Test Readiness Review

Nano-Stratospheric Aerosol Measurement

Industry Sponsor: Ball Aerospace
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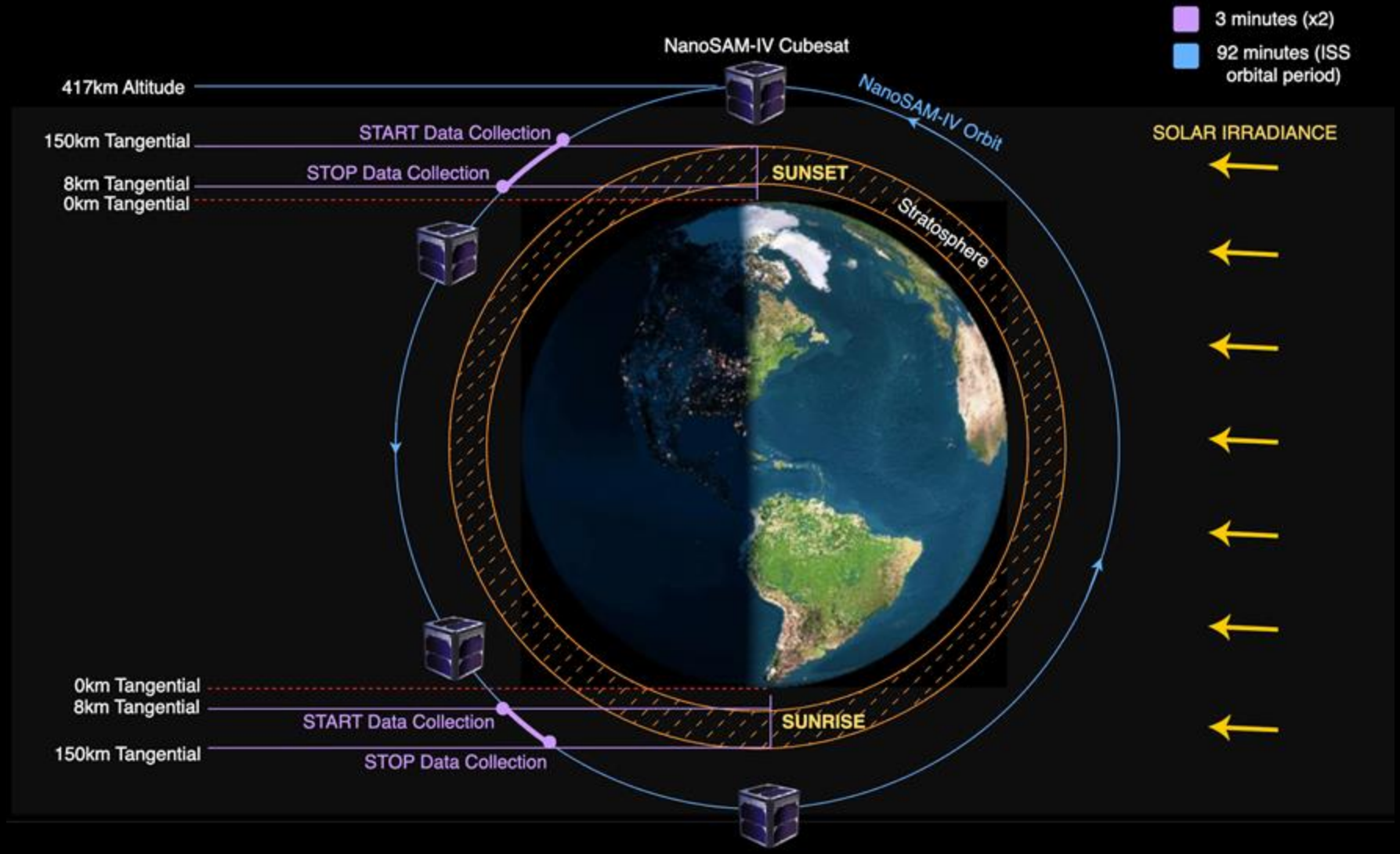
3/1/2023
11:30 – 12:20

Project Overview

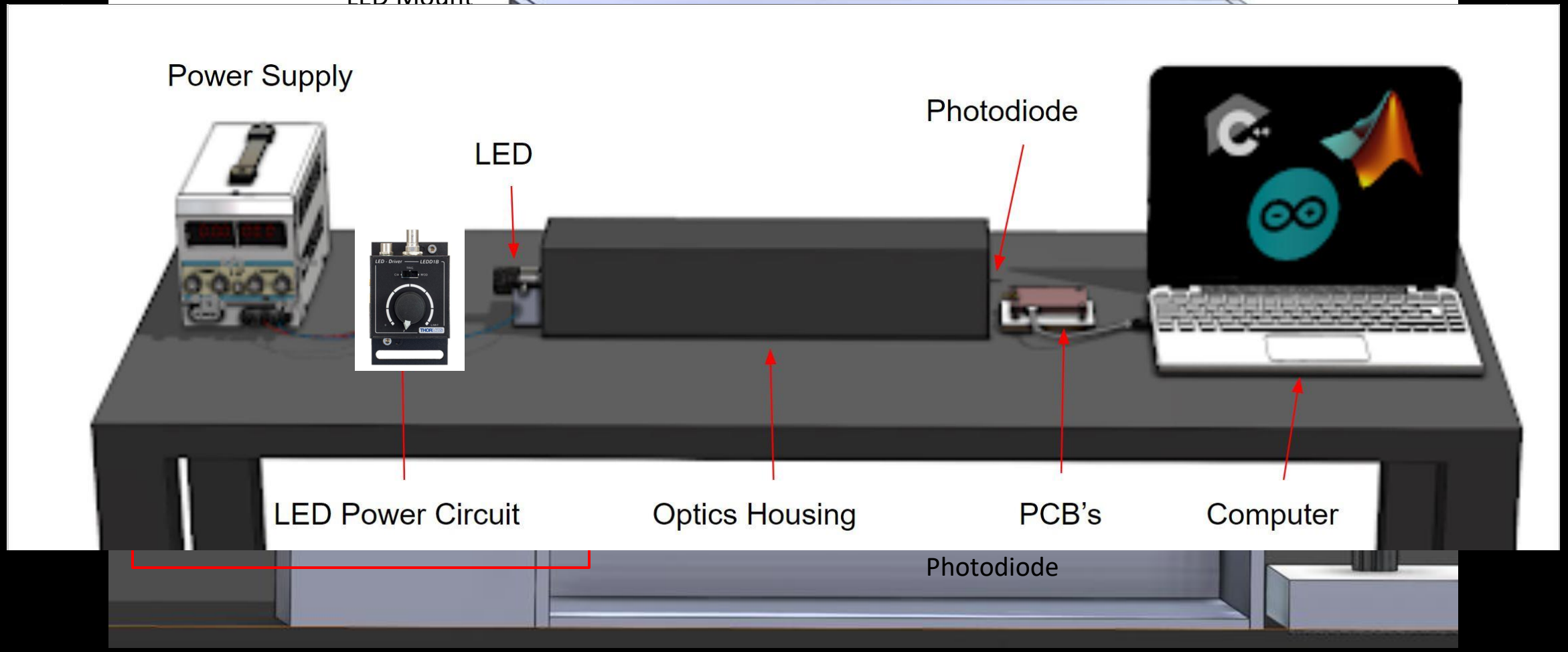
The NanoSAM-IV Mission Statement

The NanoSAM-IV team will create a laboratory simulation of the Ball Aerospace SAM program missions focusing specifically on collecting and processing simulated solar irradiance data at zero aerosol attenuation (full signal) in an automated fashion.

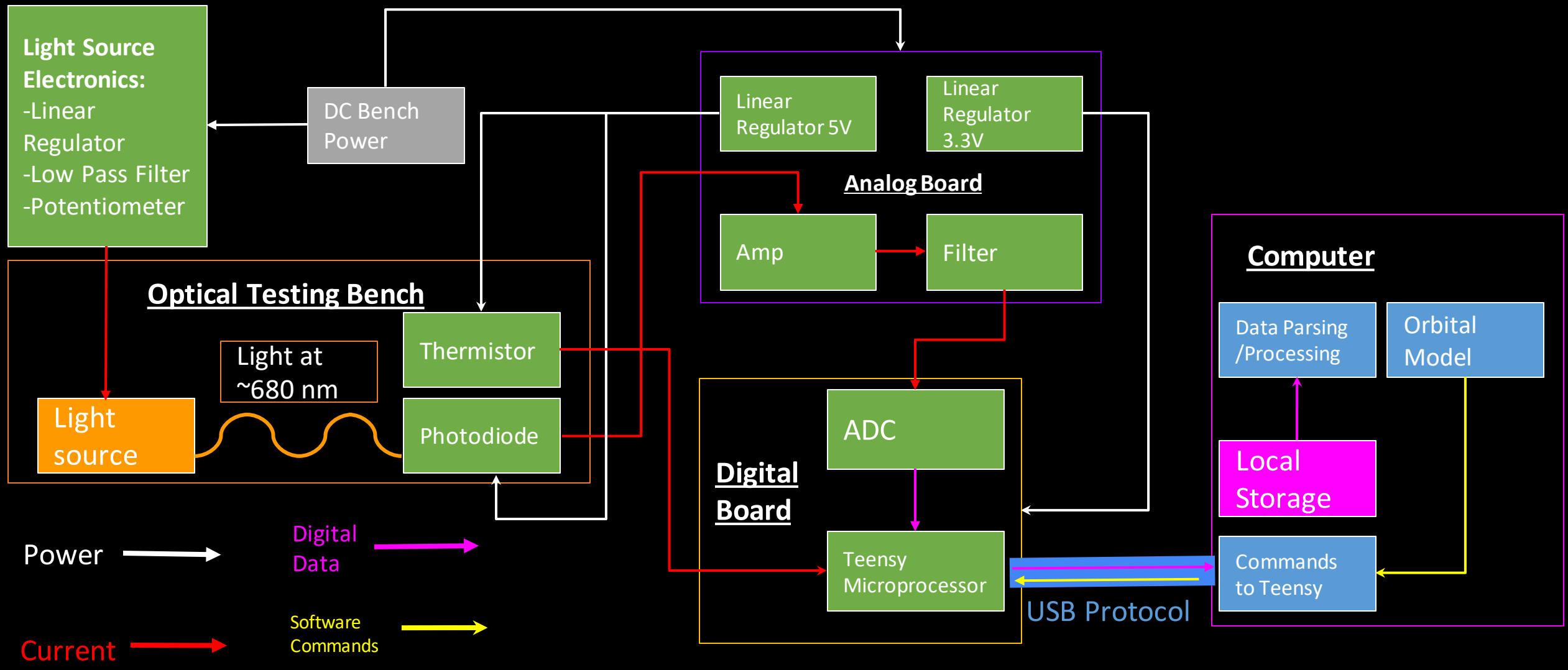
NanoSAM Mission ConOps



The NanoSAM-IV Design

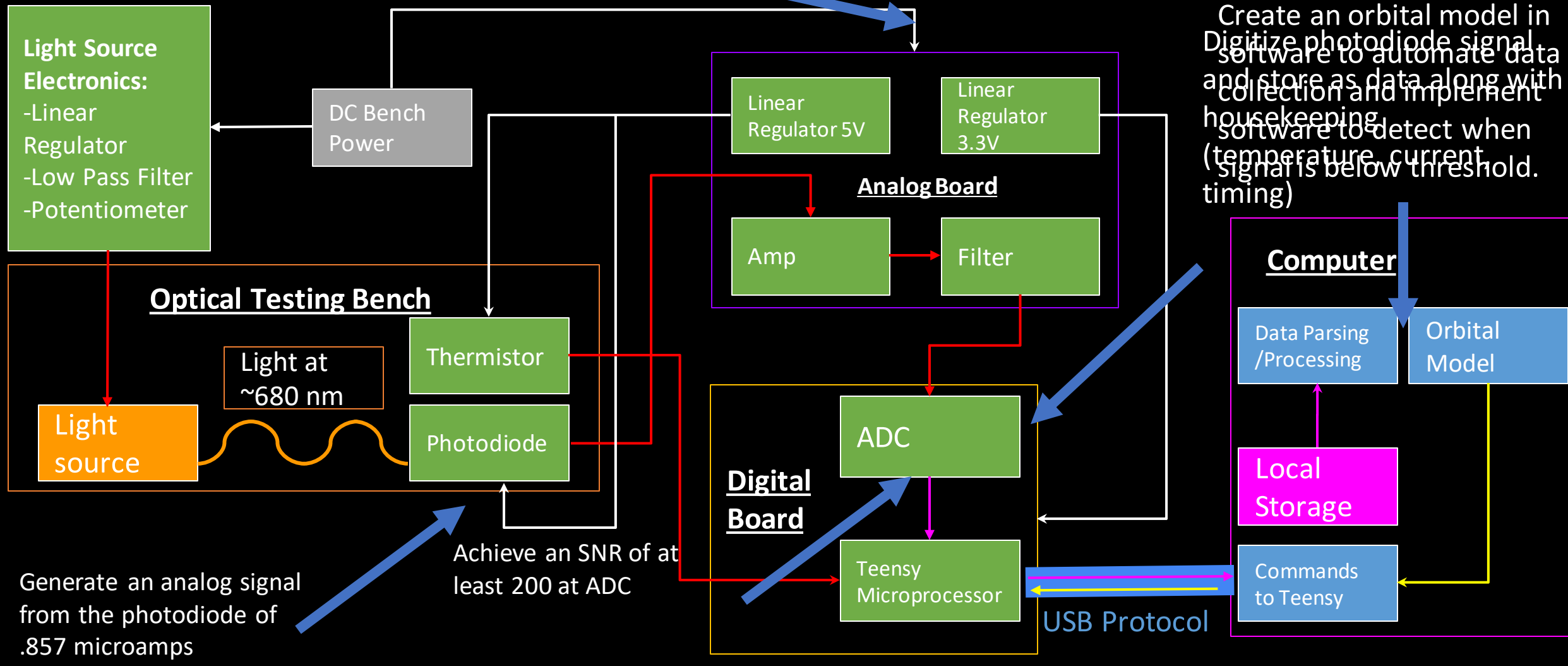


The NanoSAM-IV FBD

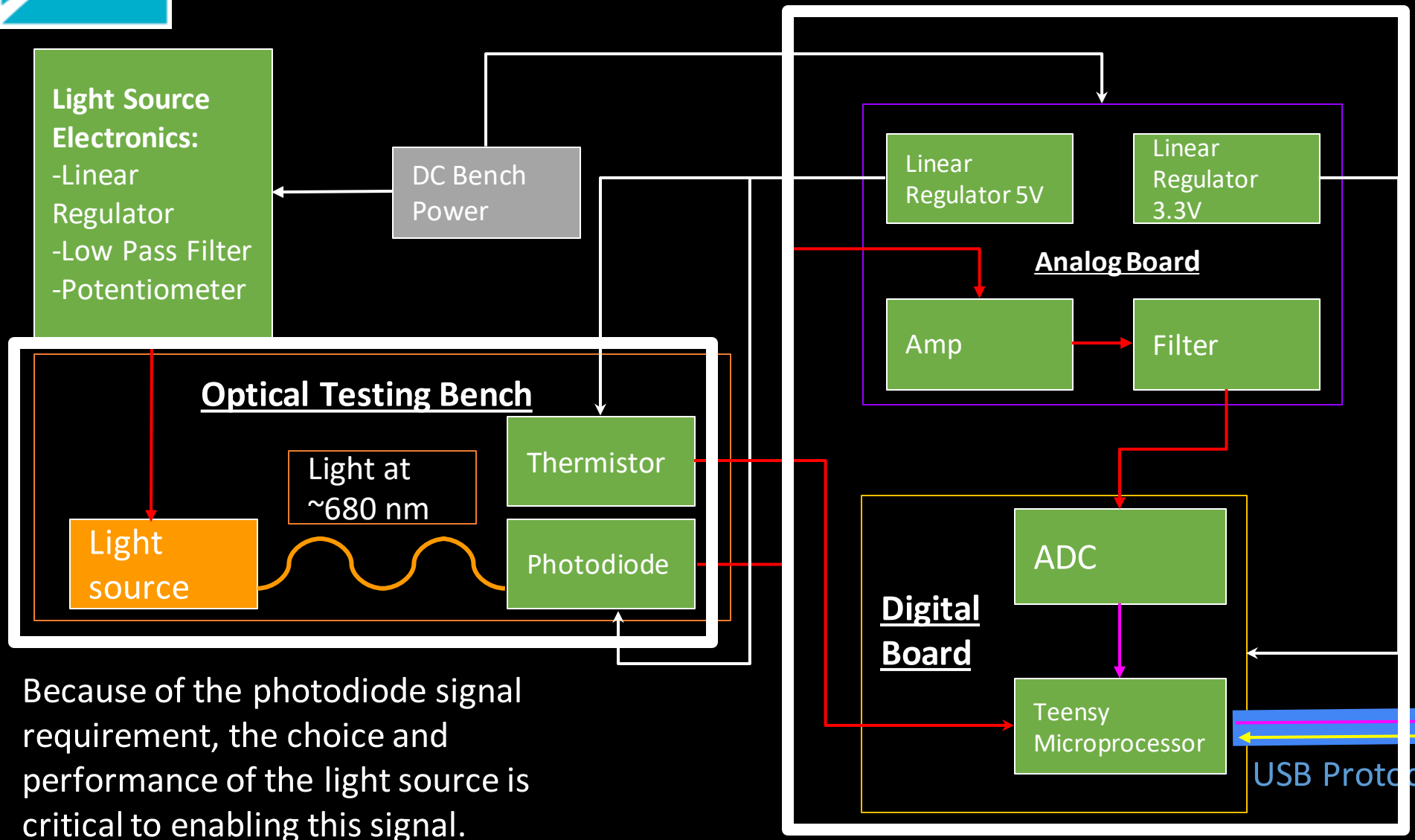


The NanoSAM-IV is Required To…

Total board power draw of at most 8 W



CPE's Based on Requirements



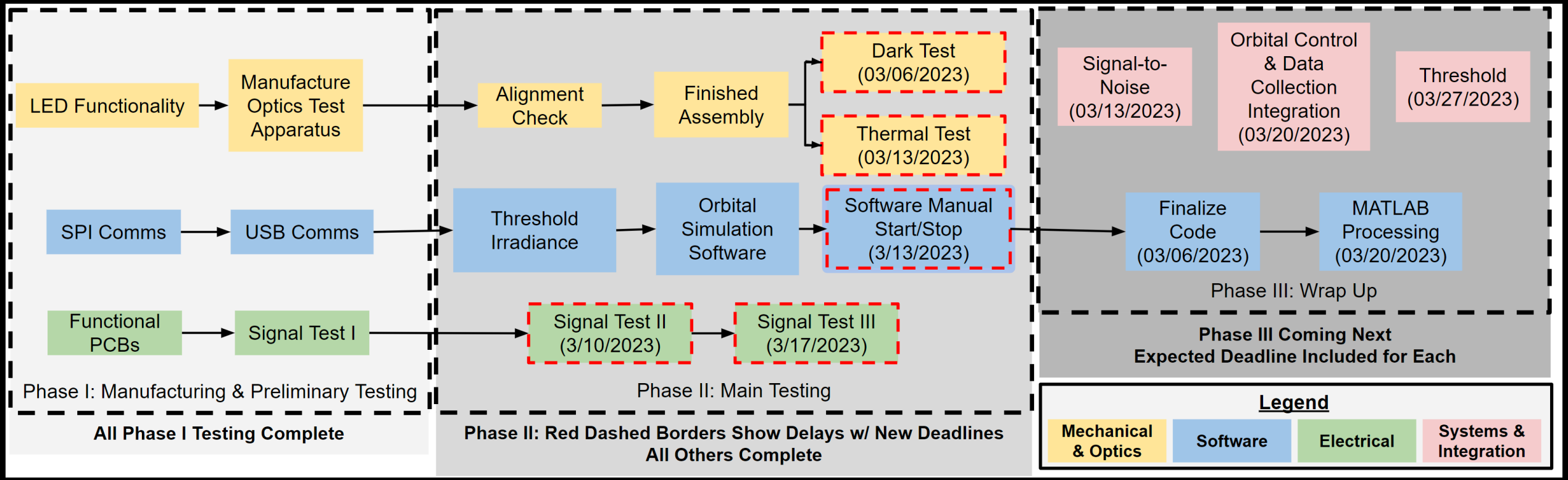
Most critical project element is the electronics boards

Software is critical to the mission of actually collecting and storing data and controlling collection times.

Because of the photodiode signal requirement, the choice and performance of the light source is critical to enabling this signal.

Schedule

Schedule Overview

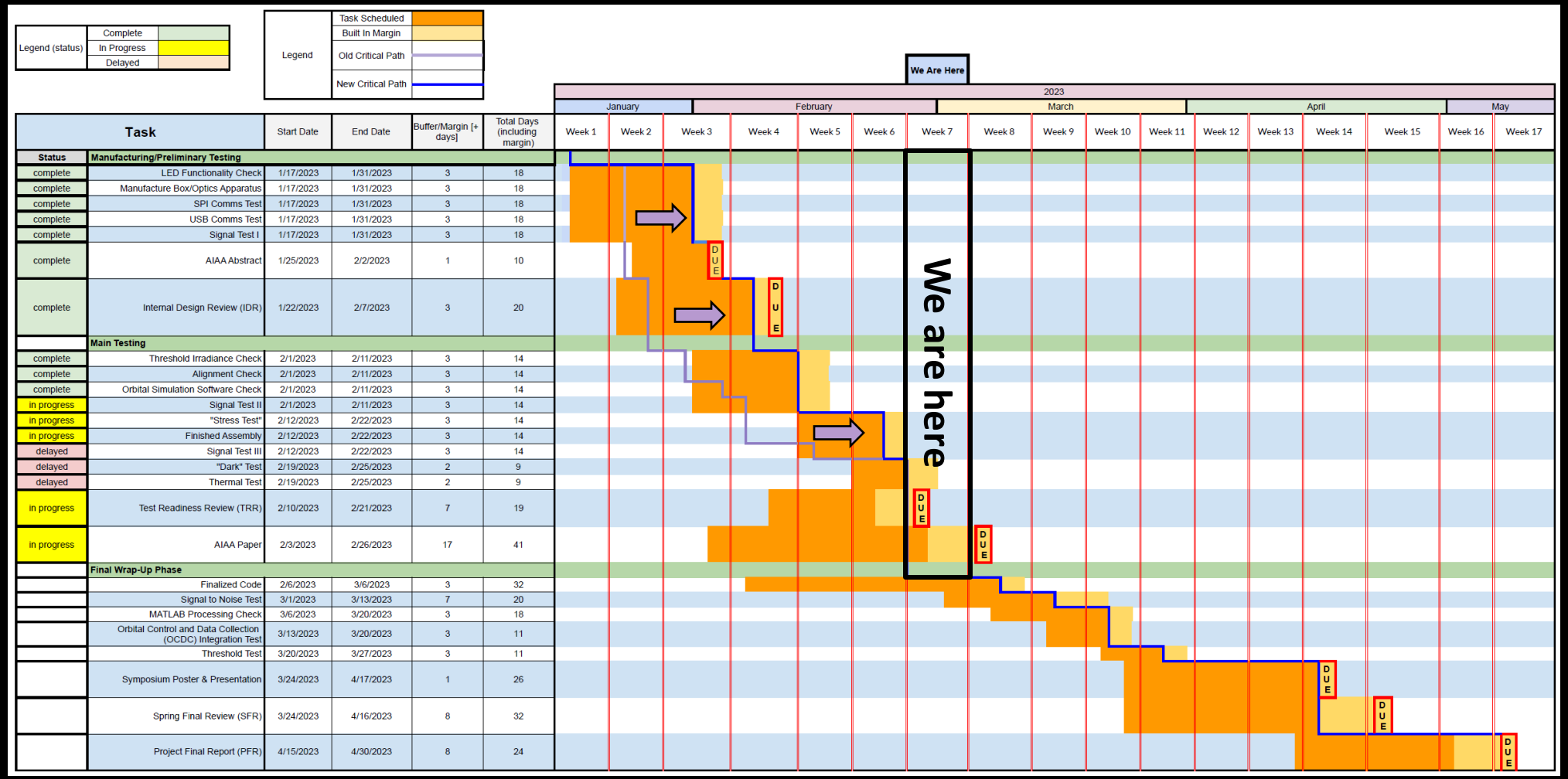


Changes to Schedule (Big Picture)

Legend (status)	
Complete	
In Progress	
Delayed	

Legend	
Task Scheduled	
Built In Margin	
Old Critical Path	
New Critical Path	

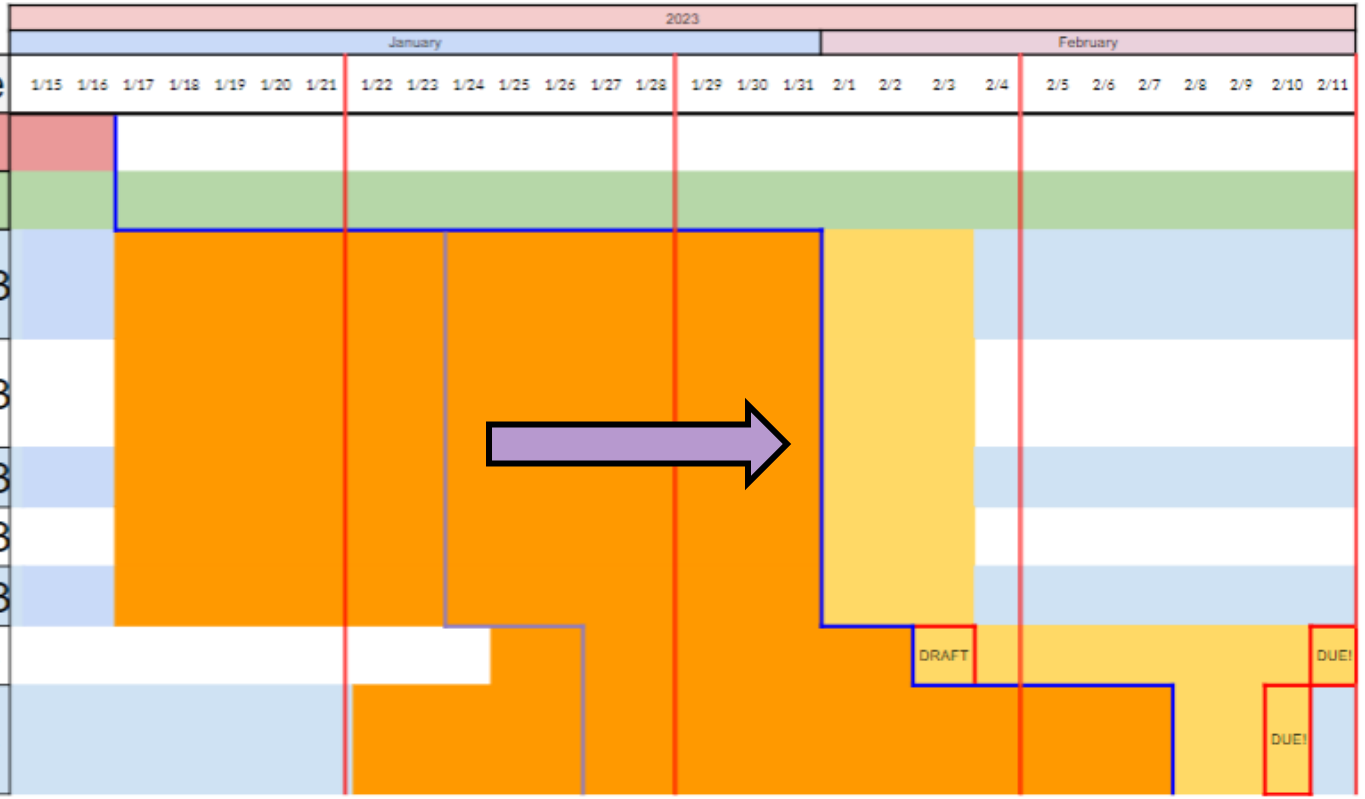
Status	Task	Start Date	End Date	Buffer/Margin [+ days]	Total Days (including margin)
	Manufacturing/Preliminary Testing				
complete	LED Functionality Check	1/17/2023	1/31/2023	3	18
complete	Manufacture Box/Optics Apparatus	1/17/2023	1/31/2023	3	18
complete	SPI Comms Test	1/17/2023	1/31/2023	3	18
complete	USB Comms Test	1/17/2023	1/31/2023	3	18
complete	Signal Test I	1/17/2023	1/31/2023	3	18
complete	AIAA Abstract	1/25/2023	2/2/2023	1	10
complete	Internal Design Review (IDR)	1/22/2023	2/7/2023	3	20
	Main Testing				
complete	Threshold Irradiance Check	2/1/2023	2/11/2023	3	14
complete	Alignment Check	2/1/2023	2/11/2023	3	14
complete	Orbital Simulation Software Check	2/1/2023	2/11/2023	3	14
in progress	Signal Test II	2/1/2023	2/11/2023	3	14
in progress	"Stress Test"	2/12/2023	2/22/2023	3	14
in progress	Finished Assembly	2/12/2023	2/22/2023	3	14
delayed	Signal Test III	2/12/2023	2/22/2023	3	14
delayed	"Dark" Test	2/19/2023	2/25/2023	2	9
delayed	Thermal Test	2/19/2023	2/25/2023	2	9
in progress	Test Readiness Review (TRR)	2/10/2023	2/21/2023	7	19
in progress	AIAA Paper	2/3/2023	2/26/2023	17	41
	Final Wrap-Up Phase				
	Finalized Code	2/6/2023	3/6/2023	3	32
	Signal to Noise Test	3/1/2023	3/13/2023	7	20
	MATLAB Processing Check	3/6/2023	3/20/2023	3	18
	Orbital Control and Data Collection (OCDC) Integration Test	3/13/2023	3/20/2023	3	11
	Threshold Test	3/20/2023	3/27/2023	3	11
	Symposium Poster & Presentation	3/24/2023	4/17/2023	1	26
	Spring Final Review (SFR)	3/24/2023	4/16/2023	8	32
	Project Final Report (PFR)	4/15/2023	4/30/2023	8	24



Changes to Schedule (Phase I)

Legend	
Task Scheduled	
Built In Margin	
Old Critical Path	
New Critical Path	

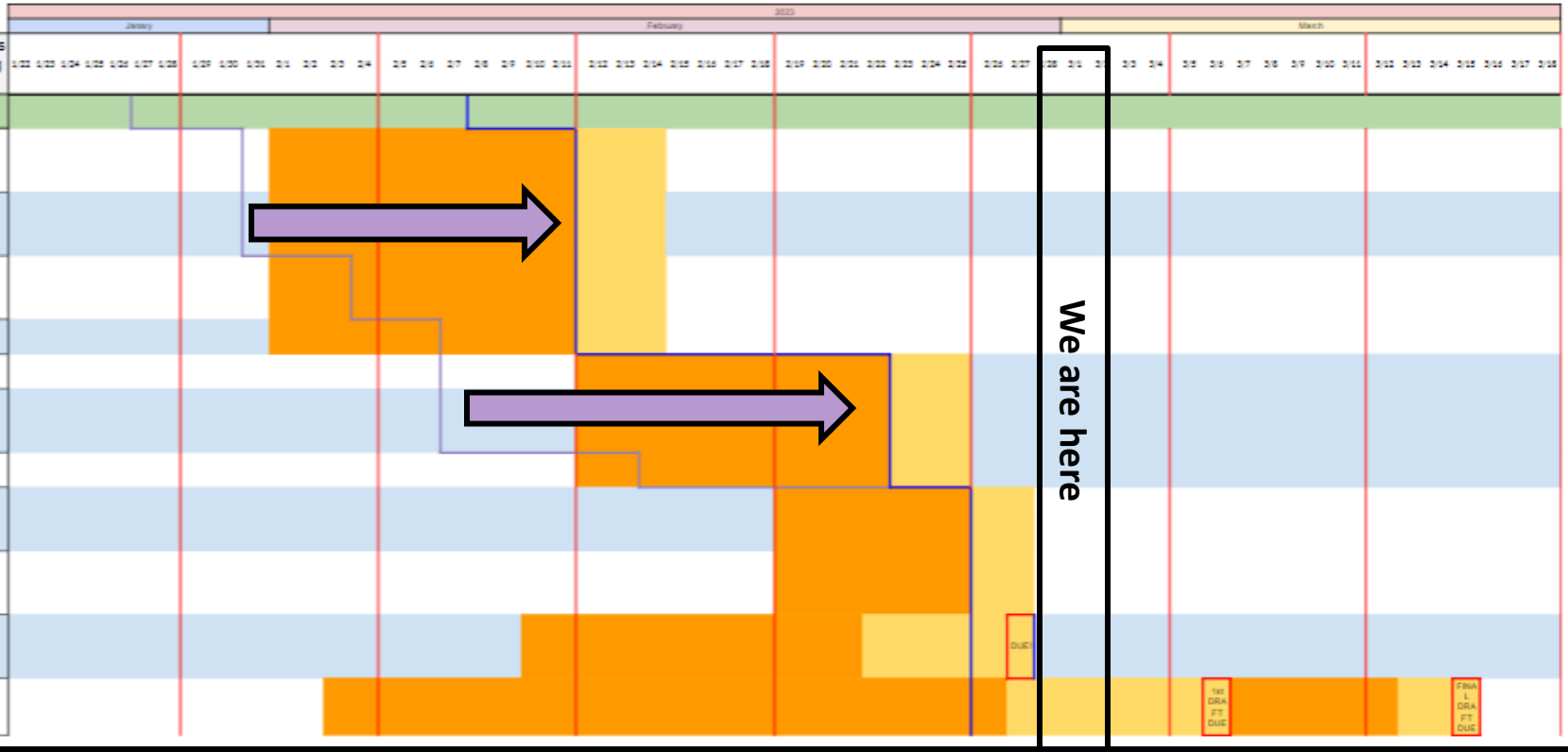
Status	Task	Sub-teams	End Date
	Winter Break		
	Manufacturing/Preliminary Testing		
complete	**LED Functionality Check**	Mechanical /Optics	1/31/2023
complete	**Manufacture Box/Optics Apparatus**	Mechanical /Optics	1/31/2023
complete	**SPI Comms Test**	Software	1/31/2023
complete	**USB Comms Test**	Software	1/31/2023
complete	**Signal Test I**	Electronics	1/31/2023
complete	**AIAA Abstract**	All	2/2/2023
complete	**Internal Design Review (IDR)**	All	2/7/2023



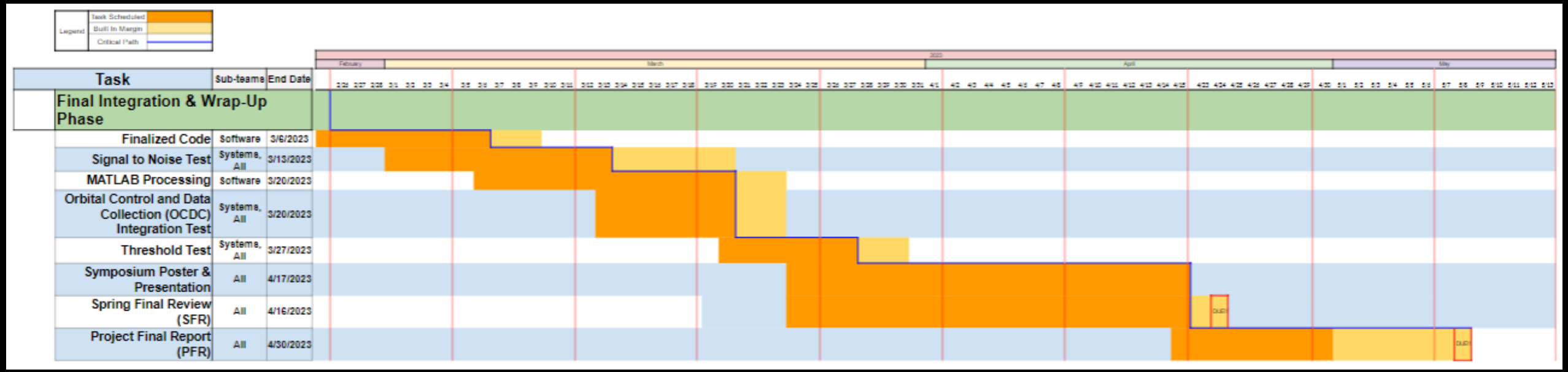
Changes to Schedule (Phase II)

Legend
Task Scheduled
Built In Margin
Old Critical Path
New Critical Path

Task		Sub-teams	End Date	Buffer/ Margin [+ days]	Total Days (including margin)
Status	**Main Testing**				
complete	**Threshold Irradiance Check**	Software	2/11/2023	3	14
complete	**Alignment Check**	Mechanical/ Optics	2/11/2023	3	14
complete	**Orbital Simulation Check**	Software	2/11/2023	3	14
in progress	**Signal Test II**	Electronics	2/11/2023	3	14
in progress	**"Stress Test"**	Software	2/22/2023	3	14
complete	**Finished Assembly**	Mechanical/ Optics	2/22/2023	3	14
delayed	**Signal Test III**	Electronics	2/22/2023	3	14
delayed	**"Dark" Test**	Mechanical/ Optics	2/25/2023	2	9
delayed	**Thermal Test**	Mechanical/ Optics	2/25/2023	2	9
in progress	**Test Readiness Review (TRR)**	All	2/21/2023	7	19
in progress	**AIAA Paper**	All	2/26/2023	17	41



Phase III: How We'll Stay On Schedule



Task	Sub-teams	End Date
Final Integration & Wrap-Up Phase		
Finalized Code	Software	3/6/2023
Signal to Noise Test	Systems, All	3/13/2023
MATLAB Processing	Software	3/20/2023
Orbital Control and Data Collection (OCDC) Integration Test	Systems, All	3/20/2023
Threshold Test	Systems, All	3/27/2023
Symposium Poster & Presentation	All	4/17/2023
Spring Final Review (SFR)	All	4/16/2023
Project Final Report (PFR)	All	4/30/2023

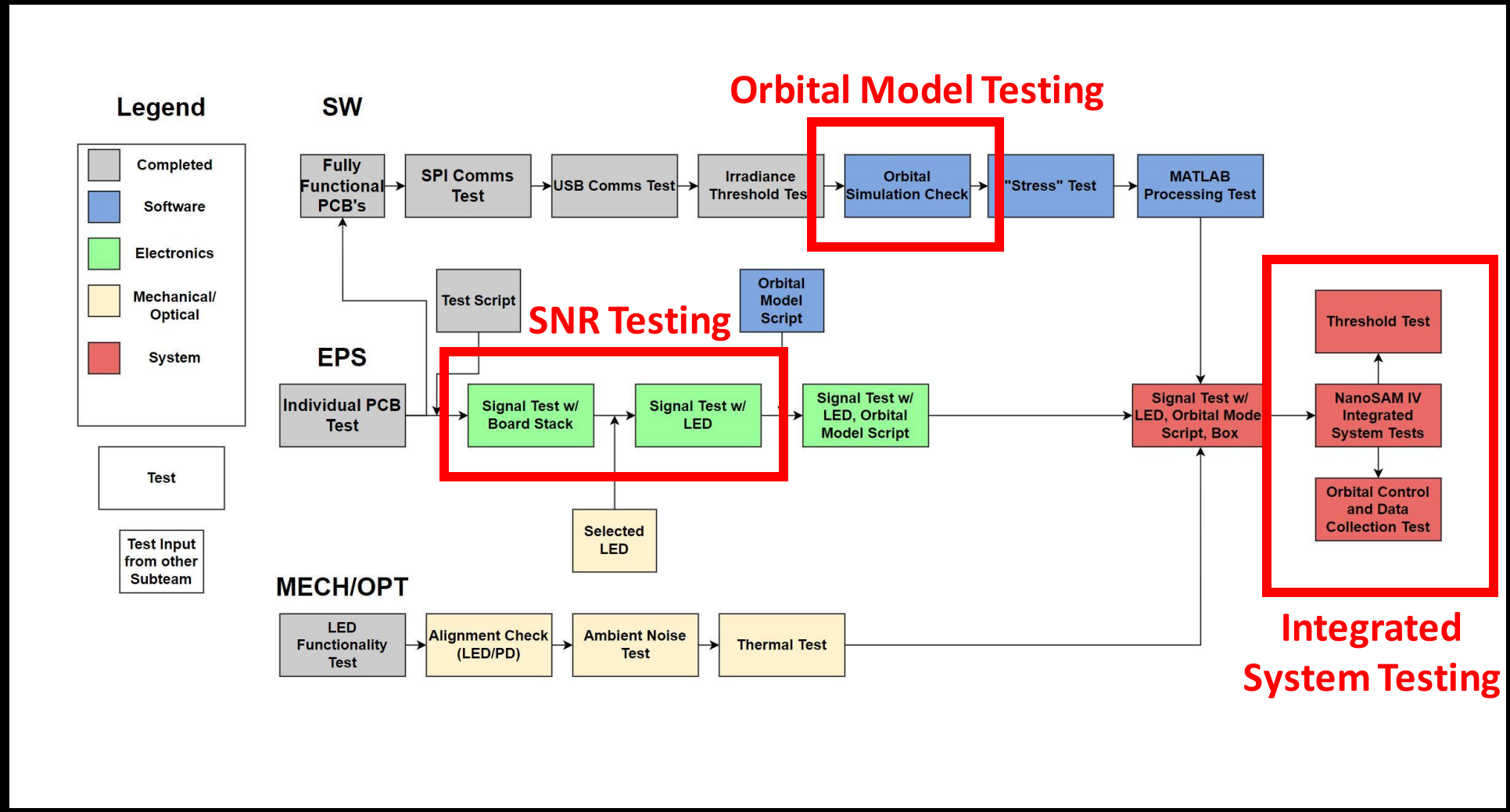
- Test in parallel
- Assign more help to tasks that need extra support
- Worst case: all testing finished before Spring Break (last week of March)
  - 2 weeks to prepare for symposium

Test Readiness

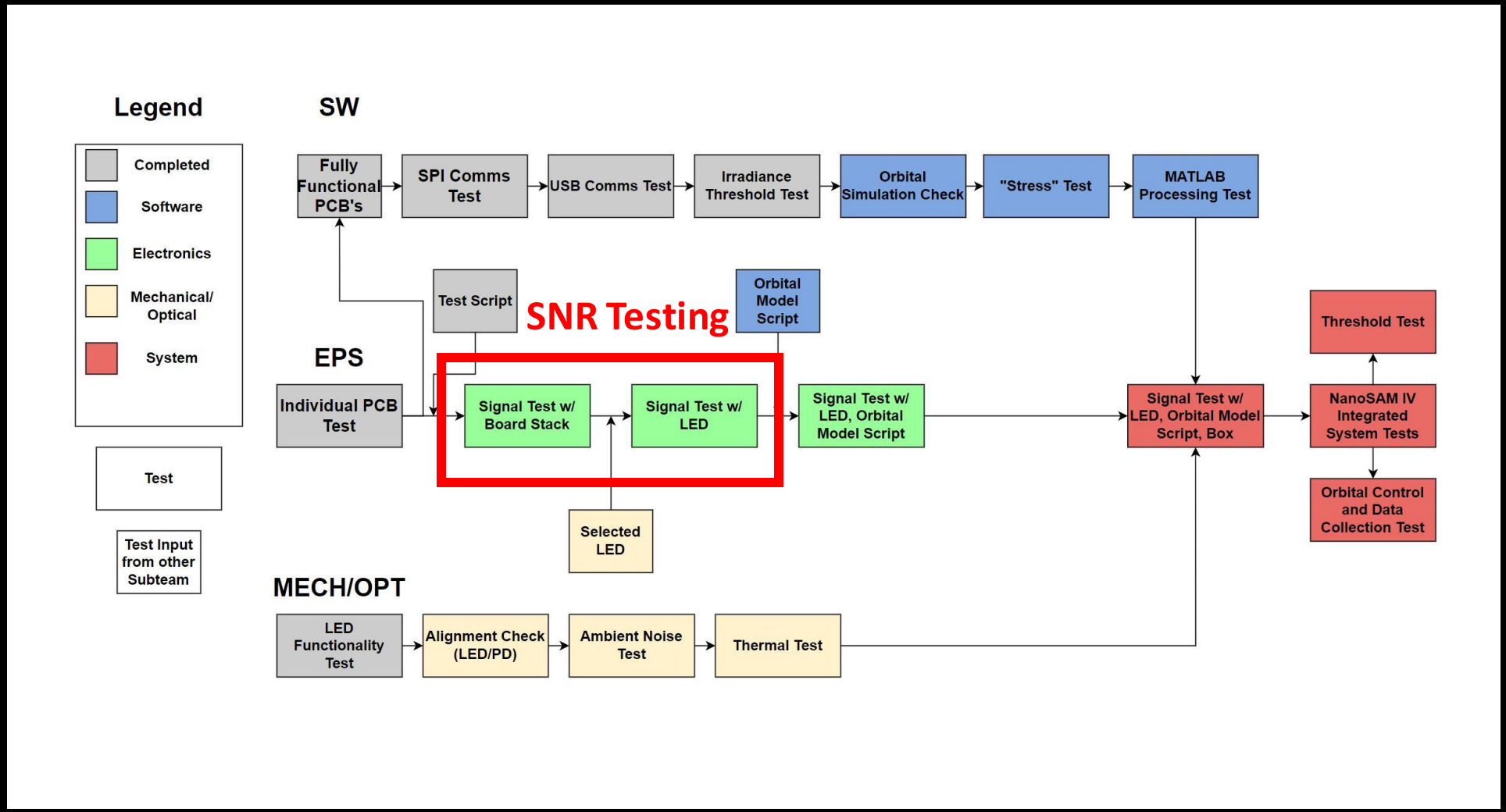
Mission Objectives

MO-01	Generate light signal that will simulate expected on-orbit, un-attenuated signal in order to test embedded system (photodiode, signal cond., ADC, microcontroller)
MO-02	Integrate embedded system design from NanoSAM II (Analog and Digital PCB's) to collect data with an SNR of 200 or greater
MO-03	Autonomous control of data collection process through timing that matches predicted orbital data collection windows
MO-04	Instrument must be appraised of when intensity of light source falls below a threshold

Test Plan Overview



Test #1 – SNR


Legend
Completed
Software
Electronics
Mechanical/ Optical
System
Test
Test Input from other Subteam
SW
Fully Functional PCB's
SPI Comms Test
USB Comms Test
Irradiance Threshold Test
Orbital Simulation Check
"Stress" Test
MATLAB Processing Test
Test Script
SNR Testing
Orbital Model Script
EPS
Individual PCB Test
Signal Test w/ Board Stack
Signal Test w/ LED
Signal Test w/ LED, Orbital Model Script
Selected LED
Signal Test w/ LED, Orbital Model Script, Box
NanoSAM IV Integrated System Tests
Threshold Test
Orbital Control and Data Collection Test
MECH/OPT
LED Functionality Test
Alignment Check (LED/PD)
Ambient Noise Test
Thermal Test

Mission Objectives

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Closed-Loop Model Verification

$$SNR_{Min} = \frac{V_{Signal,Digitized,Min}(V)}{V_{Noise,Max}(V)}$$

$$V_{Noise} = \sqrt{V^2_{Shot,PD} + V^2_{Dark,PD} + V^2_{Johnson} + V^2_{OpAmp} + V^2_{ADC}}$$

$$V_{Noise} = \sqrt{V^2_{Photodiode} + V^2_{OpAmp} + V^2_{ADC}}$$

Approximation due to very low noise values from the photodiode components

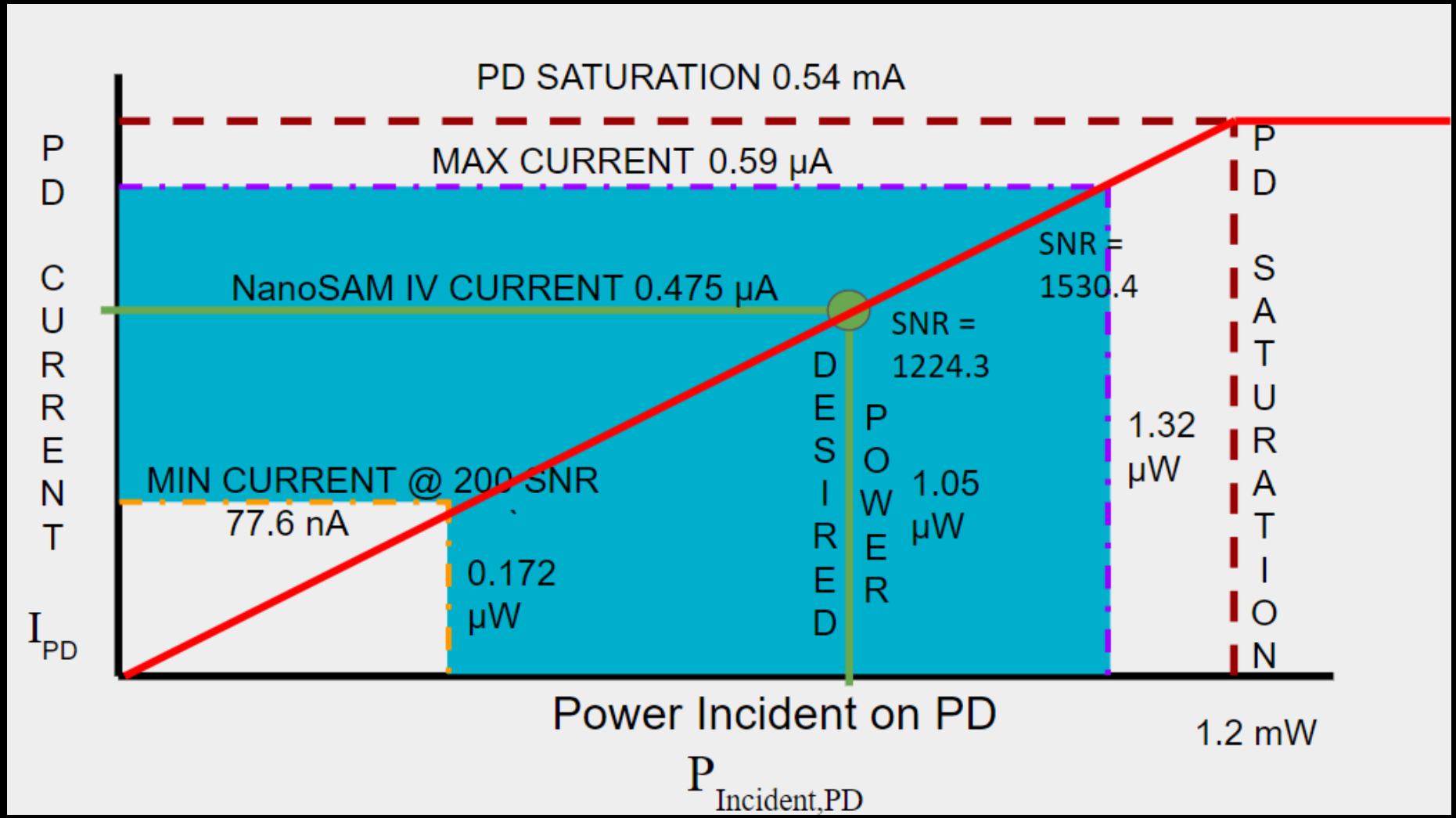
Signal Test II

Signal Test I

Expected results:

Voltage Noise	Value [V]
$V_{photodiode}^2$	2.86e-06
$V_{Op\text{-}amp}^2$	4e-08
V_{ADC}^2	2.1e-10

SNR Testing – Design Space & Bounds



SNR Testing – Pre-Requisite Tests

Pre-requisite test 1: Retrofitted and tested PCB's

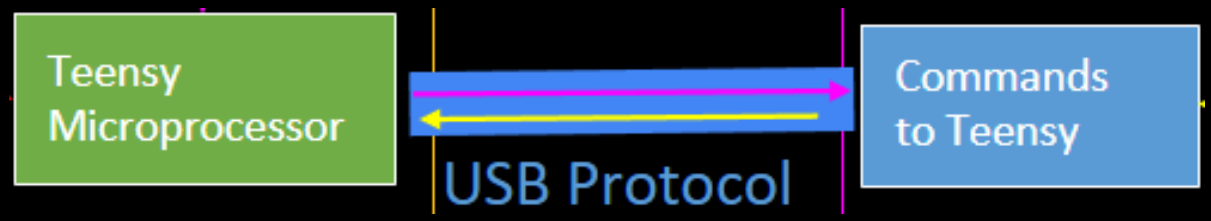
Voltage measurements were taken at all test points of the boards and actual values matched our expected measurement values

Boards components functionality

SNR Testing – Pre-Requisite Tests

Pre-requisite test 2: Software test script

Data extraction and saving from Teensy



Communication line between the computer and the Teensy microcontroller

SNR Testing – Pre-Requisite Tests

Pre-requisite test 3: Prototype optical housing

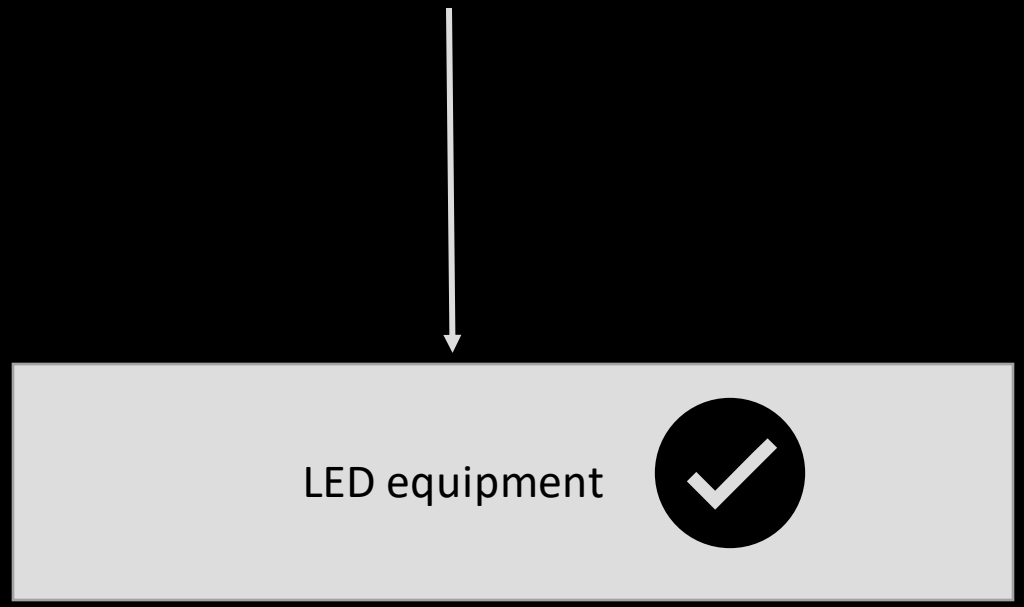
LED placement and setup

Optical housing ✓

SNR Testing – Pre-Requisite Tests

Pre-requisite 4: LED equipment

Functionality of the LED was verified and validated at desired output voltage and current



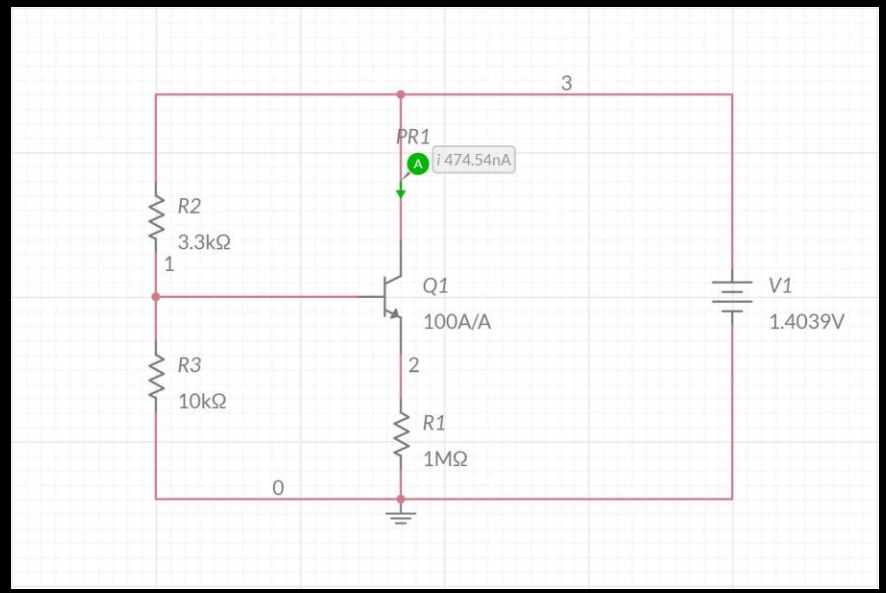
LED

LED Driver

SNR Testing – Pre-Requisite Tests

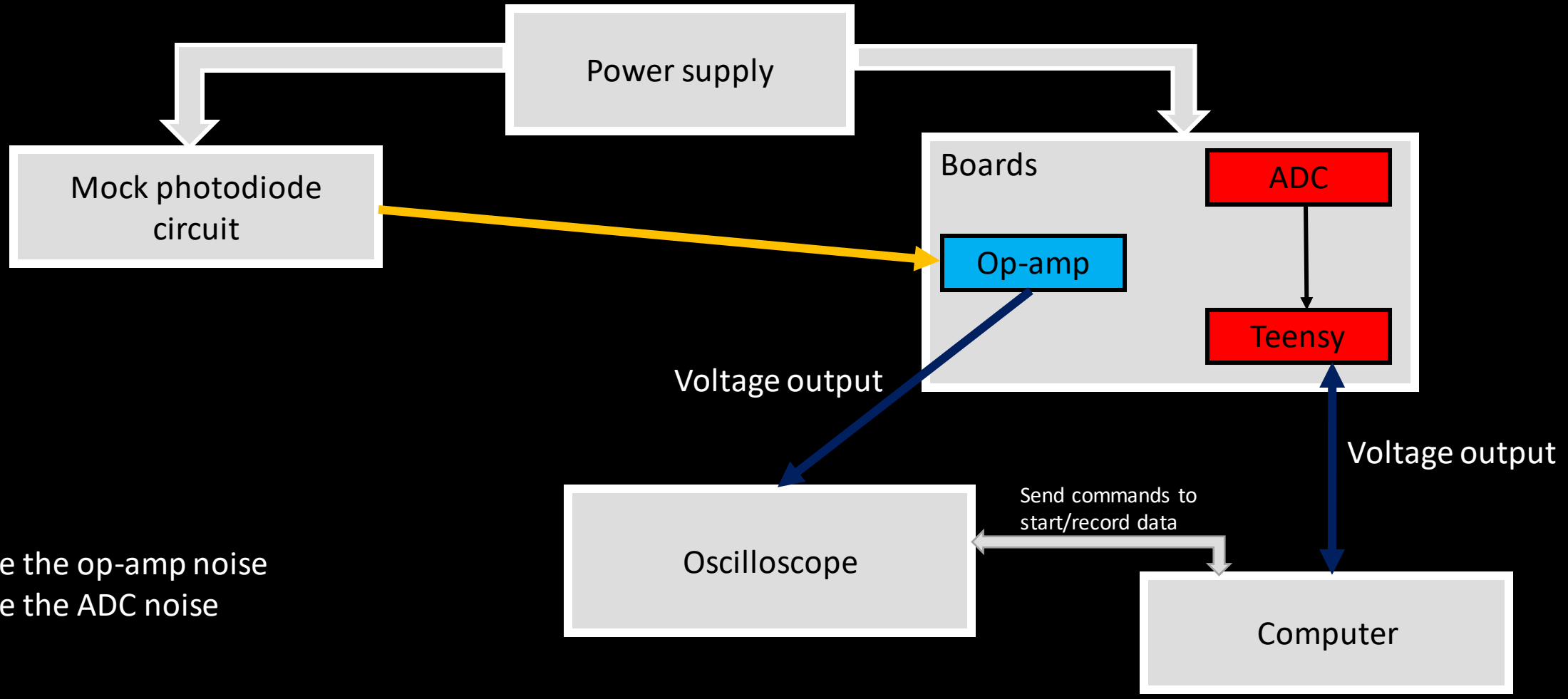
Pre-requisite test 5: Mock photodiode circuit

Outputs the desired current of 0.475 microamps



Mock photodiode circuit

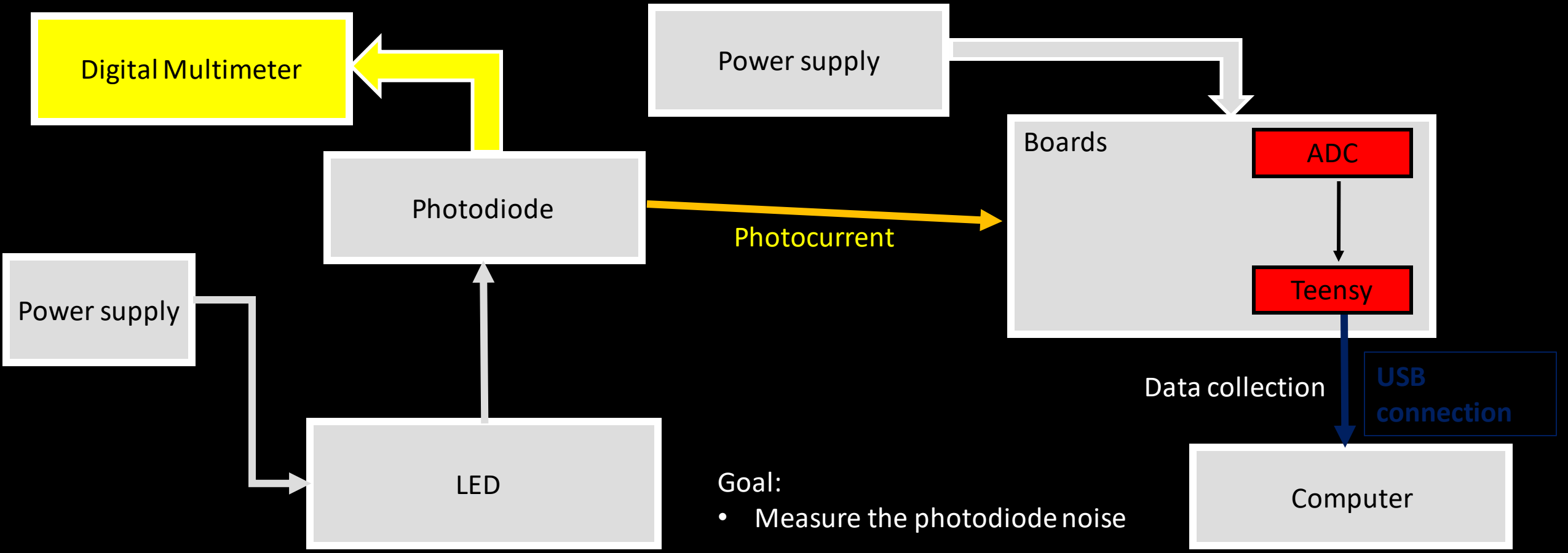
SNR Testing – Signal Test 1



Goal:

- Measure the op-amp noise
- Measure the ADC noise

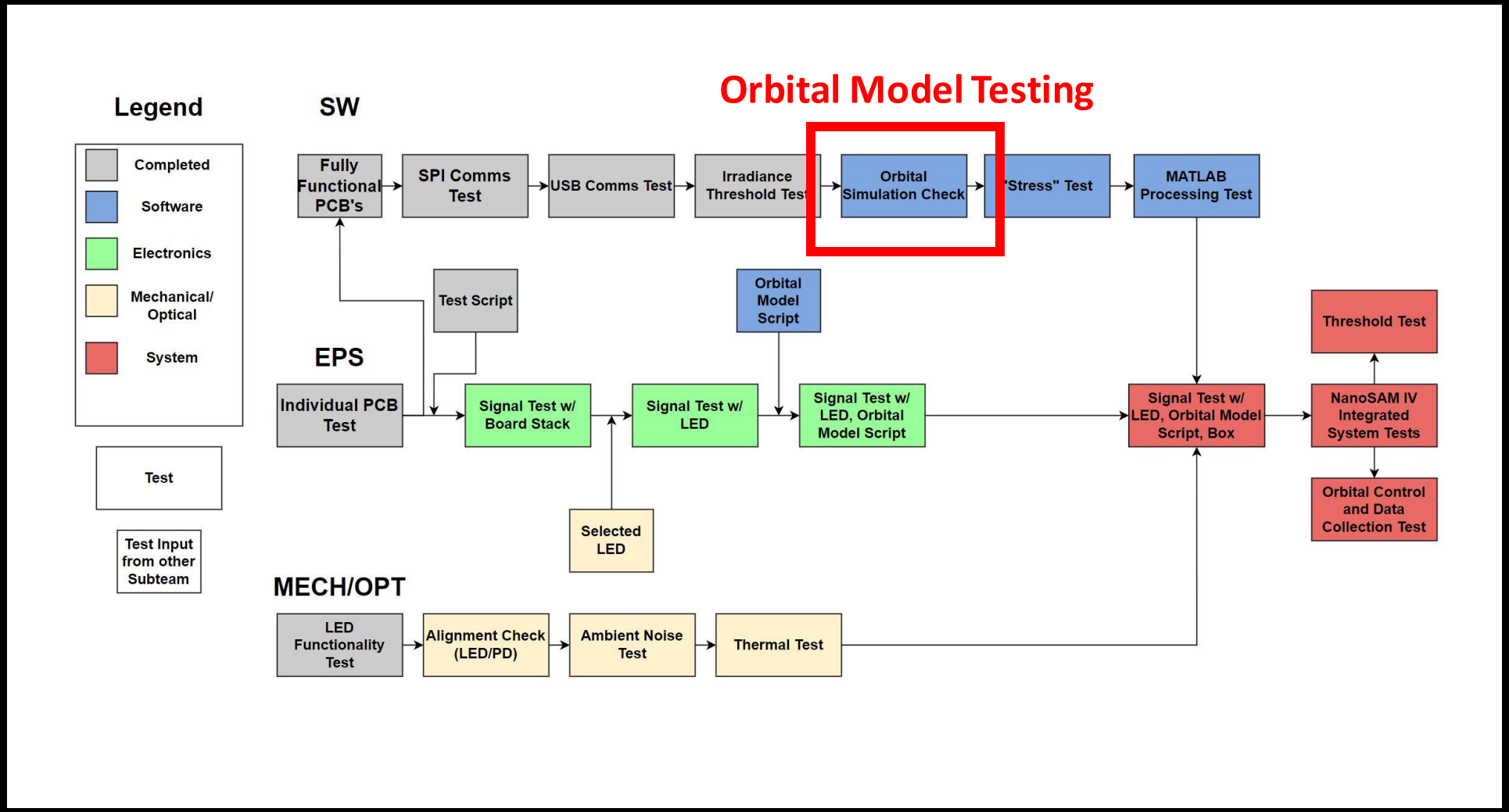
SNR Testing – Signal Test 2



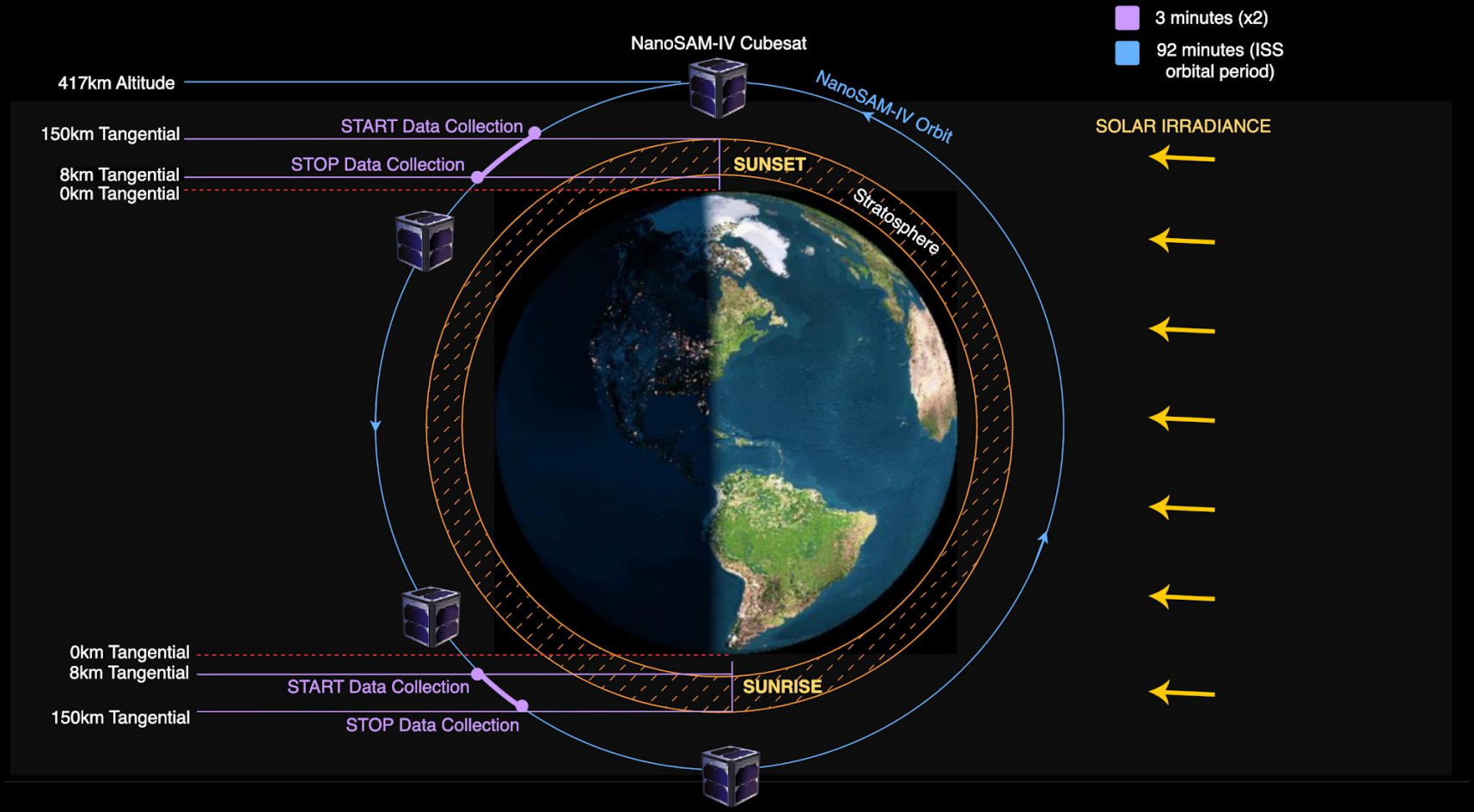
Goal:

- Measure the photodiode noise

Test #2 – Orbital Model

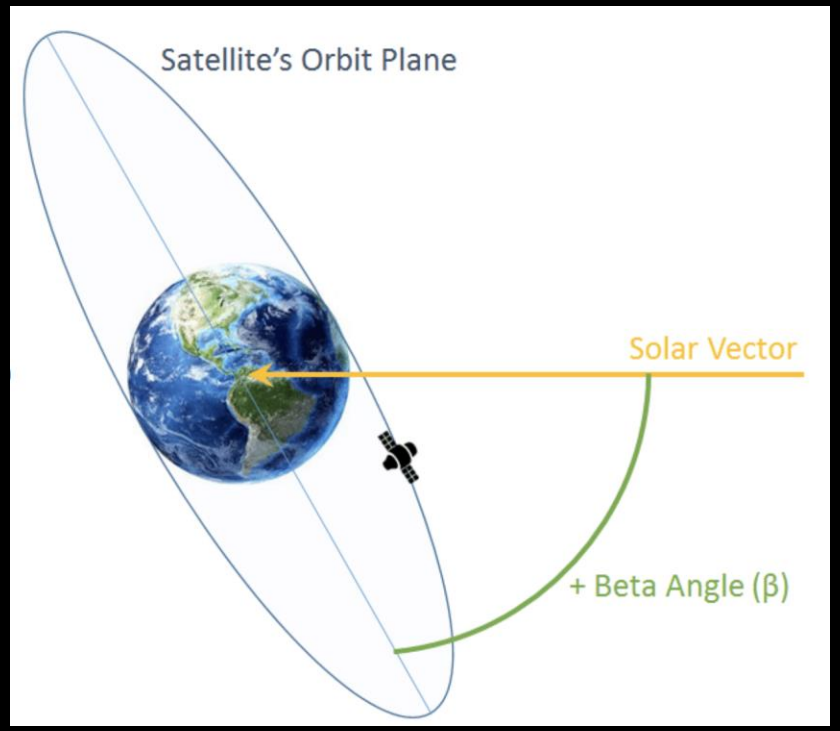


Orbital Simulation



NanoSAM-IV Orbital Model ConOps

Orbital Simulation



Solar Beta Angle Visualization

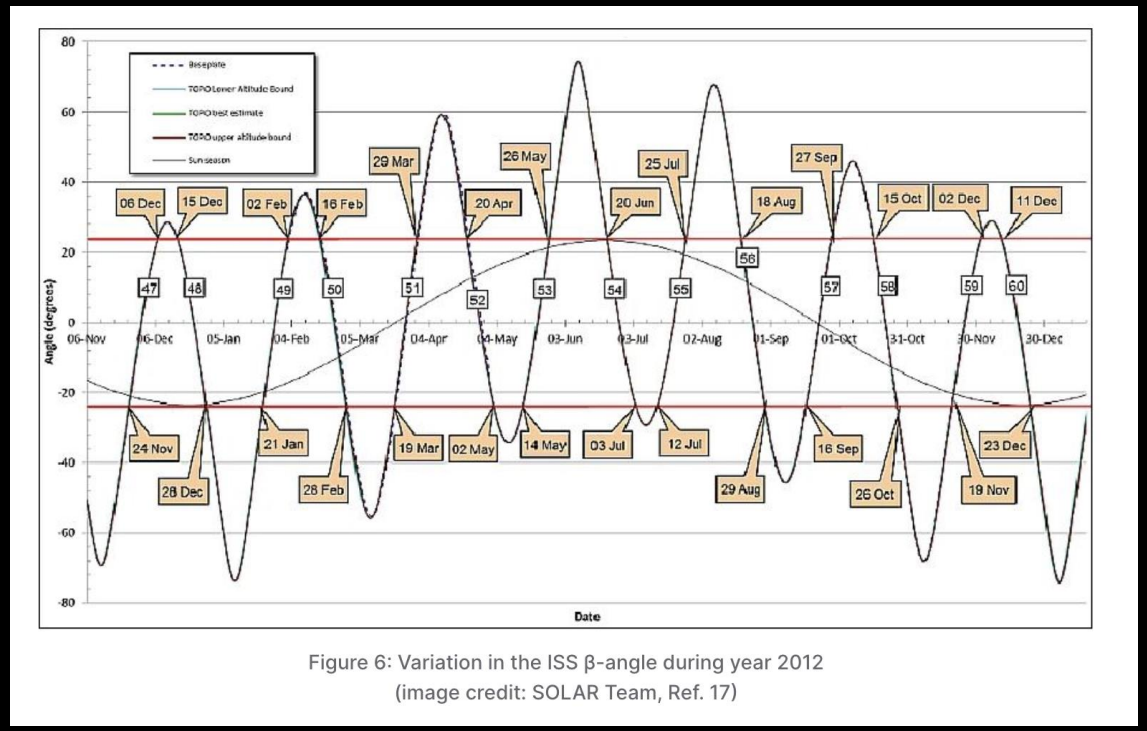


Figure 6: Variation in the ISS β-angle during year 2012
(image credit: SOLAR Team, Ref. 17)

Beta Angle Variation Over the Course of 1 Year

Math for Beta = 0°

$$\theta = \phi - \alpha$$

$$\cos(\alpha) = \frac{150 + 6371}{417.5 + 6371}$$

$$\alpha = 0.2812\, rad$$

$$\cos(\phi) = \frac{0 + 6371}{417.5 + 6371}$$

$$\phi = 0.3512\, rad$$

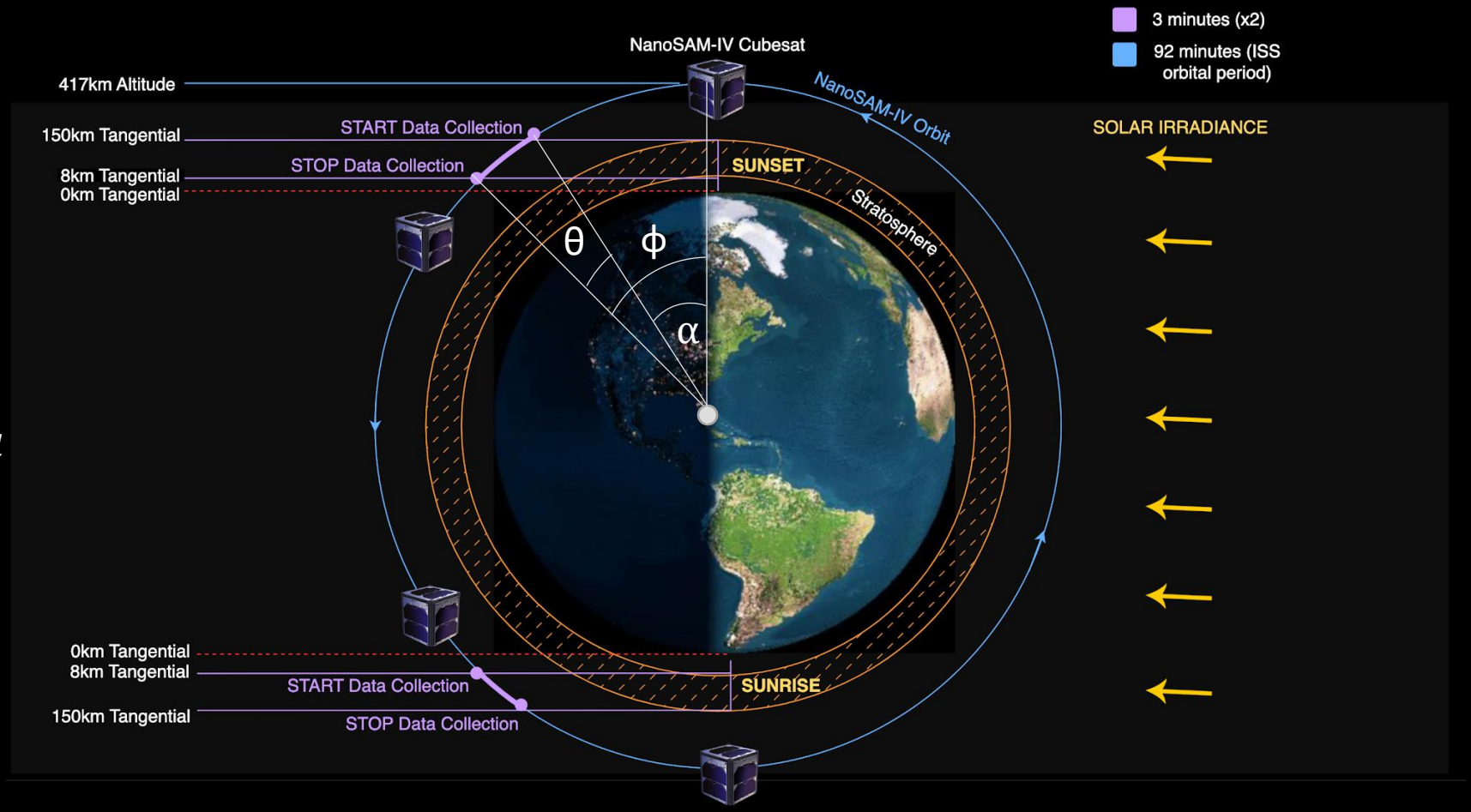
$$\theta = 0.3512 - 0.2812\, rad$$

$$\theta = 0.071\, rad$$

$$Period = 92.92\, min$$

$$T = \frac{0.071}{2\pi} * (Period)$$

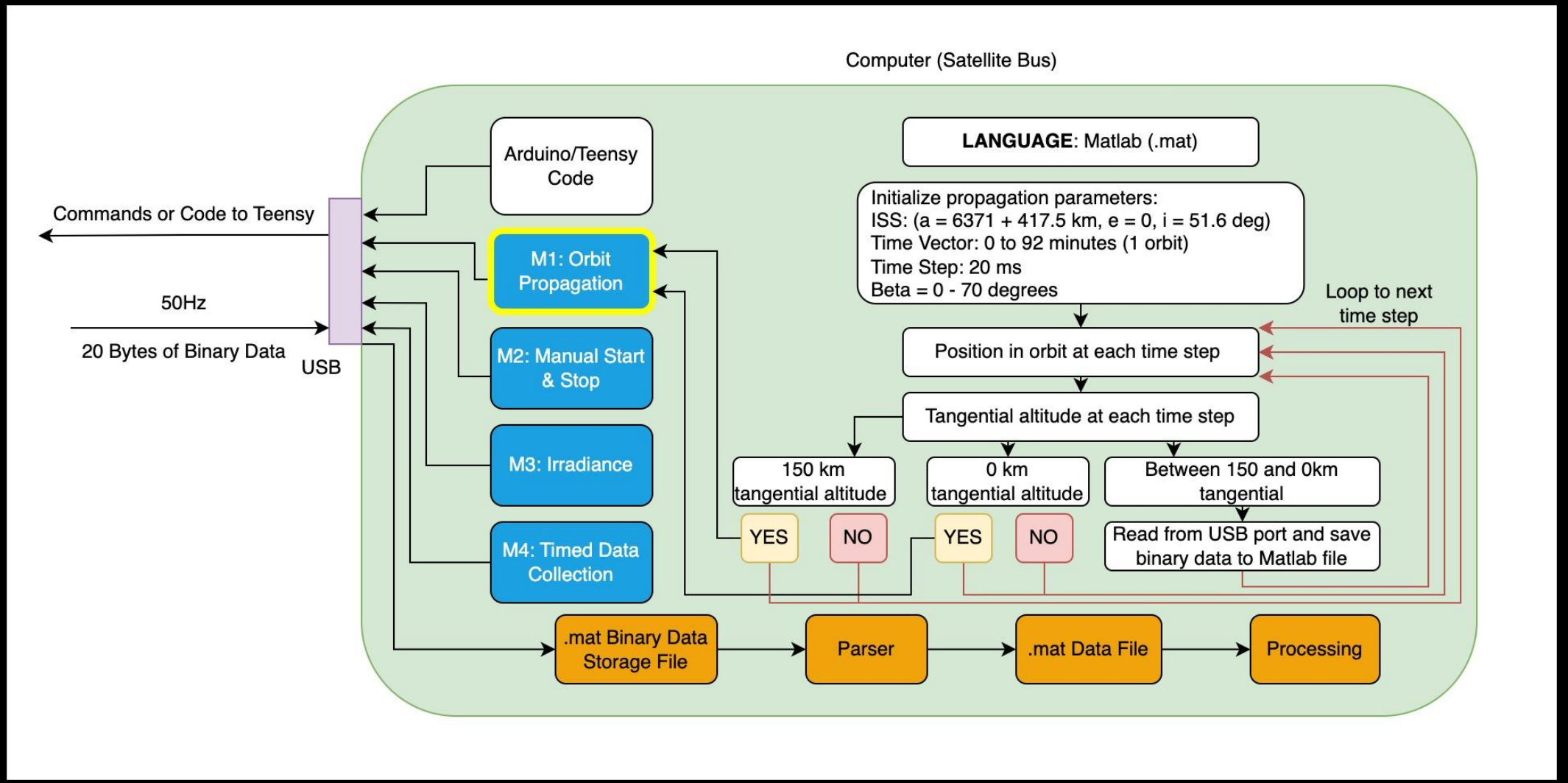
$$\underline{\boldsymbol{T = 62.80\, sec}}$$



Mission Objectives

MO-01	Generate light signal that will simulate expected on-orbit, un-attenuated signal in order to test embedded system (photodiode, signal cond., ADC, microcontroller)
MO-02	Integrate embedded system design from NanoSAM II (Analog and Digital PCB's) to collect data with an SNR of 200 or greater
MO-03	Autonomous control of data collection process through timing that matches predicted orbital data collection windows
MO-04	Instrument must be appraised of when intensity of light source falls below a threshold

Test Description



Testing Procedure

1.) Tangent altitude at each time step
2.) Plot tangent altitude vs. time for 1 orbital period
3.) Identify times to issue commands to Teensy (USB)
4.) Identify times to read data from Teensy (USB)

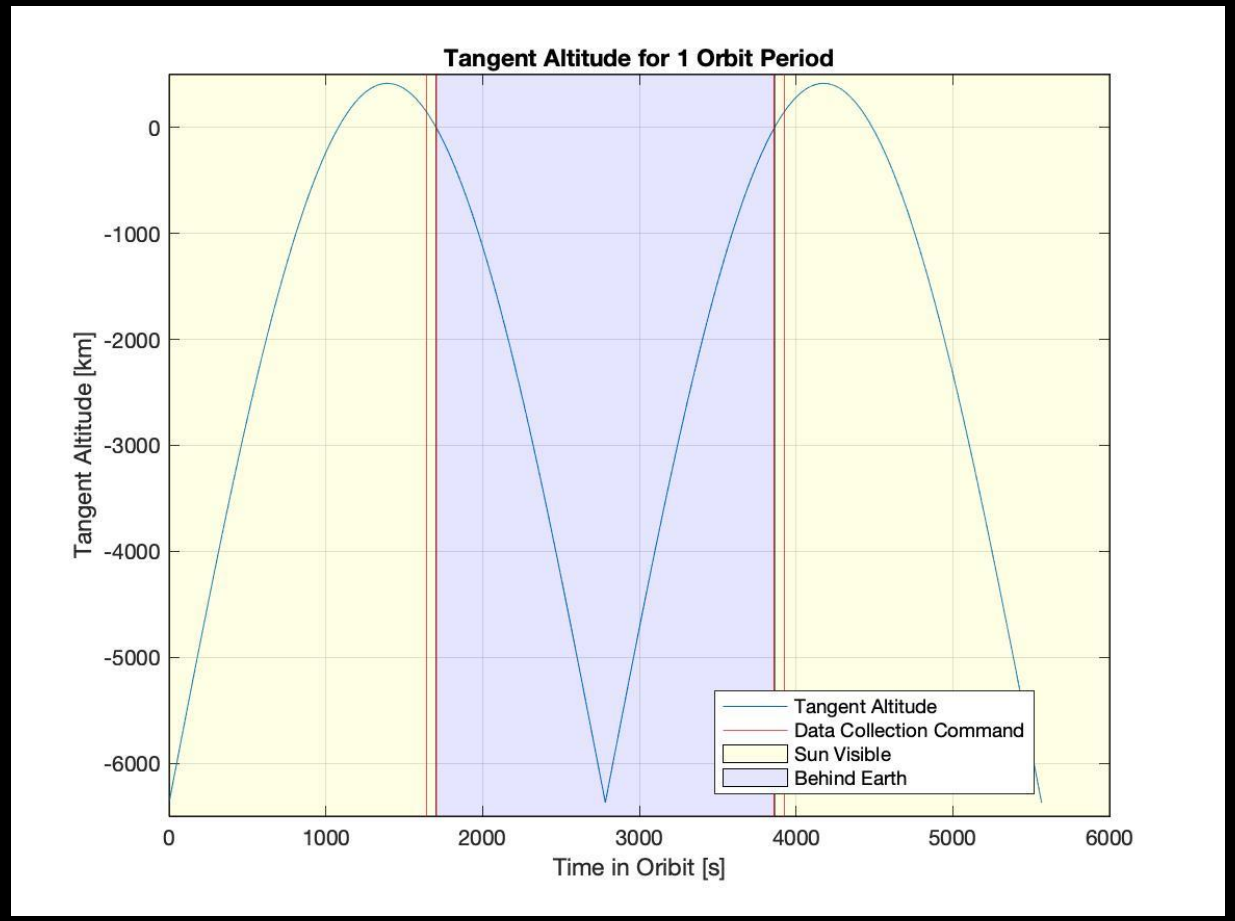
} Beta = 0°
Beta = 30°
Beta = 60°
Beta = 70°

Testing Criteria

	Indication of Sunrise and Sunset Event	Time of Sunset or Sunrise Data Collection	Tangent Altitude at Each Time Step	Maximum Tangent Altitude	Minimum Tangent Altitude	Start or Stop Data Collection Commands Issued
Beta = 0°	Yes	62.80 sec	Yes	417.5 km	Negative Value (km)	4
Beta = 30°	Yes	62.80 < X < 180 sec	Yes	417.5 km	Negative Value (km)	4
Beta = 60°	Yes	62.80 < X < 180 sec Larger than Beta = 30°	Yes	417.5 km	Negative Value (km)	4
Beta = 70°	No	N/A	Yes	417.5 km	Positive Value (km)	0

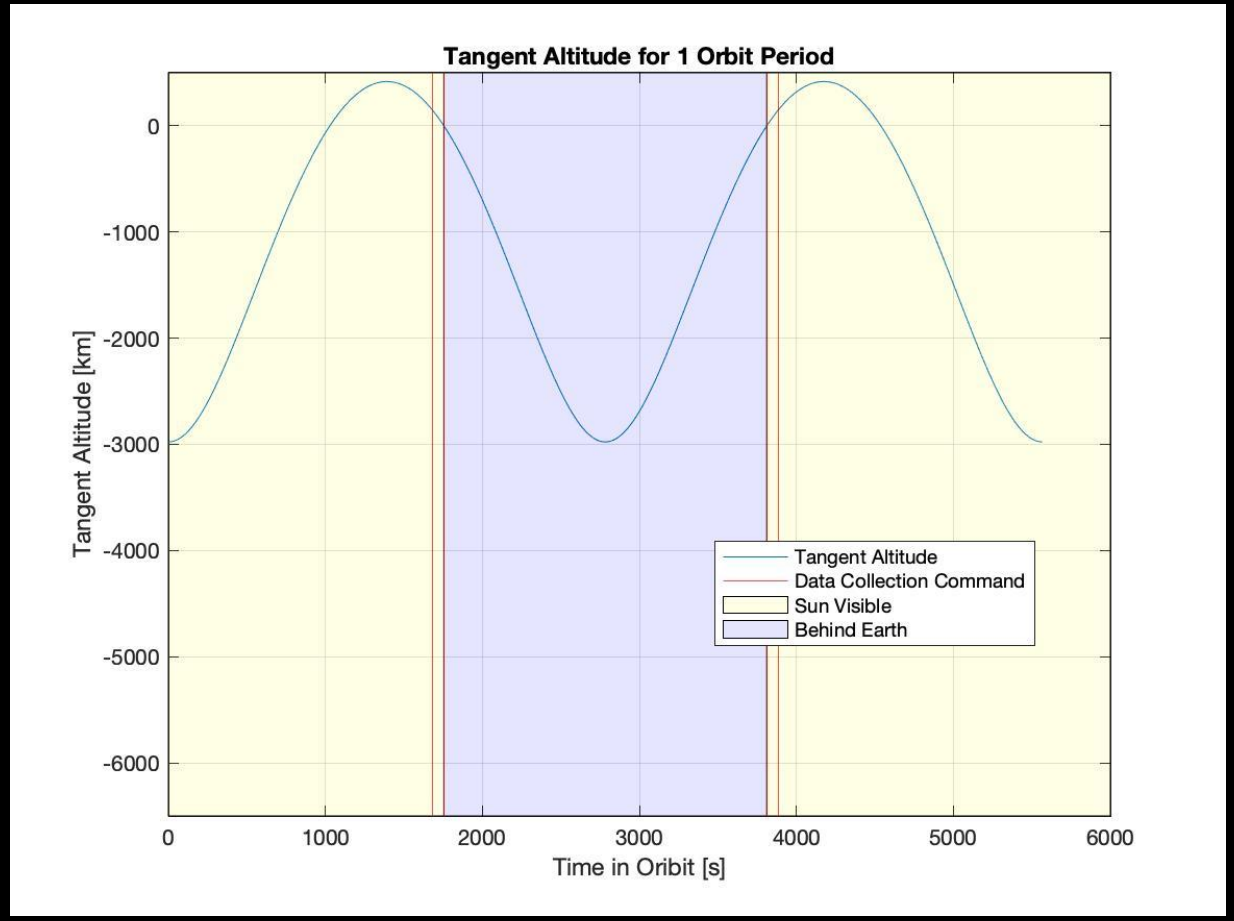
Orbital Simulation Test Results

```
Duration of Occultation Event: 62.80 s
```



Beta = 0°

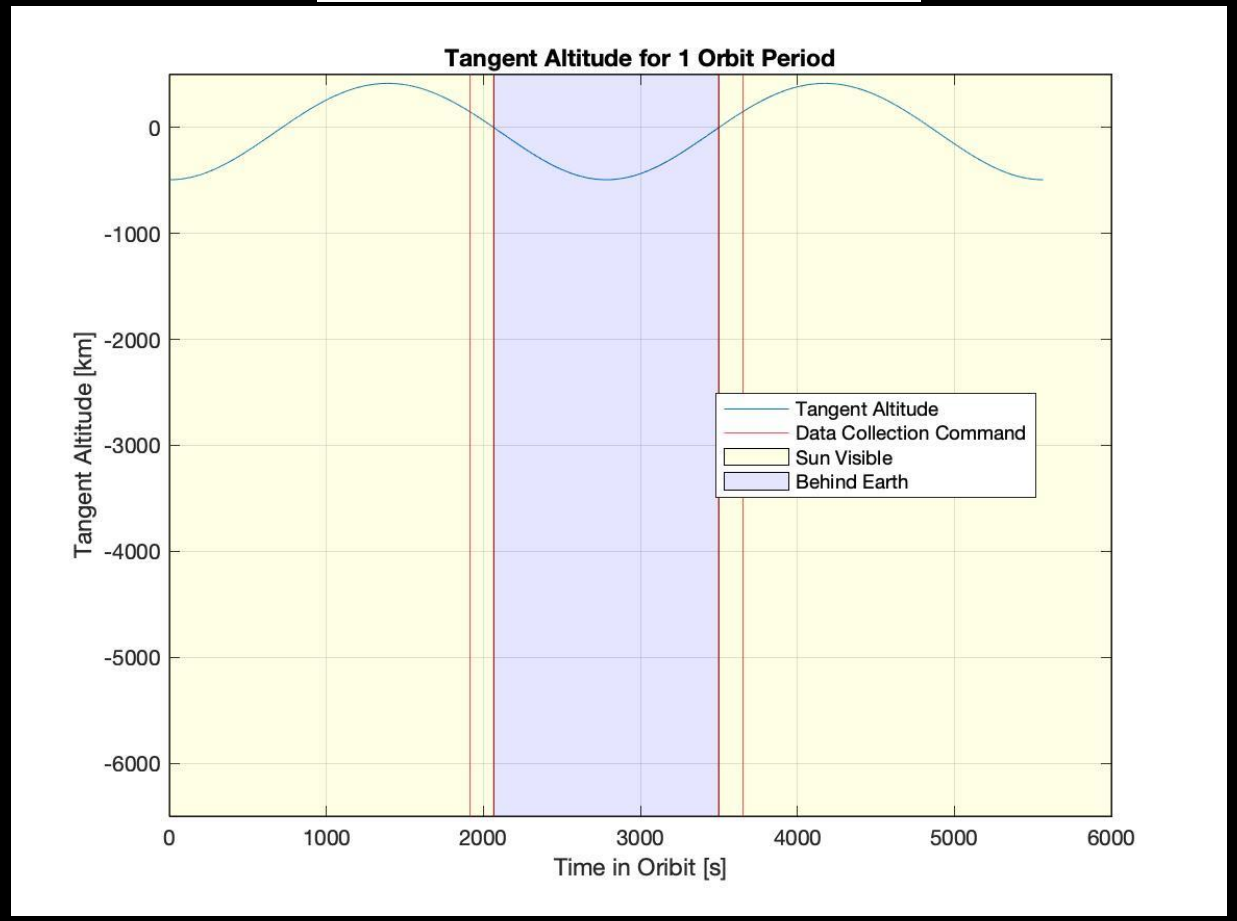
```
Duration of Occultation Event: 73.84 s
```



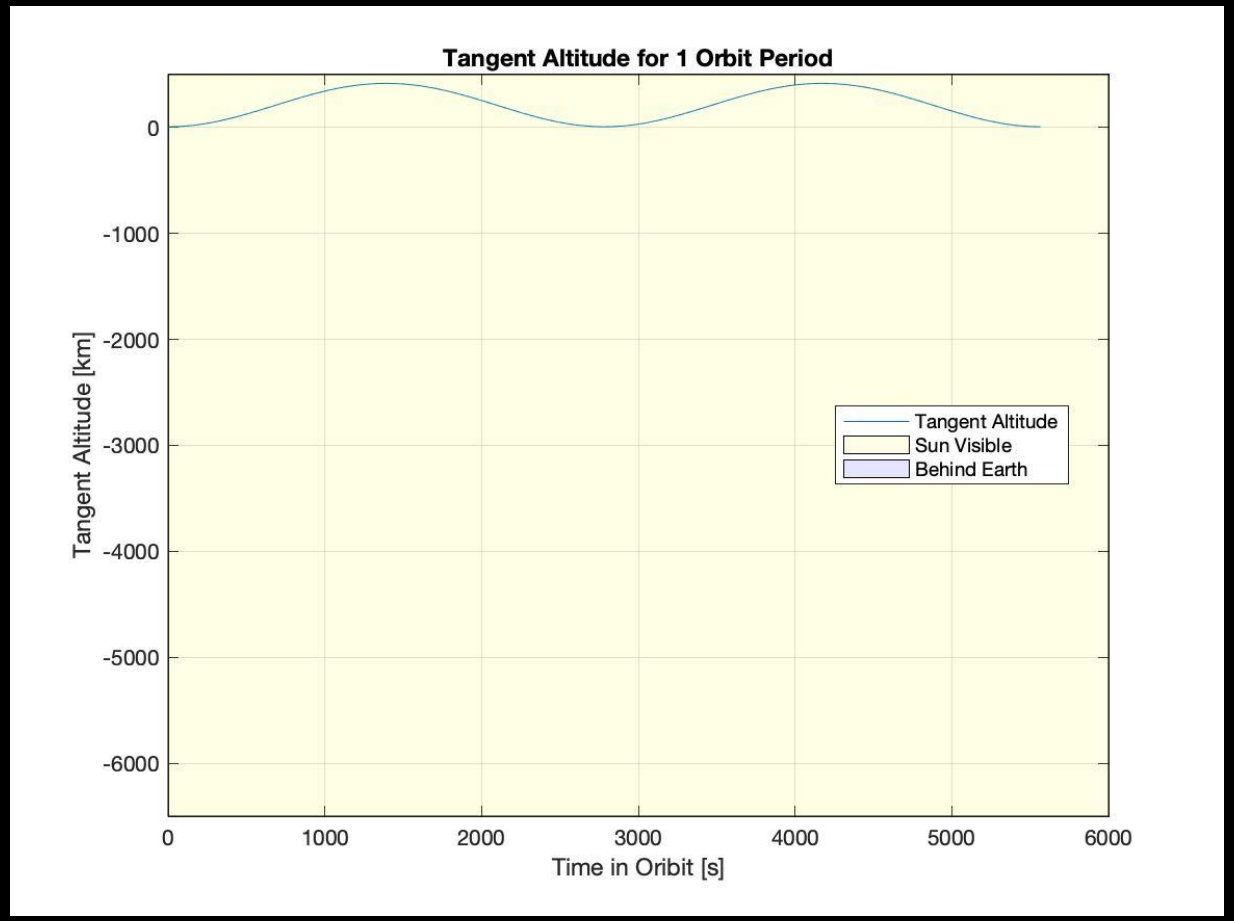
Beta = 30°

Orbital Simulation Test Results

```
Duration of Occultation Event: 153.10 s
```



Beta = 60°

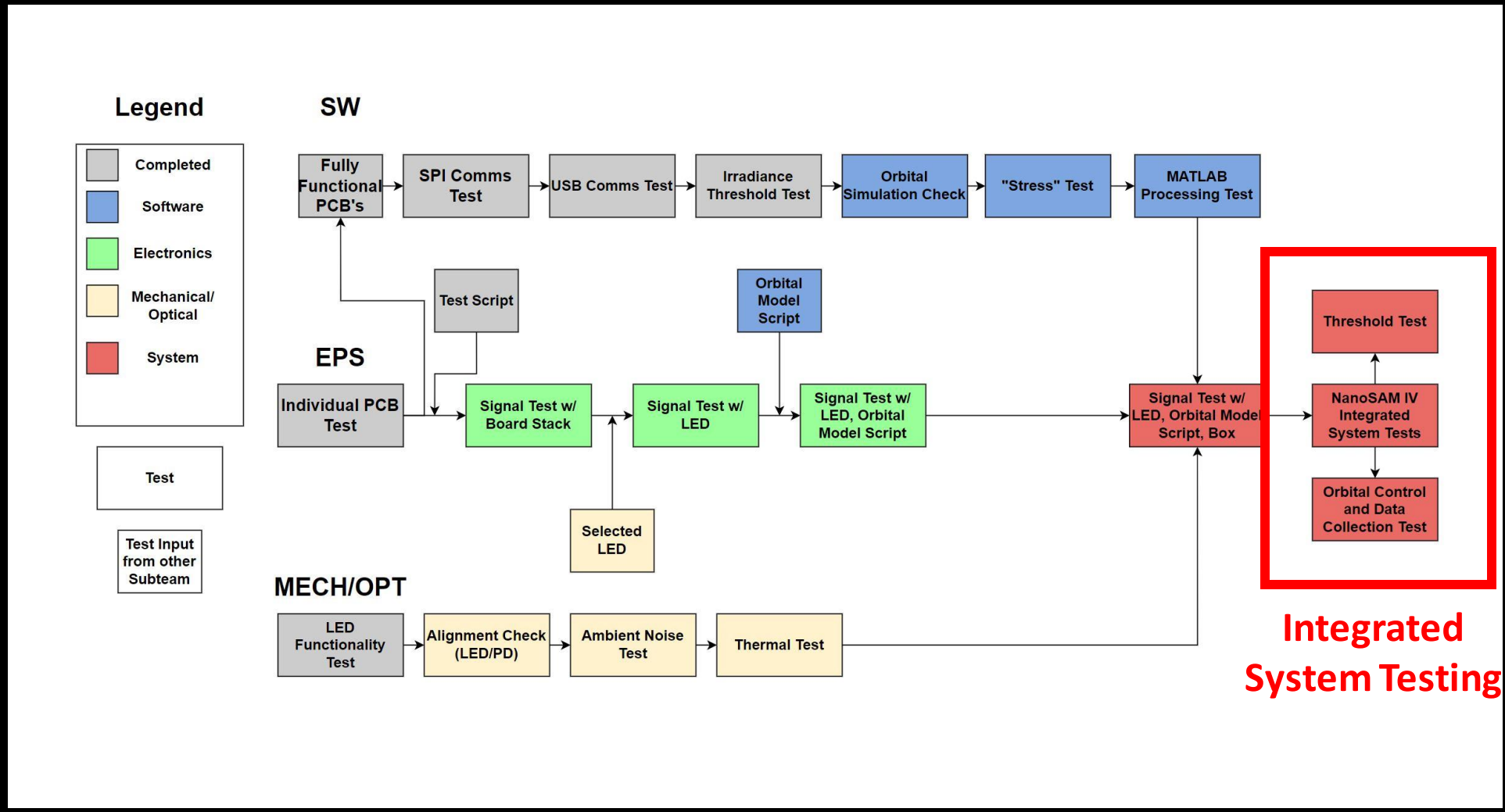


Beta = 70°

Orbit Simulation Risk Reduction

Test Pass	**Verification of code for future debugging**	**Proceed to Phase 3 – able to begin integration with full system**
Test Failure	**Potential future errors in the system**	**Delay of Phase 2**

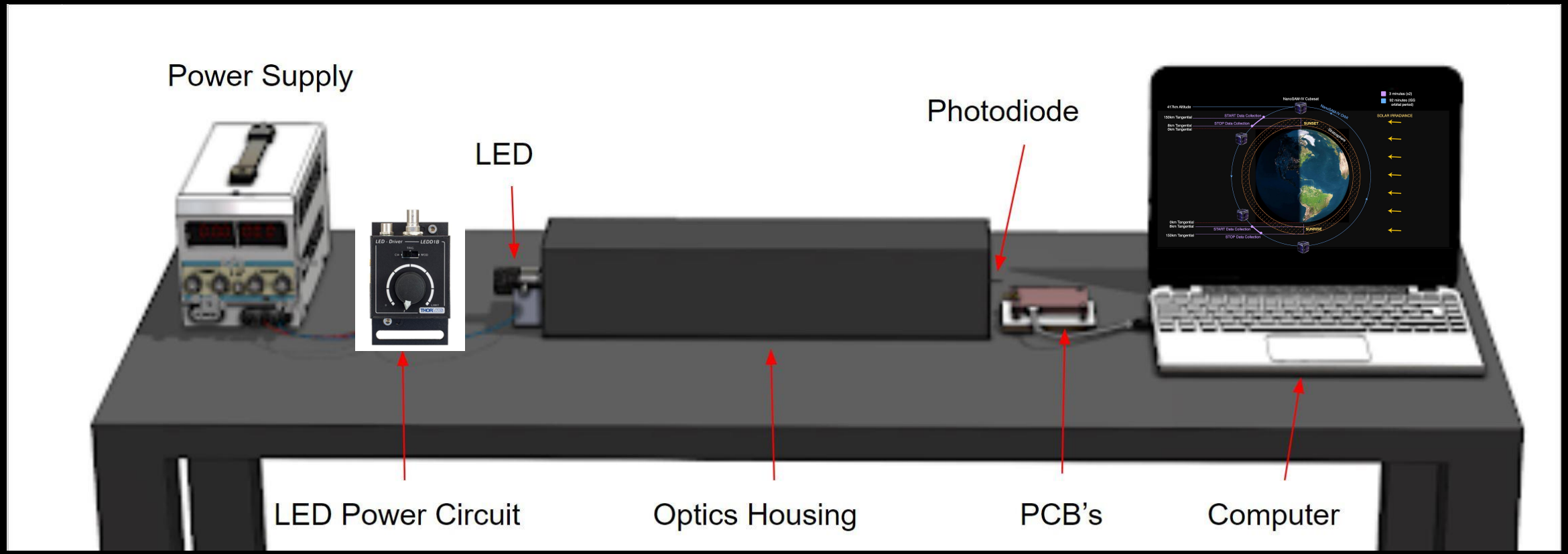
Test #3 – Integrated System



System Testing - Objectives

MO-01	Generate light signal that will simulate expected on-orbit, un-attenuated signal in order to test embedded system (photodiode, signal cond., ADC, microcontroller)
MO-02	Integrate embedded system design from NanoSAM II (Analog and Digital PCB's) to collect data with an SNR of 200 or greater
MO-03	Autonomous control of data collection process through timing that matches predicted orbital data collection windows
MO-04	Instrument must be appraised of when intensity of light source falls below a threshold

System Testing Setup



System Testing – OCDC Test

3. Photodiode signal conditioning and digitization

4. Photodiode produces 0.475 uA current as light strikes it

ADC

Op-amp

2. Teensy receives data from ADC, packages it and sends it to computer

5. LED driver provides power to LED, LED emits light at 680 nm with 210 mW power output

1. Software propagates orbital data, and issues commands to and receives data from Teensy

OCDC Test – Key Performance Metrics

- **Data Collection Windows:** Data collection should start when propagated orbital data gives tangent altitude of 150 km (sunset) or 0 km (sunrise). Stop when tangent altitude is 0 km (sunset) or 150 km(sunrise)
- **Op-amp output**: Should remain around 1 V +/- noise levels measured in SNR testing
- **Orbit Data**: Should stop propagating after 1 full orbit and match data from Orbit Model test

System Testing – Threshold Test

3. Photodiode signal conditioning and digitization

4. Noise causes Photodiode to produce current

ADC

Op-amp

2. Teensy receives data from ADC, adds bin value to 200 SNR bin value and stores it as threshold bin value

1. Software issues command to Teensy

System Testing – Threshold Test

3. Photodiode signal conditioning and digitization

4. Photodiode current will increase or decrease with LED output power

ADC

Op-amp

2. Teensy receives data from ADC, compares bin value to threshold bin value and sets flag accordingly, sends data to computer

5. LED output power will be adjusted using current knob

1. Software issues commands to and receives data from Teensy

Threshold Test – Key Performance Metrics

- **Threshold Flag:** Should be set to high when the first data point below the threshold is measured. Should be set to low when the first data point above the threshold is measured

- **Op-amp output**: Should remain around 1 V +/- noise levels measured in SNR testing

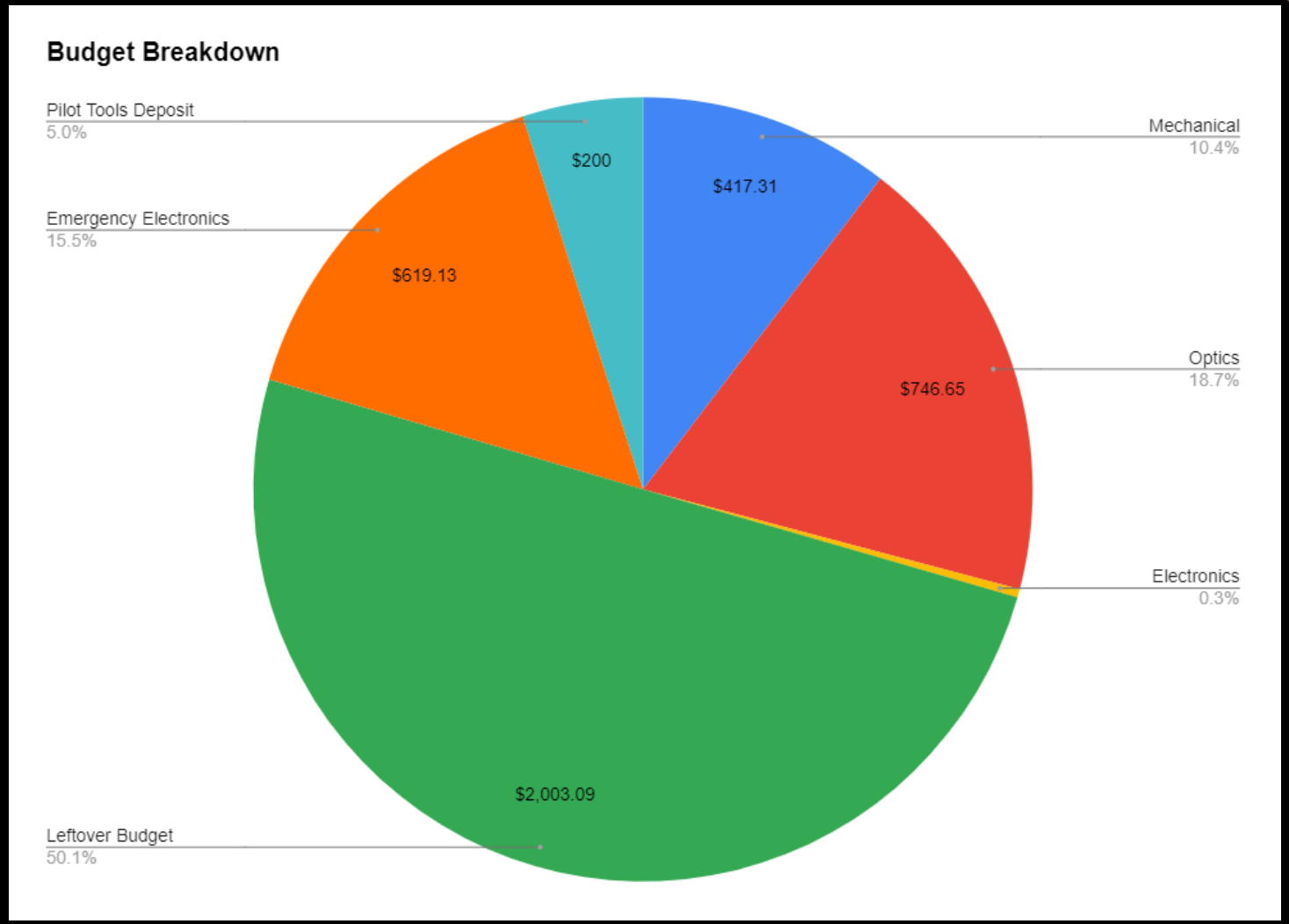
Budget

Budget Breakdown

Current Budget Left as of 2/27/2023:
$2622.22

- 15.5% of the budget is allocated for the purchase of emergency electronics – as this is the area with the highest risk of failure
- 18.7% of the budget are the LED and LED Current Driver – Critical hardware

Current Budget Left with use of emergency electronics:
$2003.09

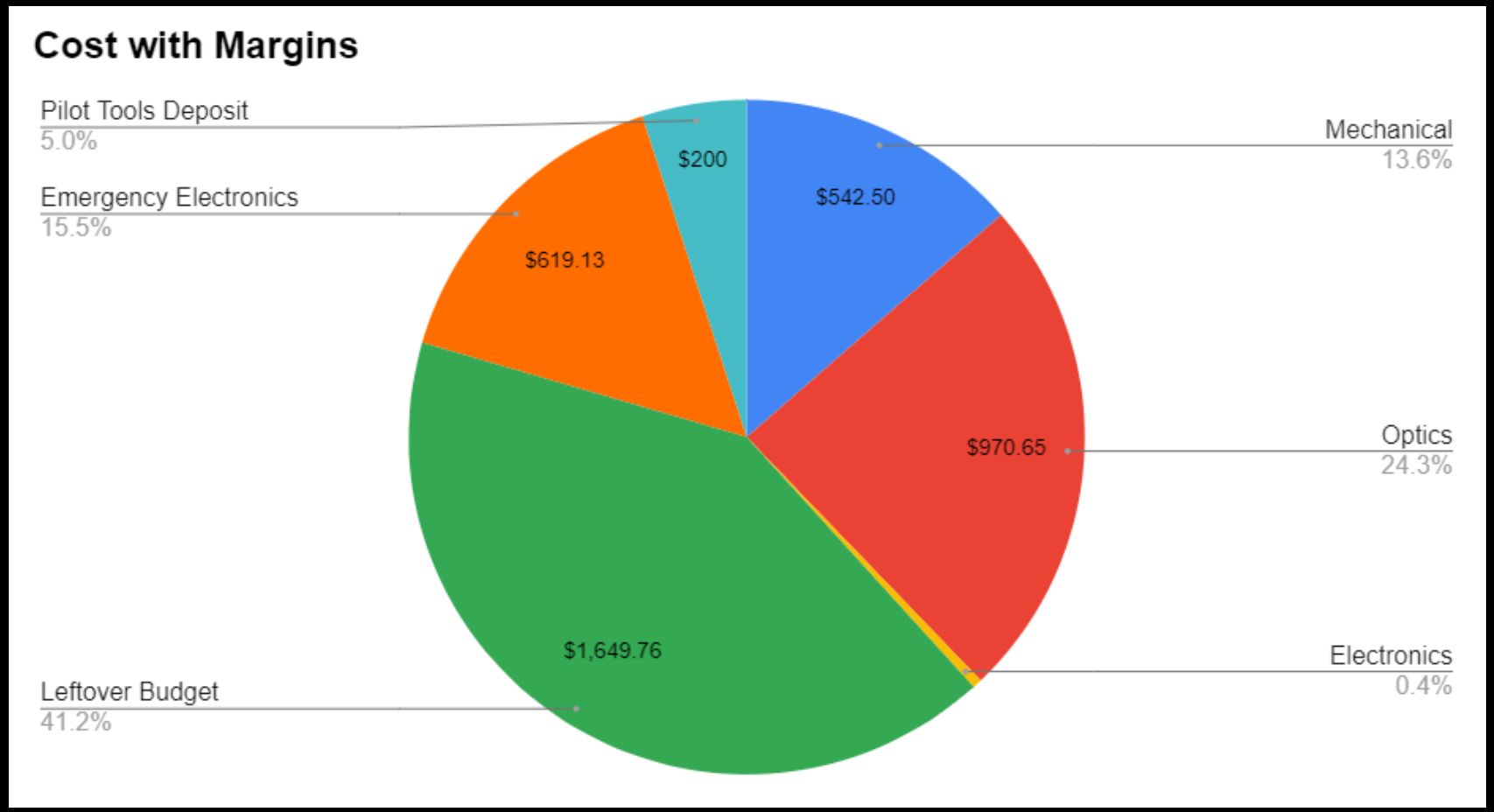


Electronics Uncertainty/Extra Cost Margin

- In the case of NanoSAM-II Board Failure/Short Circuit
  - A cost plan has been made with 30% margins to account for emergency fabrication of analog and digital boards if applicable
- Based on recent testing of analog and digital boards, manufacturing new boards is very unlikely

NanoSAM-II Board Revision Summary		
Board	Analog	Digital
PCB Manufacturing	$ 30.00	$ 30.00
Parts for Inhouse Population	$ 41.35	$ 57.41
Quantity	3	3
Subtotal	$ 214.04	$ 262.22
Fiscal Margin	30%	30%
Total	$ 278.25	$ 340.88
Overall Total		$ 619.13

Budget Breakdown with Margins



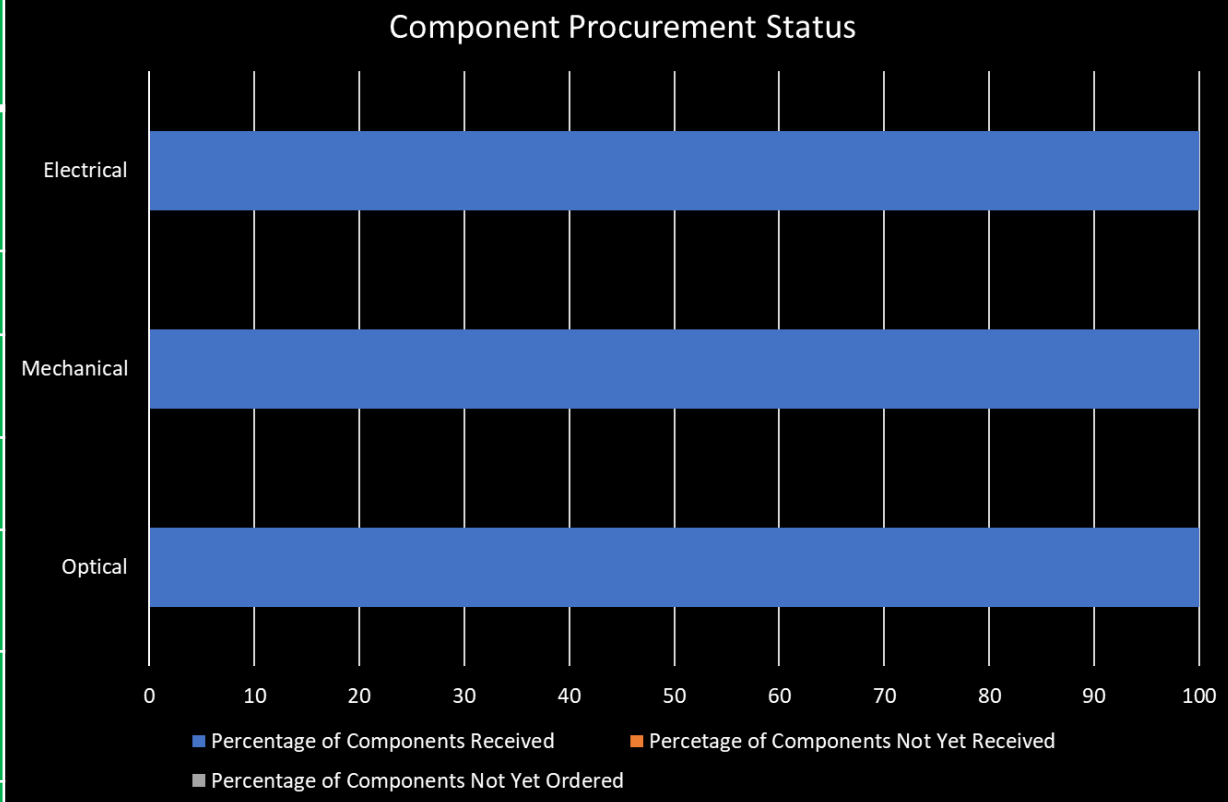
30% Margins for all Subsystems

- Mechanical ($417.31)
  - $125.19
- Optics ($746.65)
  - $224.00
- Electronics ($13.82)
  - $4.15

After additional margins and emergency considerations; leftover budget of $1649.76

Received Components

Price	Subteam	Component
$322.36	Optics	M680L4 LED, FD11A Photodiode and Connectors for Light Source Circuit
$424.29	Optics	T-Cube LED Driver
$13.82	Electronics	Resistor and Capacitor for board revisions
$9.56	Mechanical	Putty to hold thermistor in place
$68.87	Mechanical	Paint, epoxy and PLA for Optics bench and prototype bench manufacturing
$178.22	Mechanical	Aluminum for manufacturing of the Optical Bench
$97.87	Mechanical	Safety equipment and painting supplies for the optics bench
$62.79	Mechanical	More PLA for the prototype bench



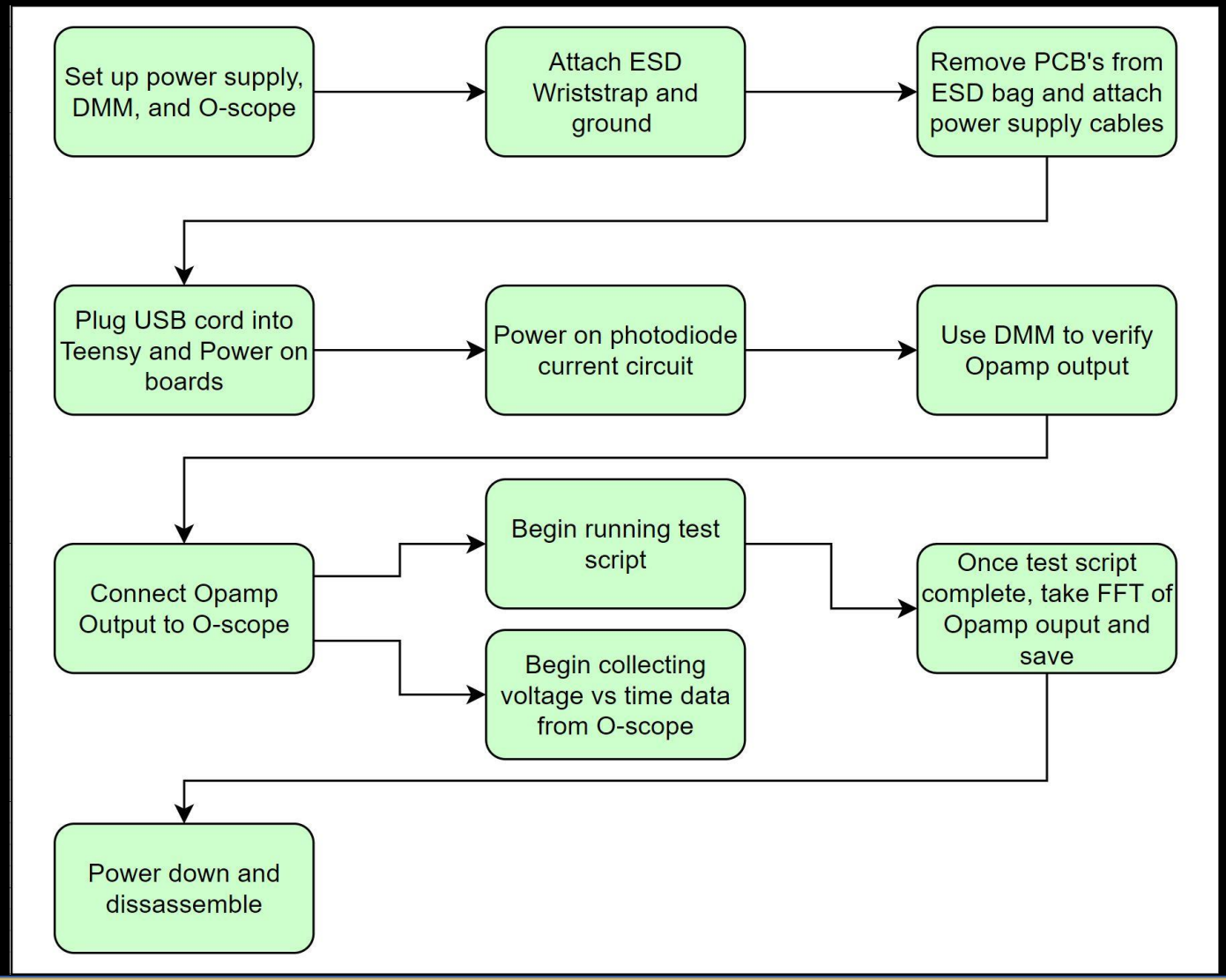
Questions?

Backup Content

SNR Testing – Signal Test 1

- In this sub-test, the mock photodiode circuit will facilitate data collection and noise measurements of Op-amp and ADC.
- Testing involves:
  1. Supplying power to boards and mock photodiode circuit
  2. Measuring the output of the op-amp with the oscilloscope
  3. ADC output will be simultaneously recorded and compared to op-amp output to determine noise
  4. Taking FFT of op-amp output (process using MATLAB) to determine its noise
- Test equipment / Facilities
  - Oscilloscope
  - Computer
  - Power supply
  - Farraday Cage
  - Electronics Lab Space

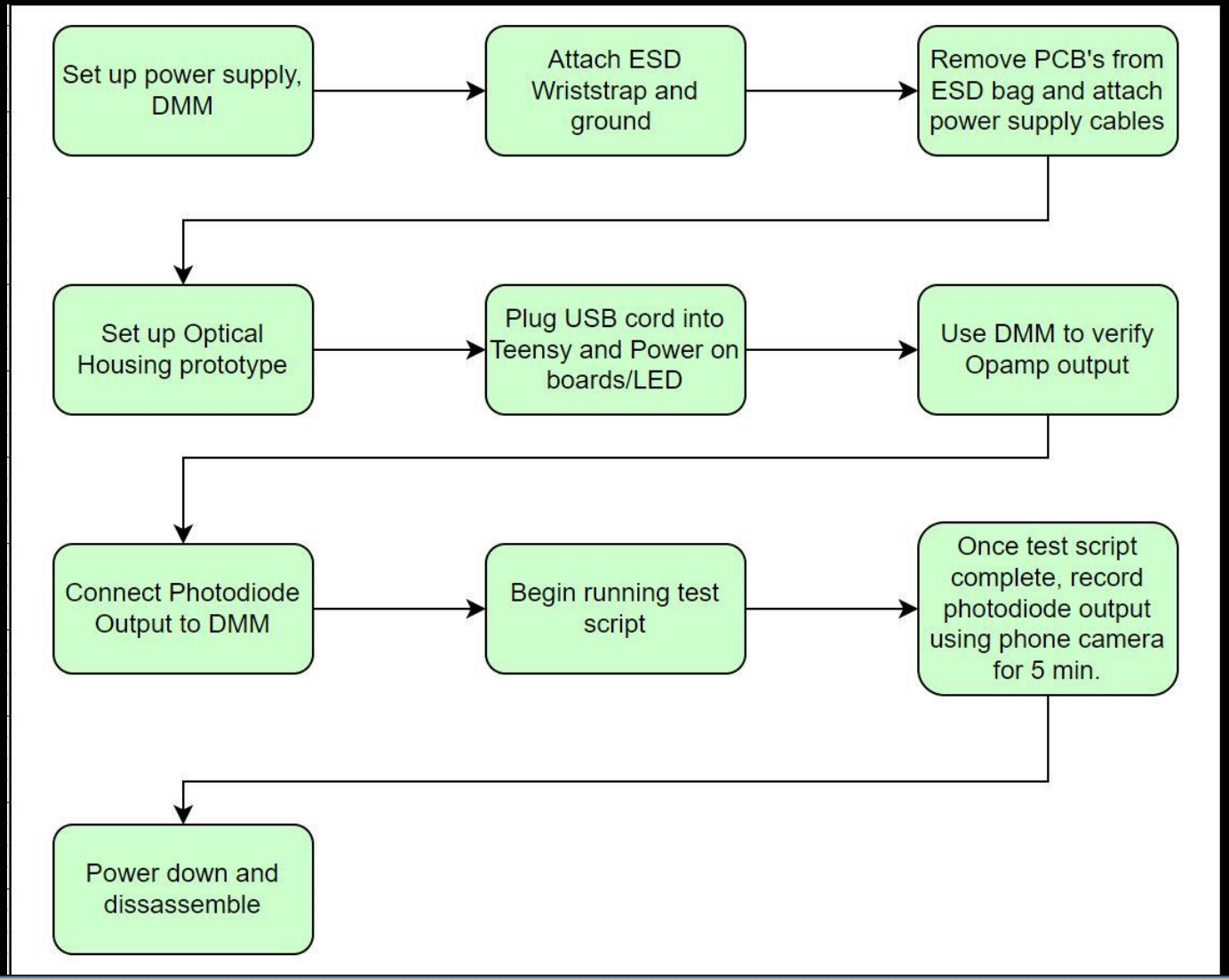
Signal Test I Flow



SNR Testing – Signal Test 2

- In this sub-test, data will be collected with the actual photodiode and its noise will be estimated.
- Testing involves:
  1. Setup prototype LED-Photodiode housing
  2. Supplying power to boards and LED
  3. Collect data from Teensy over USB
  4. Measure photodiode output with DMM and manually record current values in regular time intervals
- Test Equipment / Facilities:
  - Oscilloscope
  - Digital Multimeter
  - Computer
  - LED/LED Driver
  - Farraday Cage
  - Prototype Optical Housing Assembly
  - Power Supply
  - Electronics Lab Space

Signal Test II Flow



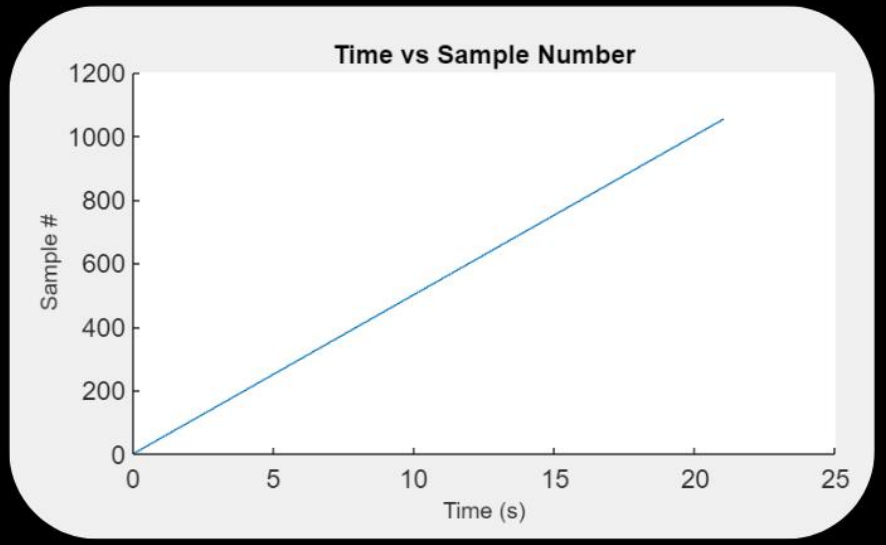
SNR Testing – Key Performance Metrics

- **ADC Noise**: Can not exceed BLANK mV (expected = BLANK mV)*
- **Op-amp Noise**: Can not exceed BLANK mV (expected = BLANK mV)*
- **Photodiode Noise**: Can not exceed BLANK uA (expected = BLANK uA)*
- **SNR***: Should occur at nominal photocurrent, 0.475 uA (expected SNR = 1224.3)
- **200 SNR**: should occur at photocurrent of 77.6 nA
- **Upper Bound SNR**: should occur at photocurrent of 594 nA (expected = 1530.4)
- *** = at Nominal Photocurrent (0.475 uA)**

Timing Software Testing

Teensy Runtime	*Average Runtime:*
commandHandling	~300 ns (worst-case)
getMessageFromSerial	x
mode3Check	x
mode4Check	x
dataCollection	~12 ms
scienceData	~ 4 ns + **0.0164 ms**
housekeepingData	~ 5 ns + 0.102 ms
thresholdCheck	x
sunsetSunrise	x
dataBuffer	~700 ns

~19.88 ms delay




```
>> mean(abs(diff(time)))

ans =

    0.0200
```

```
>> min(abs(diff(time)))

ans =

    0.0190

>> max(abs(diff(time)))

ans =

    0.0200
```

Data Processing Software Testing

Data Collection

dataRaw

1053x20 uint8

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	65	9	57	0	0	204	204	97	115	6	0	6	0	6	0	6	0	6	0	90
2	65	28	57	0	0	204	204	97	115	6	0	5	0	6	0	6	0	6	0	90
3	65	48	57	0	0	204	204	97	115	6	0	5	0	6	0	6	0	6	0	90
4	65	68	57	0	0	204	204	97	115	6	0	4	0	6	0	5	0	7	0	90
5	65	88	57	0	0	204	204	97	115	6	0	5	0	6	0	6	0	6	0	90
6	65	108	57	0	0	204	204	97	115	6	0	6	0	6	0	6	0	6	0	90
7	65	128	57	0	0	204	204	97	115	6	0	6	0	6	0	6	0	6	0	90
8	65	148	57	0	0	204	204	97	115	6	0	5	0	6	0	6	0	6	0	90
9	65	168	57	0	0	204	204	97	115	6	0	5	0	6	0	6	0	6	0	90
10	65	188	57	0	0	204	204	97	115	6	0	5	0	6	0	6	0	6	0	90

Data Parsing

dataParse

1053x11 double

	1	2	3	4	5	6	7	8	9	10	11
1	65	14601	52428	97	115	6	6	6	6	6	90
2	65	14620	52428	97	115	6	5	6	6	6	90
3	65	14640	52428	97	115	6	5	6	6	6	90
4	65	14660	52428	97	115	6	4	6	5	7	90
5	65	14680	52428	97	115	6	5	6	6	6	90
6	65	14700	52428	97	115	6	6	6	6	6	90
7	65	14720	52428	97	115	6	6	6	6	6	90
8	65	14740	52428	97	115	6	5	6	6	6	90
9	65	14760	52428	97	115	6	5	6	6	6	90
10	65	14780	52428	97	115	6	5	6	6	6	90

Data Cleaning/Converting

dataConvert

1053x11 double

	1	2	3	4	5	6	7	8	9	10	11
1	65	0	1.0000	97	115	6	6	6	6	6	90
2	65	0.0190	1.0000	97	115	6	5	6	6	6	90
3	65	0.0390	1.0000	97	115	6	5	6	6	6	90
4	65	0.0590	1.0000	97	115	6	4	6	5	7	90
5	65	0.0790	1.0000	97	115	6	5	6	6	6	90
6	65	0.0990	1.0000	97	115	6	6	6	6	6	90
7	65	0.1190	1.0000	97	115	6	6	6	6	6	90
8	65	0.1390	1.0000	97	115	6	5	6	6	6	90
9	65	0.1590	1.0000	97	115	6	5	6	6	6	90
10	65	0.1790	1.0000	97	115	6	5	6	6	6	90

Threshold Testing & Timed Collection Testing

Threshold Check

```
void mode3Check(){
  if (mode3 & (thresholdCount >= 100)){
    collect = 0;
    mode3 = 0;
  }
```

Timed Check

```
void mode4Check(){
  if (!mode4)
    return;
  mode4count++;
  if (mode4count/50 >= mode4time){
    collect = 0;
    mode4count = 0;
    mode4time = 0;
  }
```

Commands & Global Variables

Command Handling / Condition	Global Variables Changes
Orbital Model Mode Start: @M1	collect = True mode1 = True
Orbital Model Mode Stop: @S1	collect = False mode1 = False swap(sunsetCondition, sunriseCondition)
Manual Mode Start: @M2	collect = True mode2 = True
Manual Mode Stop: @S2	collect = False mode2 = False
Irradiance Threshold Mode Start: @M3	collect = True mode3 = True
Irradiance Threshold Mode Stop Condition: (threshholdCount >100)	collect = False mode3 = False
Timed Data Collect Mode Start: @M4XXX XXX is time in seconds	collect = True mode4 = True m4Count = 0 m4Max = XXX*50
Timed Data Collect Mode Stop Condition: (m4Count >m4Max)	collect = False mode4 = False

System Testing - Objectives

- The integrated system test is divided into two sub-tests: Orbital Control and Data Collection (OCDC) Test and Threshold Test

- Goal: to satisfy remaining mission objectives and is the main deliverable of the NanoSAM IV project

- The testing will satisfy the following requirements:

  - MO-03: Autonomous Control of data collection process through timing that matches predicted orbital data collection windows

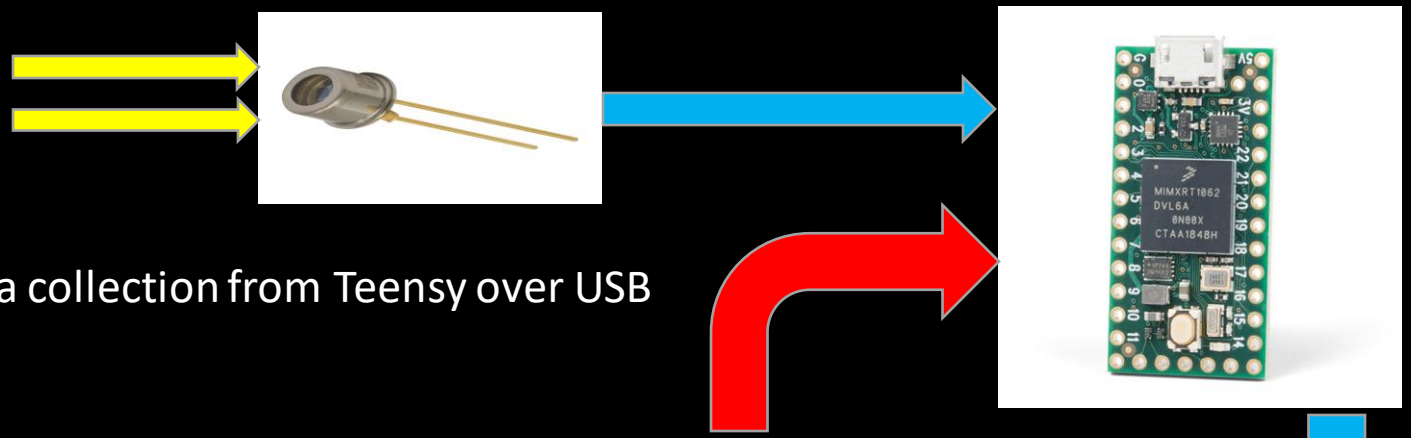
  - MO-04: Instrument must be appraised of when intensity of light source falls below an experimentally determined noise value

System Testing – Pre-requisite tests

- **Retrofitted and tested PCB's**: Voltage measurements were taken at all test points of the boards and actual values matched our expected measurement values
- **Completed data collection script**: Integrated and tested orbital model and data collection loop
- **Completed "Mode 3" Test Script**: software to determine the threshold value, collect and output threshold flag and irradiance data
- **Final optical housing assembly**: Finalized LED/Photodiode housing
- **LED equipment**: Functionality of the LED was verified and validated

System Testing – OCDC Test

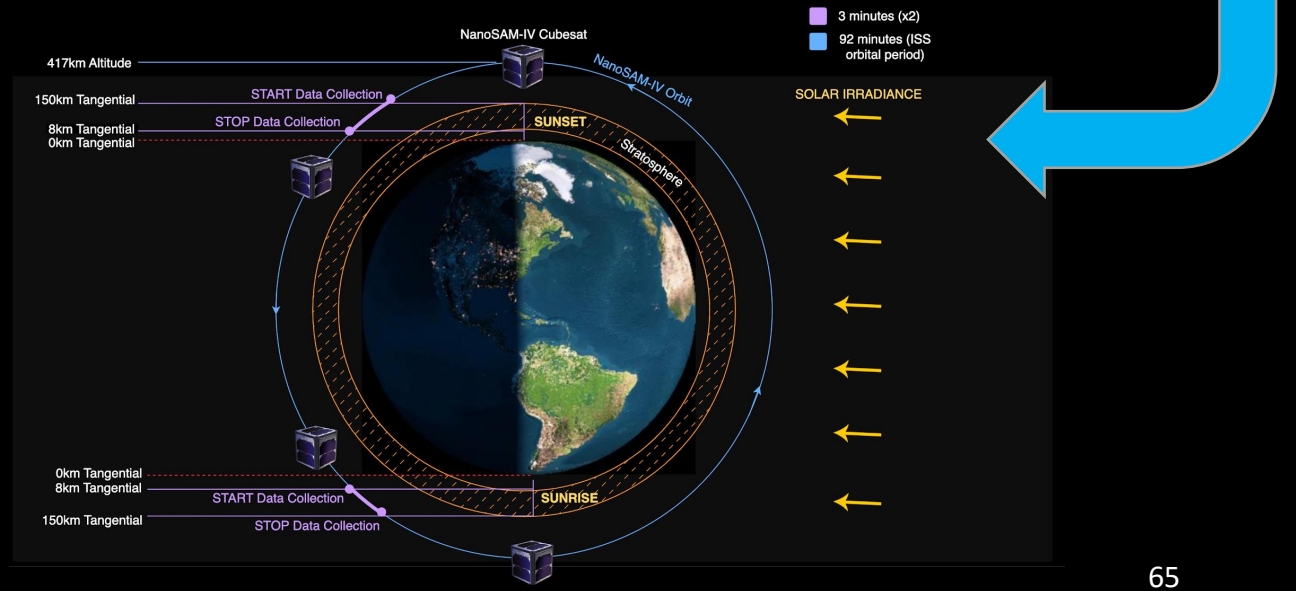
- In this sub-test, data collection will be autonomously controlled using orbital simulation. Data will be packetized according to CCSDS protocol and transferred to computer over USB for processing



- Testing involves:
  1. Setup LED-Photodiode housing
  2. Supplying power to boards and LED
  3. Propagate Orbital data to control data collection from Teensy over USB
  4. Process, verify, and plot data

- Test Equipment / Facilities:
  - LED/LED Driver
  - Optical Housing Assembly
  - Digital Multimeter
  - Farraday Cage
  - Computer
  - Power Supply

- Requirements Test will satisfy: MO-03



System Testing – Threshold Test

- In this sub-test, the LED output power will be gradually lowered past until the threshold intensity is measured by the embedded system. The power will then be raised back up and threshold flag output will be recorded

- Testing involves:
  1. Setup LED-Photodiode housing
  2. Supplying power to boards and LED
  3. Begin lowering LED supply current until Threshold flag is set to high, then raise back up until flag is low again
  4. Save Threshold flag output along with timestamps and photodiode output

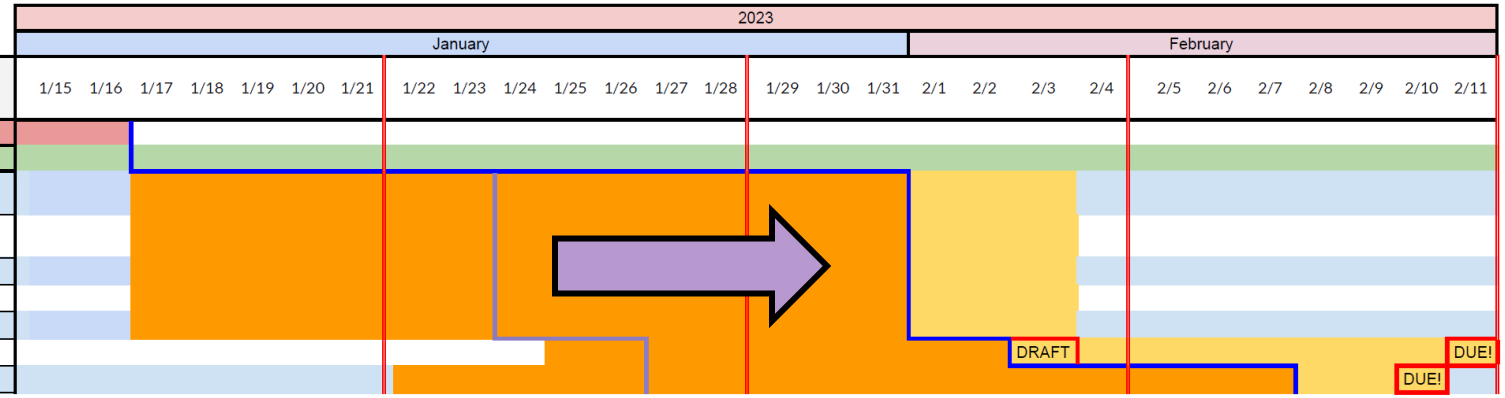
- Test Equipment / Facilities:
  - LED/LED Driver
  - Optical Housing Assembly
  - Digital Multimeter
  - Farraday Cage
  - Computer
  - Power Supply

- Requirements Test will satisfy: MO-04

Changes to Schedule (Phase I)

Legend	
Task Scheduled	
Built In Margin	
Old Critical Path	
New Critical Path	

Task	Sub-teams	End Date	Buffer/Margin [+ days]	Total Days (including margin)
Status				
Winter Break				
Manufacturing/Preliminary Testing				
complete — LED Functionality Check	Mechanical/Optics	1/31/2023	3	18
complete — Manufacture Box/Optics Apparatus	Mechanical/Optics	1/31/2023	3	18
complete — SPI Comms Test	Software	1/31/2023	3	18
complete — USB Comms Test	Software	1/31/2023	3	18
complete — Signal Test I	Electronics	1/31/2023	3	18
complete — AIAA Abstract	All	2/2/2023	9	18
complete — Internal Design Review (IDR)	All	2/7/2023	3	20

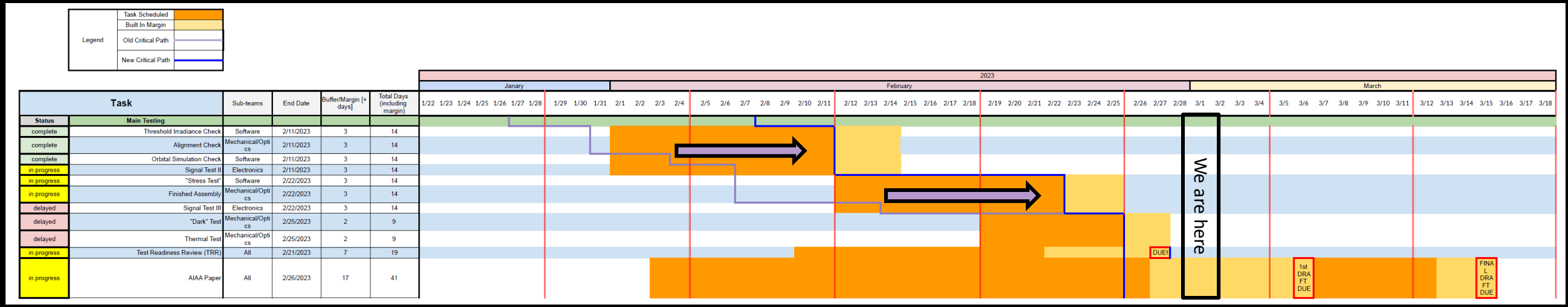


Although complete now, some tasks were behind schedule at first
- Signal Test I & Manufacturing Optics Test Apparatus
- Delays primarily due to parts/materials logistics (i.e. ordering & delivery)

Extra week buffer added to Phase I tests to accommodate actual IDR deadlines

NEW: Decision made to prototype optics test apparatus via 3D Printing before manufacturing with aluminum

Changes to Schedule (Phase II)



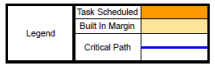
Status	Task	Sub-teams	End Date	Buffer/Margin [+ days]	Total Days (including margin)
	Main Testing				
complete	Threshold Irradiance Check	Software	2/11/2023	3	14
complete	Alignment Check	Mechanical/Optics	2/11/2023	3	14
complete	Orbital Simulation Check	Software	2/11/2023	3	14
in progress	Signal Test II	Electronics	2/11/2023	3	14
in progress	"Stress Test"	Software	2/22/2023	3	14
in progress	Finished Assembly	Mechanical/Optics	2/22/2023	3	14
delayed	Signal Test III	Electronics	2/22/2023	3	14
delayed	"Dark" Test	Mechanical/Optics	2/25/2023	2	9
delayed	Thermal Test	Mechanical/Optics	2/25/2023	2	9
in progress	Test Readiness Review (TRR)	All	2/21/2023	7	19
in progress	AIAA Paper	All	2/26/2023	17	41

Signal Test I took longer than originally projected
- Signal Test II & III delayed as a result

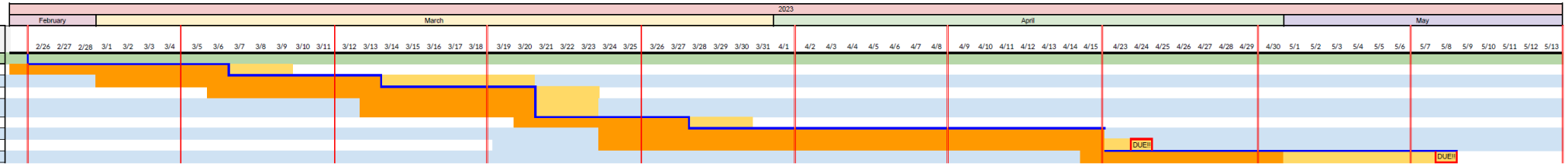
Since prototyping was 3D printed, final aluminum assembly & alignment postponed
- Avoided possible wasted time/material & re-order expensive aluminum if calculations were off
- Many tests may still move forward with 3D printed version of apparatus (such as dark/thermal tests & SNR)

Software Stress Test delayed
- May be finished in parallel with "Finalize Code" in Phase III Testing

Phase III: How We'll Stay On Schedule



Task	Sub-teams	End Date	Buffer/Margin [+ days]	Total Days (including margin)
Final Wrap-Up Phase				
Finalized Code	Software	3/6/2023	3	32
Signal to Noise Test	Systems, All	3/13/2023	7	20
MATLAB Processing Check	Software	3/20/2023	3	18
Orbital Control and Data Collection (OCDC) Integration Test	Systems, All	3/20/2023	3	11
Threshold Test	Systems, All	3/27/2023	3	11
Symposium Poster & Presentation	All	4/17/2023	1	26
Spring Final Review (SFR)	All	4/16/2023	8	32
Project Final Report (PFR)	All	4/30/2023	8	24



Finalizing Code: can be done in parallel with software "stress test" (which is in progress/nearly finished)

Signal to Noise Test: High Risk!

Direct Dependence on Signal Tests II & III, Finished Assembly, Dark & Thermal Tests (assign more help to these tasks if necessary)

Orbit Control/Data Collection: depends on Orbital Simulation Software (complete)

Threshold Test: Depends on SNR Test & MATLAB Processing (assign more help if necessary)

Previous, Current & Future Tests

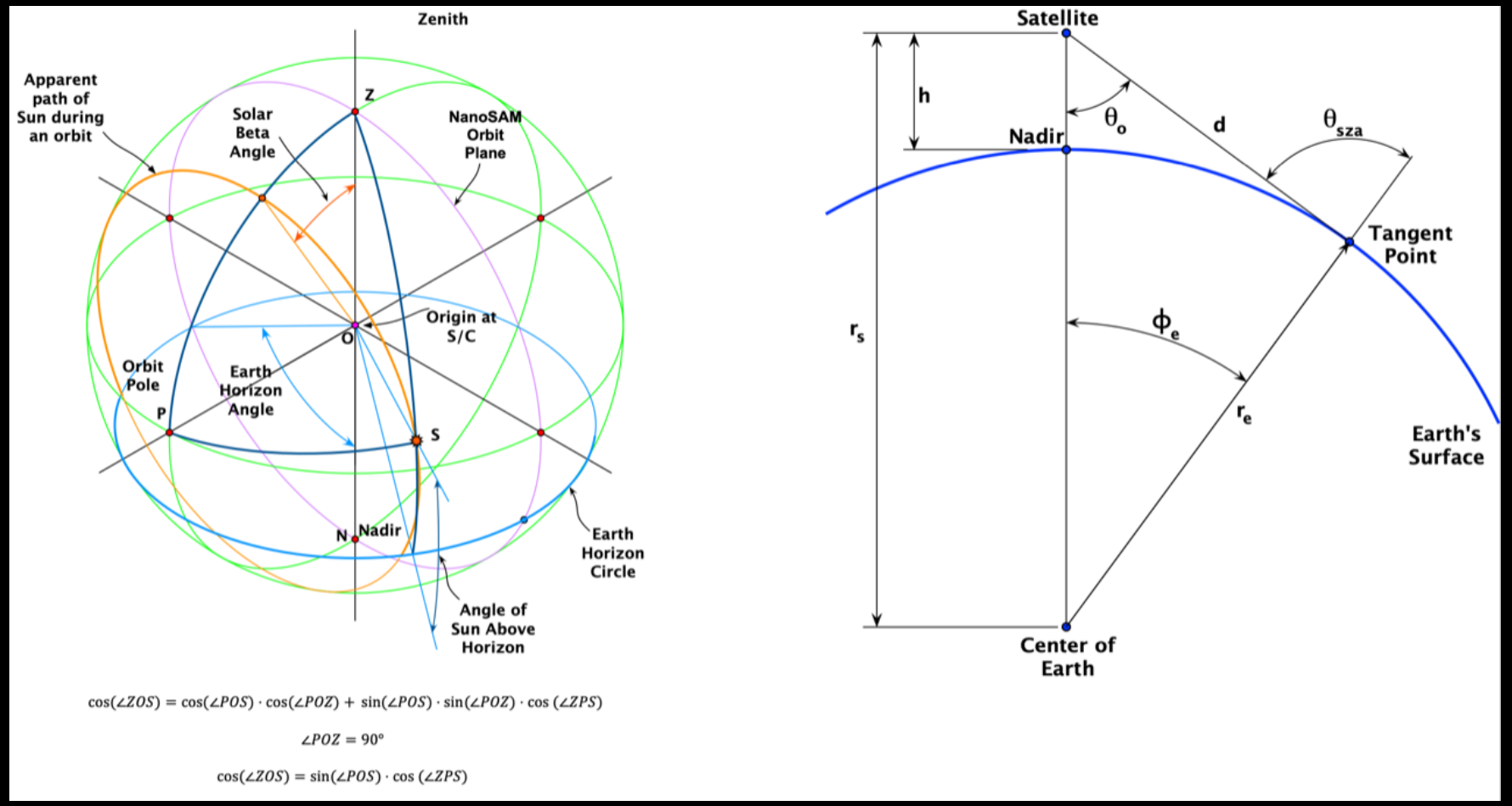
Completed or Ongoing Tests		
Test to be Performed	Tests Dependent On This Test	Status
LED Functionality Check	Alignment, Signal Test II	Complete
Manufacture Box/Optics Apparatus	Alignment	Complete
SPI Comms Test	SNR & Final Code	Complete
USB Comms Test	Stress, Threshold Irradiance	Complete
Signal Test I	Signal Test II & III, Alignment	Complete
Threshold Irradiance Check	SNR & Final Threshold Test	Complete
Alignment Check	Finished Assembly	Complete
Orbital Simulation Software Check	Stress Test	Complete
Signal Test II	Signal Test III	In Progress
Stress Test	Signal Test III	In Progress
Finished Assembly	Dark & Thermal Tests	Complete
Signal Test III	Signal to Noise (SNR) Test	Delayed
Dark Test	SNR & Final Threshold Test	Delayed
Thermal Test	SNR & Final Threshold Test	Delayed

Upcoming Testing		
Test to be Performed	Tests This Depends On	Projected Completion Date
Finalized Code	USB & SPI Comms, Orbital Model	March 6th
Signal to Noise Test	Signal Tests I, II, & III, Threshold Irradiance, Thermal Test, Dark Test	March 13th
MATLAB Processing Check	All Software Tests & Tasks	March 20th
Orbital Control and Data Collection (OCDC) Integration Test	USB & SPI Comms, Orbital Model; All Software Tests & Tasks	March 20th
Threshold Test	SNR & Matlab Processing	March 27th

Related Requirements - Backup

MO-03	Autonomous control of data collection process through timing that matches predicted orbital data collection windows
R1	Desktop computer or laptop (mock spacecraft bus) will house this control software
R2	Computer will send commands to the payload instrument
R3	Computer will receive data from the payload instrument
R4	Commands will be synched up with the orbital simulation
R5	Simulate spacecraft position on a circular orbit for at least 1 orbital period
R6	Start and stop of data collection triggered by simulated orbital position
R7	Data sampling rate is 50 Hz
R8	Two collection windows per orbit (sunset and sunrise)
R9	Start and stop data collection at 0 km and 150 km tangential to the surface of the earth depending on sunrise or sunset conditions
R10	Computer will store all data (received payload data and simulation data)

Orbital Simulation Test - Backup



$$\cos(\angle ZOS) = \cos(\angle POS) \cdot \cos(\angle POZ) + \sin(\angle POS) \cdot \sin(\angle POZ) \cdot \cos(\angle ZPS)$$

$$\angle POZ = 90°$$

$$\cos(\angle ZOS) = \sin(\angle POS) \cdot \cos(\angle ZPS)$$

Body-Centered Spacecraft Frame

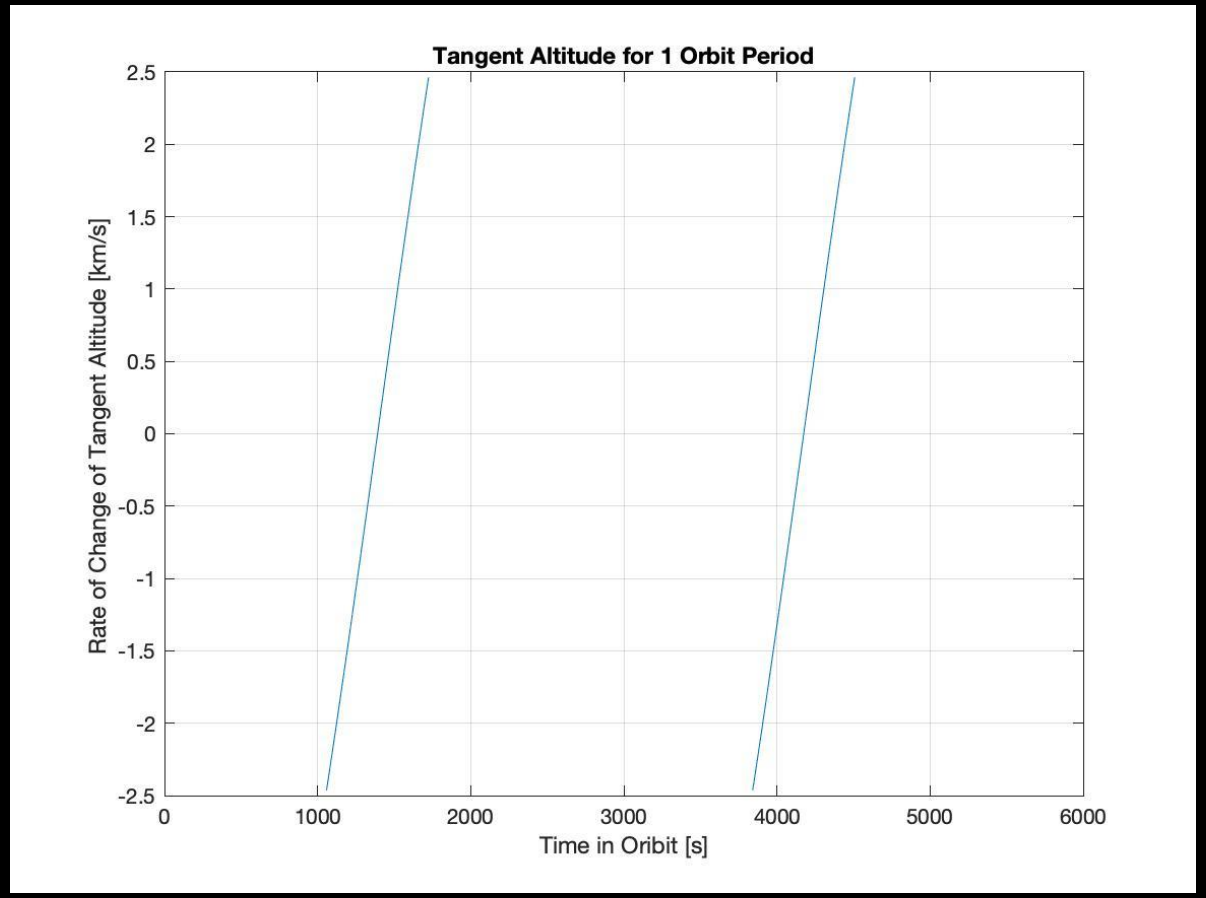
Orbit Simulation Test - Backup

- Largest rate of change when tangent altitude is near zero
- ~2.5km/s max rate (Beta = 0°)
- Corresponds with worst resolution being **0.053 km** with 20 ms time steps

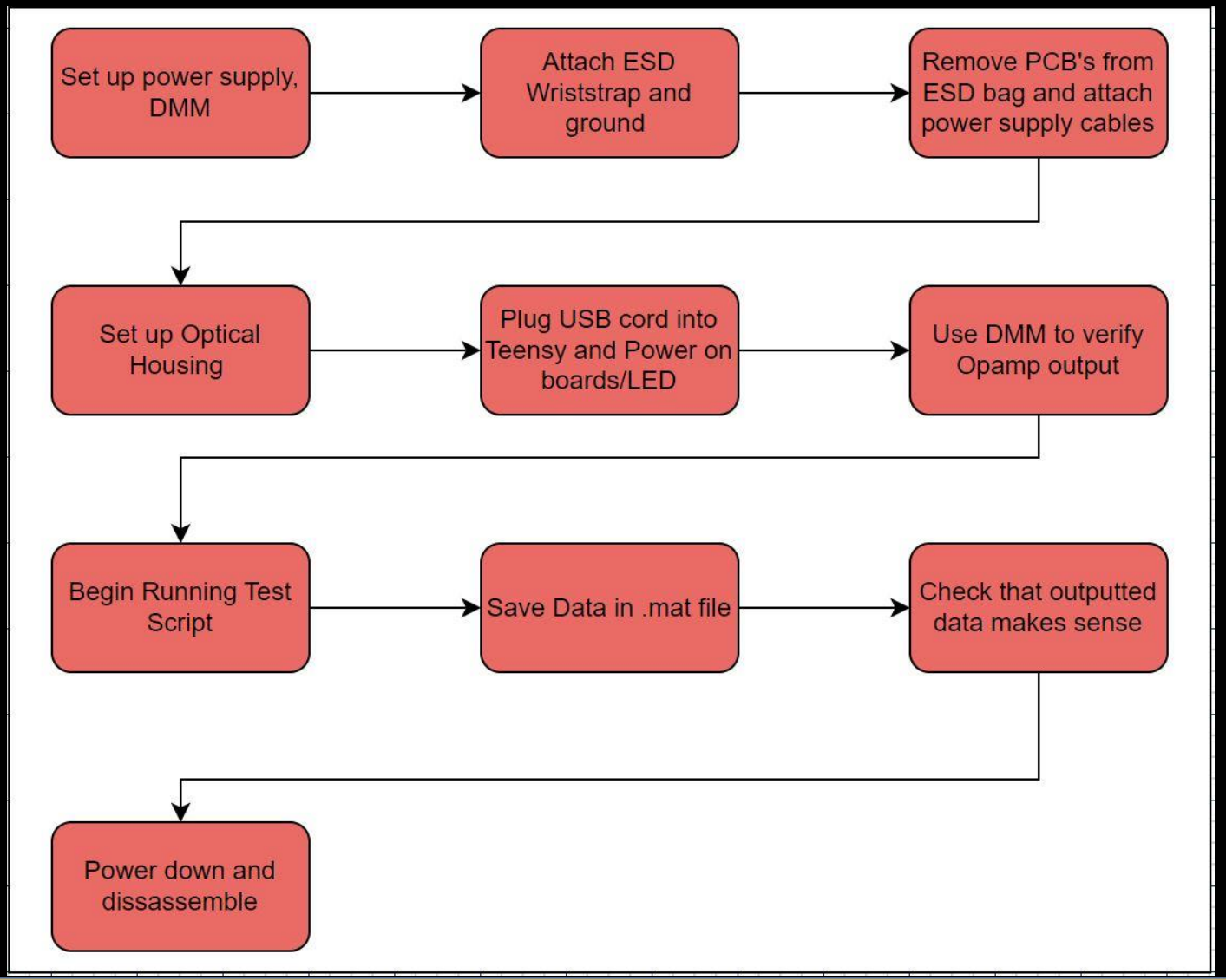
tangAlts

278319x1 double

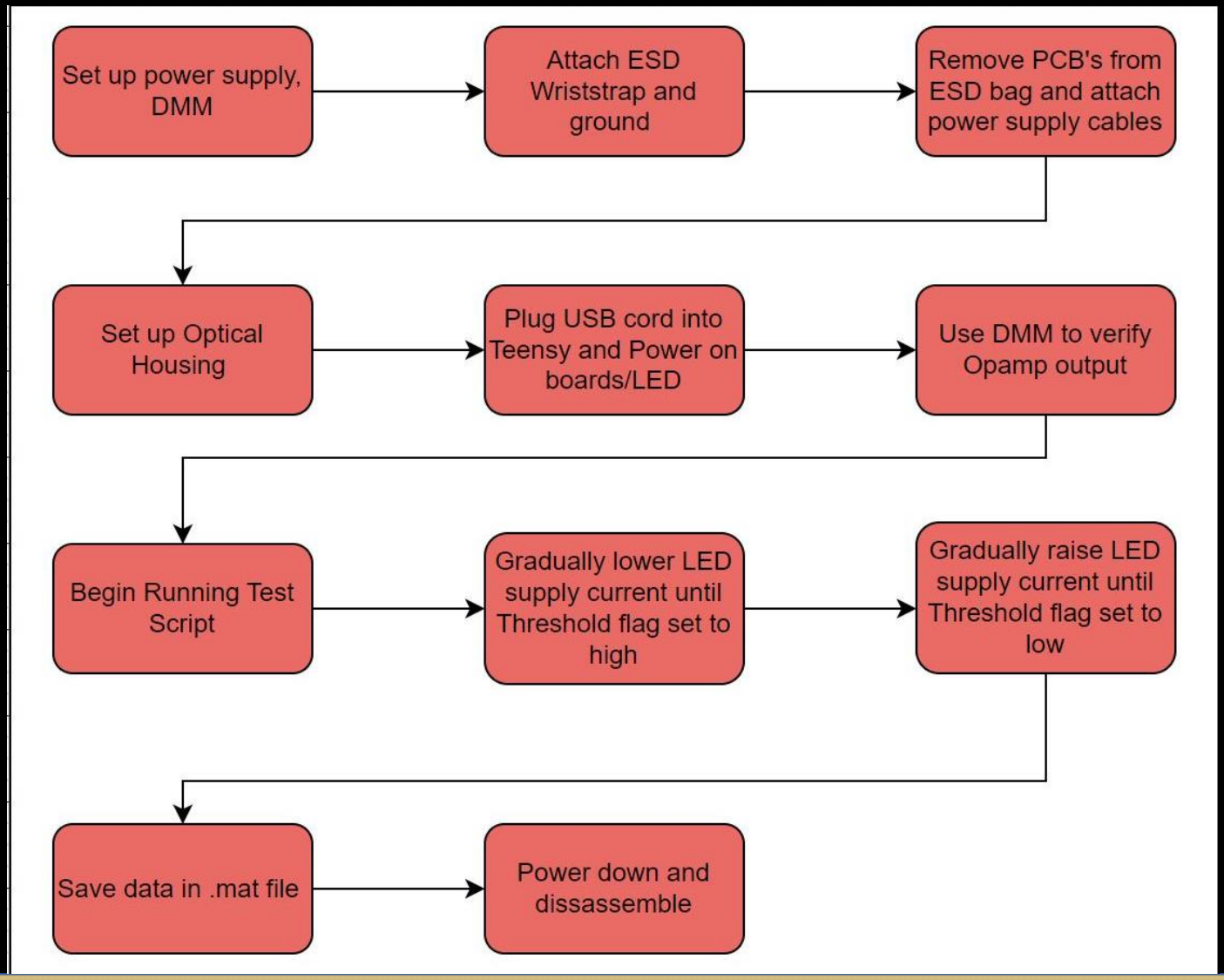
	1	2
53960	NaN	
53961	NaN	
53962	NaN	
53963	NaN	
53964	NaN	
53965	0.0207	
53966	0.0736	
53967	0.1265	
53968	0.1795	
53969	0.2324	
53970	0.2853	



OCDC Test Flow



Threshold Test Flow



Budget Uncertainties

- 30% Cost Margins will fund additional components due to uncertainties
- Electronics
  - Extra electronics components if not already possessed
- Mechanical
  - Additional materials, paint, manufacturing equipment
- Optical
  - Additional photodiode/thermistors