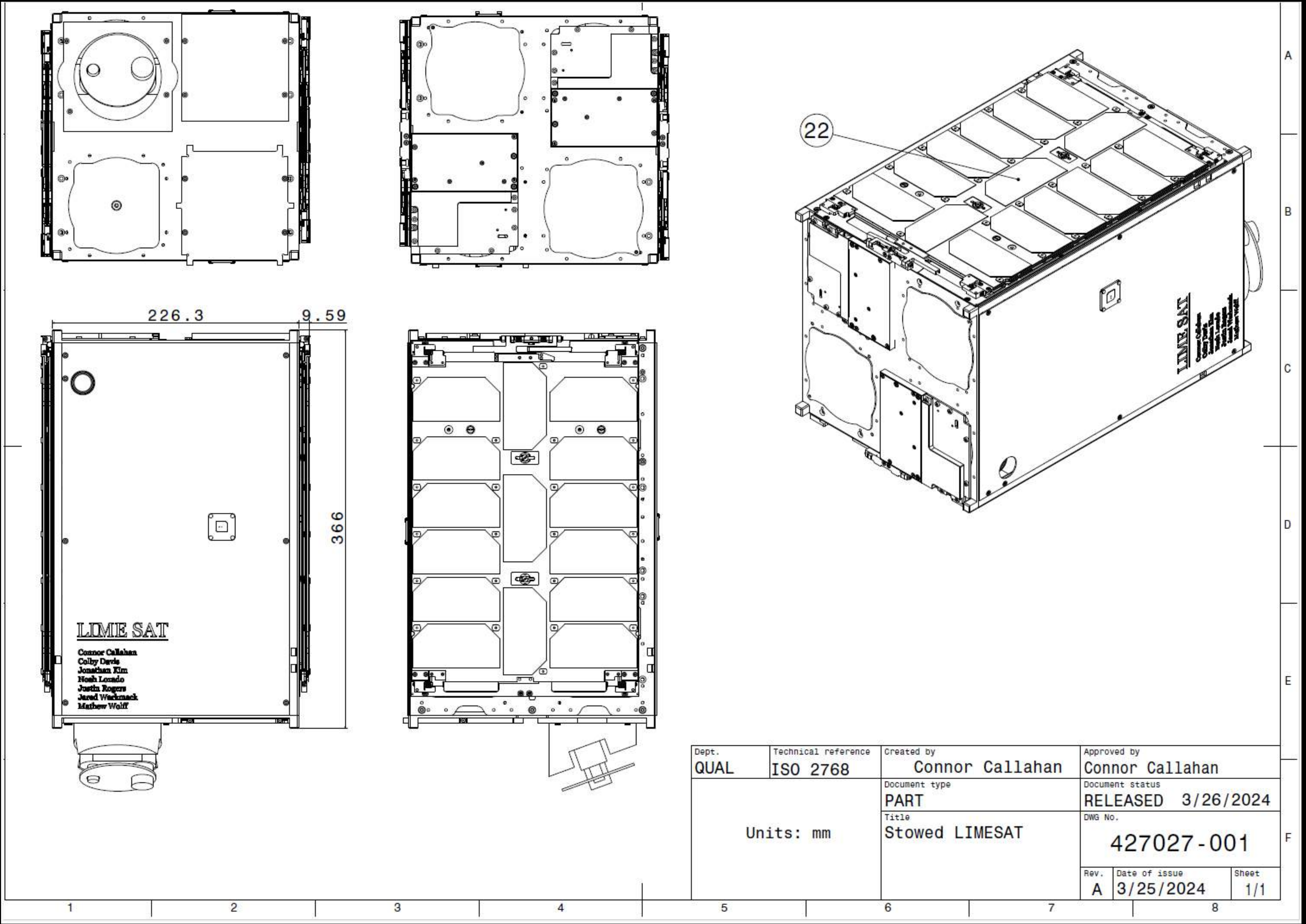
A S S E M B L Y (L I M E S A T)

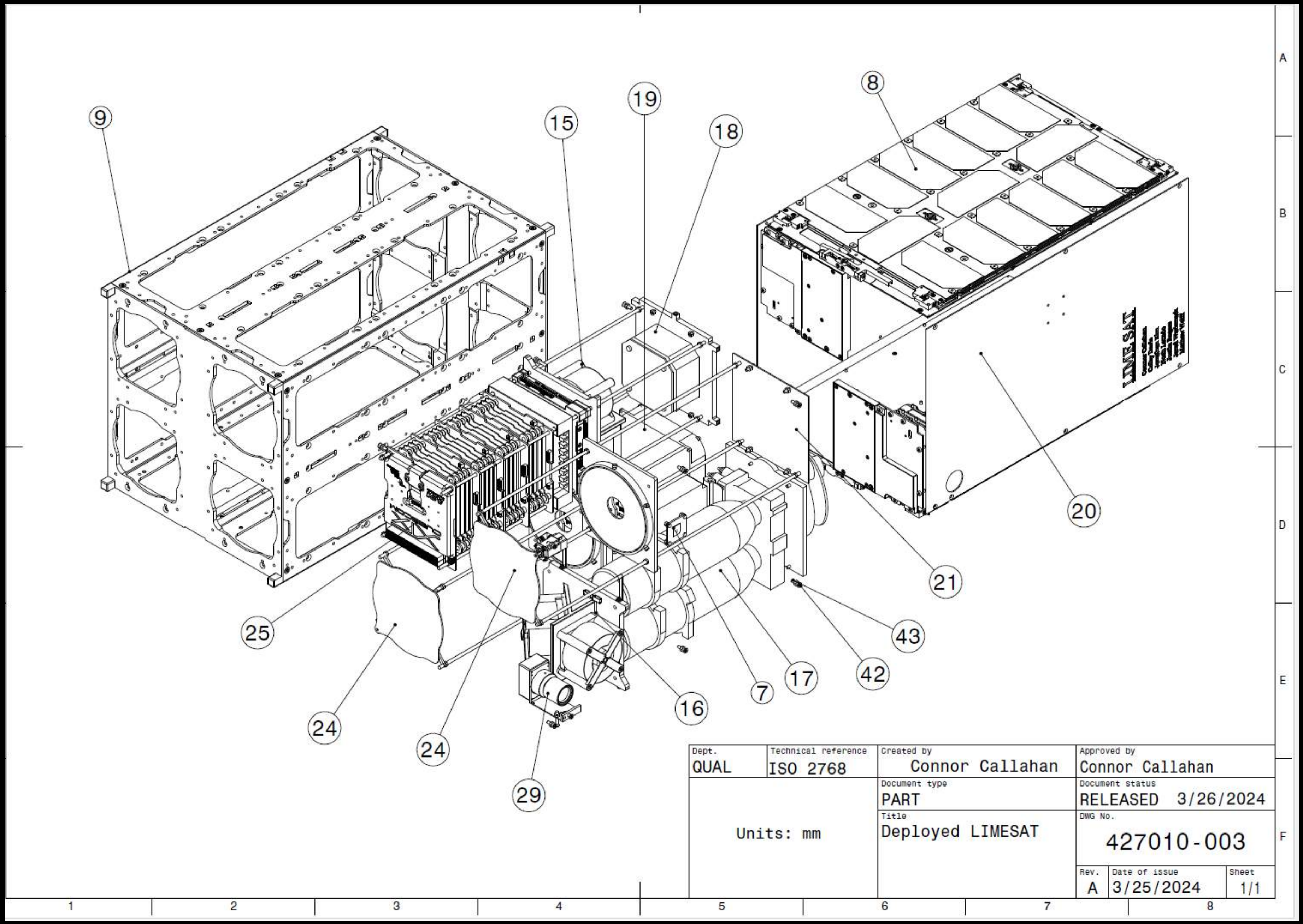


Item No.	Part No.	Description	Quantity	Material	Source
1	427001-001	Reaction Wheel -30 mNm s	4	Pre-Fab	Rocket Lab
2	427003-001	Primary Mirror	2	Glass	Syntec
3	427003-002	Secondary Mirror	2	Glass	Syntec
4	427005-001	OBC	1	Pre-Fab	Endurosat
5	427006-001	EPS	1	Pre-Fab	Endurosat
6	427007-001	CubeStar Star Tracker	2	Pre-Fab	CubeSpace
7	427008-001	X-Band Antenna Patch	2	Pre-Fab	ClydeSpace
8	427009-001	NanoPower TSP Solar Array	2	Pre-Fab	GOM Space
9	427011-001	Endurosat 12U Structure	1	Pre-Fab	Endurosat
10	427012-001	Optimus-80 Battery	2	Pre-Fab	Clyde Space
11	427013-001	X-band Transmitter	1	Pre-Fab	Clyde Space
12	427016-001	Ball Screw Motor	2	Pre-Fab	Assembly
13	427017-001	Solar Shade Assembly	2	Al 6082	In- House
14	427018-001	Star Tracker Bracket	2	Al 6082	In- House
15	427019-001	RCW Assembly X-Y	1	Al 6082	Assembly
16	427019-002	RCW Assembly Z-XZ	1	Al 6082	Assembly
17	427022-001	Spaceware Nano L Thruster	1	Pre-Fab	Spaceware
18	427023-001	ARMA ACS Module	1	Pre-Fab	Aurora
19	427024-001	MEPSI Booster Jet	1	Pre-Fab	VACCO
20	427025-001	Shielding (sides)	2	Al 6082	In-House
21	427026-001	Shielding (back)	1	Al 6082	In-House
22	427027-001	LimeSAT Assembly (stowed)	1	Pre-Fab	Assembly
23	427028-001	Thruster Assembly	1	Pre-Fab	Assembly
24	427029-001	Mirror Assembly	1	Pre-Fab	Assembly
25	427030-001	Avionics Bus	1	Pre-Fab	Assembly
26	427031-001	Bolt M3 x 7.5mm	5	Pre-Fab	McMaster-Carr
27	427032-001	Bolt M2 x10mm	5	Pre-Fab	McMaster-Carr
28	427033-001	Alvium USB90	2	Pre-Fab	Allied Vision
29	427034-001	Star Tracker Assembly	2	Pre-Fab	Assembly
30	427035-001	Nano-L Thruster Head	1	Pre-Fab	Spaceware
31	427036-001	Nano-L Propellat Tank Adaptor	1	Pre-Fab	Spaceware
32	427037-001	Nano-L Propellant Tank	1	Pre-Fab	Spaceware
33	427038-001	Nano-L Propellant Management System	1	Pre-Fab	Spaceware
34	427039-001	Nano-L Thruster Control Unit	1	Pre-Fab	Spaceware
35	427050-001	Nano-L Propellant Tank Bracket	1	Pre-Fab	Spaceware
36	427029-005	Secondary Mirror Housing	2	Pre-Fab	Assembly
37	427029-006	CMOS Body	2	Pre-Fab	Allied Vision
38	427029-006	Threaded Rod M3x343	10	Pre-Fab	McMaster-Carr
39	427029-007	Primary Mirror Housing	2	Pre-Fab	Assembly
40	427051-001	M2 Nut	8	Pre-Fab	McMaster-Carr
41	427052-001	M2x5 Screw	8	Pre-Fab	McMaster-Carr
42	427053-001	M2.5x16 Screw	30	Pre-Fab	McMaster-Carr
43	427054-001	M2.5 Nut	30	Pre-Fab	McMaster-Carr
44	427050-001	LimeSAT Assembly (deployed)	1	Composite	Assembly
45	427010-003	LimeSAT Assembly (stowed, expanded)	1	Composite	Assembly



Dept.	Technical reference	Created by	Approved by
QUAL	ISO 2768	Connor Callahan	Connor Callahan
Units: mm		Document type: PART	Document status: RELEASED 3/26/2024
		Title: LIMESAT Assembly (Deployed)	DWG No. 427050-001
			Rev. A · Date of issue 3/25/2024 · Sheet 1/1


226.3
9.59
366
22
LIME SAT
Connor Callahan
Colby Davis
Jonathan Kim
Noah Lozado
Justin Rogers
Jared Wackmack
Mathew Wolff
LIME SAT
Dept.
QUAL
Technical reference
ISO 2768
Created by
Connor Callahan
Approved by
Connor Callahan
Document type
PART
Document status
RELEASED 3/26/2024
Units: mm
Title
Stowed LIMESAT
DWG No.
427027-001
Rev.
A
Date of issue
3/25/2024
Sheet
1/1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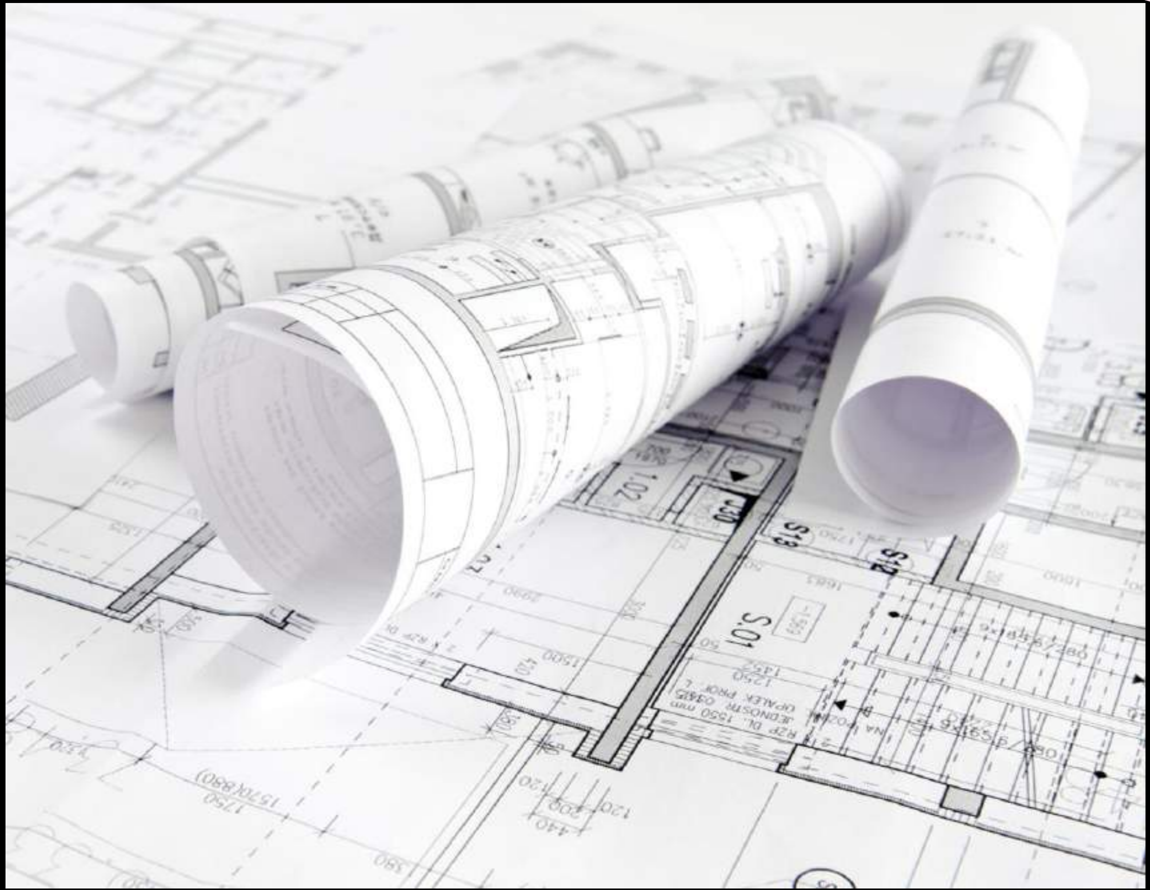
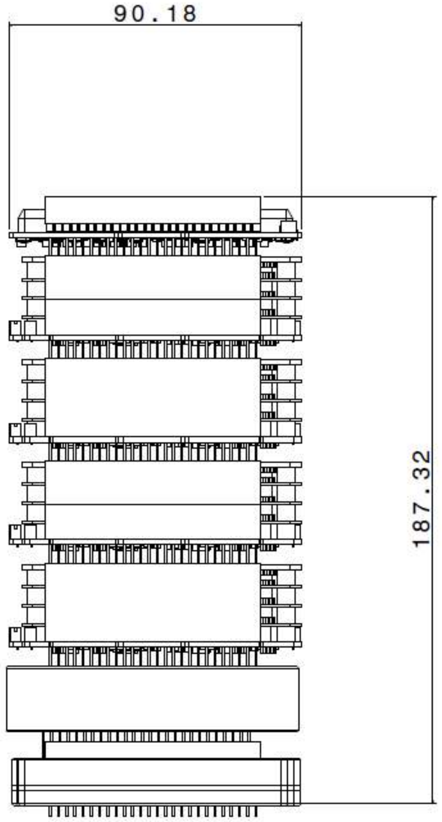
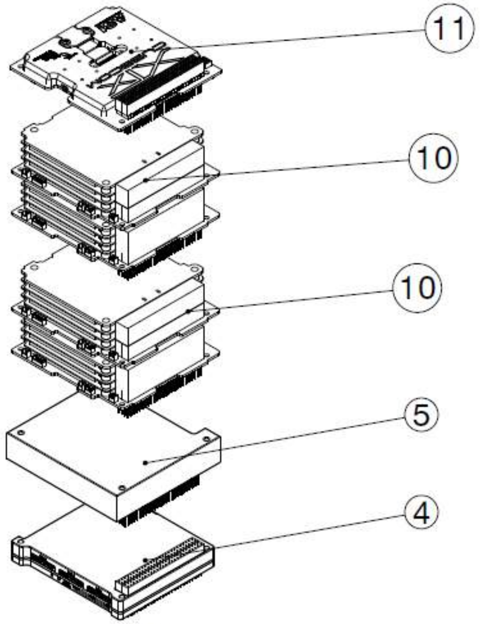
LIMESAT
Dept.
QUAL
Technical reference
ISO 2768
Created by
Connor Callahan
Approved by
Connor Callahan
Document type
PART
Document status
RELEASED 3/26/2024
Units: mm
Title
Deployed LIMESAT
DWG No.
427010-003
Rev.
A
Date of issue
3/25/2024
Sheet
1/1

SUBASSEMBLIES

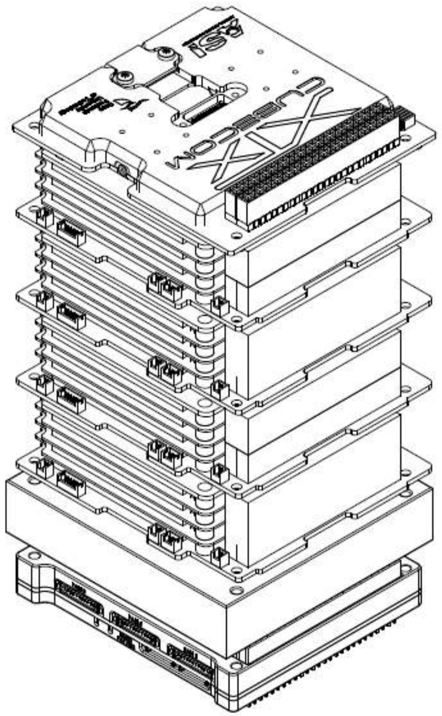




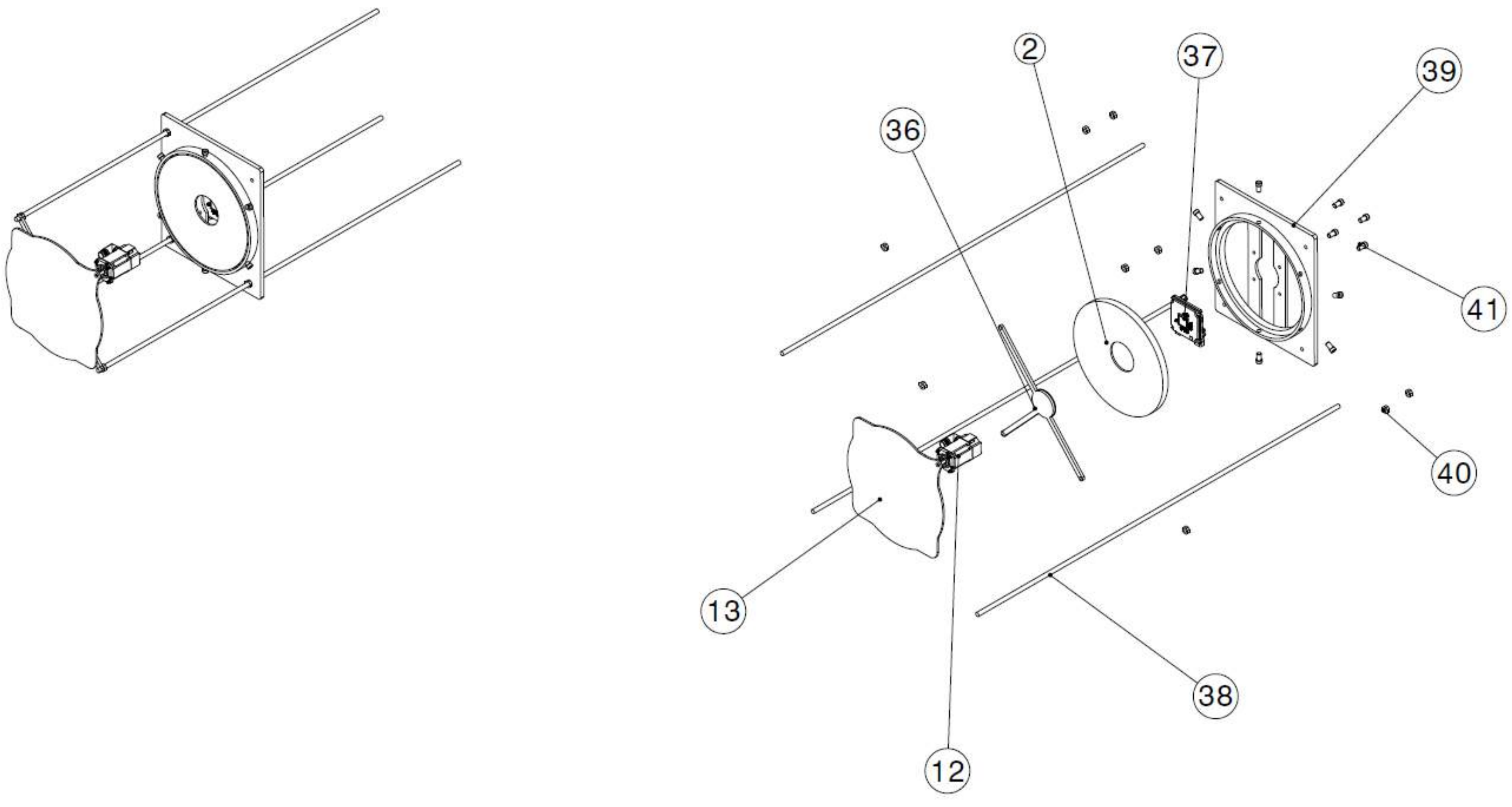
Front view
Scale: 2:1

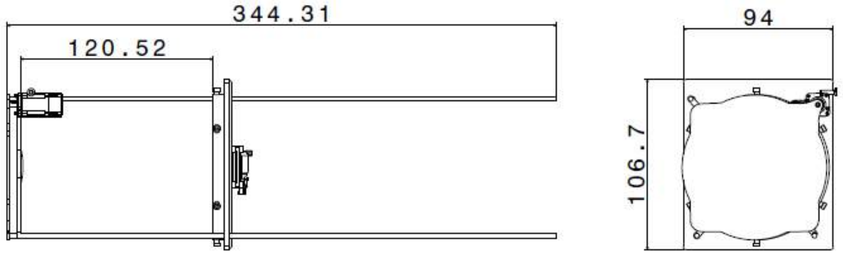


Isometric view
Scale: 1:1

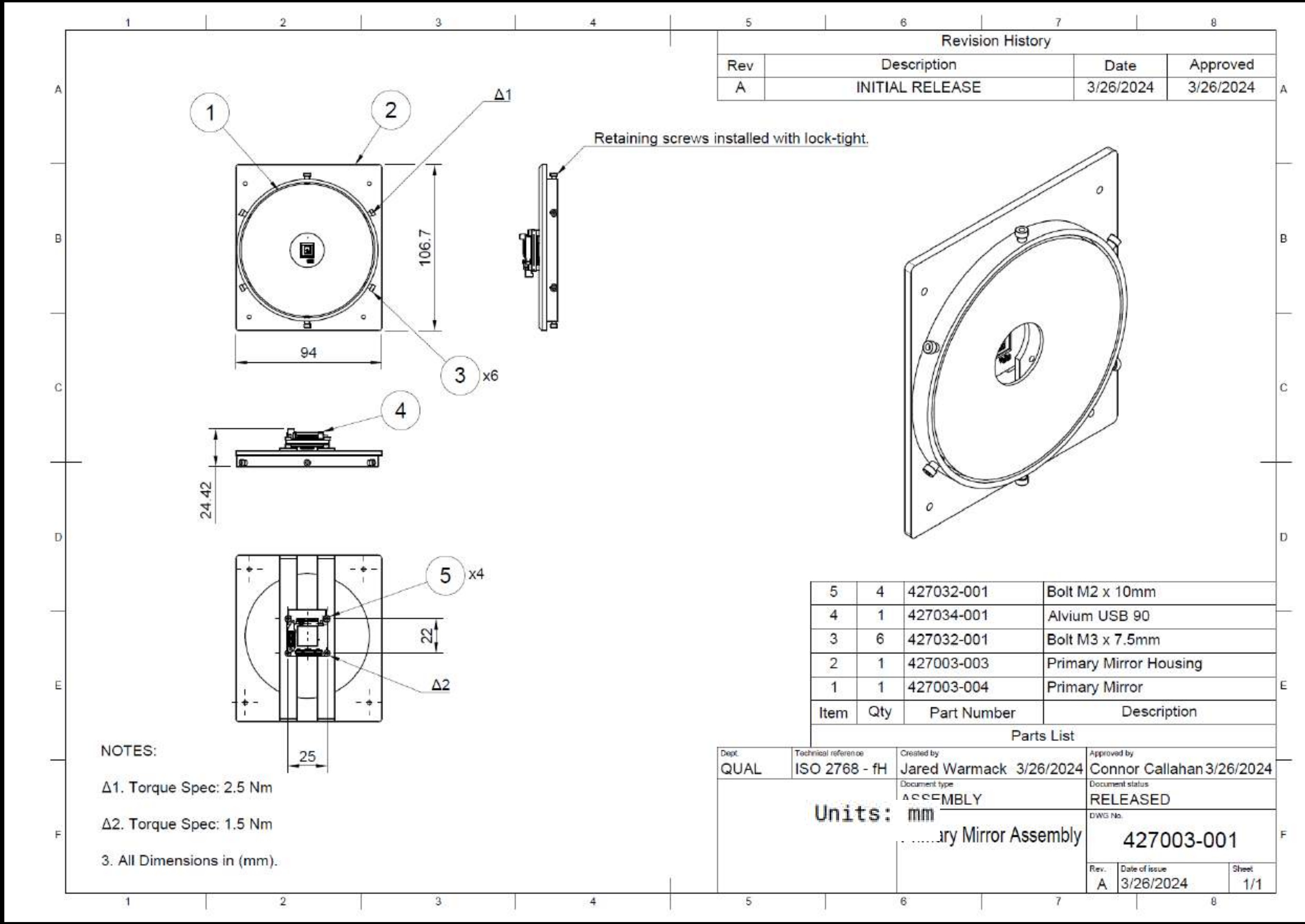


Dept.	Technical reference	Created by	Approved by
QUAL	ISO 2768	Connor Callahan	Connor Callahan
Units: mm		Document type: PART	Document status: RELEASED 3/26/2024
		Title: Avionics Bus	DWG No.: 427030-001
			Rev.: A / Date of issue: 3/25/2024 / Sheet: 1/1





Dept.	Technical reference	Created by	Approved by
QUAL	ISO 2768	Connor Callahan	Connor Callahan
		Document type: PART	Document status: RELEASED 3/26/2024
Units: mm		Title: Mirror Assembly	DWG No.: 427029-001
			Rev.: A; Date of issue: 3/25/2024; Sheet: 1/1



Revision History			
Rev	Description	Date	Approved
A	INITIAL RELEASE	3/26/2024	3/26/2024

Item	Qty	Part Number	Description
5	4	427032-001	Bolt M2 x 10mm
4	1	427034-001	Alvium USB 90
3	6	427032-001	Bolt M3 x 7.5mm
2	1	427003-003	Primary Mirror Housing
1	1	427003-004	Primary Mirror

Parts List

Dept.	Technical reference	Created by	Approved by
QUAL	ISO 2768 - fH	Jared Warmack 3/26/2024	Connor Callahan 3/26/2024
		Document type: ASSEMBLY	Document status: RELEASED
		ary Mirror Assembly	DWG No. 427003-001
			Rev. A · Date of issue 3/26/2024 · Sheet 1/1

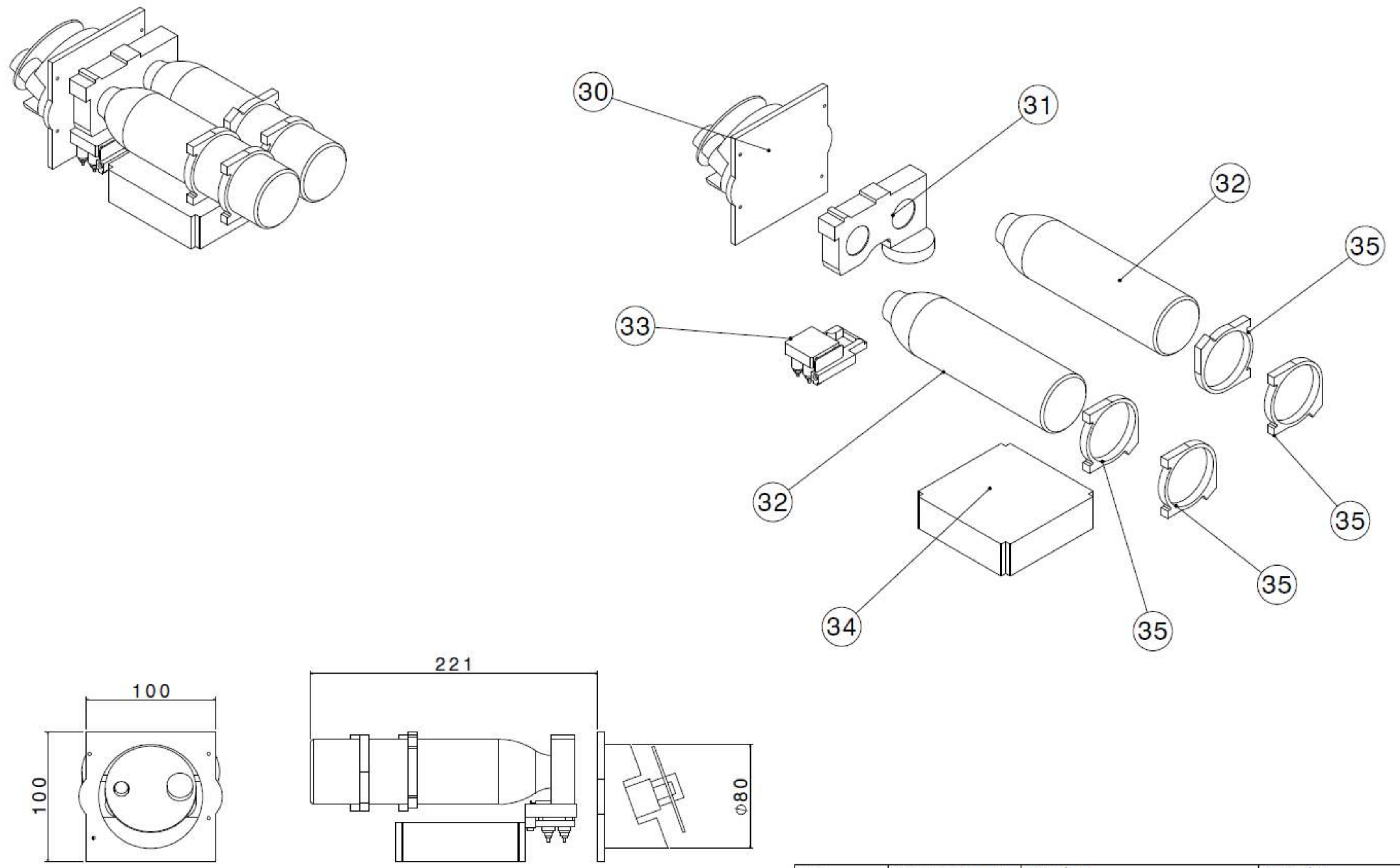
Units: mm

NOTES:

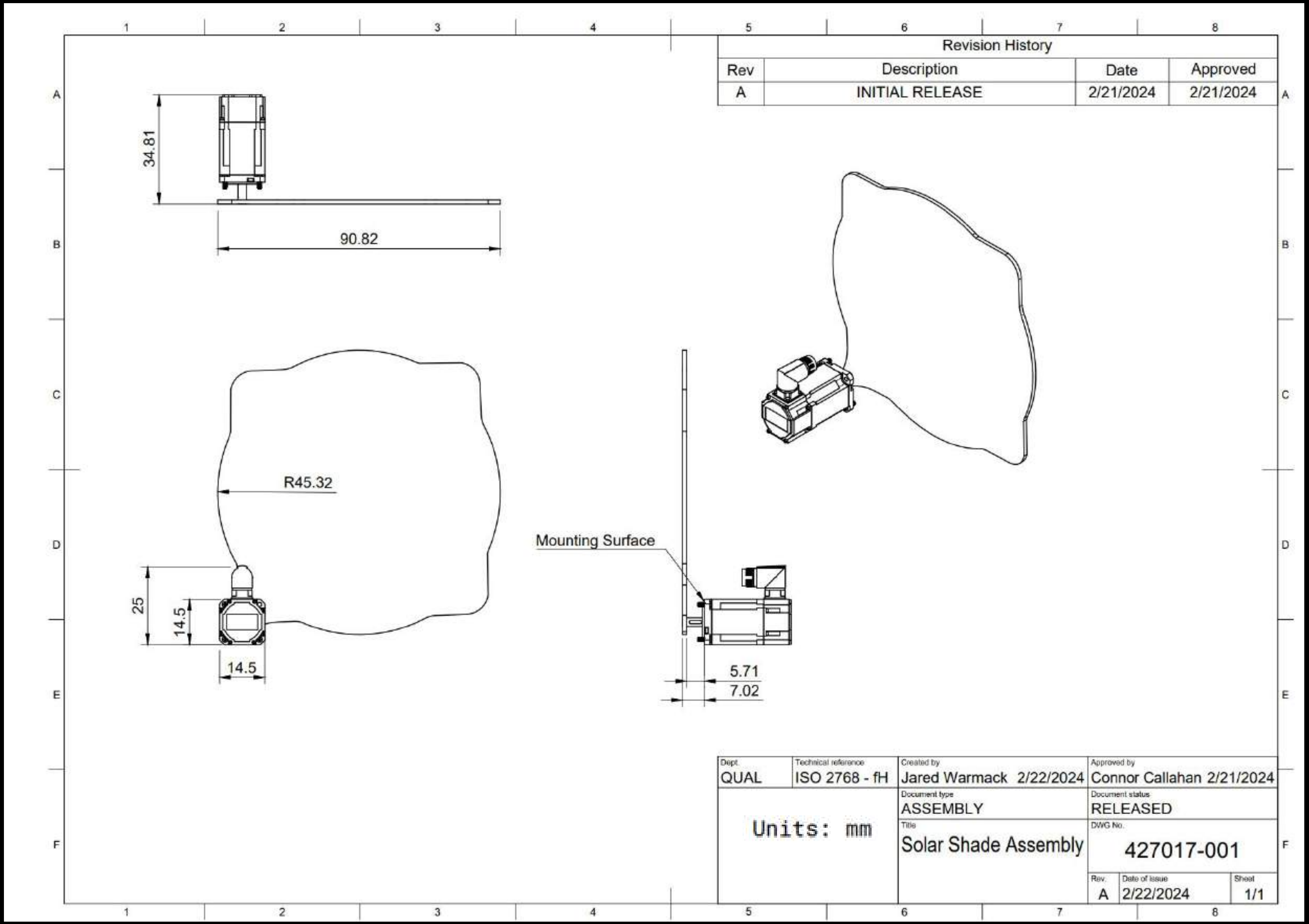
Δ1. Torque Spec: 2.5 Nm

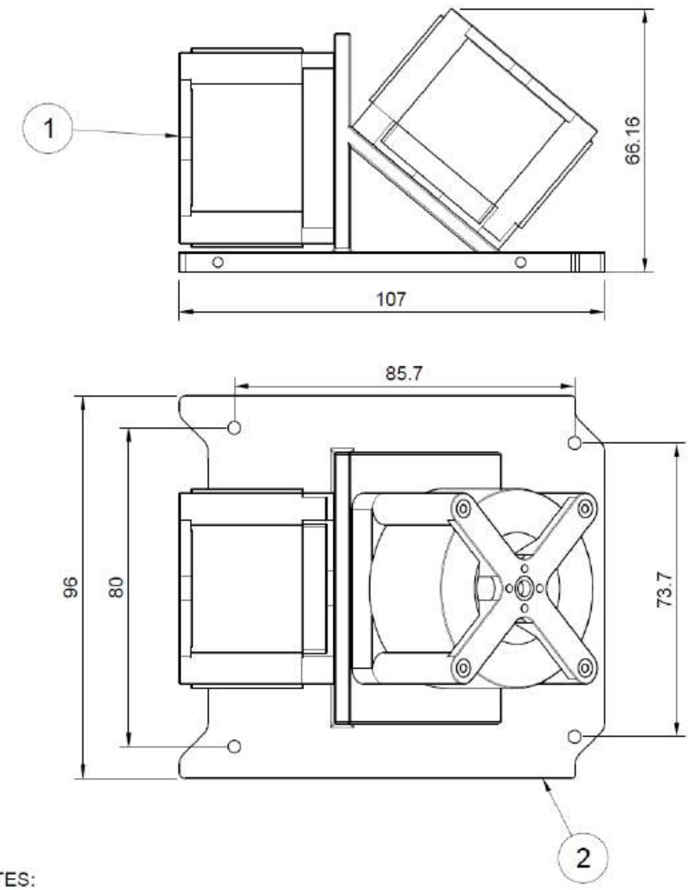
Δ2. Torque Spec: 1.5 Nm

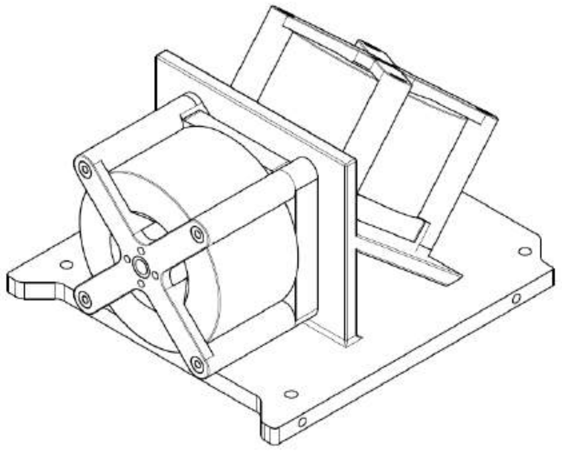
3. All Dimensions in (mm).



Dept.	Technical reference	Created by	Approved by
QUAL	ISO 2768	Connor Callahan	Connor Callahan
		Document type: PART	Document status: RELEASED 3/26/2024
Units: mm		Title: Thruster Assembly	DWG No.: 427028-001
			Rev.: A; Date of issue: 3/25/2024; Sheet: 1/1


Revision History
Rev
Description
Date
Approved
A
INITIAL RELEASE
2/21/2024
2/21/2024
34.81
90.82
R45.32
Mounting Surface
25
14.5
14.5
5.71
7.02
Dept.
QUAL
Technical reference
ISO 2768 - fH
Created by
Jared Warmack 2/22/2024
Approved by
Connor Callahan 2/21/2024
Document type
ASSEMBLY
Document status
RELEASED
Units: mm
Title
Solar Shade Assembly
DWG No.
427017-001
Rev.
A
Date of issue
2/22/2024
Sheet
1/1





Revision History			
Rev	Description	Date	Approved
A	INITIAL RELEASE	2/21/2024	2/21/2024

Item	Qty	Part Number	Description
2	1	427019-004	RCW Z-XY Bracket
1	2	427001-001	RL Reaction Wheel 30mNm s

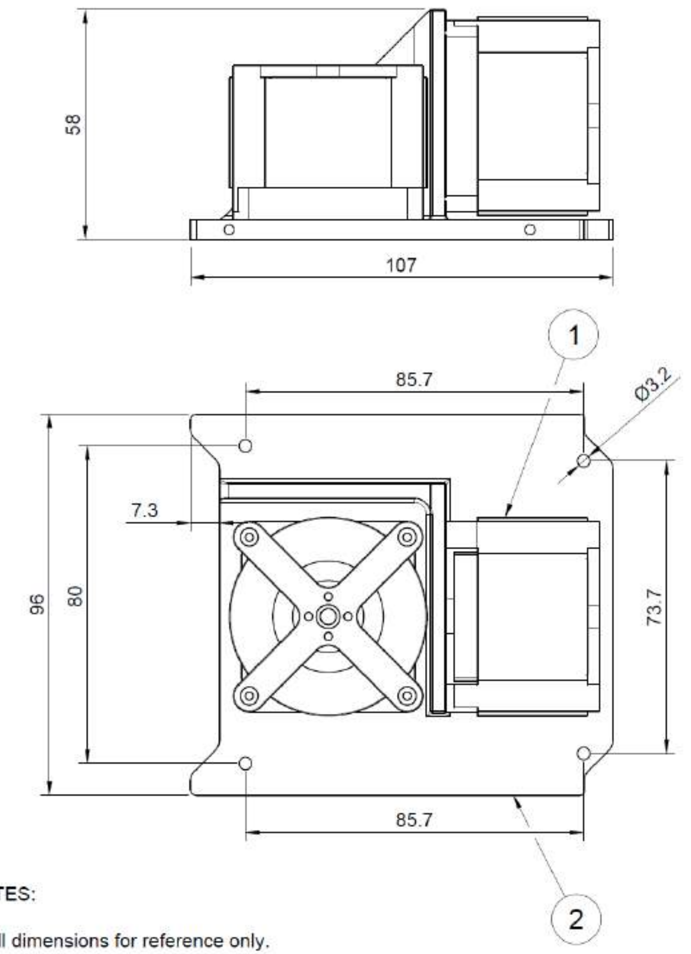
Parts List

NOTES:

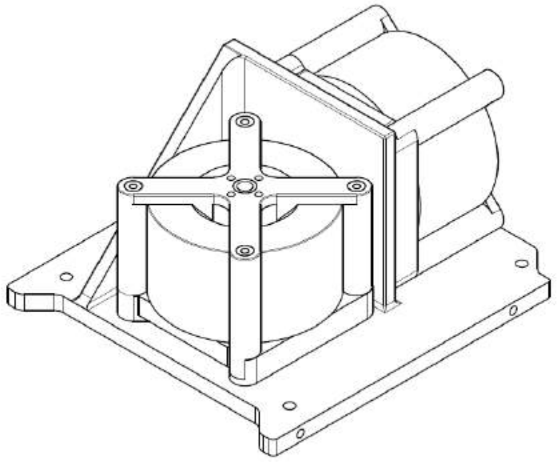
1. All dimensions for reference only.

2. All dimensions in (mm).

Dept.	Technical reference	Created by	Approved by
QUAL	ISO 2768 - fH	Jared Warmack 3/26/2024	Connor Callahan 2/21/2024
Units: mm		Document type: ASSEMBLY	Document status: RELEASED
		Title: RCW Assembly Z-XY	DWG No.: 427019-002
			Rev.: A; Date of issue: 2/22/2024; Sheet: 1/1



Revision History			
Rev	Description	Date	Approved
A	INITIAL RELEASE	2/21/2024	2/21/2024



Item	Qty	Part Number	Description
2	1	427019-003	RCW XY Bracket
1	2	427001-001	RL Reaction Wheel 30mNm s

Parts List

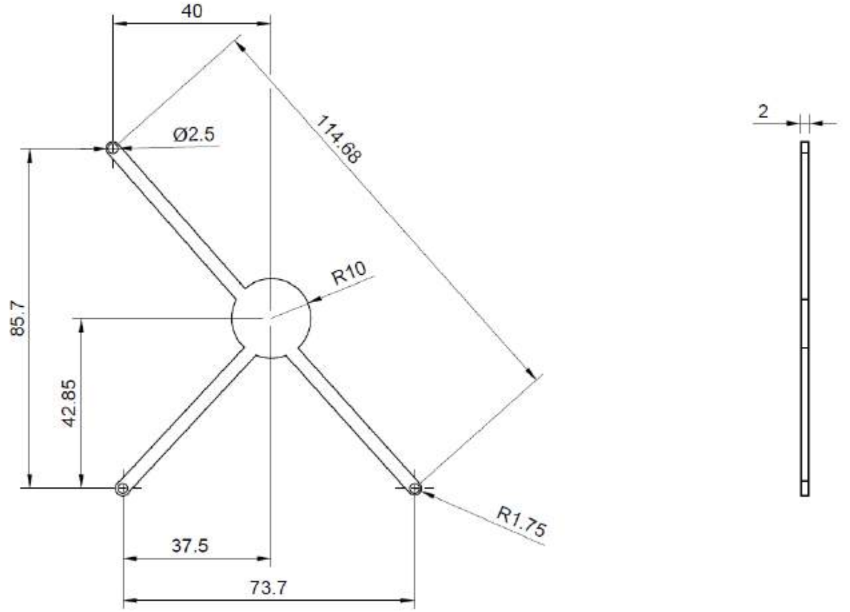
NOTES:

1. All dimensions for reference only.

2. All dimensions in (mm).

Dept.	Technical reference	Created by	Approved by
QUAL	ISO 2768 - fH	Jared Warmack 3/26/2024	Connor Callahan 2/21/2024
Units: mm		Document type: ASSEMBLY	Document status: RELEASED
		Title: RCW Assembly X-Y	DWG No.: 427019-001
			Rev.: A; Date of issue: 2/22/2024; Sheet: 1/1

Revision History			
Rev	Description	Date	Approved
A	INITIAL RELEASE	2/21/2024	2/21/2024



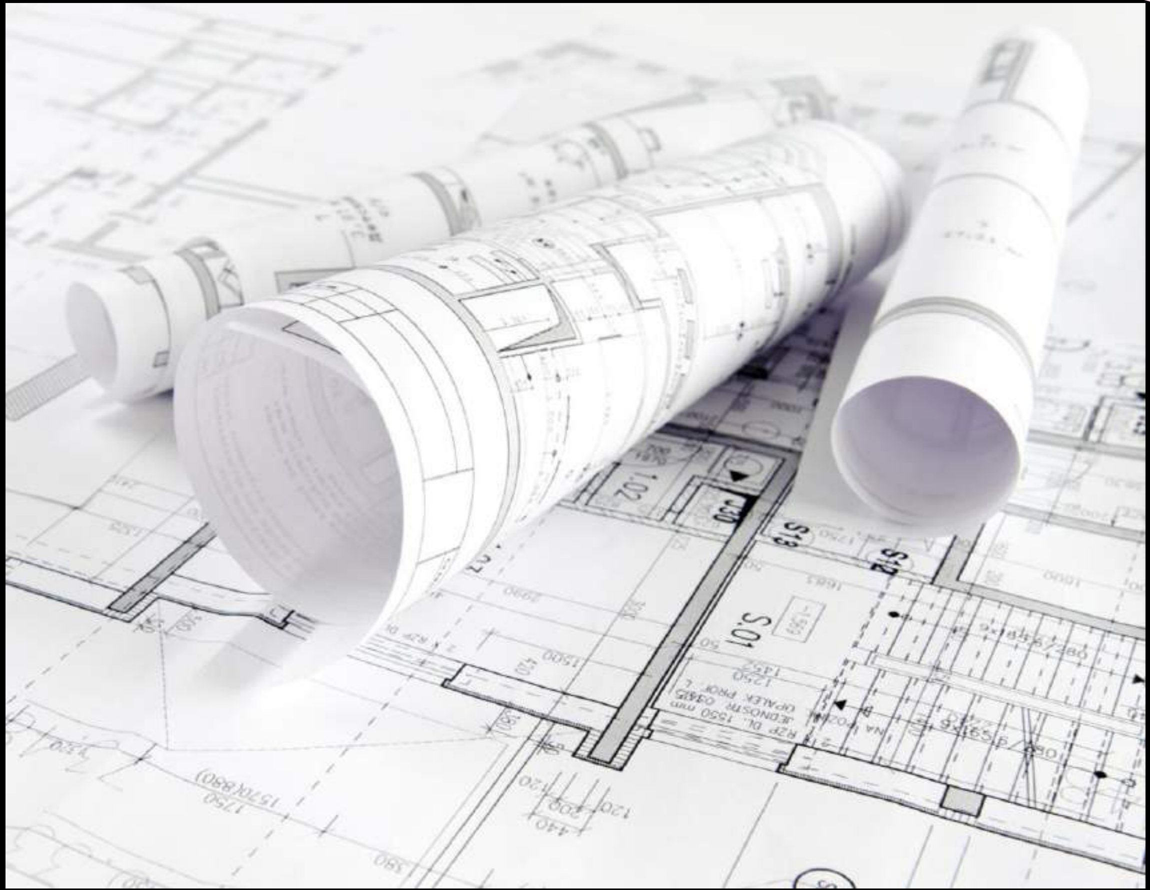
NOTES:

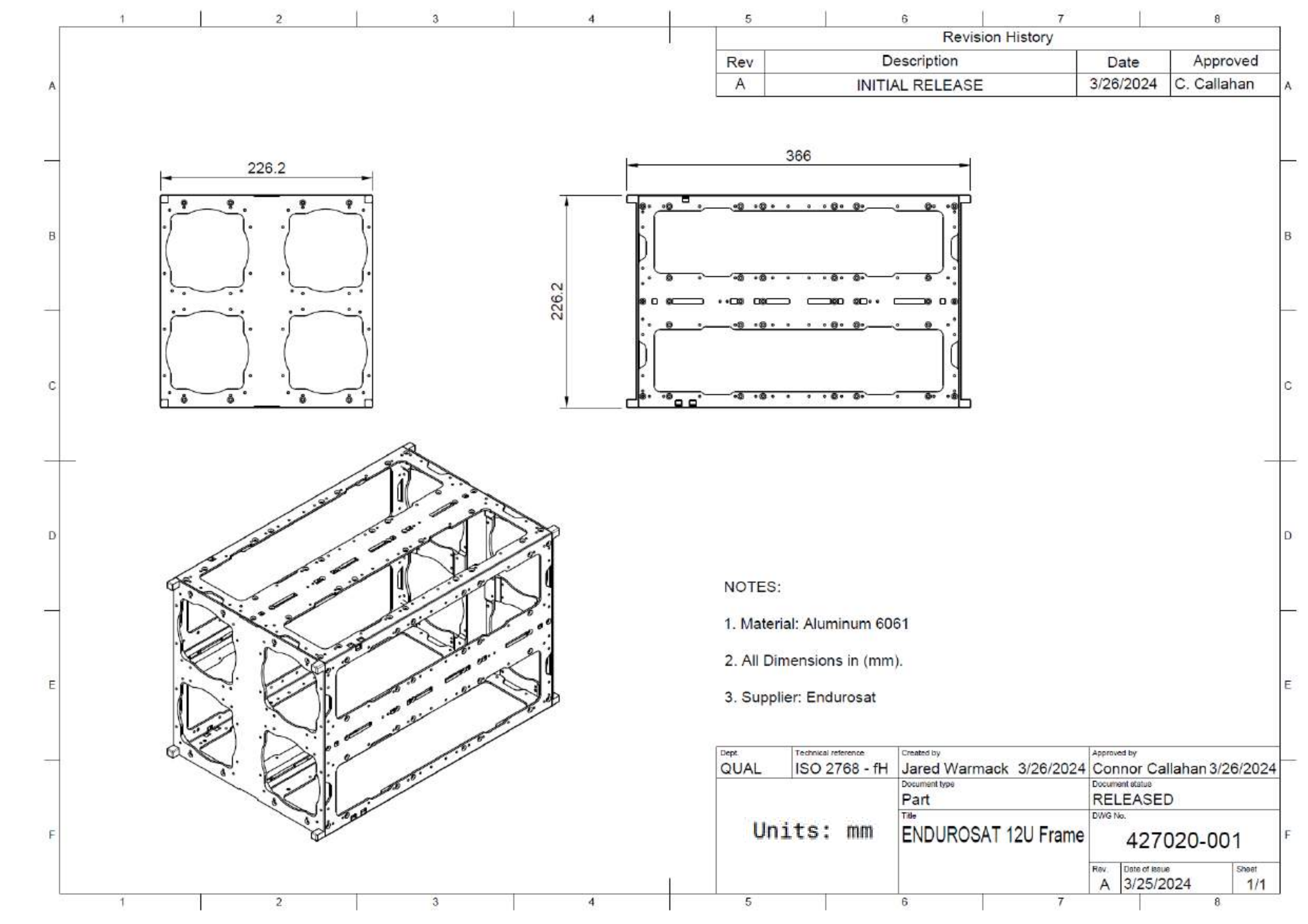
1. Material: Aluminum 6061

2. Solid machining or water jet only.

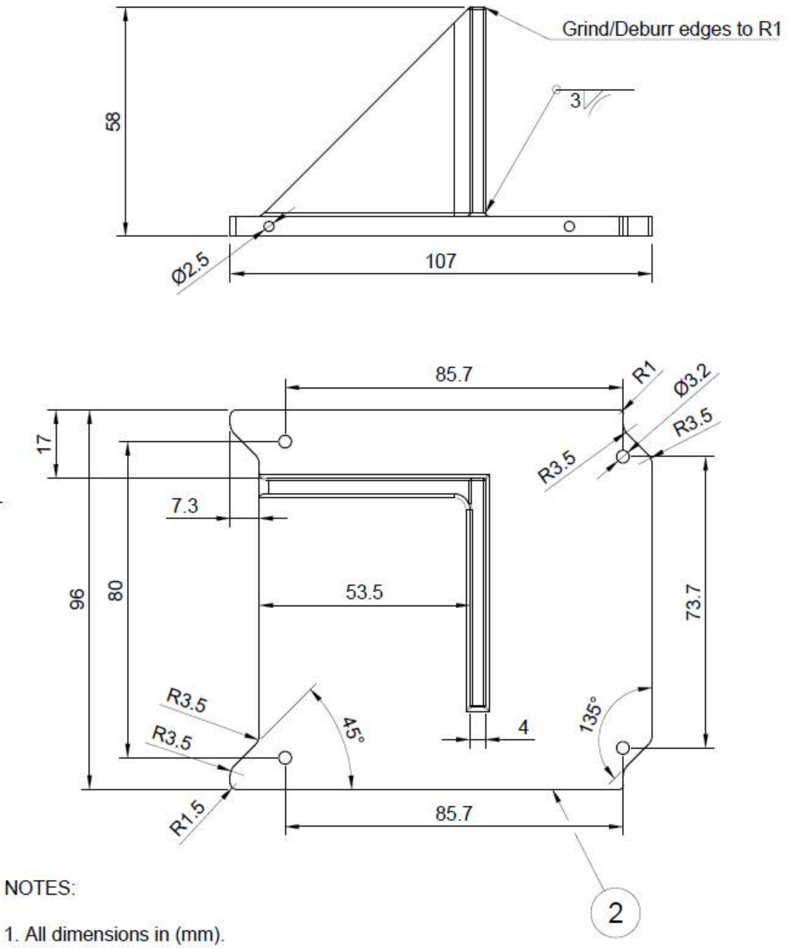
Dept.	Technical reference	Created by	Approved by
QUAL	ISO 2768 - fH	Jared Warmack 2/22/2024	Connor Callahan 2/21/2024
Units: mm		Document type: PART	Document status: RELEASED
		Title: Secondary Mirror Housing	DWG No. 427003-005
			Rev. A · Date of issue 2/22/2024 · Sheet 1/1

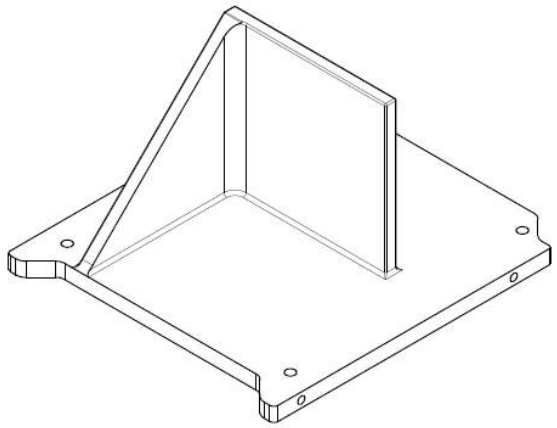
PARTS




Revision History
Rev
Description
Date
Approved
A
INITIAL RELEASE
3/26/2024
C. Callahan
226.2
366
226.2
NOTES:
1. Material: Aluminum 6061
2. All Dimensions in (mm).
3. Supplier: Endurosat
Dept.
QUAL
Technical reference
ISO 2768 - fH
Created by
Jared Warmack 3/26/2024
Approved by
Connor Callahan 3/26/2024
Document type
Part
Document status
RELEASED
Units: mm
Title
ENDUROSAT 12U Frame
DWG No.
427020-001
Rev.
A
Date of issue
3/25/2024
Sheet
1/1

Revision History			
Rev	Description	Date	Approved
A	INITIAL RELEASE	2/21/2024	2/21/2024





Item	Qty	Part Number	Description
2	1	427019-003	RCW XY Bracket

Parts List

NOTES:

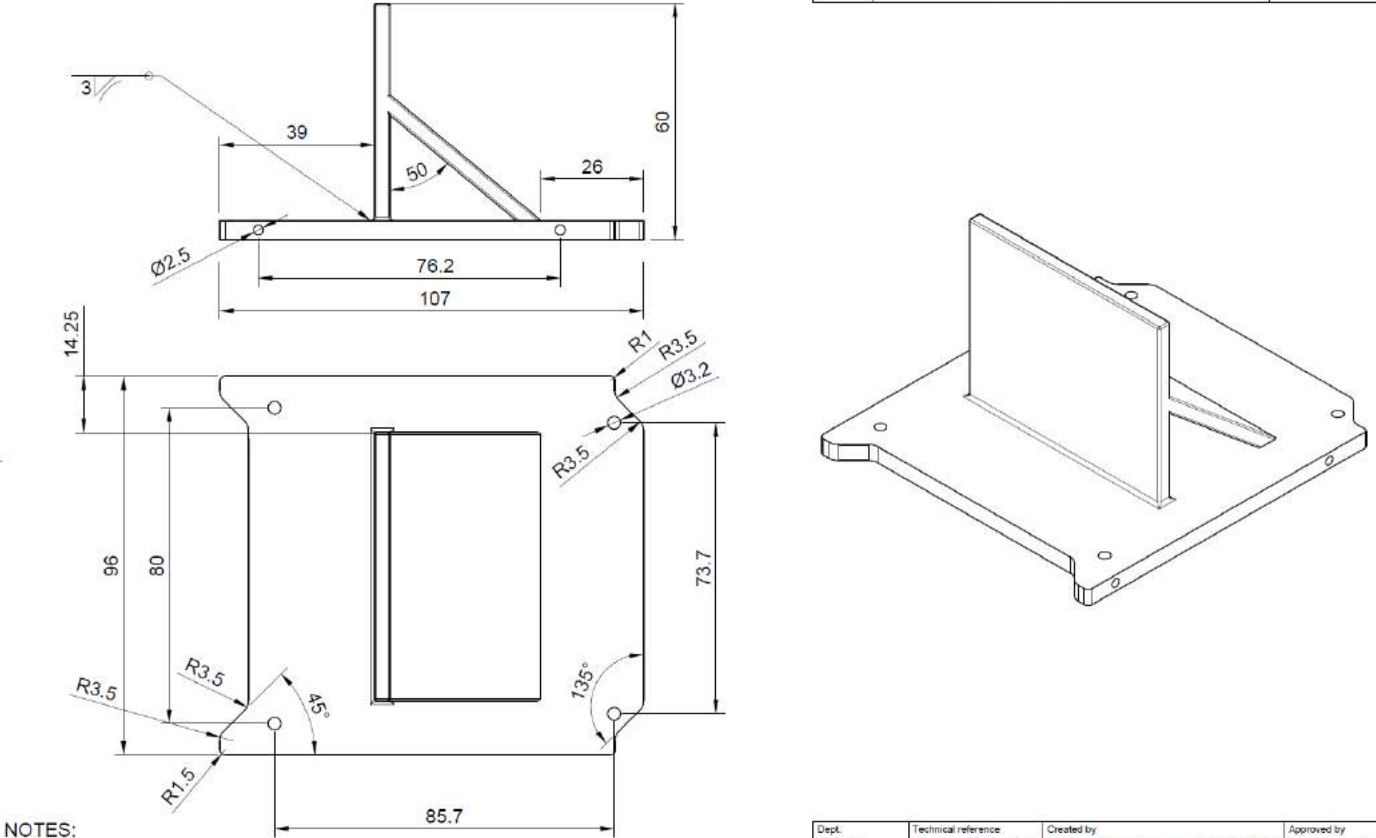
1. All dimensions in (mm).

2. Material: Aluminum 6061

3. Pre-heat to 200°C before welding.

Dept. QUAL	Technical reference ISO 2768 - fH	Created by Jared Warmack 3/26/2024	Approved by Connor Callahan 2/21/2024
Units: mm		Document type ASSEMBLY	Document status RELEASED
		Title RCW X-Y Bracket	DWG No. 427019-003
			Rev. A, Date of issue 2/22/2024, Sheet 1/1

Revision History			
Rev	Description	Date	Approved
A	INITIAL RELEASE	2/21/2024	2/21/2024

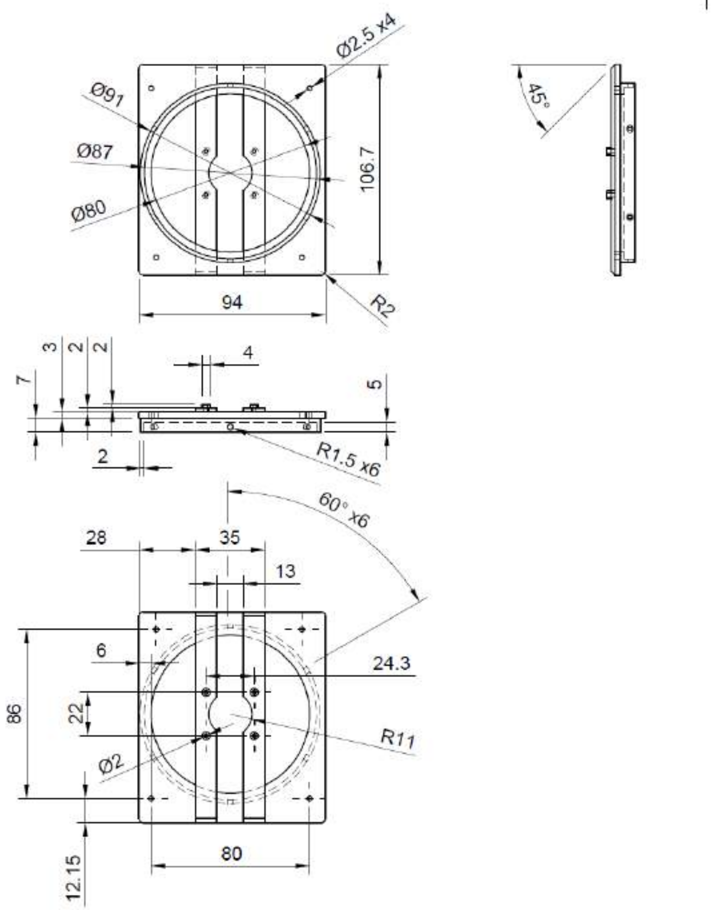


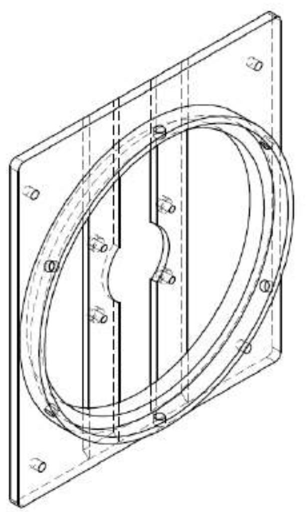
NOTES:

1. All dimensions in (mm).
2. Material: Aluminum 6061
3. Pre-heat to 200°C before welding

Dept.	Technical reference	Created by	Approved by
QUAL	ISO 2768 - fH	Jared Warmack 3/26/2024	Connor Callahan 2/21/2024
Units: mm		Document type: Part	Document status: RELEASED
		Title: RCW Z-XY Bracket	DWG No.: 427019-004
			Rev: A · Date of issue: 2/22/2024 · Sheet: 1/1

Revision History			
Rev	Description	Date	Approved
A	INITIAL RELEASE	3/26/2024	3/26/2024





NOTES:

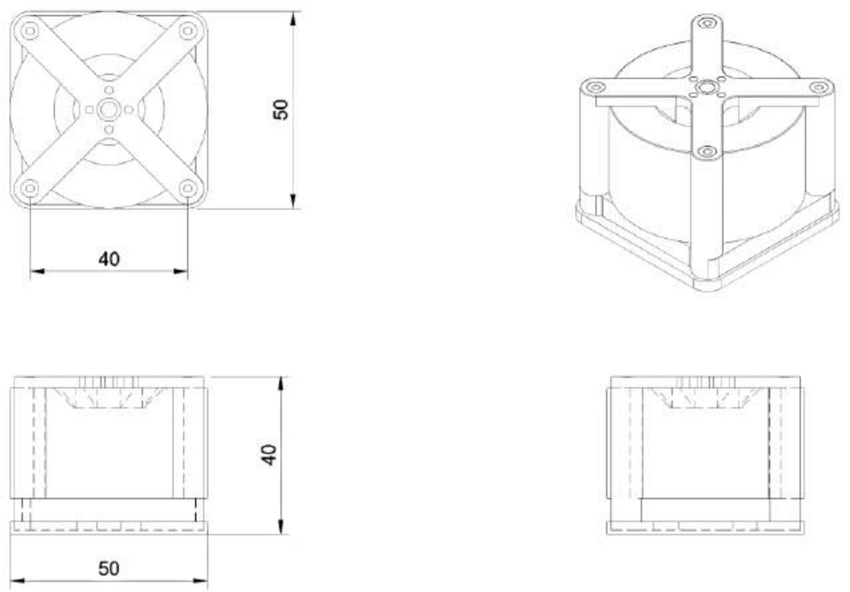
1. Material: Aluminum 6061

2. All Dimensions in (mm).

Dept.	Technical reference	Created by	Approved by
QUAL	ISO 2768 - fH	Jared Warmack 3/26/2024	Connor Callahan 3/26/2024
Units: mm		Document type: PART	Document status: RELEASED
		Title: Primary Mirror Housing	DWG No.: 427003-001
			Rev.: A; Date of issue: 3/26/2024; Sheet: 1/1

Revision History			
Rev	Description	Date	Approved
A	INITIAL RELEASE	11/30/2023	C. Callahan

Details removed for clarity.



NOTES:

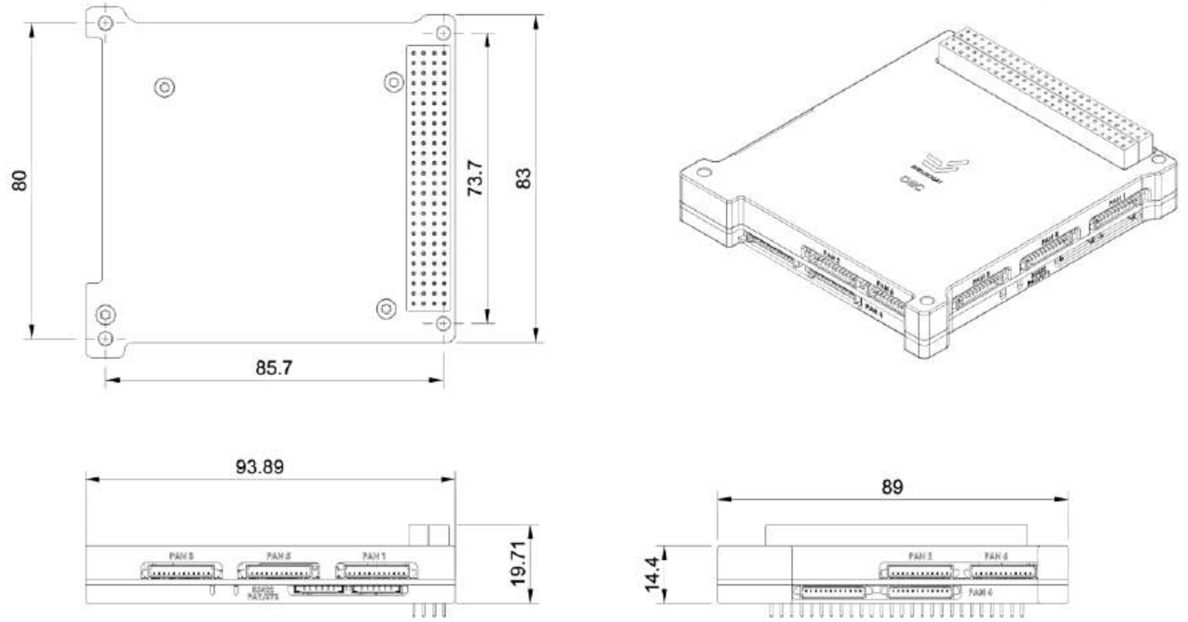
1. Sinclair Interplanetary (Rocket Lab) RW-0.03 Reaction Wheel

2. Mass: 185g

3. COM: Along the center of rotation +20mm above the base.

Dept.	Technical reference	Created by	Approved by
QUAL	ISO 2768 - fH	Jared Warmack 12/1/2023	Connor Callahan 12/01/2023
Units: mm		Document type: PART	Document status: RELEASED
		Title: Reaction Wheel - 30 mNm s	DWG No. 427001-001
			Rev. A · Date of issue 11/30/2023 · Sheet 1/1

Revision History			
Rev	Description	Date	Approved
A	INITIAL RELEASE	12/1/2023	C. Callahan

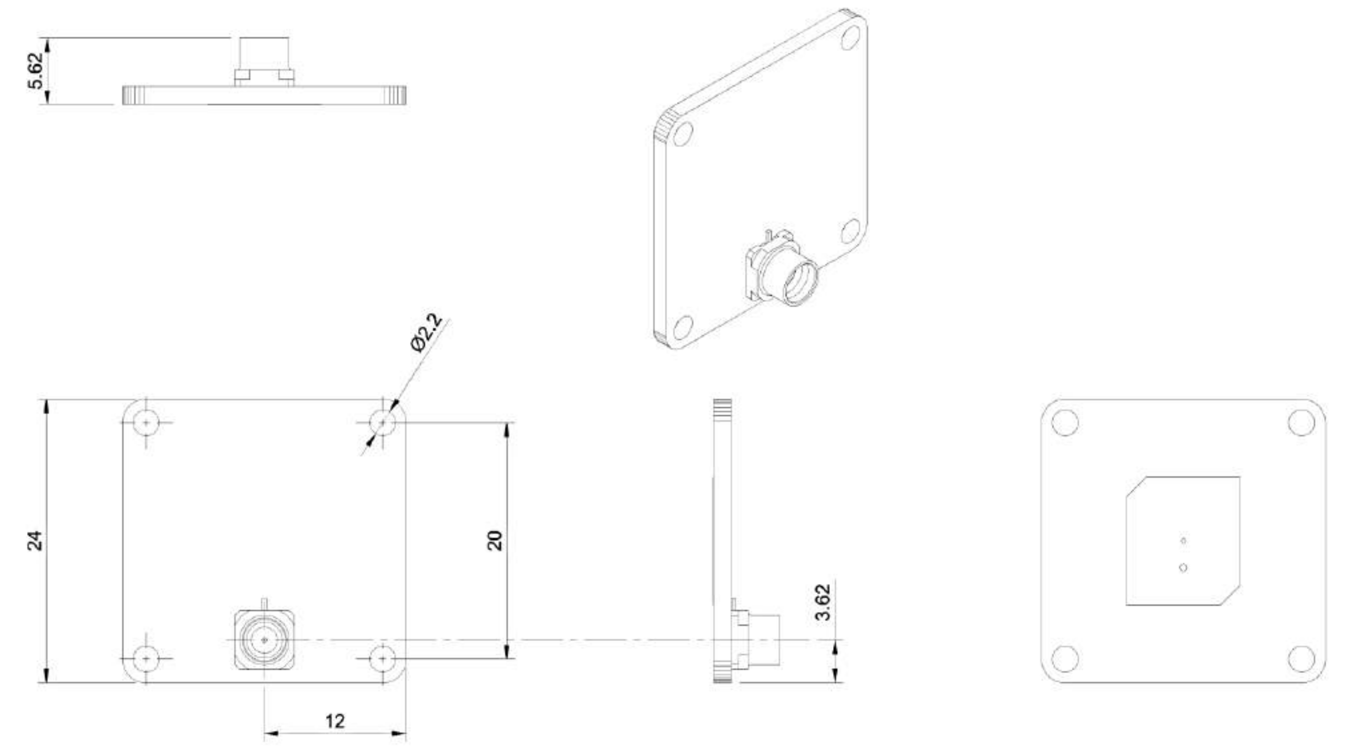


NOTES:

1. Endurosat Onboard Computer (OBC)
2. Mass: <130g

Dept.	Technical reference	Created by	Approved by
QUAL	ISO 2768 - fH	Jared Warmack 12/1/2023	Connor Callahan 12/01/2023
Units: mm		Document type: PART	Document status: RELEASED
		Title: Onboard Computer	DWG No. 427005-001
			Rev. A; Date of issue 12/01/2023; Sheet 1/1

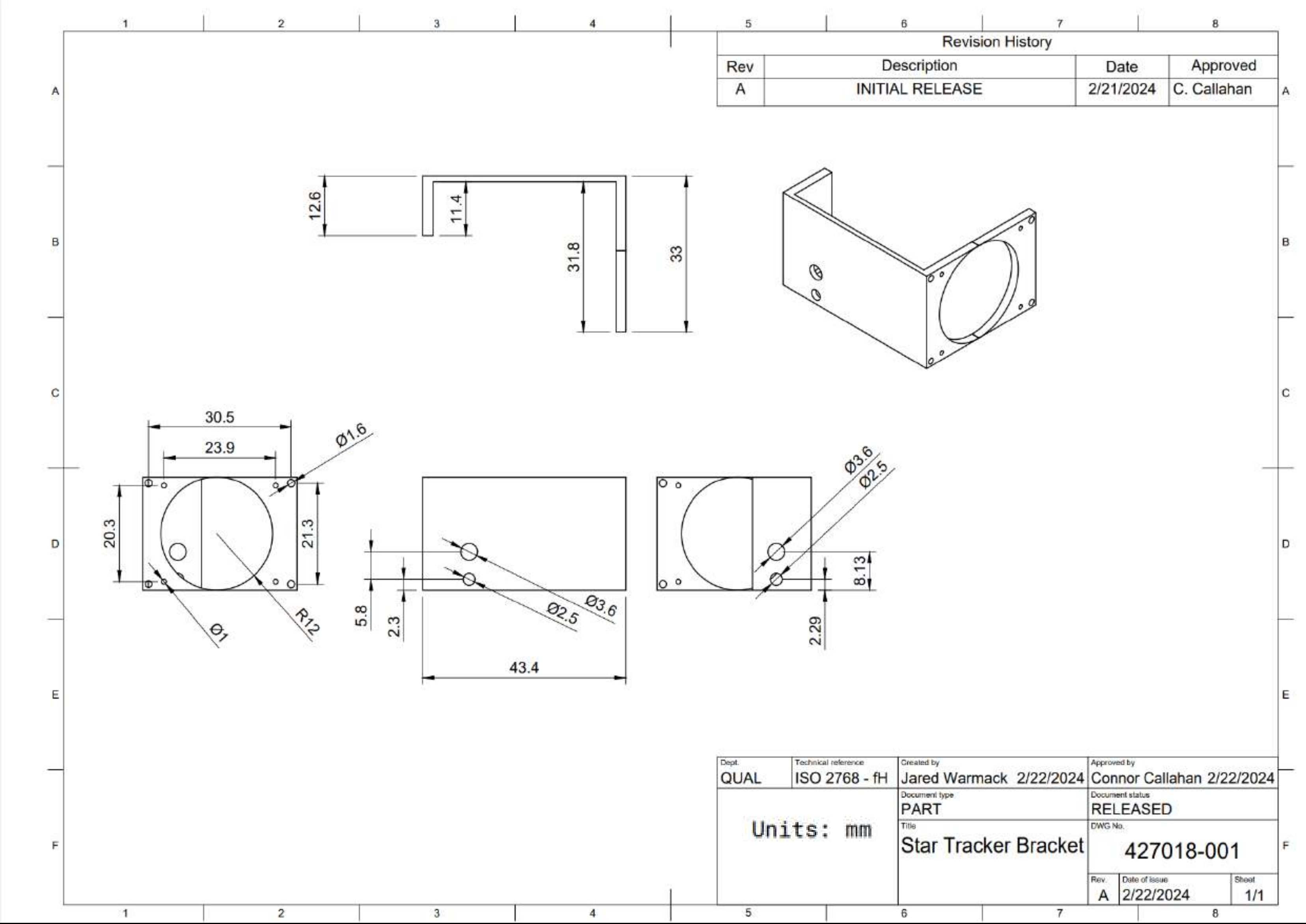
Revision History			
Rev	Description	Date	Approved
A	INITIAL RELEASE	12/1/2023	C. Callahan



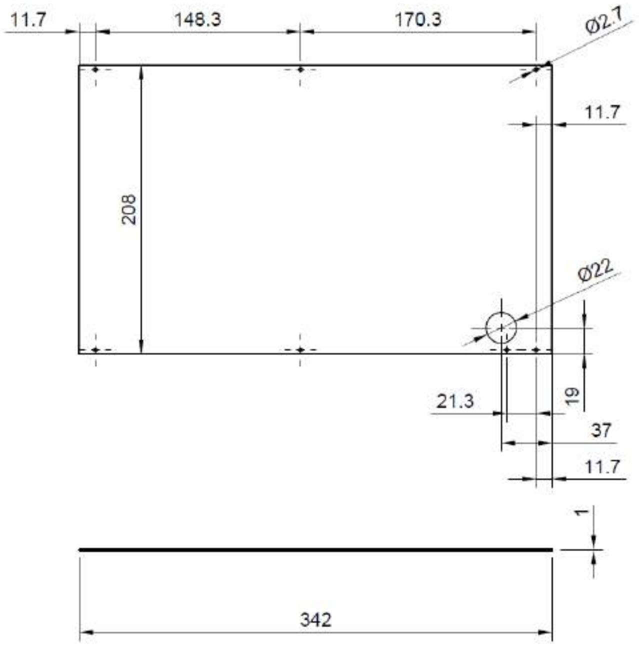
NOTES:

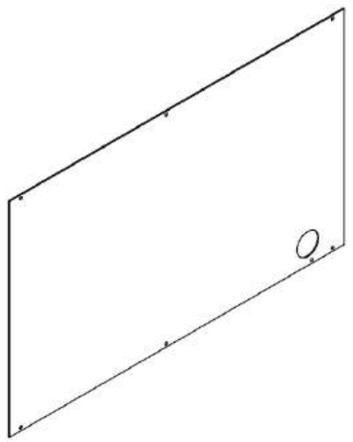
1. Endurosat X-Band Patch Antenna
2. Mass: <3g

Dept.	Technical reference	Created by	Approved by
QUAL	ISO 2768 - fH	Jared Warmack 12/1/2023	Connor Callahan 12/01/2023
Units: mm		Document type: PART	Document status: RELEASED
		Title: X-Band Antenna Patch	DWG No.: 427008-001
			Rev.: A; Date of issue: 12/01/2023; Sheet: 1/1


Revision History
Rev
Description
Date
Approved
A
INITIAL RELEASE
2/21/2024
C. Callahan
12.6
11.4
31.8
33
30.5
23.9
Ø1.6
20.3
21.3
Ø1
R12
5.8
2.3
Ø2.5
Ø3.6
43.4
Ø3.6
Ø2.5
8.13
2.29
Dept.
QUAL
Technical reference
ISO 2768 - fH
Created by
Jared Warmack 2/22/2024
Approved by
Connor Callahan 2/22/2024
Units: mm
Document type
PART
Document status
RELEASED
Title
Star Tracker Bracket
DWG No.
427018-001
Rev.
A
Date of issue
2/22/2024
Sheet
1/1

Revision History			
Rev	Description	Date	Approved
A	INITIAL RELEASE	2/21/2024	2/21/2024





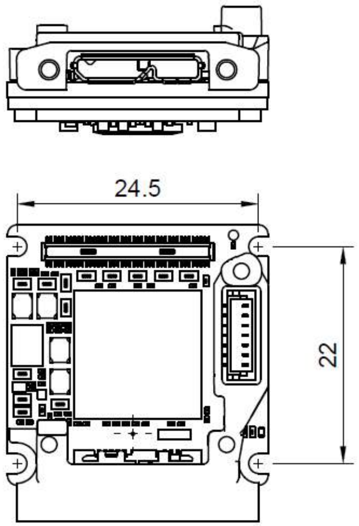
NOTES:

1. Material: Aluminum 6061

2. All Dimensions unless otherwise specified in (mm).

Dept.	Technical reference	Created by	Approved by
QUAL	ISO 2768 - fH	Jared Warmack 2/21/2024	Connor Callahan 2/21/2024
Units: mm		Document type: PART	Document status: RELEASED
		Title: Shielding (Side)	DWG No.: 427025-001
			Rev.: A; Date of issue: 2/22/2024; Sheet: 1/1

Revision History			
Rev	Description	Date	Approved
A	INITIAL RELEASE	3/29/2024	



NOTES:

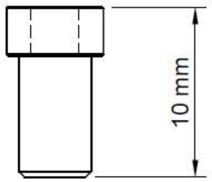
1. Dimensions for reference only.

2. All dimensions in (mm).

3. Supplier: Allied Vision

Dept.	Technical reference	Created by	Approved by
QUAL	ISO 2769 - fH	Jared Warmack 3/29/2024	C. CALLAHAN 3/26/2024
Units: mm		Document type: PART	Document status: RELEASED
		Title: Alvium USB90	DWG No.: 427033-001
			Rev.: A; Date of issue: 3/26/2024; Sheet: 1/1

Revision History			
Rev	Description	Date	Approved
A	INITIAL RELEASE	3/29/2024	C. CALLAHAN



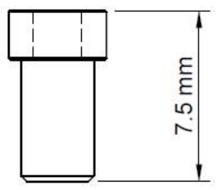
NOTES:

1. Material A-286 Stainless Steel

2. M2 thread

Dept. QUAL	Technical reference ISO 2768 -fH	Created by Jared Warmack 3/29/2024	Approved by C. CALLAHAN 3/26/2024
Units: mm		Document type PART	Document status RELEASED
		Title Bolt M2 x 10	DWG No. 427032-001
			Rev. A · Date of issue 3/26/2024 · Sheet 1/1

Revision History			
Rev	Description	Date	Approved
A	INITIAL RELEASE	3/29/2024	C. CALLAHAN



NOTES:

1. Material A-286 Stainless Steel

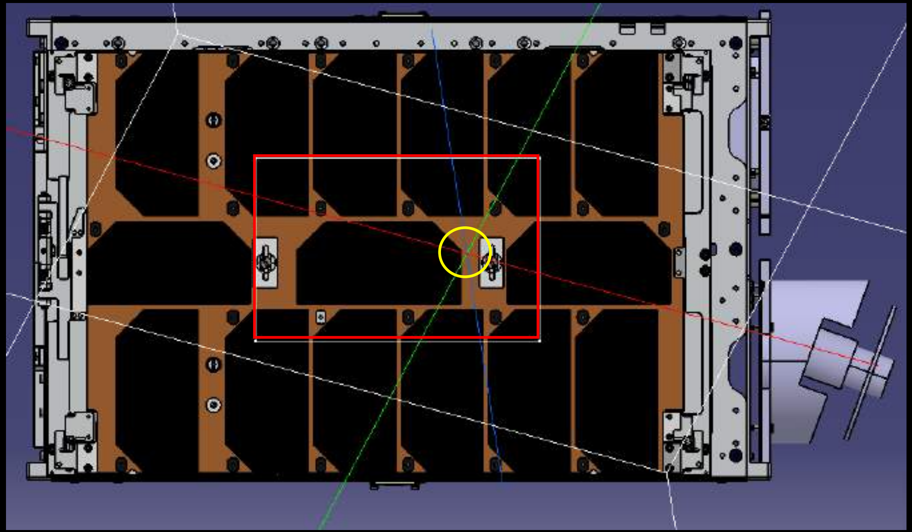
2. M3 thread

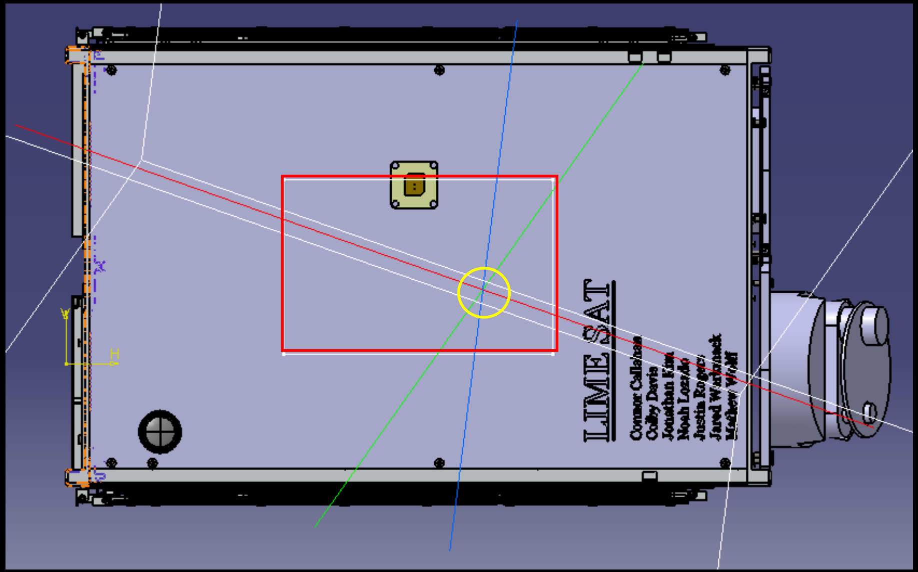
Dept.	Technical reference	Created by	Approved by
QUAL	ISO 2768 -fH	Jared Warmack 3/29/2024	C. CALLAHAN 3/26/2024
Units: mm		Document type: PART	Document status: RELEASED
		Title: Bolt M3 x 7.5	DWG No.: 427031-001
			Rev.: A / Date of issue: 3/26/2024 / Sheet: 1/1

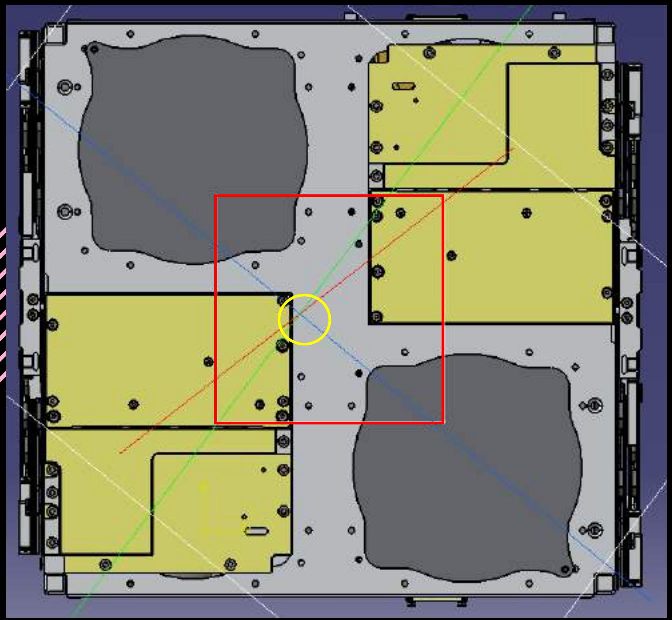
Assembly Procedures

- First, assemble Solar Shade Sub-assembly
- Next, assemble the following sub-assemblies: Avionics Bus, Mirror(uses Solar Shade sub-assembly), Primary Mirror RCW Z-XY, RCW X-Y
- Next, install Avionics Bus onto frame
- Next, install Thruster, Mirror, Primary Mirror, RCW Z-XY, RCW X-Y sub-assemblies onto frame, wiring up with Avionics Bus
- Next, install remaining parts except for solar panels and shielding, wiring up with Avionics Bus as needed
- Next, install solar panels and wire up with Avionics bus
- Finally, install shielding onto rest of CubeSAT

Center of Mass (Stowed)







Constraints:

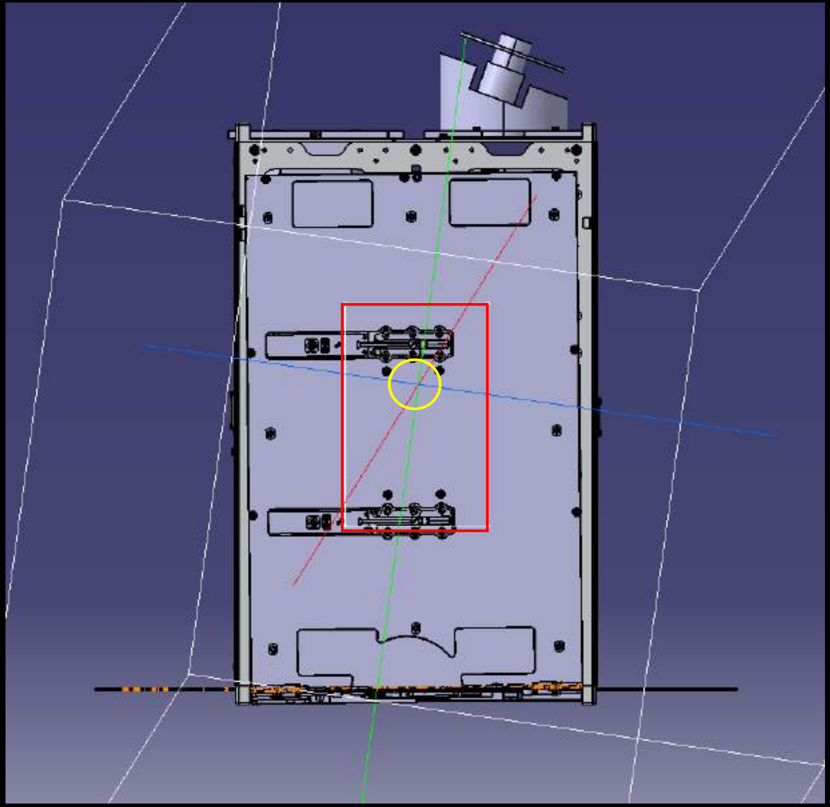
- X = +/- 45 mm
- Y = +/- 45 mm
- Z = +/- 70 mm
- Values are within constraints

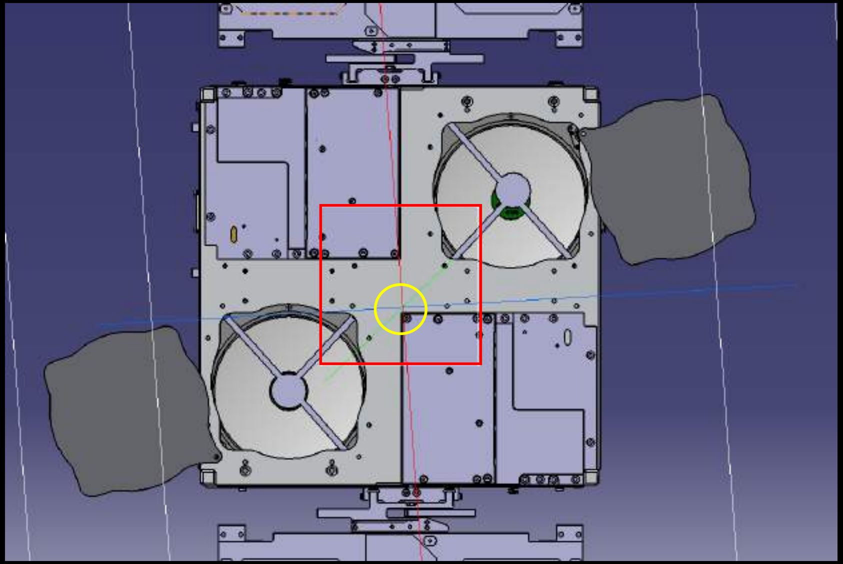
Red Boxes: Constraints

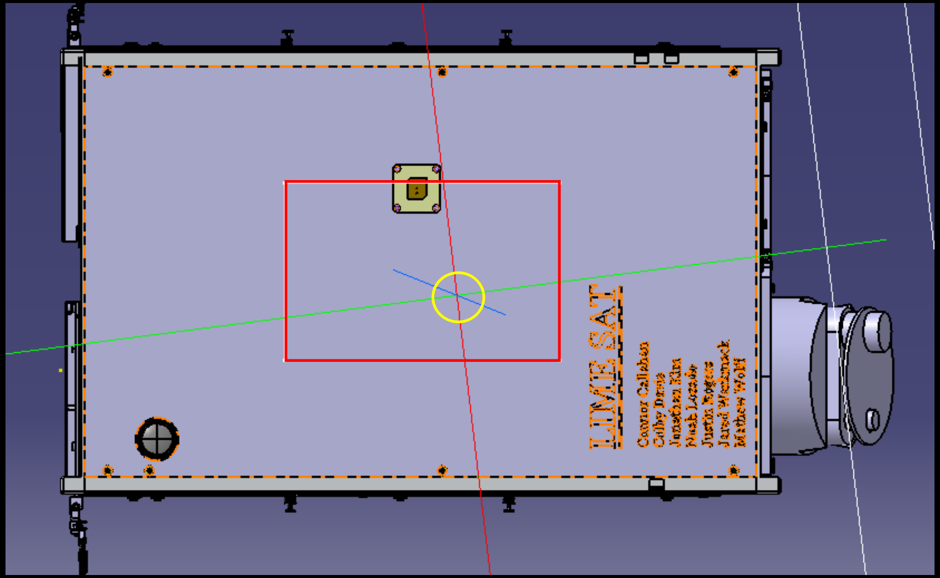
Yellow Circles:

CG location

Center of Mass (Deployed)







Constraints:

- X = +/- 45 mm
- Y = +/- 45 mm
- Z = +/- 70 mm
- Values are within constraints

Red Boxes: Constraints

Yellow Circles:

CG location

Moment of Inertia (Deployed)

- All units in grams * square millimeters ($g * mm^2$)
- L_{xx} = 288589048.80 L_{xy} = -3813100.15 L_{xz} = 6896655.06
- L_{yx} = -3813100.15 L_{yy} = 330596142.62 L_{yz} = -8296628.53
- L_{zx} = 6896655.06 L_{zy} = -8296628.53 L_{zz} = 85853689.05

Moment of Inertia (Stowed

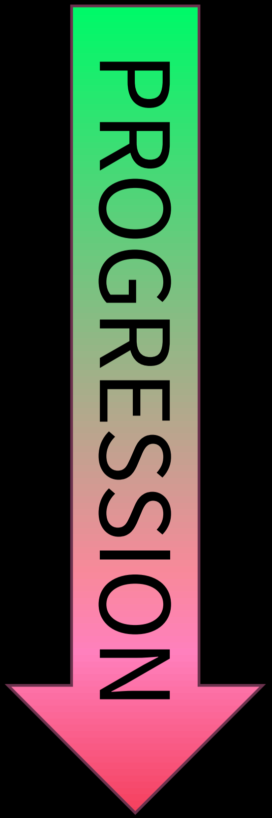
All units in grams * square millimeters

L_{xx} = 47257199.31 L_{xy} = -3805456.06 L_{xz} = 6091600.64

L_{yx} = -3805456.06 L_{yy} = 74660846.15 L_{yz} = -7754612.55

L_{zx} = 6091600.64 L_{zy} = -7754612.55 L_{zz} = 70511403.51

Vibration Analysis



- **Cumulative Mass Fractions** (% of total mass which has contributed to *a* mode)
- **Participation Factors** (is the mass contributing to or dampening vibration)
- **Effective Masses** (Amount of mass participating in each *discrete* mode)
- **Ratios** (How significant each mode is WRT the *most significant* mode)
- **Effective Mass Ratio** (% of total mass participating in each mode)
- **Frequency Response and Stress-Strain-Deformation Analysis**

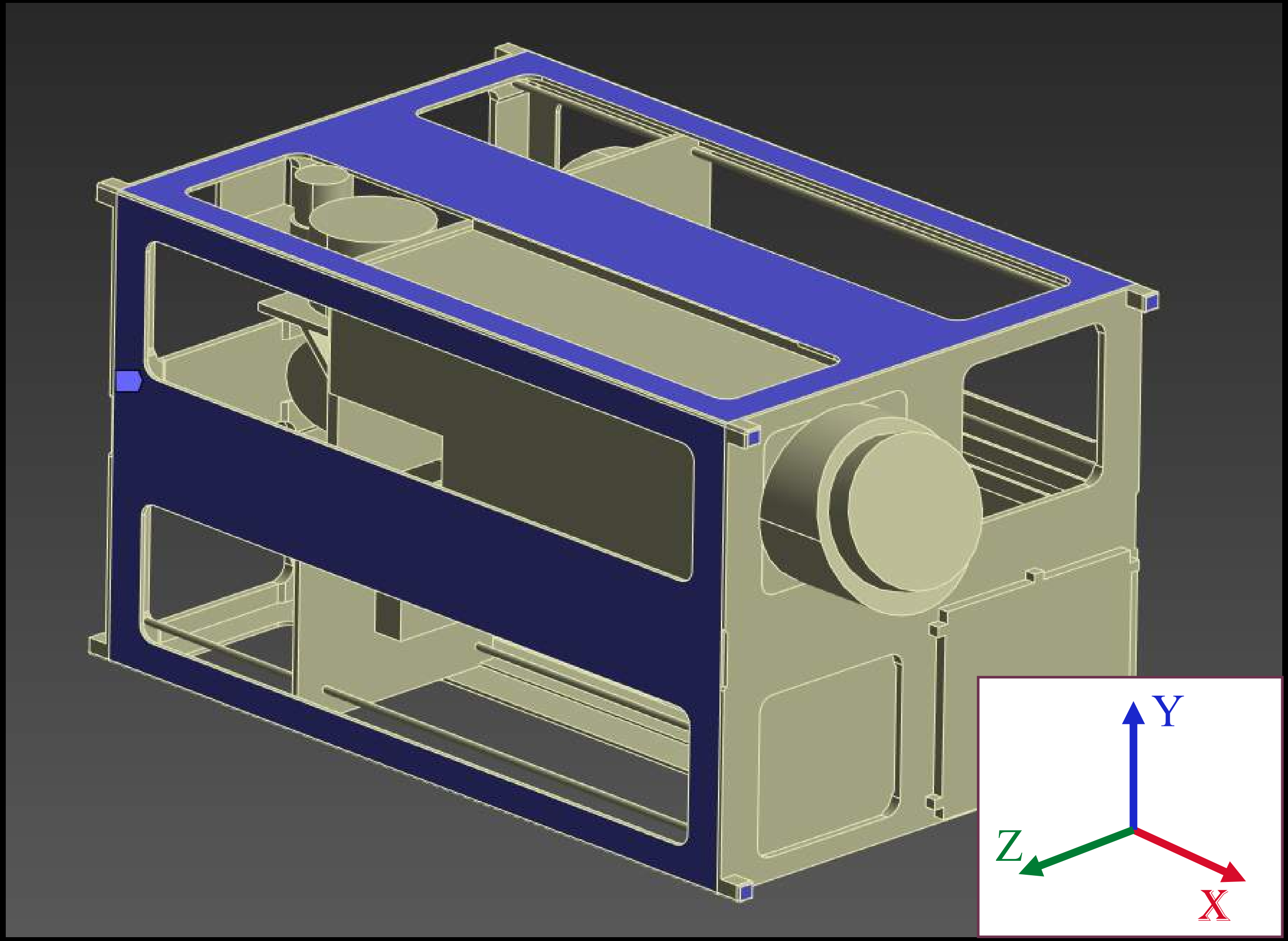
Assumptions

Coordinate System Definition:

Due to how ANSYS imported the geometry, the Z and X directions have been transformed such that:

- X is the primary axis
- Y and Z are the minor axes.

All Harmonics were solved for a 3.5g "launch scenario" case, sweeping a range from 10Hz to 20kHz

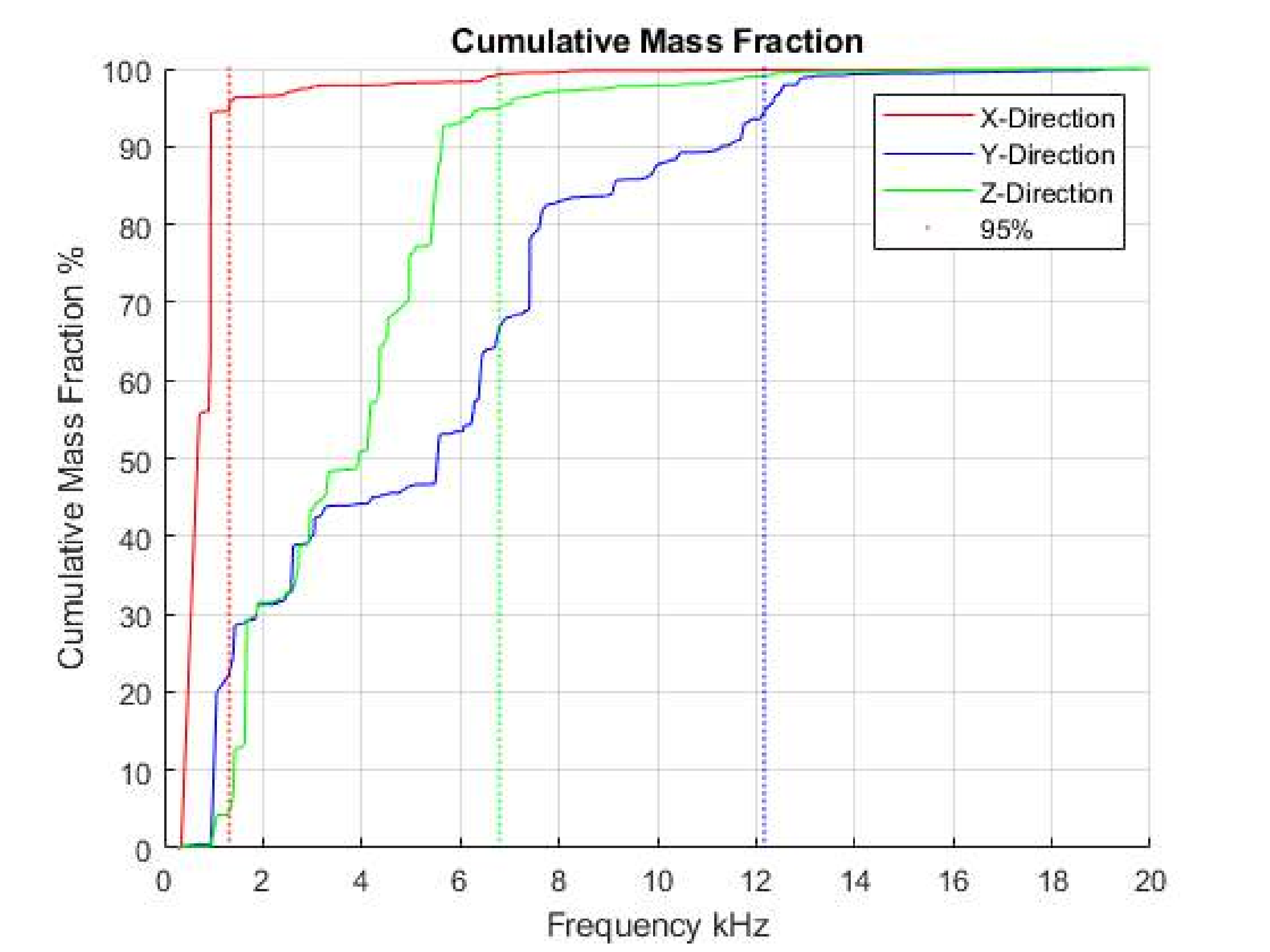


Cumulative Mass Fractions

- After 95% of the mass has contributed to a mode, we truncate the data.
- Each coordinate has a different cut-off frequency

- X: ~1600Hz
- Y: ~12000Hz
- Z: ~7000Hz

- All *significant* data will be located below these frequencies.



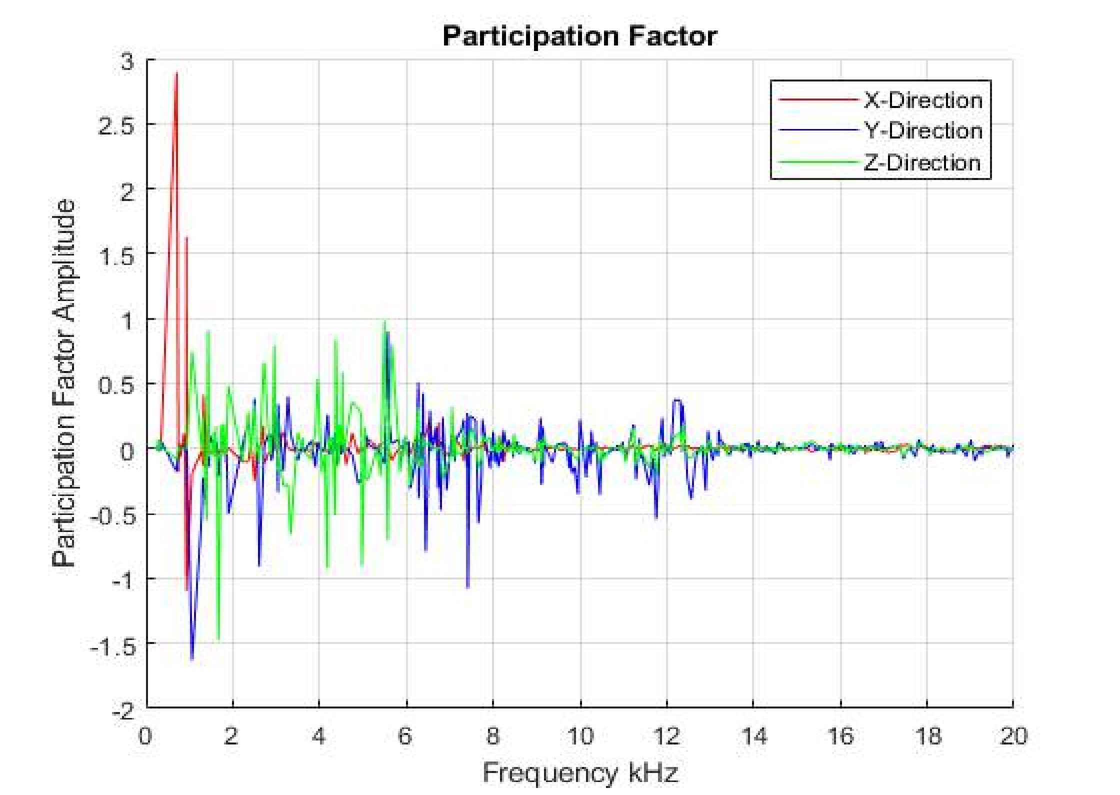
Participation Factor

- The participation factor is a measure of the mass's contribution to the excitation in a coordinate direction.

- Contributions can either be positive or negative. <u>Both</u> contribute to deformation and must be considered.

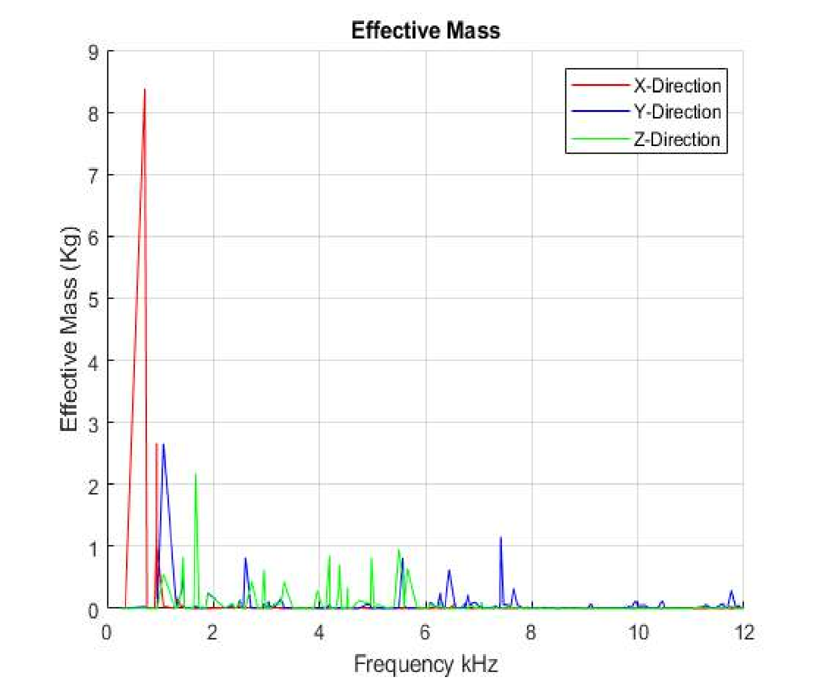
- **Negative Factor:** Deformation is opposite of vibration direction

- **Positive Factor:** Deformation is in the vibration direction

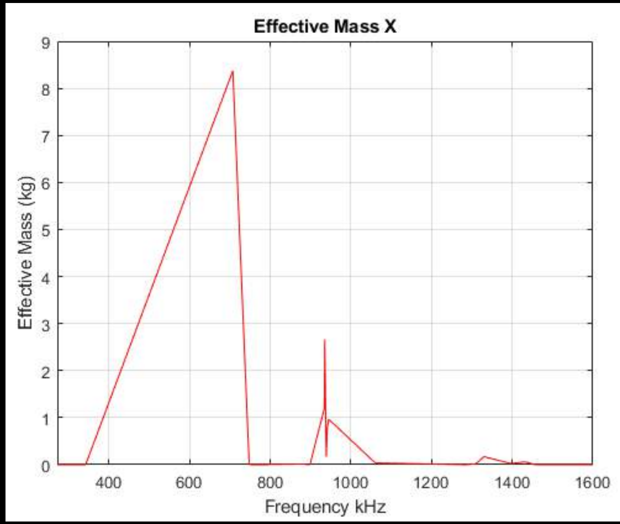


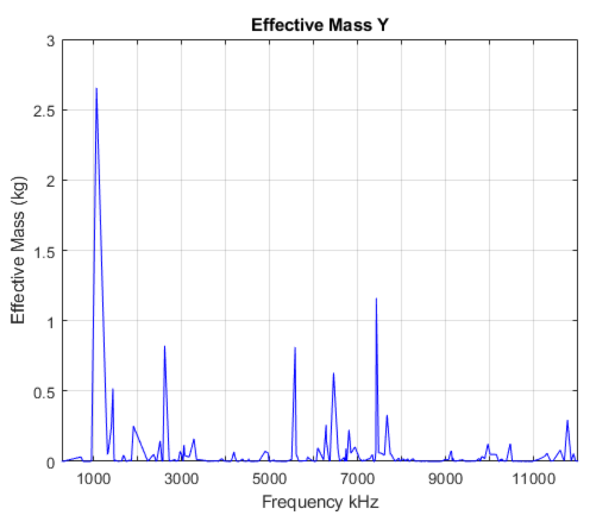
Effective Masses

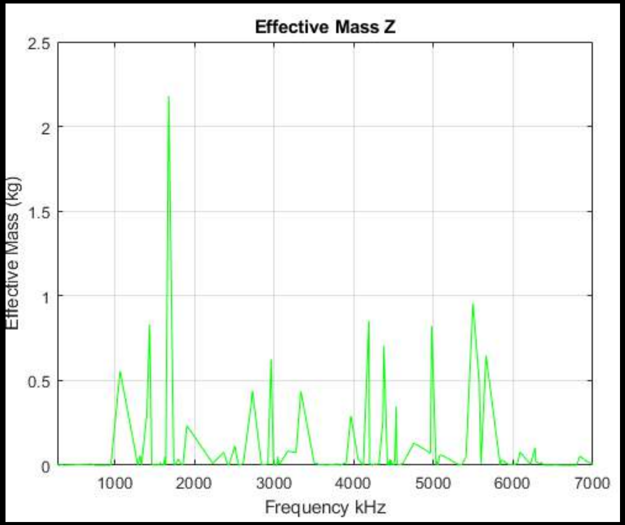
- Demonstrates in kilograms how much of the body mass participates in each mode.
- The second mode (707Hz) is noteworthy for having the highest effective mass.
- The higher in frequency we go the fewer significant modes we find.
- We will further narrow down which modes are significant by analyzing their ratios.



Effective Masses Cont.







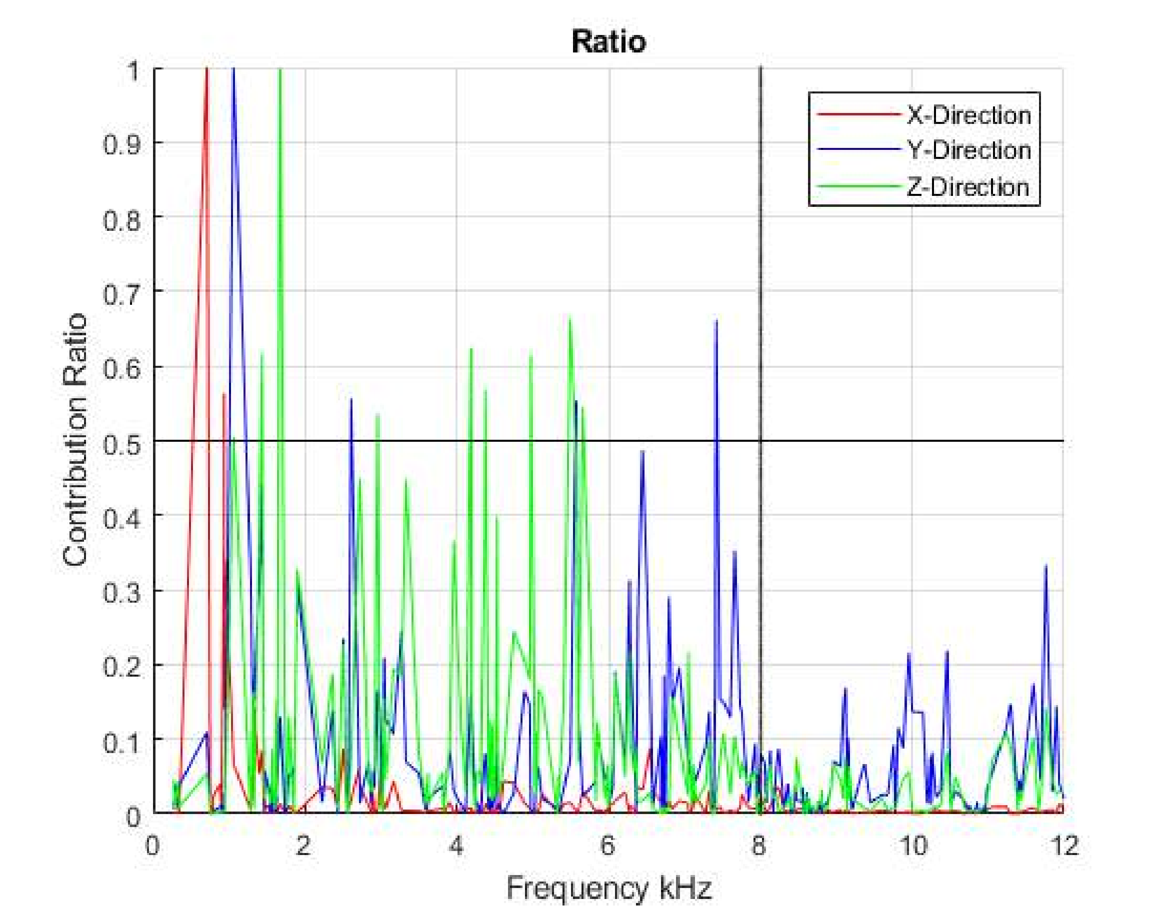
- X Direction has a few highly significant modes
- Y Direction has a widely spread distribution of decreasingly significant modes
- Z Direction has an evenly distributed grouping of significant modes

Ratios

- The Ratio is the measure of each mode as a fraction of that direction's <u>most significant mode</u>.

- In this analysis we have chosen to only observe modes which are at least *half* as energetic as the most significant modes in each direction. This corresponds to all modes which have peaks in the upper left quadrant of figure.

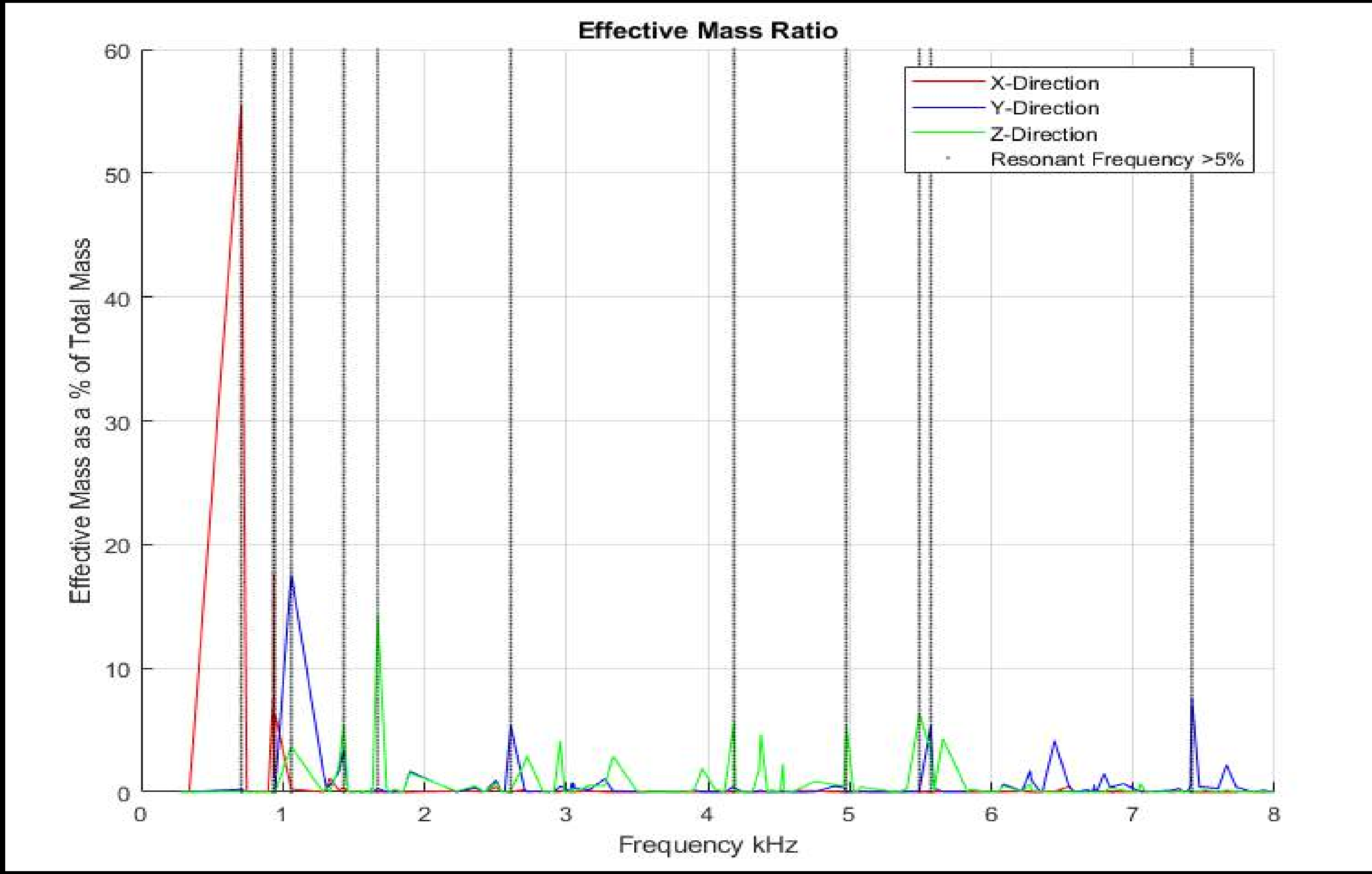
- This corresponds to frequencies all below 8000Hz



Effective Mass Ratio’s

- The EMR is % of the total body’s mass which participates in excitation of a mode.

- Here, 12 modes are highlighted. Each has a contribution from at least 5% of the total mass of the structure in a single direction’s excitation.



Effective Mass Ratio’s Cont.

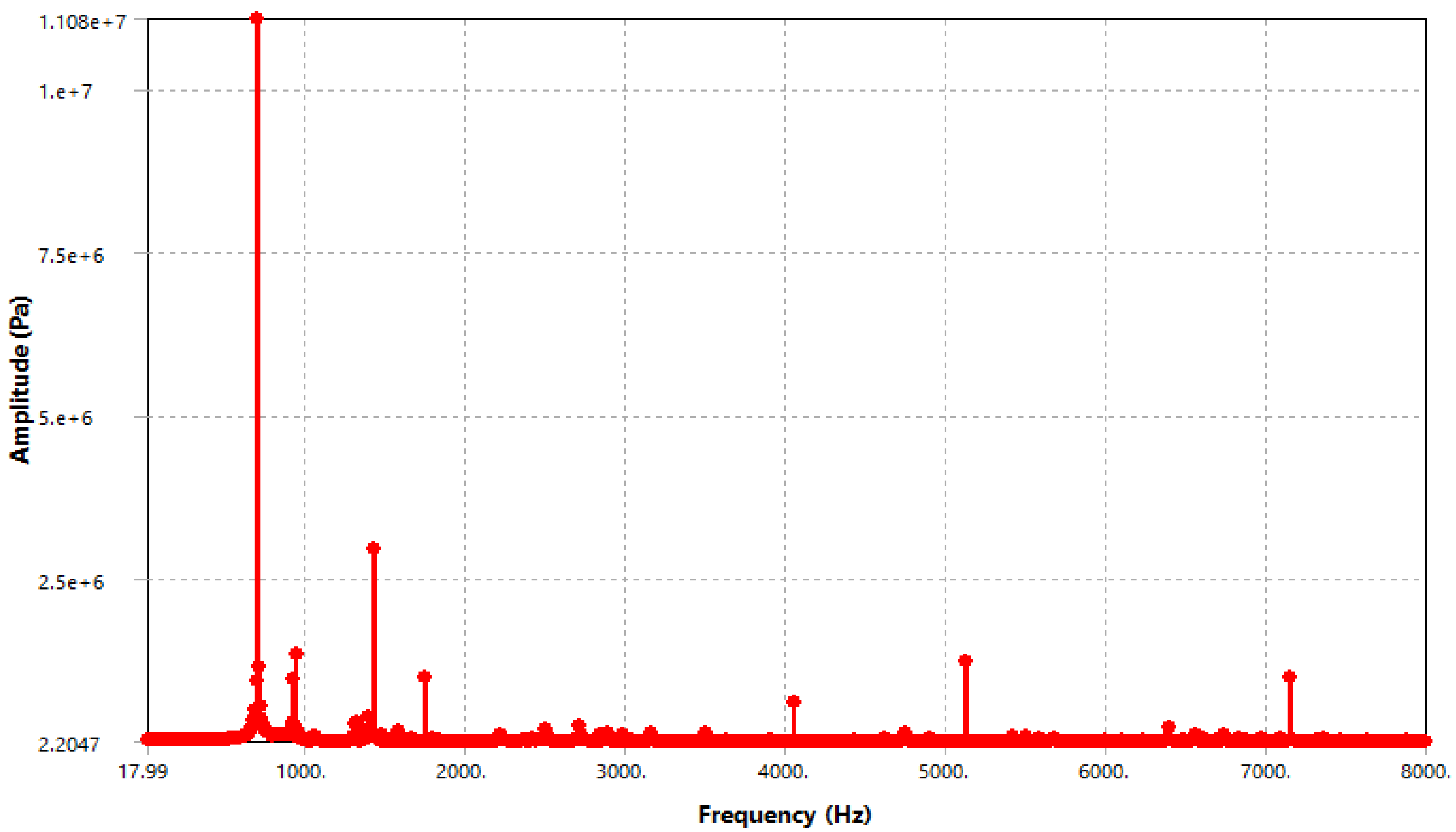
- 12 Modes meet the criteria for our attention.

- X-Direction (Primary Axis)
- Y-Direction (1st Transverse Axis)
- Z-Direction (2nd Transverse Axis)

- We will observe the harmonic effects at these frequencies in the next slides, starting with the most significant.

Effective Mass Ratio	Frequency (Hz)
55.8 %	707 Hz
17.48 %	945 Hz
17.48 %	1060 Hz
14.47 %	1670 Hz
7.84 %	7416 Hz
6.63 %	944 Hz
6.33 %	5494 Hz
5.73 %	2608 Hz
5.73 %	4185 Hz
5.73 %	4976 Hz
5.73 %	5572 Hz
5.43 %	1431 Hz

Frequency Response – Stress X Axis



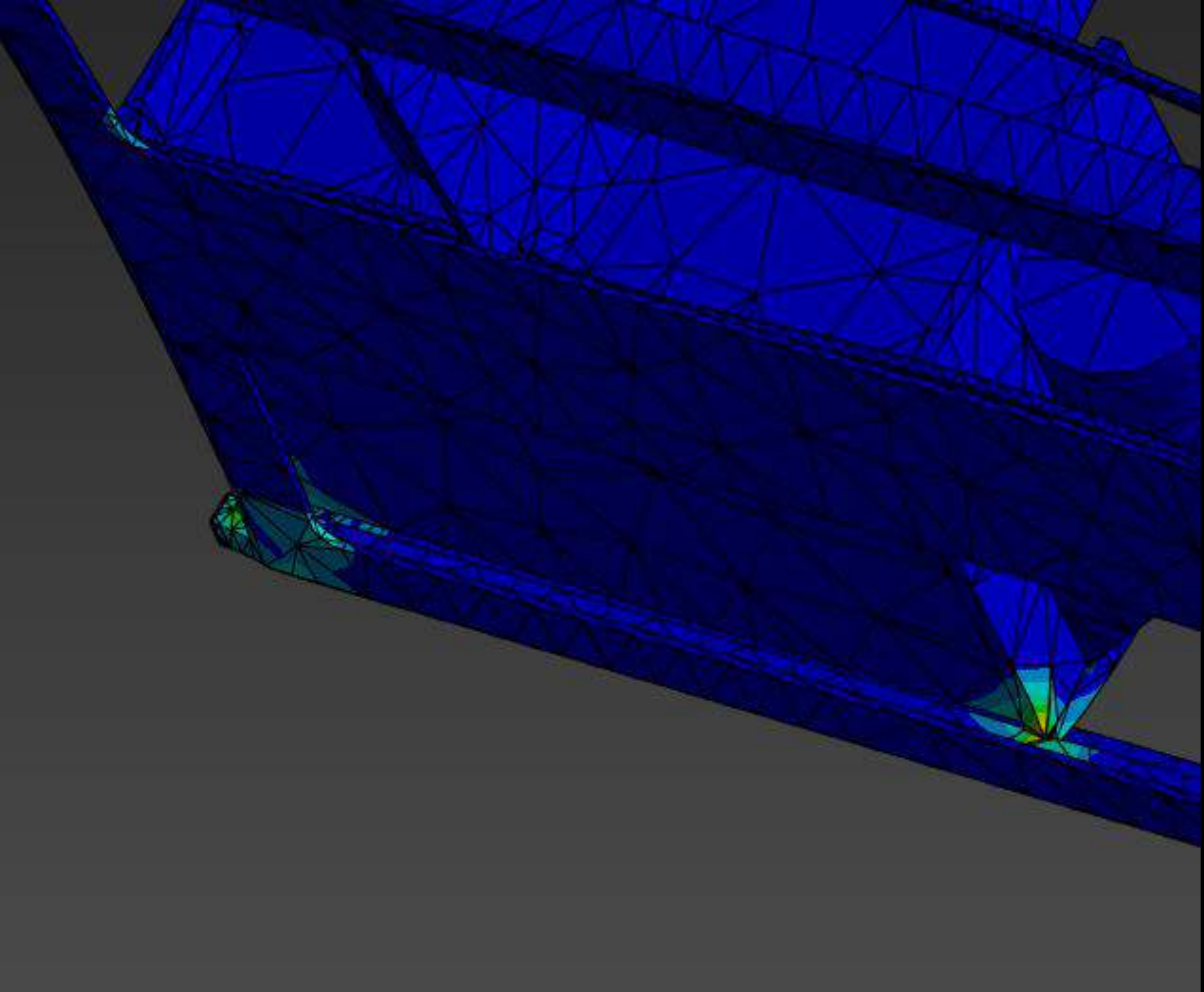
Frequency vs Maximum Stress:

Most Significant Mode: 707 Hz
Max Stress: 11 Mpa

Max Allowable Stress: 240 Mpa

F.O.S = 21.8

Since the most significant mode satisfies the safety criteria, we will omit the calculations for the remaining modes.

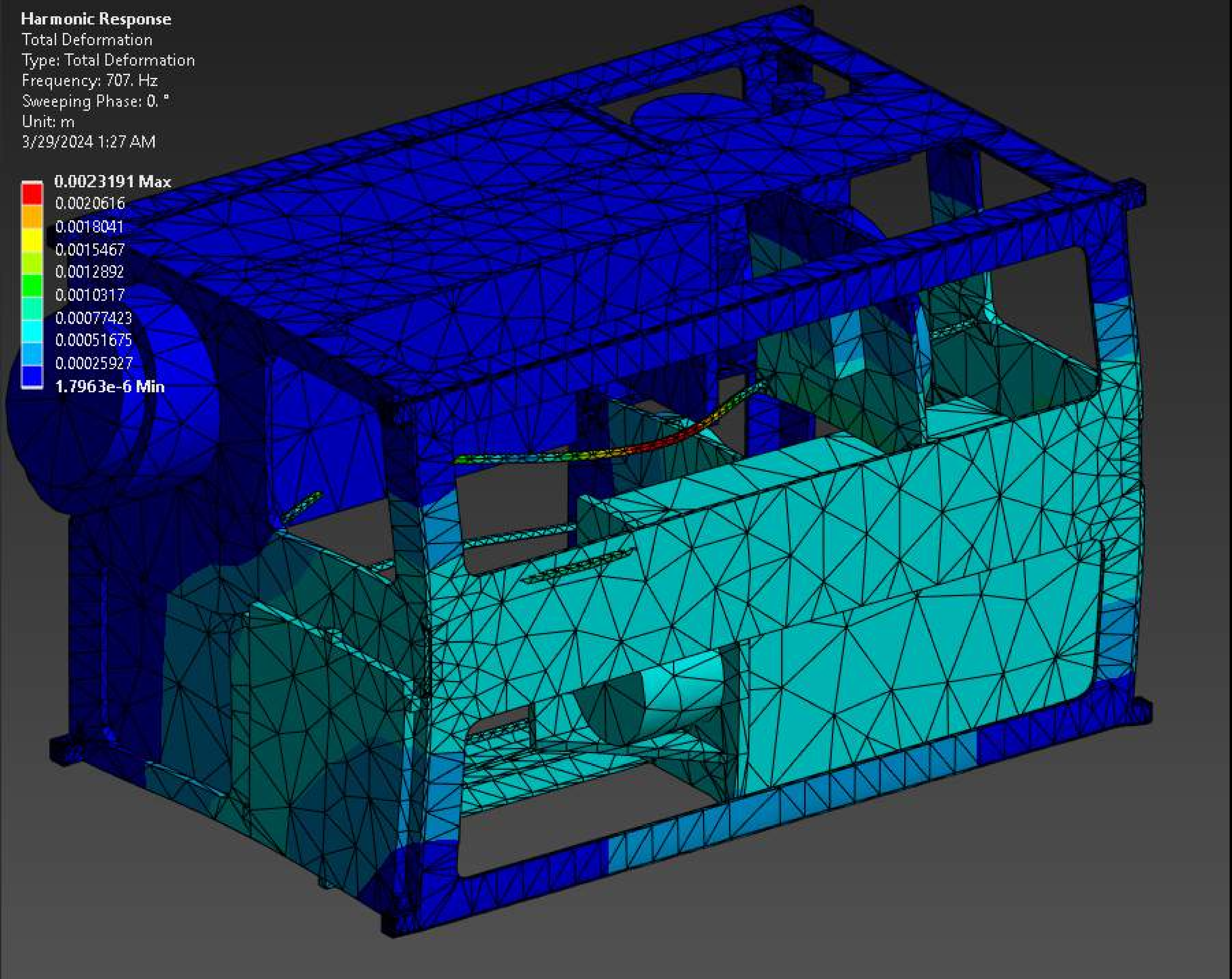


Stress Concentration 707 Hz

<u>Von Mises Stress at 707 Hz</u>

Feet and RCW bracket welds carry highest concentrations of stress.

Maxima are well within allowable limits (previous slide), but additional supports may be considered to prevent fatigue stress cracks from forming.



Deformation 707 Hz

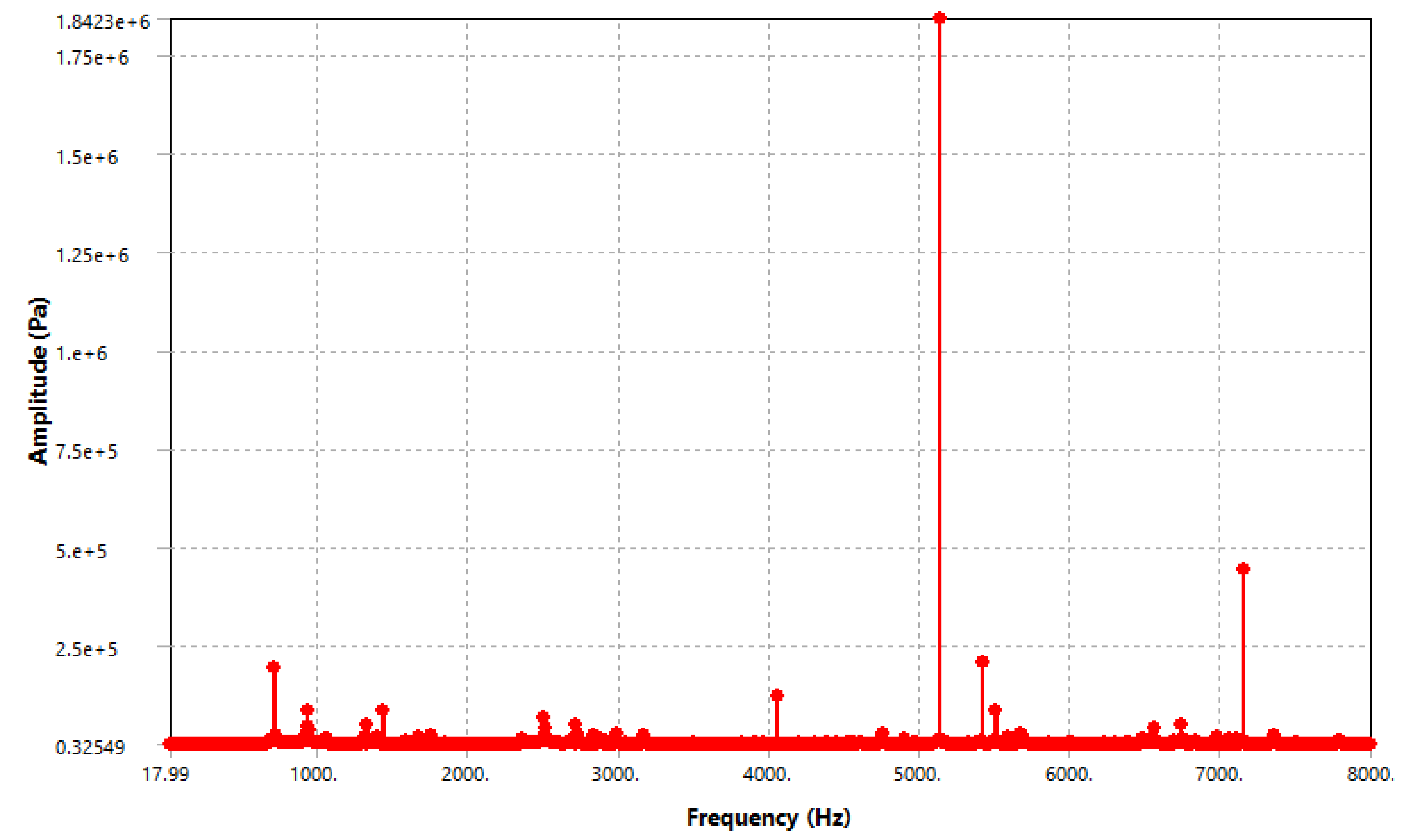
Max Deformation at 707 Hz

Connecting Rod: 2.3mm

Max Allowable Deflection in a rod (L/120): 2.8mm

F.O.S. = 1.22

Frequency Response – Stress Y Axis



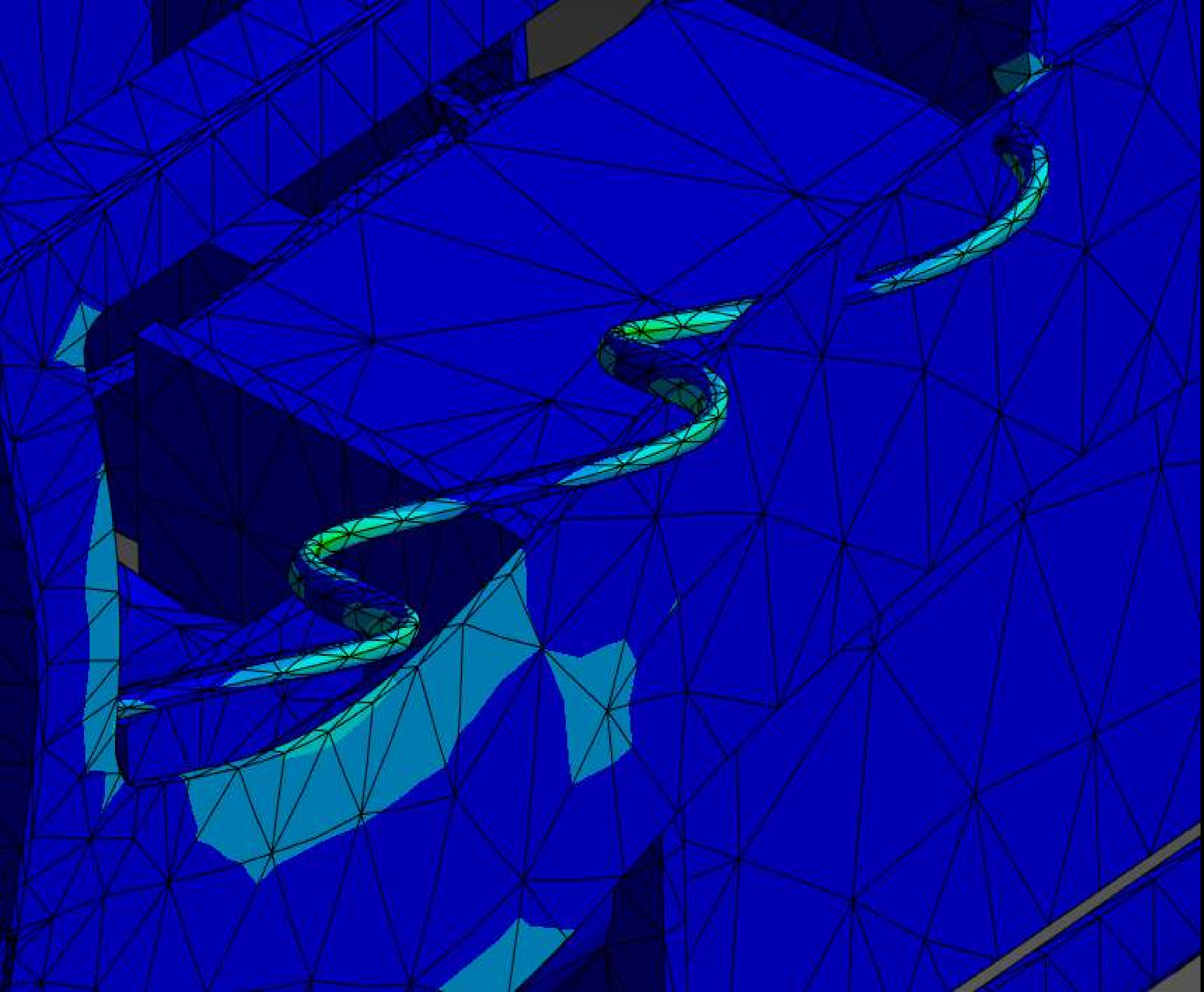
Frequency vs Maximum Stress:

Most Significant Mode: 5132 Hz
Max Stress: 1.84 Mpa

Max Allowable Stress: 240 Mpa

F.O.S = 130

Since the most significant mode satisfies the safety criteria, we will omit the calculations for the remaining modes in this direction.

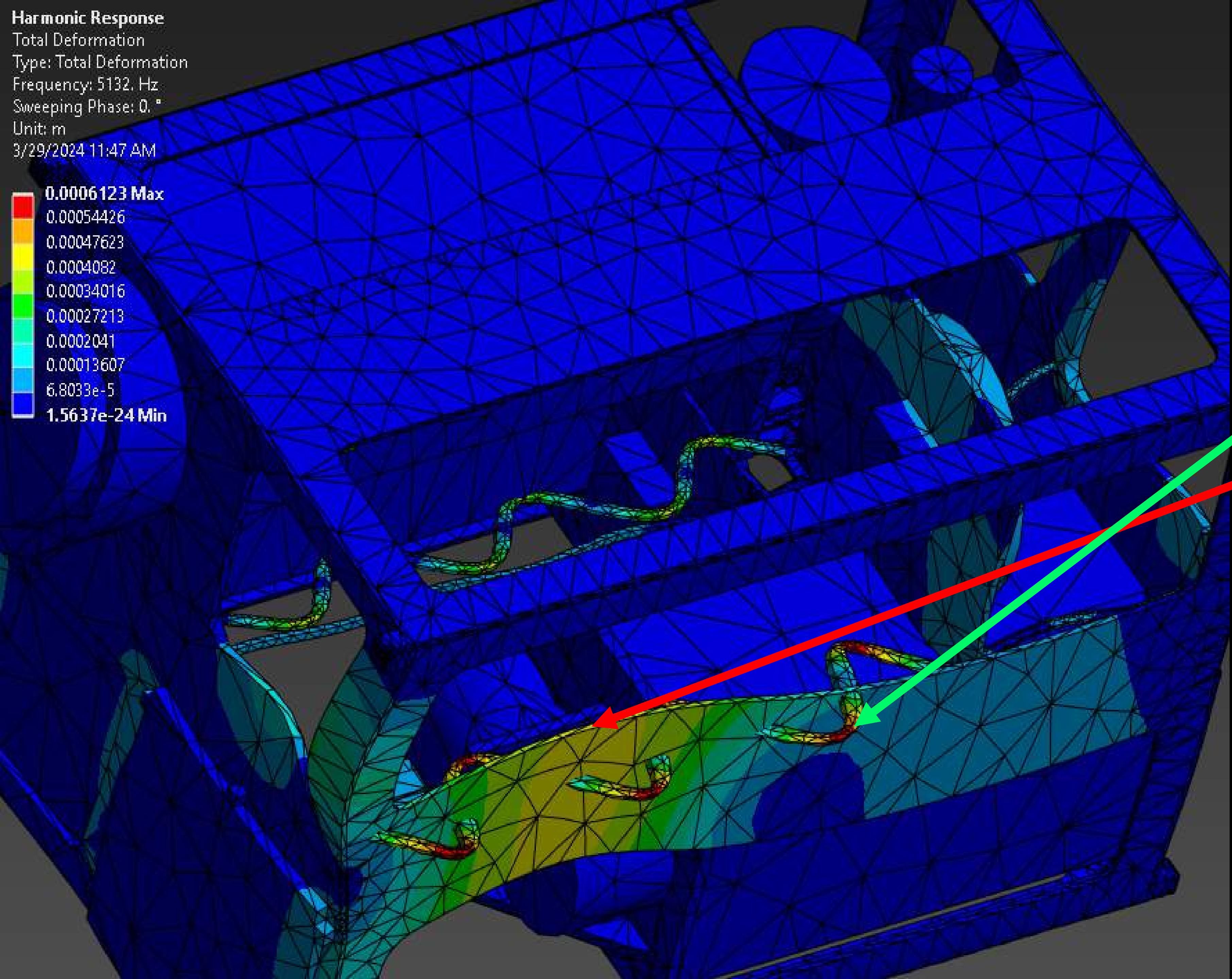


Stress Concentration 5132 Hz

<u>Von Mises Stress at 5132 Hz</u>

Connecting rods carry highest concentrations of stress.

Maxima are well within allowable limits (previous slide).



Deformation 5132 Hz

Max Deformation at 5132 Hz

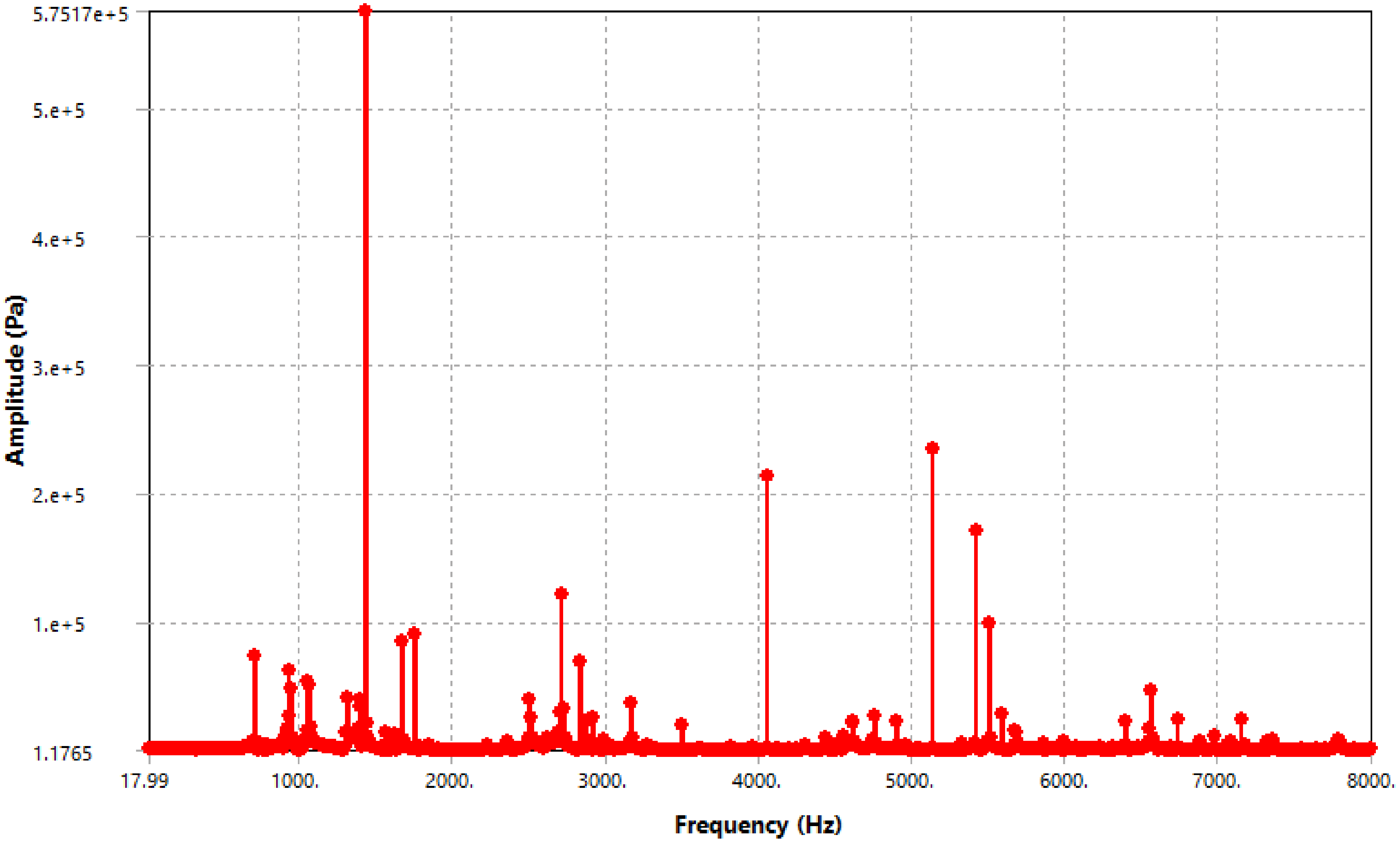
Connecting Rod: 0.6mm

Frame: 0.47mm (long transverse direction negligible)

Max Allowable Deflection in a rod (L/120): 2.8mm

F.O.S. = 4.7

Frequency Response – Stress Z Axis



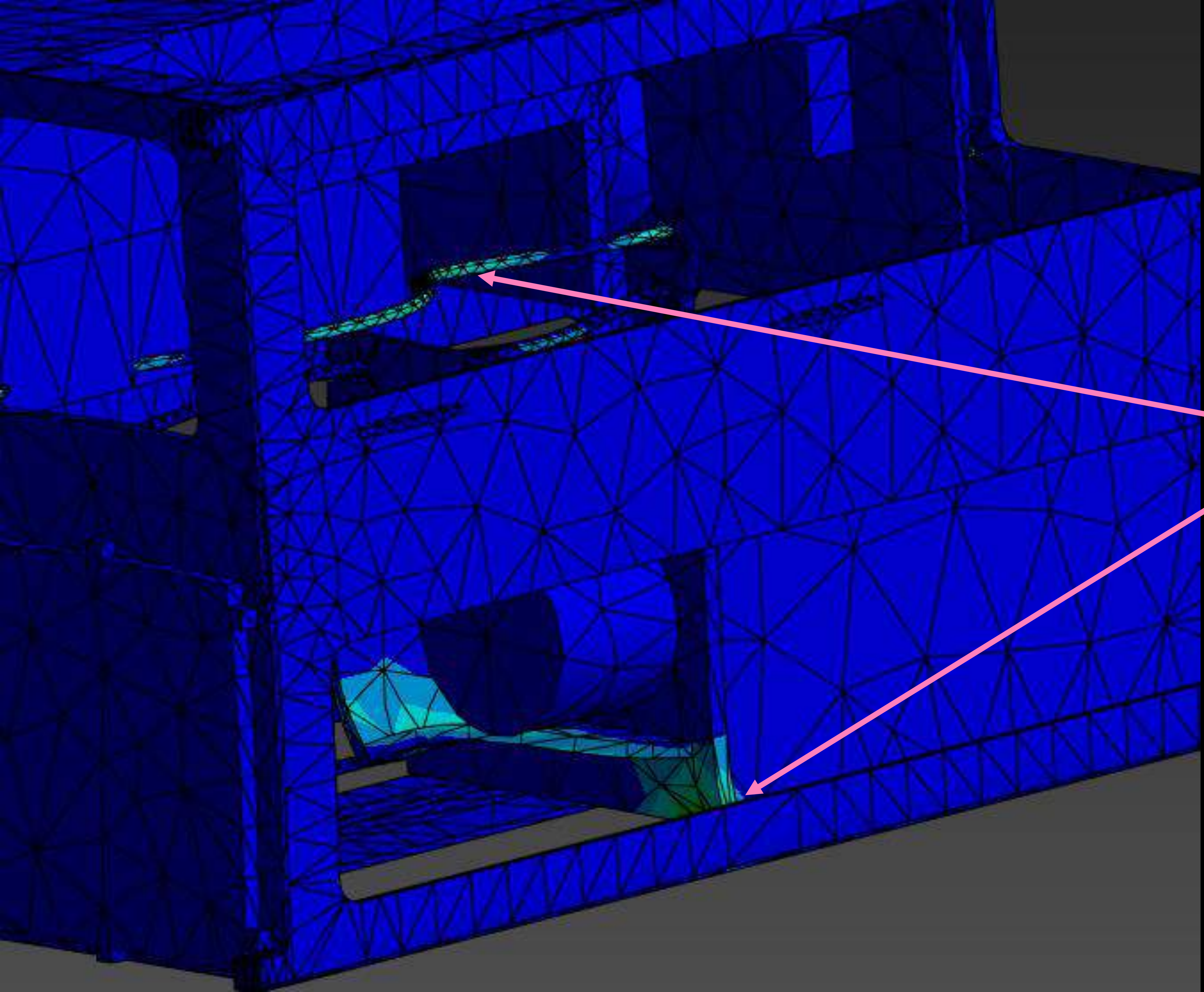
Frequency vs Maximum Stress:

Most Significant Mode: 1432 Hz
Max Stress: .575 Mpa

Max Allowable Stress: 240 Mpa

F.O.S = 417

Since the most significant mode satisfies the safety criteria, we will omit the calculations for the remaining modes.

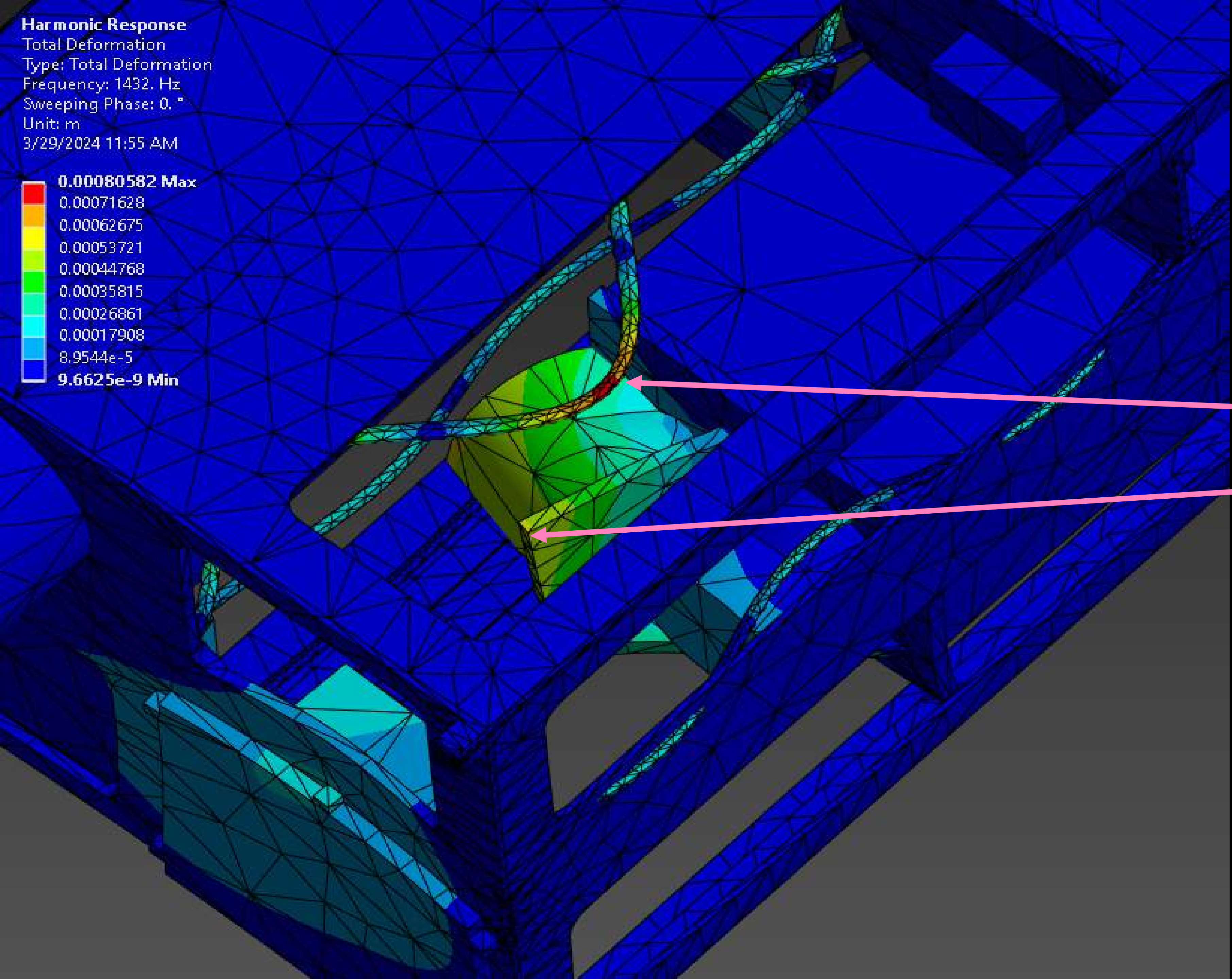


Stress Concentration 1432 Hz

Von Mises Stress at 1432 Hz

Connecting rods and RCW brackets carry highest concentrations of stress.

Maxima are well within allowable limits (previous slide).



Deformation 1432 Hz

Max Deformation at 1432 Hz

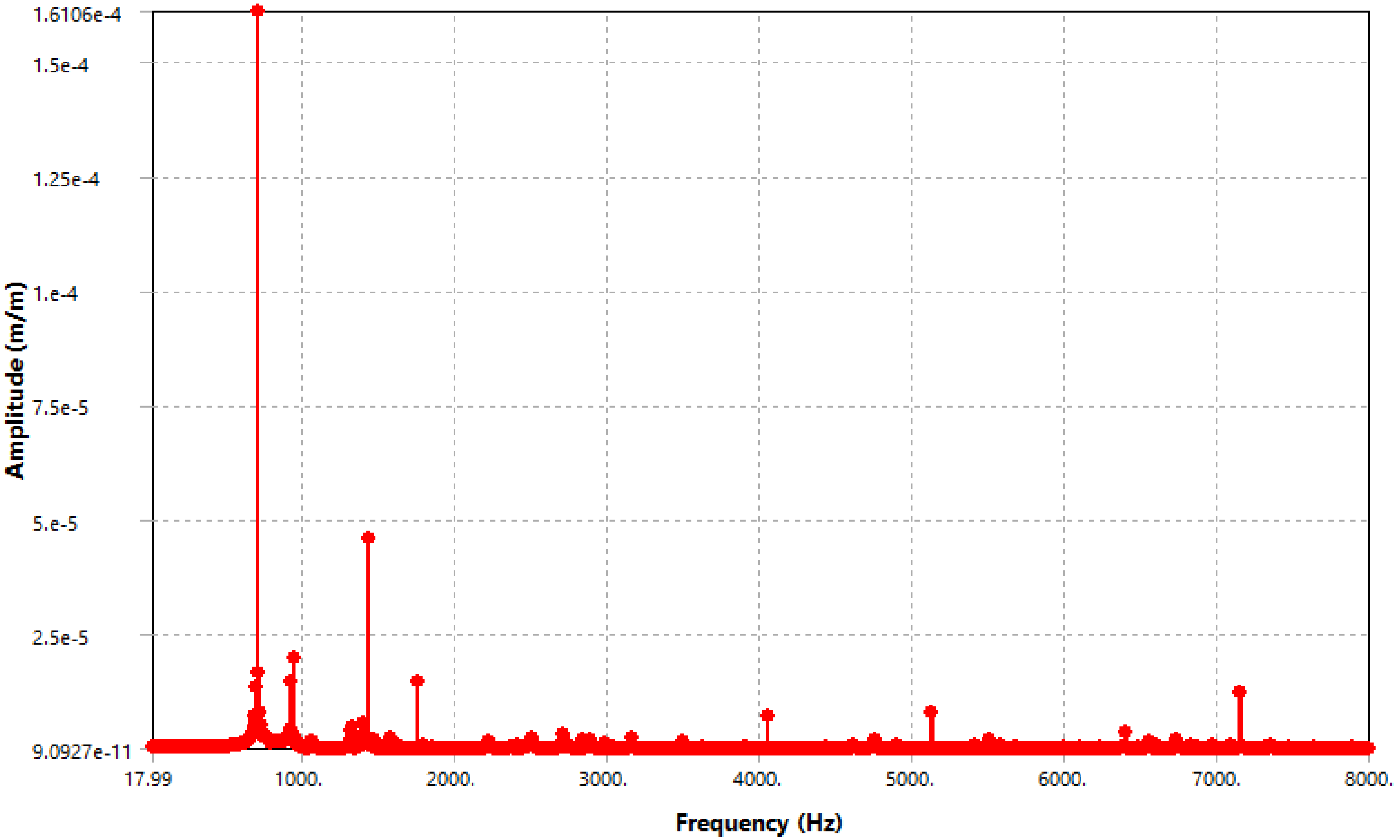
Connecting Rod: 0.8mm

RCW Bracket: 0.63mm

Max Allowable Deflection in a rod (L/120): 2.8mm

F.O.S. = 3.5

Frequency Response – Strain X Axis



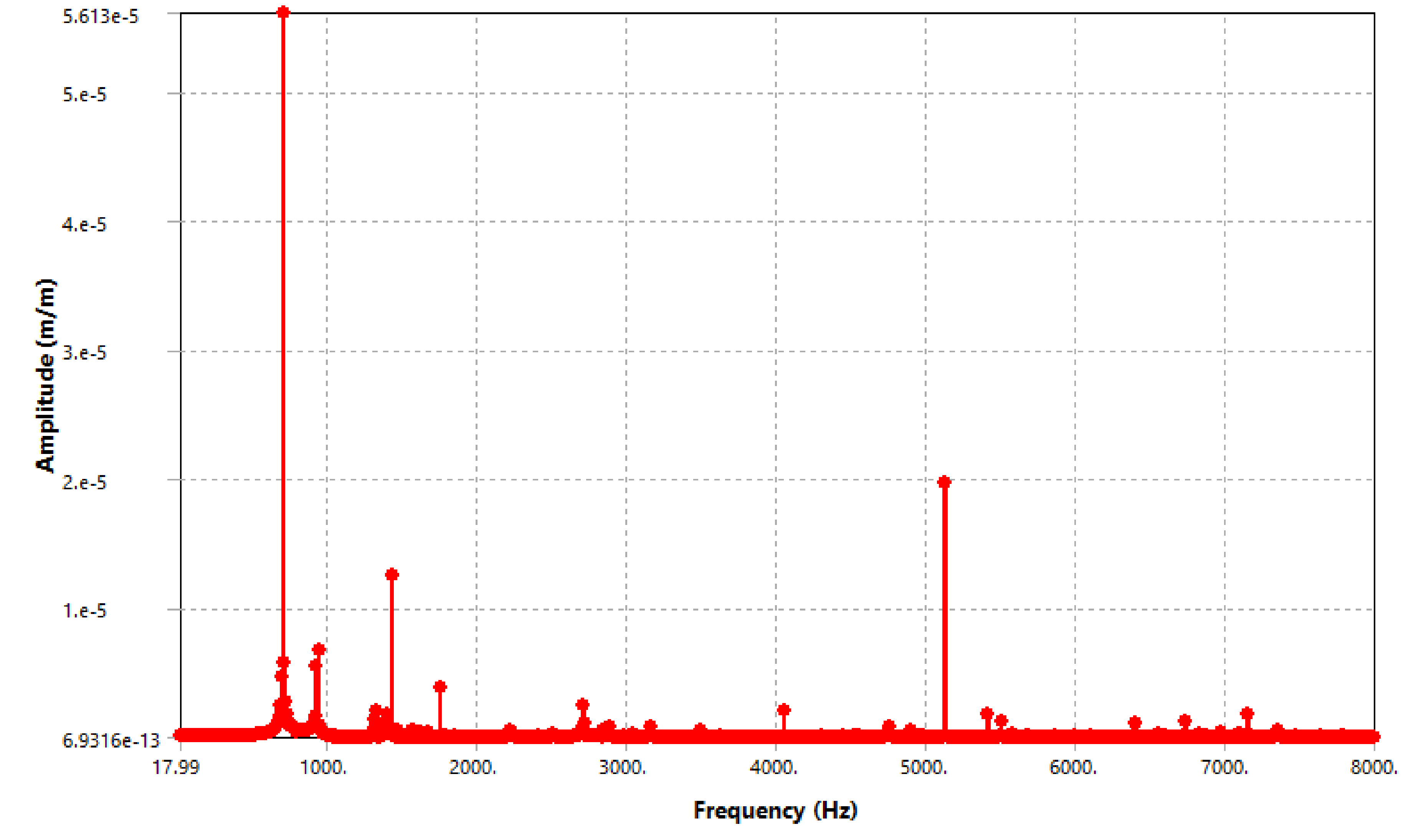
Frequency vs Maximum Strain:

Most Significant Mode:
707 Hz
Max Strain: .016%

Max Allowable Strain: 8%

F.O.S = 500

Frequency Response – Strain Y Axis



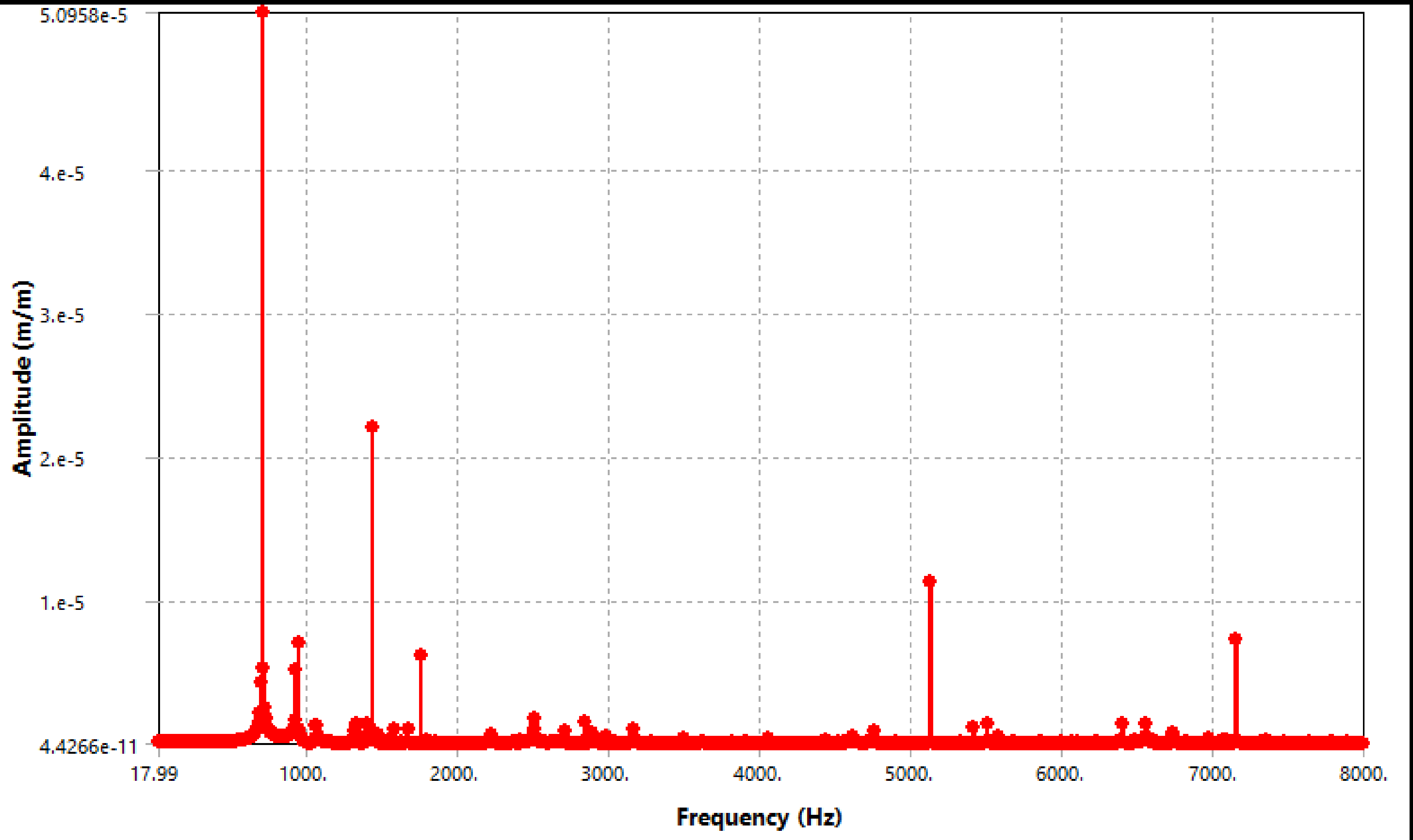
Frequency vs Maximum Strain:

Most Significant Mode: 707 Hz
Max Strain: .0056%

Max Allowable Strain: 8%

F.O.S = 1400+

Frequency Response – Strain Z Axis



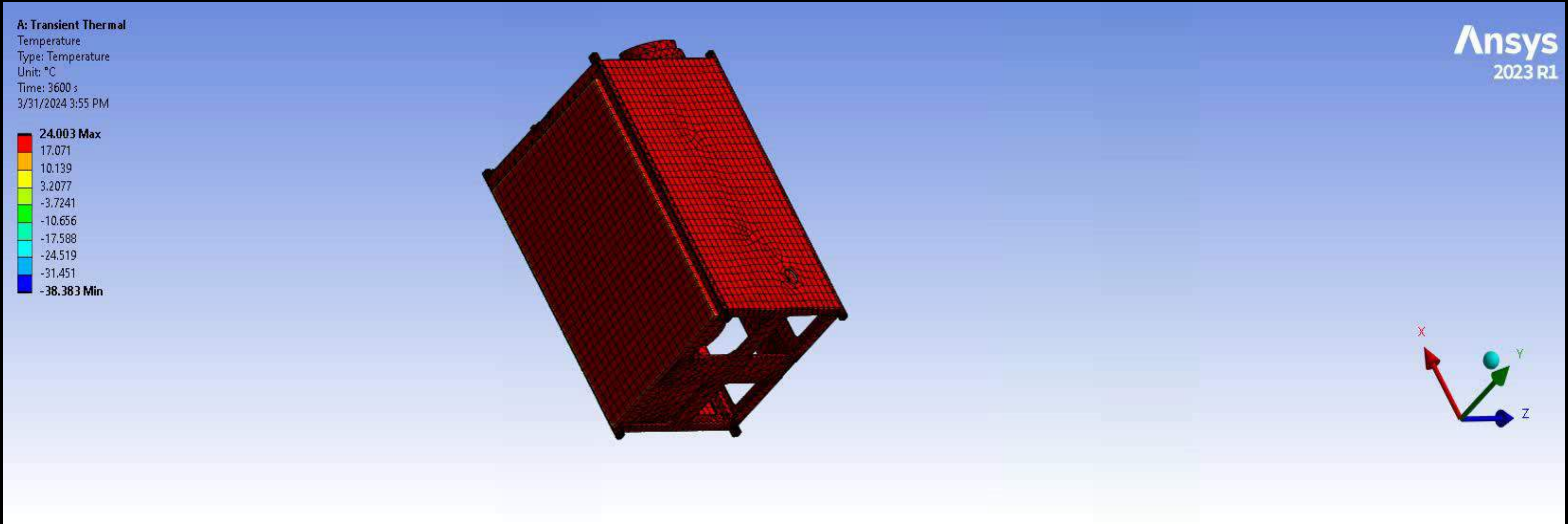
Frequency vs Maximum Strain:

Most Significant Mode:
707 Hz
Max Strain: .0051%

Max Allowable Strain: 8%

F.O.S = 1500+

Thermal Analysis: Stowed



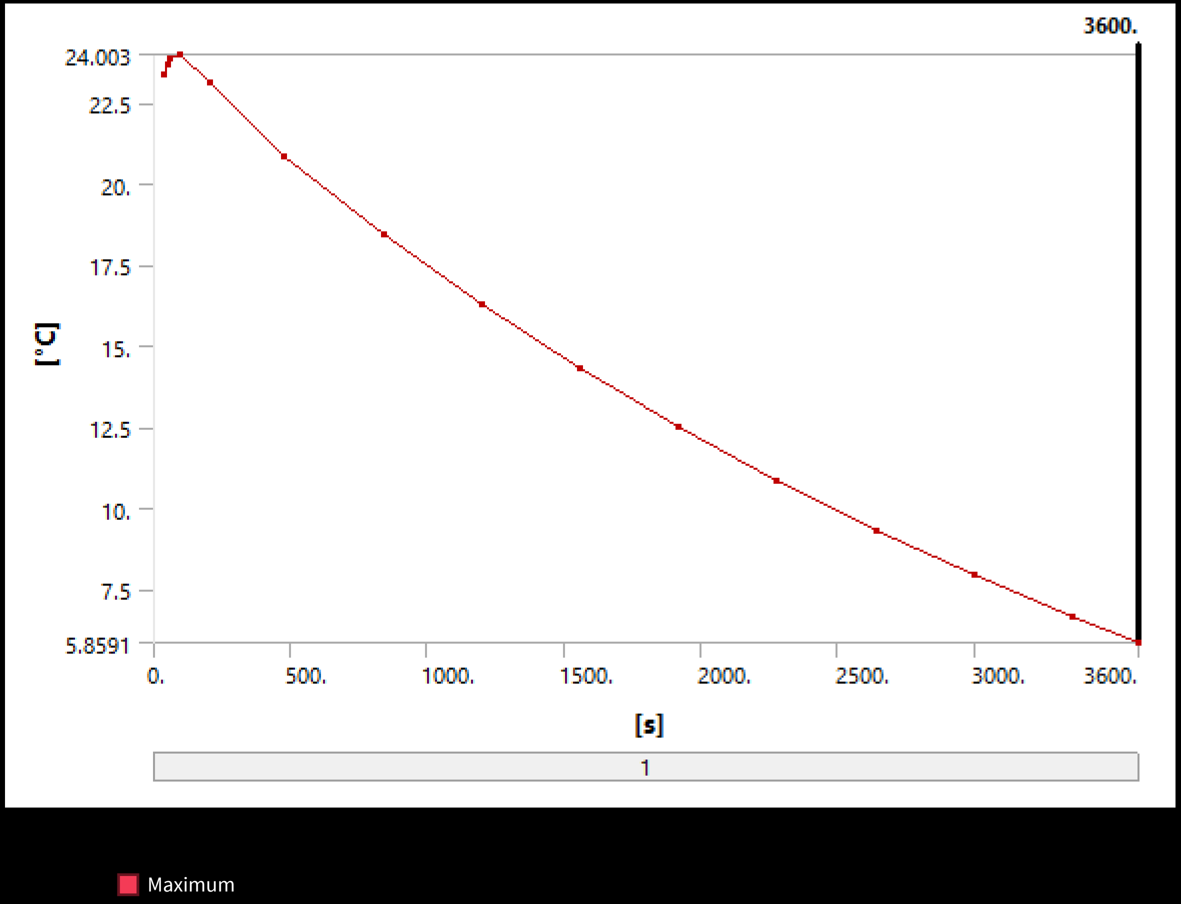
Thermal Analysis: Stowed

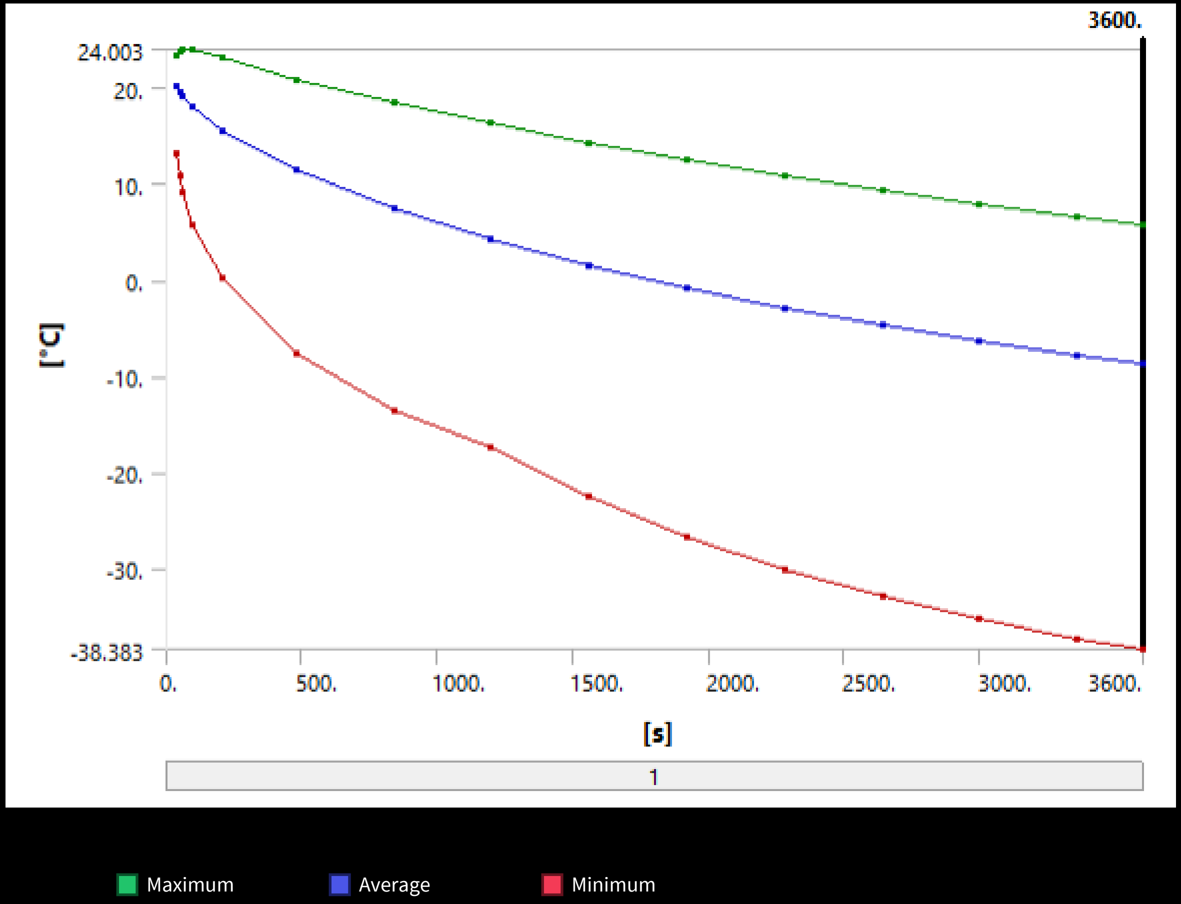
Temperature Change Over an Hour

	Time [s]	Minimum [°C]	Maximum [°C]	Average [°C]
1	36	13.11	23.362	20.156
2	48	10.879	23.688	19.62
3	60	9.1383	23.905	19.14
4	96	5.836	24.003	17.975
5	204	0.2153	23.14	15.523
6	478.06	-7.5238	20.855	11.44
7	838.06	-13.509	18.439	7.4788
8	1198.1	-17.467	16.289	4.2635
9	1558.1	-22.497	14.322	1.5423
10	1918.1	-26.686	12.514	-0.81542
11	2278.1	-30.112	10.854	-2.8879
12	2638.1	-32.933	9.3321	-4.7269
13	2998.1	-35.272	7.9346	-6.3692
14	3358.1	-37.221	6.6578	-7.8424
15	3600	-38.383	5.8591	-8.7654

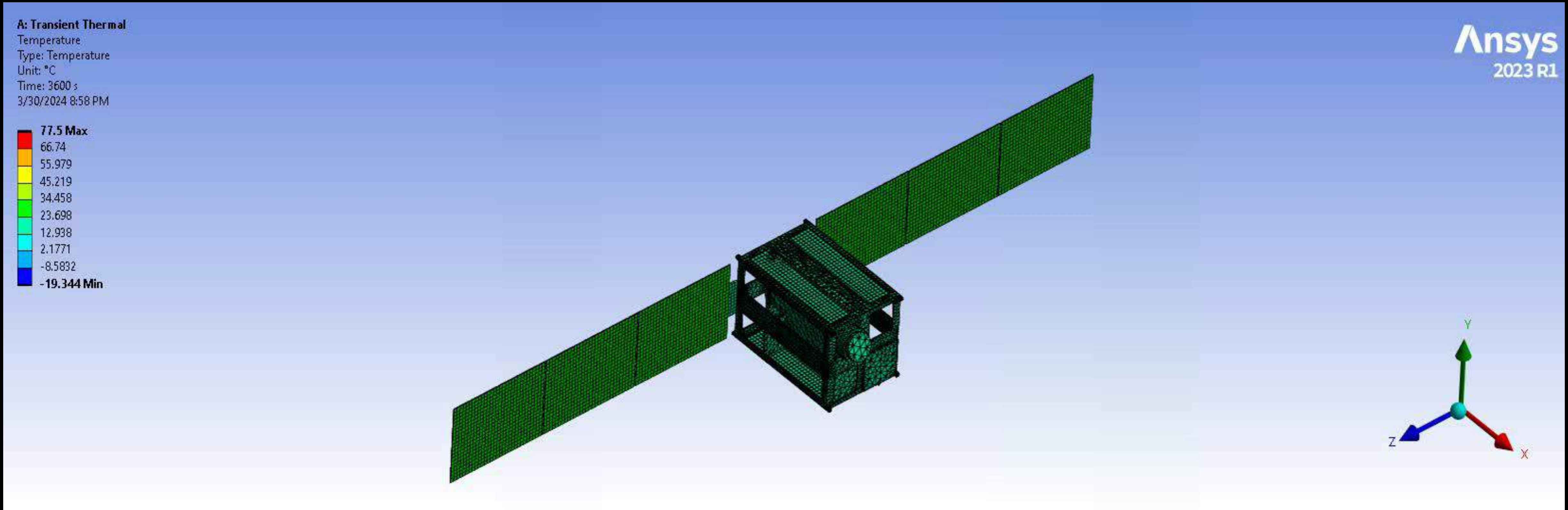
Thermal Analysis: Stowed

Temperature Change Over an Hour





Thermal Analysis: Deployed



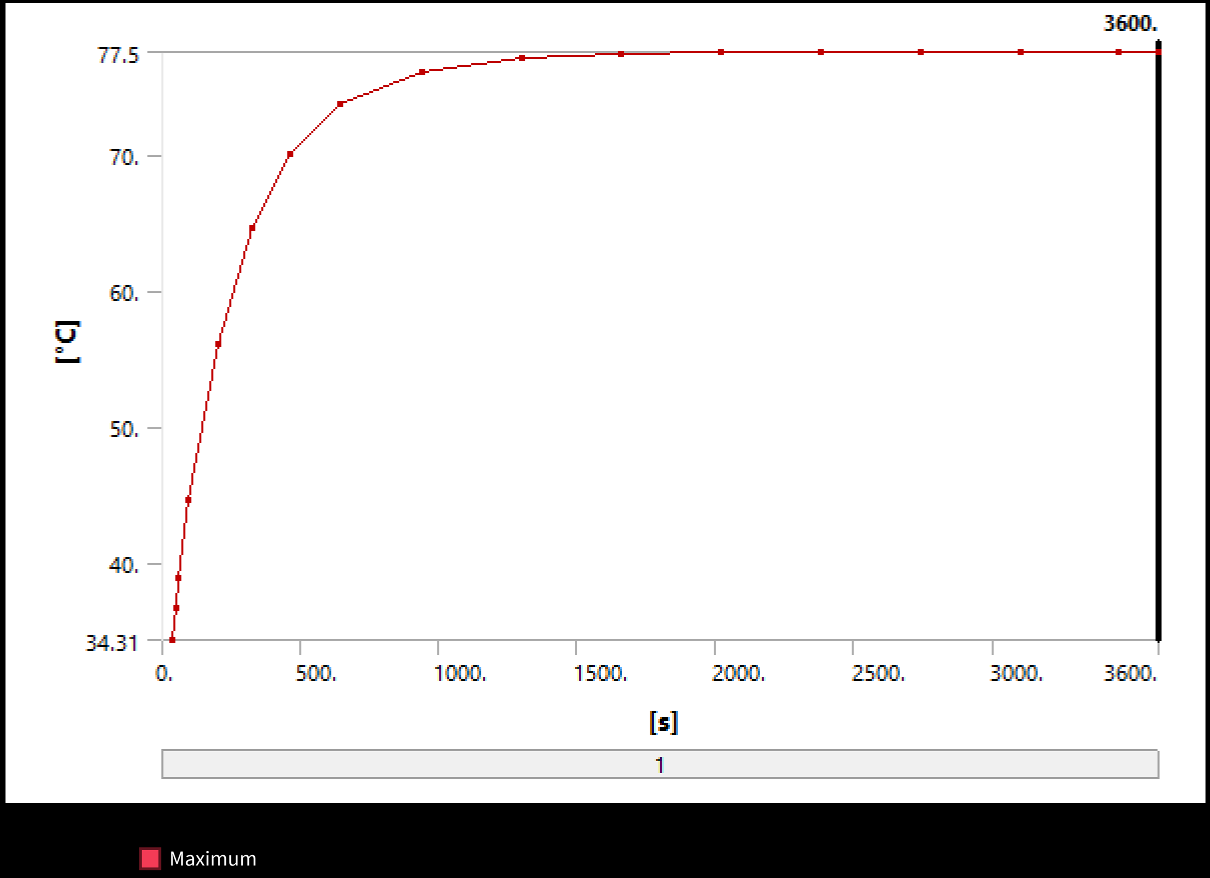
Thermal Analysis: Deployed

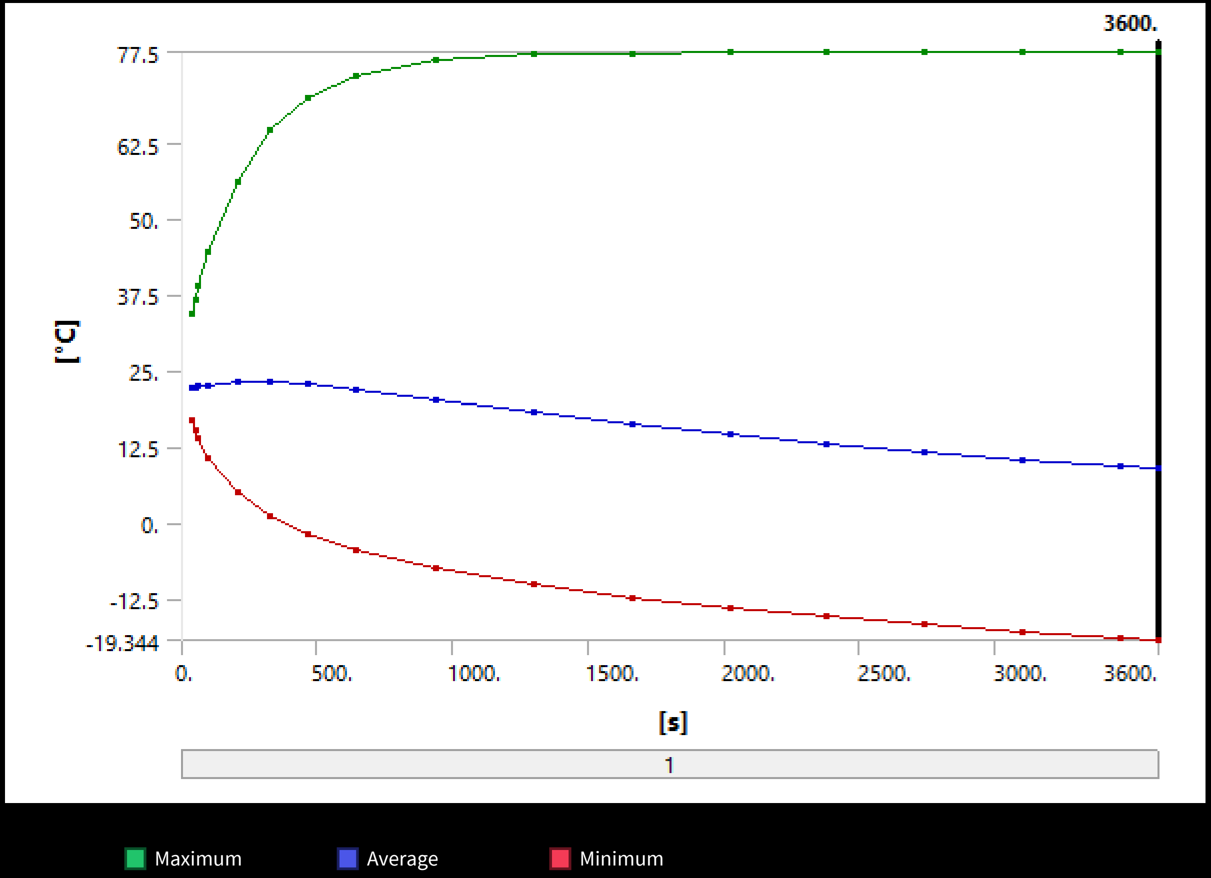
Temperature Change Over an Hour

	Time [s]	Minimum [°C]	Maximum [°C]	Average [°C]
1	36	16.787	34.31	22.22
2	48	15.285	36.656	22.282
3	60	13.916	38.8	22.359
4	96	10.7	44.538	22.629
5	204	5.1069	56.085	23.166
6	328.11	1.1603	64.507	23.236
7	464.29	-1.7729	69.984	22.854
8	640.28	-4.4474	73.654	21.976
9	938.59	-7.5405	76.039	20.209
10	1298.6	-10.238	77.007	18.133
11	1658.6	-12.347	77.333	16.235
12	2018.6	-14.067	77.444	14.531
13	2378.6	-15.529	77.481	13.002
14	2738.6	-16.807	77.494	11.628
15	3098.6	-17.937	77.498	10.389
16	3458.6	-18.952	77.5	9.2683
17	3600	-19.344	77.5	8.8433

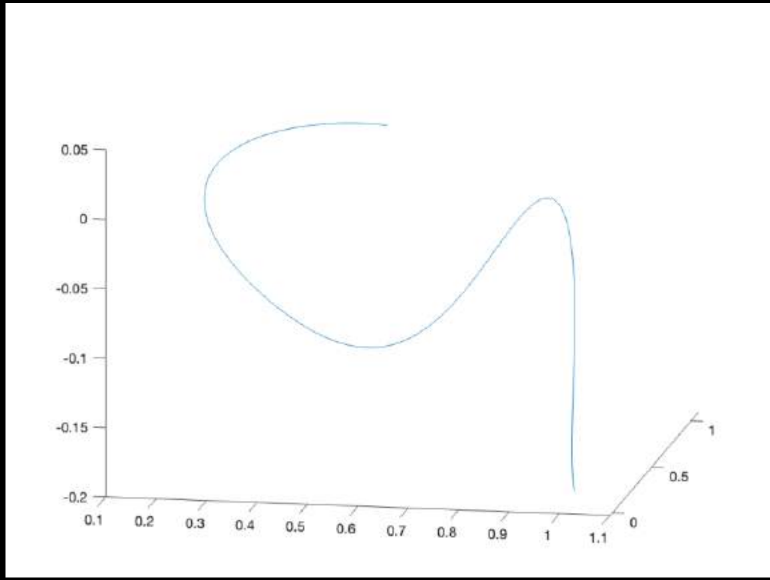
Thermal Analysis: Deployed

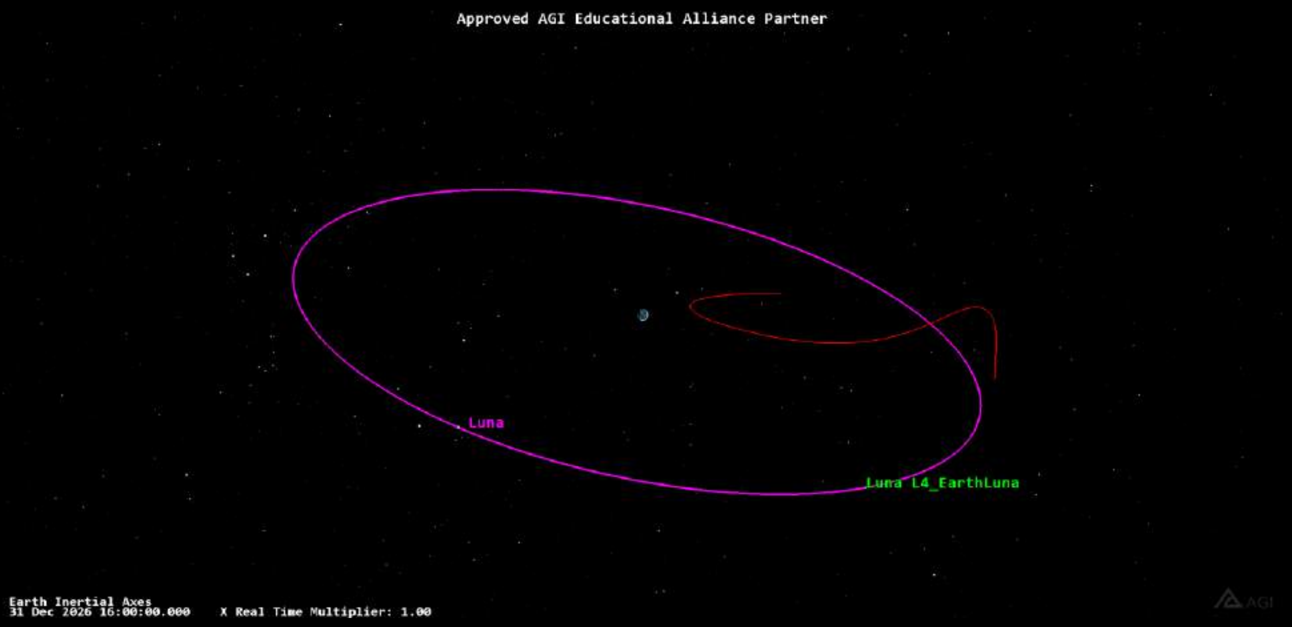
Temperature Change Over an Hour



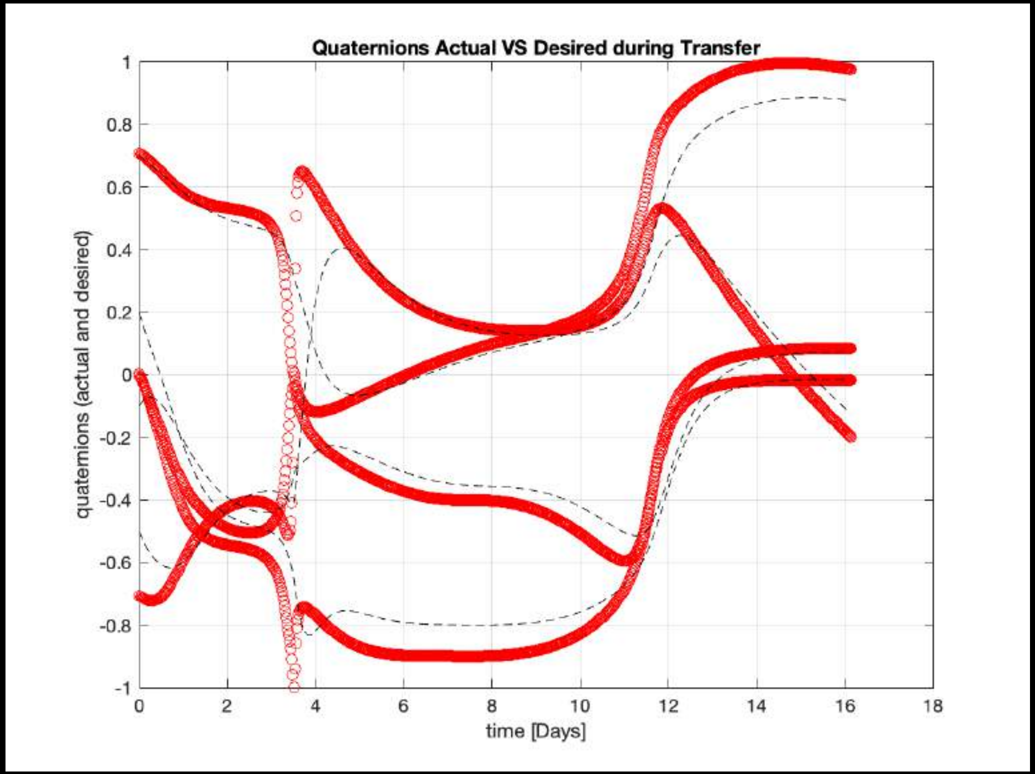


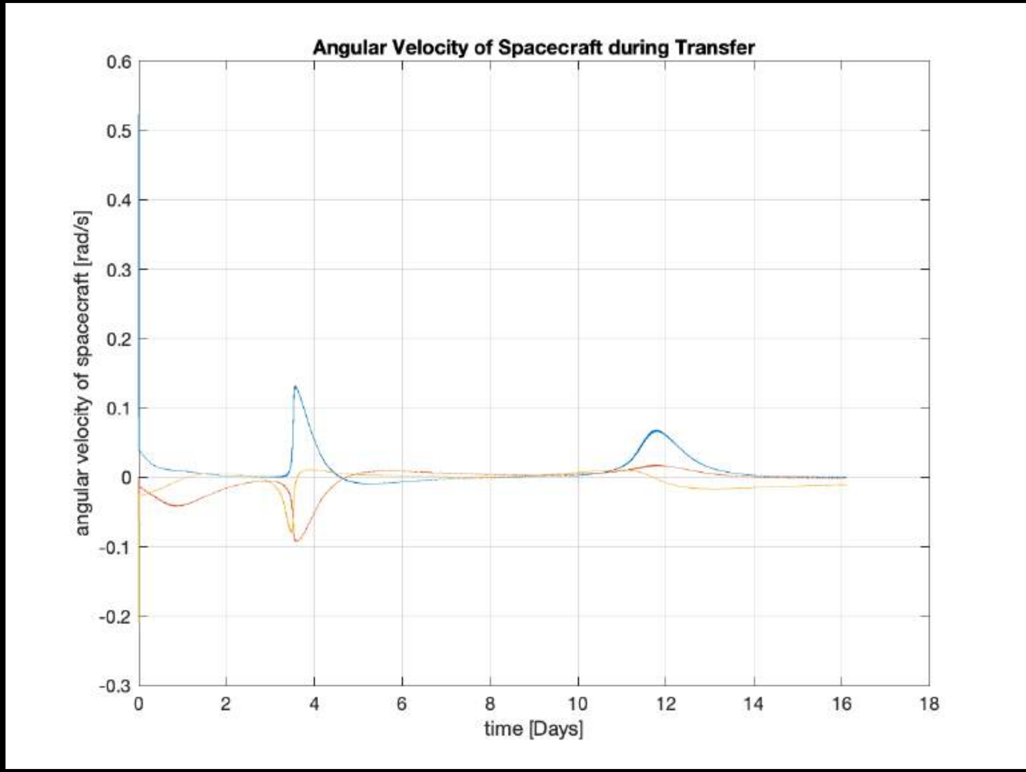
New Transfer Trajectory



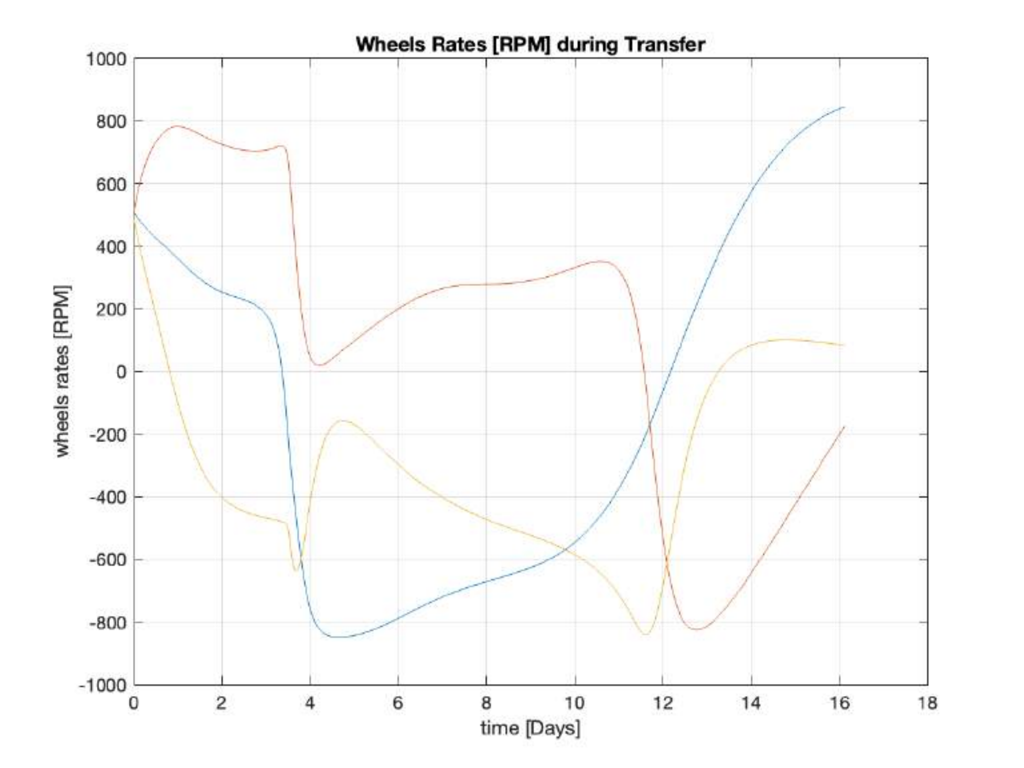


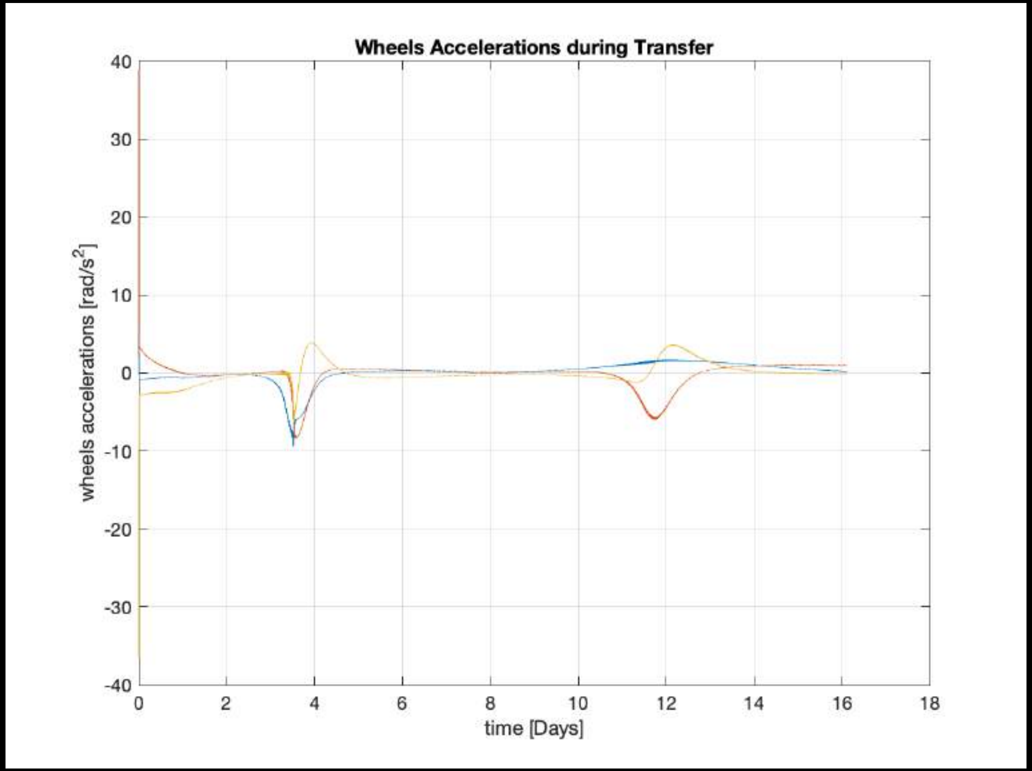
Attitude Control Transfer Orbit



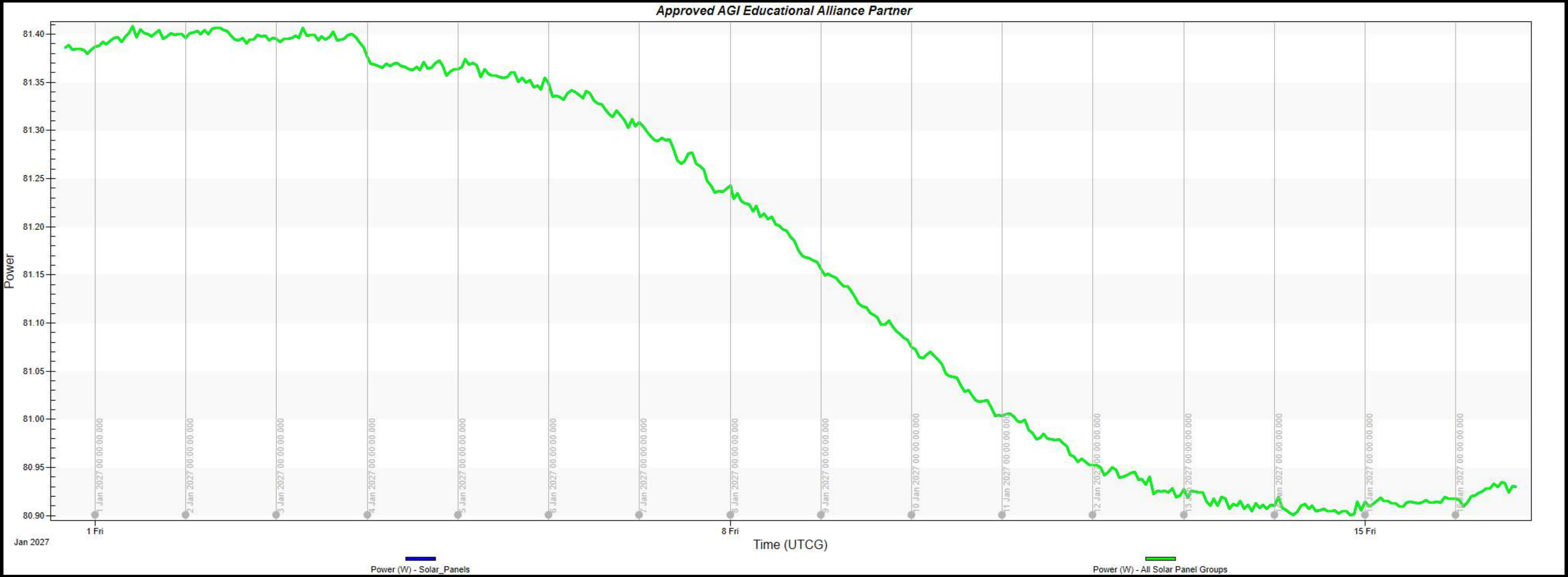


Attitude Control Transfer Orbit

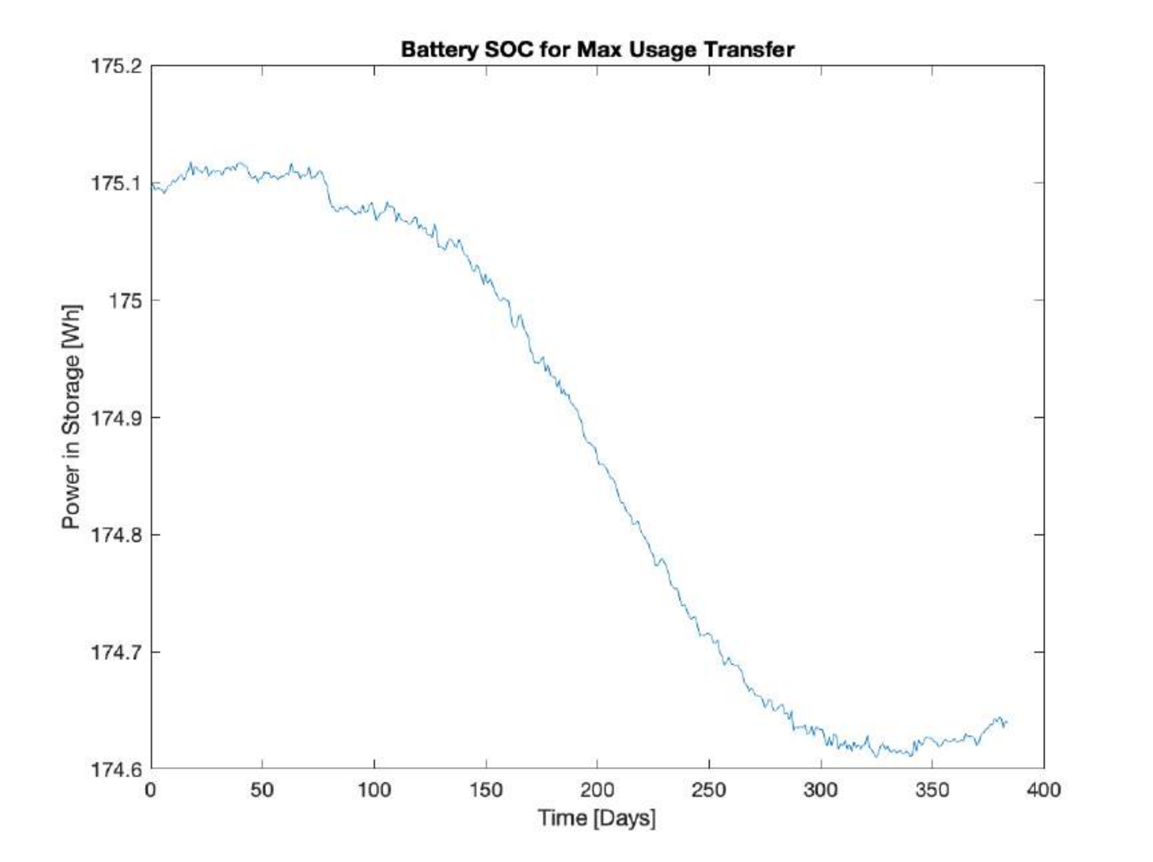


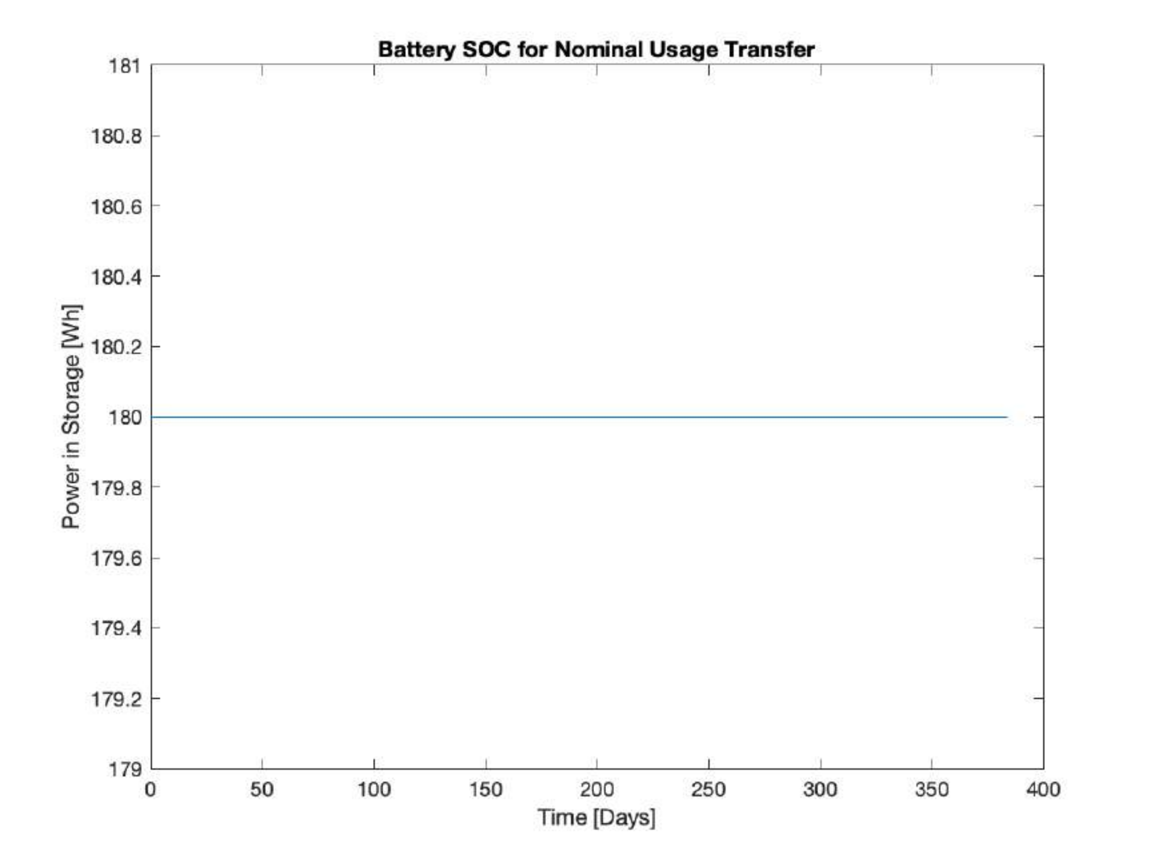


Power Generation during Transfer Orbit

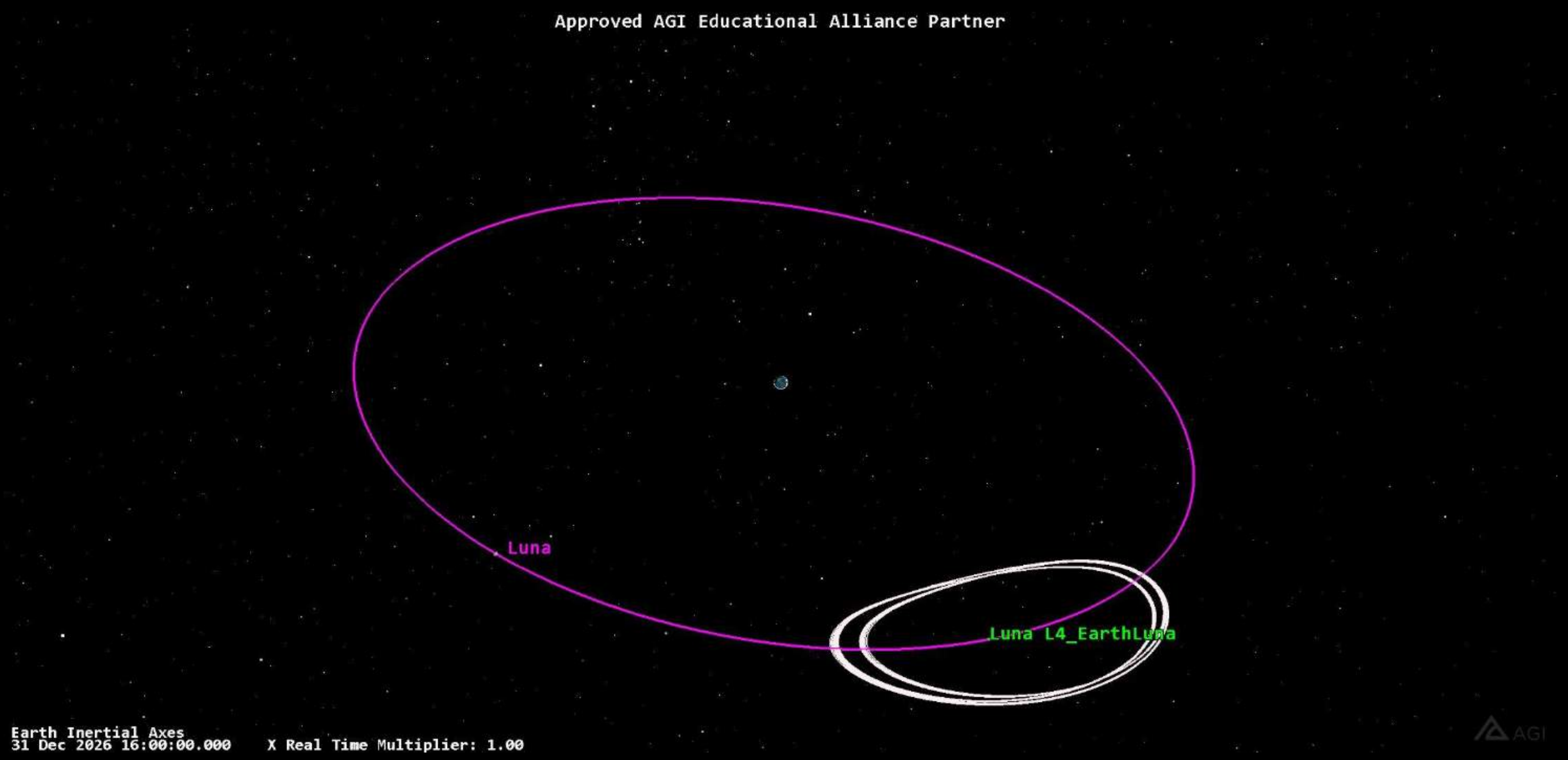


Battery State of Charge during Transfer Orbit

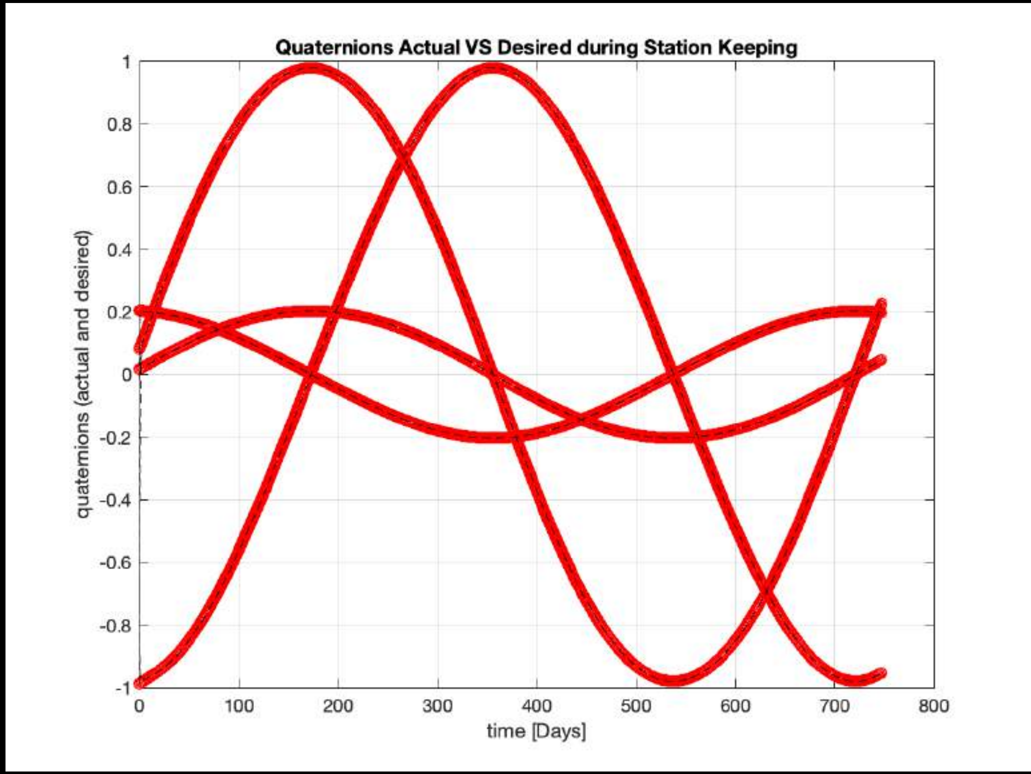


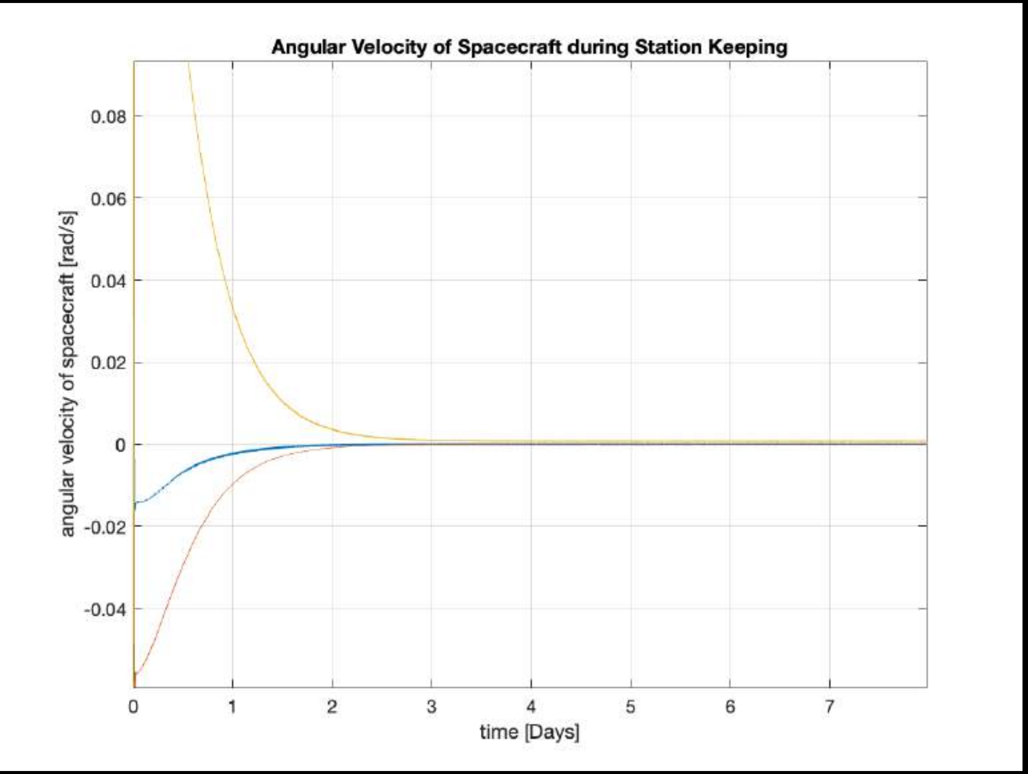


New Station Keeping Trajectory

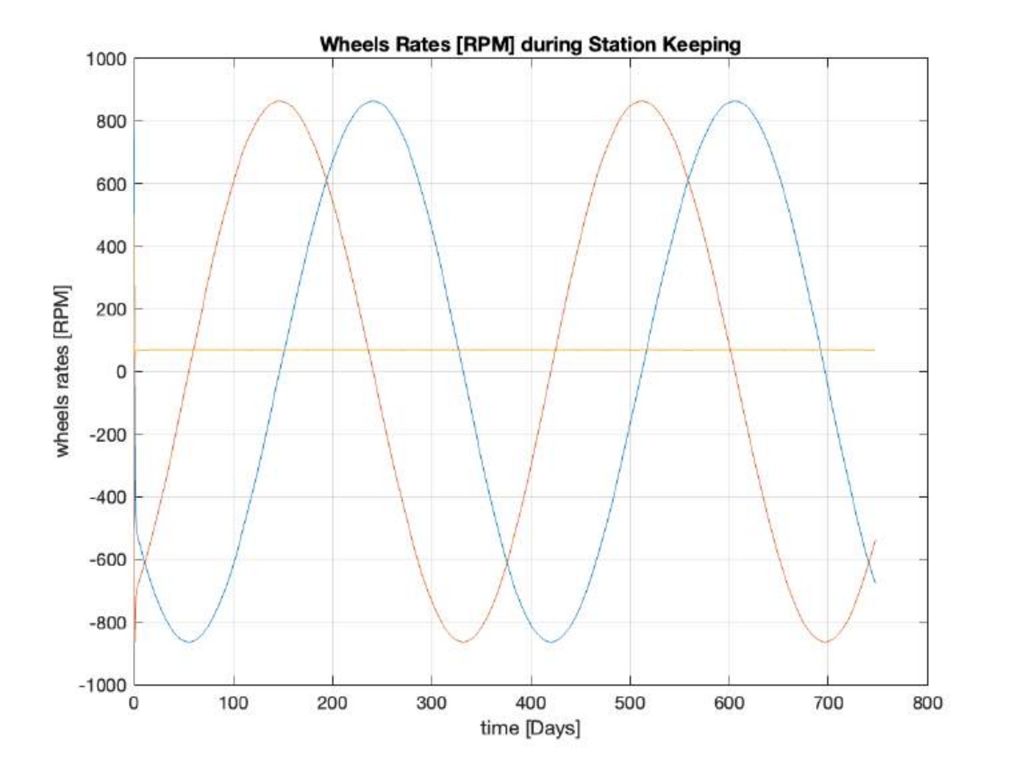


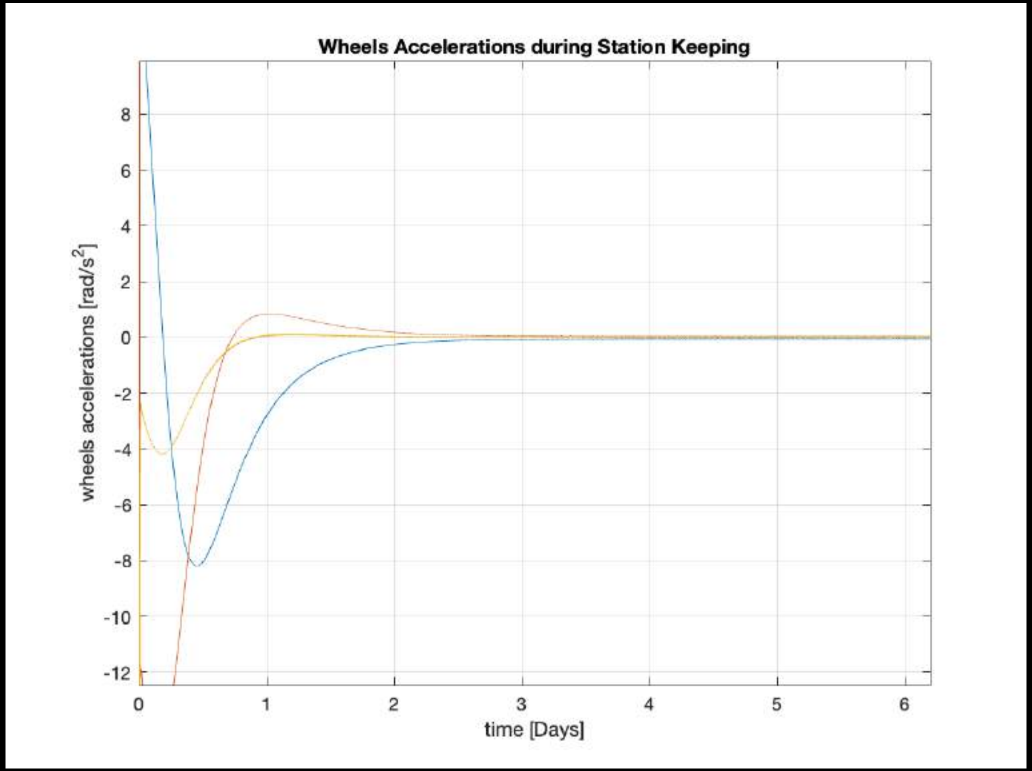
Attitude Control Station Keeping



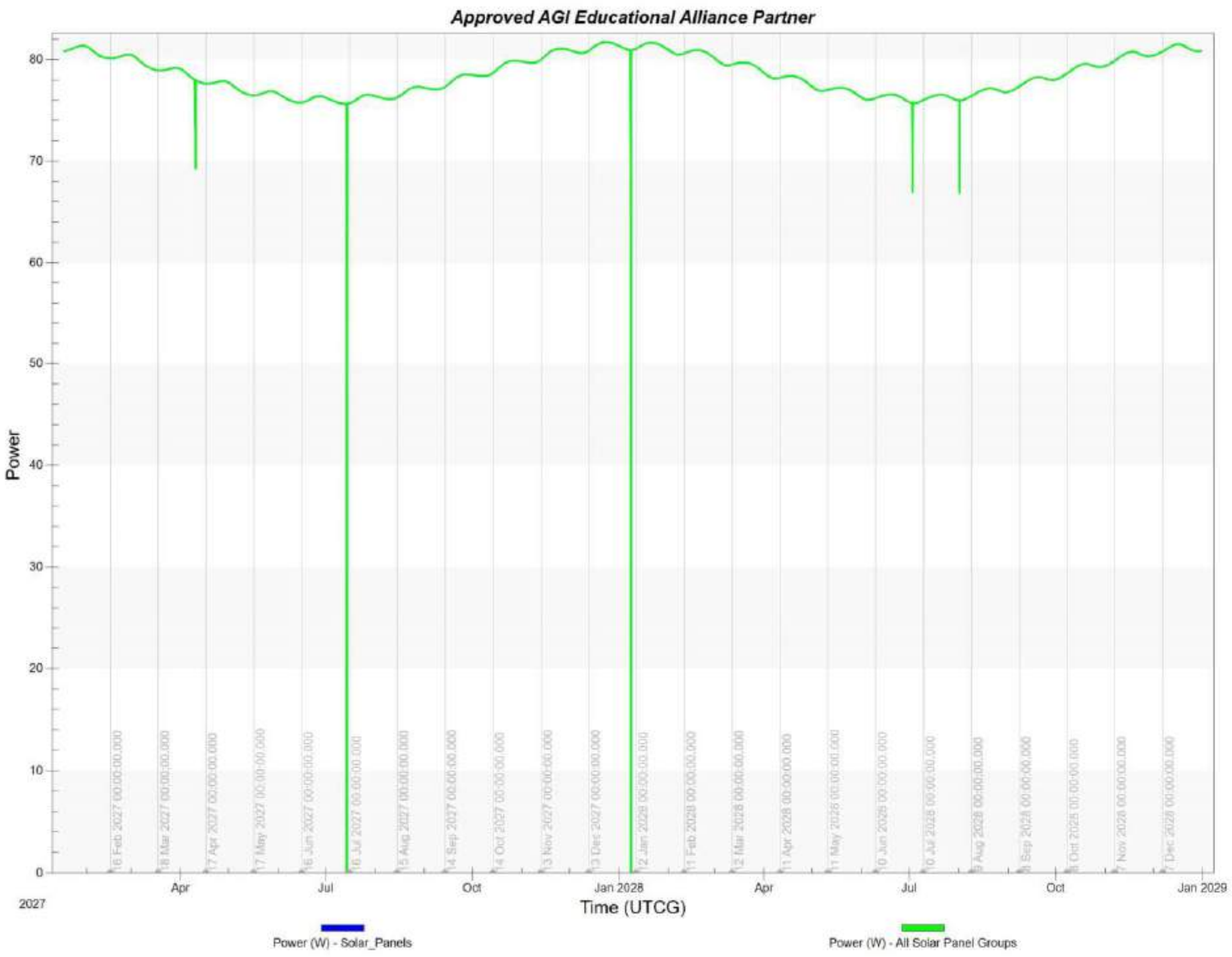


Attitude Control Station Keeping

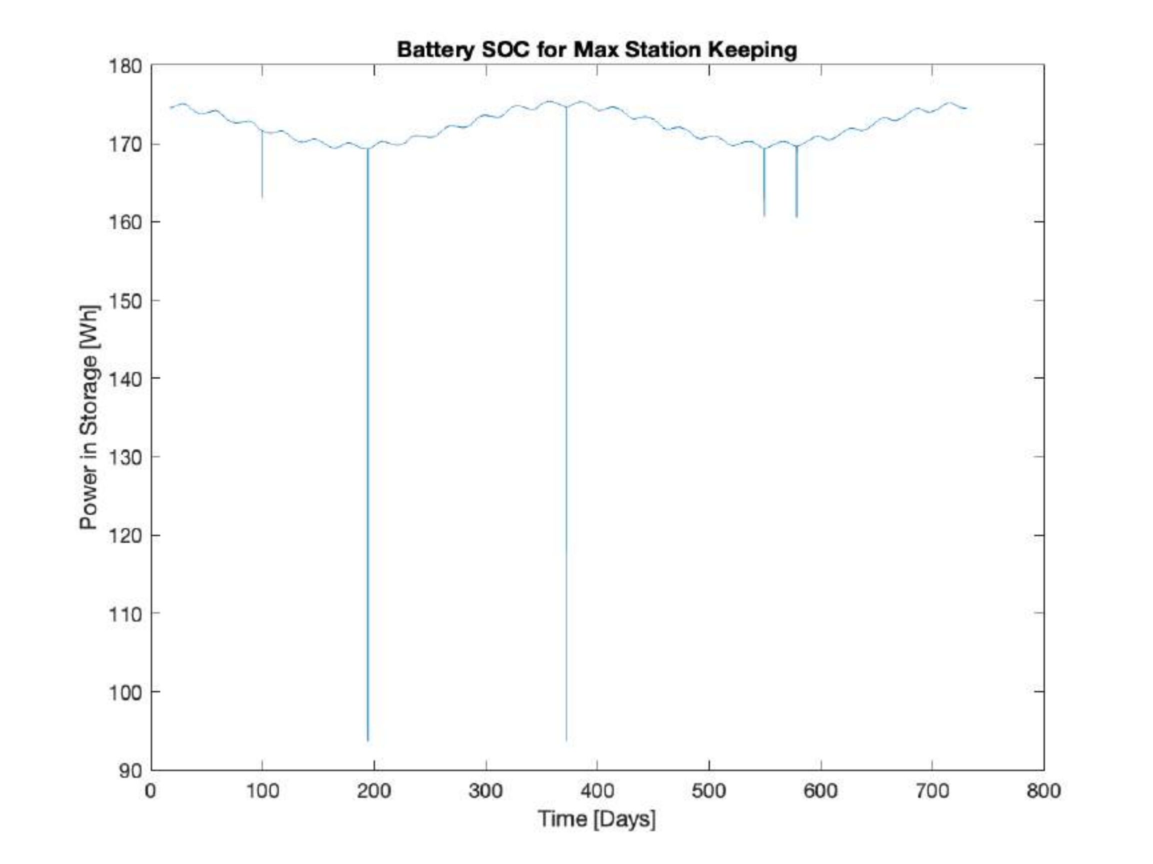


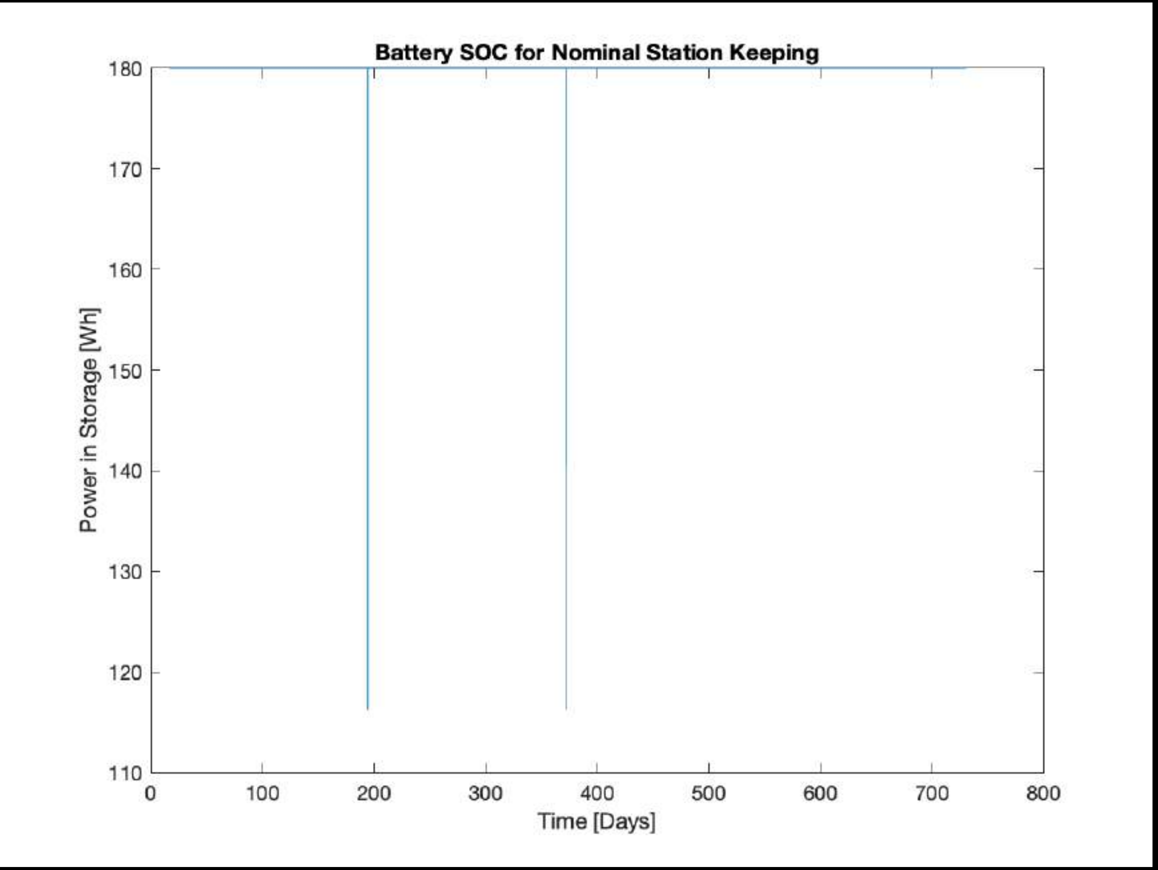


Power Generation During Station Keeping



Battery State of Charge during Station Keeping

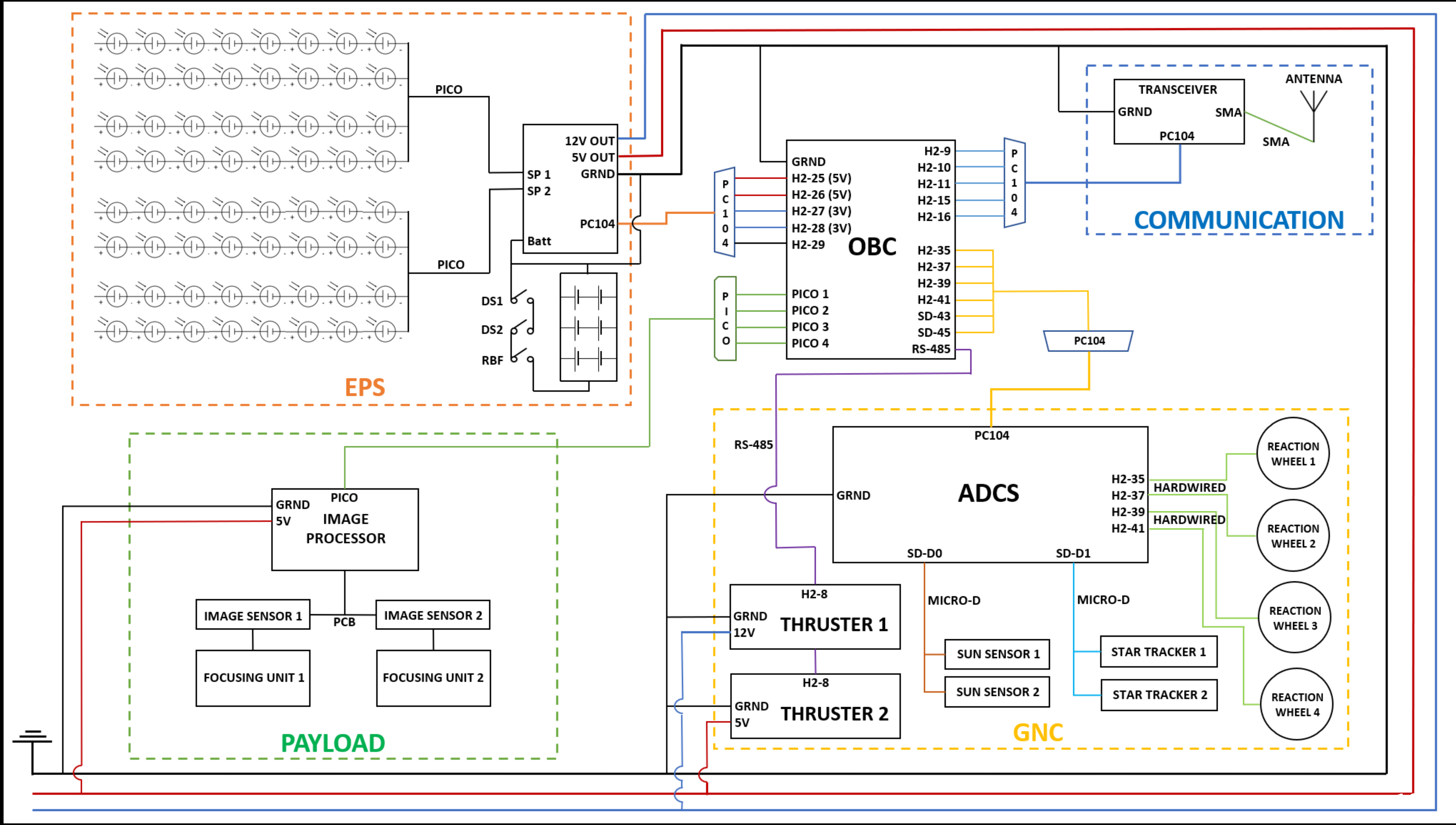




Environmental Test Plan

- Thermal Vacuum Testing: Micaplex Vacuum Chamber, subjecting model to temperatures ranging from –20°C to 77.5°C
- Vibration Testing: NanoRacks Hard-Mount Vibration test, Sweep frequency range from 0-20kHz

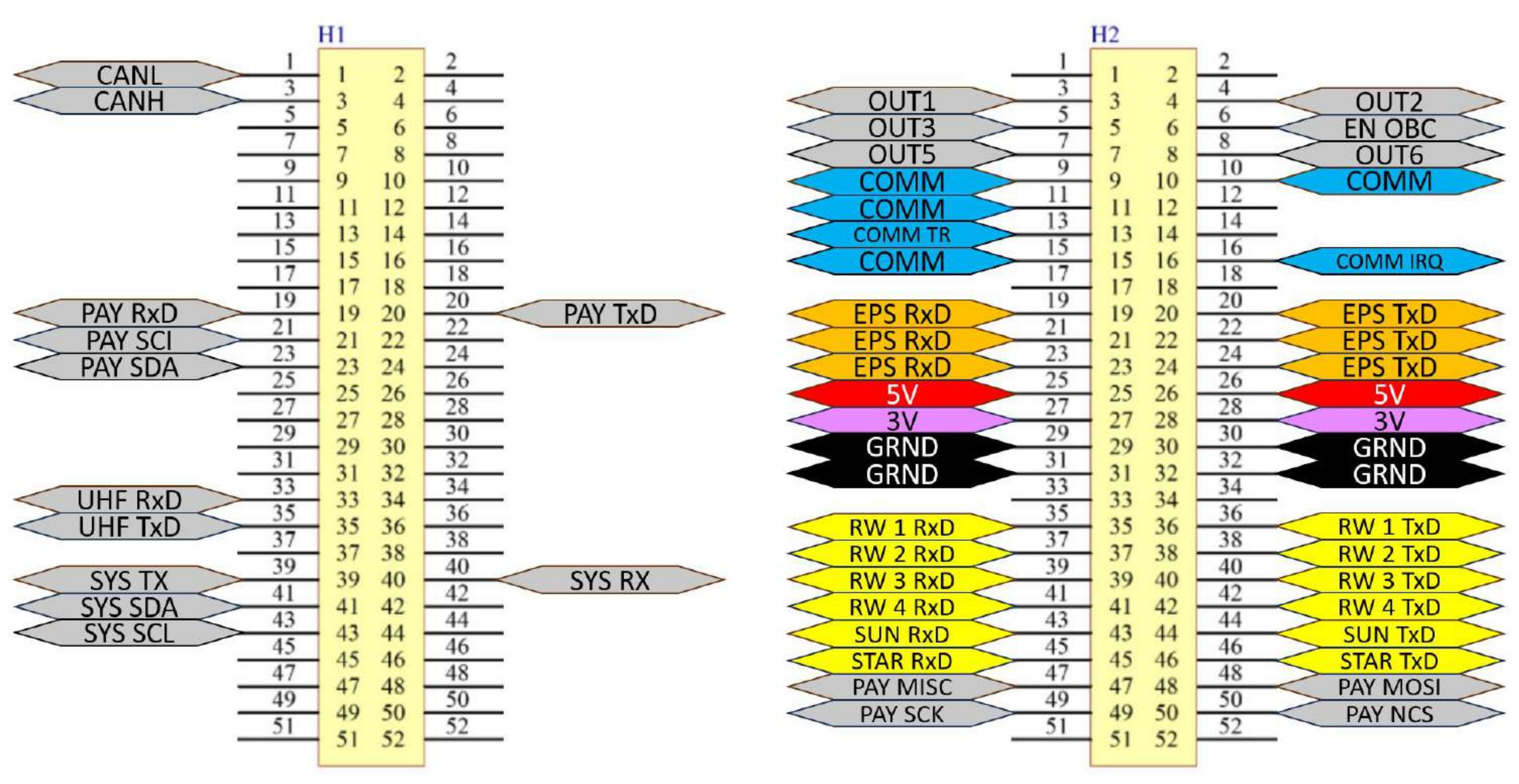
Electrical Schematic



Power-on Inhibit Logic

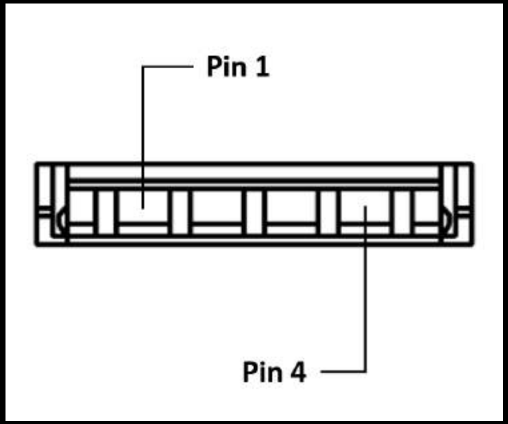
- Initial Condition: Pre-launch
  - RBF pin inserted, Two switches in the OFF position
  - EPS does not supply power
- RBF Pin Removal
  - CubeSat ready for launch
- Physical Switch Activation
  - Confirms the intention to power up the CubeSat
- Timer Initiation: 30-minute starts
  - Ensures that the system does not activate immediately
- EPS Activation
  - After 30-mins, the EPS automatically begins supplying power to the system

PINOUT: PC104 (Stacked) OBC, EPS, BATTERY, ADCS, COMM



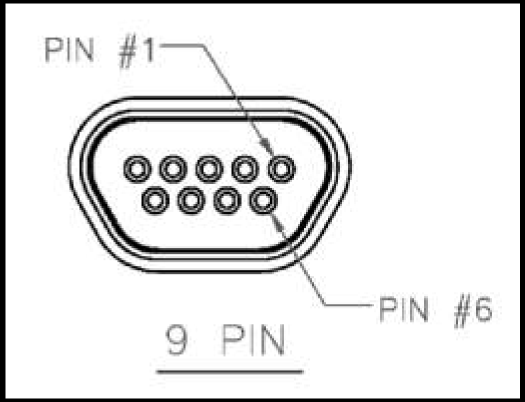
PINOUTS

PICO: Payload



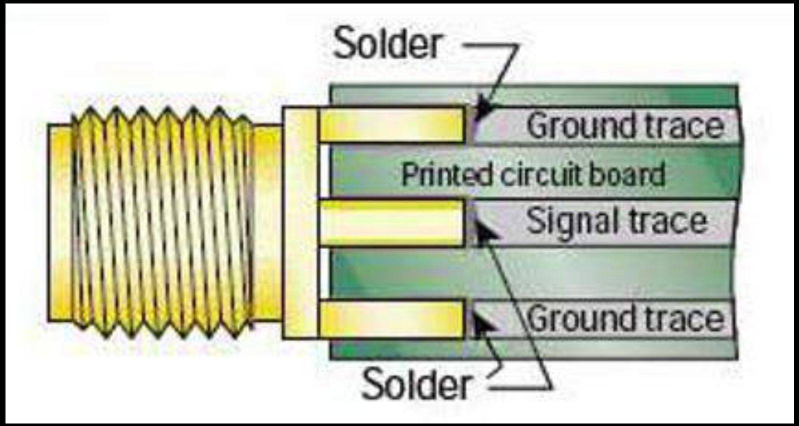
Pin 1	TxD +
Pin 2	TxD -
Pin 3	RxD +
Pin 4	RxD -

Micro-D: Sensors

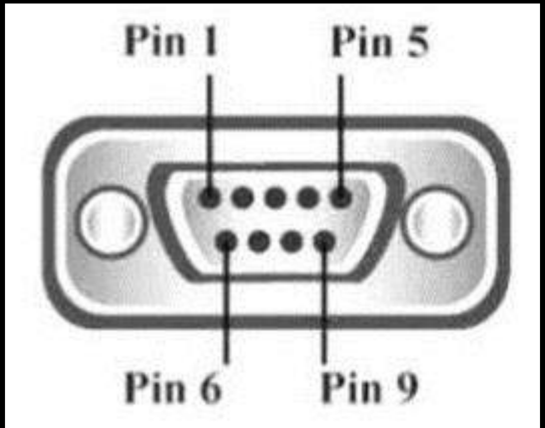


Pin 1	3V
Pin 2	GND
Pin 3	TxD
Pin 4	RxD
Pin 5	N/C
Pin 6	3V
Pin 7	GND
Pin 8	TxD
Pin 9	RxD

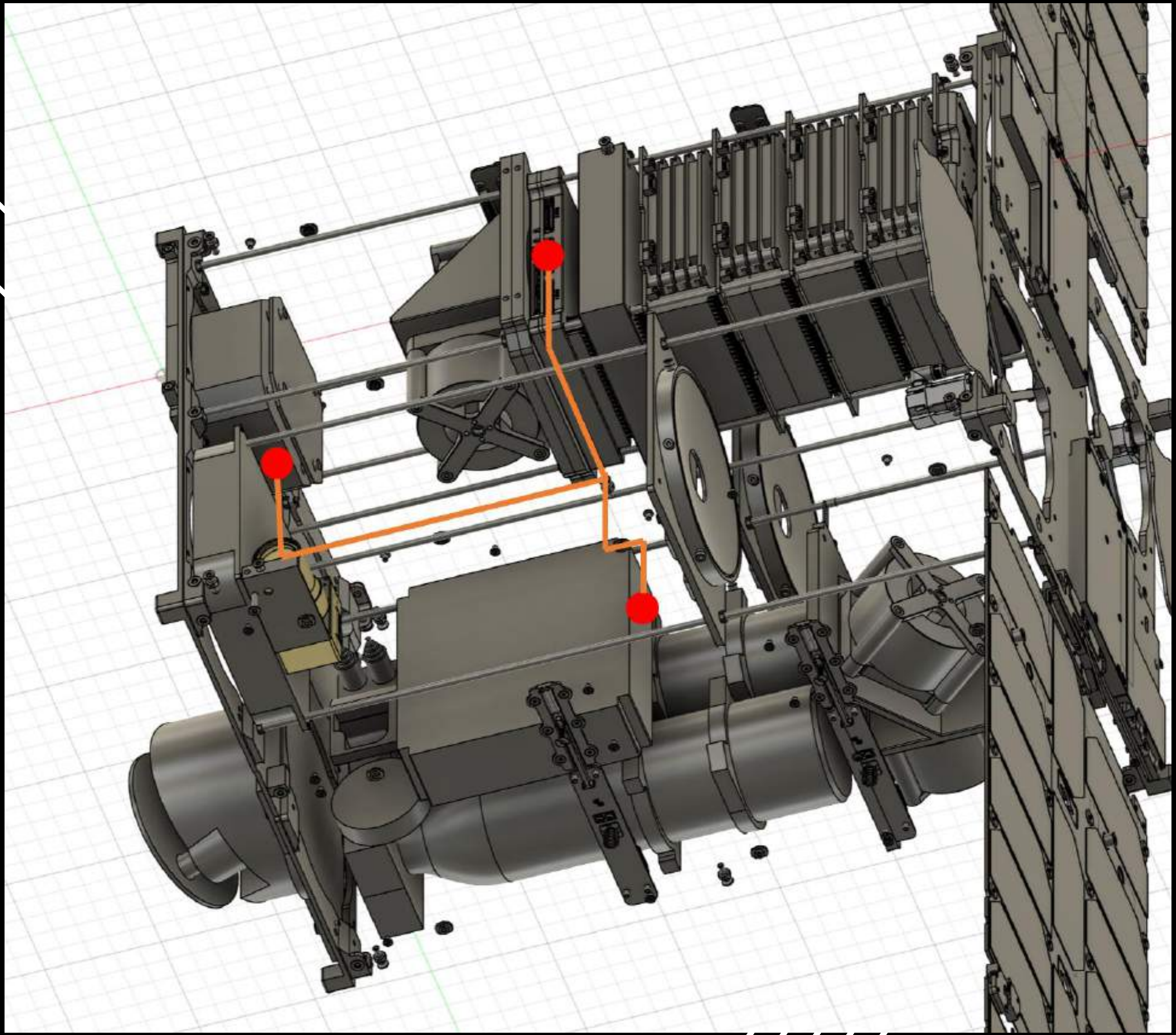
PINOUT: SMA ANTENNA



PINOUT: RS-485 THRUSTER



Pin 1	TxD -
Pin 2	TxD +
Pin 3	RxD -
Pin 4	RxD +
Pin 5	N/C
Pin 6	TxD -
Pin 7	TxD +
Pin 8	RxD -
Pin 9	RxD +



WIRE ROUTING:

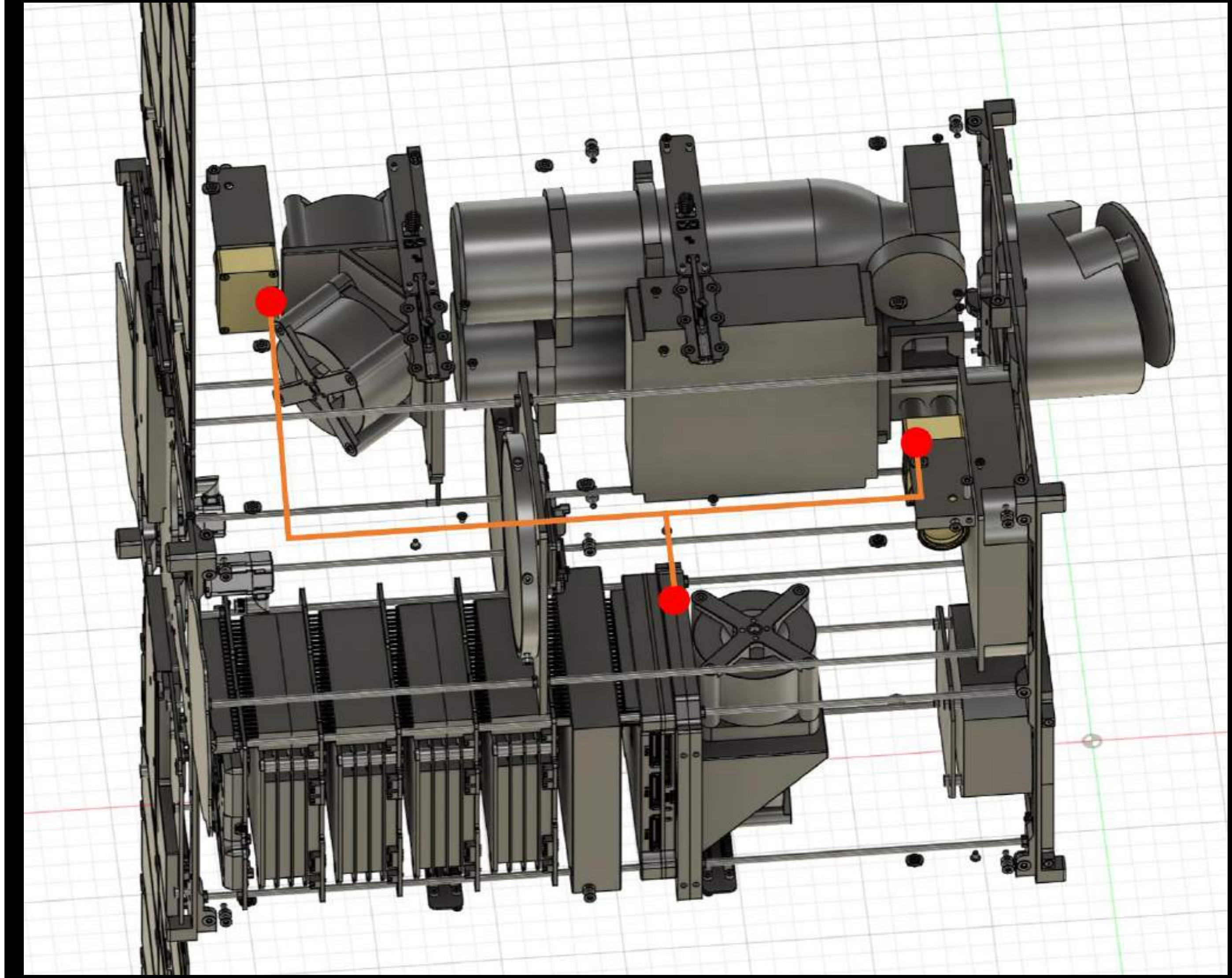
THRUSTER

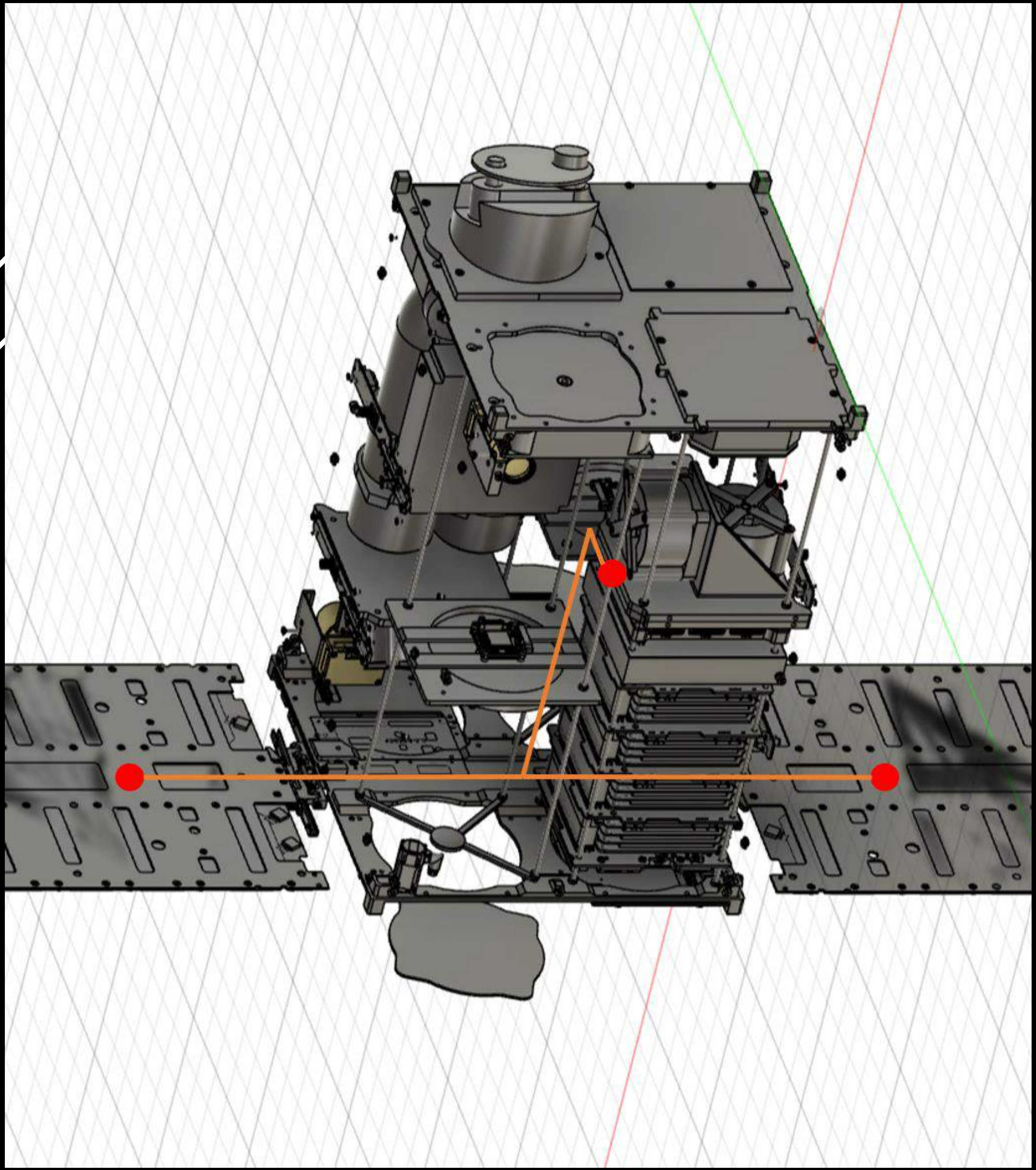
R-485

WIRE ROUTING:

STAR TRACKER

MICRO-D





WIRE ROUTING:

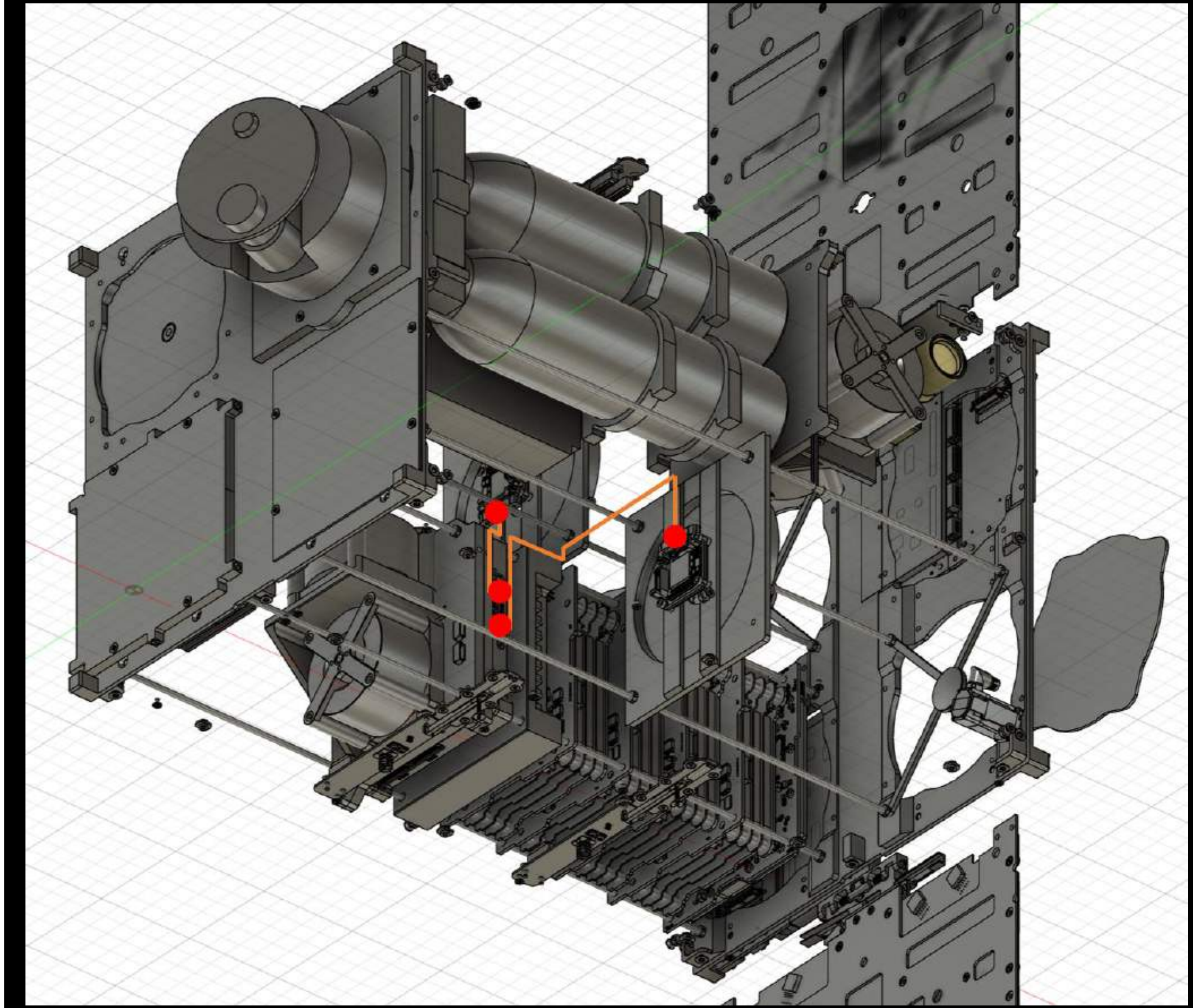
SUN SENSOR

MICRO-D

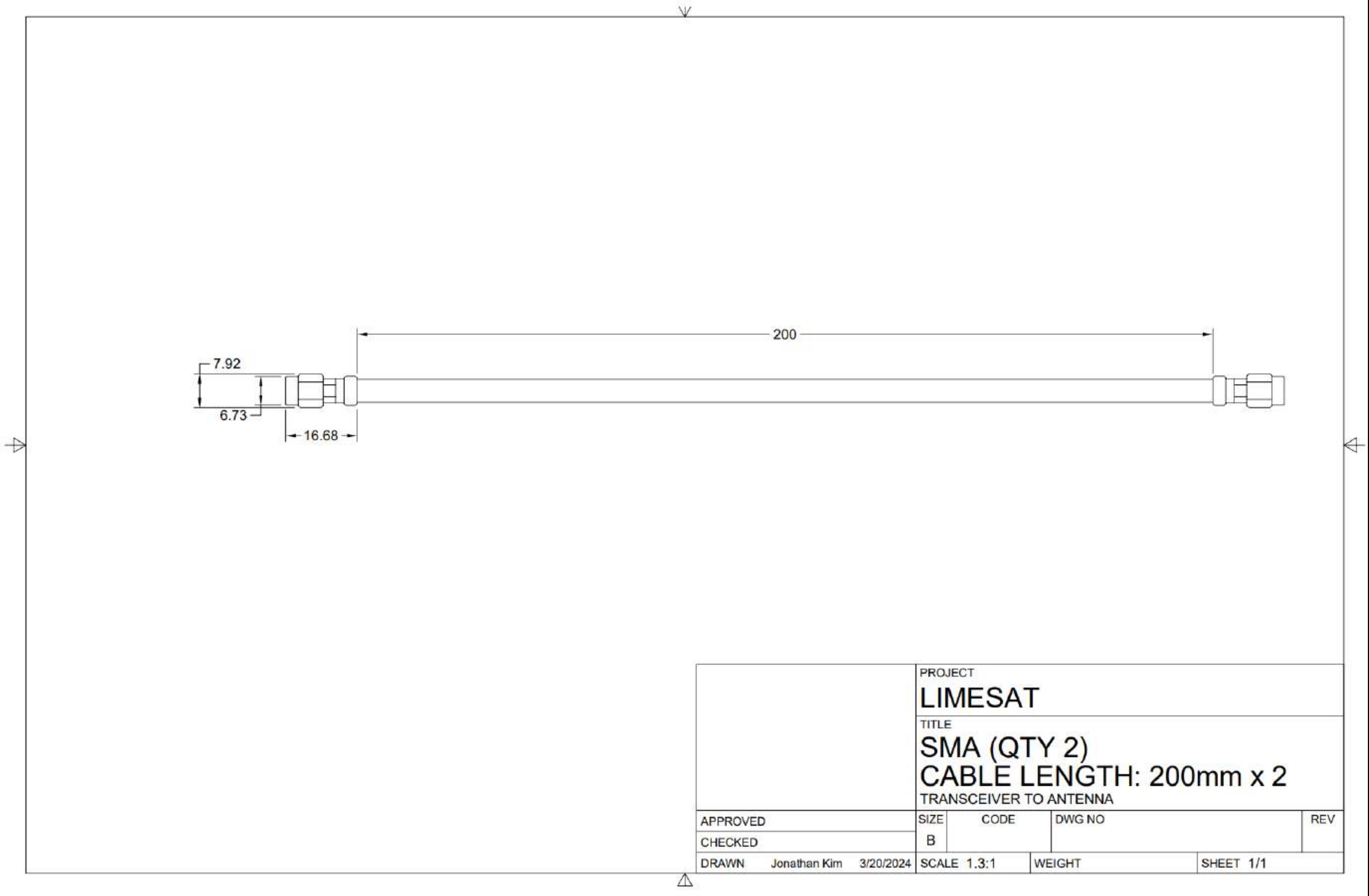
WIRE ROUTING:

PAYLOAD

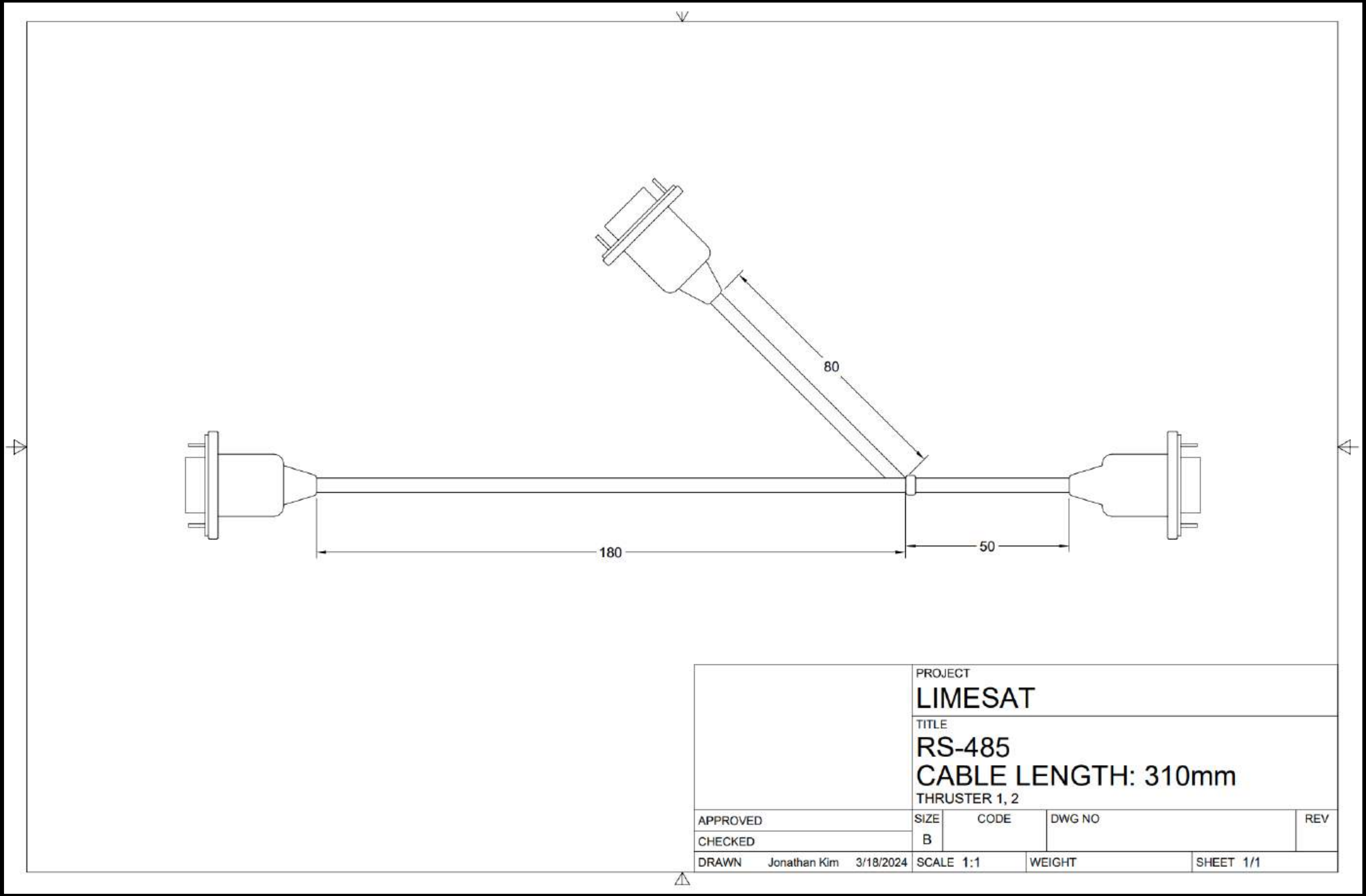
PICO



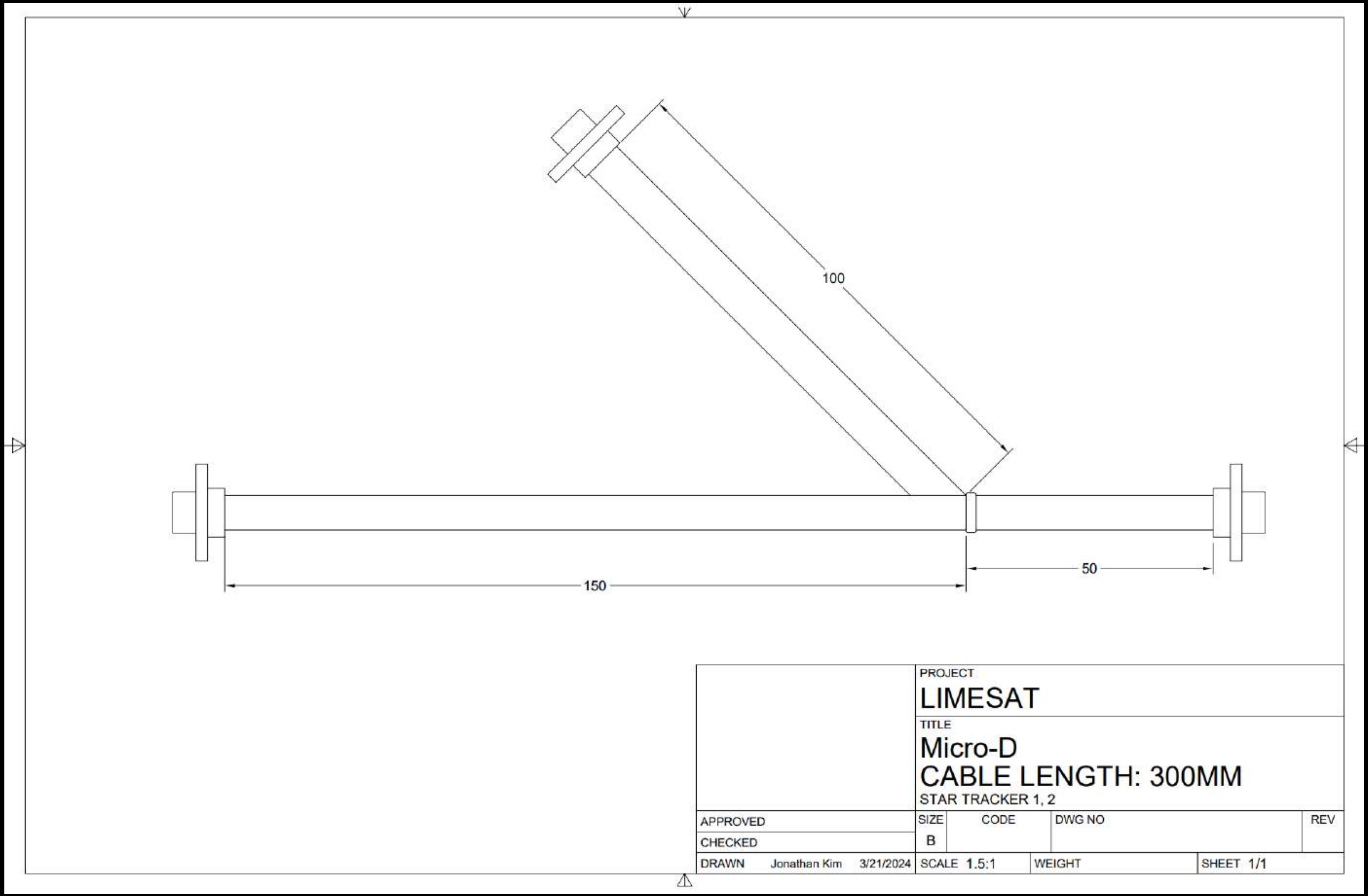
Wire Harness: SMA



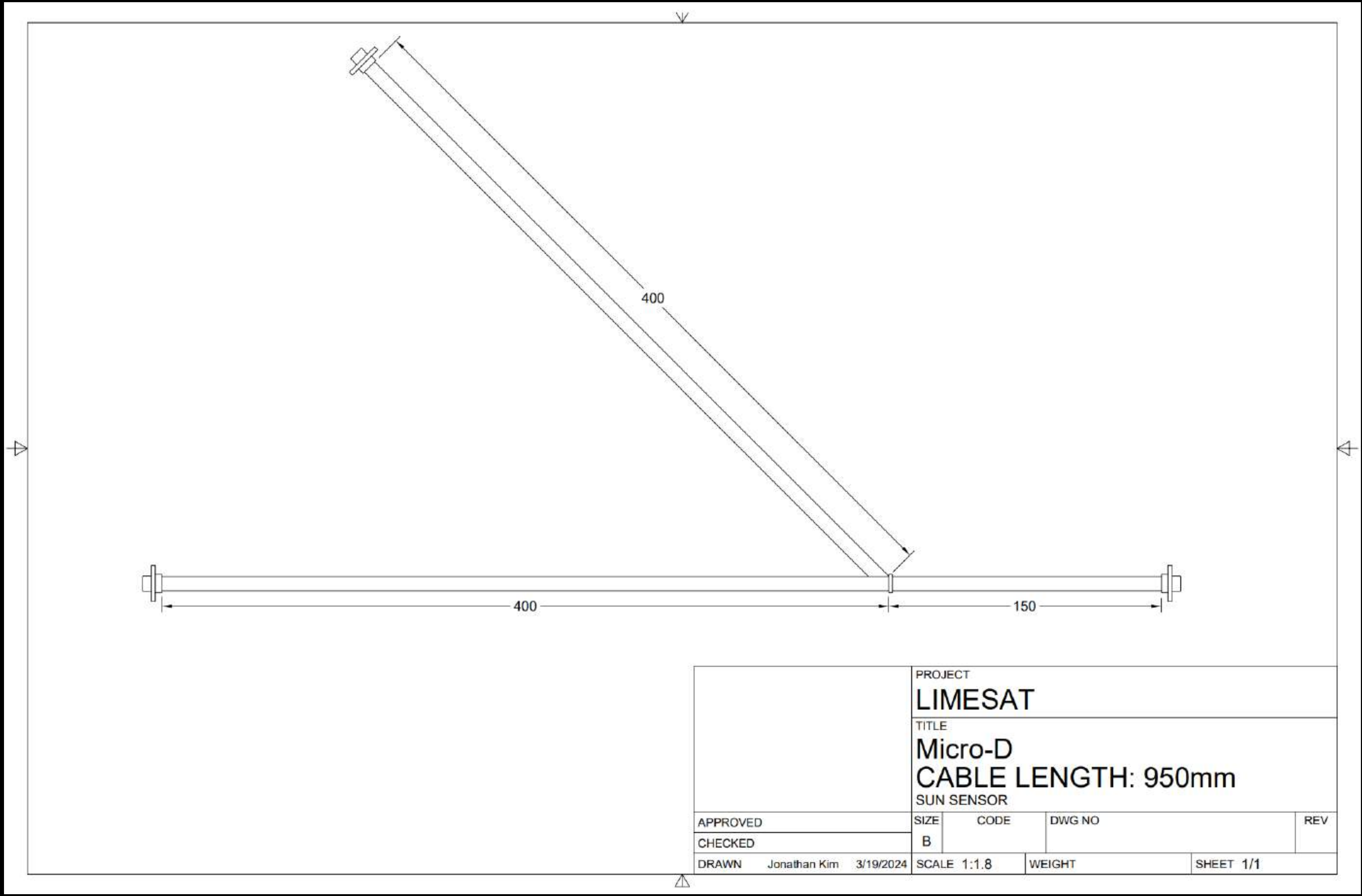
Wire Harness: RS-485



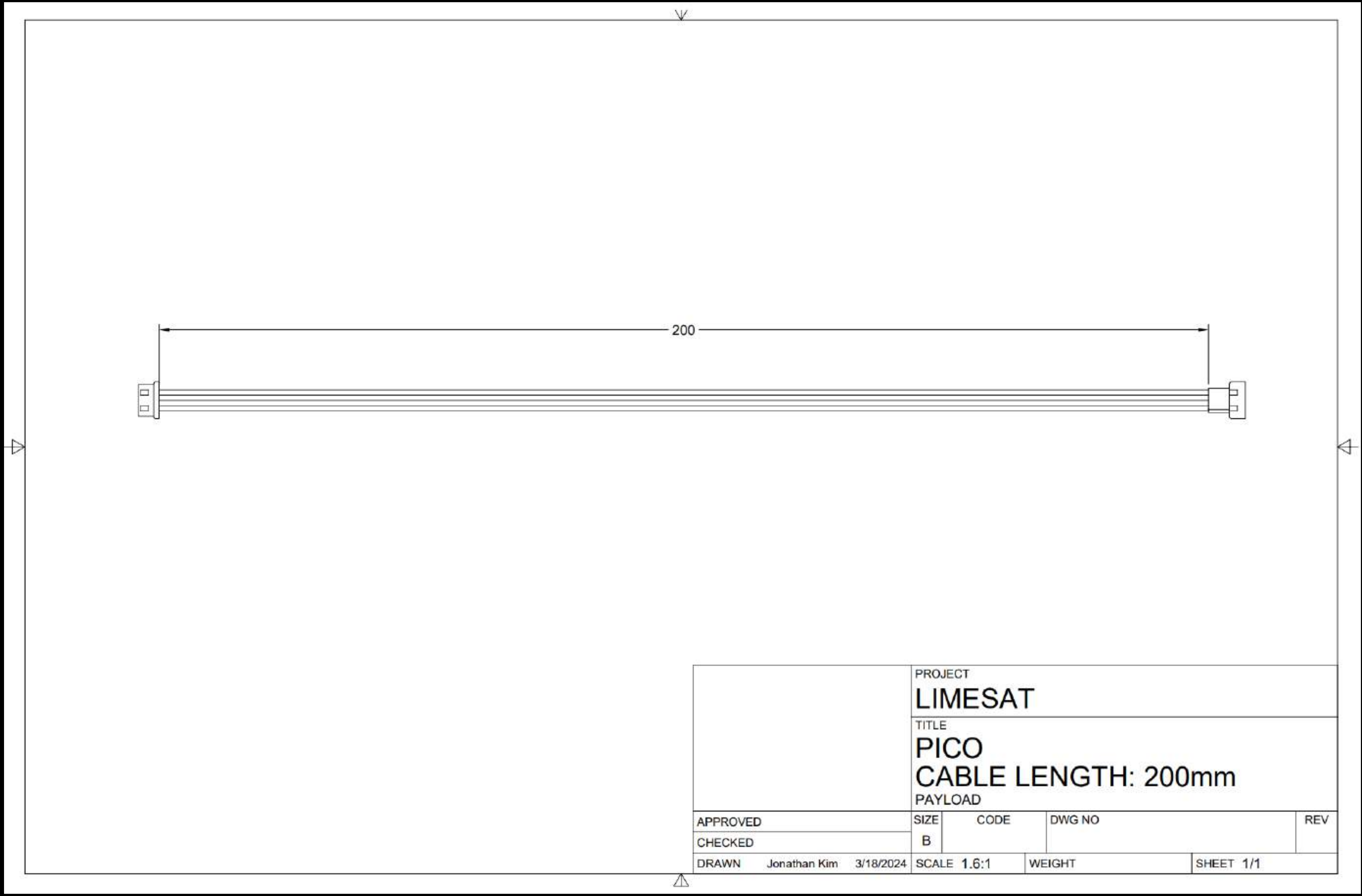
Wire Harness: Micro-D 1



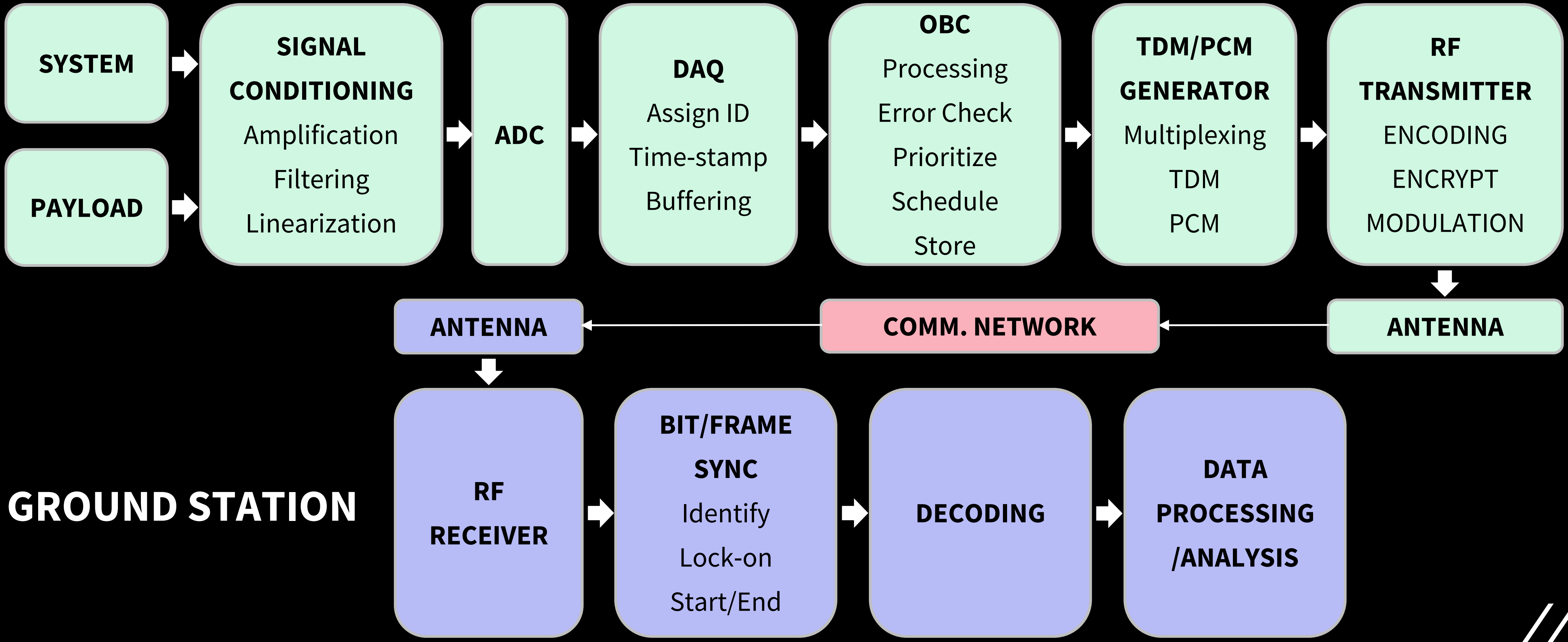
Wire Harness: Micro-D 2



Wire Harness: PICO



Telemetry Data Flow



Data Transmission (Delivery)

Type: X-Band
Frequency: 8.375 GHz

Downlink Data Rate: 50Mbps

- **Can transmit 375MB of data per min.**

Telemetry Data Size
Less than 200 bytes per each packet

- **System Status & Performance**
- **Position & Attitude**
- **Etc.**

OBC

- **8GB Secured Onboard Memory**
- **SD Card Memory Expansion Ready**

Communication Network (Ground Station)

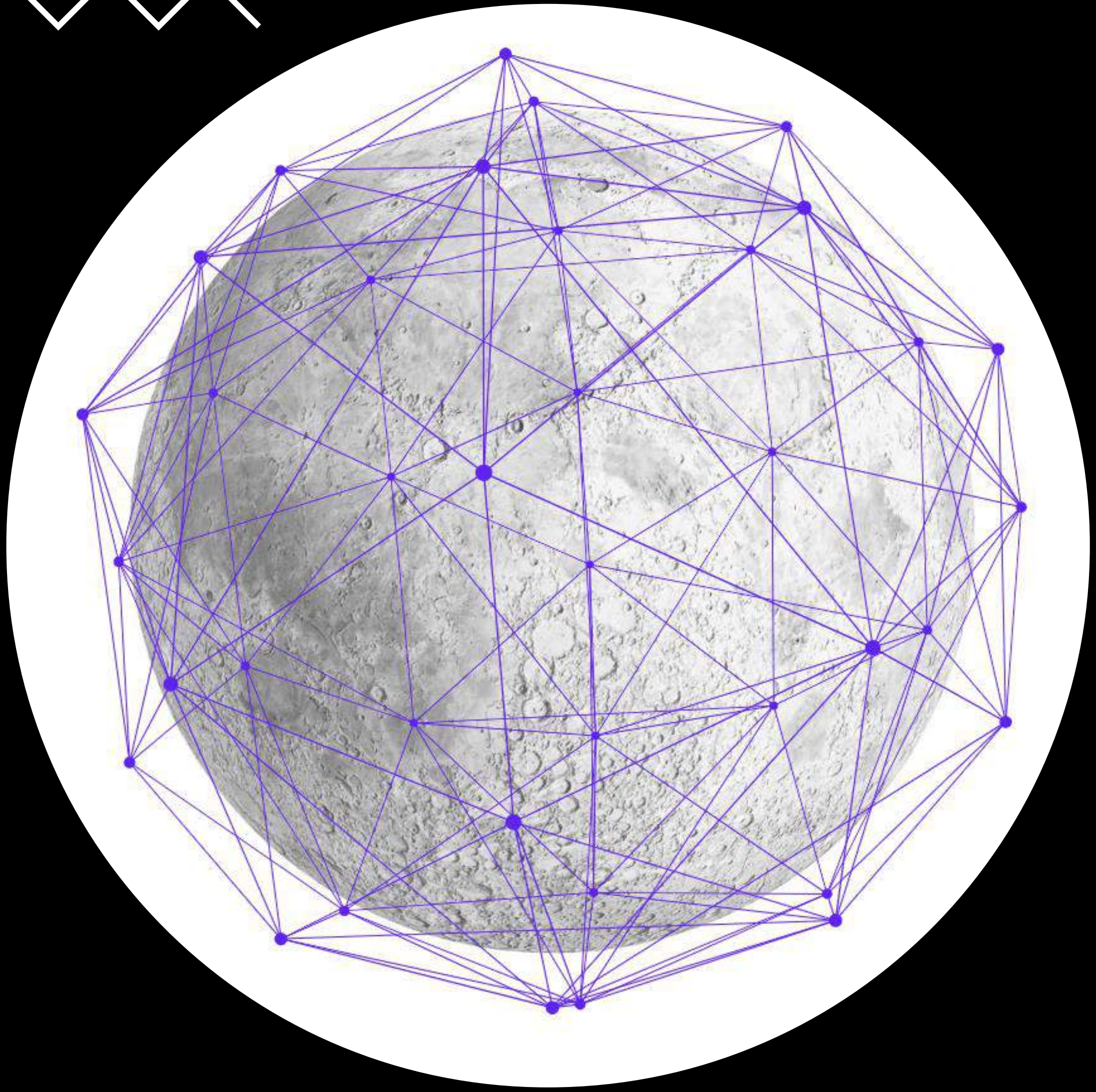
Crescent Space by Lockheed Martin

Parsec Network: Operational in 2026
End-to-End Communication Service

Reserved: Approx. $10.00 per min
On-Demand: Approx. $22.00 per min

Telemetry & Position Data

- Once every 6 hours (1 min each)
- Reserved: 4 mins per day ($1,200 per month)
- On-Demand: 1 mins ($22 per transmission)



Communication Network Coverage Area & Time

Parsec Lunar Network

- System of small satellites working in unison to allow for seamless connection to the Earth
- Satellite network create an orbiting relay network that provides complete communication and navigation coverage
- End-to-end communication services that deliver data back to Earth securely and efficiently

QUESTIONS?

Sources

- LunOSTAR Program Level Requirements

Appendix

Requirement Level	Requirement Number	Requirement	Verification Model A	O	D	T	R	Verification Methods	Status
		Administration							
0	1.0	There shall be a budget of one million dollars for design, development, and mission operations.			X			Verify prices of parts with design parameters and determine, if necessary, that parts are within budget.	
		Space System							
0	2.0	There shall be a 12U Satellite (20x20x34.05cm) which contains all necessary equipment and materials to conduct the scientific objectives and support mission operations.		X	X			Compare completed plan with physical measurements to ensure validity.	
1	2.1	There shall be a Bus.			X			The bus will be designed considering structural loads during launch, and any other necessary maneuvers	
2	2.1.1	There shall be an Electrical Power System (EPS) able to provide stable power, ensuring the fulfillment of energy requirements for both spacecraft systems and observatory mission equipment.			X		X	Calculate power requirements of each system and design or choose a preexisting system that meets those power needs	
3	2.1.1.1	The EPS shall include a rechargeable battery capable of storing enough energy to power the operational needs of the spacecraft during periods when solar power generation is not possible.		X		X	X	Test battery capability with reference to batteries datasheet and verify battery capacity and output.	
3	2.1.1.2	The EPS shall include solar panels that can generate sufficient power to meet the operational needs of the spacecraft.			X		X	Verify with solar panel datasheet that sufficient power can be created to keep batteries charged.	
4	2.1.1.2.1	Deployable solar panels shall have independent restraint mechanisms.			X	X		Verify that procured solar panel restraints can restrain solar panel design and test the restraint mechanism.	
3	2.1.1.3	The EPS shall distribute power to all systems compatible with their voltage and current requirements.		X	X	X	X	Test that electrical power system can verify where power is needed and distribute power accordingly and compare to datasheet.	
3	2.1.1.4	The EPS shall regulate power to stable levels that meet the requirements of all systems of the spacecraft.		X		X	X	Test that power supplied to components is steady and the amount of noise is minimal with reference to the datasheet.	

Appendix

Requirement Level	Requirement Number	Requirement	Verification Model A	O	D	T	R	Verification Methods	Status
3	2.1.1.5	The EPS shall have a lifespan that exceeds 25-month mission duration, accounting for environmental factors.					X	Compare usage of power system to expected mission duration.	
2	2.1.2	There shall be an Environmental System designed to ensure that the satellite systems and payload can withstand the various conditions they will encounter from launch to the end of the mission.	X		X			Structural design will ensure no failure from G loads, protective material around payload will protect from vibrational loads/resonance.	
3	2.1.2.1	Materials and controls will be put into place to manage thermal pressures from the environment.	X		X		X	Thermal simulation will be done and compared to sage temperature allowances for materials used.	
3	2.1.2.2	Cosmic Radiation should be managed to mitigate damage to payload, instruments, and electronics.					X	Compare expected radiation levels to references for sensitive electronics and instruments.	
3	2.1.2.3	Solar Radiation should be managed to mitigate damage to structures, payload, instruments, and electronics.	X		X	X	X	Simulate sunlight exposure time and heating/cooling cycles, Test materials for UV resistance, payload shielded from direct sun exposure.	
3	2.1.2.4	Components of satellite will be able to operate in vacuum conditions without convective cooling.			X	X	X	Design and test cooling system that can mitigate temperatures on electronic and instruments to appropriate levels dependent on their reference sheet.	
3	2.1.2.5	The satellite shall be resistant to electro-magnetic interference.			X	X		Design satellite with protection from EMI in the form of insulation and frequency hopping techniques.	
2	2.1.3	There shall be a Communication system able to provide reliable and secure two-way communication between the spacecraft and Earth-based ground stations.			X	X	X	Choose a communication system which is capable of transmitting and receiving from cislunar space and test communication system for functionality.	

Appendix

Requirement Level	Requirement Number	Requirement	Verification Model					Verification Methods	Status
			A	O	D	T	R		
3	2.1.3.1	The communication system shall be able to provide the essential uplink and downlink data rates for both payload data and command/control instructions.			X	X	X	Test uplink and downlink data rates and compare to reference sheet.	
3	2.1.3.2	The communication system shall have adequate antenna coverage to establish a stable signal link between the spacecraft and the ground station.			X		X	Review manufacturer documentation, datasheets, and design documents.	
3	2.1.3.3	The communication system shall be operated within VHF and UHF frequency bands, in compliance with international regulations.				X	X	Test the system under controlled environment to check both transmit and receive data within the specified VHF and UHF bands.	
3	2.1.3.4	The communication system shall have error detection and correction techniques to ensure the integrity of transmitted and received data.	X			X		Simulate transmission scenarios with injected errors to observe the system's ability to detect and correct them.	
2	2.1.4	There shall be a Computing system able to manage and process data, execute commands, and control spacecraft operations.	X	X	X	X		The computing system will be designed/chosen based off necessary possessing power for spacecraft systems	
3	2.1.4.1	The computing system shall have sufficient processing power to process all spacecraft operations.	X			X		Overload the system with tasks and data to evaluate how it performs under maximum stress.	
3	2.1.4.2	The computing system shall manage all data by collecting, storing, and transmitting it.	X		X	X		Simulate the entire process of data collection, storage, and transmission to ensure seamless integration of all steps.	
3	2.1.4.3	The computing system shall have the ability to receive and implement software updates transmitted from the ground station.			X	X		Simulate a software update and ability to rollback if update fails or causes issues.	

Appendix

Requirement Level	Requirement Number	Requirement	Verification Model A	O	D	T	R	Verification Methods	Status
3	2.1.4.4	The computing system shall incorporate security measures to protect the system against unauthorized access.	X		X		X	Perform vulnerability assessment and security architecture analysis and simulate various threat scenarios to determine how system would respond.	
3	2.1.4.5	The computing system shall uphold precise timekeeping, in synchronization with a universal time standard, for all mission operations and data logging.	X			X		Test synchronization with a universal time standard source.	
3	2.1.4.6	The computing system shall promptly and accurately carry out commands received from the ground station.	X			X		Simulate by transmitting a series of commands from a ground station and observe the system's response and accuracy.	
2	2.1.5	There shall be an Attitude Control System.			X	X	X	MATLAB/Simulink	
3	2.1.5.1	The attitude of the spacecraft should be controlled within ± 10 arcseconds during each occultation opportunity.	X					The control system simulation shall be conducted in MATLAB/Simulink	
3	2.1.5.2	The ACS shall provide stable control of the spacecraft.	X		X			MATLAB/Simulink	
2	2.1.6	There shall be a Propulsion system.			X	X	X	Nozzle and system will be designed considering thrust requirements and physics of space propulsion	
3	2.1.6.1	The Propulsion system shall have adequate fuel for the duration of the prescribed mission length, and an additional 5% ΔV for unplanned/recovery maneuvers.	X		X			Maneuvers and attitude control system desaturation shall be simulated using STK/MATLAB/Simulink	
3	2.1.6.2	The Propulsion system shall enable controlled disposal at the end of the mission life.	X		X			The design should account for enough fuel for disposal.	
2	2.1.7	There shall be a Navigation system.		X	X	X	X	Star Tracker/Sun Sensor	

Appendix

Requirement Level	Requirement Number	Requirement	Verification Model					Verification Methods	Status
			A	O	D	T	R		
3	2.1.7.1	The Navigation system should consist of an adequate selection of Star Tracker, Horizon Sensor, Gyroscope, Sun Sensor, or others, in order to accurately determine the orientation and position of the spacecraft.			X			Validate each sensor's functionality and integration in simulated conditions.	
2	2.1.8	There shall be a Telemetry and Tracking system able to monitor and determine the spacecraft's location, orientation, and velocity to enable precise orbital and attitude adjustments.			X		X	Star Tracker for location, Sun Sensor for Orientation, velocity with respect to the lunar surface	
3	2.1.8.1	The T&T system shall consistently gather telemetry data from all subsystems and payloads to monitor health and operational status.	X				X	Simulate a scenario where the system collects data from all subsystem and payload as intended.	
3	2.1.8.2	The T&T system shall provide accurate tracking data of the spacecraft's position, and velocity measurements.	X					Simulate software algorithms and methods for tracking to ensure accuracy.	
3	2.1.8.3	The T&T system shall have all telemetry data be time-tagged.	X			X		Simulate by injecting series of events or data into the system and verify that each data point has an associated time stamp.	
2	2.1.9	There shall be a Structural system able to provide housing and protection for all subsystems and payloads.			X			Hand calculations will be used to test the structural design.	Complete d
3	2.1.9.1	The material of the spacecraft will be an Aluminum alloy			X		X	Material will be inspected to confirm it follows NASA-STD-6016A standards	Complete d
4	2.1.9.1.1	The aluminum alloy should be resistant to general corrosion, pitting, intergranular corrosion, and stress corrosion cracking			X	X	X	Material will be inspected to confirm it follows NASA-STD-6016A standards	

Appendix

Requirement Level	Requirement Number	Requirement	Verification Model A	O	D	T	R	Verification Methods	Status
3	2.1.9.2	The structural system of the spacecraft will adhere to NASA guidelines and refrain from using any hazardous materials such as Beryllium, cadmium, mercury, silver, or any other such materials.					X	Material will be inspected to confirm it follows NASA-STD-6016A standards	
3	2.1.9.3	Any non-metallic materials used will have a Total Mass Loss (TML) and Collected Volatile Condensable Material (CVCM) equal to or lower than a maximum1.0 percent TML and a maximum 0.10 percent CVCM.					X	Material will be inspected to confirm it follows NASA guidelines based on current outgassing data	
3	2.1.9.4	Geometry and Dimensions shall comply with the standard CubeSat unit system and will comply with the 12U specification.		X	X			20 cm x 20 cm x 34.05 cm, rectangular prism shape	Completed
3	2.1.9.5	The payload should be able to withstand around 0.5 Gs of stress during Lunar launch				X		The payload will be vibration tested to ensure it can survive shock from ignition	Complete d
1	2.2	There shall be an Observatory Payload.			X			Observatory will use Near UV imaging techniques	
2	2.2.1	There shall be a Telescopic Array of 2 co-aligned telescopes to view the solar corona, consisting of Optics Assemblies and Focal Plane Modules (FPM).			X			The design will include two observational telescopes.	
3	2.2.1.1	The Optics Assembly shall consist of focusing lenses which transfer optical information to the FPM.			X		X	Verify type of data transfer is possible with telescope being used through reference sheet.	
3	2.2.1.2	The Focal Plane Module shall consist of a Near Ultra-Violet (NUV) sensitive CCD capable of interfacing with the data transmission hardware.			X	X	X	Verify data can be collected in NUV using reference sheet compared to test and that data can be transferred with chosen hardware.	

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Requirement Level	Requirement Number	Requirement	Verification Model A	O	D	T	R	Verification Methods	Status
2	2.2.2	There may be a deployable mast to accommodate additional focal length/parallax.			X			Mast will be designed with proper curvature for accurate imaging, design and testing at a ground facility will verify results	
2	2.2.3	The observatory payload shall have the capability to measure over the NUV range of 300-400 nm.			X	X	X	Choose telescope with given capabilities with reference to a datasheet and test for accuracy.	
2	2.2.4	The observatory shall have an angular resolution with half power diameter <3 arcseconds.			X	X	X	Choose telescope with given capabilities with reference to a datasheet and test for accuracy.	
	3.0	Ground System							
0	3.0	Pre-Flight Handling			X			A storage unit meeting the humidity, temperature, and sterilization requirements will protect the payload. Design will also consider launch loads	
1	3.1	The Satellite and components shall not be subjected to humidity greater than 70% or less than 30% during construction or storage or transportation.		X	X			Preexisting facilities with humidity and temperature requirements will be used, or one will be constructed if need be	
1	3.2	The Satellite and components shall not be subjected to a temperature greater than 23°C or less than 13°C during construction or storage or transportation.		X	X			Preexisting facilities with humidity and temperature requirements will be used, or one will be constructed if need be	
1	3.3	The Satellite shall be sterilized at determined intervals during construction and maintained in an ISO Class 8 clean room during all phases of the mission prior to launcher integration.		X	X			Regularly inspect and test post-sterilization to confirm the absence of contaminants.	

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1	3.4	Data Acquisition systems shall maintain compatibility with all relevant Communication Systems Requirements in 2.1.1.3	X		X	X		Simulate scenarios by injecting data into the system.	
		Validation and Testing							
0	4.0	All components of satellite shall be compared to physical plans for validation and tested for functionality.		X	X	X		Components will be measured to verify design is correct	
1	4.1	Measurement of satellite components' dimensions shall be compared to planned dimensions.		X	X		X	Use CAD model with reference to datasheets on various components.	
1	4.2	Satellite shall be tested for functionality of the electrical power system.		X		X	X	Tests will be done by running all systems simultaneously to ensure the power source can withstand the load placed on it as designed.	
2	4.2.1	Solar cells will be tested before launch to ensure adequate generation of power for satellite functions.	X				X	STK	
2	4.2.2	The EPS shall be tested to ensure distribution of power to appropriate instruments and verify the correct amount of power is being sent to specific satellite components.		X		X		Required power for every instrument/ component will be demanded and then feedback will be recorded.	
1	4.3	Optical instruments shall be tested for functionality before launching the satellite.		X		X		Telescopes and other instruments will be placed in an environment simulating mission conditions	
2	4.3.1	Main observing optical instrument shall be tested to verify an angular resolution with half-power diameter <3 arcseconds can be achieved.		X	X	X	X	Validation of physical test of optical instrument chosen with datasheet for optical instrument to ensure proper functionality.	
2	4.3.2	Main observing optical instrument shall be tested to verify solar radiation measurements can be made in Near UV range of 300-400nm.			X		X	Measurements will be conducted and analyzed in a test to confirm near UV capabilities	

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Requirement Level	Requirement Number	Requirement	Verification Model			Verification Methods			Status
			A	O	D	T	R		
1	4.4	All elements of satellite will be tested to comply with environmental standards.	X	X		X		Satellite will be tested to withstand thermal stresses, radiation, attitude control, tracking, and observation of solar corona	
2	4.4.1	The satellite's thermal protection and all components of exterior faces shall be able to withstand a temperature range of –250 to 250 degrees Fahrenheit.	X		X		X	Using thermal simulation along with a prepared CAD model of the satellite along with datasheets of components.	
2	4.4.2	The satellite shall be able to withstand material stresses due to thermal shock between lit and shaded regions.	X		X		X	Using thermal simulation along with a prepared CAD model of the satellite along with datasheets of components.	
1	4.5	The propulsion system shall be tested to ensure accuracy of commanded thrust and impulse.	X		X	X	X	MATLAB Simulink along with reference to propulsion system datasheet through tests shall be used.	
1	4.6	The attitude system shall be tested for functionality and accuracy of controls within ± 10 arcseconds.	X		X		X	MATLAB Simulink along with reference to propulsion system datasheet shall be used.	
		Operations							
0	5.0	There shall be procedures and timelines for every section of the operation			X				
1	5.1	There shall be pre-flight procedures and timelines.							
2	5.1.1	The Satellite shall undergo a charging cycle to optimize capacity upon deployment and lifetime cyclability before delivery.		X		X	X	Battery cycle testing shall be conducted, and data sheet referenced.	

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Requirement Level	Requirement Number	Requirement	Verification Model					Verification Methods	Status
			A	O	D	T	R		
2	5.1.2	The Satellite shall be stored in an ISO Class 8 clean room before delivery.					X	ISO Class 8 clean room will ensure sterilization, observation of components will check for unwanted contamination	
2	5.1.3	The Satellite shall be made 'safe' and flight-ready by means of "Remove Before Flight" safety features before delivery.		X	X		X	Inspectors shall verify that RBF implements are in place.	
2	5.1.4	The Satellite shall undergo a final flight readiness inspection to be signed by the Project Manager(s), Principal Investigator(s), and Technical Authority.		X			X	Inspectors shall validate dimensions, the engagement of any single use deployment mechanisms, power systems, state of charge, etc.	
1	5.2	Deployment			X				
2	5.2.1	The satellite shall be deployed from Gateway orbital science station at the cislunar L2 LaGrange point.			X			The design shall comply with the Nanoracks dimension specifications and launch requirements.	
3	5.2.1.1	The deployment readiness date shall be NLT 31 December 2026			X		X	Frequent progress checks and effective planning will ensure the deadline is made	
3	5.2.1.2	The Mission Elapsed Time (MET) shall begin when spacecraft is deployed from Gateway.			X			The release of a depression switch shall initiate the MET Timer	
3	5.2.1.3	The Satellite shall enable primary power to the Bus NET T+ 00:30:00 from the MET.				X		The Boot-On command shall be sent 30 minutes after the MET begins	
1	5.3	Station Keeping	X		X			Regularly scheduled maintenance checks will be conducted to ensure station is performing as planned	

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2	5.3.1	The Satellite's orbital period around L4 shall be near the orbital period of the Moon around the Earth, within a tolerance TBD.	X		X			The orbit shall be validated with STK simulation/MATLAB/Simulink	
1	5.4	End-of-Life			X			Deorbiting the satellite into a graveyard orbit will ensure safe End-of-Life is responsible	
2	5.4.1	The Satellite should be decommissioned in a responsible and timely manner at the mission conclusion.	X		X			TBR in accordance with NASA NID 8715.129	

Thermal Analysis

Max Temp.	Max Flux	Min Temp.	Min Flux
-70.69 C	1415.96 W/m^2	-140.6 C	1309.39 W/m^2