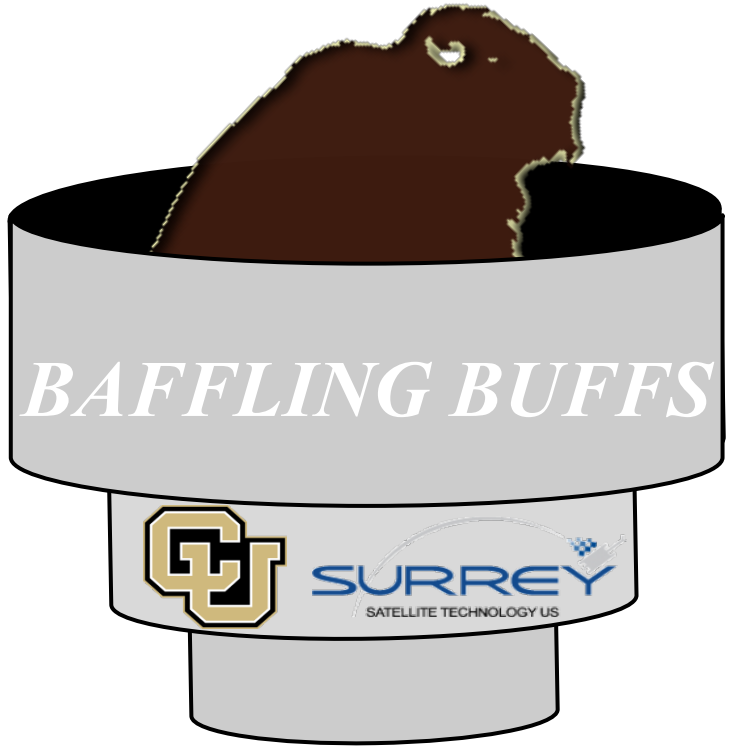
Test Readiness Review

Customer:
Scott Taylor,
Surrey Satellite Technology U.S.



PAB Advisor:
Josh Stamps,
Sierra Nevada Corporation

Presenting: Anthony Anglin, Emmett Bailey, Aspen Coates, Zach McConnel, Sierra Williams

Other Team Members: Lindsay Goldworm, Elizabeth Luke, Nicholaus Monahan, Mary Scites

Overview

Project Motivation

- Star trackers need to **see dim light** from distant stars
- They **compare** what they see with on board star catalog to make spacecraft attitude adjustments
- Nearby bodies emit/reflect stray light which **hinders** star trackers ability to see dim light
- Baffles **attenuate and eliminate** stray light from nearby bodies
- **Lightweight deployable** baffle for smallsats

Project Goals

- **Develop a prototype** deployable baffle for a star tracker to be used on a small satellite platform

- **Design and manufacture** a deployable baffle to limit stray light into an optical sensor

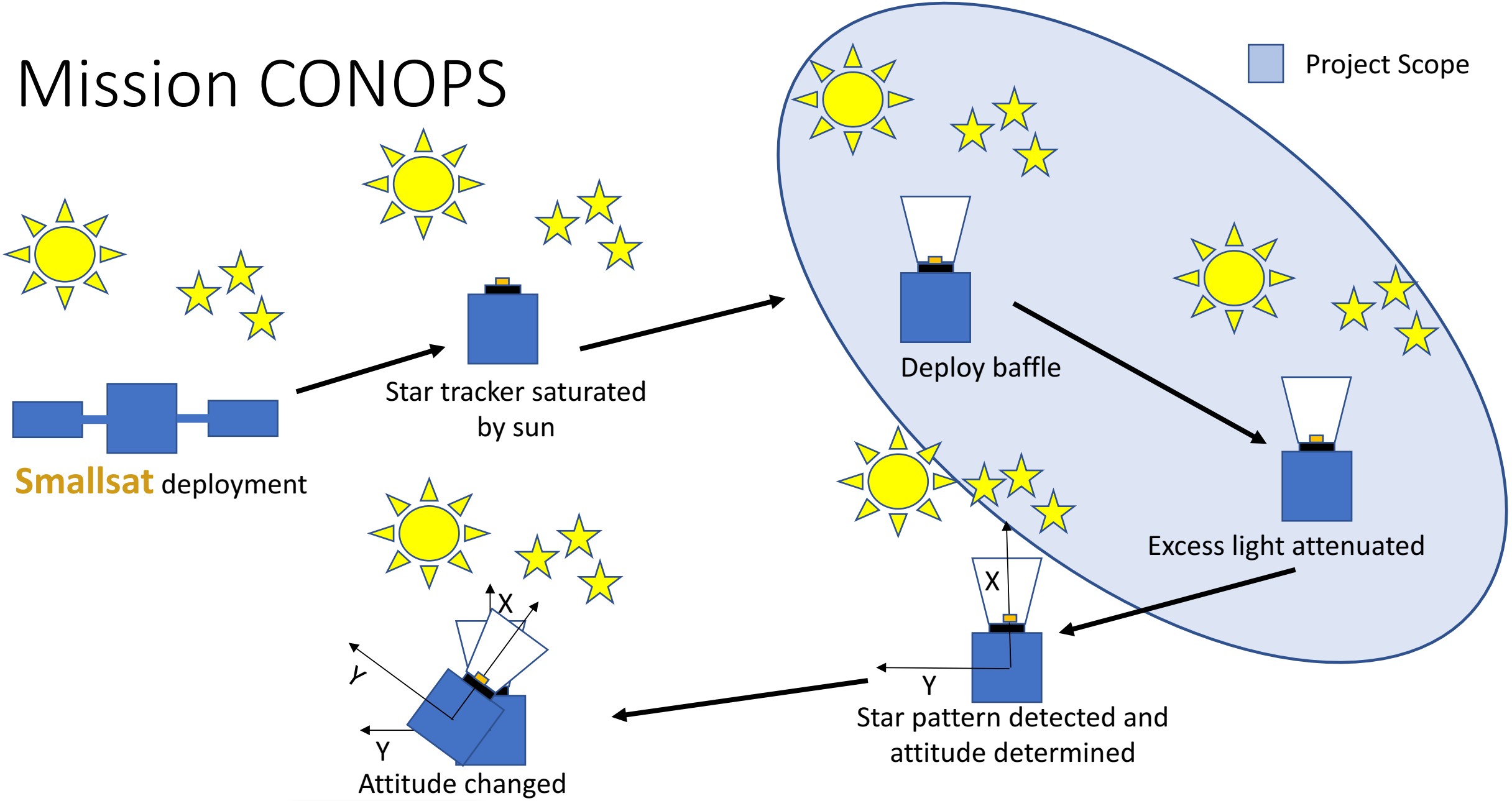
- **Develop a test methodology** and instrumentation suite to measure performance of the baffle for stray light elimination

- **Perform the tests** for the deployment and stray light elimination of the baffle

Requirements & Levels of Success

Functional Requirements	Tier 1	Tier 2
FR1: Baffle shall be deployable	Manual deployment	Electronic deployment with wired connection
FR2: Baffle shall conform to stowed volume constraint	175 mm x 175 mm x 50 mm	125 mm x 125 mm x 50 mm
FR3: Baffle shall adhere to mass constraint	< 500 grams	< 300 grams
FR4: Baffle shall attenuate light to 99.9%	At 40° light incidence angle	At 30° light incidence angle

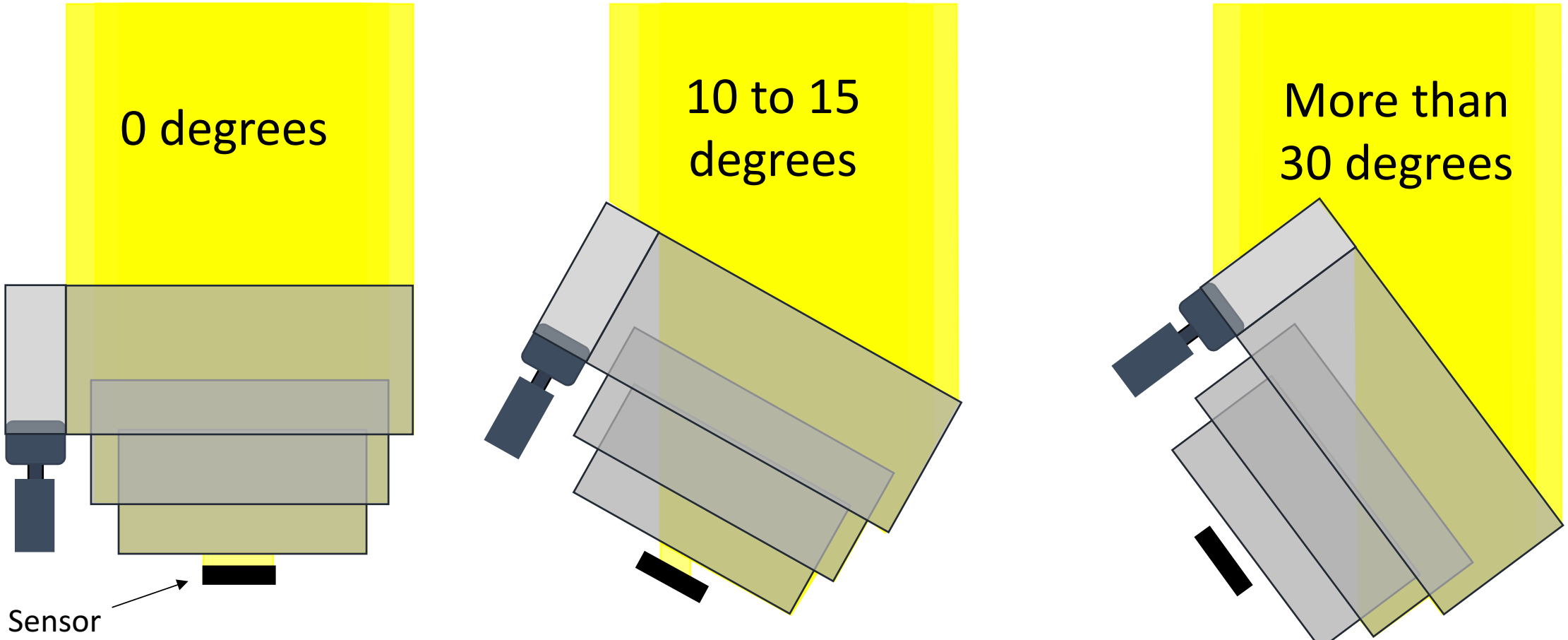
Mission CONOPS



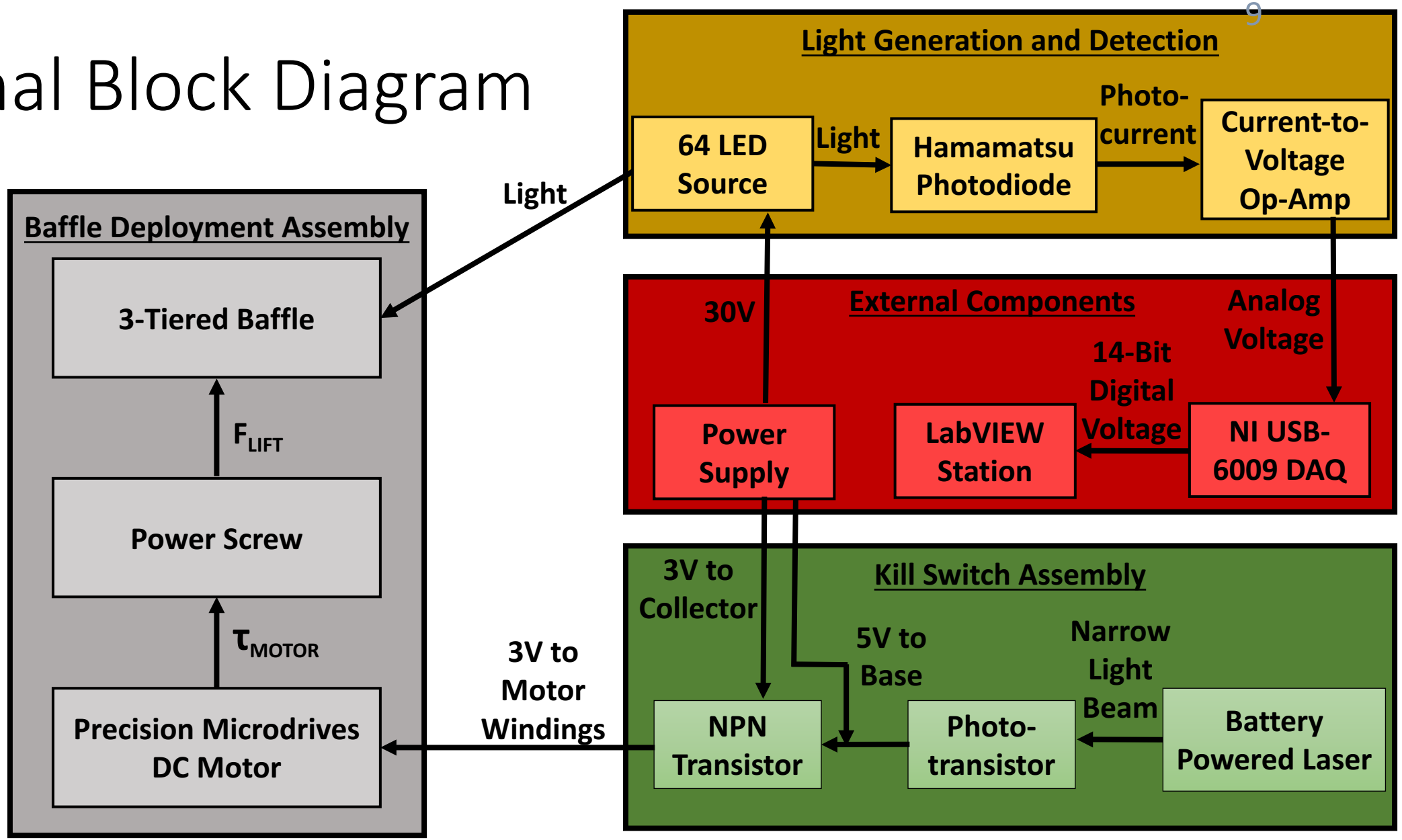
Deployment CONOPS

Power Screw Rotates
Baffle Deploys

Light Attenuation CONOPS

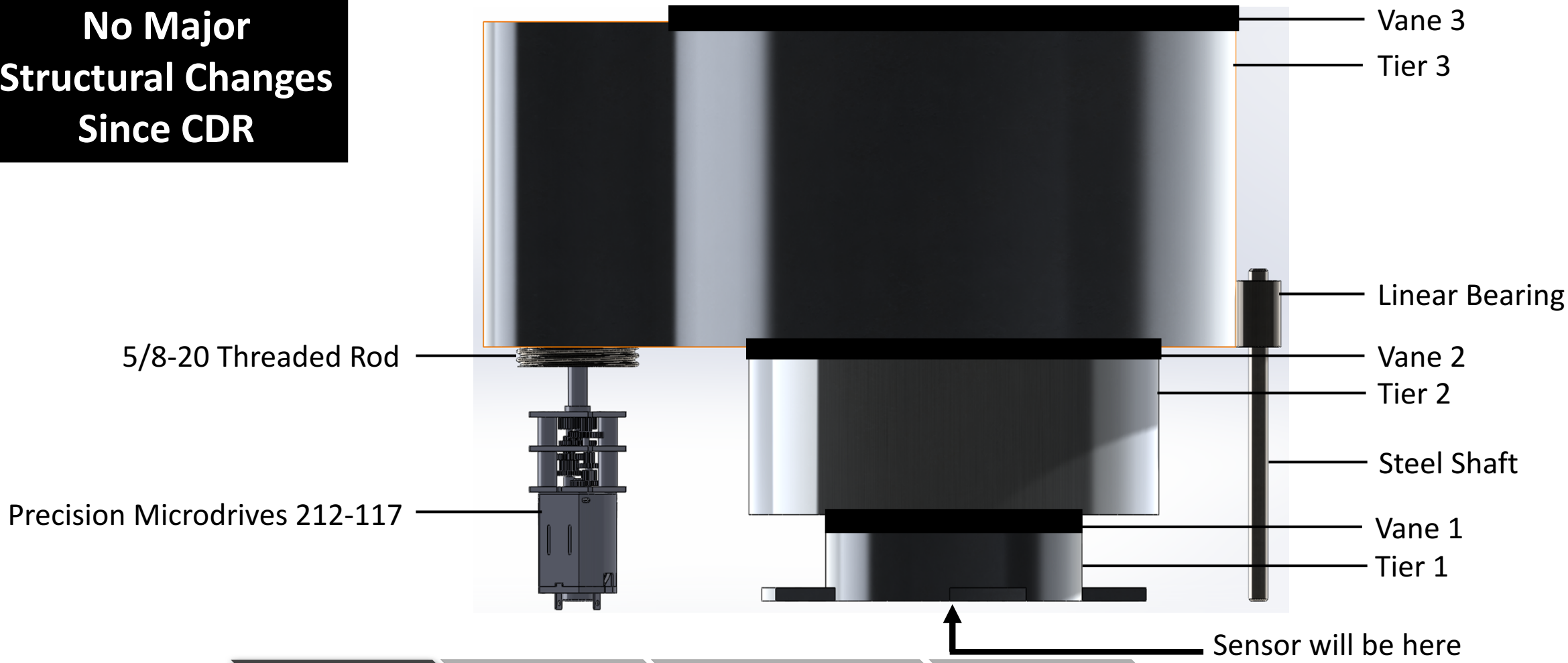


Functional Block Diagram

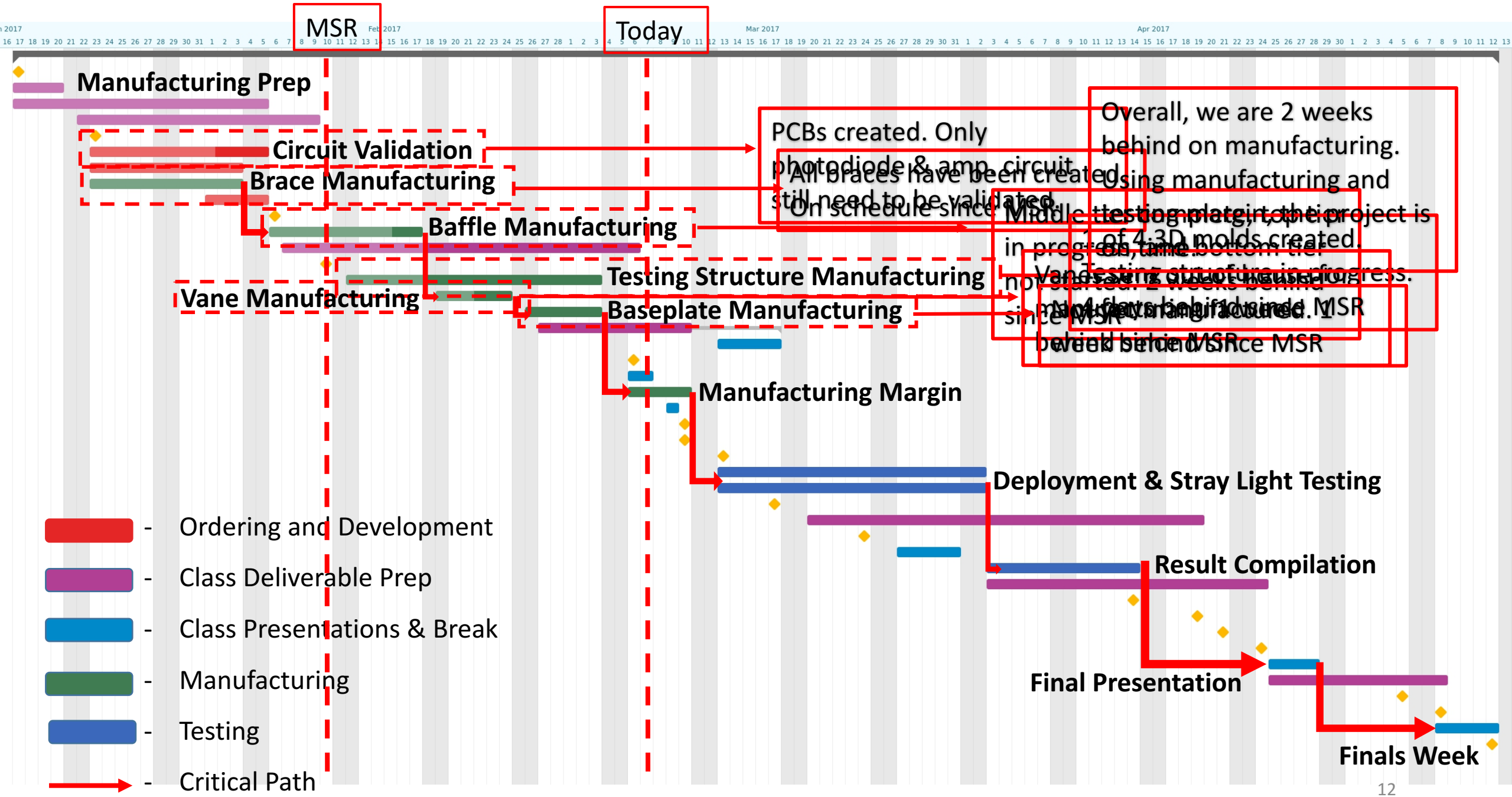


Baseline Design: CDR vs. Now

No Major Structural Changes Since CDR



Schedule


MSR
Today
Feb 2017
Mar 2017
Apr 2017
Manufacturing Prep
Circuit Validation
Brace Manufacturing
Baffle Manufacturing
Testing Structure Manufacturing
Vane Manufacturing
Baseplate Manufacturing
Manufacturing Margin
Deployment & Stray Light Testing
Result Compilation
Final Presentation
Finals Week
PCBs created. Only photodiode & amp circuit still need to be validated.
All braces have been created. On schedule since MSR
Middle testing plate, 1 of 4 3D molds created. Testing structure in progress. 1 week behind since MSR
Overall, we are 2 weeks behind on manufacturing. Using manufacturing and testing plate, the project is on time.
- Ordering and Development
- Class Deliverable Prep
- Class Presentations & Break
- Manufacturing
- Testing
- Critical Path

Test Readiness Overview

- Light Attenuation & Symmetry Tests
- Deployment Testing

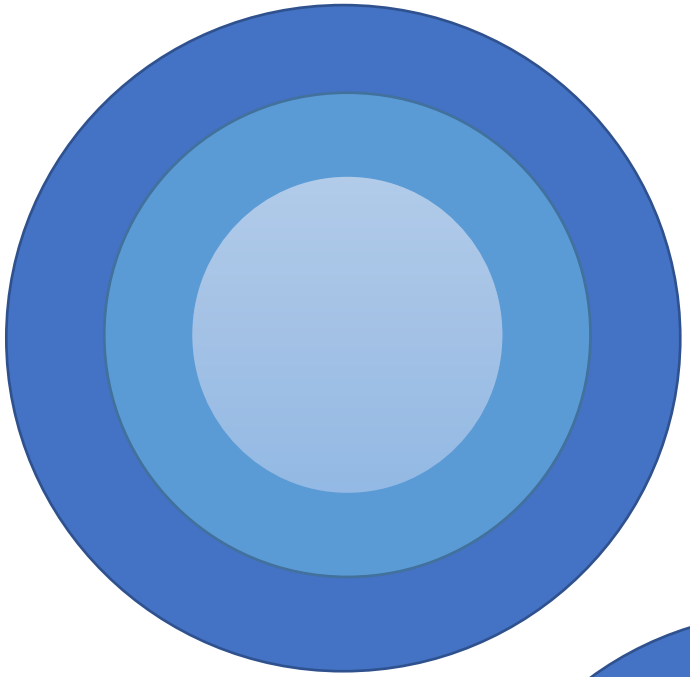
Test Readiness

Light Attenuation & Symmetry Tests

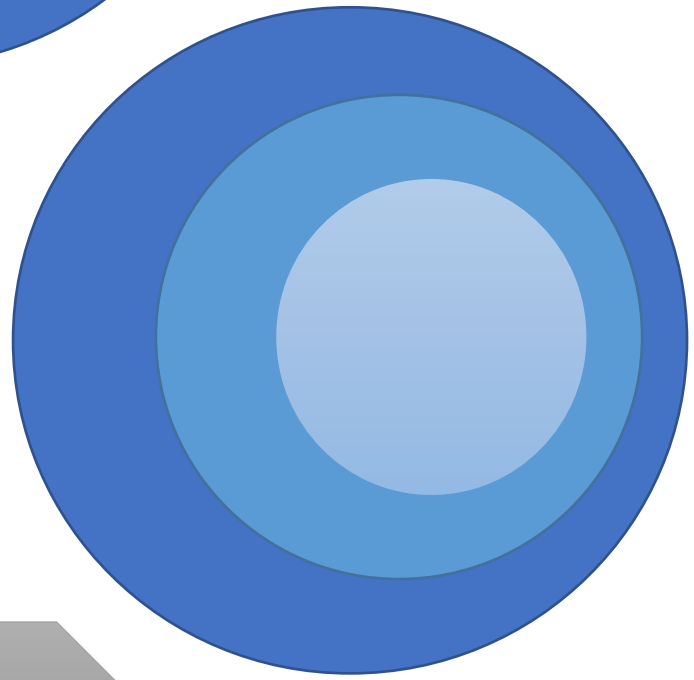
Light Attenuation Overview

- Will be testing light attenuation with respect to pointing angle

- Two different tests:
  - Symmetric
  - Asymmetric



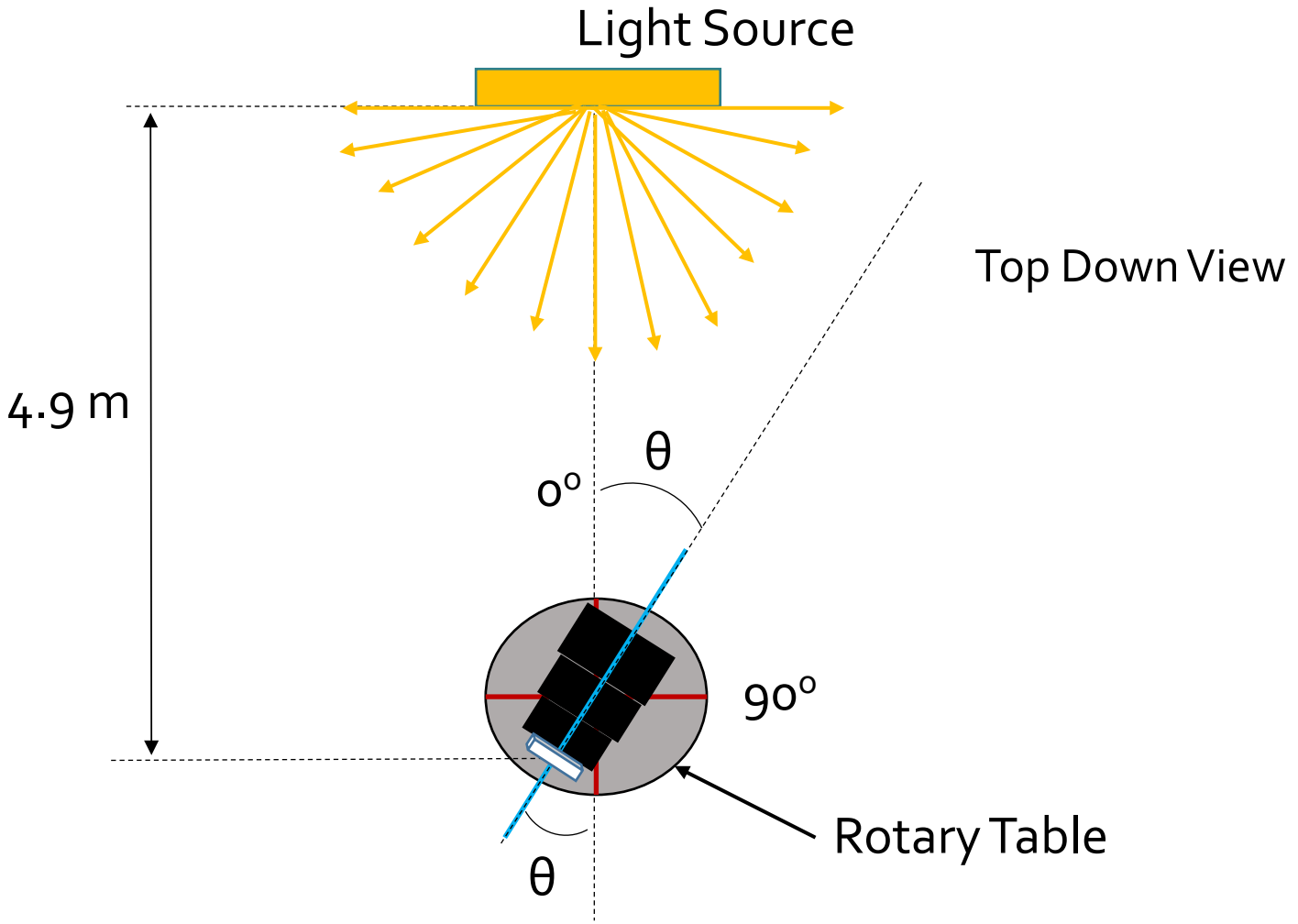
Symmetric Baffle



Asymmetric Baffle

Light Attenuation Test

Will validate light attenuation requirements!

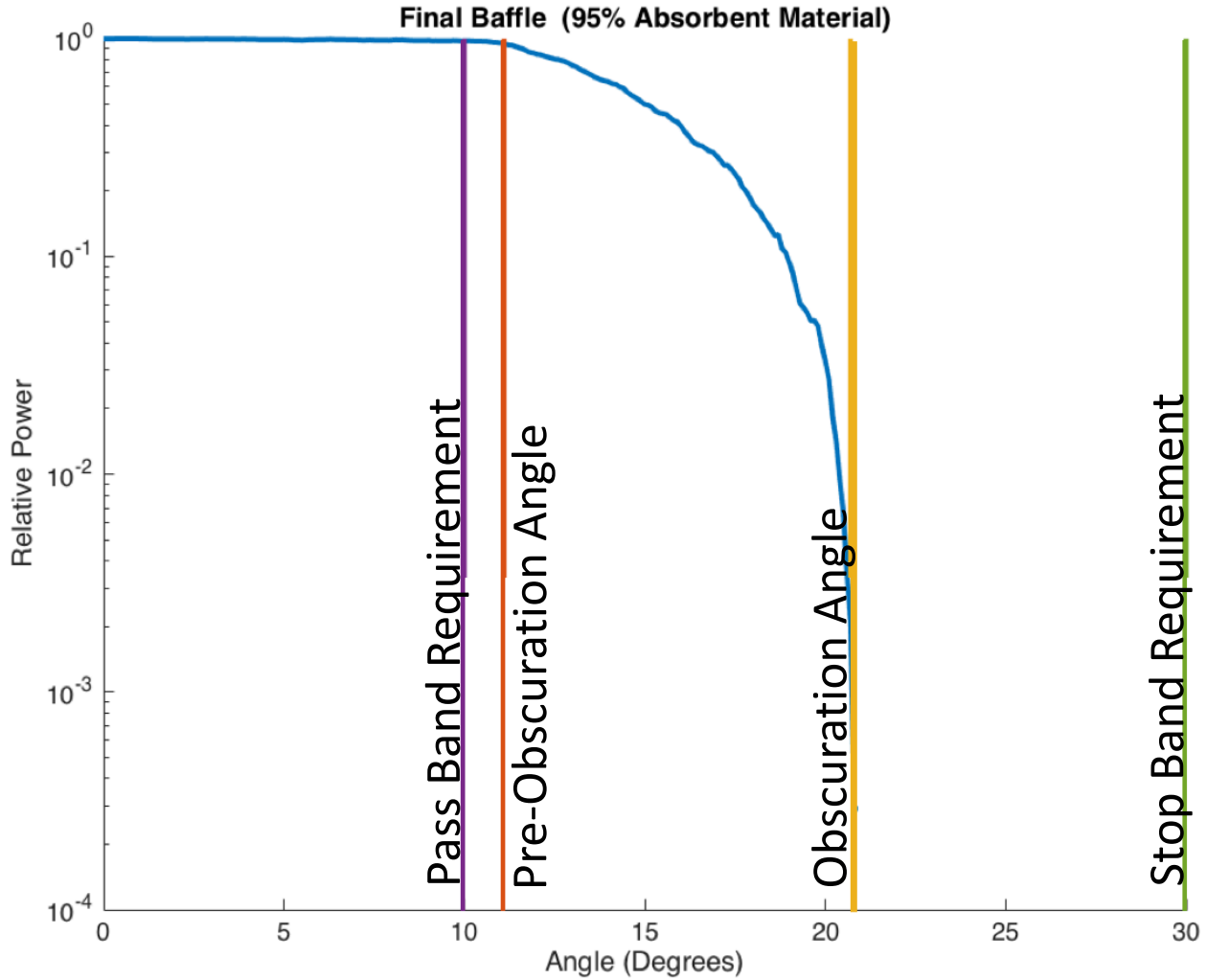


Requirements To Be Validated

- Light attenuation testing will verify both of these requirements
- Will be testing baffle symmetry and asymmetry

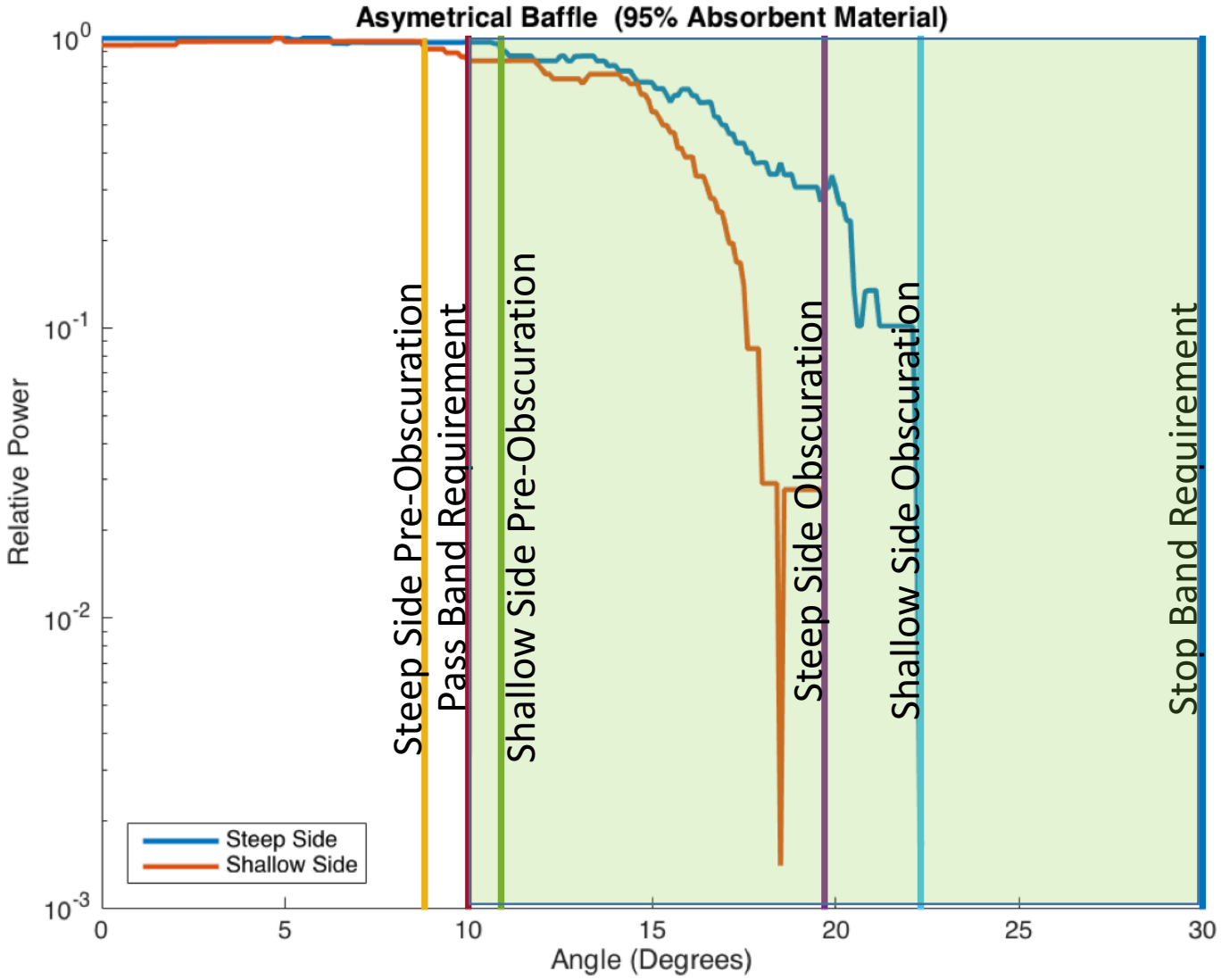
Requirement	Relative Incident Power (P/P_0)	Angle (Degrees)
Pass-Band (DR4.3)	> 95%	10°
Stop-Band (DR4.2)	< 0.1%	30°

Zemax Validation – **Symmetric** Model Expected Results



	Final Model
Pre-Obscuration Angle	11.1°
Obscuration Angle	20.7°

Zemax Validation – **Asymmetric** Model Expected Results

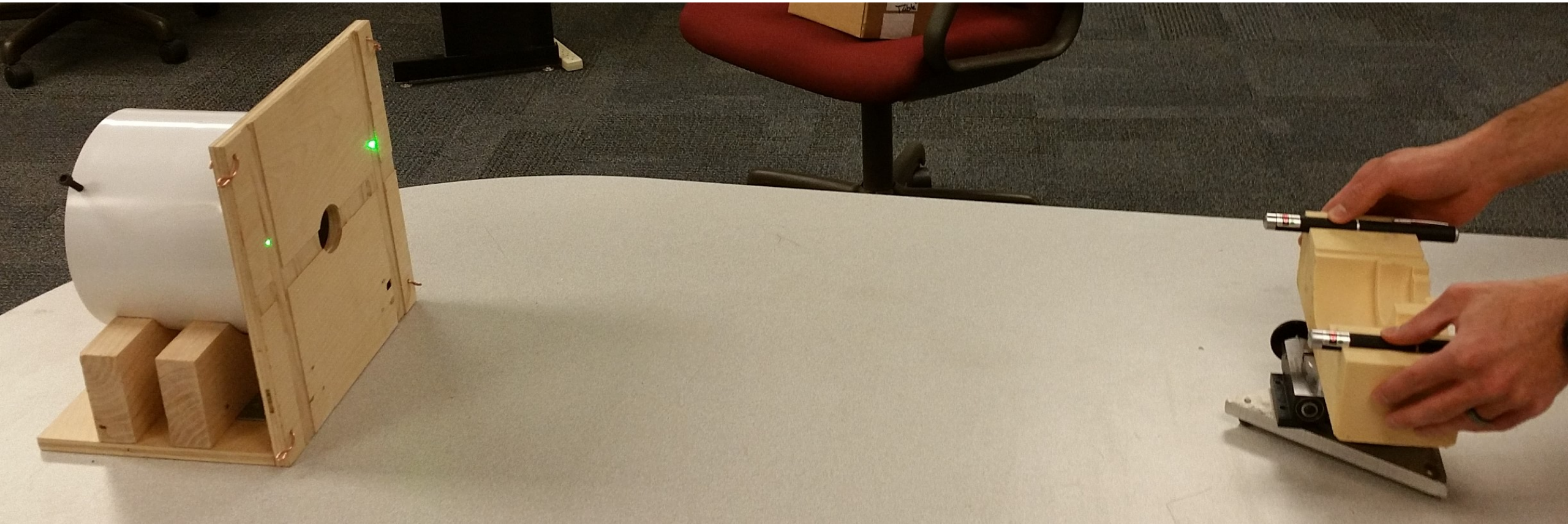


	Steep Side	Shallow Side
Pre-Obscuration Angle	8.8°	10.9°
Obscuration Angle	19.7°	22.3°

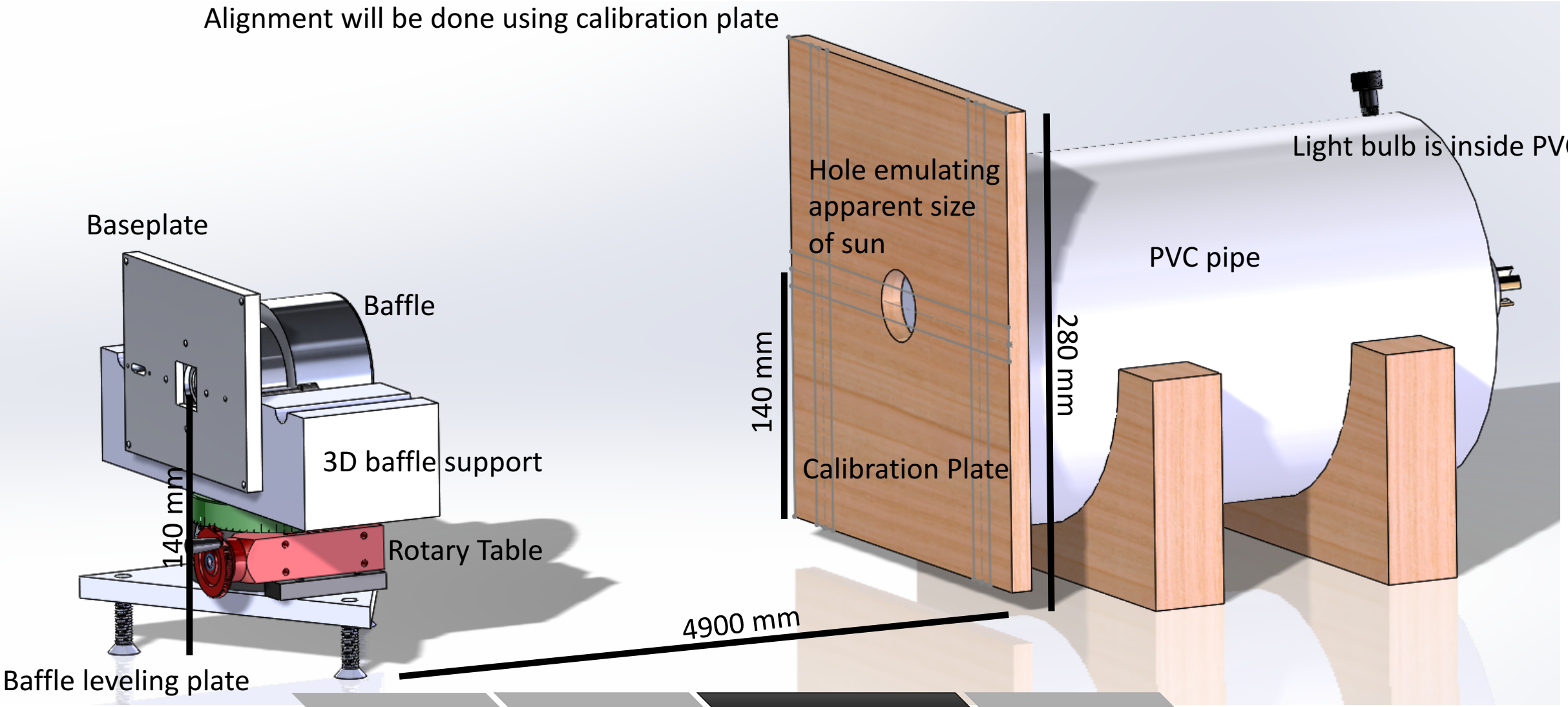
Test Readiness

Light Attenuation Test Fixtures

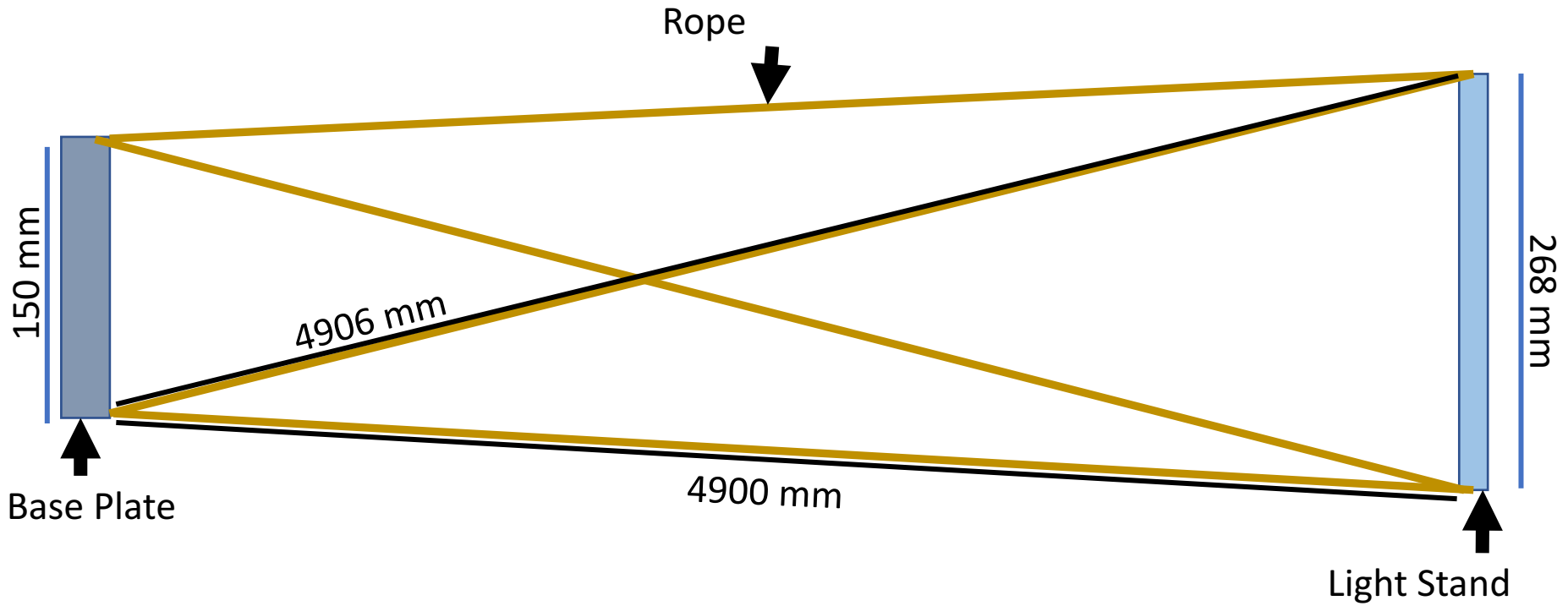
Light Attenuation Test Fixtures – Exploded View



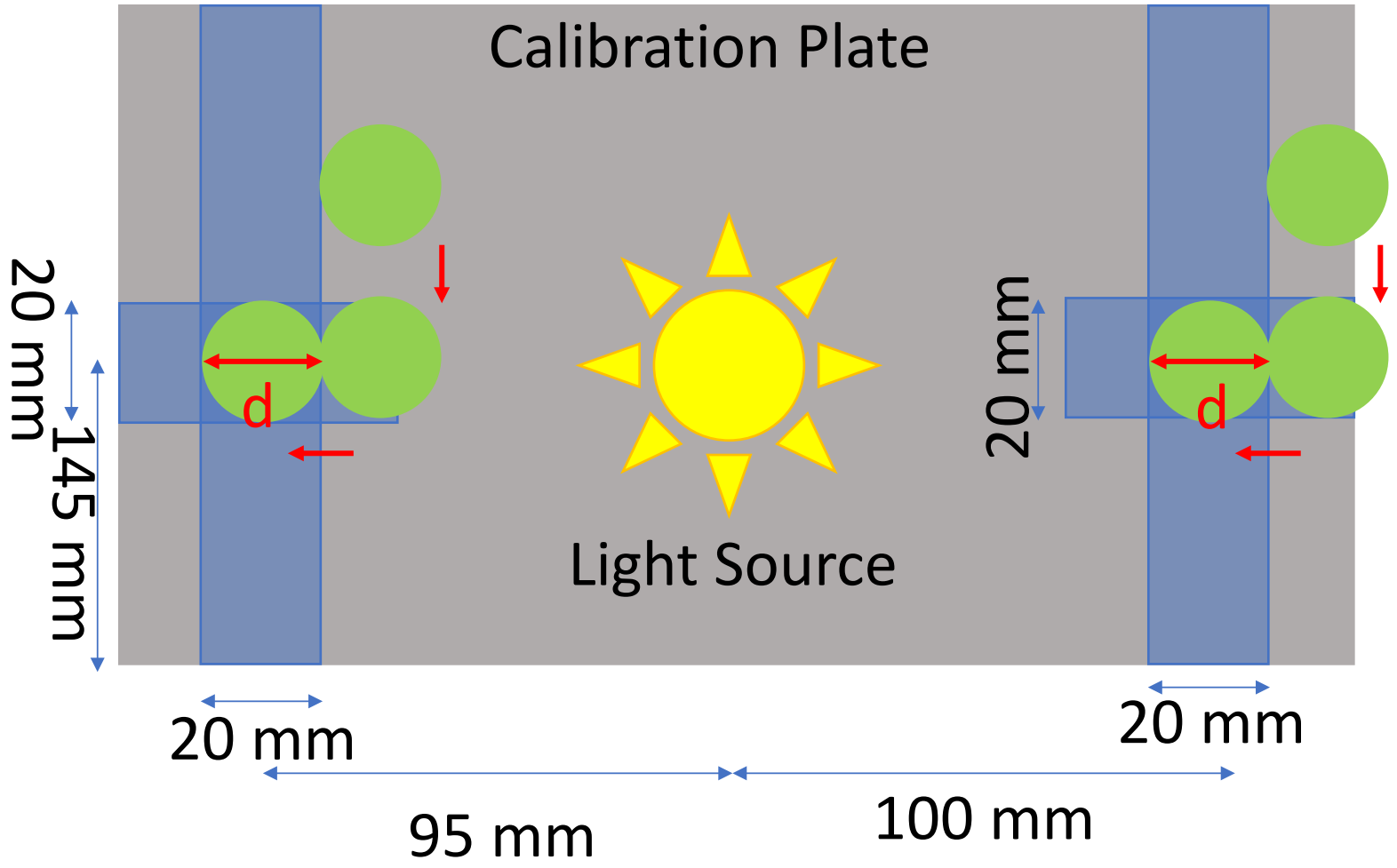
Light Attenuation Test Fixtures – Exploded View



Calibration Method – Position



Calibration Method – Orientation



Calibration Test Tolerances

Part	Tolerance	Requirements
Rope (Distance)	$\pm 200mm$ changes FOV by $<0.01°$	Apparent sun diameter $= 0.5°$ Error: $<2\%$
Laser (Orientation)	$\pm 20mm$ + Manufacturing Error Changes Results Angle by 0.40°	Pre-obscuration Margin: 1.1° Obscuration Margin: 9.3°

Light Attenuation & Symmetry Tests

Equipment and Needed Facilities

- CNL cleanroom
- Photodiode handling items
- Laser Safety Glasses

Risk

- Delicate photodiode routinely cleaned.
- ESD safe environment
- Ground all electronics

Light Attenuation Test Concerns

Risk	Mitigation
Alignment of sensor & light source	Calibration plate
Static electricity	Grounded electrical components
Eye damage from laser pointers	Laser safety glasses for calibration
Photodiode contamination	• Paint mask & powder free nitrile gloves • Clean photodiode with 99% isopropyl alcohol and ESD swabs • Clean both sides of the filter • Handle photodiode with plastic antistatic tweezers • When not in use, store the photodiode in an ESD bag and a second ESD bag with desiccant • Will only handle photodiode in clean room

Light Attenuation Test Procedure

- Take P_0 measurement at 0°
- Take power (P) measurements every 4°
- Between 8°-12°, and 28°-32°, measurements will be taken every 0.1°
- Calculate light attenuation using relative power measurement P/P_0

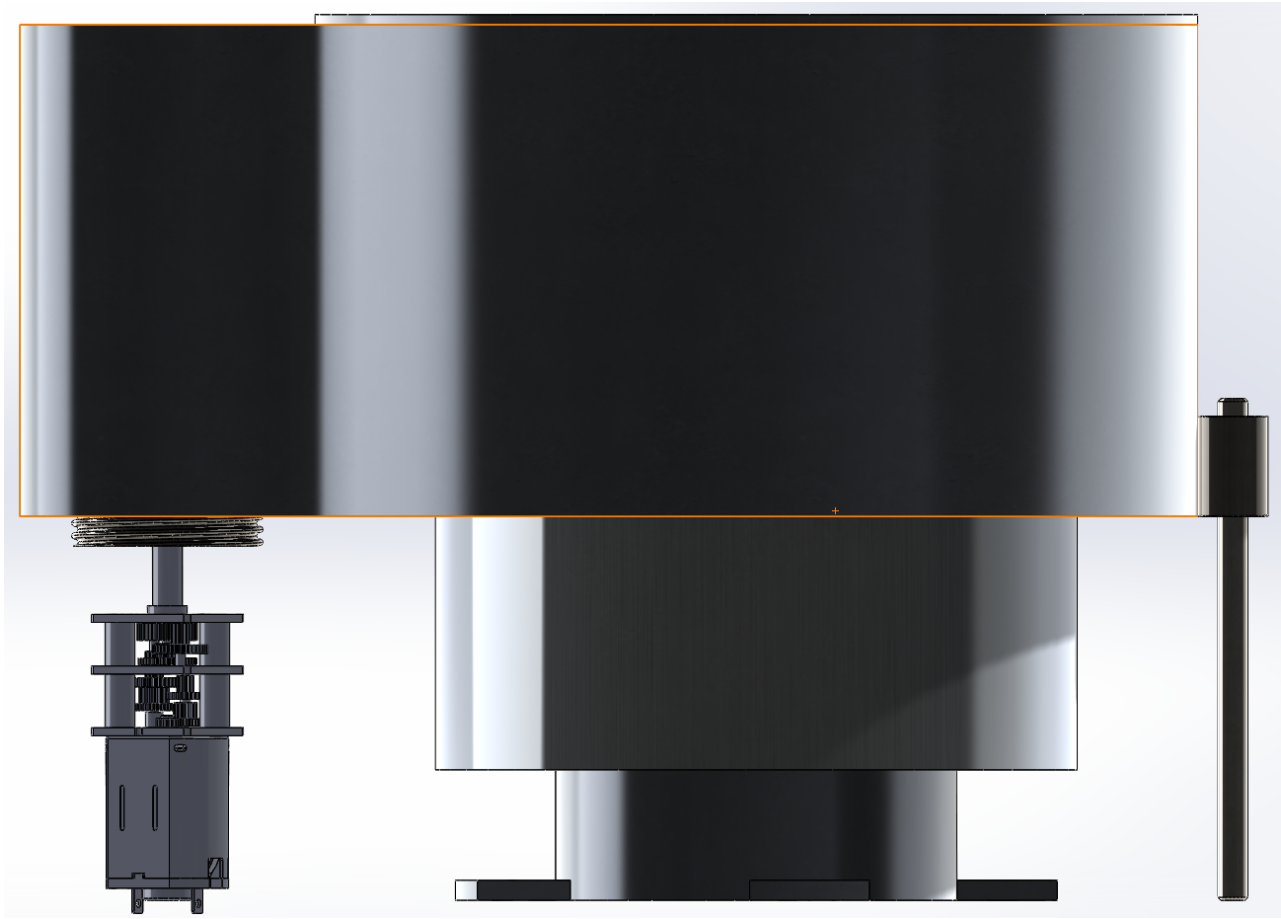
Full test procedures available upon request

Test Readiness

Deployment Testing

Deployment Testing Overview

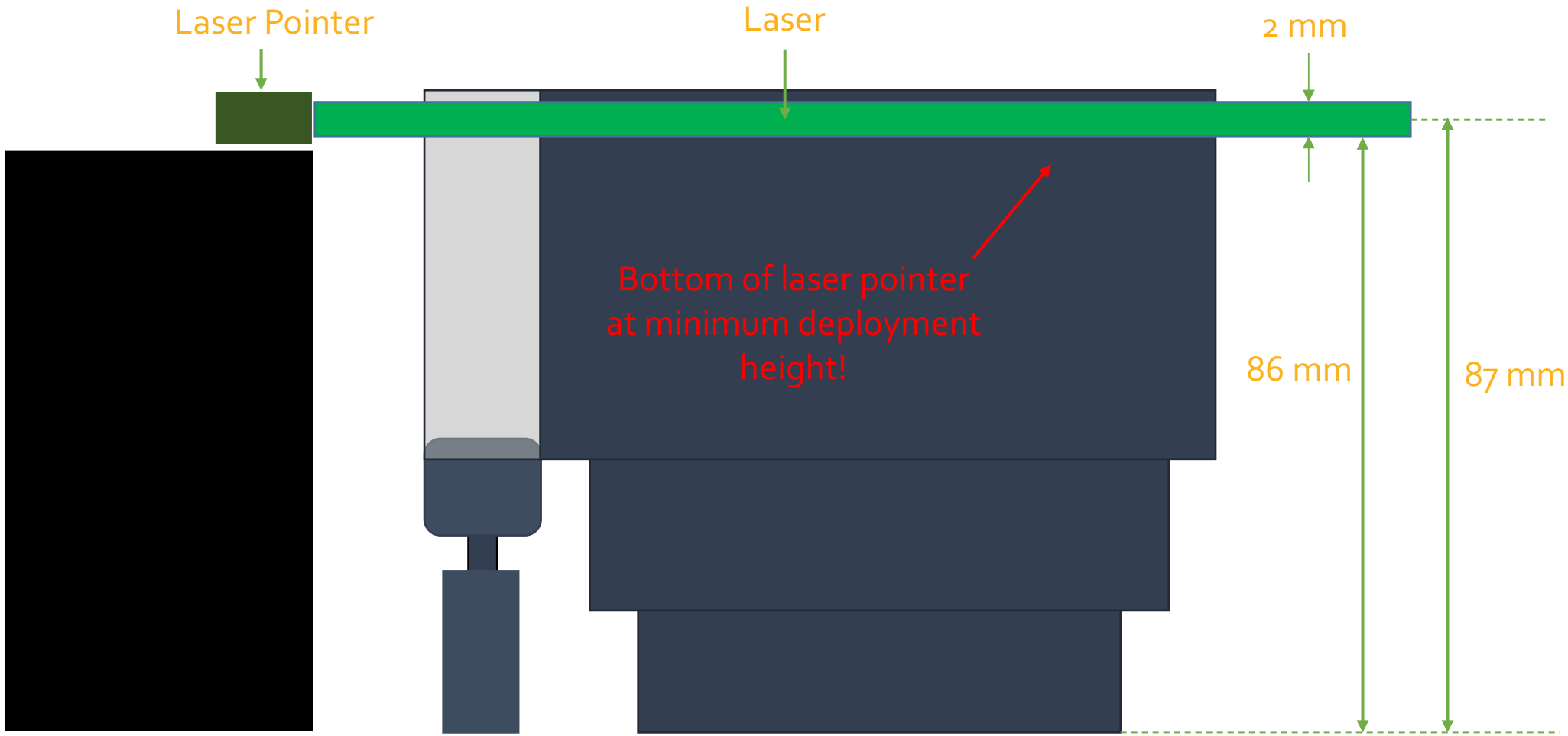
- Will be testing deployment with respect to the minimum and maximum allowable deployment heights



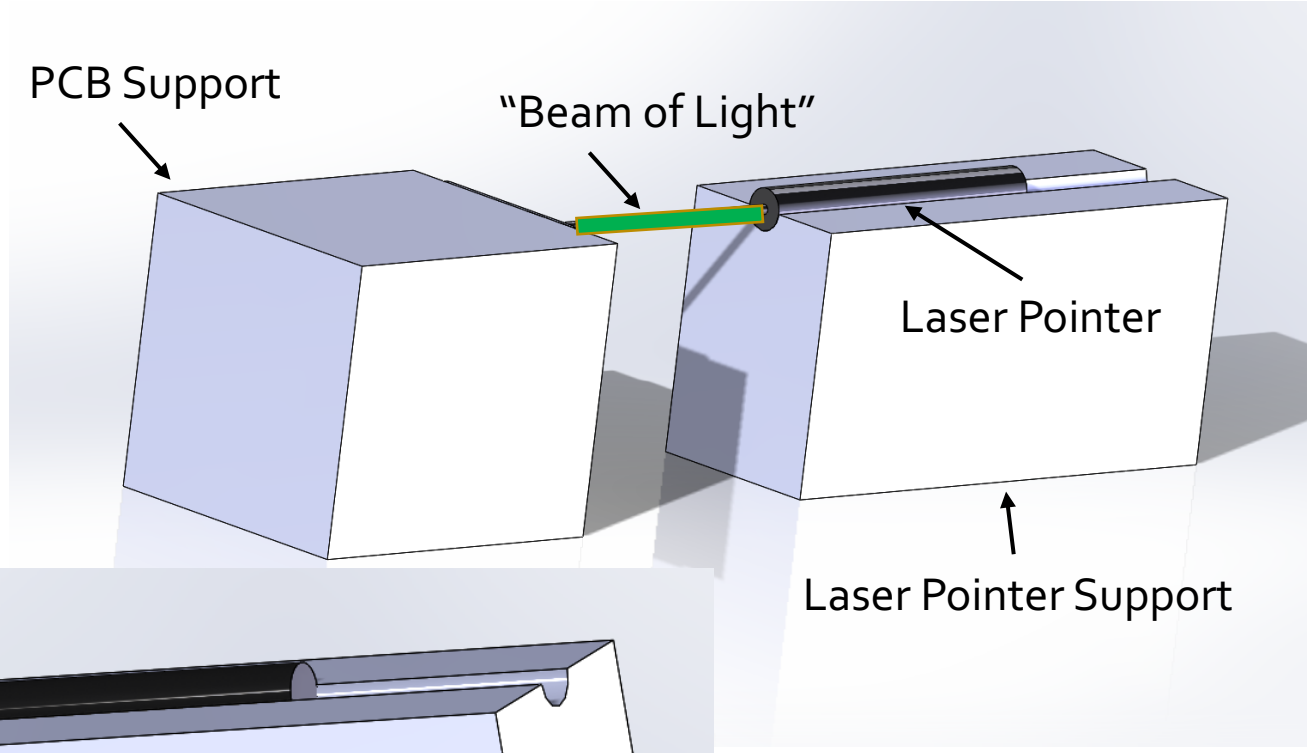
Deployment Testing Overview

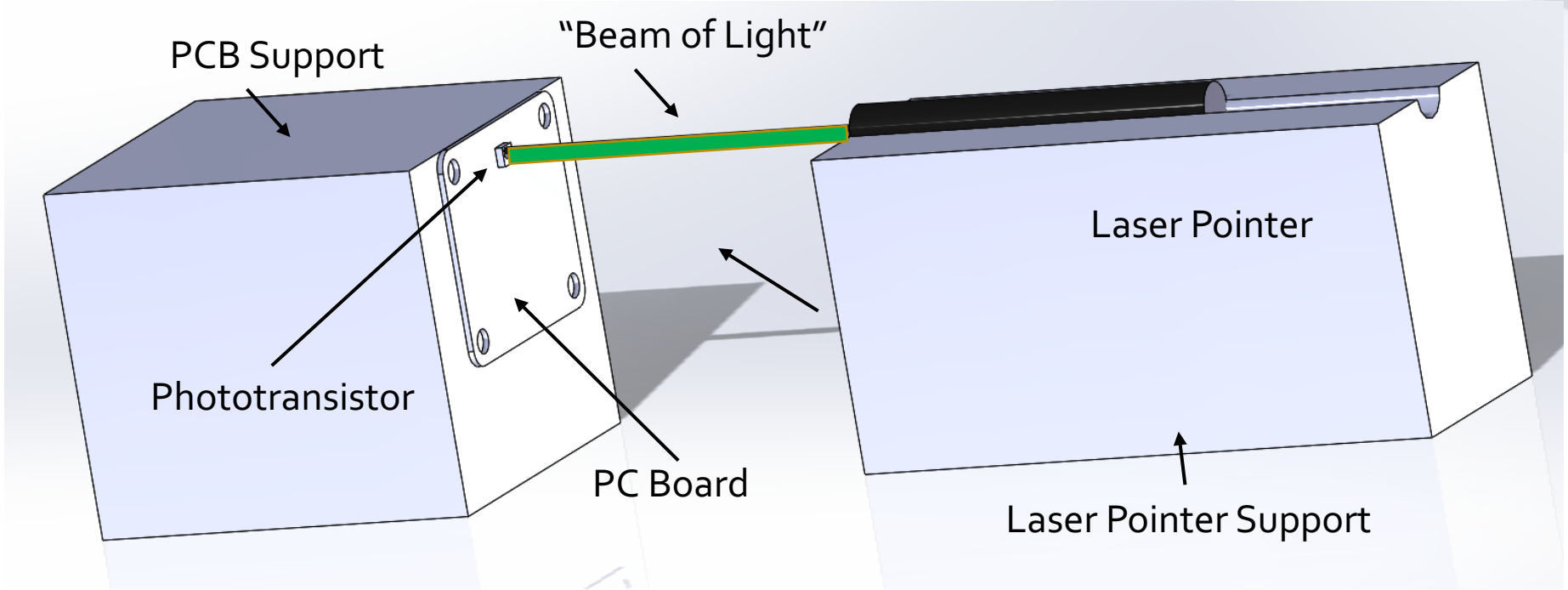
- **Objective:**
  - To ensure baffle can transition from a stowed to a deployed state within the expected range
- How It Reduces Risk:
  - Optical performance will not be compromised if baffle deploys within acceptable height
- Associated Model & Circuit Validation:
  - Kill switch circuit (validated)
- Key Data:
  - Average height of fully deployed baffle
  - **Expect:** 87 mm ± 1 mm
- **Requirement:**
  - FR1: Baffle shall be deployable

Deployment Testing



Deployment Test Set Up





Deployment Test Procedure

- Ensure bottom of laser pointer is at acceptable minimum deployment height
- Turn on laser pointer to start deployment
- When fully deployed, laser light to phototransistor will be impeded causing voltage to motor to stop ending deployment
- Repeat for maximum acceptable deployment height

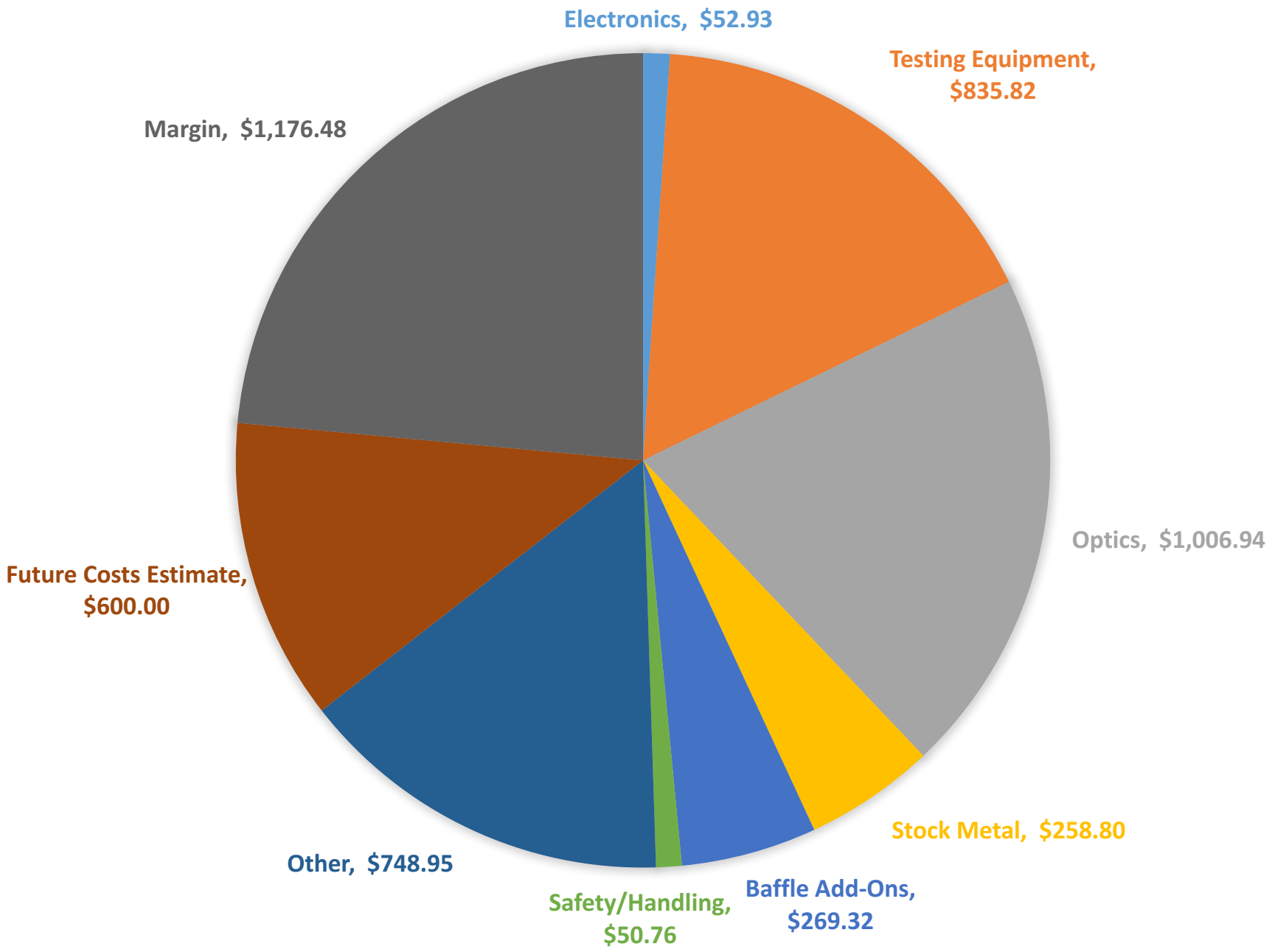
- Location:
  - Bobby's Lab

Testing Status

Test	Status:	Awaiting:
Light Attenuation Test (Symmetrical)	Not completed	• 1 3D baffle negative • Baffle • Baseplate
Light Attenuation Test (Asymmetrical)	Not completed	• 2 3D baffle negatives • Baffle • Baseplate
Deployment Test	Not completed	• Baffle • Baseplate • Laser pointer support • PCB • PCB support

Budget

BUDGET



Electronics - $52.93
Testing Equipment - $835.82
Optics - $1,006.94
Stock Metal - $258.80
Baffle Add-Ons - $269.32
Safety/Handling - $50.76
Other - $748.95
Future Costs Estimate - $600.00

Sum - $3,823.52

Margin - $1,176.48

References

References

- http://cnl.colorado.edu/cnl/index.php?option=com_content&view=article&id=211&Itemid=155
- http://www.cleanairtechnology.com/cleanroom-classifications-class.php
- https://static.rapidonline.com/catalogueimages/Module/M071087P01WL.jpg

Backup Slides

Backup Slides

- Zemax
  - Final Model Specs
  - Asymmetric Model Specs
  - Parallel Ray Model
    - Specs
    - Results
  - Mesh Refinement Study
    - Specs
    - Results
    - Analysis
  - 4 Photodiodes Specs
- Baffle Negative CAD

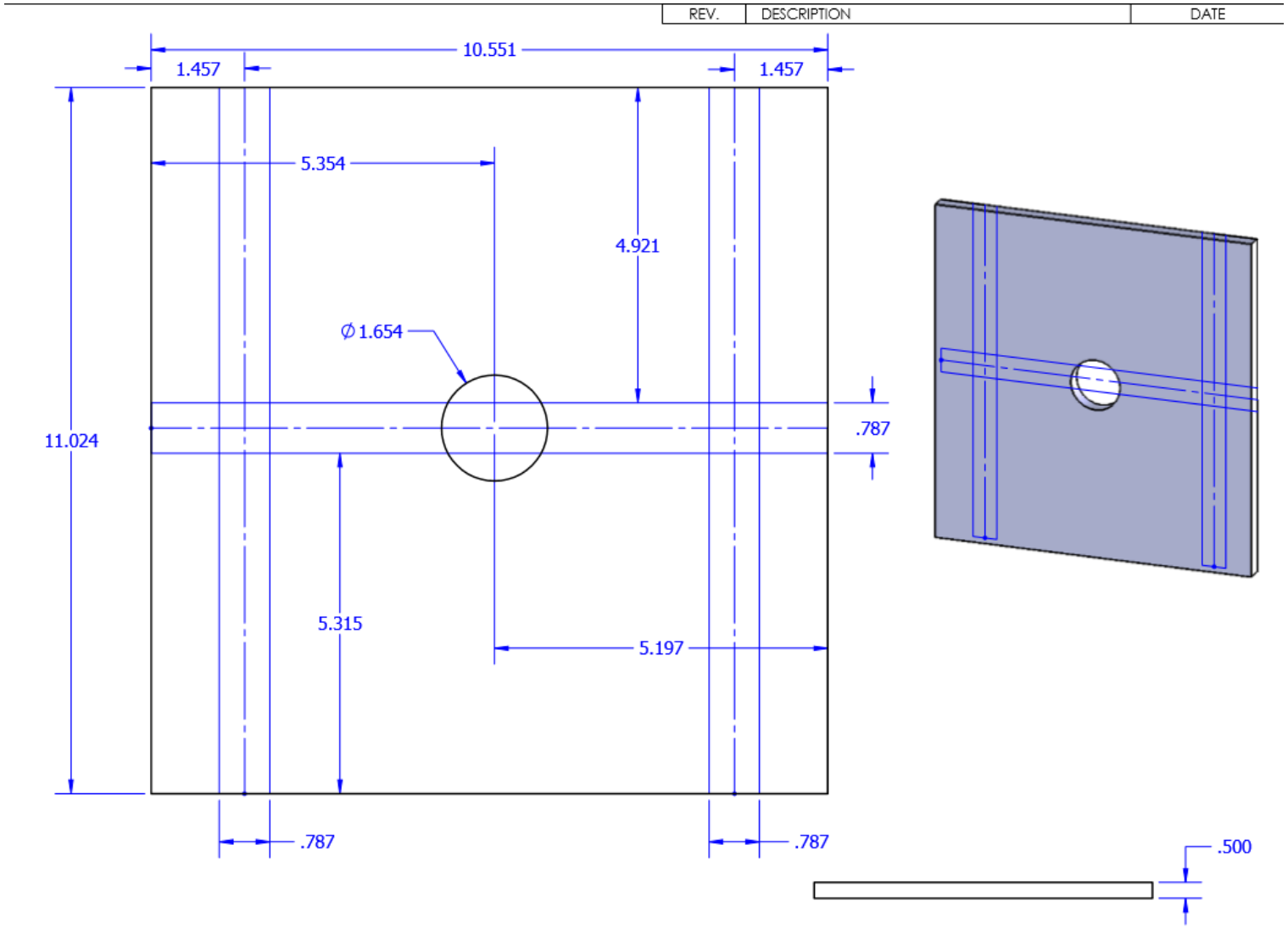
Breakdown

- Electronics
  - Includes PC board, resistors, batteries and other small components
- Testing Equipment
  - Includes lasers, light bulbs, diffuser disk, and test setup material
- Optics
  - Includes filter, primary photodiode, and backup photodiodes
- Stock Metal
  - Includes Aluminum 2024-T4
- Baffle Add-Ons
  - Includes thread tap, bearing, shaft, motor, and gear
- Safety/Handling
  - Includes alcohol cleaner, ESD safe tweezers, gloves, dust mask, and static control bag
- Other
  - Includes epoxy, adhesive, printing, Aeroglaze coating and shipping costs
- Future Costs Estimate
  - Vanes ($150), Coating application ($200), Felt ($250)

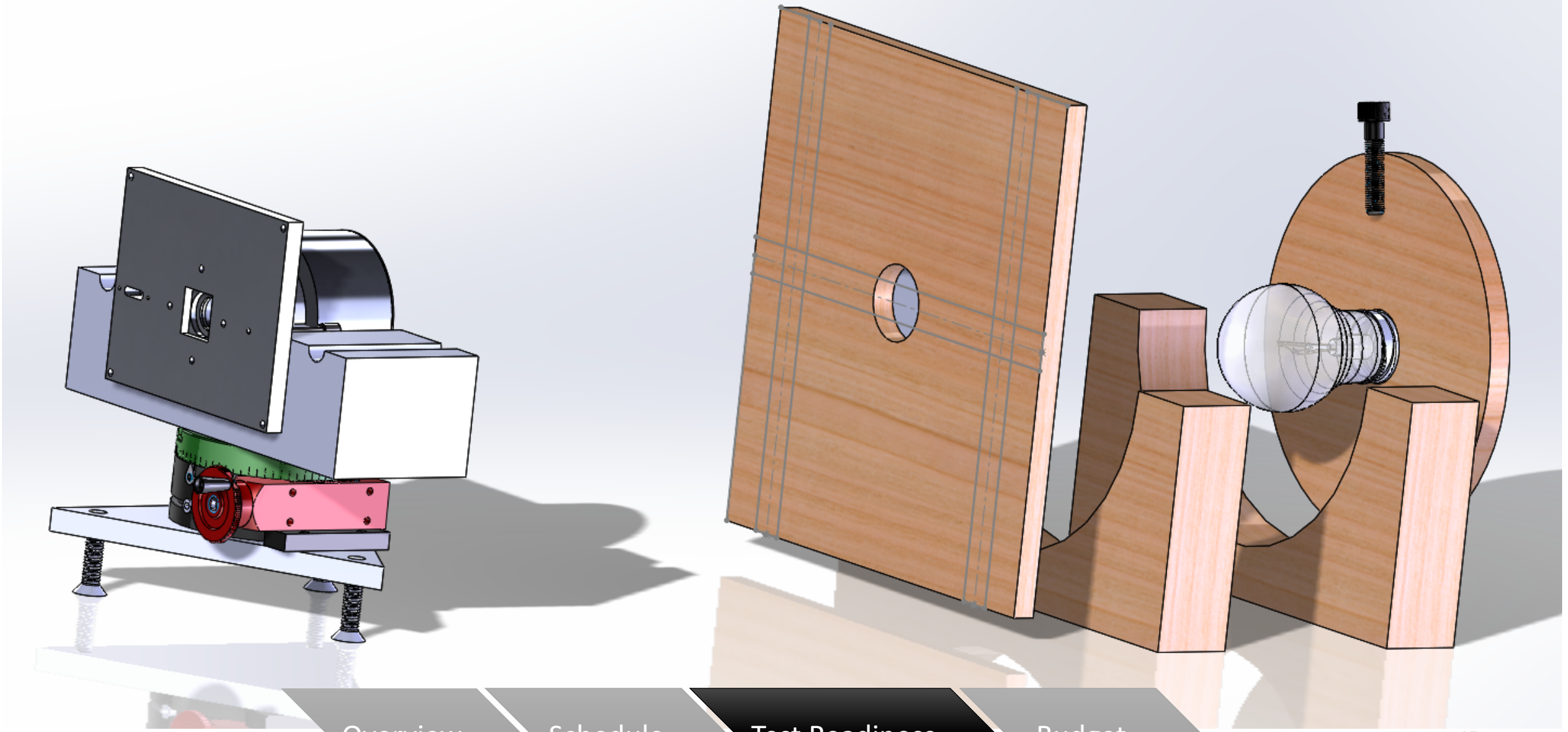
Financial Summary

- All items (except 1) are currently in the locker
  - Felt for the light attenuation test needs to be purchased
- Future cost include:
  - Re-ordering items/stock material if necessary
  - Outsourcing vanes
    - $150
    - Will get back this week
  - Application of coating on baffle
    - 2-3 days

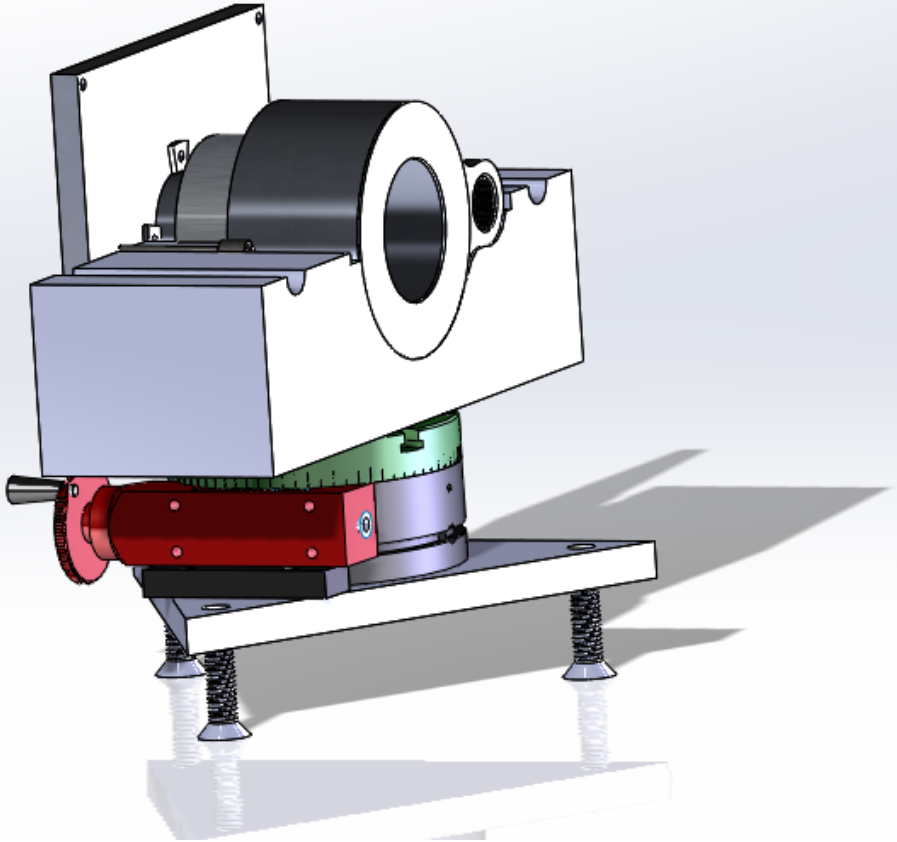
Light Attenuation Test - Calibration Plate

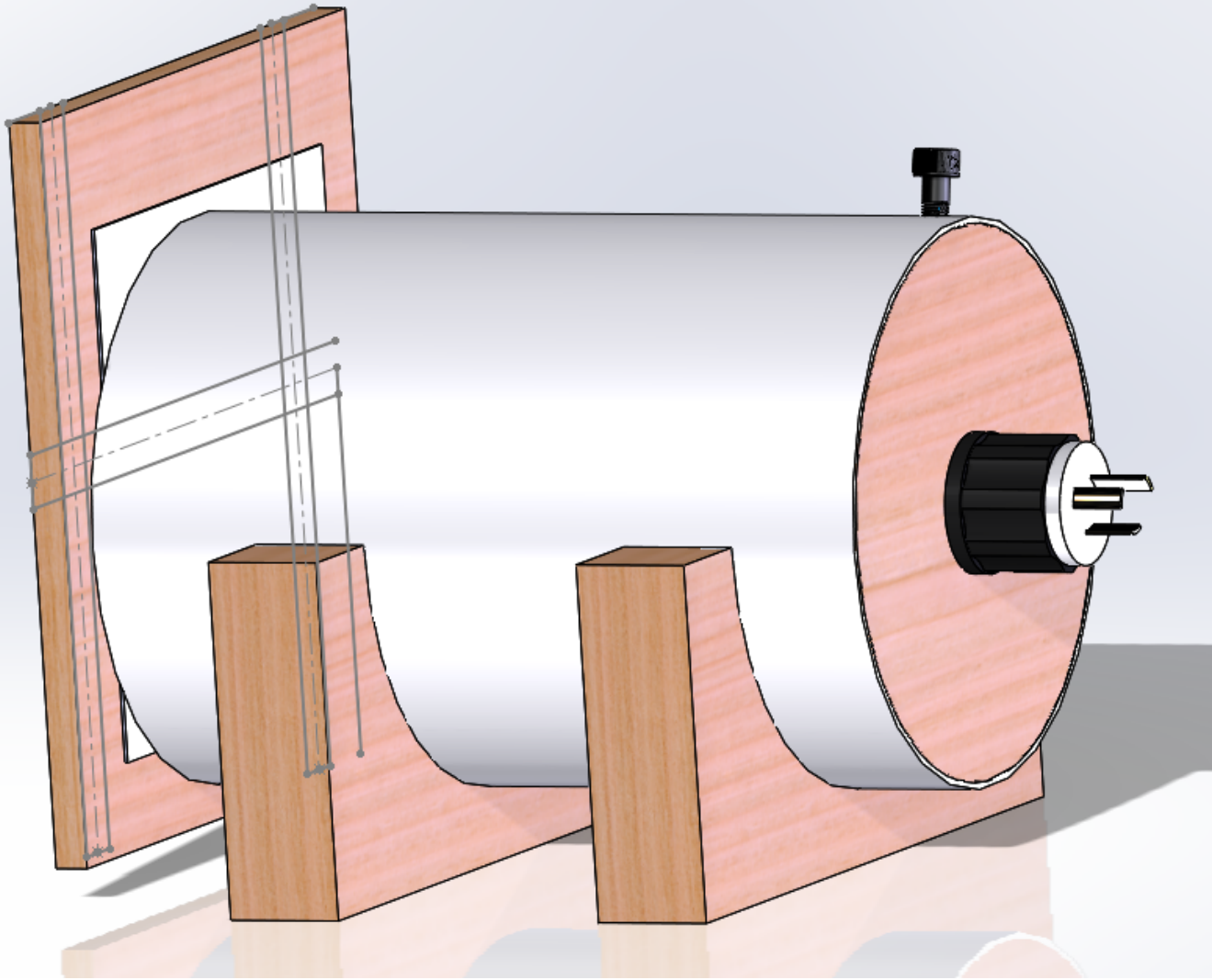


Light Attenuation Test Fixtures- Exploded View

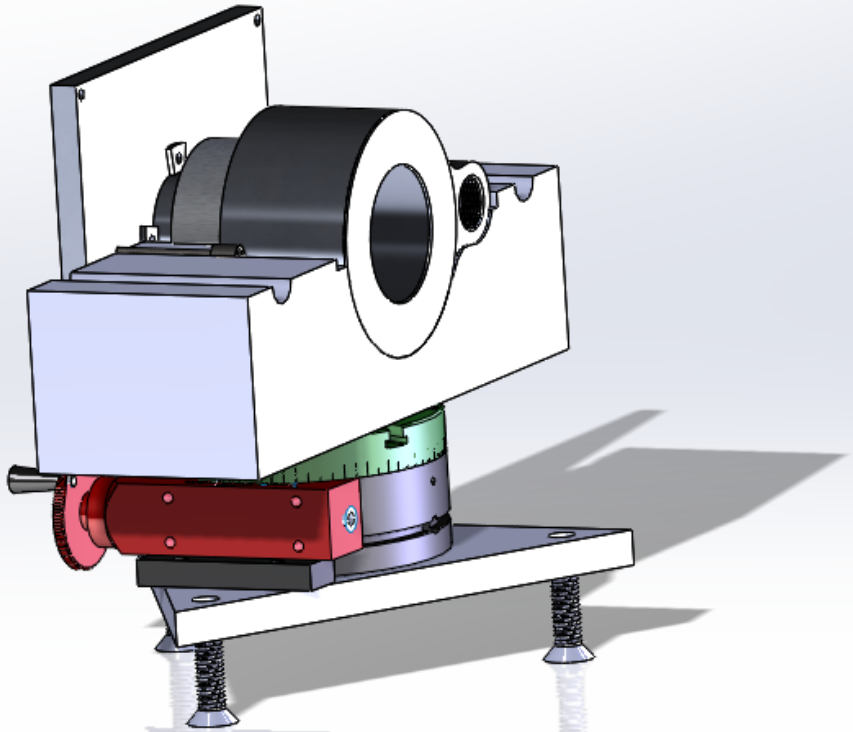


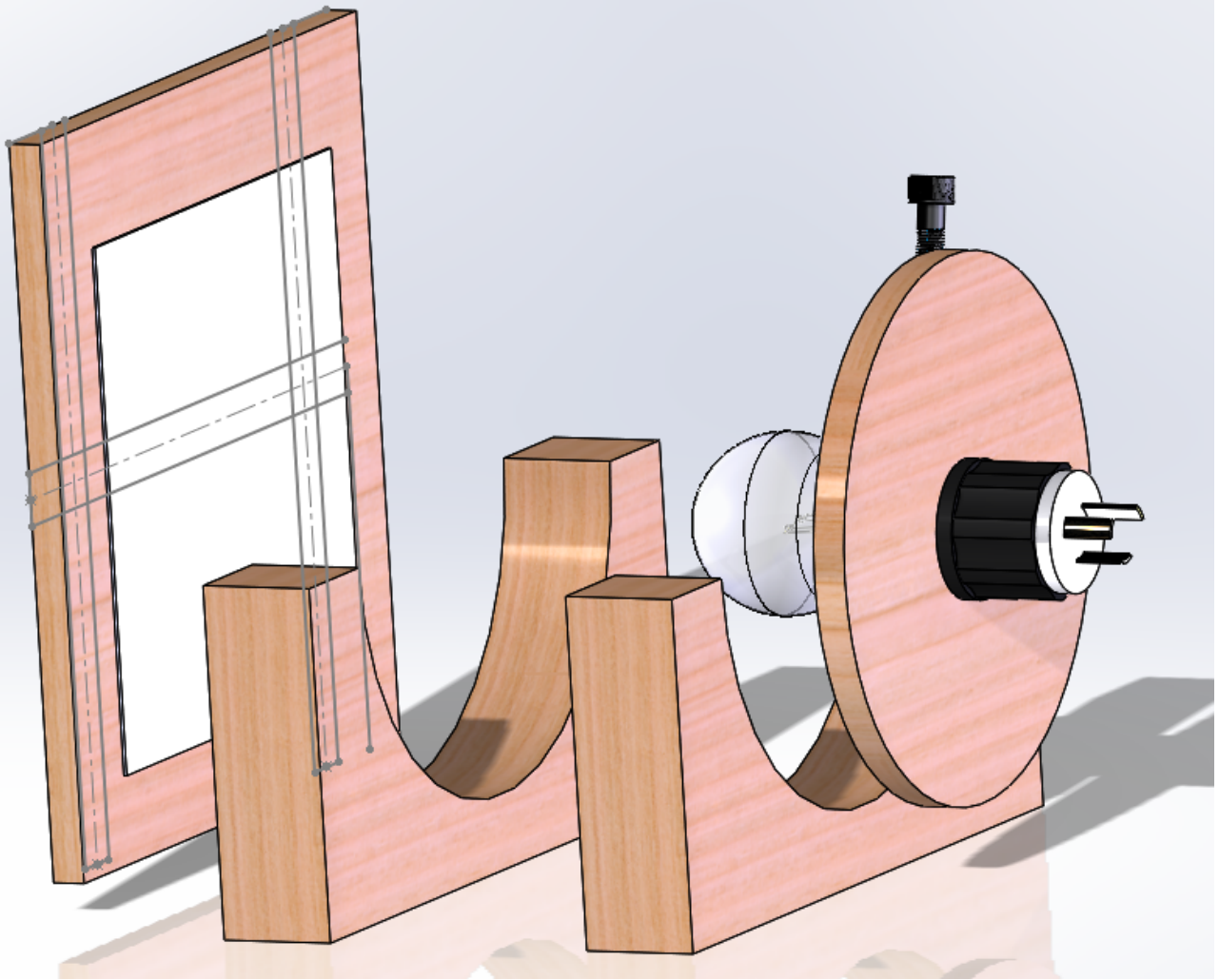
Light Attenuation Test Fixtures



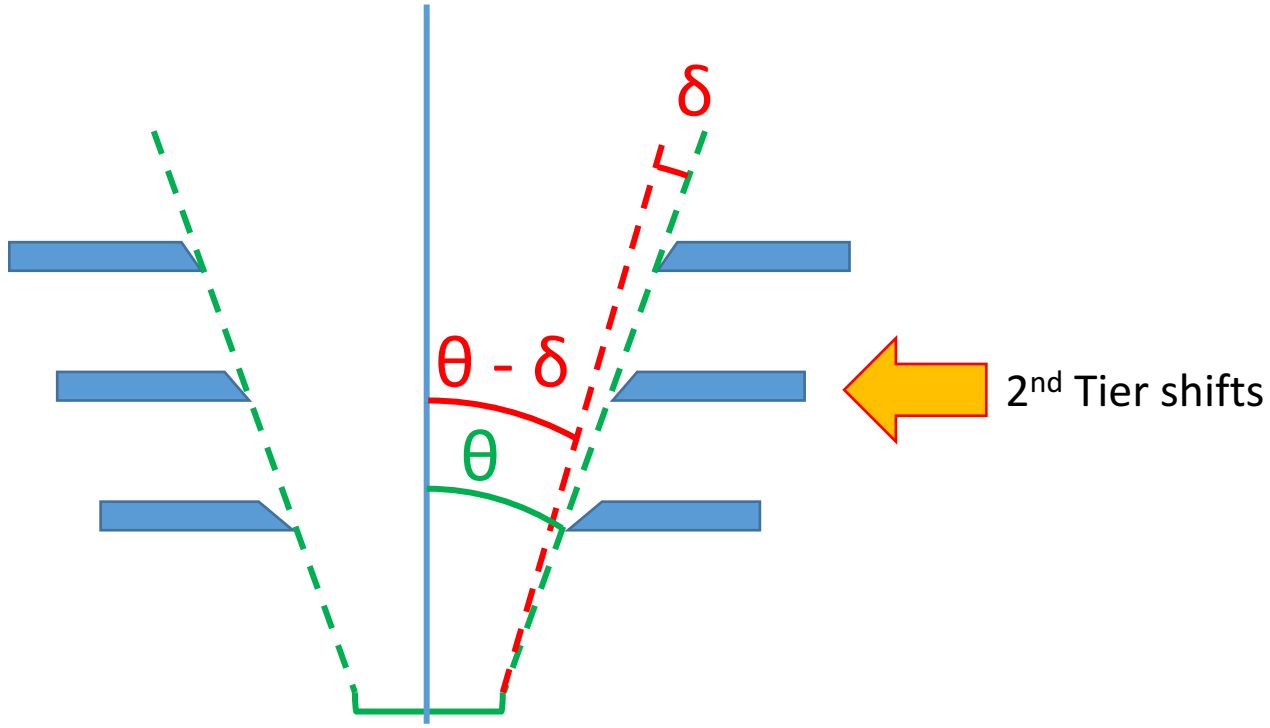


Light Attenuation Test Fixtures

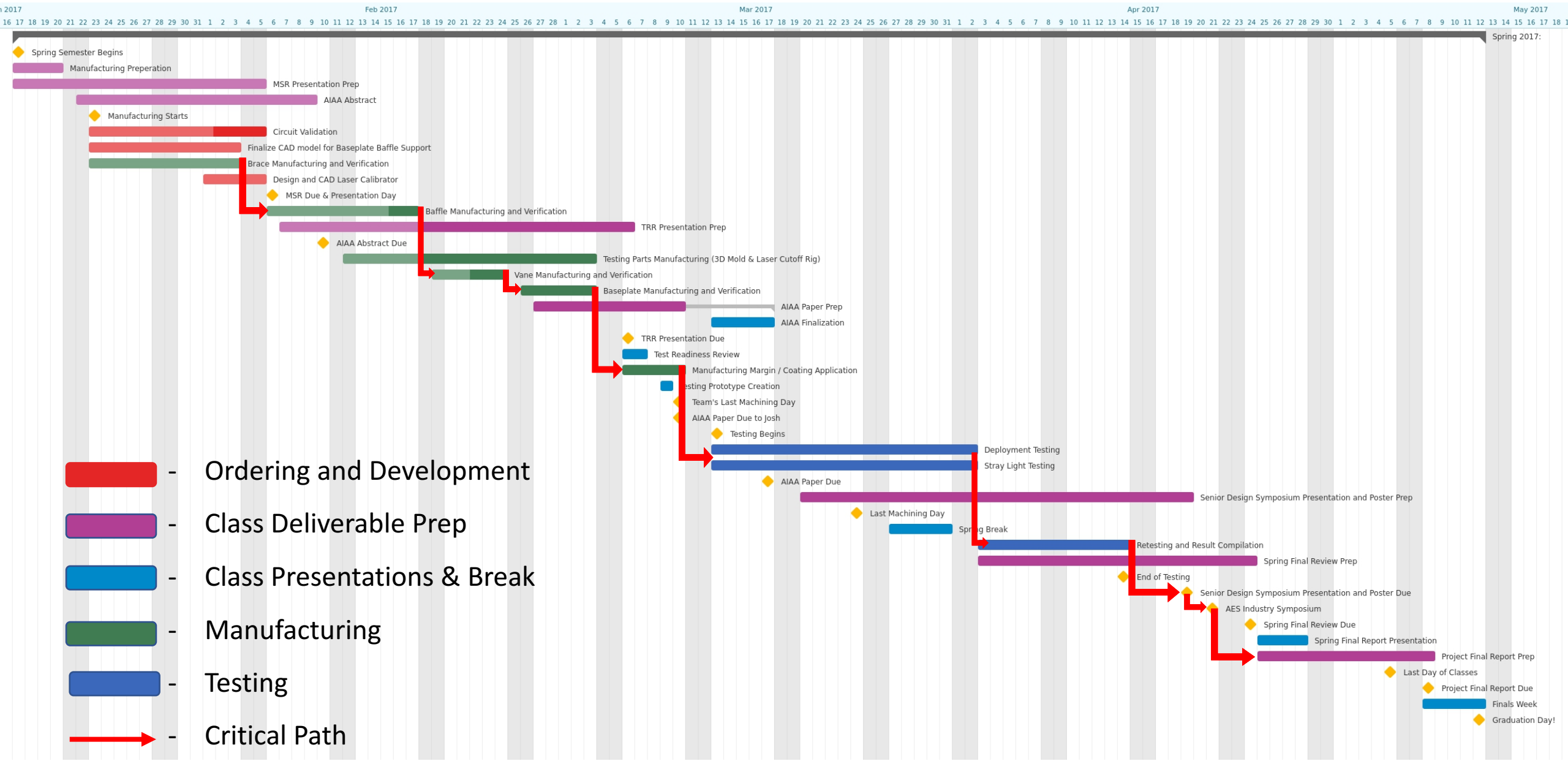




2nd Tier shift–Primary Degree of Freedom

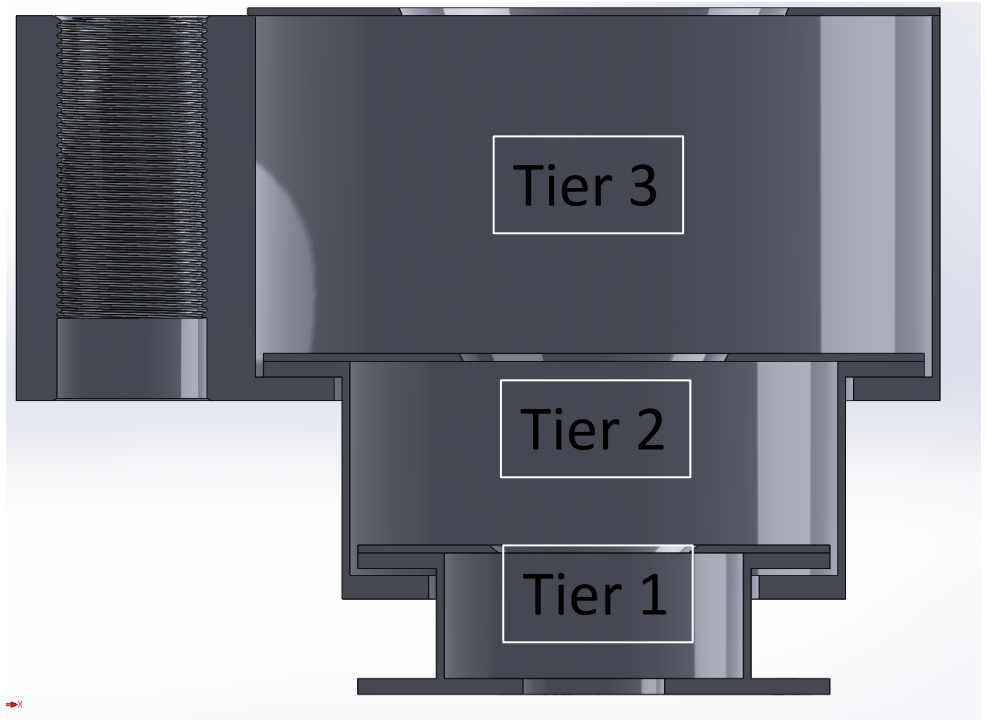


- 'Shallow Side's' effective FOV remains the same.
- 'Steep Side's' new field of view is 'designed' – 'perturbed angle'


Feb 2017
Mar 2017
Apr 2017
May 2017
Spring 2017:
Spring Semester Begins
Manufacturing Preperation
MSR Presentation Prep
AIAA Abstract
Manufacturing Starts
Circuit Validation
Finalize CAD model for Baseplate Baffle Support
Brace Manufacturing and Verification
Design and CAD Laser Calibrator
MSR Due & Presentation Day
Baffle Manufacturing and Verification
TRR Presentation Prep
AIAA Abstract Due
Testing Parts Manufacturing (3D Mold & Laser Cutoff Rig)
Vane Manufacturing and Verification
Baseplate Manufacturing and Verification
AIAA Paper Prep
AIAA Finalization
TRR Presentation Due
Test Readiness Review
Manufacturing Margin / Coating Application
esting Prototype Creation
Team's Last Machining Day
AIAA Paper Due to Josh
Testing Begins
Deployment Testing
Stray Light Testing
AIAA Paper Due
Senior Design Symposium Presentation and Poster Prep
Last Machining Day
Spring Break
Retesting and Result Compilation
Spring Final Review Prep
End of Testing
Senior Design Symposium Presentation and Poster Due
AES Industry Symposium
Spring Final Review Due
Spring Final Report Presentation
Project Final Report Prep
Last Day of Classes
Project Final Report Due
Finals Week
Graduation Day!
- Ordering and Development
- Class Deliverable Prep
- Class Presentations & Break
- Manufacturing
- Testing
- Critical Path

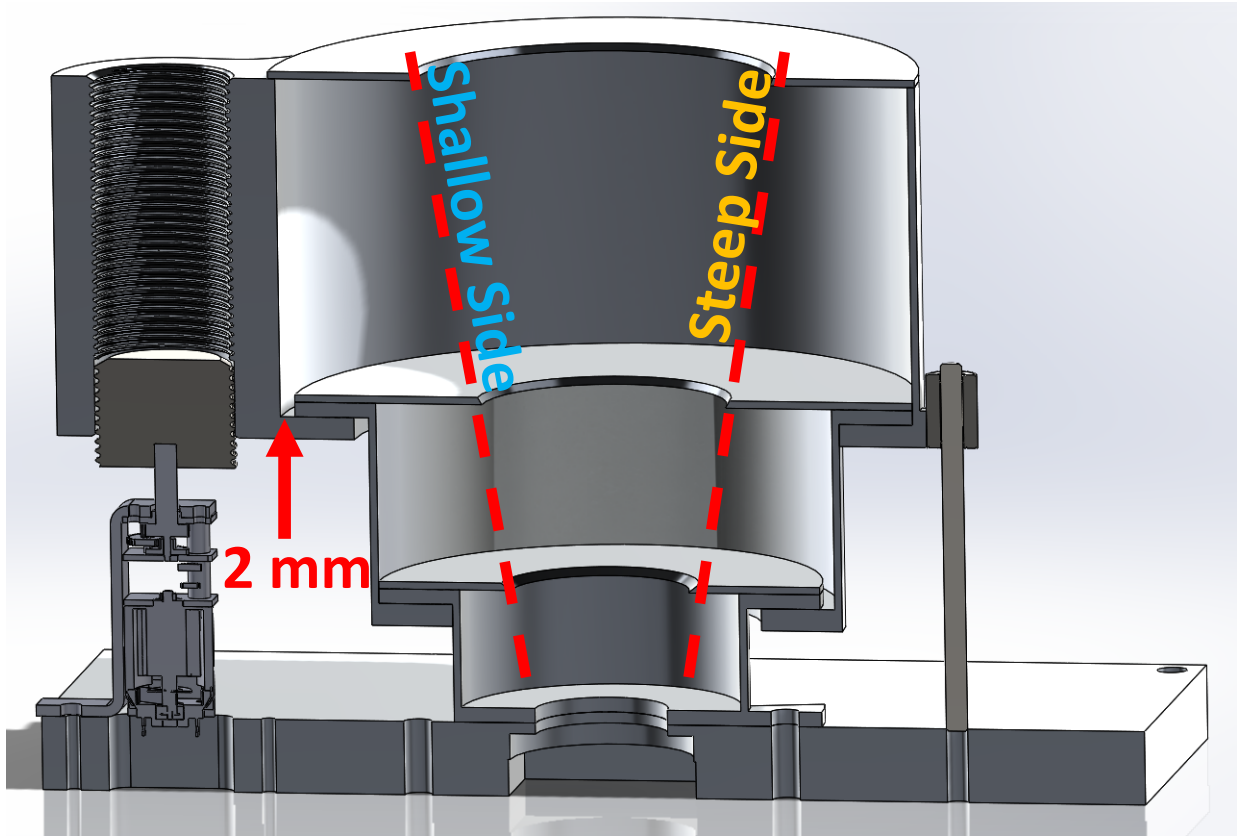
Specification – Final Model

- Baffle Model: Fully deployed with vanes and coating
- Resolution: 0.1°
- Angle Sweep: (0° to 30°)
- Number of rays from light source:
  - 200,000,000 rays

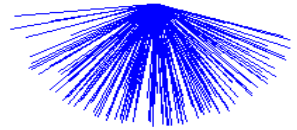


Specification - Asymmetric Test

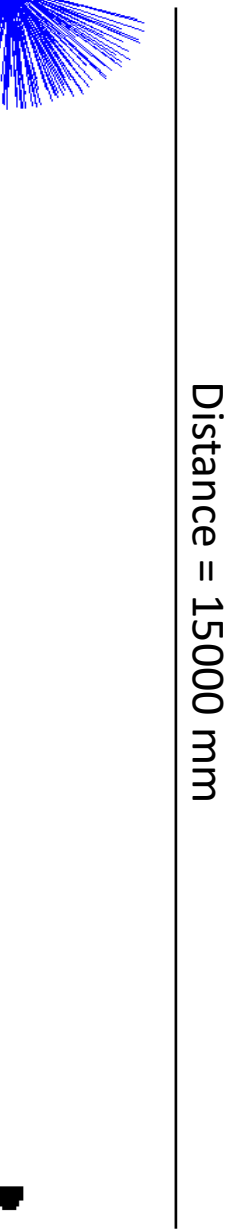
- Baffle Model: Maximum middle tier offset fully deployed with vanes and coating
- Resolution: 0.1°
- Angle Sweep: (0° to 30°)
- Number of rays from light source:
  - 10,000,000 rays



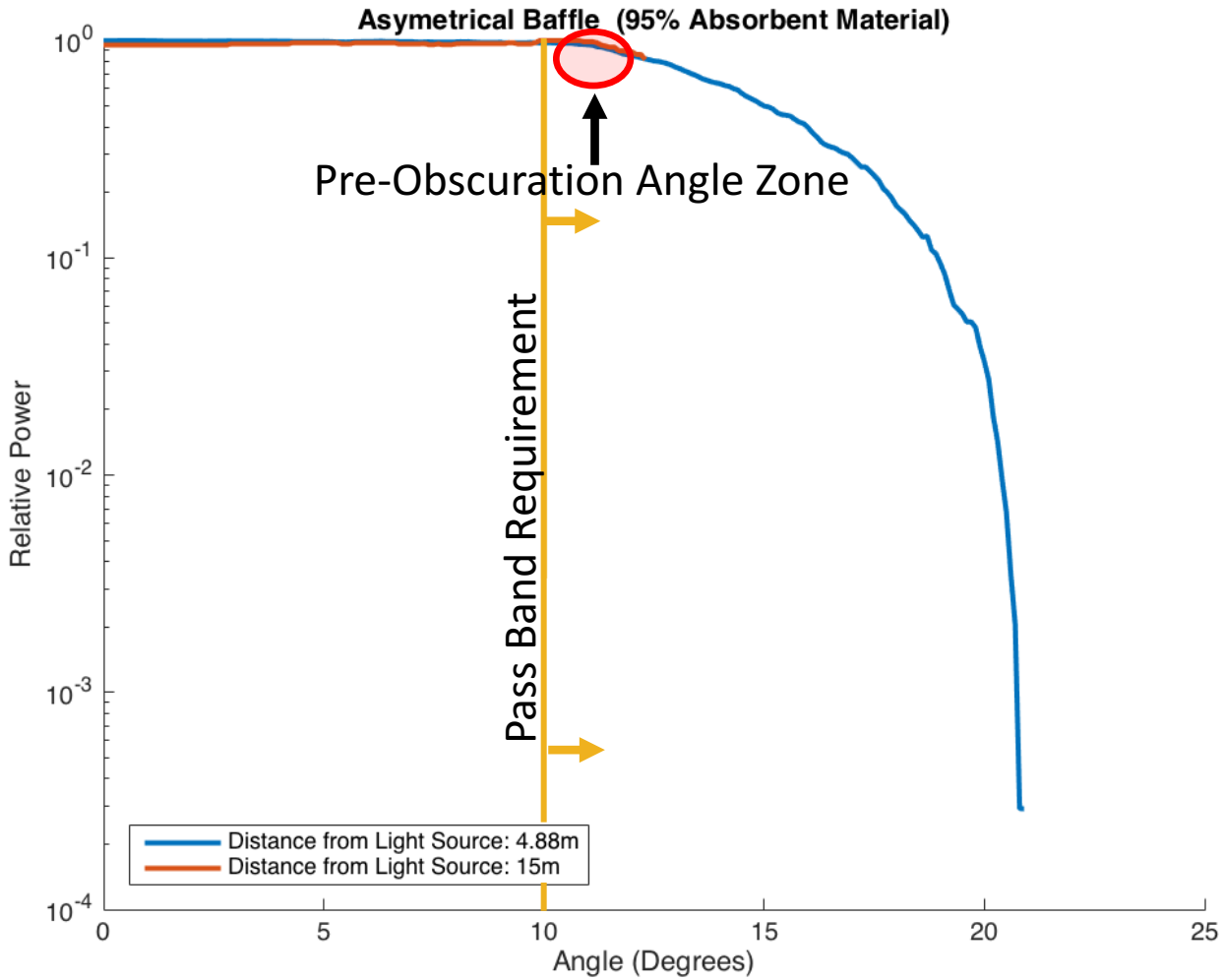
Specifications – Parallel Rays



- Baffle Model: Symmetric fully deployed with vanes and coating
- Resolution: 0.1°
- Angle Sweep: (0° to 12.4°)
- Distance: 15 m
- Number of rays from light source:
  - 200,000,000 rays



Results – Parallel Rays

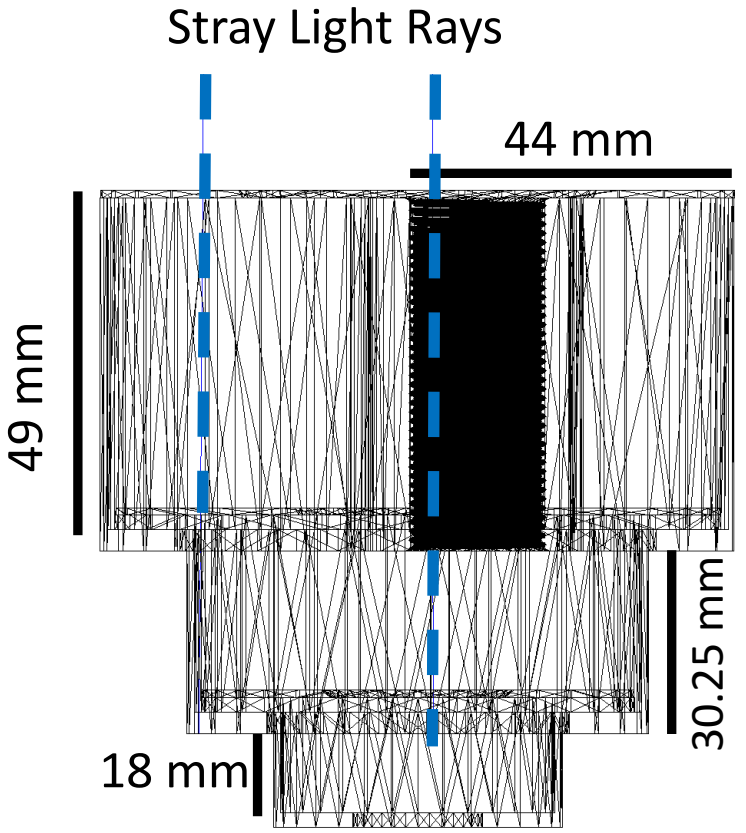


	15m	4.88m
Pre-Obscuration Angle	11.4°	11.1°
Obscuration Angle	N/A	20.7°

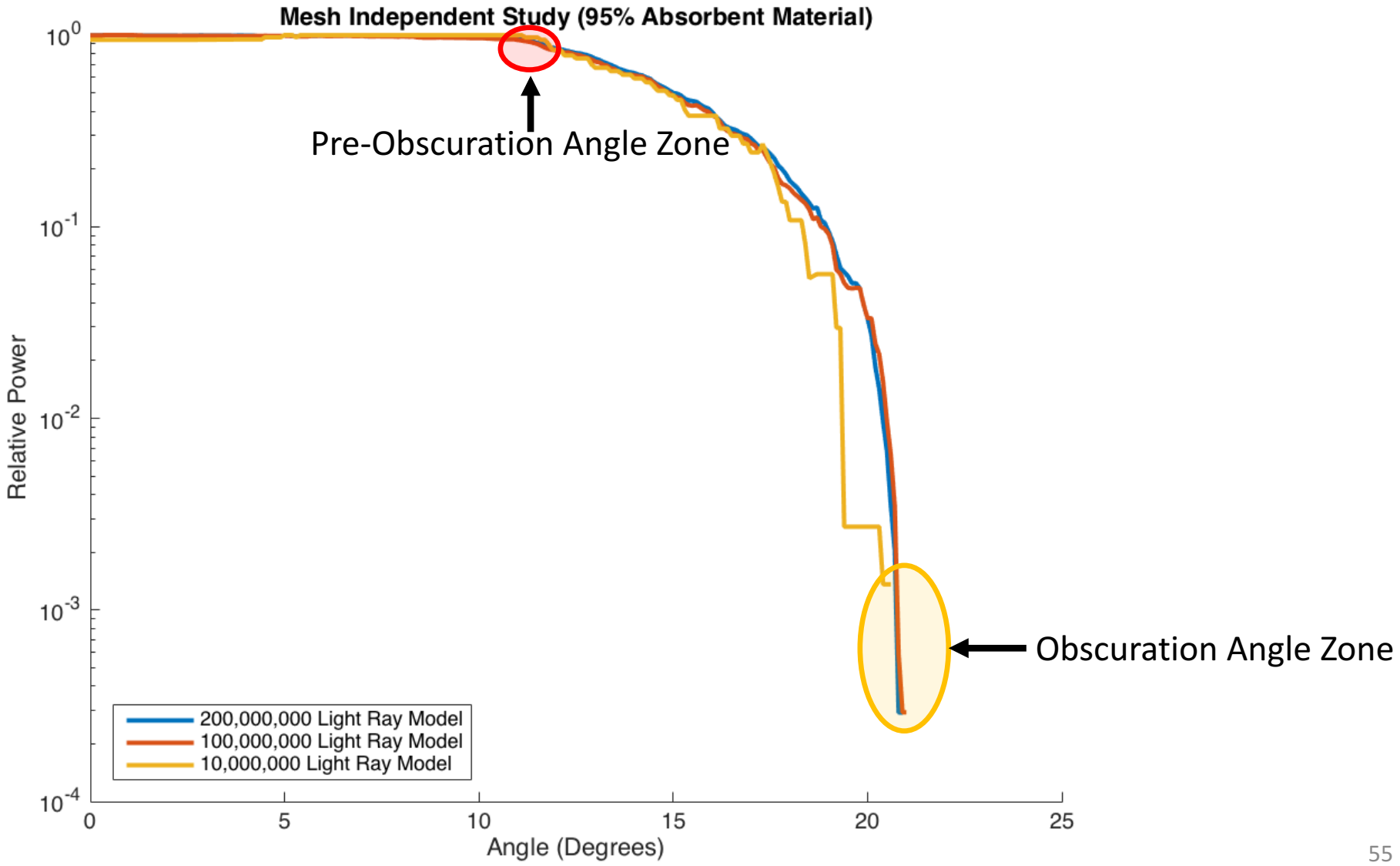
	15m	4.88m
Angle From Parallel	0.19°	0.58°

Specifications - Mesh Independence

- Baffle Model: Symmetric fully deployed with vanes and coating
- Resolution: 0.1°
- Angle Sweep: (0° to 30°)
- Distance: 4.88 m
- Number of rays from light source:
  - 10,000,000 rays
  - 100,000,000 rays
  - 200,000,000 rays



Results-Mesh Independence



Analysis-Mesh Independence

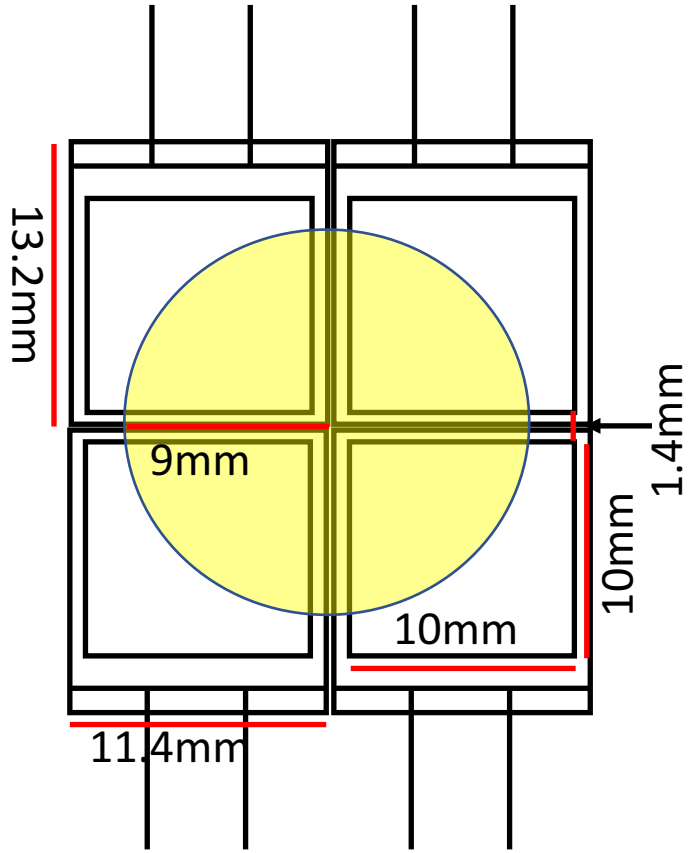
	Requirement	10,000,000 Rays	100,000,000 Rays	200,000,000 Rays (Truth)
Pre-Obscuration	>10°	11.5°	10.9°	11.1°
Obscuration	<30°	21.1°	20.7°	20.7°

$$Percent\ Error = \frac{|Experimental\ - Truth|}{Truth} \text{ x } 100$$

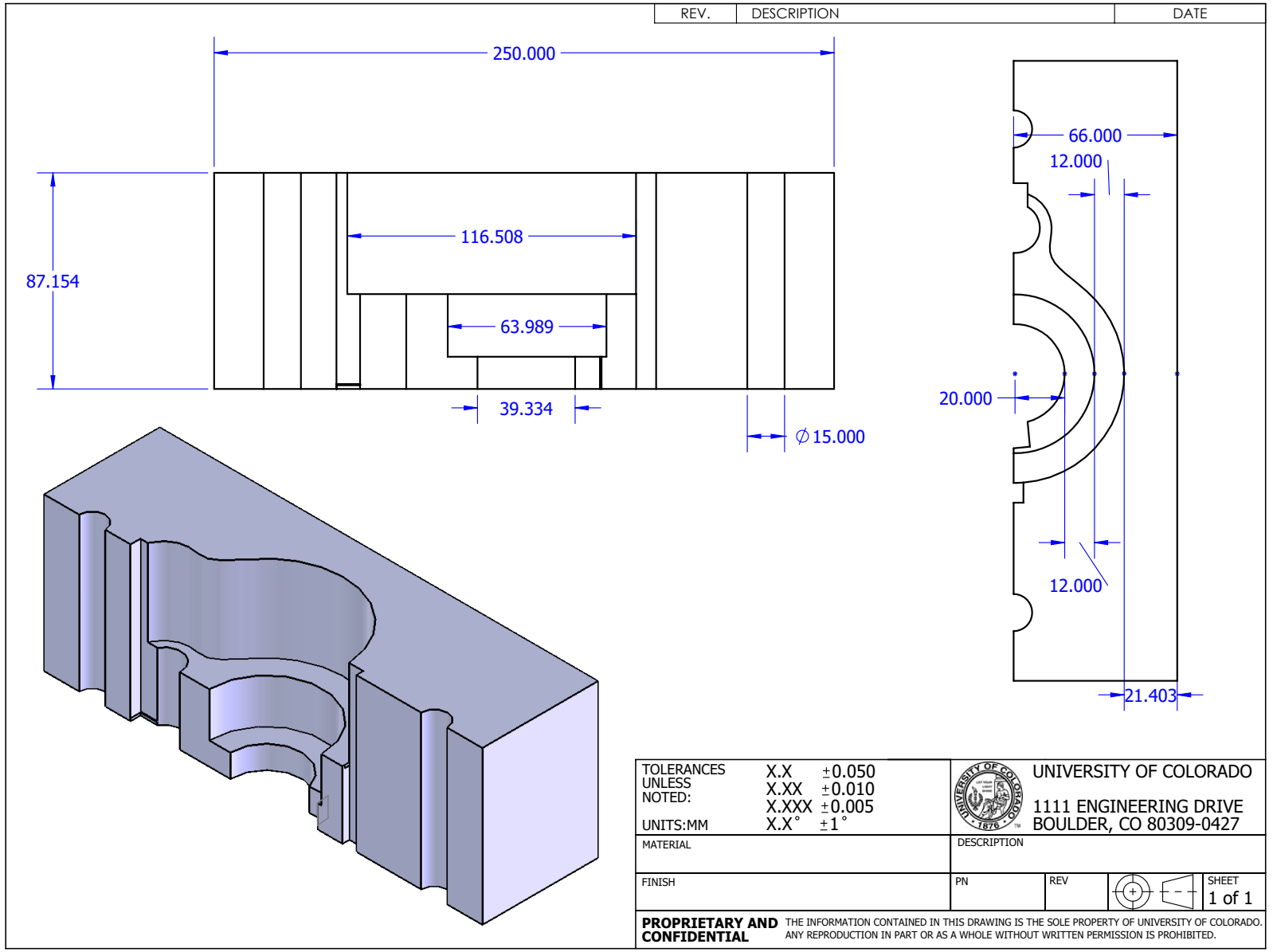
	10,000,000 Rays	100,000,000 Rays
Pre-Obscuration Error	3.6%	1.8%
Obscuration Error	1.9%	0

Specification – 4 Photodiodes

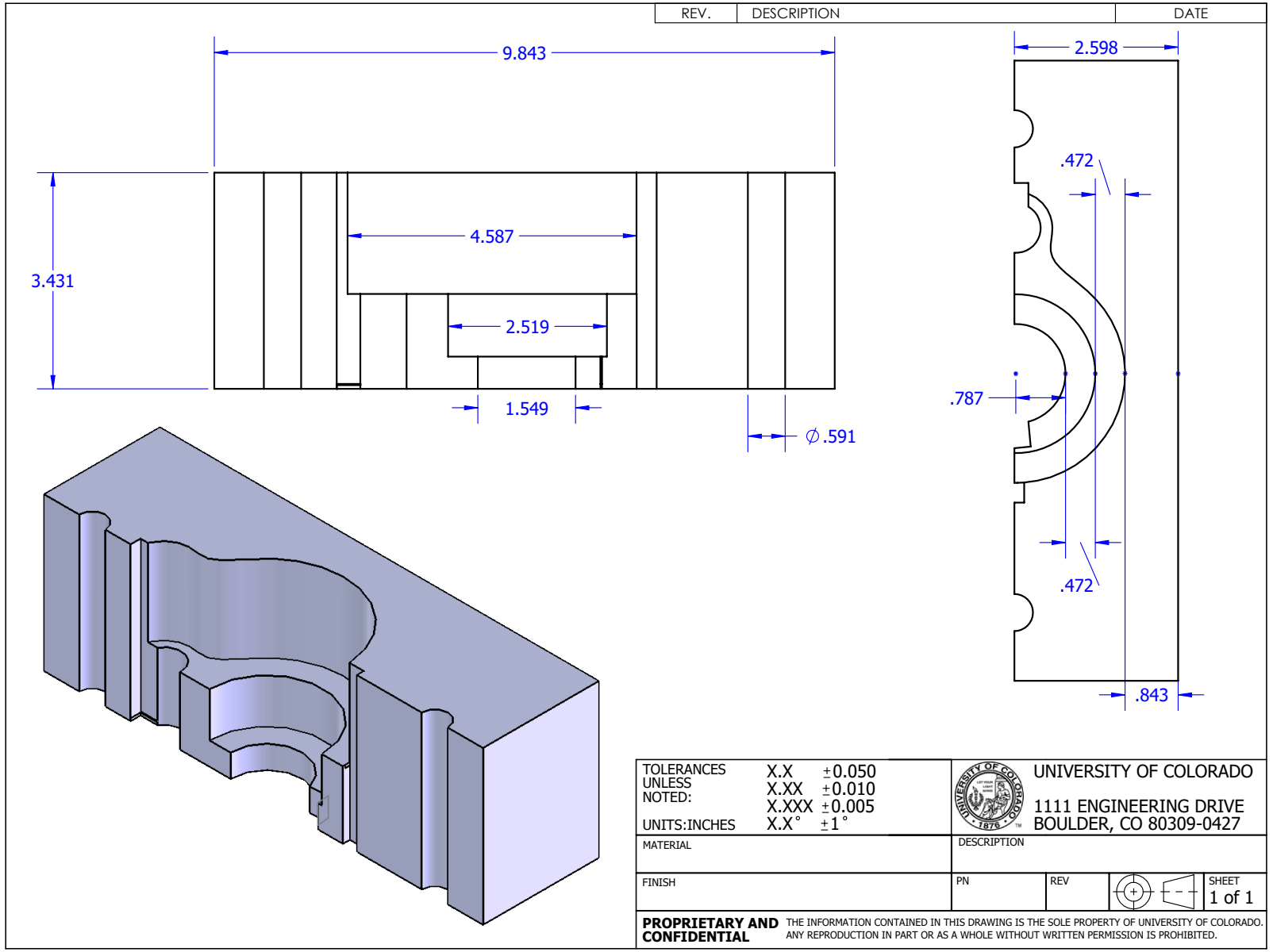
- Baffle Model: Maximum middle tier offset fully deployed with vanes and coating
- Resolution: 0.1°
- Angle Sweep: (0° to 30°)
- Number of Detectors: 4
- Number of rays from light source:
  - 10,000,000 rays
- Not Completed as of (03/06/17)



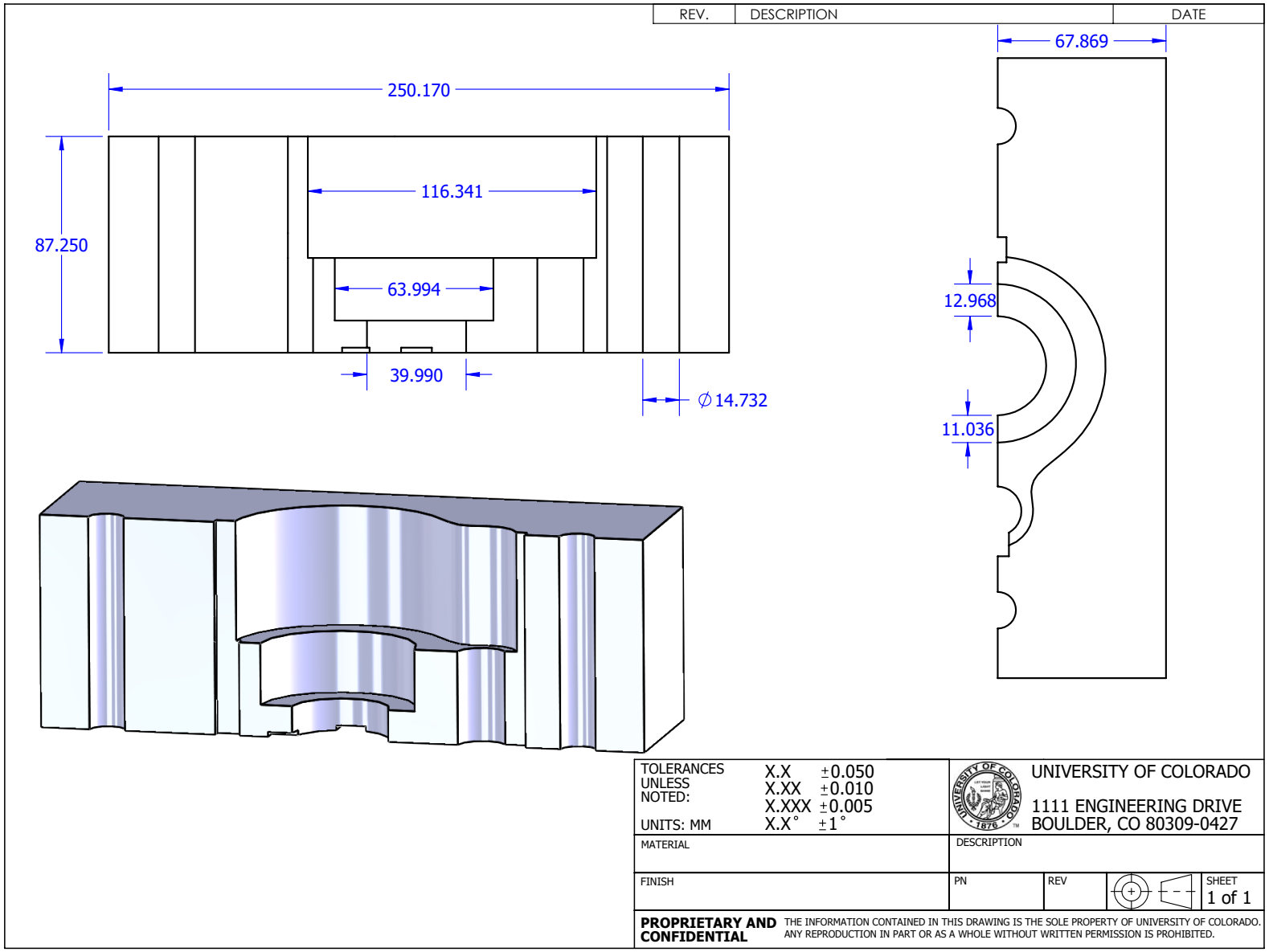
MOLD A – horizontal orientation, symmetrical lineup (metric units)



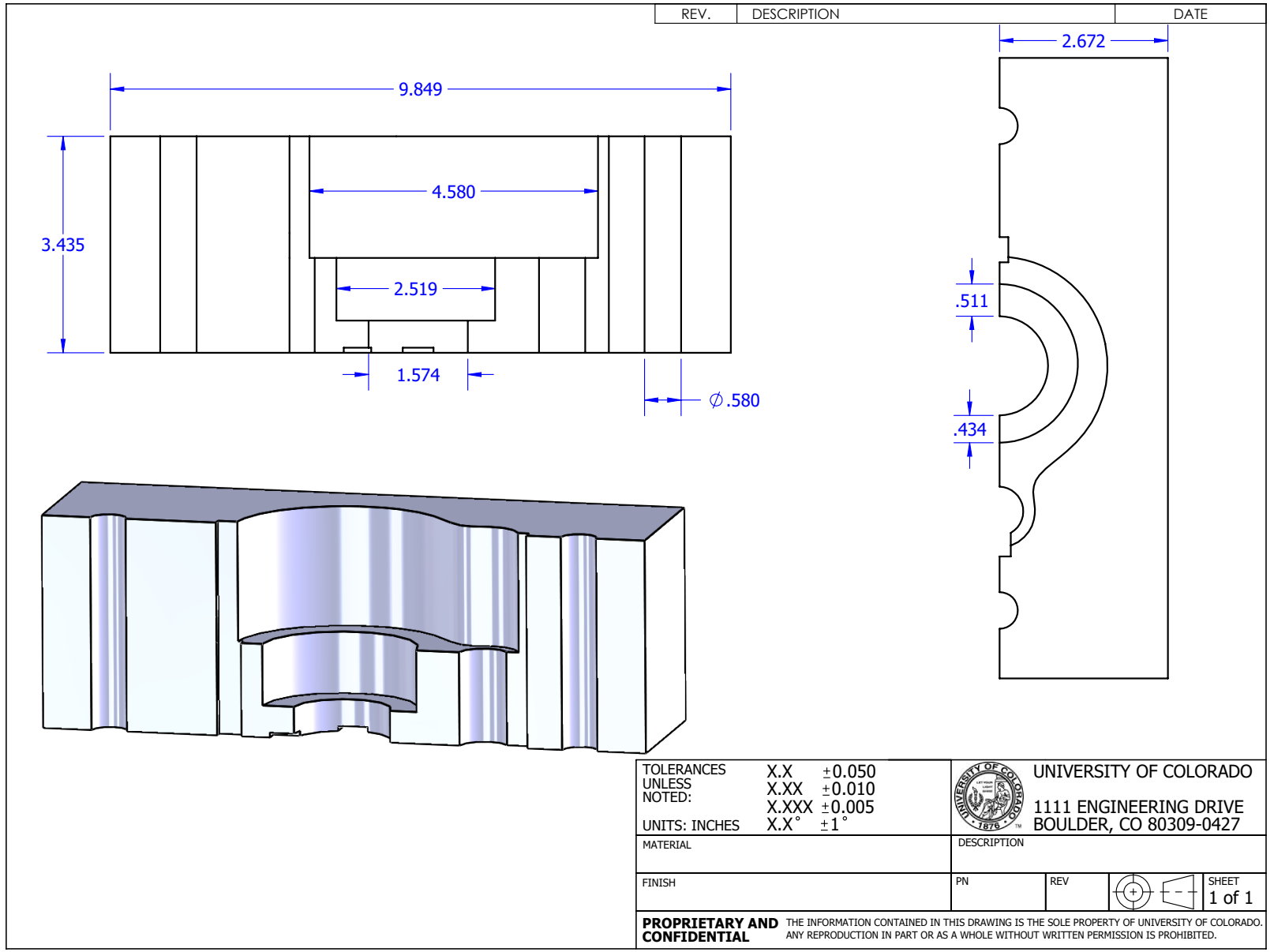
MOLD A – horizontal orientation, symmetrical lineup (English units)



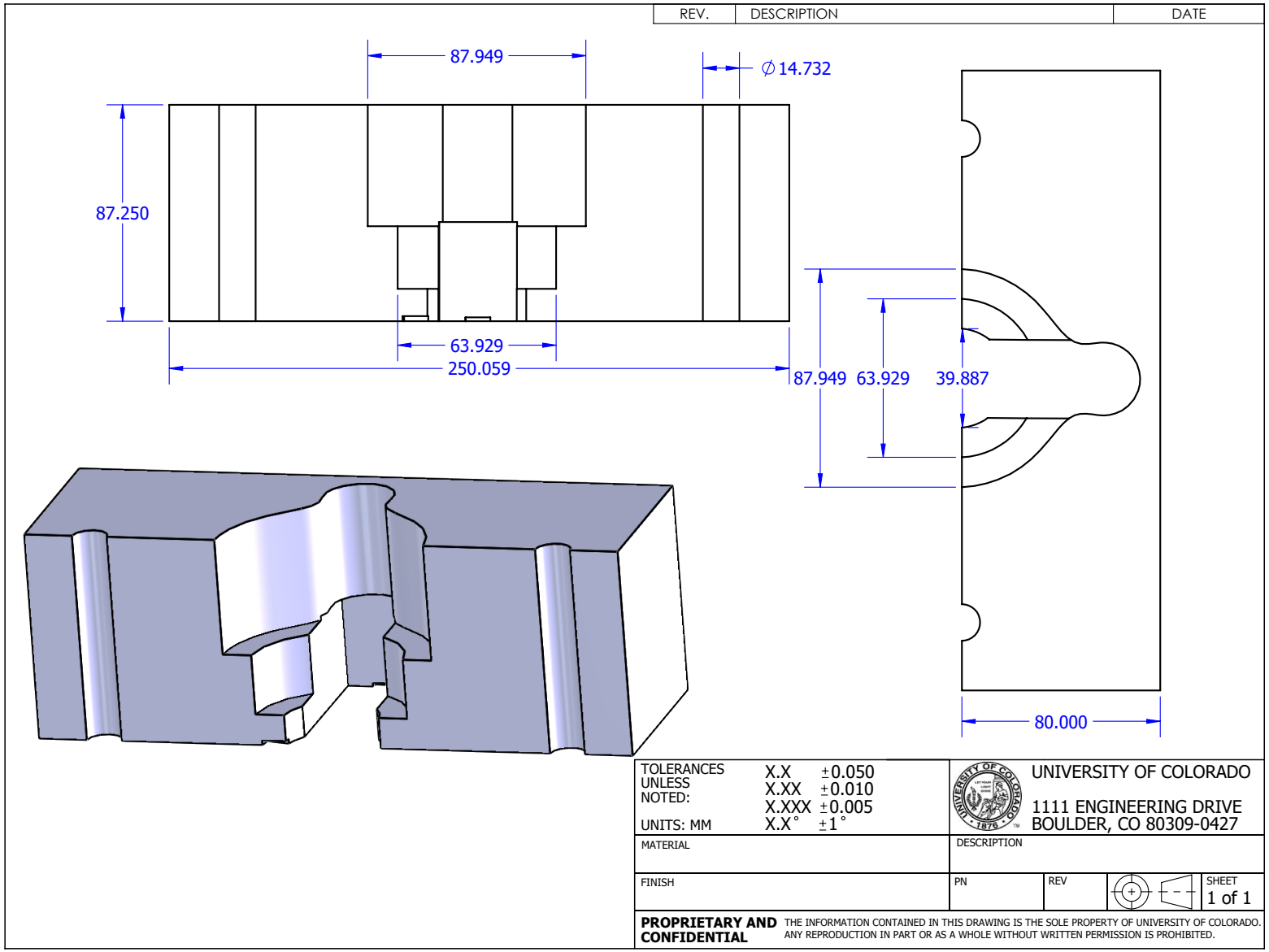
MOLD B – horizontal orientation, asymmetrical lineup (metric units)



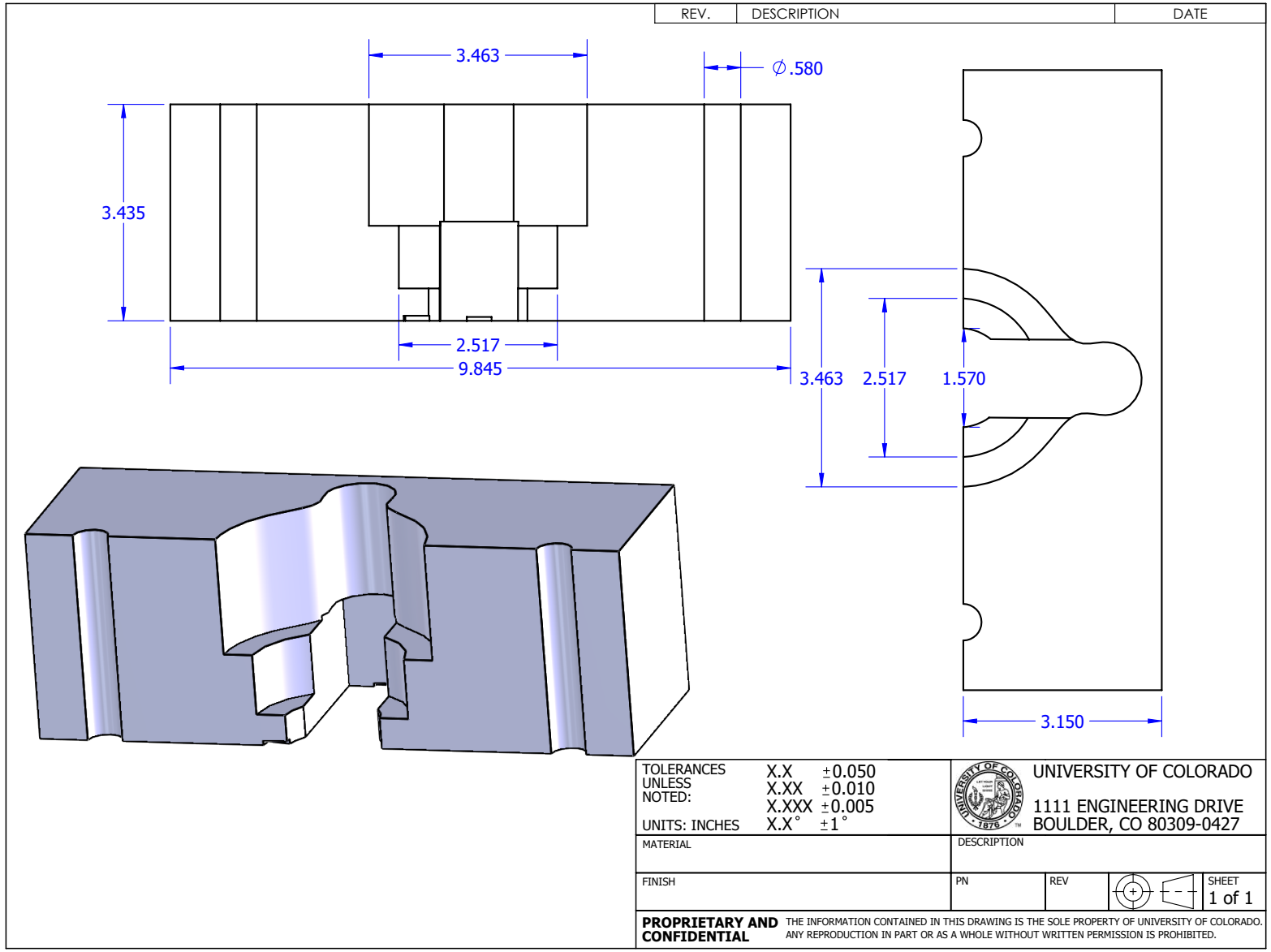
MOLD B – horizontal orientation, symmetrical lineup (English units)



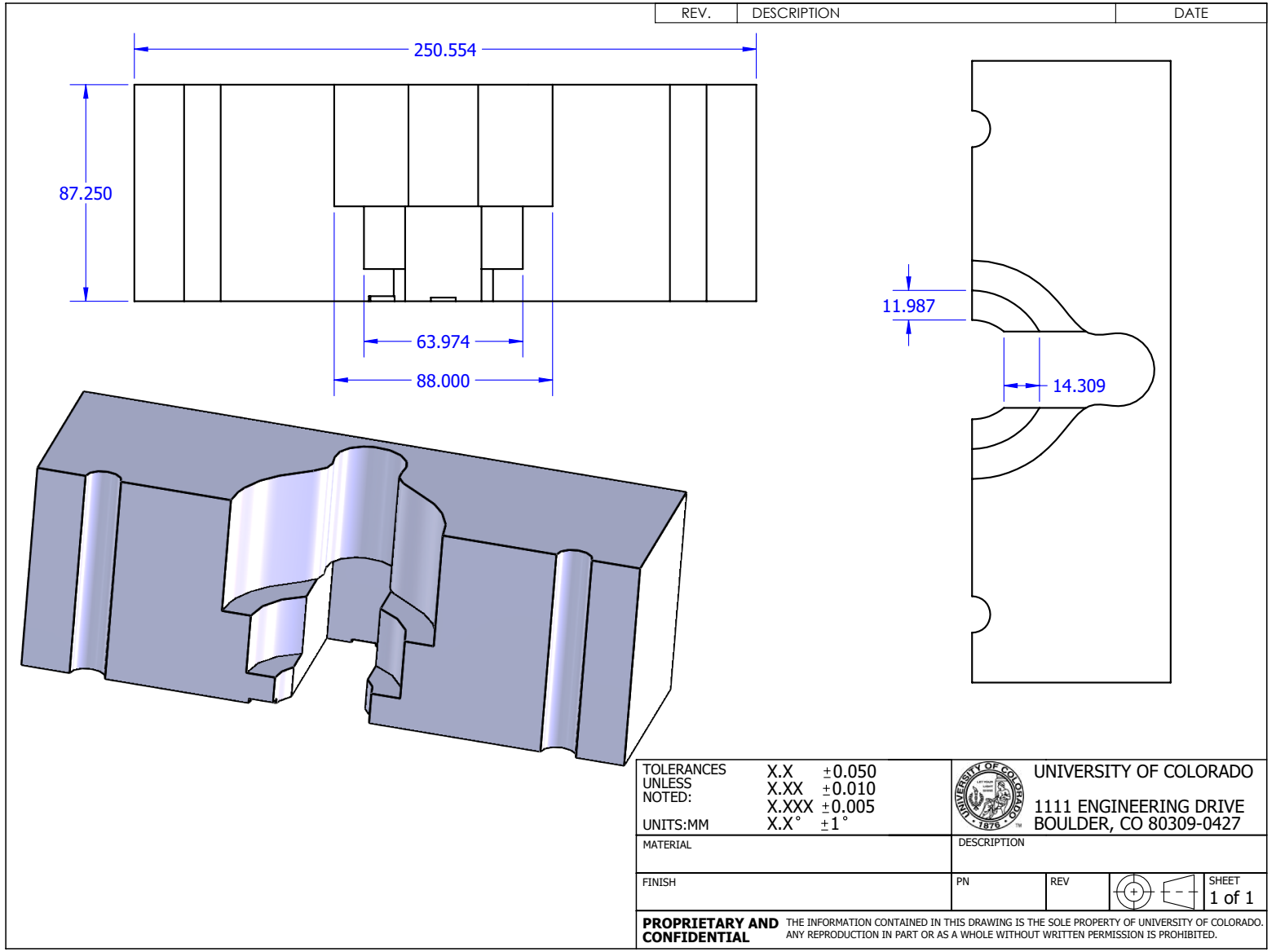
MOLD C – vertical orientation, symmetrical lineup (metric units)



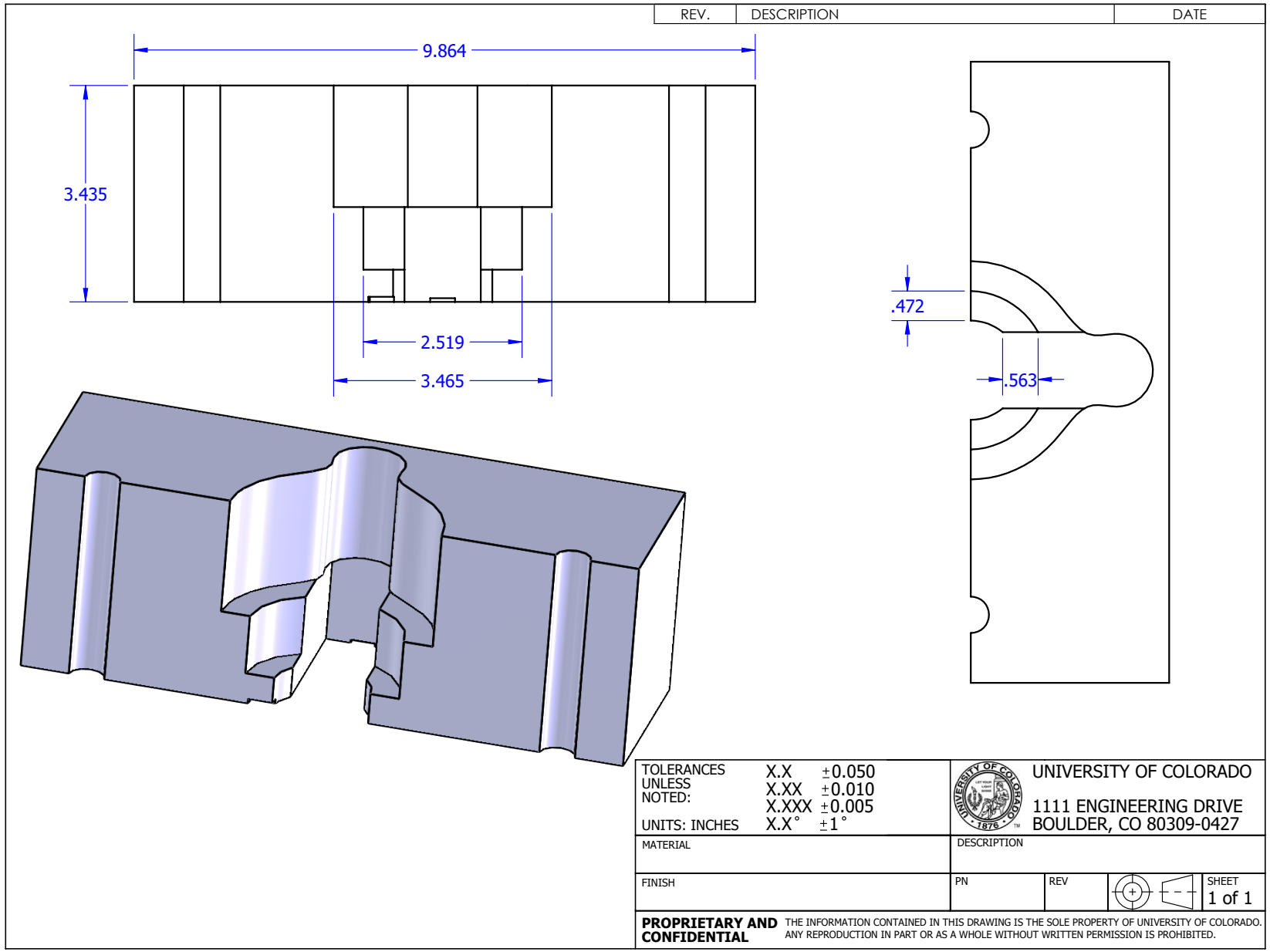
MOLD C – vertical orientation, symmetrical lineup (English units)



MOLD D – vertical orientation, asymmetrical lineup (metric units)

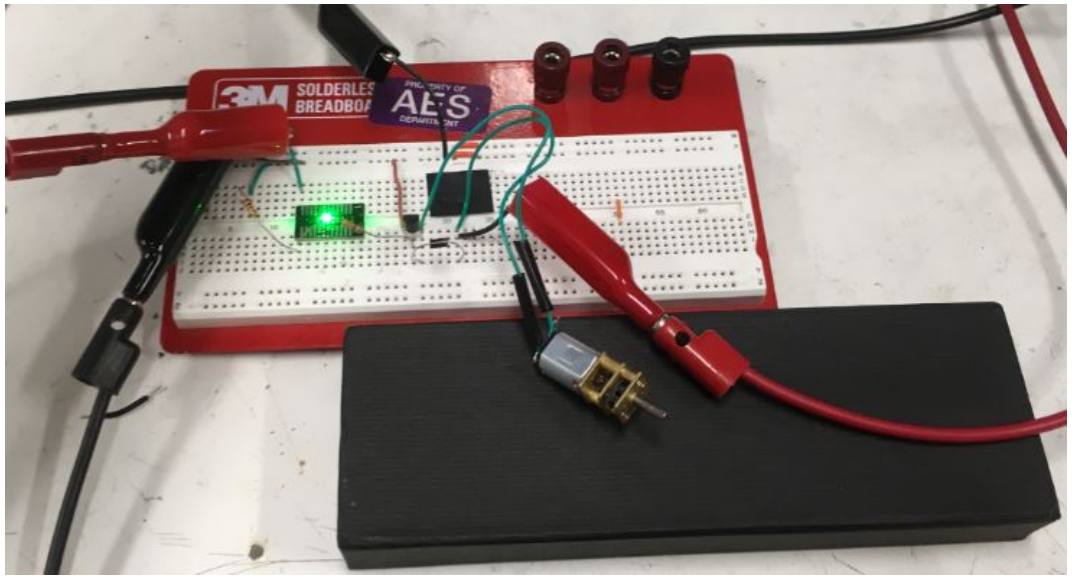


MOLD C – vertical orientation, asymmetrical lineup (English units)



Electronic Circuits – Breadboard Testing

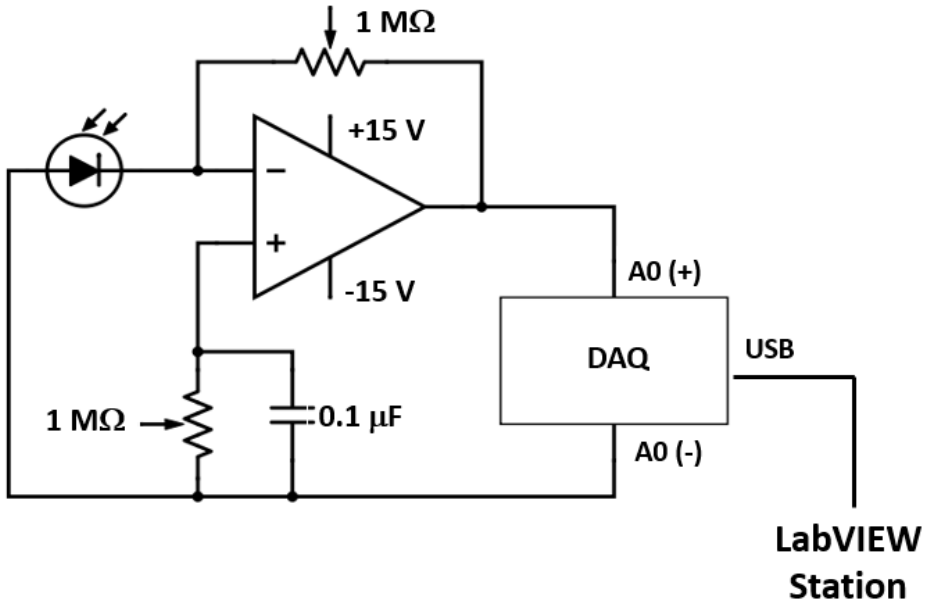
Motor Deployment Circuit/Kill Switch



- STATUS: Verified via breadboard test
- PLAN: Order PCB and solder components
- COMPLETION: March 14
- ADDITIONAL INFO: Phototransistor is only sensitive to high intensity green light (530 nm)
  - Dark room not required for deployment testing
  - Personnel safety hazards reduced due to well lit testing area

Electronic Circuits – Breadboard Testing

Sensor and Amplifier Circuit



- STATUS: Breadboard testing in progress (March 6)
- PLAN: Complete testing, order PCB, and solder components
- COMPLETION: March 14
- ADDITIONAL INFO: Breadboard testing delayed due to the need for cleanroom controls for safe handling of component
  - Colorado Nanofabrication Laboratory granted free access
  - Photodiode soldering will also be performed at this site
  - Light attenuation testing will also be performed at this site

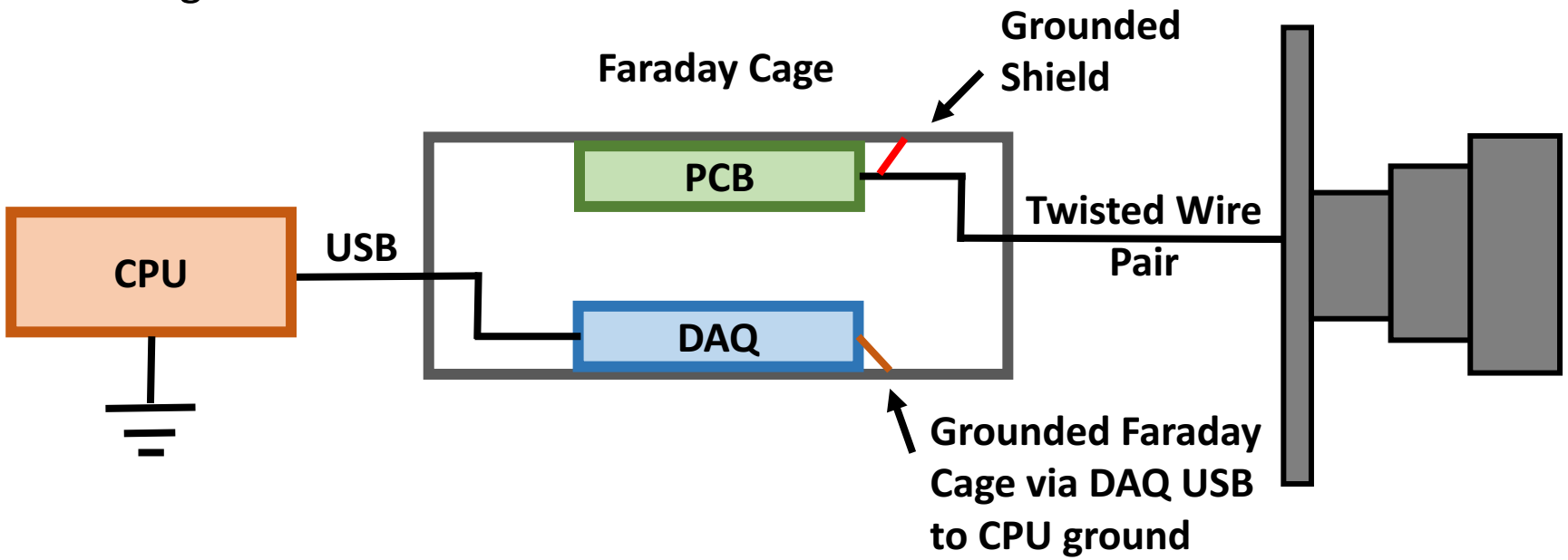
Cleanroom Controls

- **Granted free access to Colorado Nanofabrication Laboratory cleanroom facility**
  - Typically $58/hour
- **Class 1000 cleanroom – Fewer particles than normal ambient air by a factor of 1000**
  - Cleaner than a Class 10,000 cleanroom
- **Considered necessary for safe handling of Hamamatsu photodiode**
- **Additional equipment required**
  - Blue coat and booties
- **Night access granted to facilitate clean Light Attenuation testing**
  - Eliminates need to hermetically seal the filter/photodiode assembly on the baffle baseplate

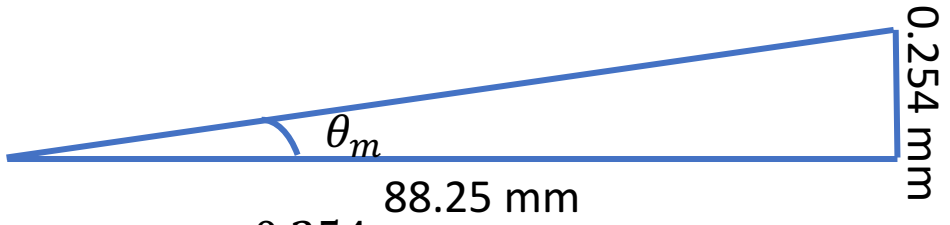
Sensor and Amplifier Circuit – Noise Reduction

- Twisted, shielded wire pair for photodiode leads
  - Ground shield to reduce noise

- Faraday Cage – Metal enclosure for circuit
  - Grounded via GND pin on DAQ to reduce noise
  - Salvaged from Electronics Lab

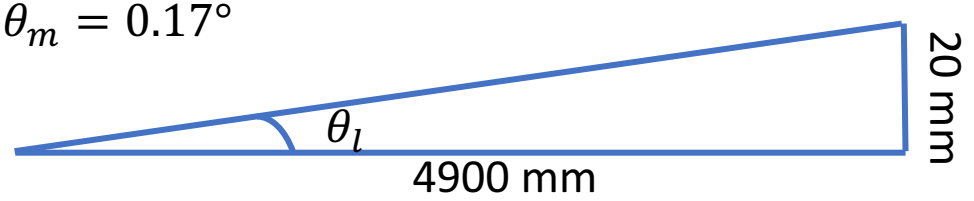


Orientation Verification



$$\theta_m = \tan^{-1}\left(\frac{0.254}{88.25}\right)$$

$$\theta_m = 0.17°$$



$$\theta_l = \tan^{-1}\left(\frac{20}{4900}\right)$$

$$\theta_l = 0.23°$$

$$\theta = \theta_l + \theta_m$$

$$\theta = 0.23° + 0.17°$$

$$\theta = 0.40°$$