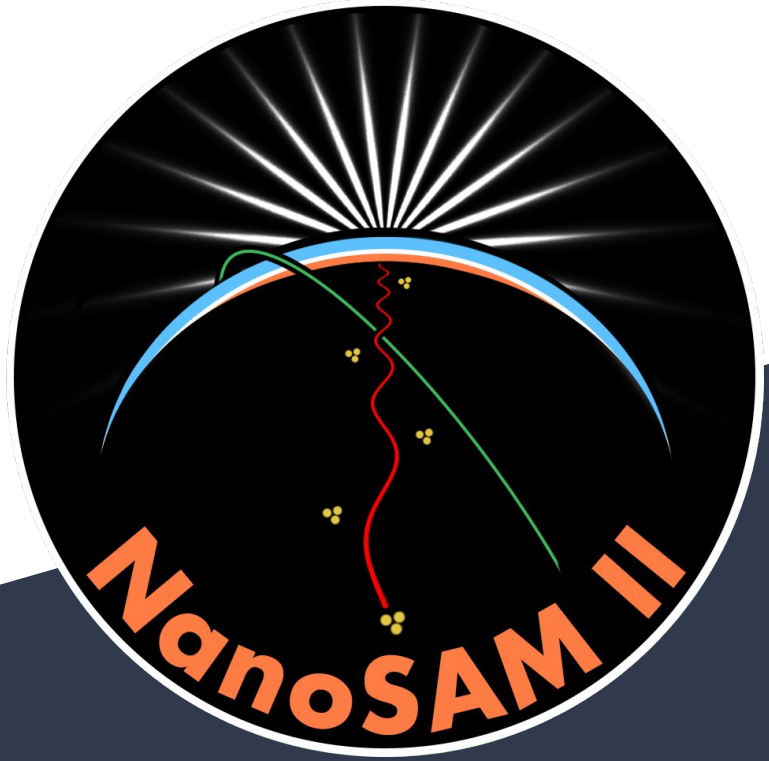
NanoSAM II

Nano-Stratospheric Aerosol Measurement

Testing Readiness Review

March 3, 2021



Ball Aerospace

University of Colorado Boulder
Department of Aerospace Engineering Sciences

Agenda

NanoSAM II
TRR

- Overview
- Schedule
- Test Readiness
- Budget

Project Overview

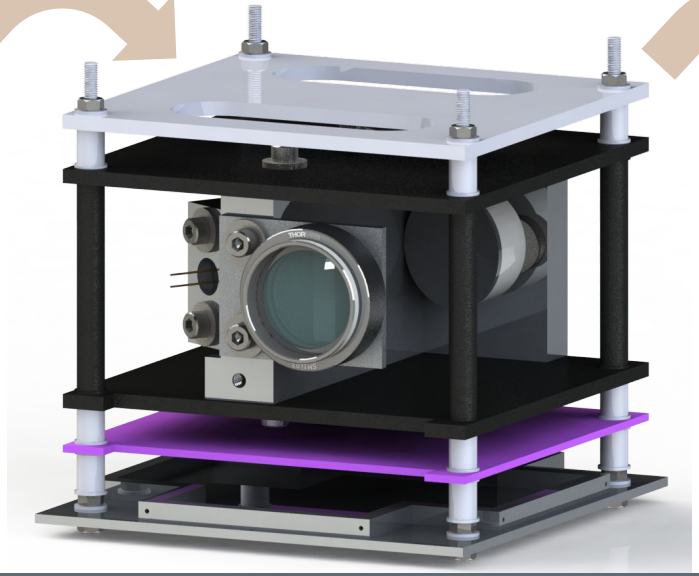
Abby Hause

Project Background & Purpose

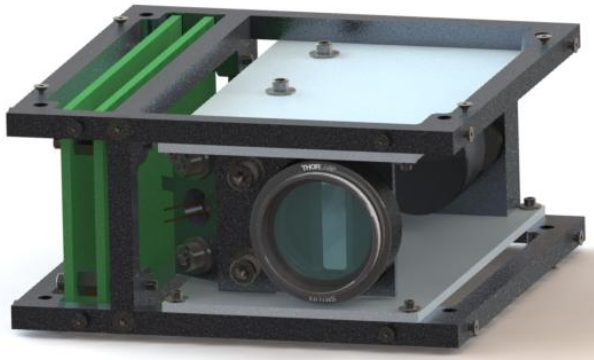
SAM/SAGE Instruments
(1979-1984, 2001-2006, 2011-Current)
Bulky, High Cost, Low Data Volume

SAGE III on ISS [4]

NanoSAM I
(2019-2020)
Optical Instrument for CubeSat Footprint

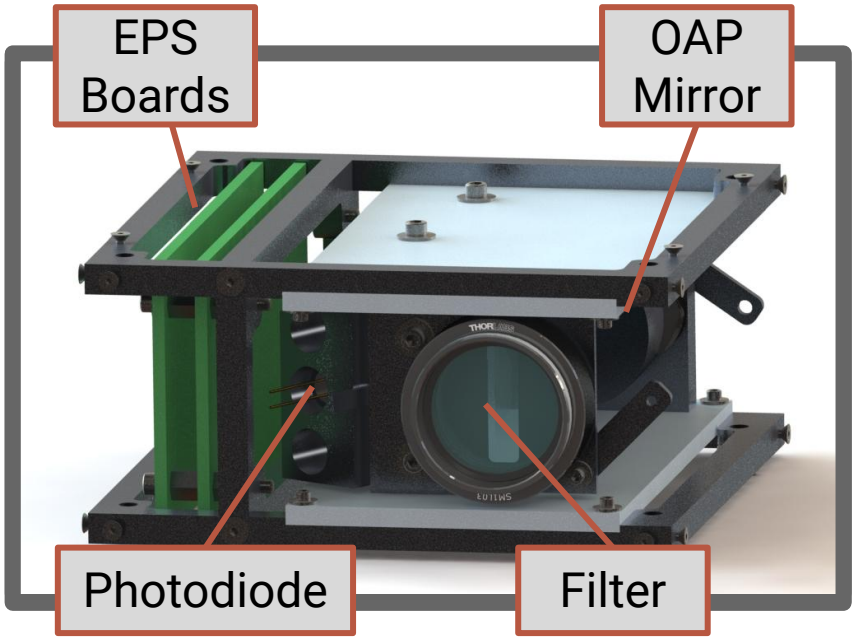


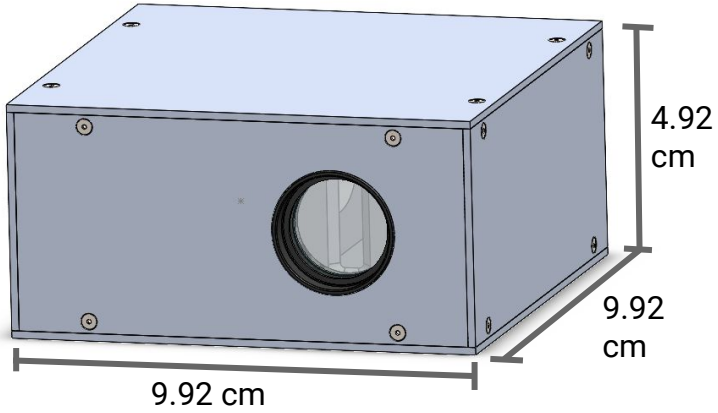
NanoSAM II
(2020-Current)
Integrated 0.5U CubeSat Payload



NanoSAM Mission CONOPS

NanoSAM II Payload

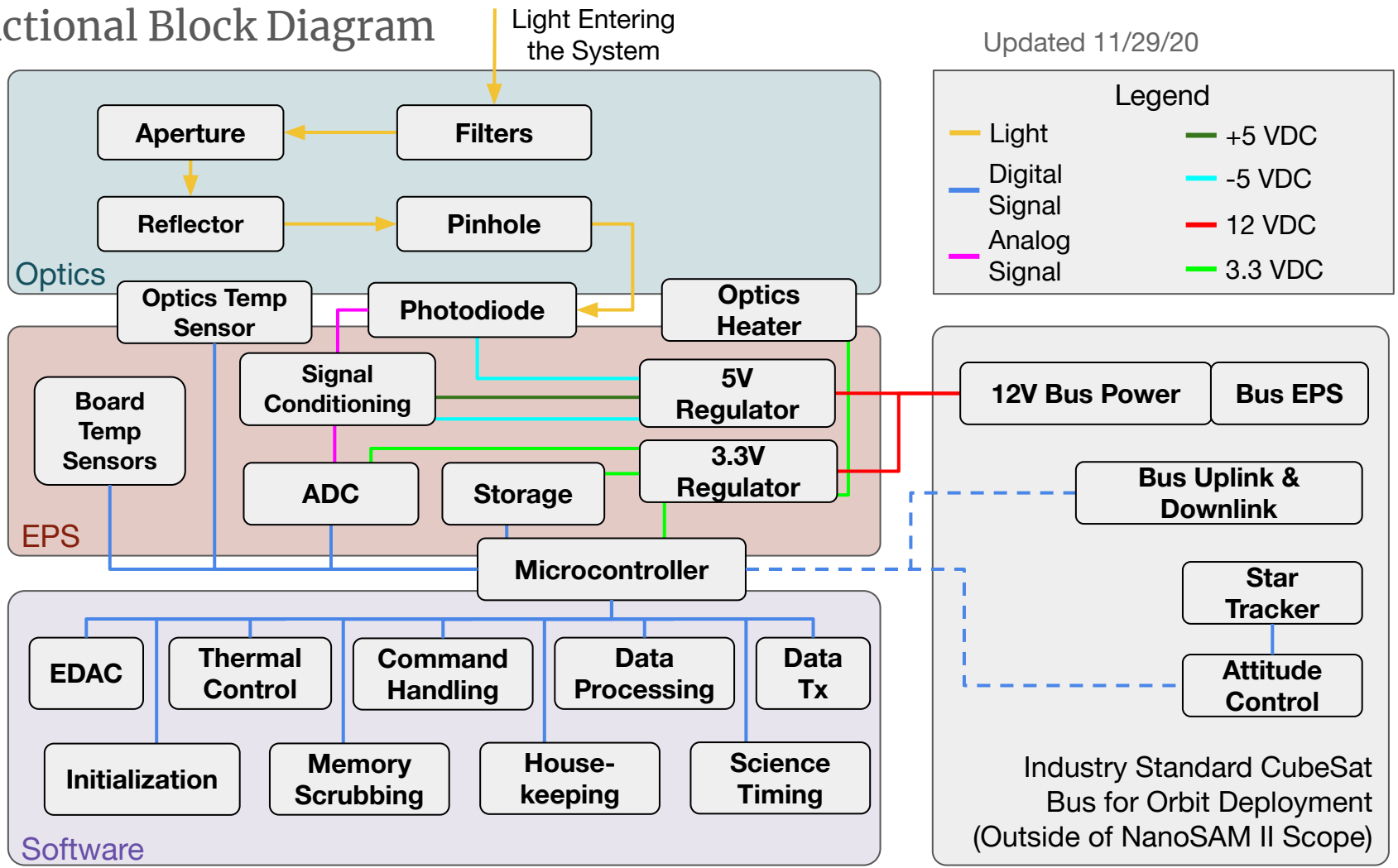




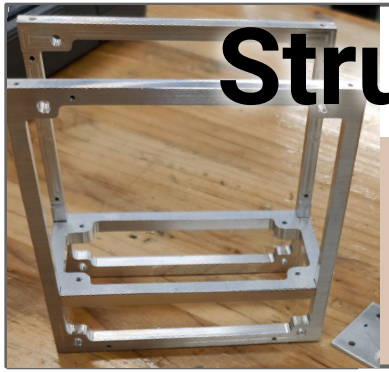
Mass: 0.48 kg
Size: 0.5 U

Gathers Irradiance Measurements at 50 Hz

Functional Block Diagram

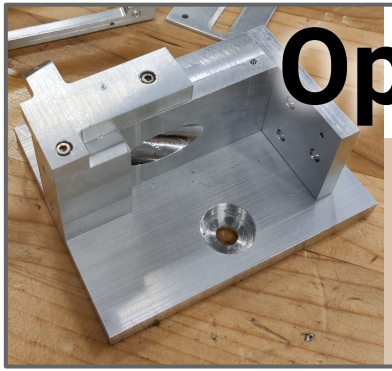


Status on Critical Project Elements



Structure

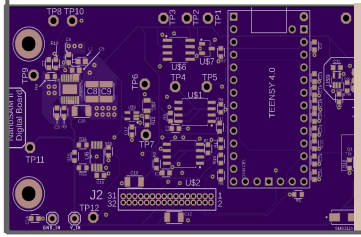
0.5U Payload Form Factor



Optics

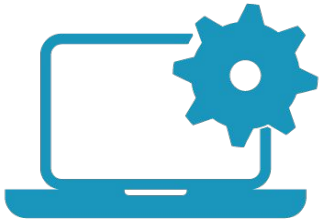
Match SAM-II Instrument Legacy Performance

Electronics



Low-Noise Signal Processing

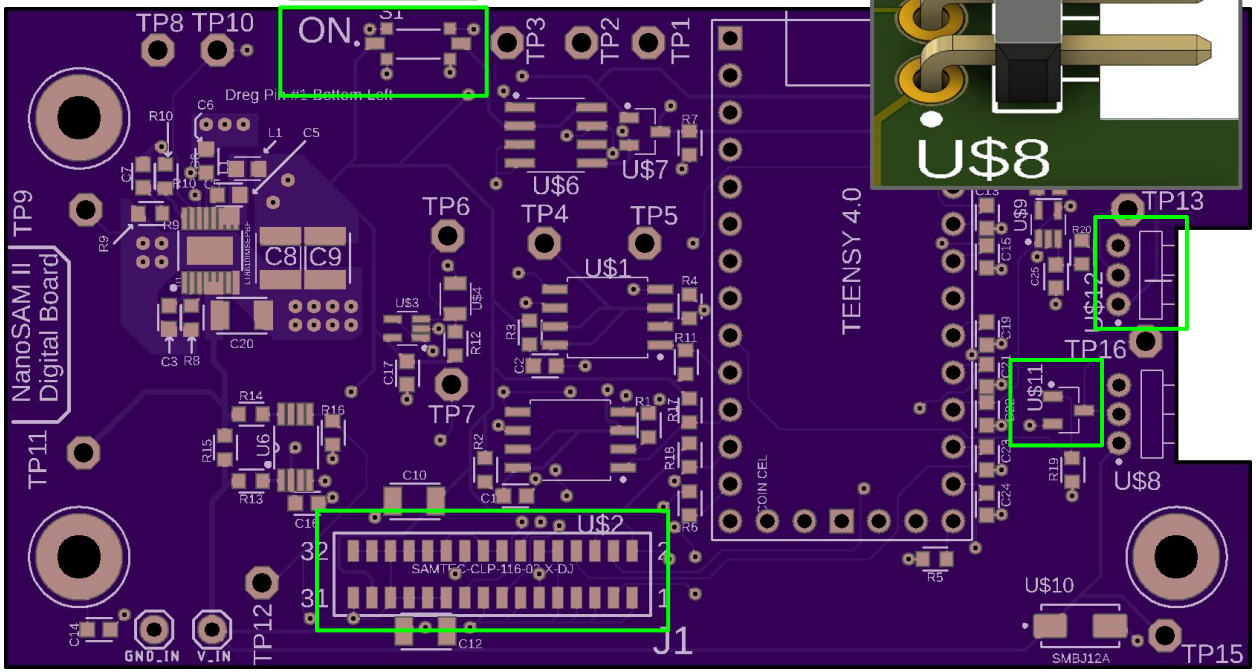
Software



Timely and Reliable Data Collection

Electronics Design V2

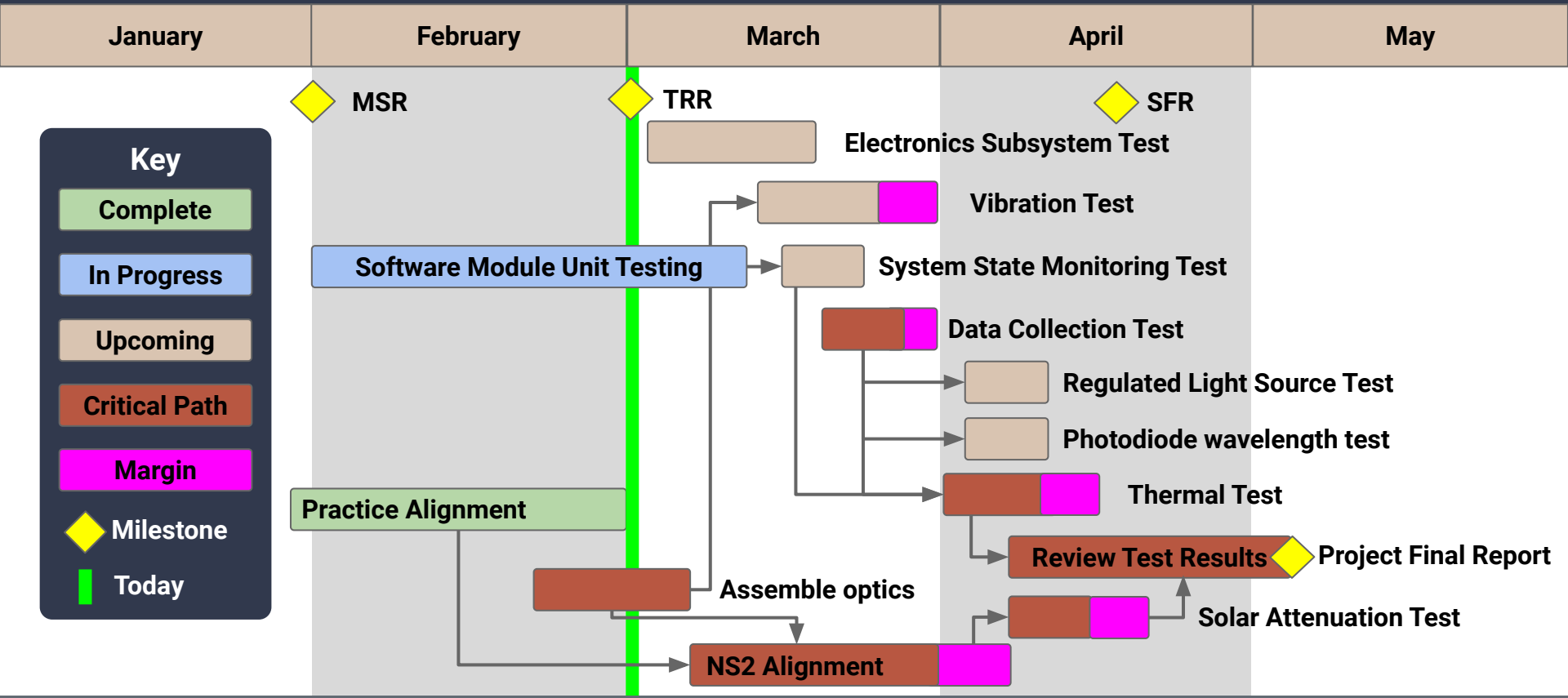
- **Manufacturing tolerance on B2B copper pads**
- **New digital B2B layout with surface mount**
- **Larger resistor heater MOSFET**
- **Watchdog hardware switch**
- **Clip Connectors for ease**
- **Increased isolation of the ground planes**



Schedule

Abby Hause

Schedule (Testing Focus)



Test Readiness

Matt Bridges, Jashan Chopra, Axel Haugland

Testing Rationale (Subsystems)

Tests Needed	Requirements Verified
Electronics Subsystem Test	Data Capture (1.0), Communications (2.0), **Power Consumption (1.5)**
Software Unit Testing	Error Checking (1.3), Fault Mitigation (2.2)
Optics Alignment	**SAM-II Equivalent Optics (3.0)**, **MTF (3.2.2)**
Optics FOV Measurements	**Vertical Resolution (3.2), FOV (3.2.1)**

*** Bold -** Fully verifiable, Unbold - Partially verifiable

Testing Rationale (System Level)

Tests Needed	Requirements Verified
Data Collection Test (Electronics/Software)	**Data Capture (1.0)**, **Sampling rate (1.1.1)**, **Processing rate (1.1.1.1)**, **Data Collection Bit Size (1.1.2)**, **Storage Size (1.1.3)**, **Communications (2.0)**
System State Monitoring (Electronics/Software)	**Housekeeping (1.4.1-3), Fault Mitigation (2.2), Error Checking (1.3)**
Data Window Timing (Electronics/Software)	**Data Collection Timing (1.1.4), Calibration (1.2)**
Regulated Light Source Test (Integrated System)	**Optics Data (1.1)**, SNR (2.1), SAM-II Equivalent Optics (3.0), **Wavelength (3.1)**
Solar Attenuation Test (Integrated System)	**SNR (2.1), SAM-II Equivalent Optics (3.0)**

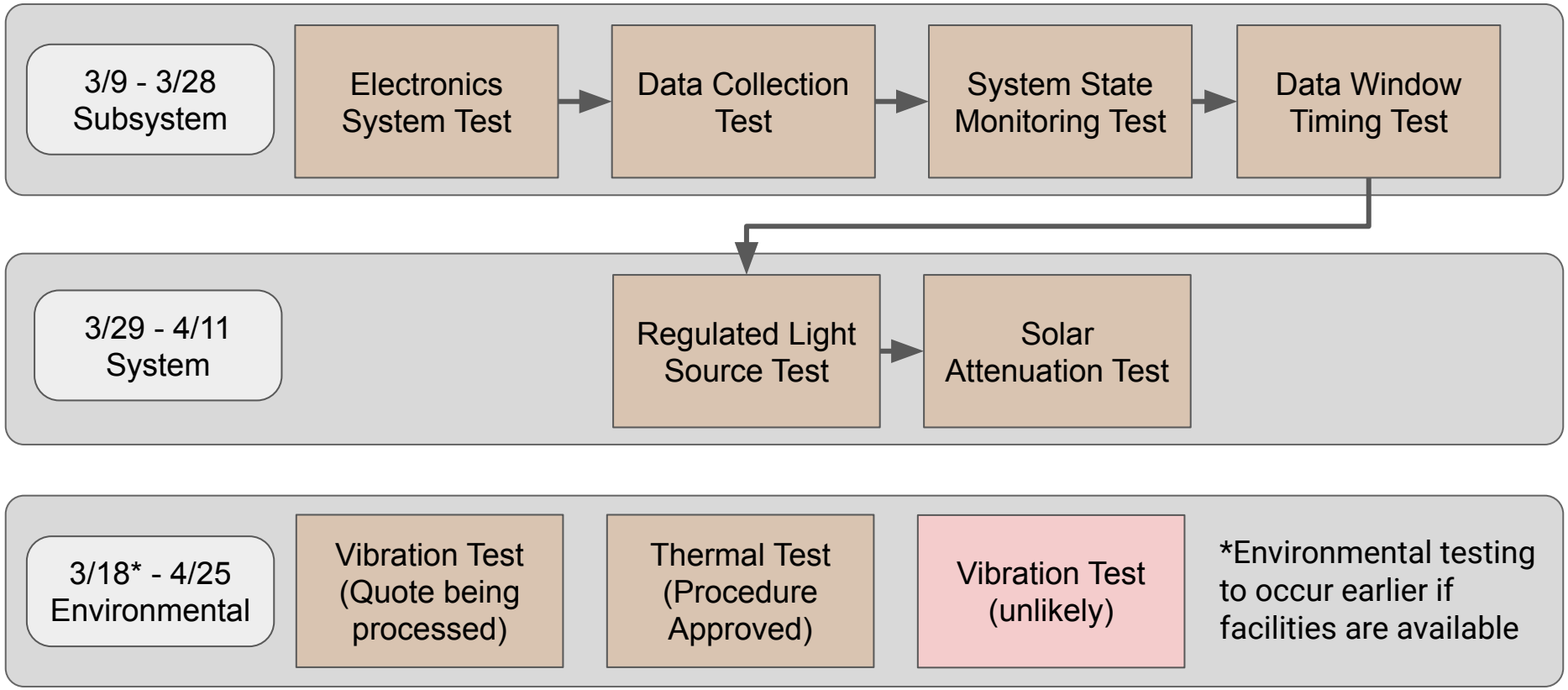
*** Bold -** Fully verifiable, Unbold - Partially verifiable

Testing Rationale (Environmental Tests)

Tests Needed	Requirements Verified
Vibration Test	**Vibration (5.1.1-2)**
Thermal Test	**Thermal (5.2.1-2)**
Vacuum Test	Vacuum (5.3) Likely to not be verified due to limited facility availability, however this requirement is not essential to Level 3 success

*** Bold -** Fully verifiable, Grey - unlikely to be verified

Overall Testing Flow



Risk Reduction

Electronics Assembly Tests

- Validate our manufacturing and design
- Ensures electronics debugging is not an issue in further testing

System Integration Tests

- Provide ample opportunity for system adjustment and calibration
- Meeting requirements in ground testing leads to greater beneficial margin b/w requirements and system capability
- Increase future NanoSAM team resources

Flight Readiness Tests

- Begin assessment of flight feasibility
- Provide most valuable analysis opportunity on structural capabilities
- Increase future NanoSAM team resources

Testing Safety

Equipment Safety

Electronics:
- ESD Mats in lab
- ESD wristbands for MOSFET handling

Optics:
- Proper cleanliness procedures when handling/operating
- Airtight storage of sensitive components for future teams

Other:
- Proper procedures applied in the use of external testing equipment

Personnel Safety

Covid-19 Precautions:
- Use of masks and social distancing
- Follow CU policy when on campus, and proper policy in other facilities
- Sign up for lab spaces
- Prioritize the safety of our community over the timeline of the project

Before Feb 15: R2R forms + Procedures (email Nancy Glaze, 6 feet apart, masks)

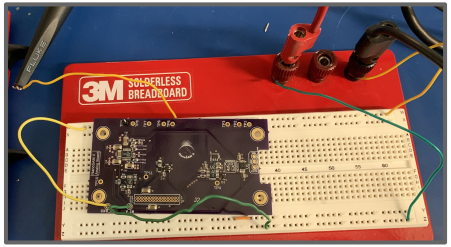
Electronics System Tests

Requirements V&V

1.0: Data Capture
- The supporting electronics and software shall digitize, packetize, and store housekeeping data and information collected from the photodiode
- The system uses less than 7.3W with the heater running.

2.0: Communications
- Communicates with laptop for ground testing

3/4 - 3/9	Individual Analog Board Test	Individual Digital Board Test
3/11 - 3/16	Basic Integration and Teensy Test	Electronics External Devices Test
3/16 - 3/19	Create Test Setup for Software Integration Tests	



Electronics System Tests Specifics

		I.C
	Test operator must be grounded. **Testing must be done on an ESD safe mat.**	
1	Set pow	
2	Orientat	
3	Connec corner c	
4	Connec board, r	
5	Connec Open Te	
6		

13	Measure the voltage of Teensy pin 15 Expected Value: Same as T5 Actual Value: _____	
14	Measure volta Expected Valu	
15	Measure volta connector. Expected Valu	
16	Calculate the $R_T = [(T5/T3)$	
17	Calculate the equation. $T = [(ln(R_T /$	
18	Measure volta Expected Valu	

21	Shut off power supply, digital multimeter, and any additional used equipment.	
22	Disconnect GND_IN and V_IN banana plugs from the board.	
23	Place the disconnected board in an ESD safe storage location.	

Testing Notes:

_____

_____

_____

_____

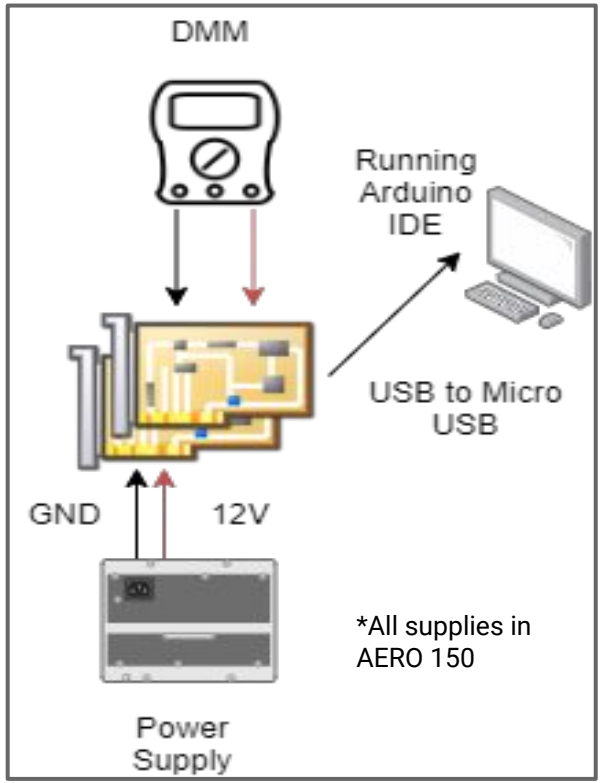
_____

_____

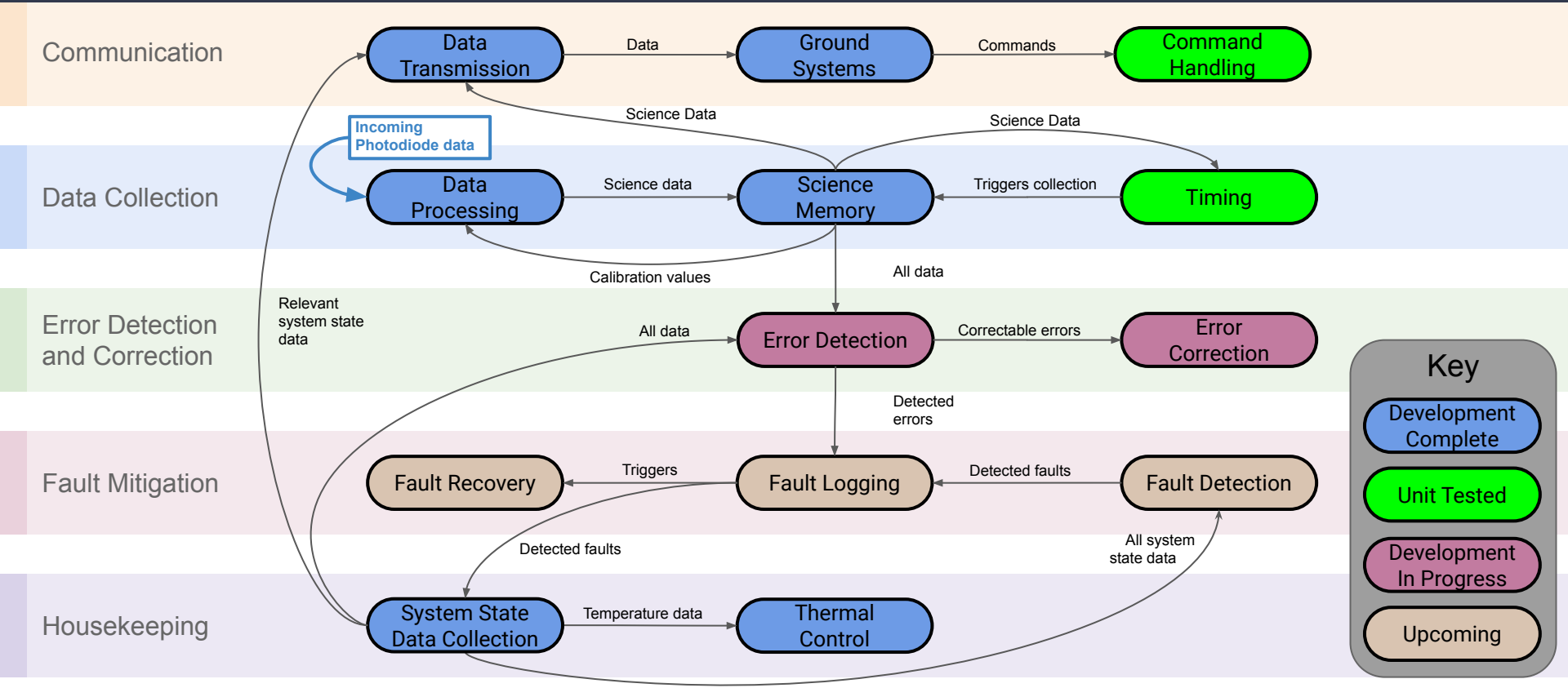
_____

_____

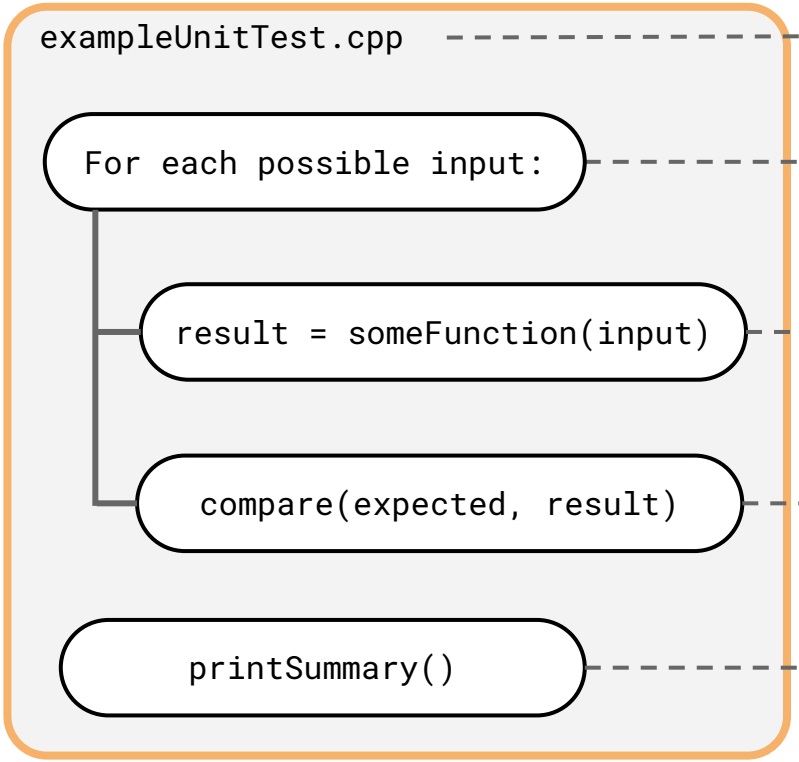
Test Operator signature: _____



Software Dev/Testing Status



Unit Testing Methodology



Driver function for the unit test is a separate entity from NanoSAM II Flight Software. Unique functions are written for each NanoSAM II module that can be tested without hardware

Loop through all possible inputs to function being tested

Input is stubbed in rather than coming from hardware

Results of the operation are compared with the value that they should return

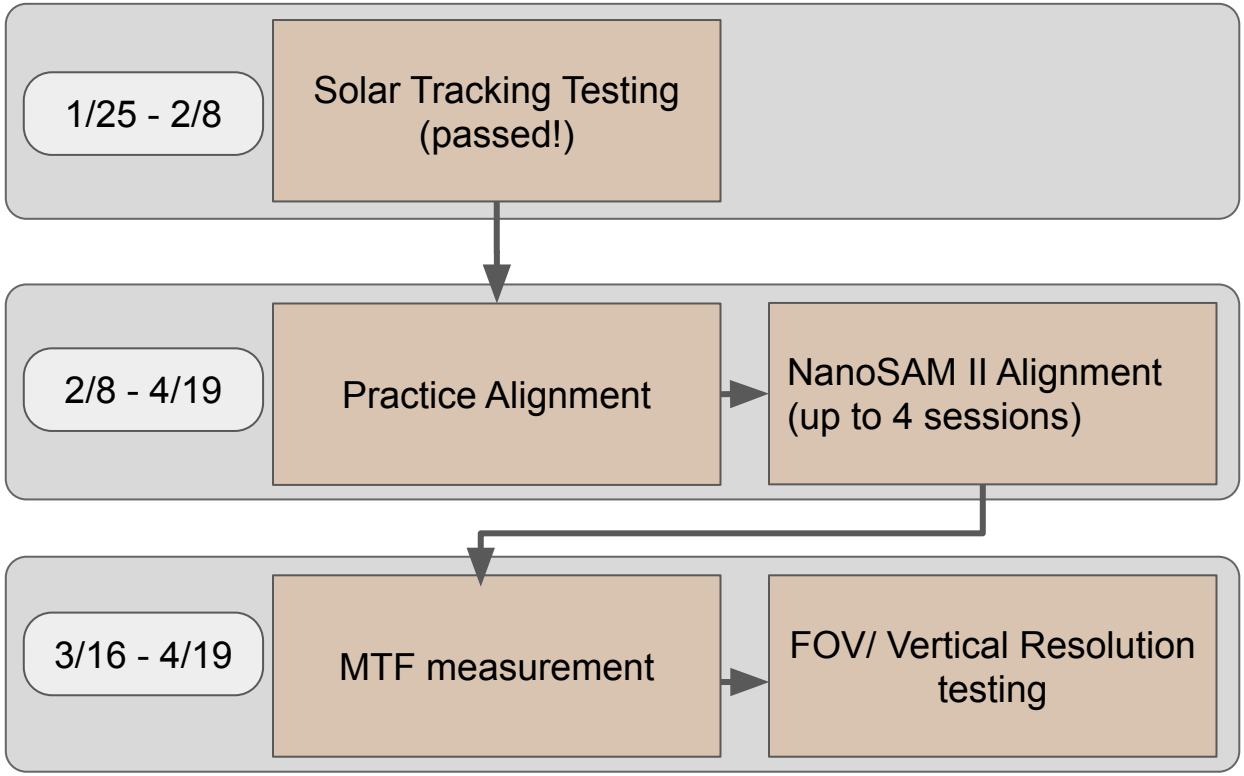
Prints the percentage of tests that passed along with a description of each that failed to give the test operator a clear path for debugging

Alignment Status / Other optics tests

Requirements V&V

3.0: SAM-II Equivalent Optics

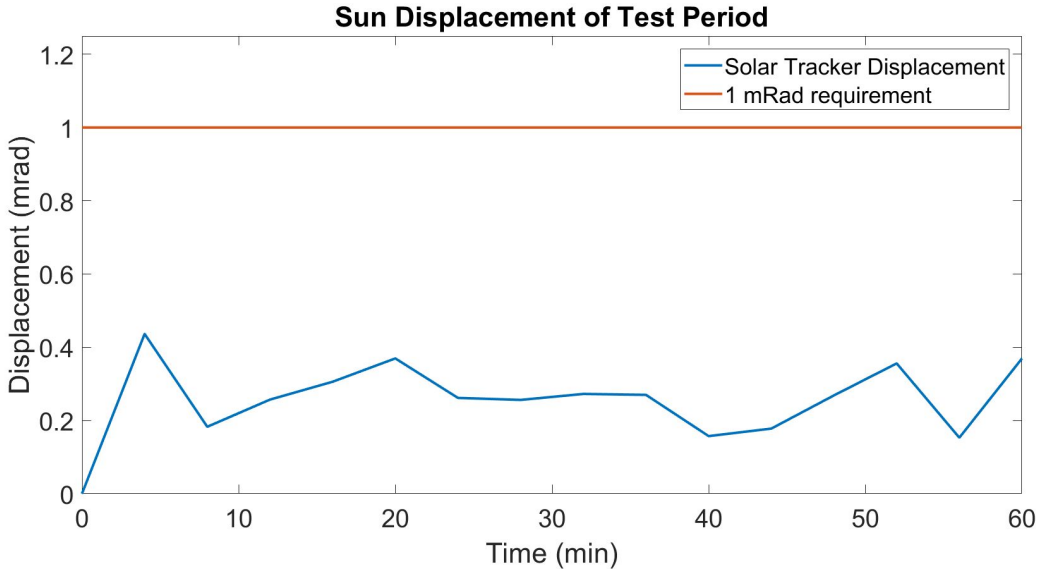
- 1.3 arcmin FOV
- 1 km vertical resolution
- MTF (Modulation Transfer Function) of 0.74
- Tracking accuracy of 1 mRad or finer during ground testing



Solar Tracking Test

3.0: SAM-II Equivalent Optics

- Tracking accuracy of 1 mRad or finer during ground testing



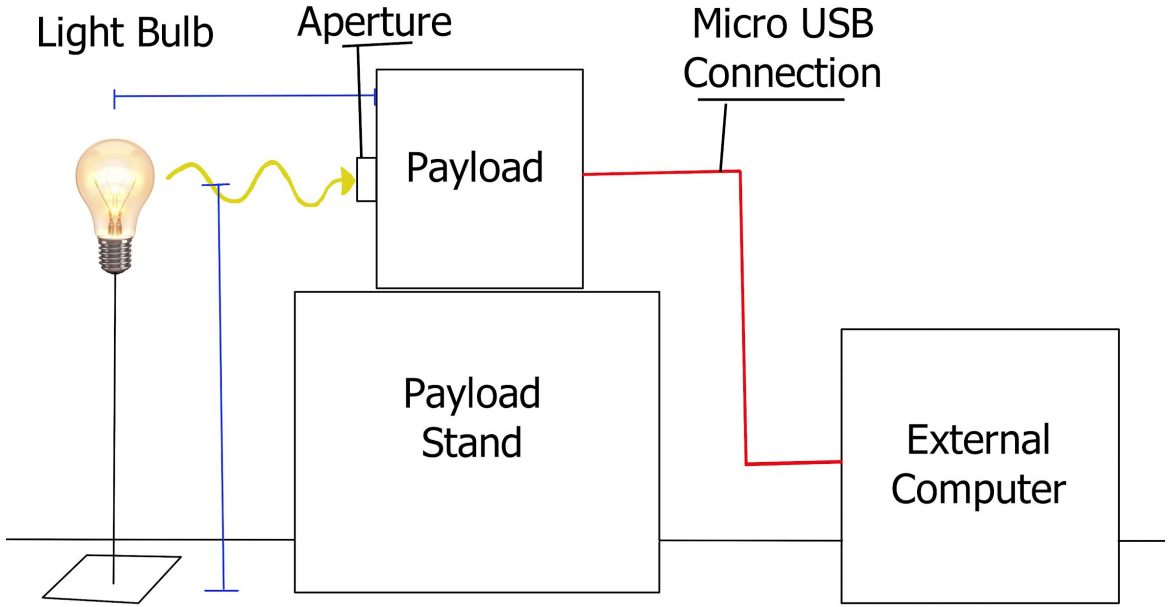
Regulated Light Test

Requirements V&V

1.0: Data Capture
- Optics data transferred and processed at desired size and rate

2.0 Communications
- SNR value from photodiode dark current

3.0 SAM-II Equivalent Optics
- Irradiance values equivalent to light bulb output around 1.03 um



Test Facilities: Dark room

Expected data: Light bulb irradiance data to compare to expected
No light irradiance data to find dark current for SNR

Solar Attenuation Test

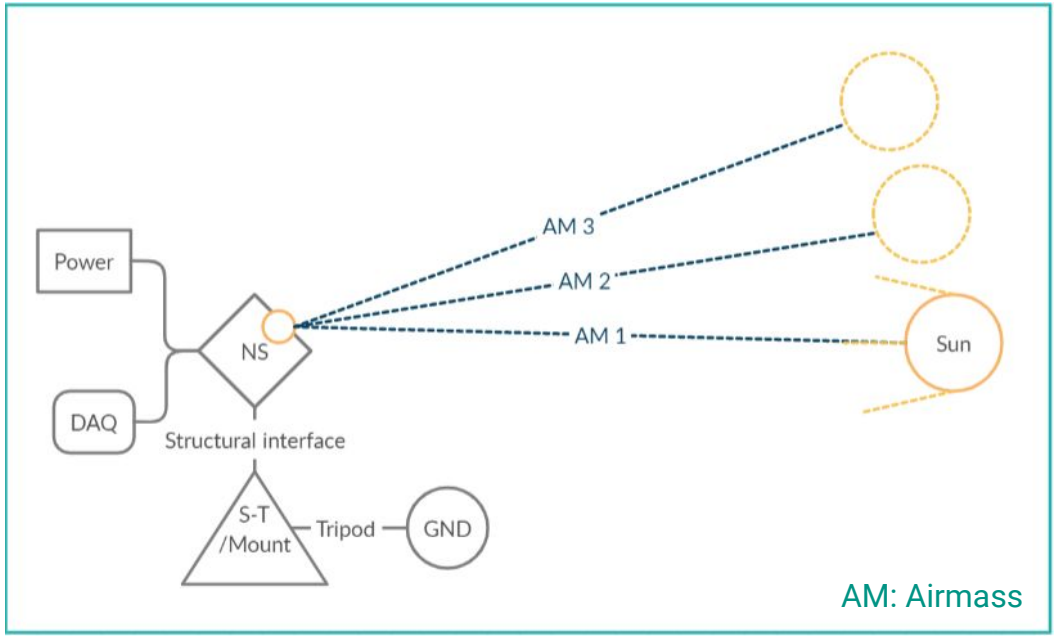
Requirements V&V

1.0: Data Capture
- Data collected and transferred as desired
- Calibration data stored

2.0 Communications
- SNR value from photodiode dark current

3.0 SAM-II Equivalent Optics
- Irradiance values equivalent to solar output at 1.03 um
- Tracks solar trajectory

4.0 Payload Dimensions
- 0.5U Volume, 0.615 kg



Test Facilities: Open outdoor space on sunny day

Expected data: Solar irradiance data to compare to expected
Weight and mass of payload

Facility Usage

Thermal Test

Procedure complete
(Approved on 2/23)
TestEquity 115A-F Chamber
Run by Dr. Scott Palo in AERO
-73°C to +175°C chamber range, testing -20°C to +50°C

Vibration Test

Altius Space Machines facility
Low level sine sweep for resonant frequencies
Test procedures in-progress.
$200/hr for 3-4 hrs.

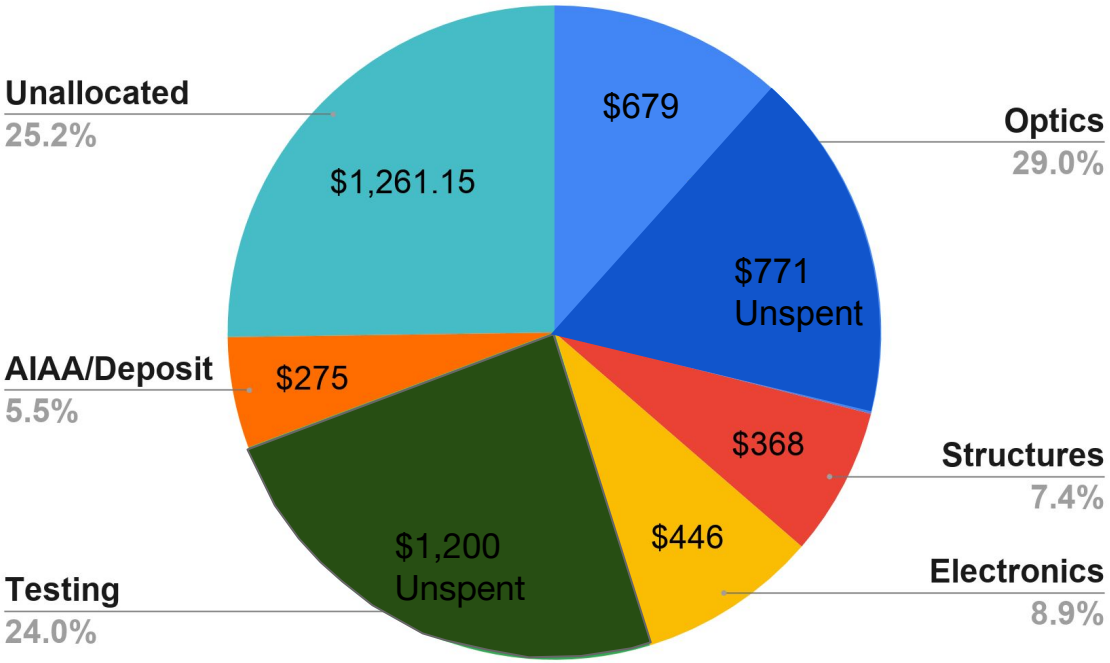
Vacuum Test

Test procedure and request form in-progress.
JANA chamber
Run by Professor Nabity
50 mtorr achievable

Budget

Jashan Chopra

Budget Update



Update Summary

- Allocated funds for 4 hours of vibe testing
- Allocated funds for optics shim cutting
- Purchased all new components required for electronics redesign
- Purchased vibration testing equipment

Remaining Purchases

- Vibration testing facilities
- Additional OAP mirror
- Optics shim cutting
  - Still considering options
  - Currently allocated funds for electrical discharge machining

Acknowledgements

Our Customers:

Jim Baer & Jaykob Velasquez
Ball Aerospace

CU Aerospace Department:

Dr. Allison Anderson
The PAB

Our Peer Evaluators:

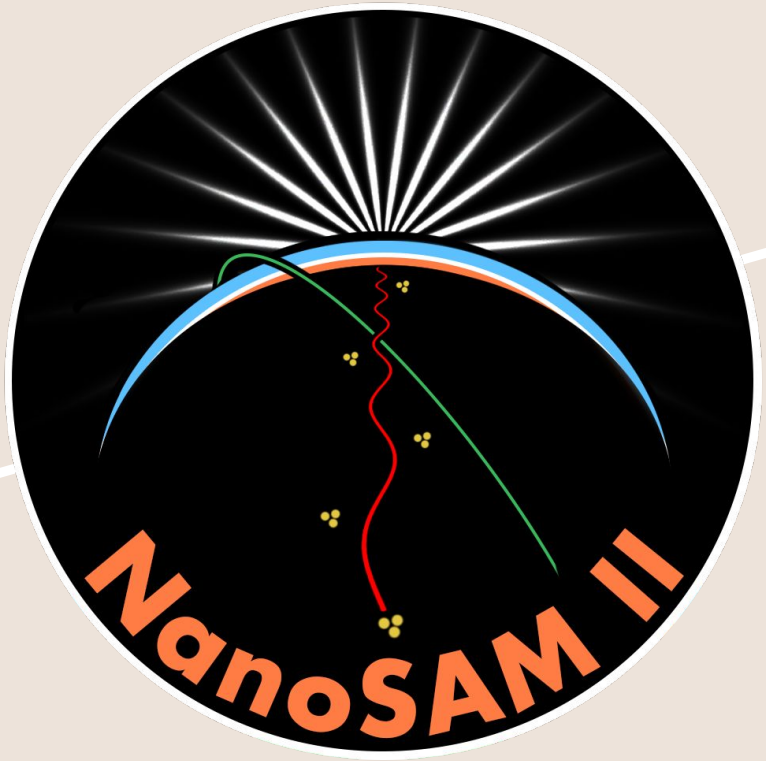
Lara Buri & Colin Claytor

… and all of our personal friends who should send us a bill for their time doing engineering review

Our Local Professionals:

Meadowlark Optics Inc
Blue Canyon Technologies
John Ferguson

Questions



References

[1] QB50:System Requirements and Recommendations. Issue 7, Section 1.6 "Thermal Control" and Section 2.2 "Resonance Survey." Published 13 Feb 2015.
https://www.qb50.eu/index.php/tech-docs/category/QB50_Systems_Requirements_issue_76e8e.pdf?download=89:qb50-docs

[2] Anderson, B. & Justus, C. & Batts, G. “Guidelines for the Selection of Near-Earth Thermal Environment Parameters for Spacecraft Design” 2001.

[3] Henninger H. John, ”Solar Absorptance and Thermal Emittance of Some Common Spacecraft Thermal-Control Coatings” Goddard Space Flight Center, April 1984.
https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19840015630.pdf

[4] “SAGE III on ISS”, Wikipedia, Last Edited 10 September 2020.
https://en.wikipedia.org/wiki/SAGE_III_on_ISS#/media/File:SAGE_III_Instrument.jpg

[5] Mason, J. & Woods, T. “Miniature X-Ray Solar Spectrometer (MinXSS) – A Science-Oriented, University 3U CubeSat.”
https://arxiv.org/pdf/1508.05354.pdf

[6] Anderson, J. & Et. Al “NanoSAM II Preliminary Design Report”. Published 13 October 2020.

References

[7] “3U CubeSat Structure” ISIS Space, https://www.isispace.nl/product/3-unit-cubesat-structure/

[8] “PC/104 Specification” PC/104 Embedded Consortium. Version 2.6, October 13, 2008 https://pc104.org/wp-content/uploads/2015/02/PC104_Spec_v2_6.pdf

[9] “2000 ASTM Standard Extraterrestrial Spectrum Reference E-490-00.” National Renewable Energy Laboratory. https://www.nrel.gov/grid/solar-resource/spectra-astm-e490.html

[10] “General Environmental Verification Standard: GSFC-STD-7000”, Office of the NASA Chief Engineer, NTSS Version 7.0, 30 Sep 2015, updated 29 March 2019. https://standards.nasa.gov/standard/gsfc/gsfc-std-7000

[11] Kim, Sung-Hwa & Hwangbo, Chang-Kwon. “Temperature Dependence of Transmission Center Wavelength of Narrow Bandpass Filters Prepared by Plasma Ion-Assisted Deposition.” Journal of the Korean Physical Society. Vol. 45, No. 1, July 2004. https://inis.iaea.org/search/search.aspx?orig_q=RN:41100734

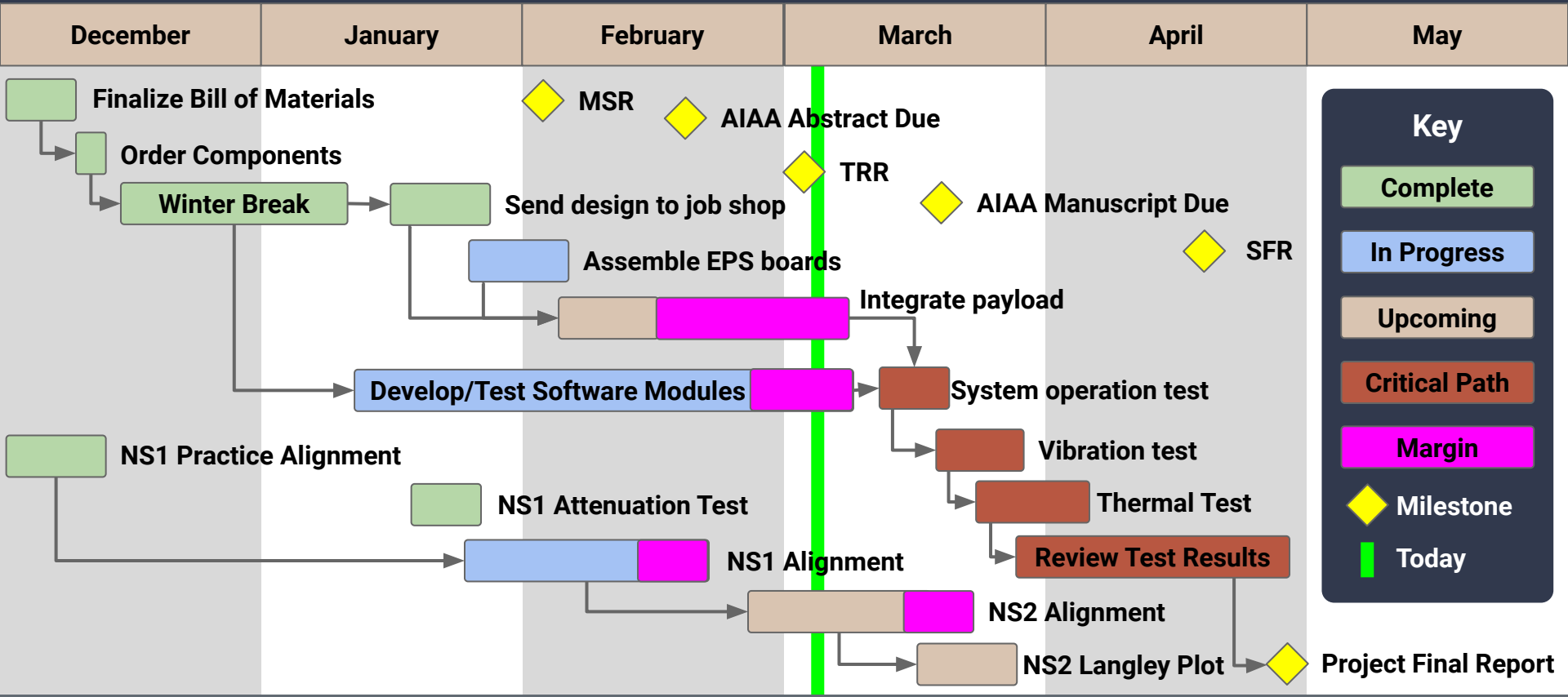
[12] McCormick, M. P. Et. Al. “Satellite Studies of the Stratospheric Aerosol.” Bulletin American Meteorological Society. Vol. 60, No. 9, September 1979.

Backup Slides

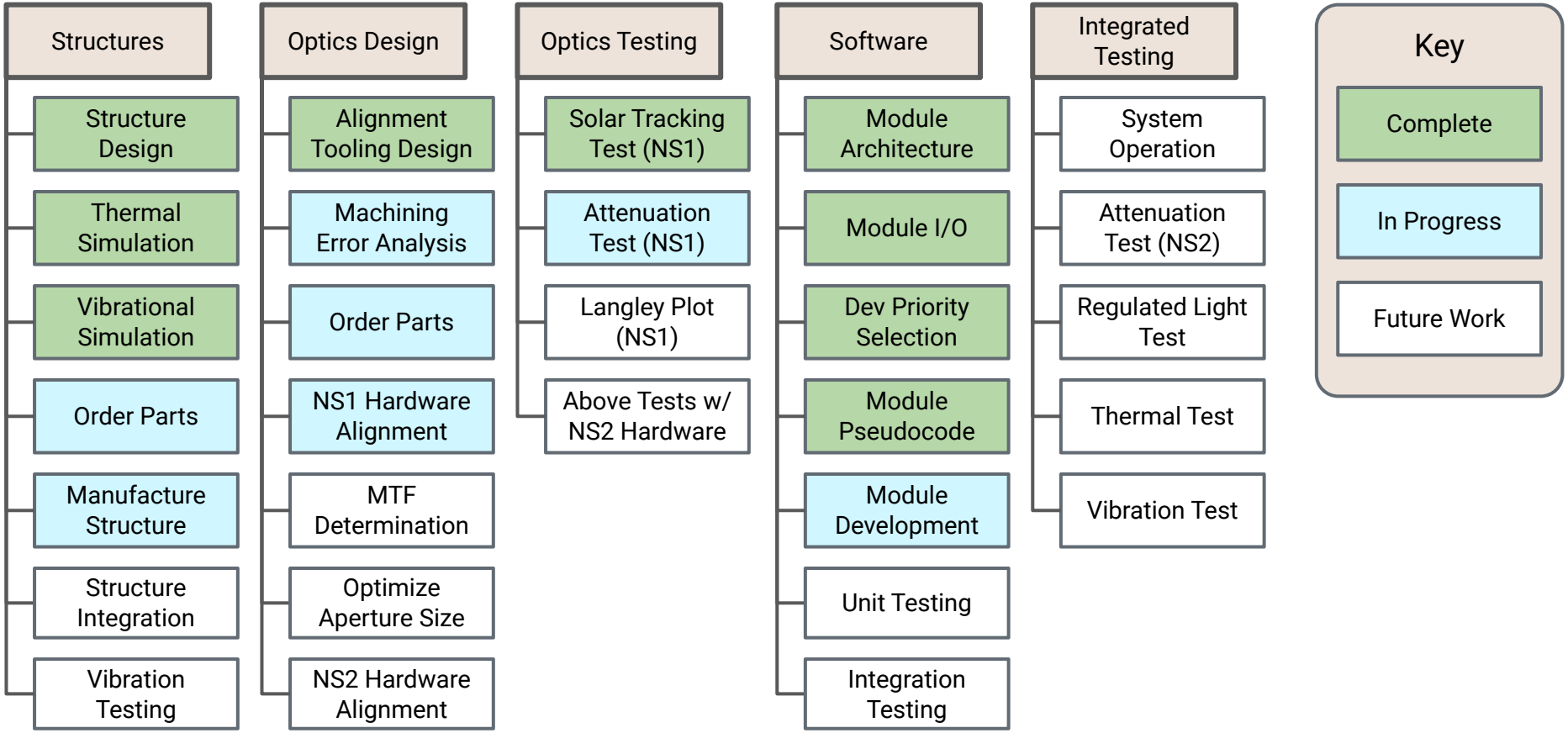
Table of Contents

Backup Slides

Old Schedule



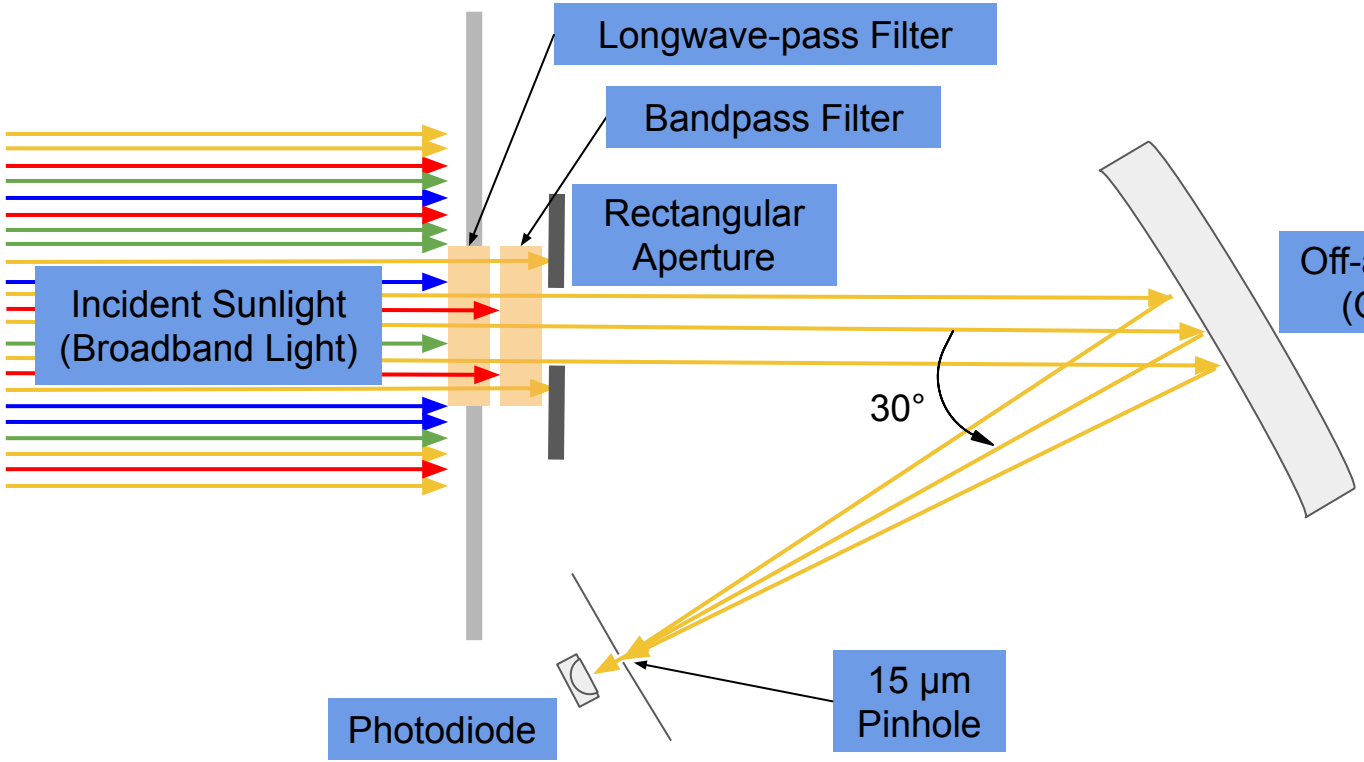
Work Breakdown Structure

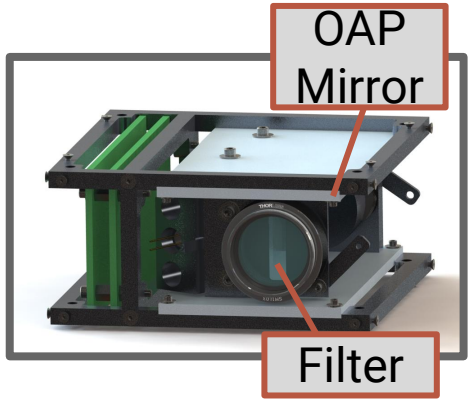


Levels of Success

	Lvl 1 (solar tracking test)	Lvl 2 (Improved Ground Performance)	Lvl 3 (Flight Capability)
Payload Housing	The payload housing contains the integrated electronics board and optics bench inside a 0.5U enclosure.	The payload housing structural interface is compatible with an industry standard bus.	The payload housing functions within the operating temperature range of -20◦C to 50◦C and its lowest vibrational natural frequency is greater than 100Hz [10].
Data Capture	Software and electronics acquires, digitizes, packetizes, and downloads raw data from a photodetector to a computer at a rate of at least 50Hz within the mission specific measurement schedule detailed in the CONOPS.	Error checking measures are implemented in the ground software to detect data corruption occurring during transmission.	Data is transferred from the payload to a computer emulating an industry standard CubeSat bus communications system [11].
Electronics & Control	The redesigned electronics board successfully controls and powers all on-board operations and has a footprint compatible with the 0.5U payload enclosure.	The redesigned electronics board supports all optical design improvements.	The redesigned electronics board remains within the operating temperature range of -20◦C to 50◦C and its lowest vibrational natural frequency is greater than 100Hz [10].

Optics Instrument Overview





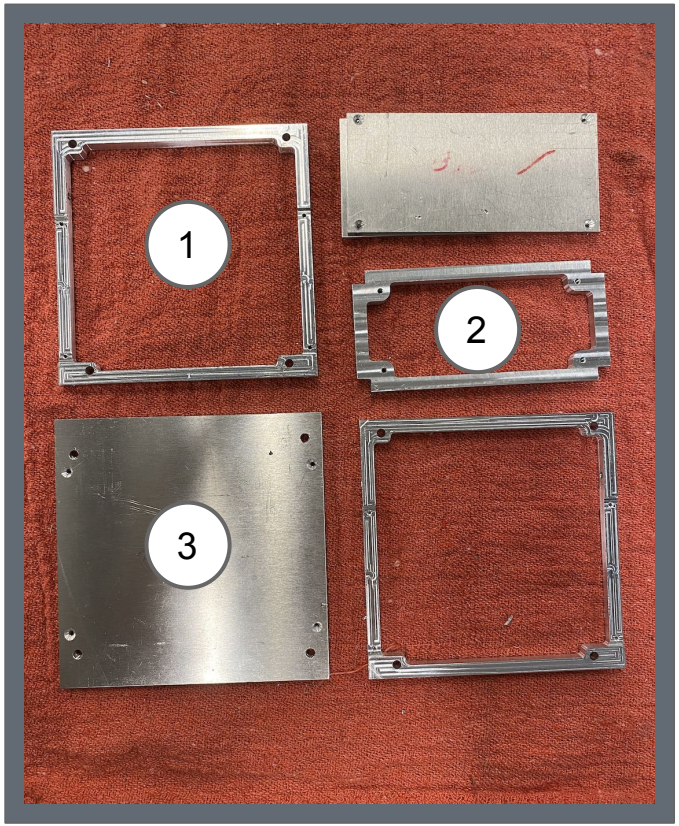
Structure Parts and Quantities

S01: Structural Ribs (2x)
S02: EPS Board Rib (1x)
S03: Top/Bottom Walls (2x)
S04: Left/Right Walls (2x)
S05: Front Wall (1x)
S06: Back Wall (1x)
S07: Structural to Board Rib Screws (4x)
S08: 0.5 cm PCB Spacers (4x)
S09: 0.25 cm PCB Spacers (4x)

S010: PCB Screws (4x)
S011: PCB Washers (4x)
S012: External Wall Screws (24x)
S013: Optics Bench to Thermal Isolator Screws (4x)
S014: Optics Bench to Thermal Isolator Washers (4x)
S015: Thermal Isolator to Structural Rib Screws (8x)
S016: Thermal Isolator to Structural Rib Washers (8x)
S017: Fiberglass Isolators (2x)

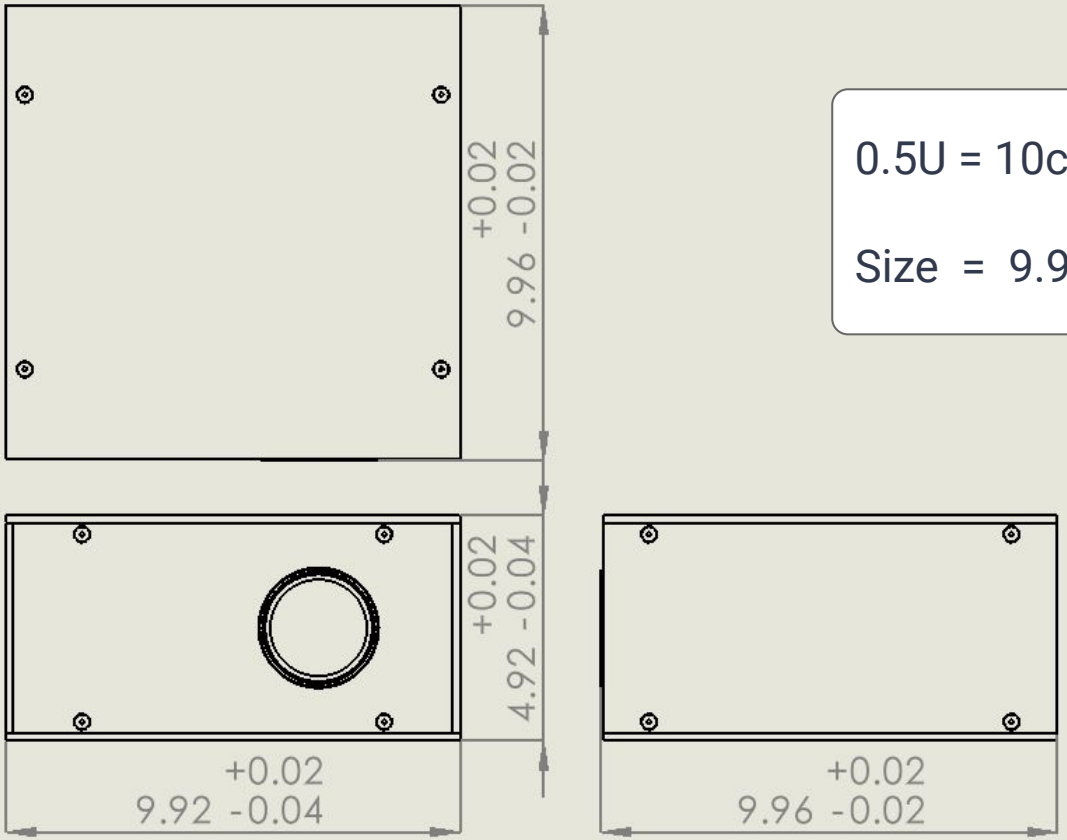
* Parts all Ordered from McMaster Carr

Structures Parts Status



Completed (Job Shop 01)	To be Completed
• Horizontal Ribs (1) • EPS Mount Rib (2) • All Housings/Walls (3)	• Board-Board Spacers • Small EPS Spacers • Thermal Isolators

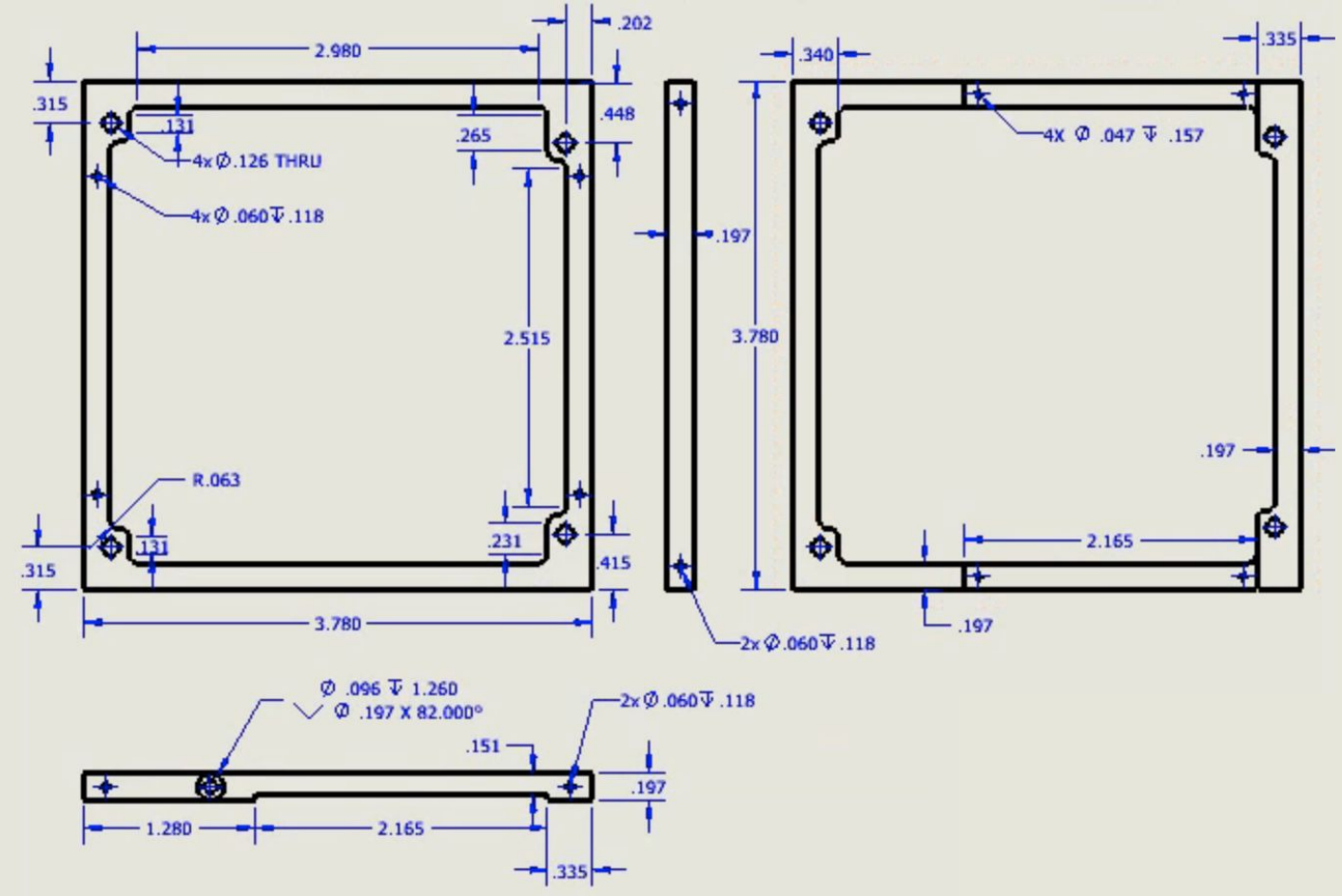
NanoSAM II Dimensioned Drawing



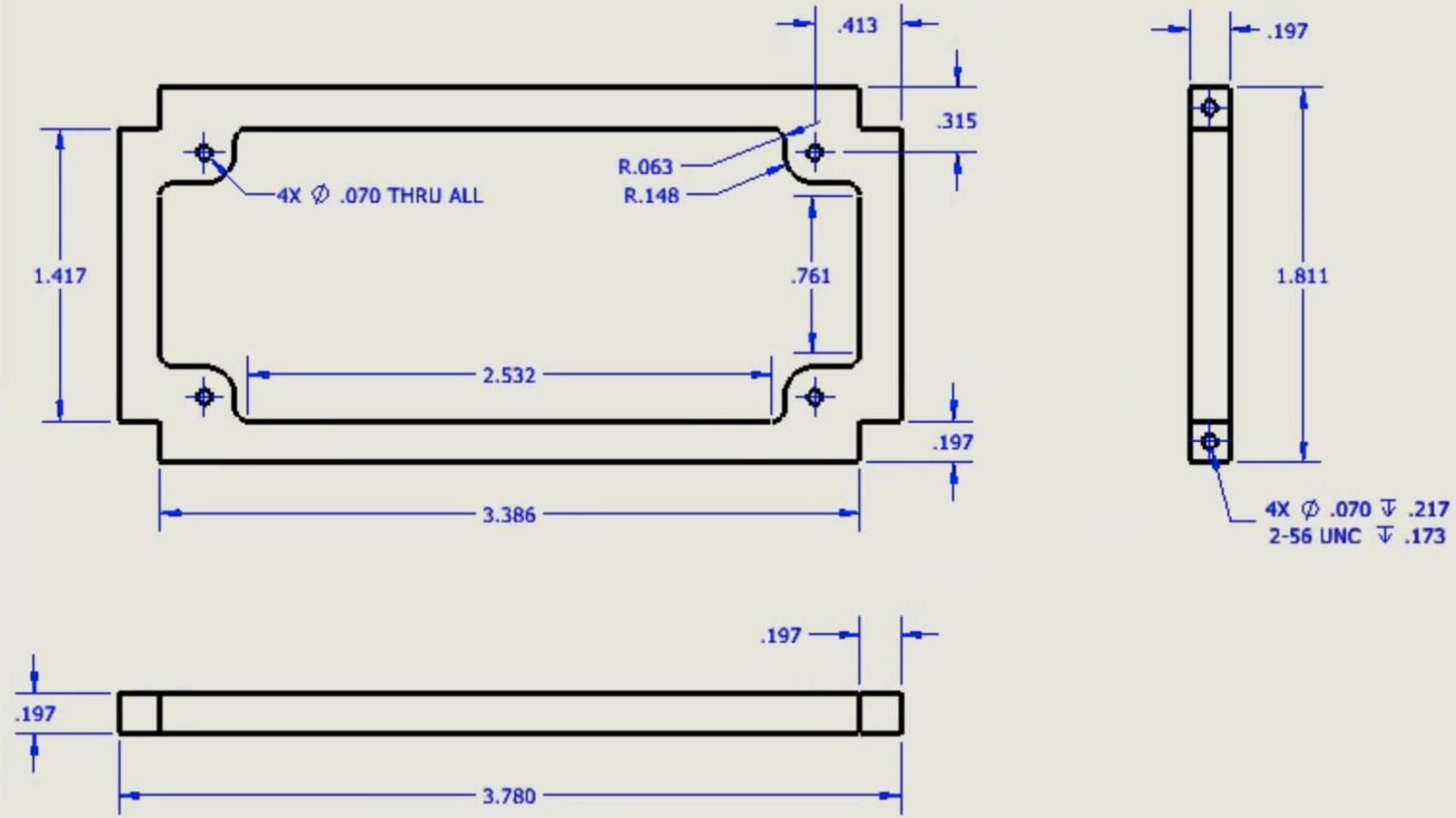
0.5U = 10cm x 10cm x 5cm

Size = 9.96cm x 9.92cm x 4.92cm

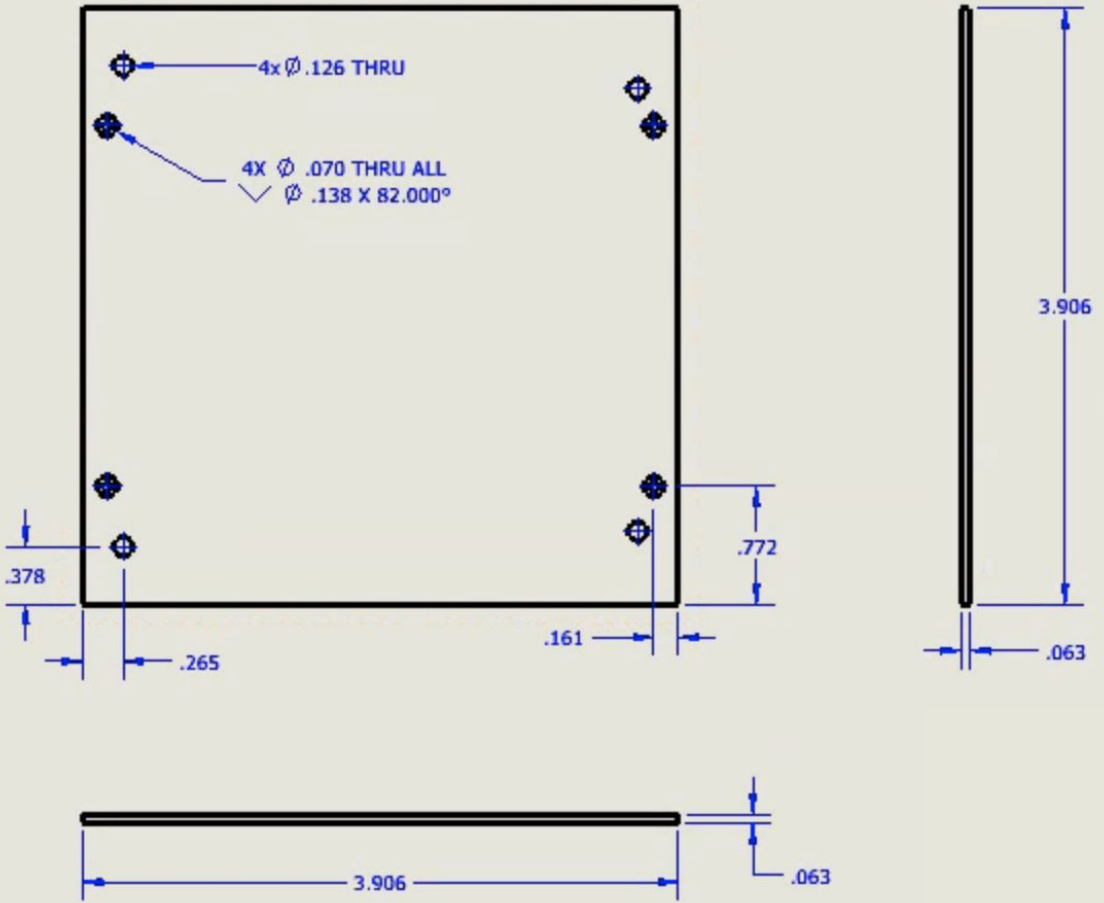
NanoSAM II Horizontal Rib Drawing



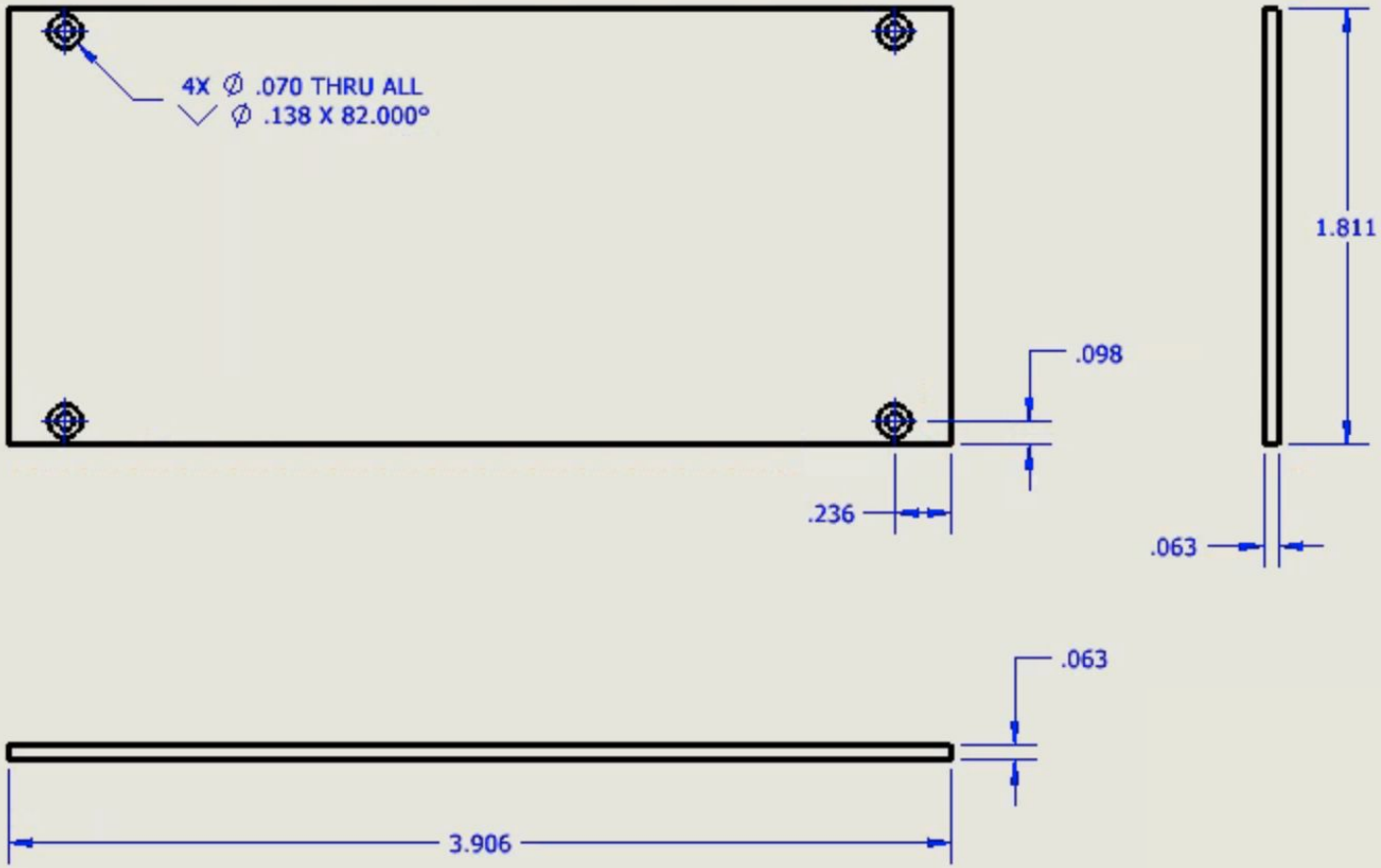
NanoSAM II EPS Board Rib Drawing



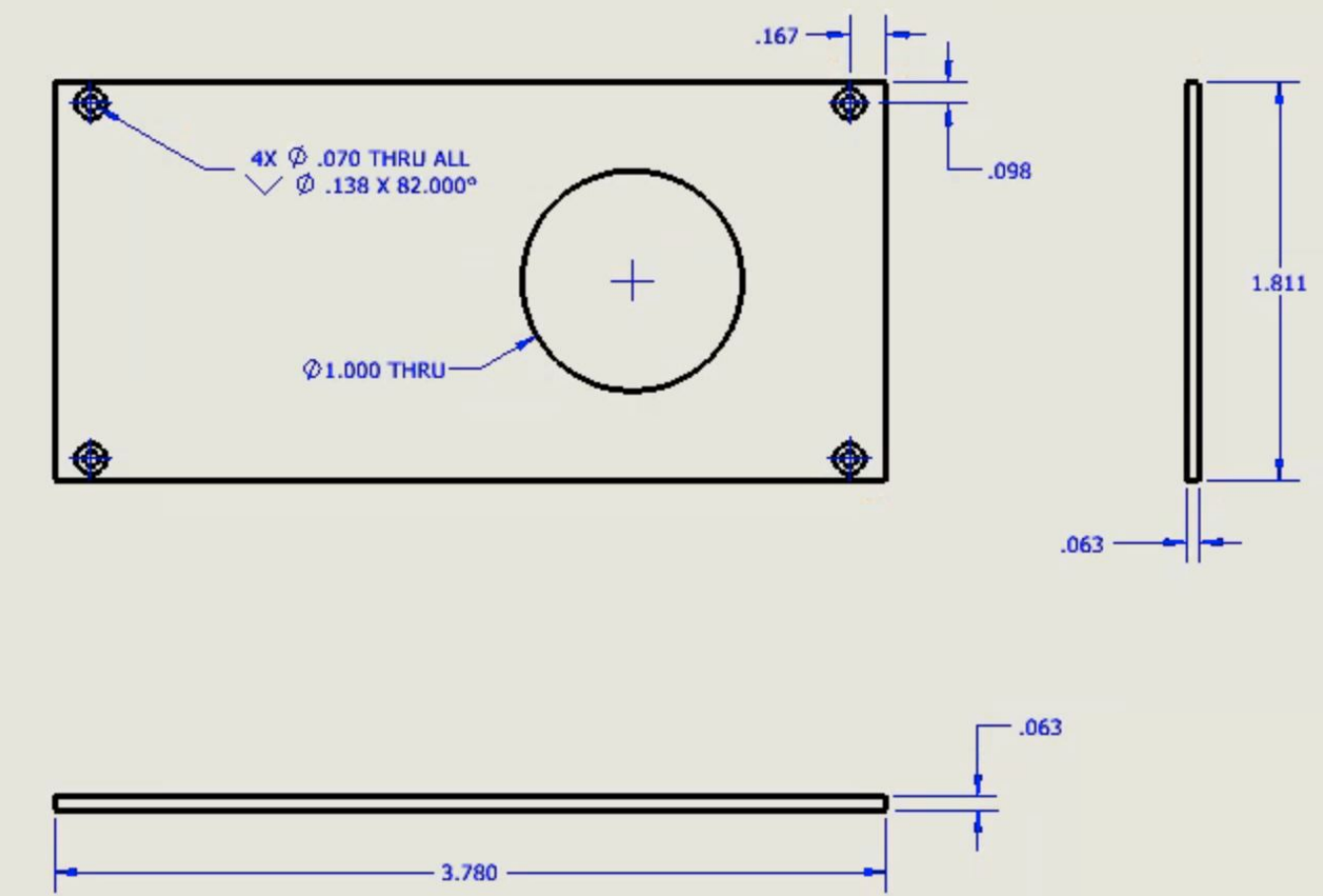
NanoSAM II EPS Top/Bottom Housing Drawing



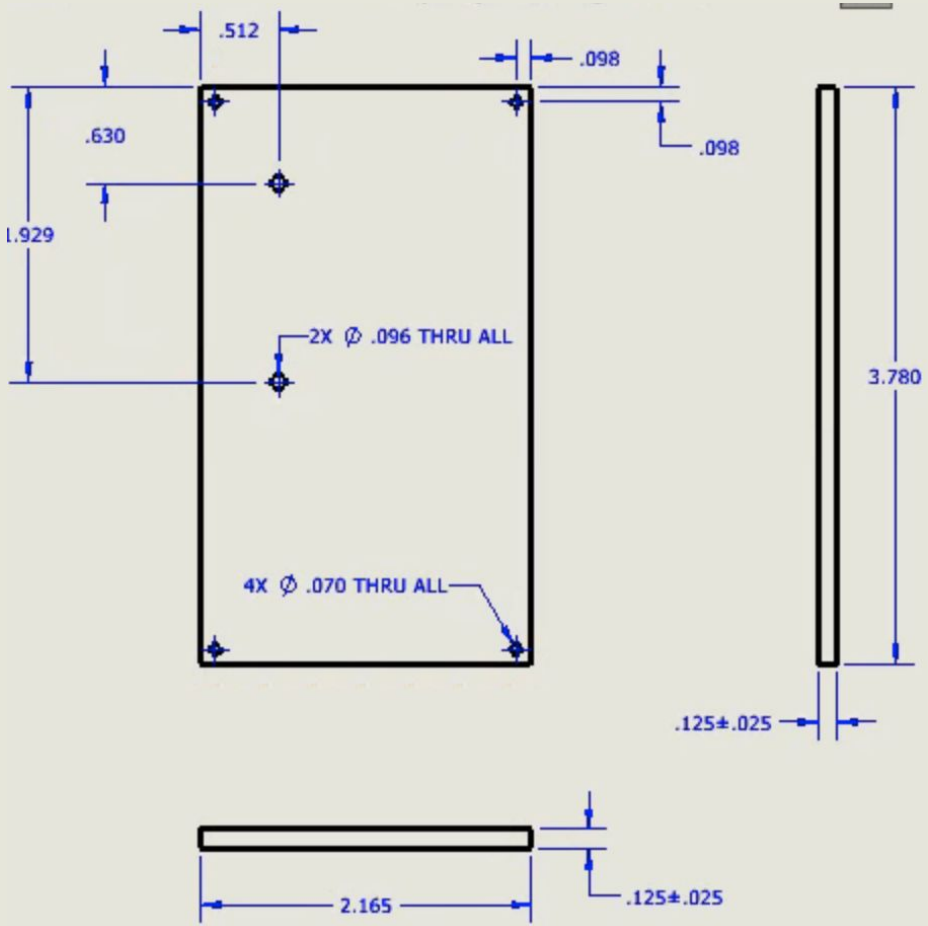
NanoSAM II Left/Right Housing Drawing



NanoSAM II Front Housing Drawing



NanoSAM II Bench Isolator Drawing



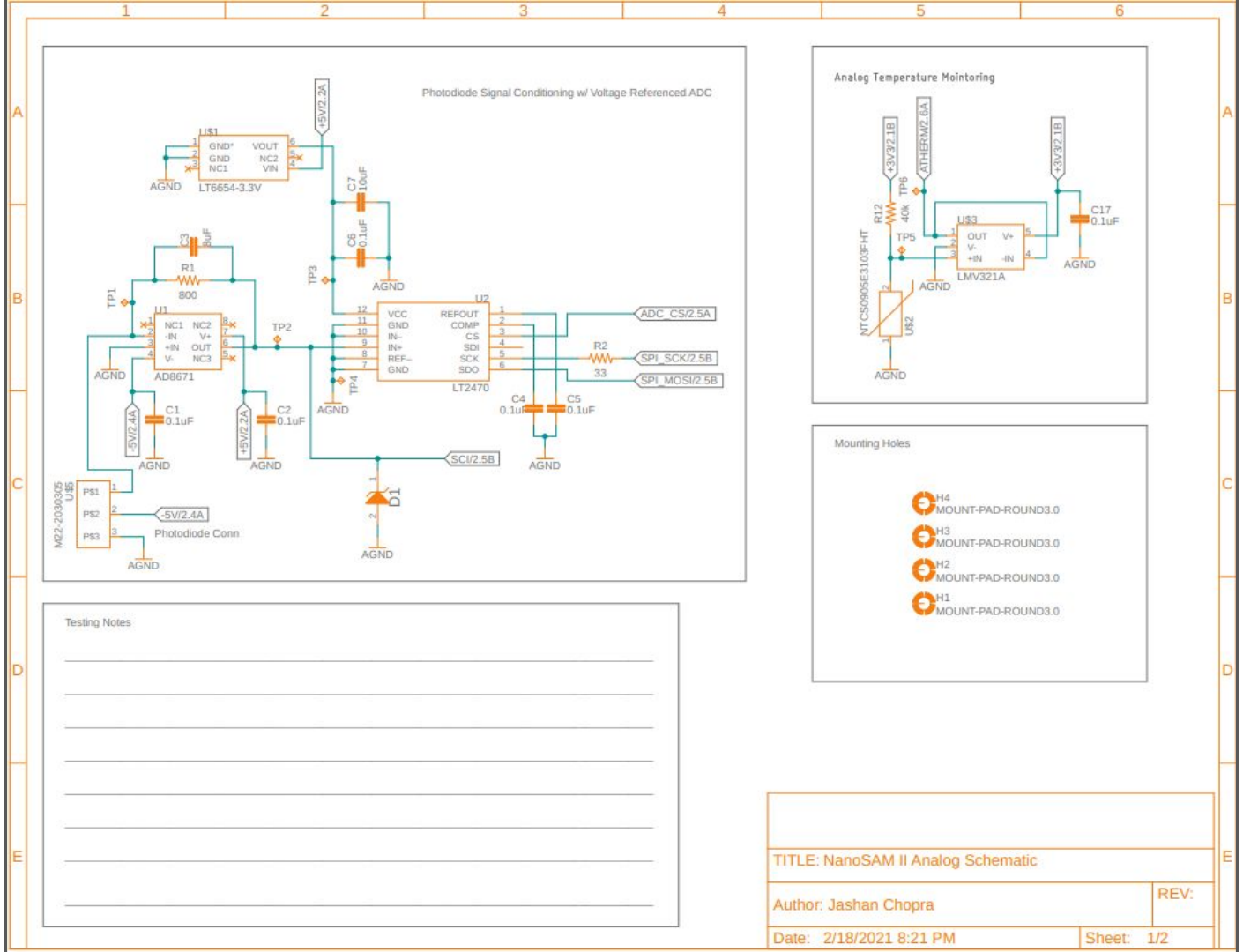
Electronics: Test Points

Test Point	Description	Expected Value	Checks?
1	Pre Feedback Resistor	Depends on light source	Photodiode working
2	Post Transimpedance Amplifier	Depends on light source	Transimpedance amp working
3	ADC Vcc	3.3V	Voltage reference working
4	ADC Ref-	GND	ADC reference good
5	Analog Thermistor Voltage Divider Output	Depends on temperature	Thermistor good
6	Analog Thermistor Voltage Buffer Output	Should be the same as T5	Voltage follower good
7	5V Regulator Positive Output	+5V	Bipolar regulator good
8	5V Regulator Negative Output	-5V	Bipolar regulator good
9	5V Regulator EPAD Ground	GND	Bipolar regulator good
10	Voltage Bus Input	System Vin	Voltage source good
11	Current Sense Output	Backsolve for Vin	Current sense monitor good

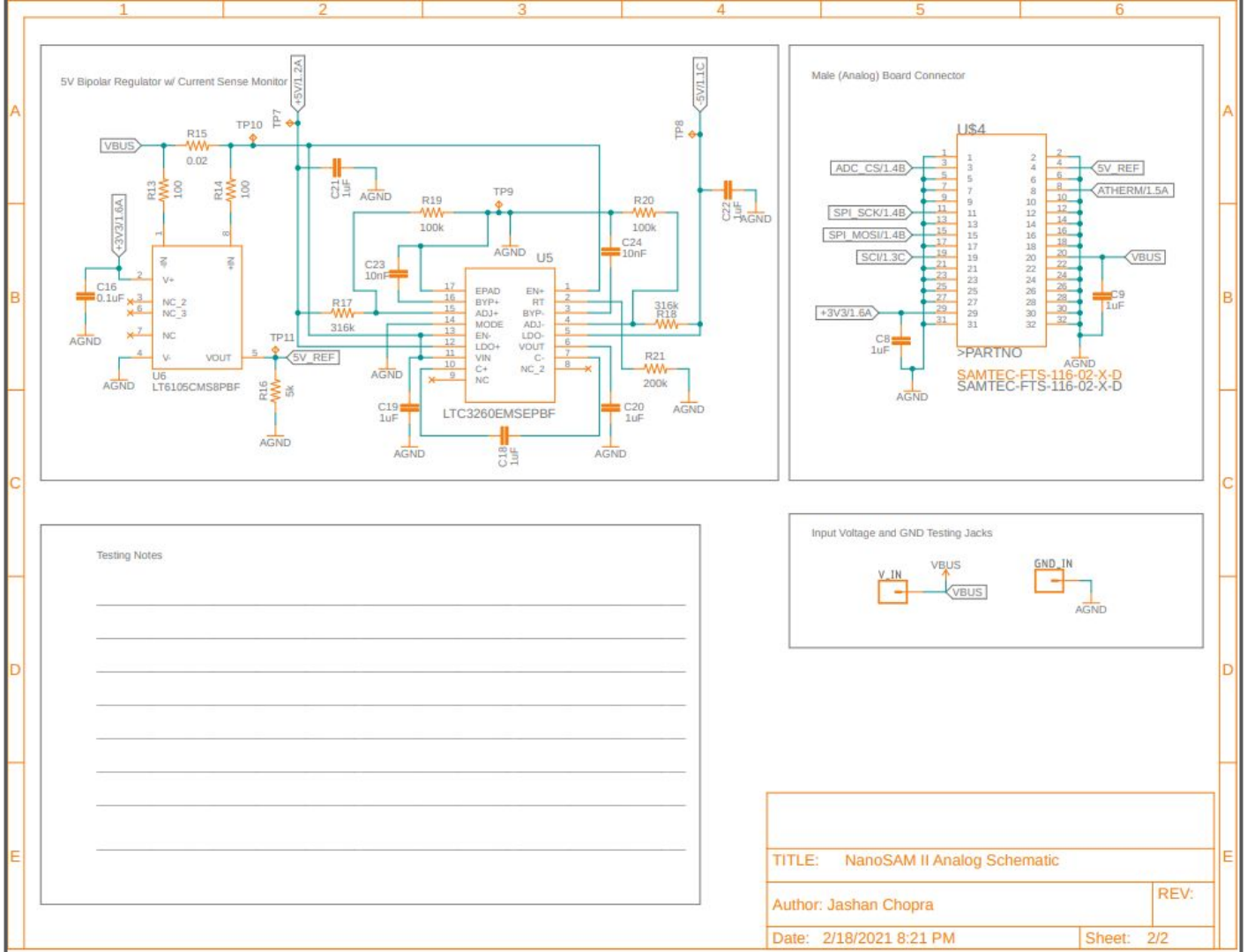
DIGITAL BOARD TEST POINTS

Test Point	Description	Expected Value	Checks?
1	Microcontroller Vin	3.3V	Microcontroller getting required power, also checks MOSFET not busted
2	Watchdog RST Signal	3.3V	If watchdog triggers, RST goes high
3	Watchdog /ST Signal	3.3V, 50ns width square	Microcontroller outputs watchdog signal
4	Flash 1 Vin (U$1)	3.3V	Flash 1 power
5	Flash 2 Vin (U$2)	3.3V	Flash 2 power
6	Digital Thermistor Voltage Divider Output	Depends on temperature	Thermistor good
7	Digital Thermistor Voltage Buffer Output	Should be the same as T6	Voltage follower good
8	3.3V Regulator Output	3.3V	Linear regulator good
9	3.3V Regulator GND	GND	Linear regulator good
10	3.3V PG Pin	High (~3.3V)	Linear regulator good
11	Voltage Bus Input	System Vin	Voltage source good
12	Current Sense Output	Backsolve for Vin	Current sense monitor good
13	Optical Bench Thermistor	Depends on temperature	Thermistor good
14	Optical Thermistor Voltage Buffer Output	Same as T13	Voltage follower good
15	Resistor Heater Vin	~System Vin (minus TVS diode drop)	Use to check heating resistor voltage drop
16	Resistor Heater GND	~GND (+MOSFET Drop)	Use to check heating resistor voltage drop

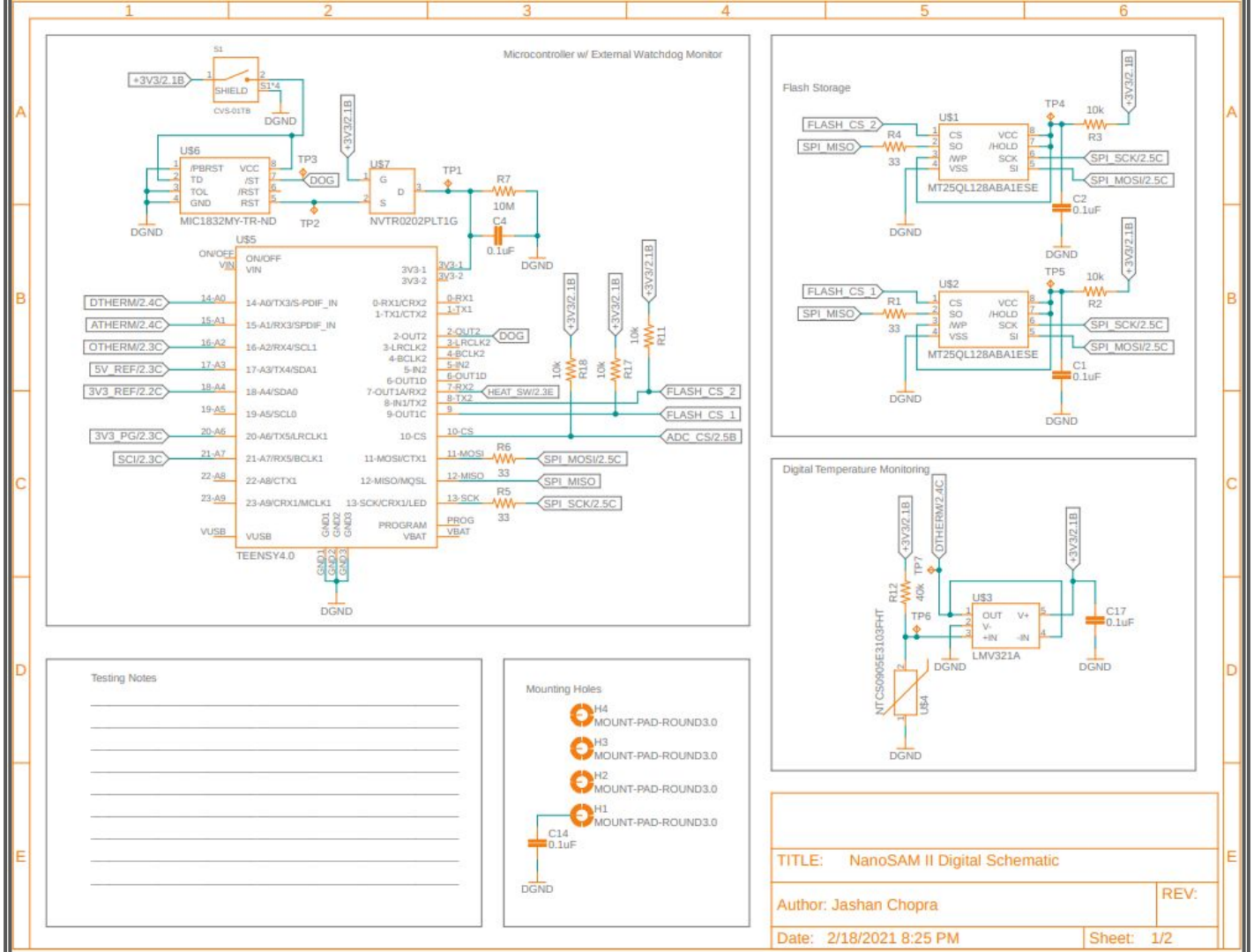
Analog Board (1/2)



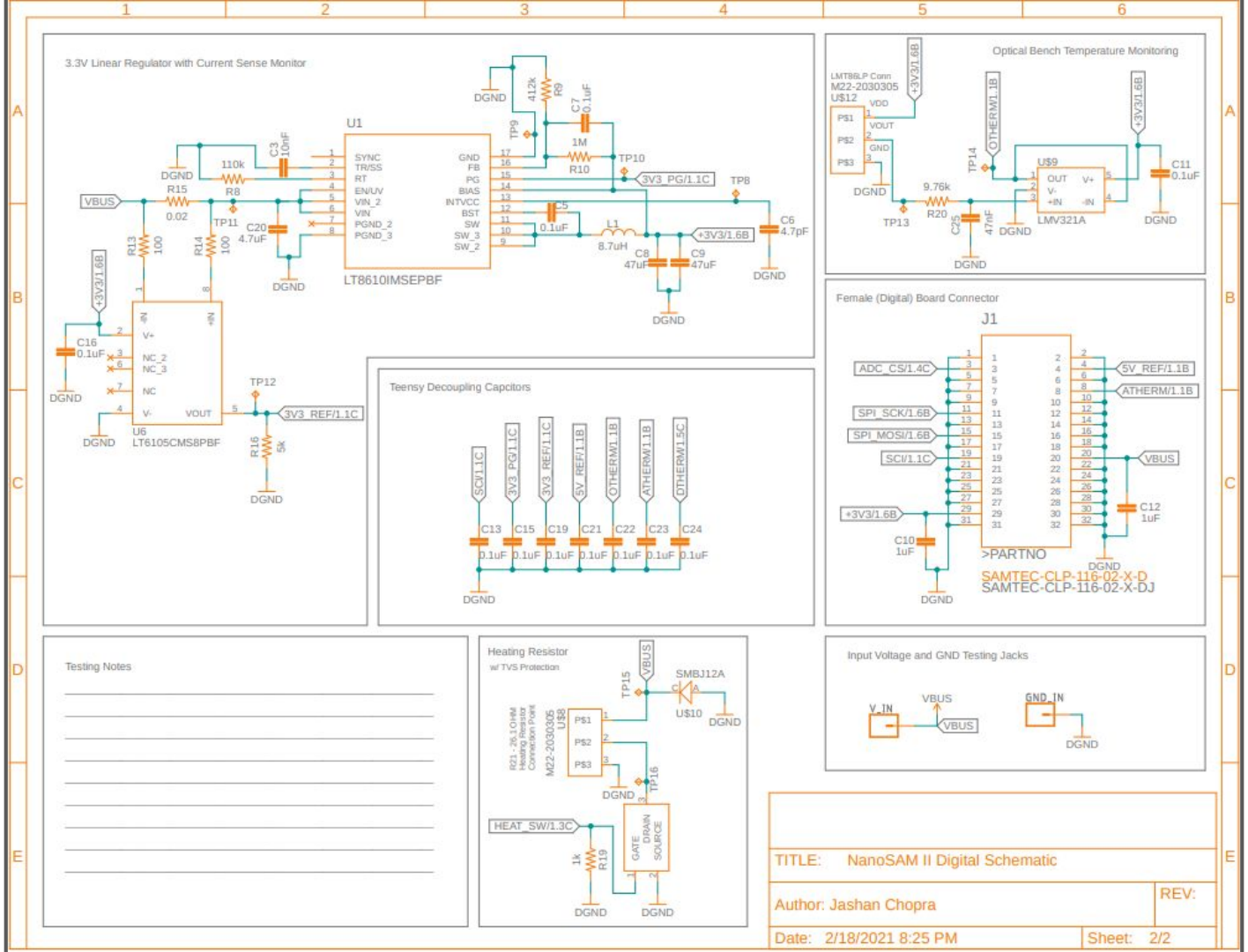
Analog Board (2/2)



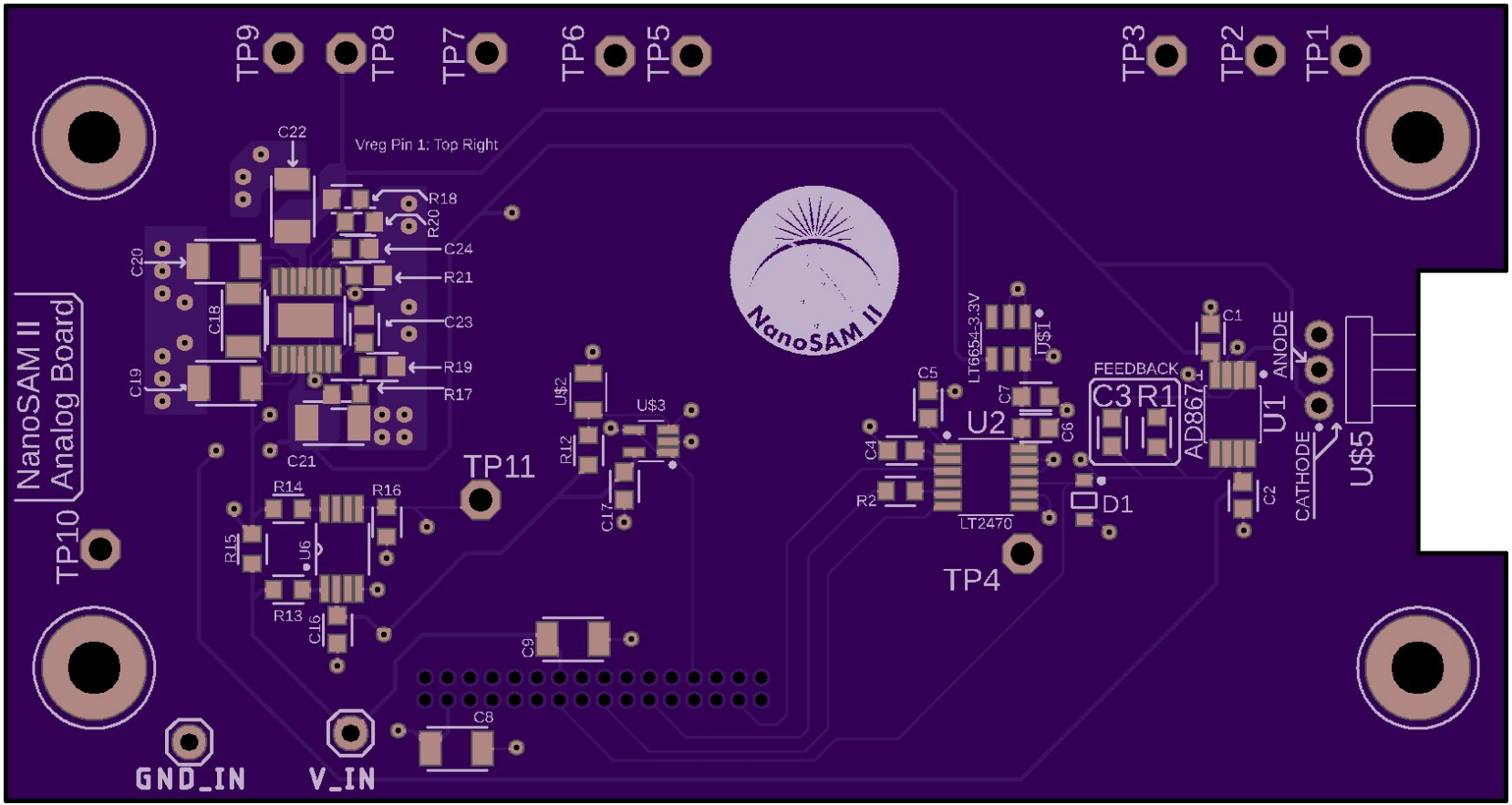
Digital Board (1/2)



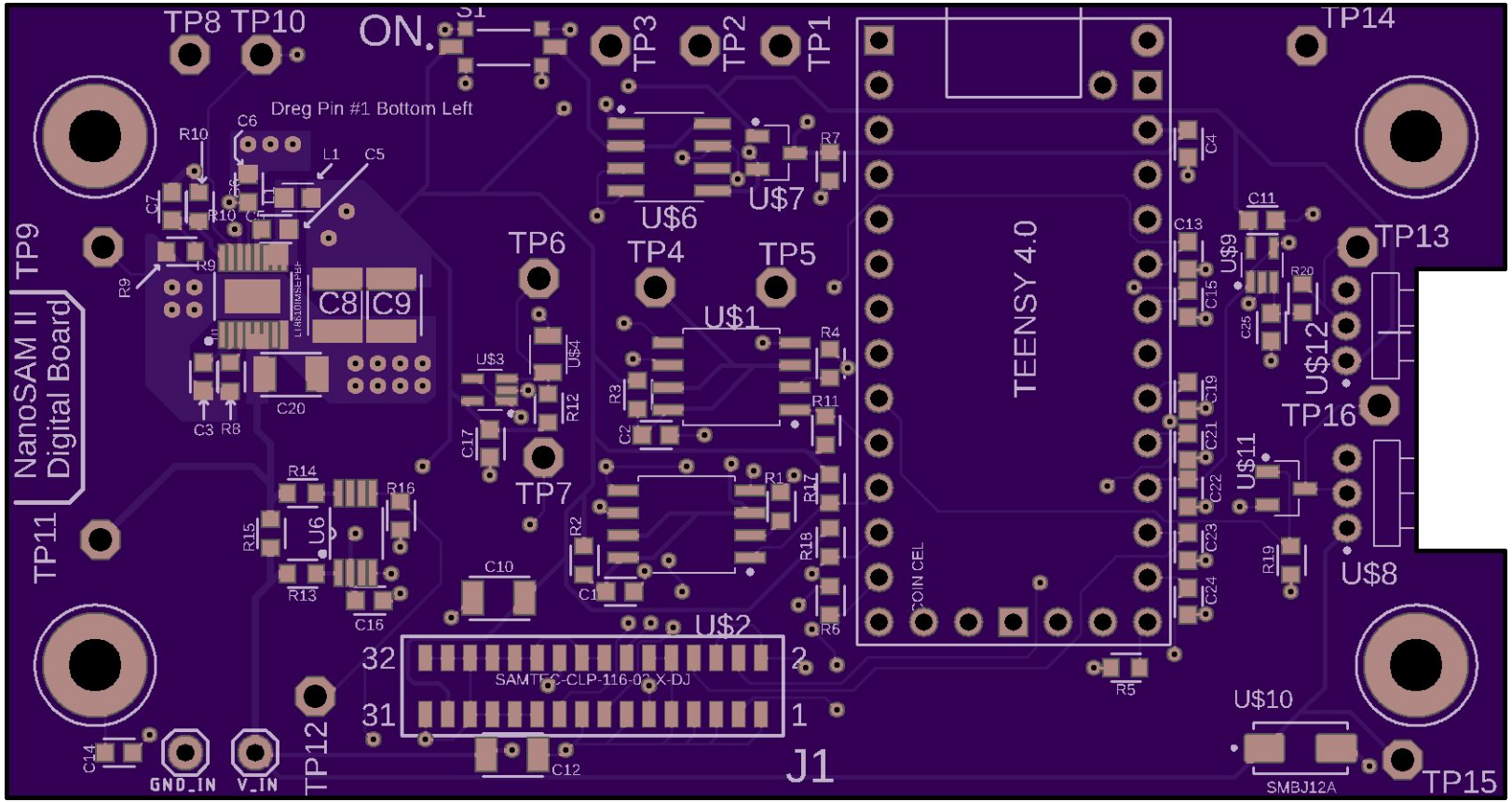
Digital Board (2/2)



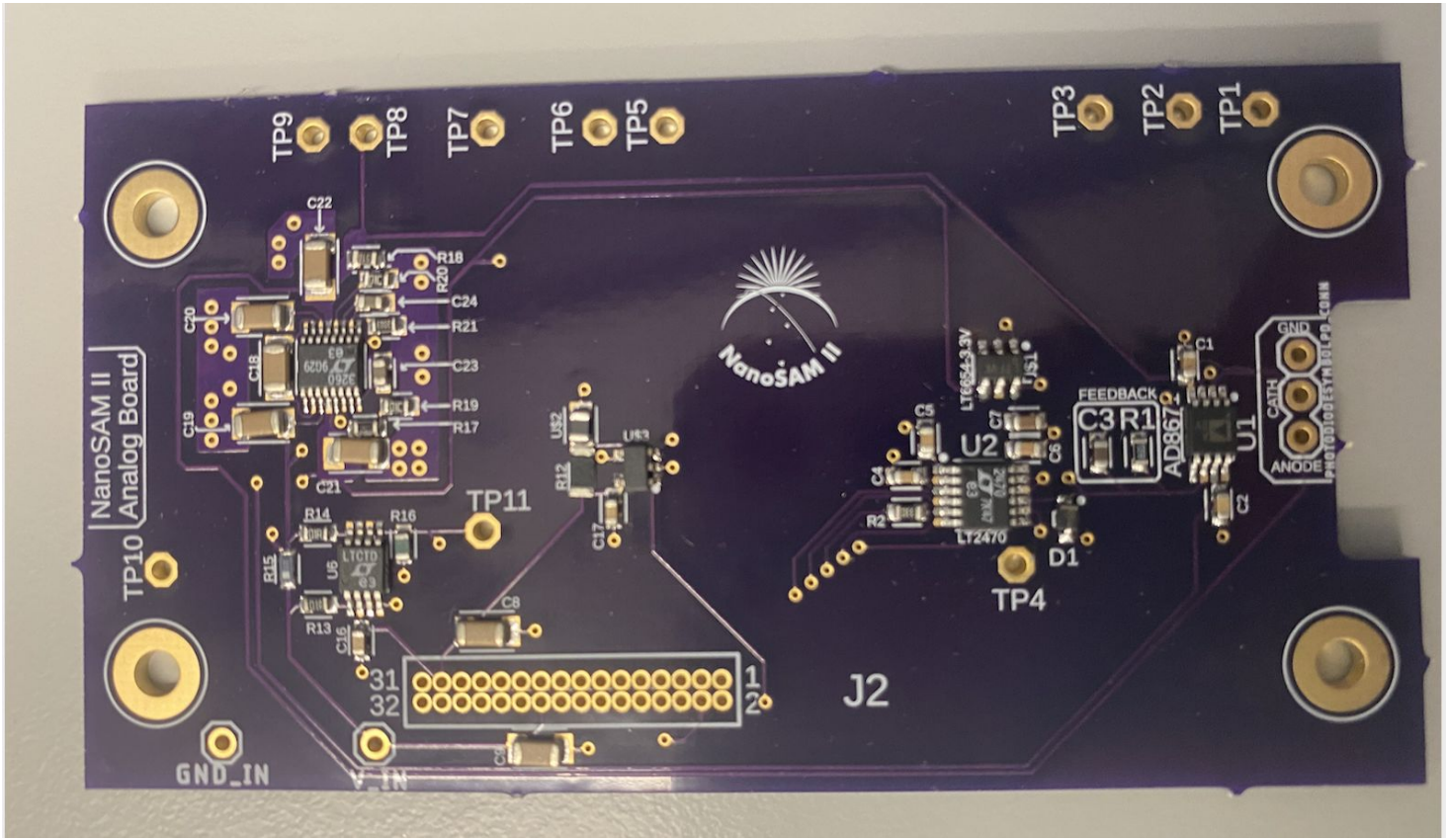
OSHPark CAM Job Render [Analog]



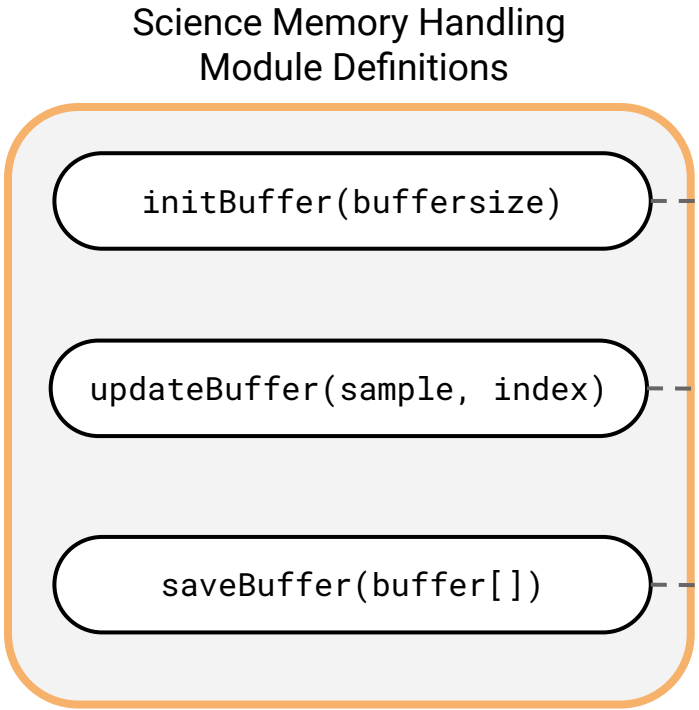
OSHPark CAM Job Render [Digital]



Completed Analog Board



Science Memory Handling Module Breakdown



Called to initialize buffer array in memory if it does not exist

Add the sample gathered by data processing module to the buffer
Overwrite oldest buffer element if the buffer is full

Saves buffer from temporary storage (array) to long-term memory (file)
Calls an EDAC module function to apply a Hamming code to the buffer
Clears buffer once stored to long-term memory