COMPASS

*University of **<u>CO</u>**lorado **<u>M</u>**odel **<u>P</u>**ositioning - St**<u>A</u>**tic - **<u>S</u>**y**<u>S</u>**tem*

Test Readiness Review

02 March 2016

Nicholas Gilland, Brandon Harris, Kristian Kates, Ryan Matheson, Amanda Olguin, Kyle Skjerven, Anna Waltemath, Alex Wood

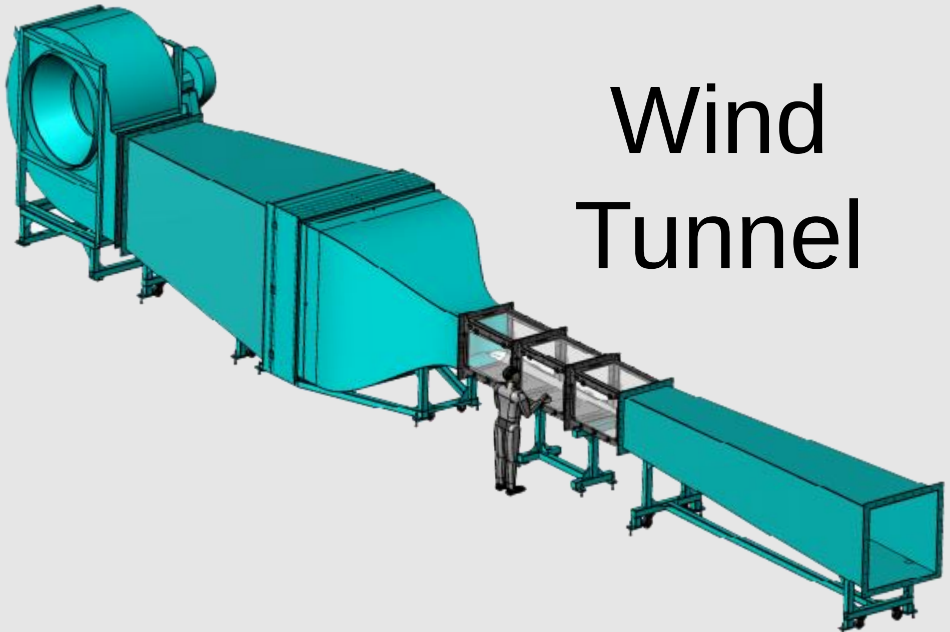
Agenda

Section	Presenter
Overview	Alex
Schedule	Mandy
Test Readiness	Kristian & Nick
Budget	Mandy

Overview

Project Purpose and Objectives

Provide a model positioning system for the wind tunnel on East Campus



Wind Tunnel

- **Statically position a model in 4 DoF**
- **Mobility of entire system**
- **Easily maintainable for future use**
- **Interface with current wind tunnel**
- **Failsafes within hardware and software**

Levels of Success

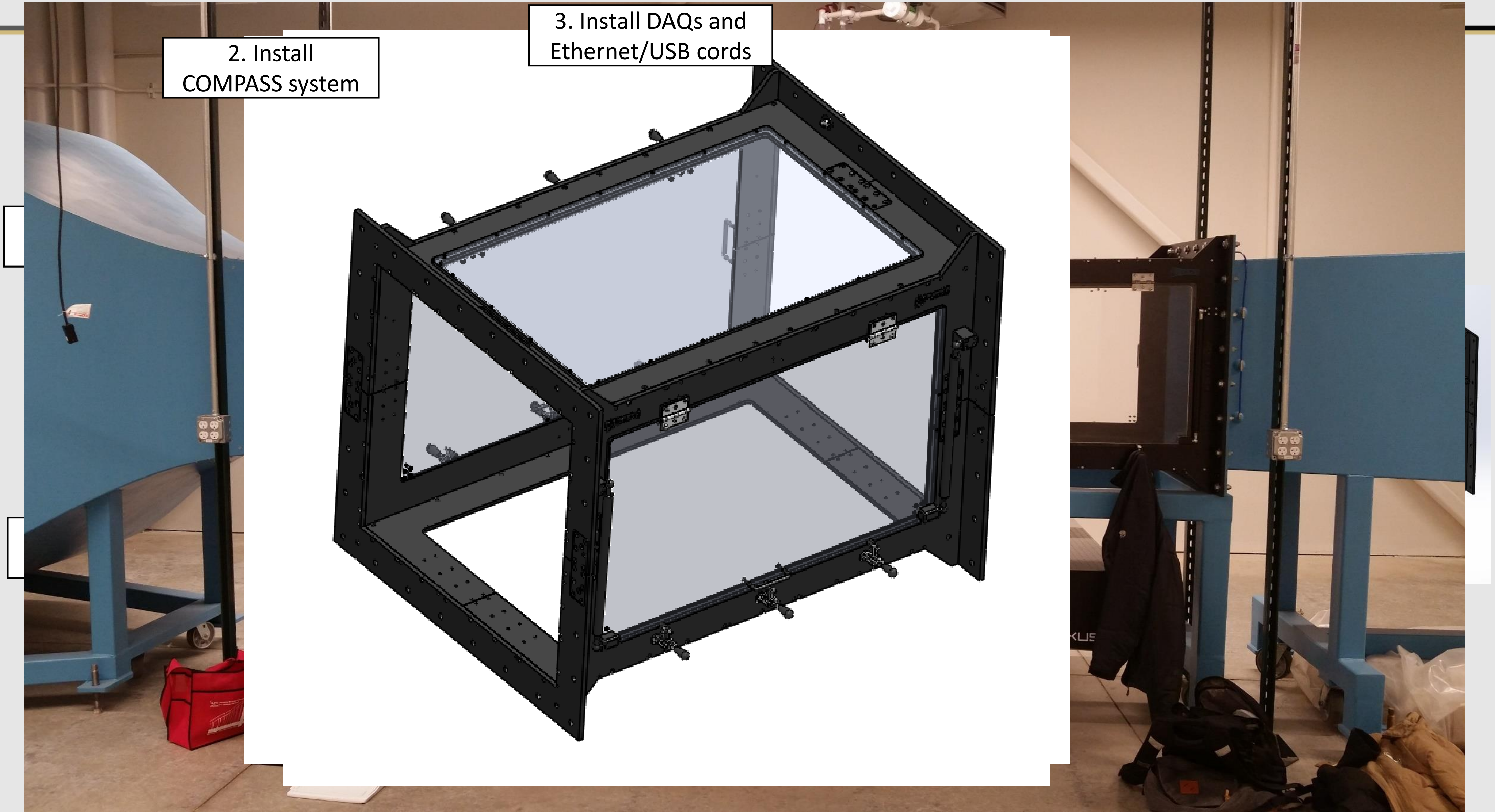
	DoF	Range	Position/Angular Accuracy	Testing Expectations	Levels of Communication
Level 1	Pitch Yaw	Pitch = ± 30° Yaw = ± 30°	Pitch = ± 0.1° Yaw = ± 0.1°	Basic verification of movement	Command through local computer
Level 2	“ “ Roll	“ “ Roll = ± 45°	“ “ Roll = ± 0.5°	VICON w/o static load	“ “
Level 3	“ “ Plunge	“ “ Plunge = ± 10 cm	“ “ Plunge = ± 5 mm	VICON w/ static load	Remote command through local area network
Level 4	“ “	“ “	“ “	In tunnel w/ aerodynamic load	“ “

Highest Level of Success Reached by:

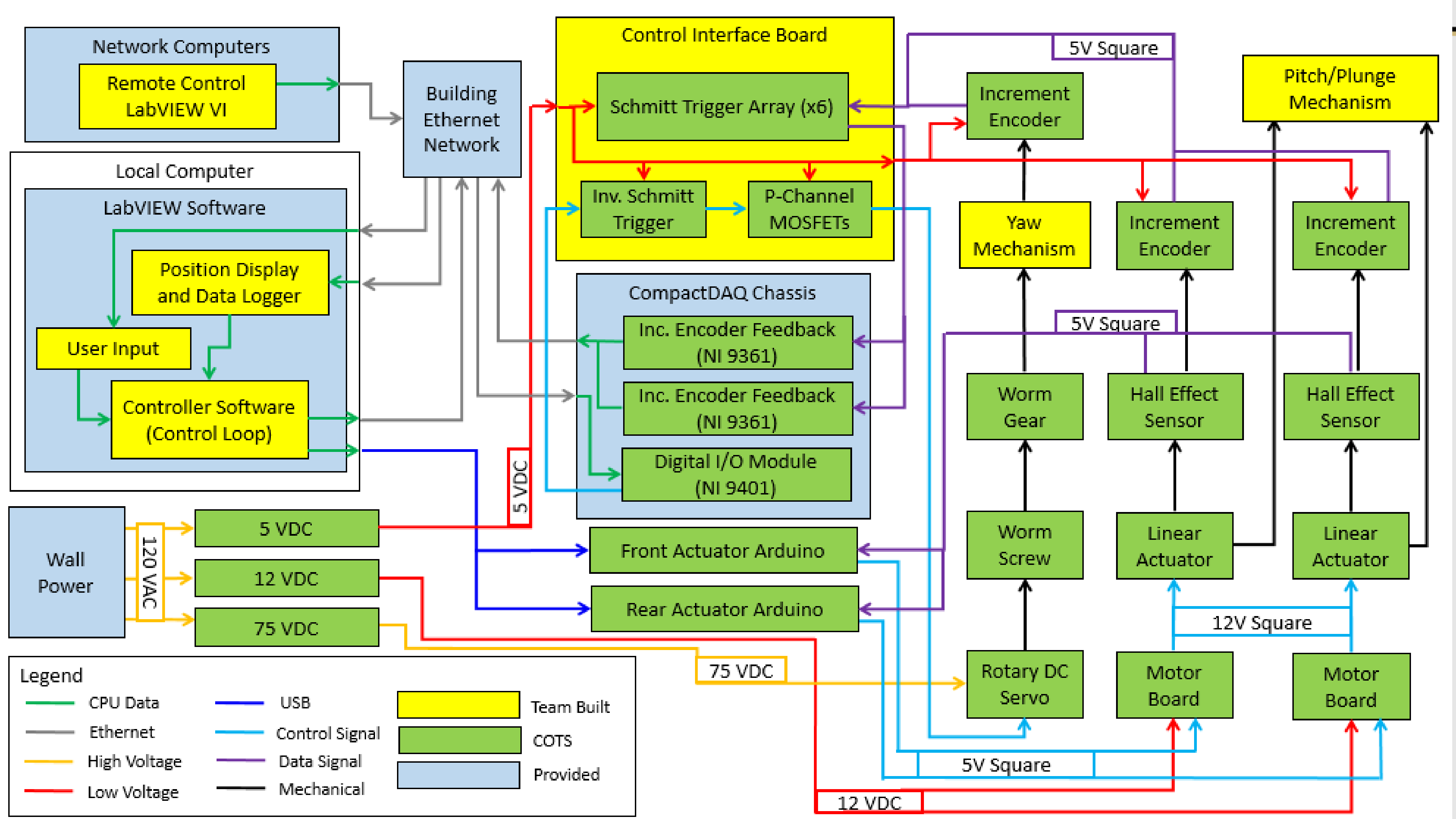
Complete by Design Symposium (Level 3)

Complete by End of Semester (Level 4)

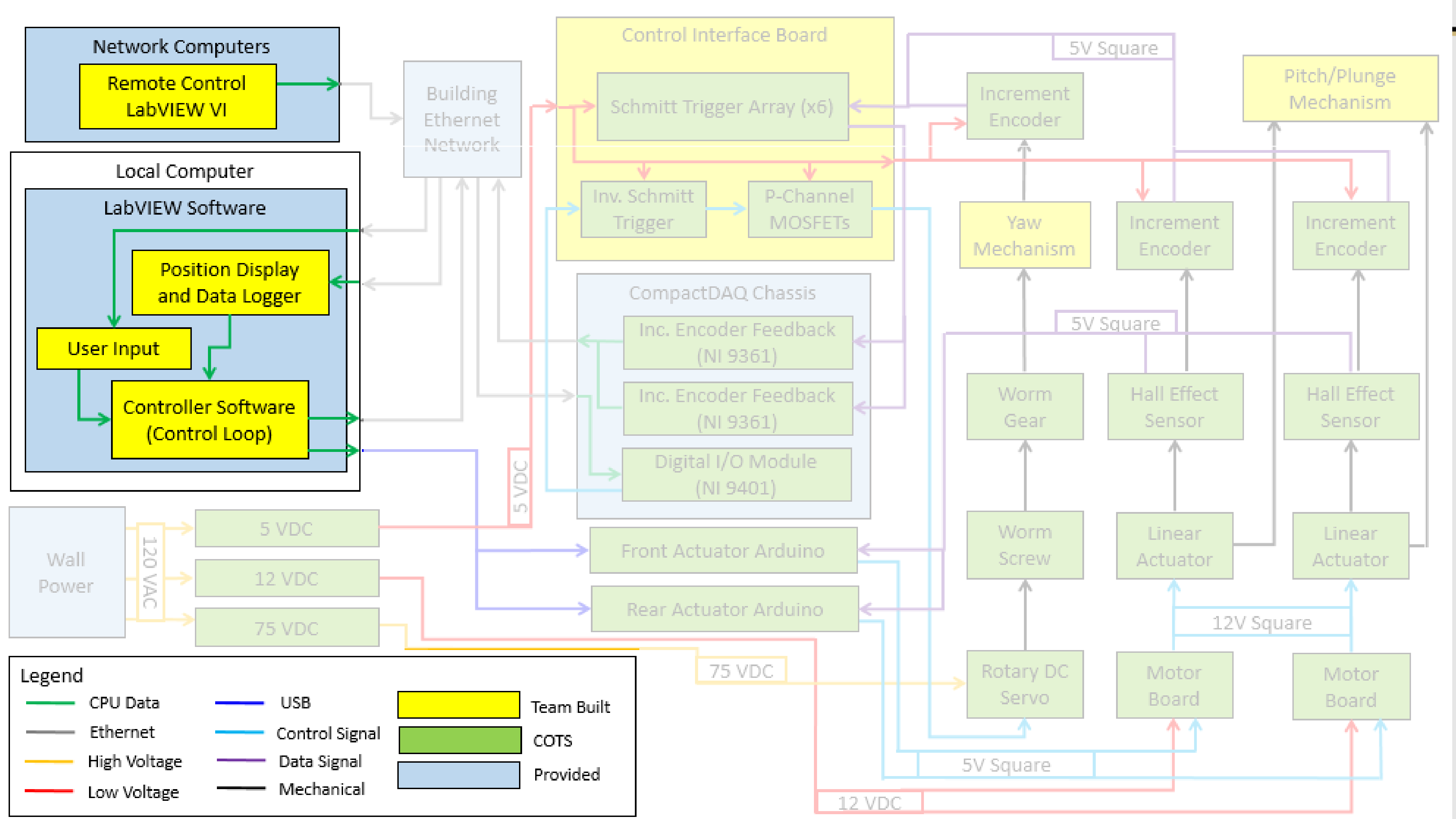
Operational CONOPS



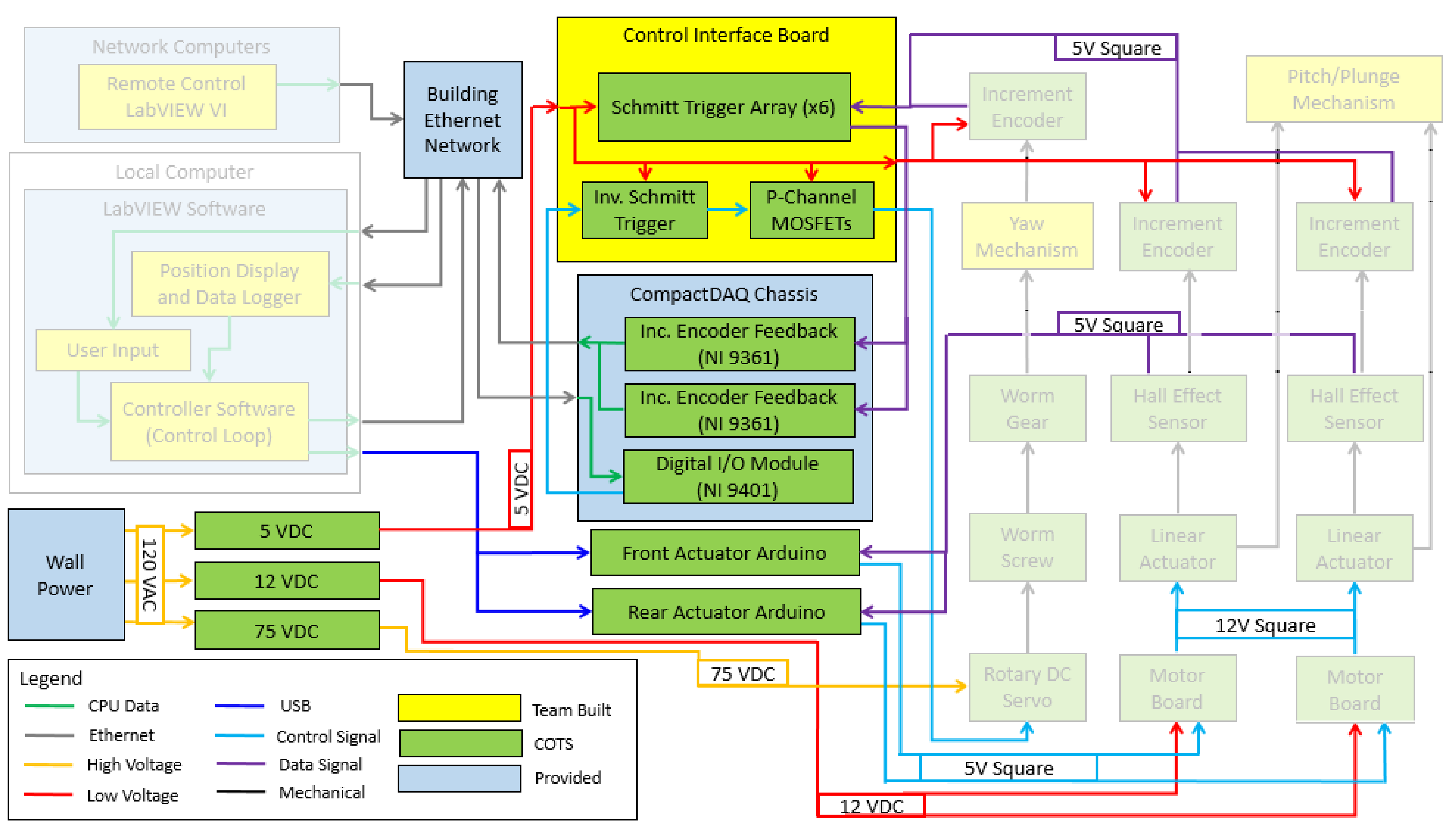
Functional Block Diagram



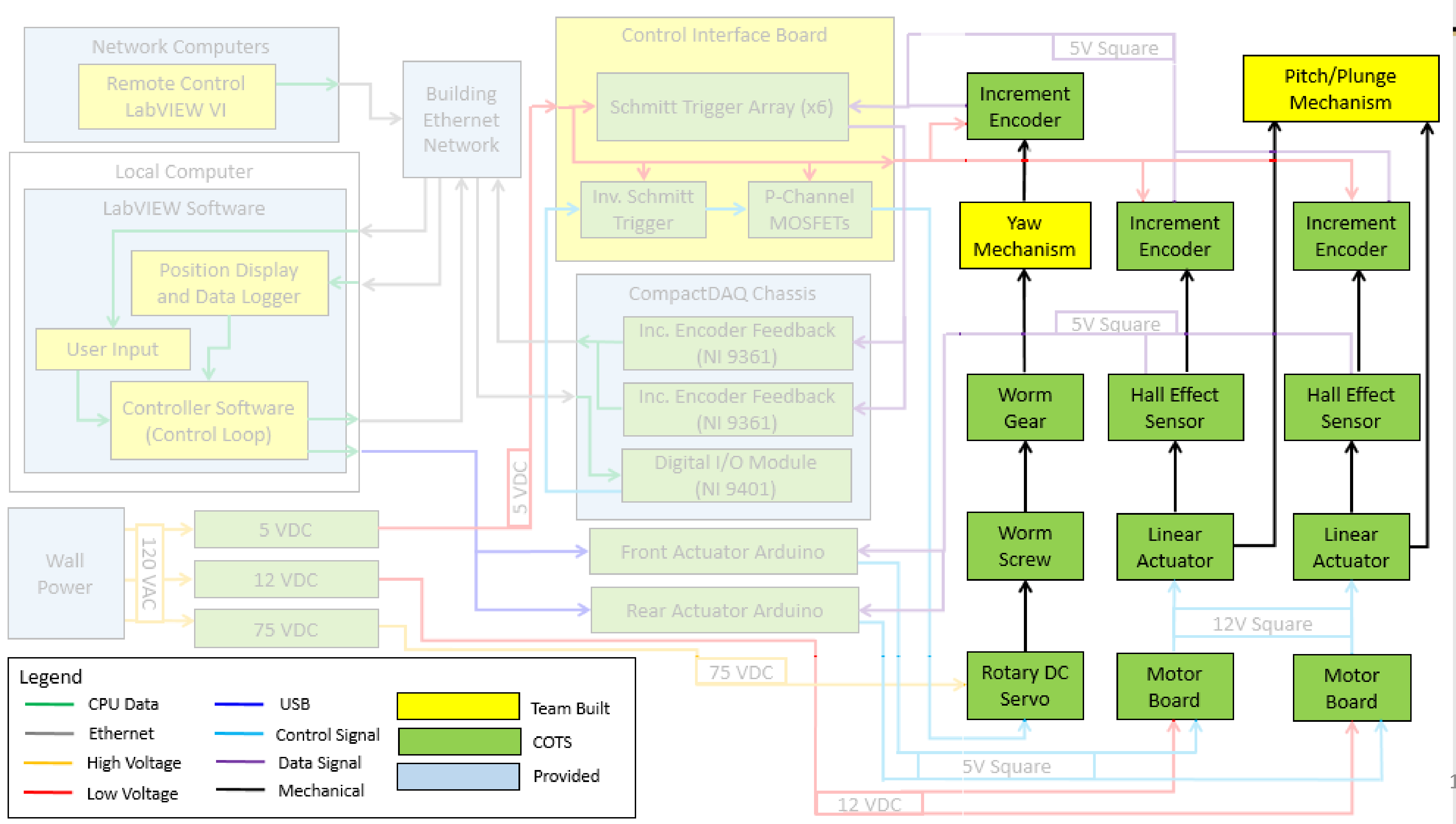
FBD - Computer/Software



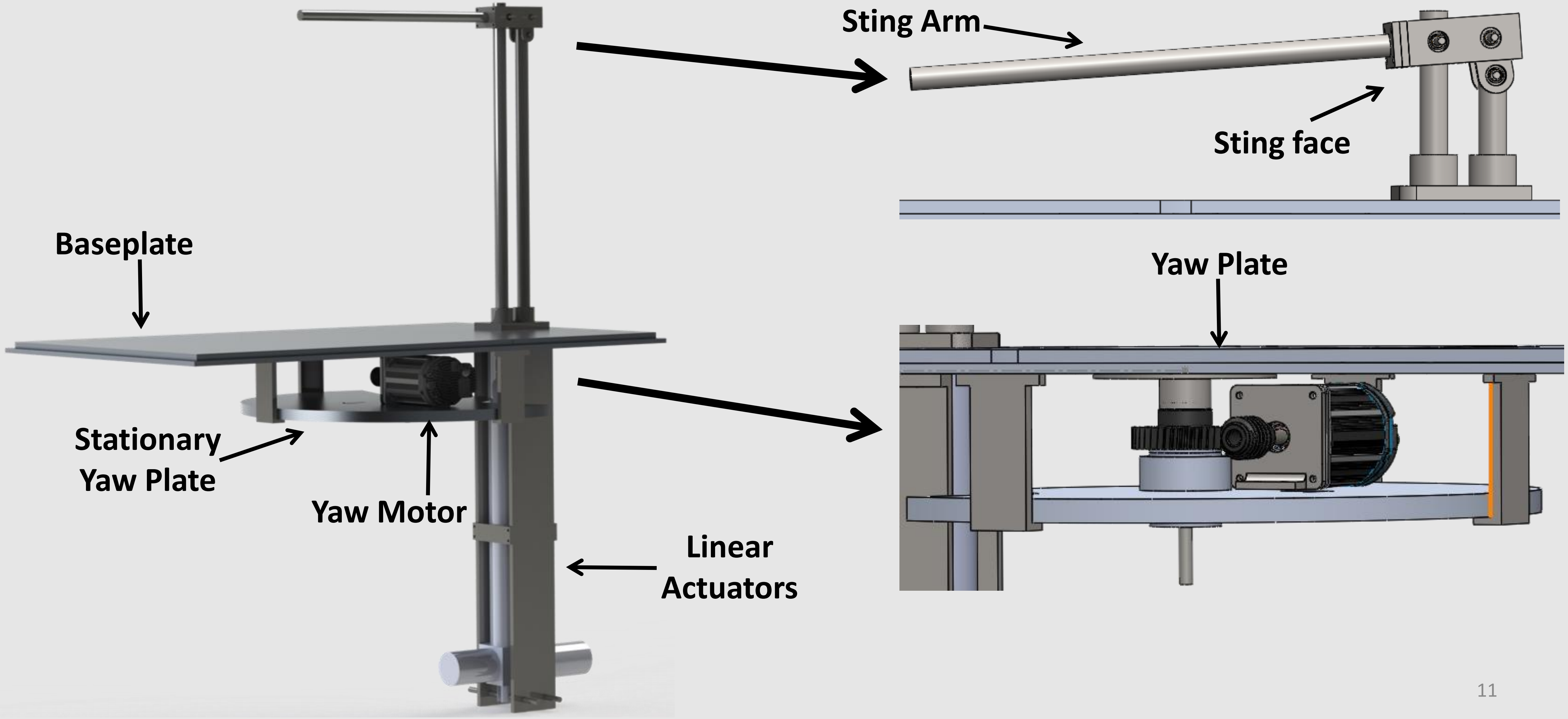
FBD - Electrical Interface



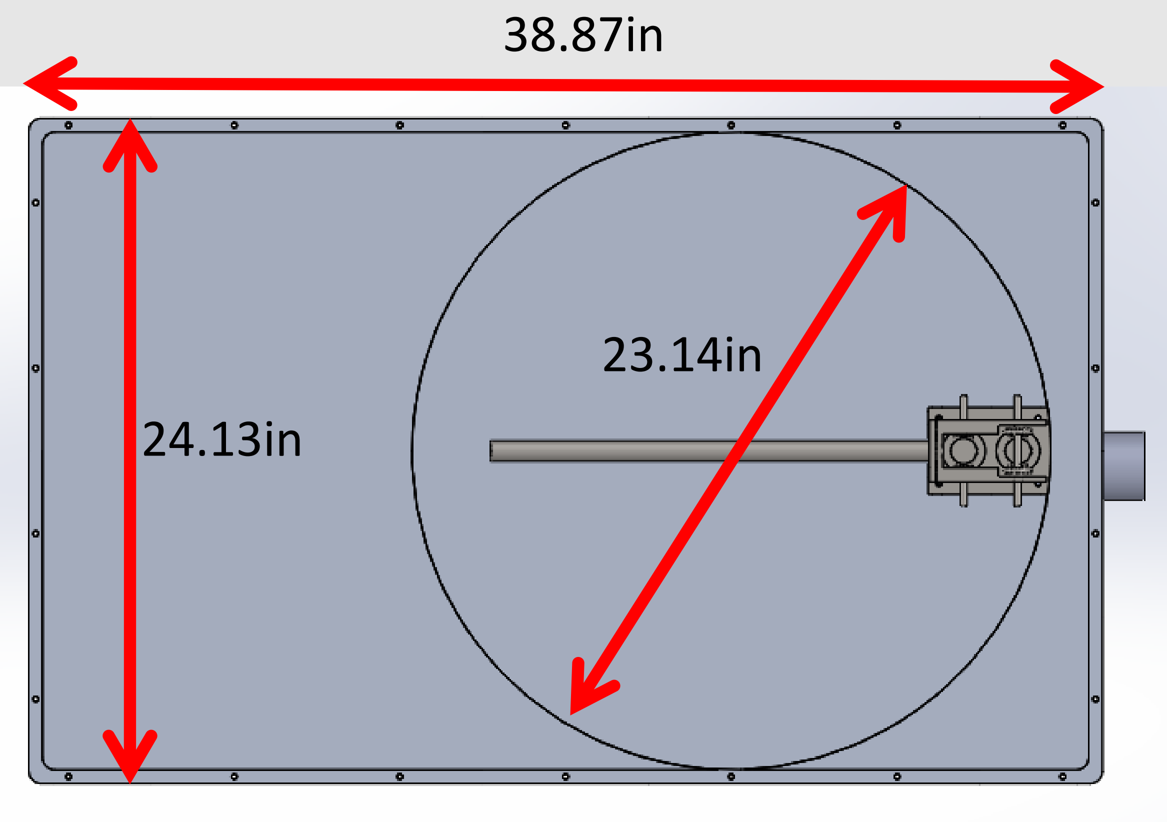
FBD - Positioning System

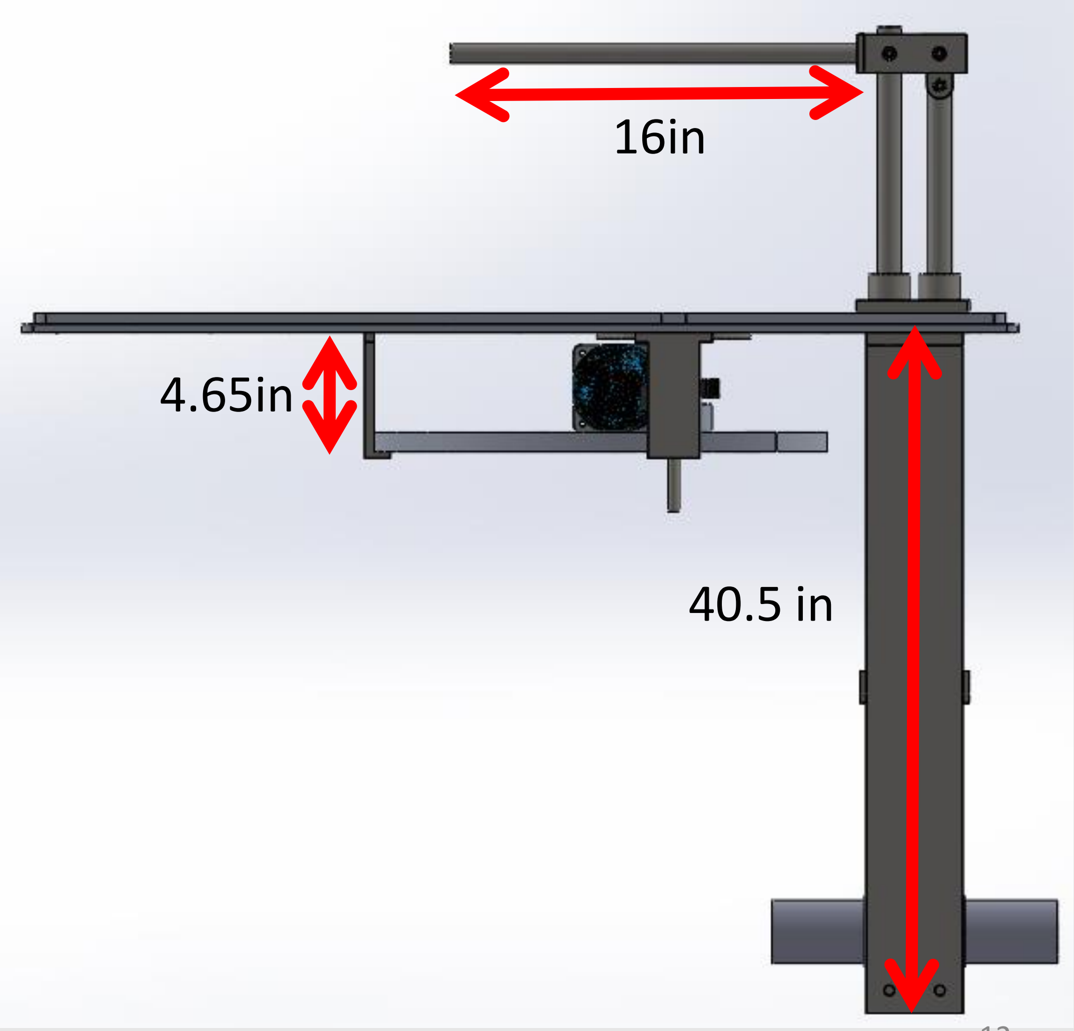


Baseline Design



Baseline Design: Major Dimensions





Critical Project Elements

CPE.1: Manufacturing base plate
- Issues with installation in the wind tunnel if manufactured incorrectly
- Lack of funds to buy material for a second plate

CPE.2: LabVIEW communication

CPE.2.1: DAQ communication for yaw system
- Signal generation not behaving as expected

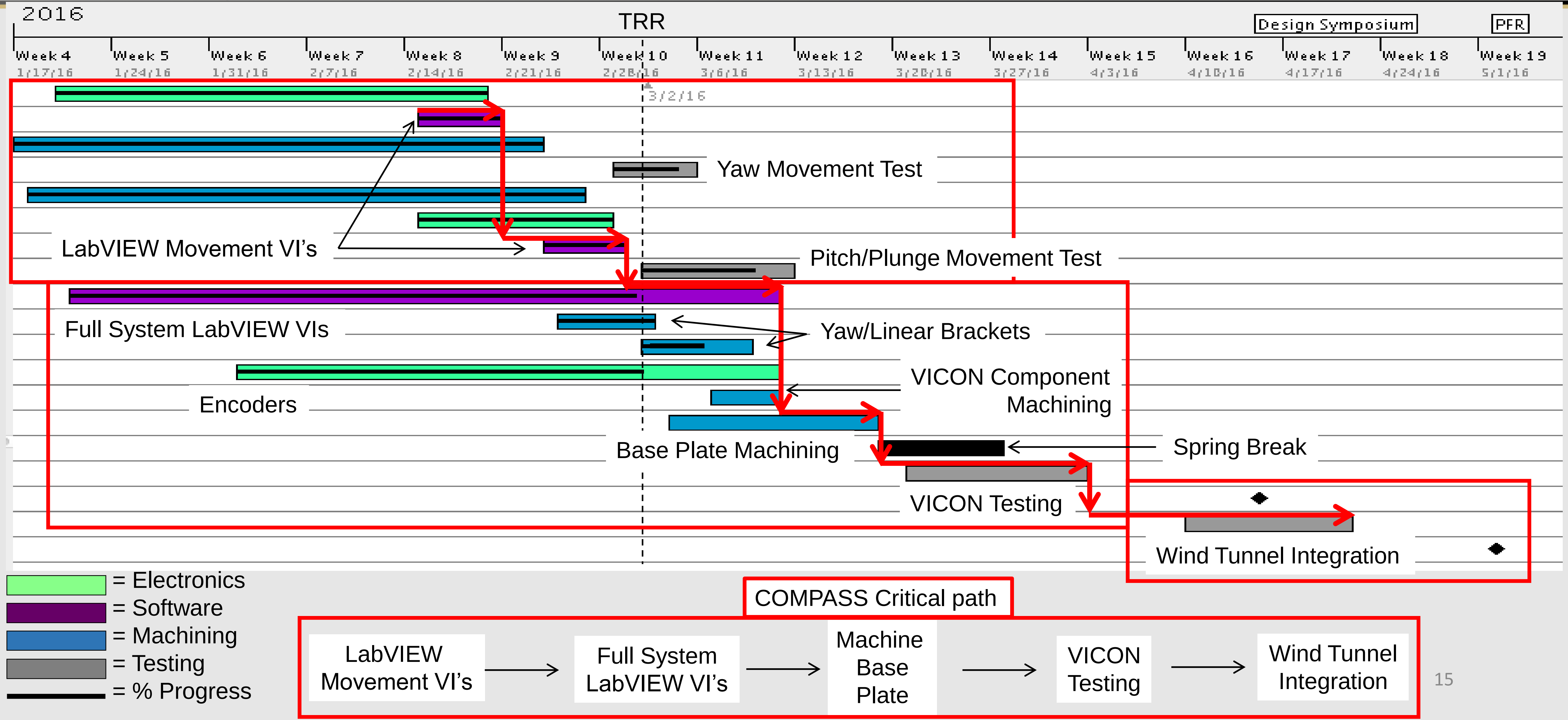
CPE.2.2: Arduino communication for linear system
- Establishing consistent communication

CPE.3: VICON testing system
- Learning curve and usage

CPE.4: System verification within the wind tunnel while under aerodynamic load
- High number of man hours to complete test
- Availability of resources

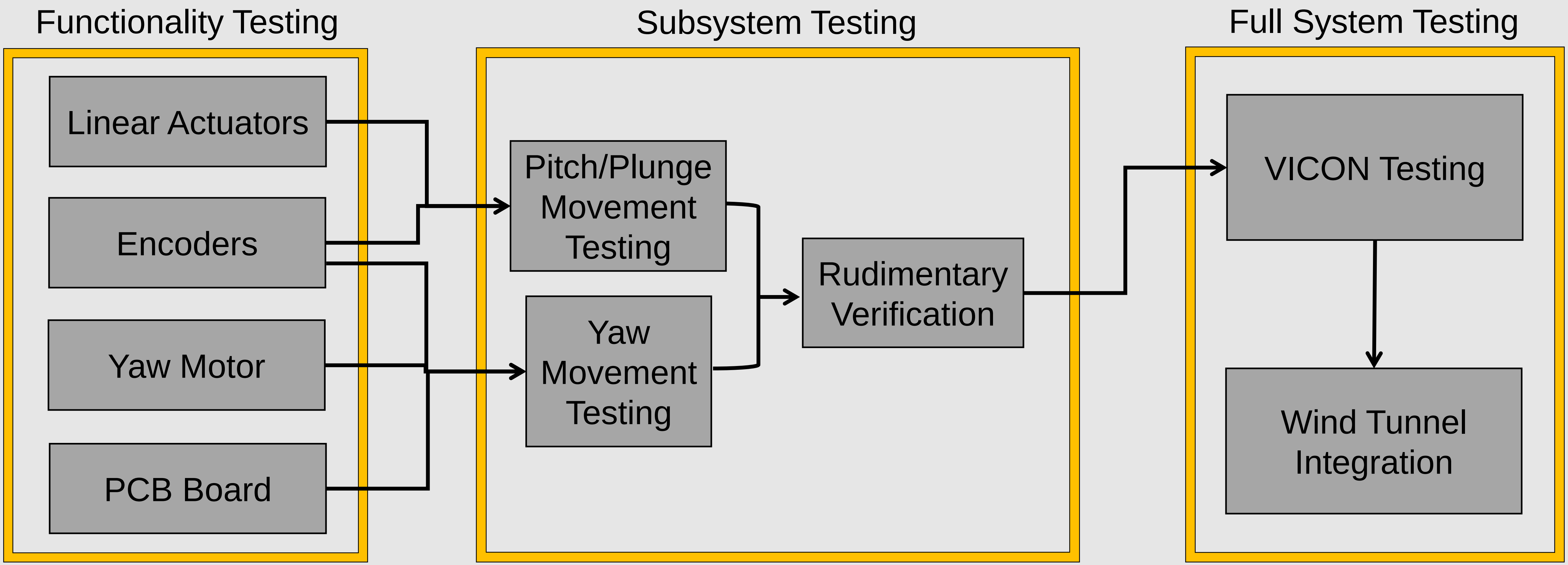
Schedule

Project Schedule



Test Readiness

Testing Scope



In Progress Testing

Component Functionality Tests

Testing For: General functionality of procured components

Test Fixtures: N/A

Test Equipment: Multimeter, Oscilloscope, Power Supplies etc.

Test Procedure: Verify that the procured component meets specs provided by manufacturer.

Component Functionality Testing

Status: **80%**

Requirements: N/A (Tests do not satisfy any Design Requirements)

Importance: **LOW**

Component	Test	Pass/Fail
Teknic Servo Motor	Programming and basic movement (Control from Arduino)	Pass
PCB Board Rev. B	Test of Schmitt Trigger and MOSFET circuit (Square Wave Input)	Pass
NI 9401 Module	Digital I/O output to trigger MOSFET gate	Pass
Linear Actuator	Actuation using provided Arduino and code	Pass
Incremental Encoder	Observe square wave output on lines	Pass
NI 9401 Module	Square wave pulse train output at 800 Hz	Fail
NI 9361 Module	Measure counts from incremental encoders	Fail

Yaw Subsystem Movement

Status: IN PROGRESS (80%)

Requirements: N/A

Importance: HIGH

Location: Trudy's Lab

Level of Success: Level 1 (Testing and Communication)

Completed	
In Progress	
Not Started	

Components Needed for Test

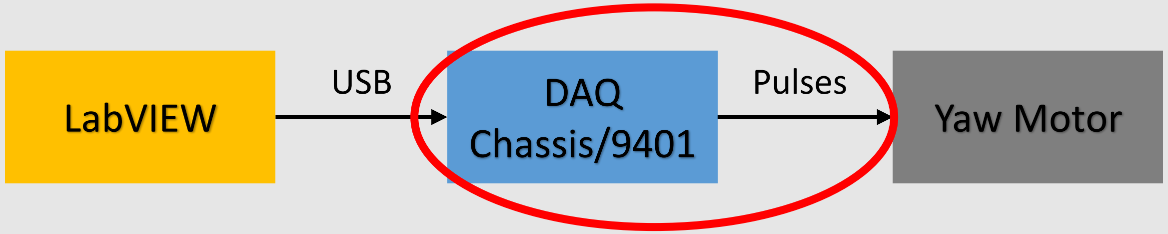
Mechanical	Yaw Plate	Yaw Base Plate	Motor Bracket	Yaw Shaft Flange	Spacer	Worm Gear	Worm Screw	Bearings
Electrical	Teknic Motor	NI 9401	PCB Board	Power Supply				
Software	Yaw Control VI							

Yaw Subsystem Movement

- **Testing For**: Ability to command and control entire yaw subsystem via LabVIEW interface.
- **Test Fixtures**: Hydraulic lift cart, board supports
- **Test Equipment**: Yaw Subsystem, Station w/ LabVIEW, Connecting cables
- **Test Procedure**: Command angle via LabVIEW, monitor yaw subsystem and record movement visually
- **Data Collected**: Visually validate movement

Challenges:

- Cannot hit appropriate frequency of pulse train for angle change input
- Ensuring minimal slop in yaw gear



Pitch/Plunge Subsystem Movement

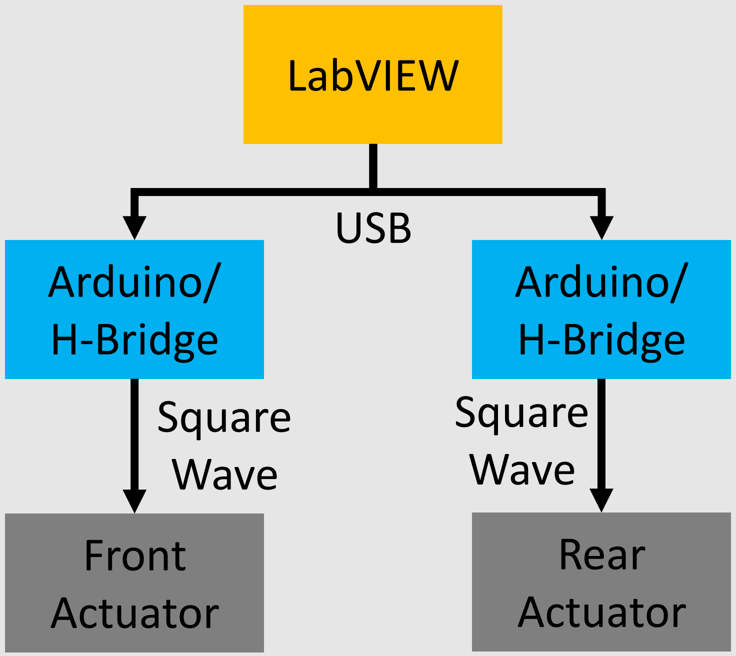
Status: IN PROGRESS (75%)

Requirements: N/A

Importance: HIGH

Location: Trudy's Lab

Level of success: Level 1 (Testing and Communication)



Components Needed for Test

Mechanical	Linear Bracket x2	Linear Collar x2	Linear Bearing Mount
Electrical	Linear Actuator x2	Arduino x2	Power Supply
Software	Linear Control VI	NI Visa	

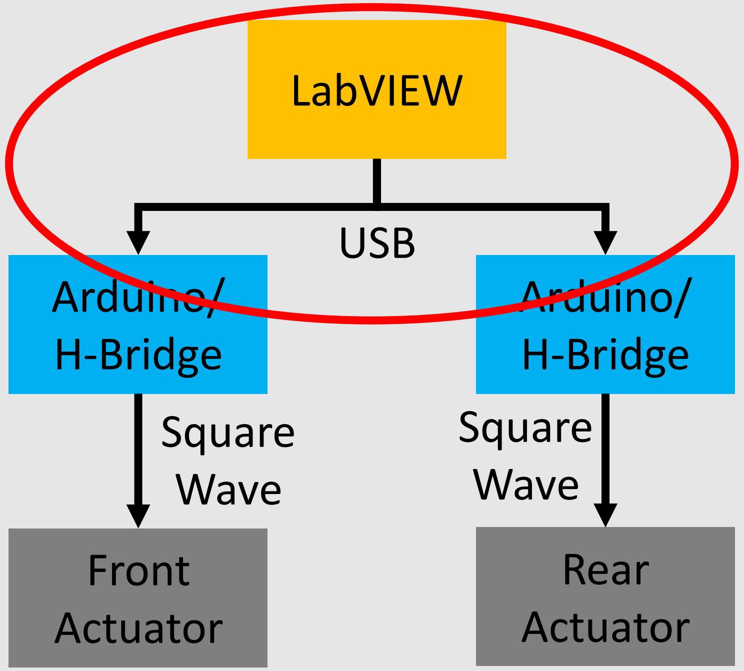
Completed	
In Progress	
Not Started	

Pitch/Plunge Subsystem Movement

- **Testing For**: Ability to command and control entire pitch/plunge subsystem via LabVIEW interface.
- **Test Fixtures**: Clamps, sawhorses
- **Test Equipment**: Pitch/Plunge Subsystem, Station w/ LabVIEW, Connecting cables.
- **Test Procedure**: Command pitch/plunge via LabVIEW, monitor and record motion of system.
- **Data Collected**: Visually validate movement

Challenges:

- Consistent and reliable communication between linear actuator Arduinos and LabVIEW



Future Tests

Rudimentary Verification

Status: NOT STARTED

Importance: MEDIUM

Location: Trudy's Lab

Level of Success: Level 1

Design Requirements Verified

Range: ± 30° yaw, ± 30° pitch, ± 45° roll, ± 10 cm plunge

Accuracy: ± 0.1° yaw, ± 0.1° pitch, ± 0.5° roll, ± 0.5 mm plunge

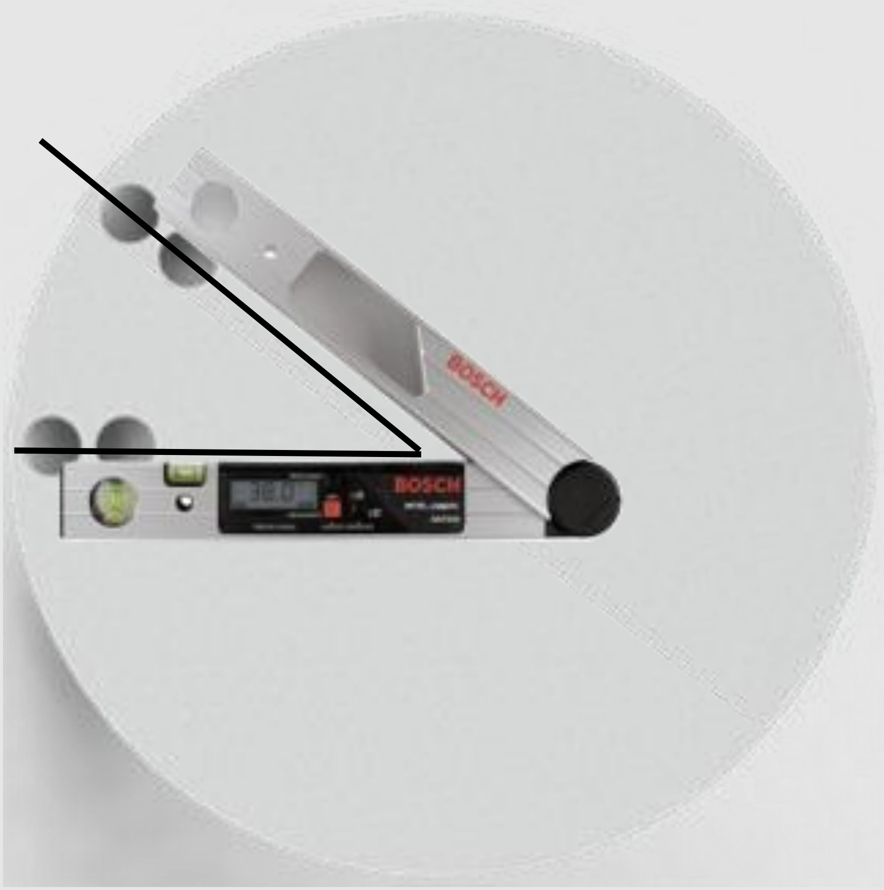
Completed	(green)
In Progress	(yellow)
Not Started	(red)

Components Needed for Test

Mechanical	Base Plate			
Electrical	Yaw Subsystem	Linear Subsystem	DAQ Chassis	Encoder x3
Software	Yaw Control VI	Linear Control VI		

Rudimentary Verification

- **Testing For**: Rudimentary verification of accuracy and range in pitch, roll, yaw and plunge in addition to code debugging.
- **Test Fixtures**: Sawhorses to support entire COMPASS system
- **Test Equipment**: Pitch/Plunge Subsystem, Yaw Subsystem, station w/ LabVIEW, digital protractor, digital angle finder
- **Test Procedure**: Command pitch, yaw, plunge to COMPASS, wait for system to finish movement and then record new position with test equipment.
- **Data Collected**: Angle measurements with rudimentary tools are accurate to within 0.1°



VICON

Status: NOT STARTED

Importance: HIGH

Location: Idea Forge

Level of Success: Level 2 (Without Load)

Level 3 (With Load)

Design Requirements Verified

Range: ± 30° yaw, ± 30° pitch, ± 45° roll, ± 10 cm plunge

Accuracy: ± 0.1° yaw, ± 0.1° pitch, ± 0.5° roll, ± 0.5 mm plunge

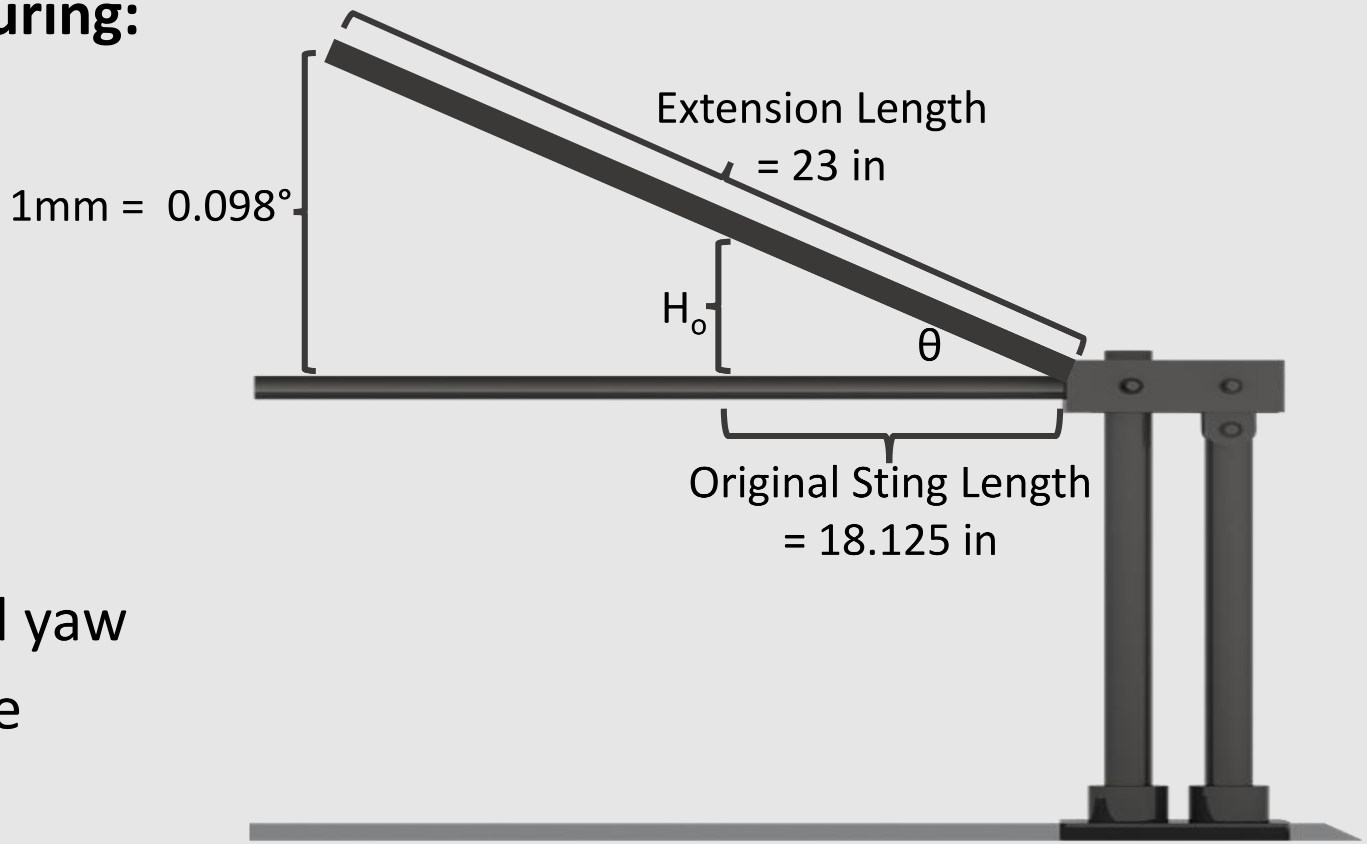
Components Needed for Test:

Mechanical	Extension Arm	Universal Mounting Hub
Software	Initialization VI's	Functionality VI's

VICON

VICON Bonita B-10 capable of measuring:

- **± 0.5 mm** in translation
- **± 0.5 deg** in rotation



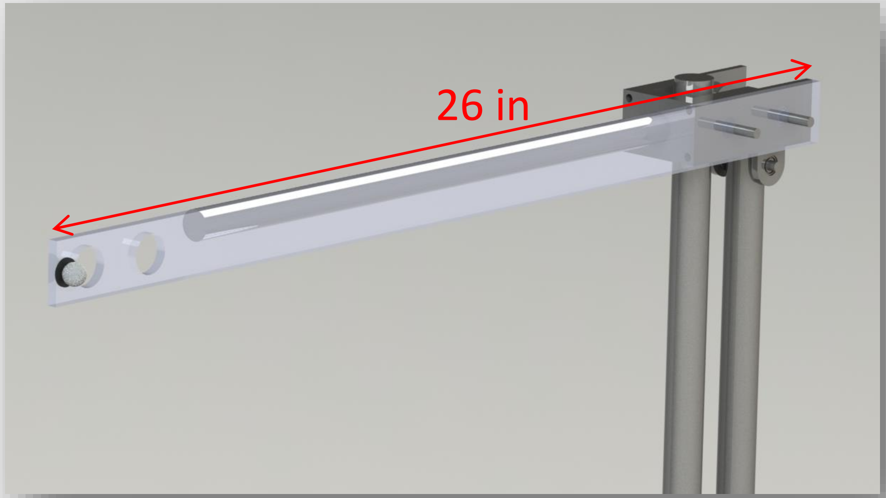
Design Requirements:

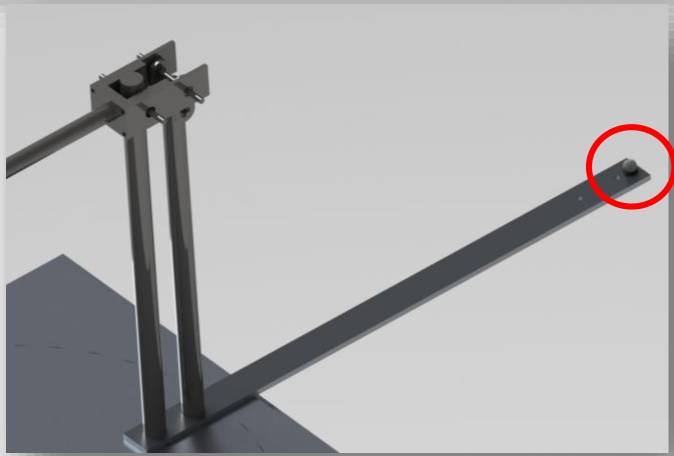
- **± 0.5 deg** in rotation for roll
- **± 0.1 deg** in rotation for pitch and yaw
- **± 0.5 mm** in translation for plunge

To verify COMPASS entirely using VICON, an extension arm must be implemented to reach needed displacements for pitch and yaw. Angle of movement can be solved for using displacement of nodes and the law of cosines.

VICON Without Load

- **Testing For**: Precision verification of accuracy and Range in pitch, roll, yaw and plunge
- **Test Fixtures**: Extension Arm, Sawhorses
- **Test Equipment**: Full COMPASS system, VICON system, pearl markers, station w/ LabVIEW, station w/ VICON
- **Test Procedure**: Record initial location of pearl markers from VICON. Command new position to COMPASS and record new coordinates of markers. Repeat as needed.
- **Data Collected**: x, y, z location of pearl markers. Using location and extension arm length, can back out angle traveled through.





VICON With Load

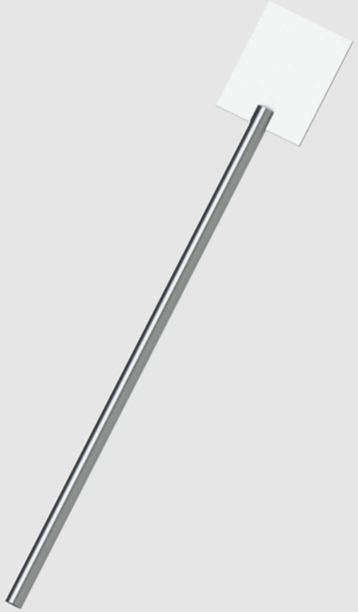
- **Connect** universal mounting hub and pearl markers to sting shaft. Record x, y, z location of pearl markers from VICON

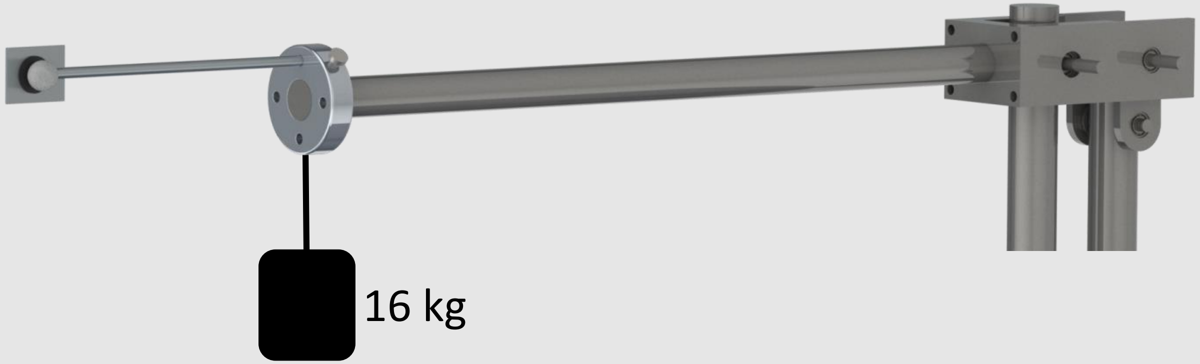
- **Connect** simulated load of airfoil with maximum lift to mounting hub: **16 kg**

- **Command** COMPASS to maximum deflection of **30°** in pitch

- **Collect** x, y, z location data of pearl markers from VICON

- **Analyze** x, y, z location data to calculate and confirm pitch angle (law of cosines)





Wind Tunnel: Aerodynamic Load

Status: **NOT COMPLETE**

Importance: **HIGH**

Location: East Campus Wind Tunnel

Level of Success: Level 4

Design Requirements Verified

Range: ± 30° yaw, ± 30° pitch, ± 45° roll, ± 10 cm plunge

Accuracy: ± 0.1° yaw, ± 0.1° pitch, ± 0.5° roll, ± 0.5 mm plunge

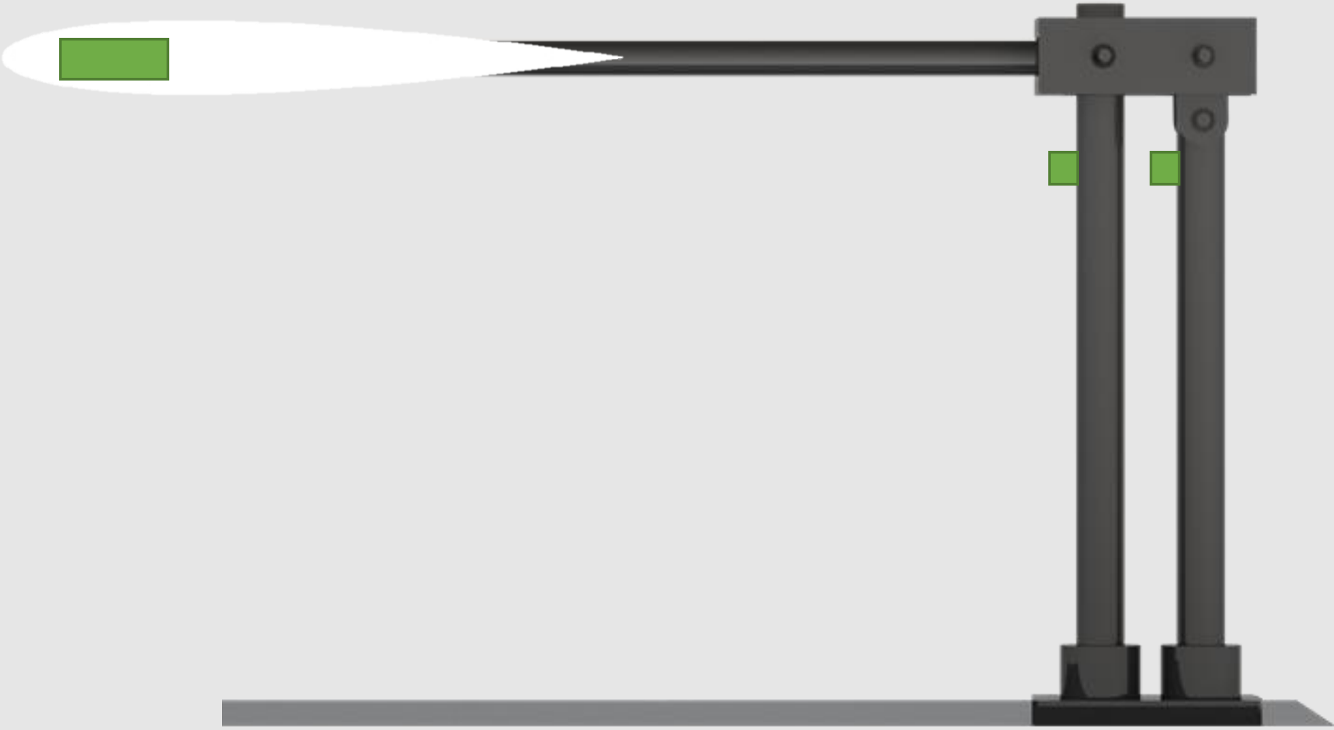
Highest Level of Success

Components Needed For Test

Electronics	ADXL 326 Accel.	EVAL-ADXL326Z	NI 9209	NI 9234	PCB 325C65 x2
Software	Accelerometer VI				

Wind Tunnel: Aerodynamic Load

- **Testing For:** Accuracy and Range in pitch under aerodynamic load as well as vibration characterization of linear actuators
- **Test Fixtures:** Wind Tunnel
- **Test Equipment:** Full COMPASS system, station w/ LabVIEW, accelerometer, test airfoil
- **Test Procedure:** Place full COMPASS system under aerodynamic load to measure deflection and characterize vibrations.
- **Data Collected:** Acceleration in 2 axis to calculate pitch angle and vibration measurements of linear actuators



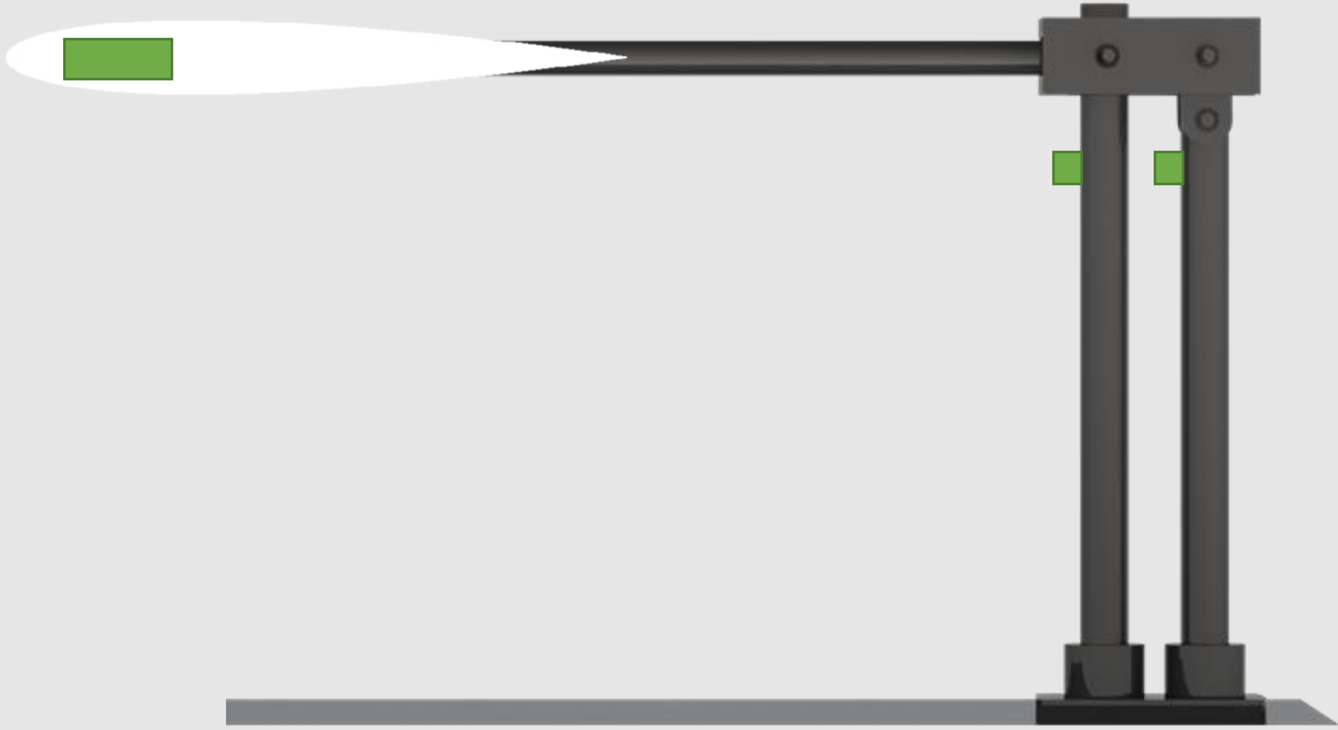
Wind Tunnel Testing

Pitch Verification

- Mount **ADXL 326** accelerometer inside hollow airfoil: Sensitivity of **57 mv/g**
- A **0.1°** inclination corresponds to **1.7 mv**
- Read signal using 24 bit NI 9209 DAQ module. Resolution of **1.2 mv/bin**
- 1.2 mv/bin < 1.7 mv: **SUFFICIENT FOR VERIFICATION**
- Challenges: Shielding for noise

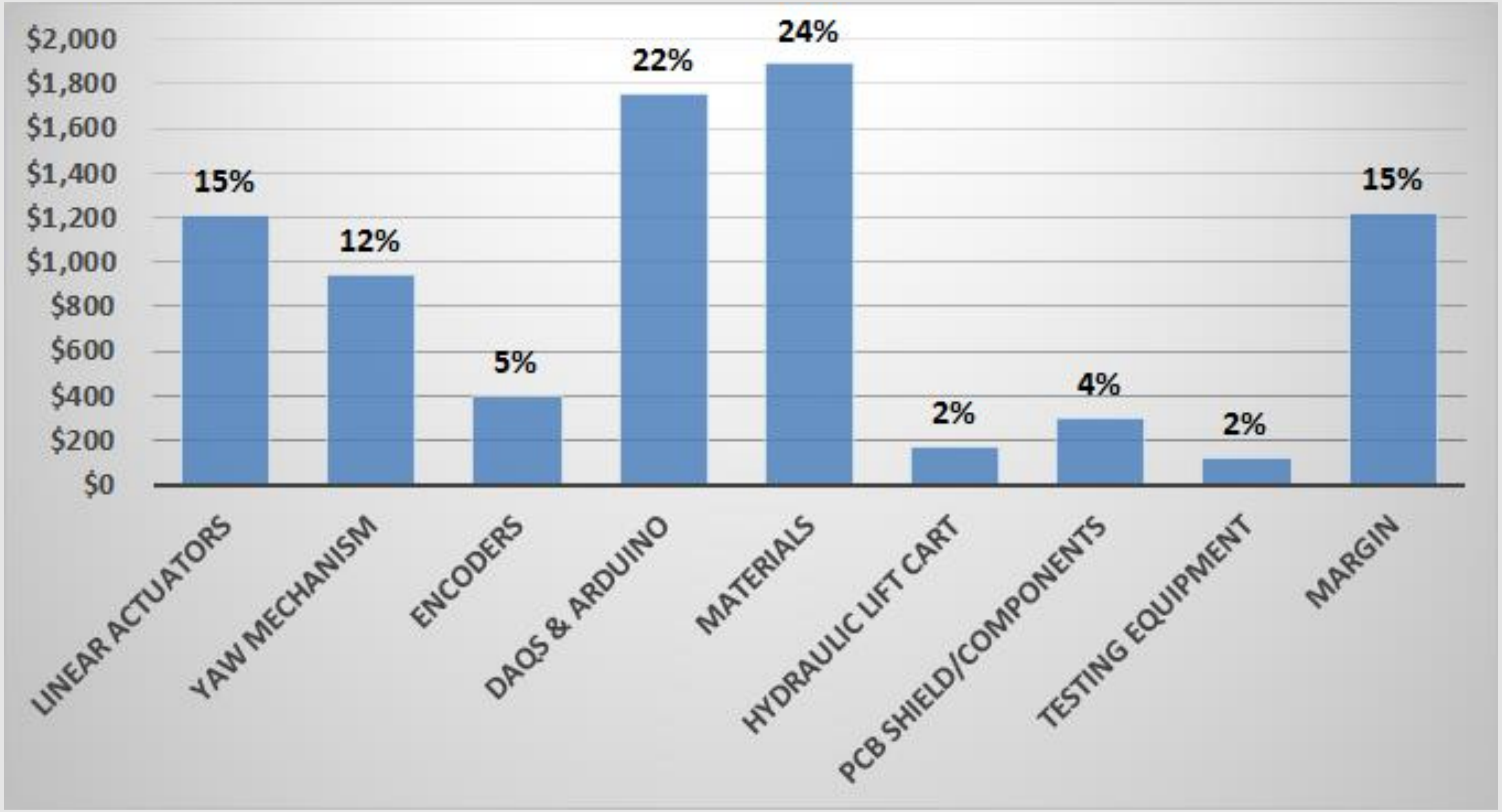
Vibration Characterization

- Mount **PCB 325C65** accelerometers to linear actuators to characterize vibrations: sensitivity of **100 mv/g**
- Read signal using 24 bit **NI 9234 DAQ** module



Budget

Budget



Course Budget: $5000

EEF Addition: $3000

Total Budget: $8000

Margin: $1212, 15%

Parts Price Change From MSR

Parts	Expected Price at MSR	Actual Price at TRR
Baseplate/Yaw plate Aluminum	$1196	$1196
Encoders	$1644	$395
NI (2 9361/9401) + Arduino	$1778	$1756
Yaw Motor	$781	$781
Linear Actuators	$1205	$1205
Hydraulic Lift Cart	$172	$172
Bearings	$388	$388
Worm Gear/Screw	$166	$166
Sting Rods	$25	$30
Materials + Screws/Nuts	$90	$82
PCB Shield/Components	$119	$297
Testing Equipment	Not Assessed	$120
Printing	$200	$200
Margin	$236, 3%	$1212, 15%

Additional Funding Allocation

- **12% Margin Allocation**
  - Additional Cabling
  - Linear Actuator Rod Fairing
  - Linear Actuator Bracket Aluminum
  - PCB Components

Questions?

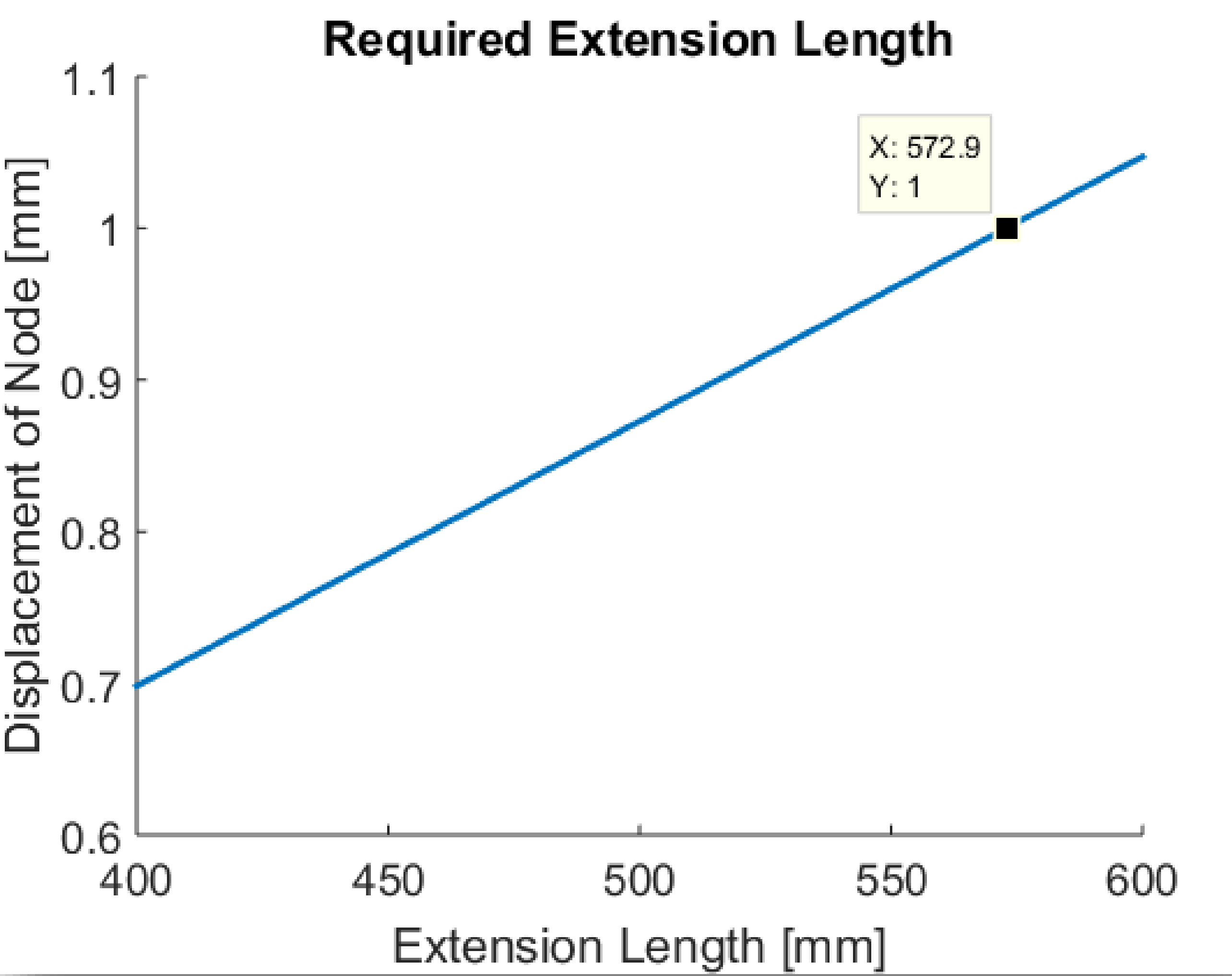
Back-up Slides

Extension Calculation

Result:

1 mm displacement = **573 mm** arm

573 mm ≈ 23 inch arm



Calculations for Accelerometer

$$\Delta A_{OUT}\,[g] \cong 1\,g \times \sin(P)$$

For 0.1 degrees, A = 1.7 mv

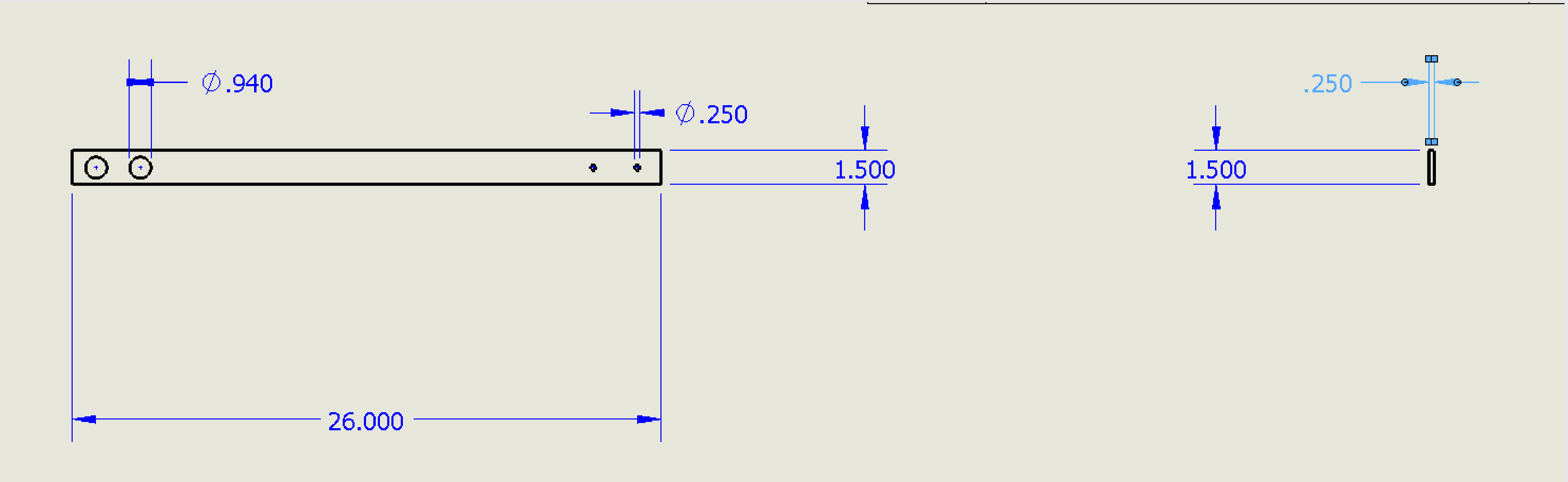
$$\frac{A_{X,OUT}}{A_{Y,OUT}} = \frac{1\,g \times \sin(\theta)}{1\,g \times \cos(\theta)} = \tan(\theta)$$

$$\theta = \tan^{-1}\left(\frac{A_{X,OUT}}{A_{Y,OUT}}\right)$$

Use to calculate angles from measurements

Extension Arm

- Length: 26 inches
- Width: 1.5 inches
- Large Hole D: 0.94 inches
- Small Hole D: 0.25 inches

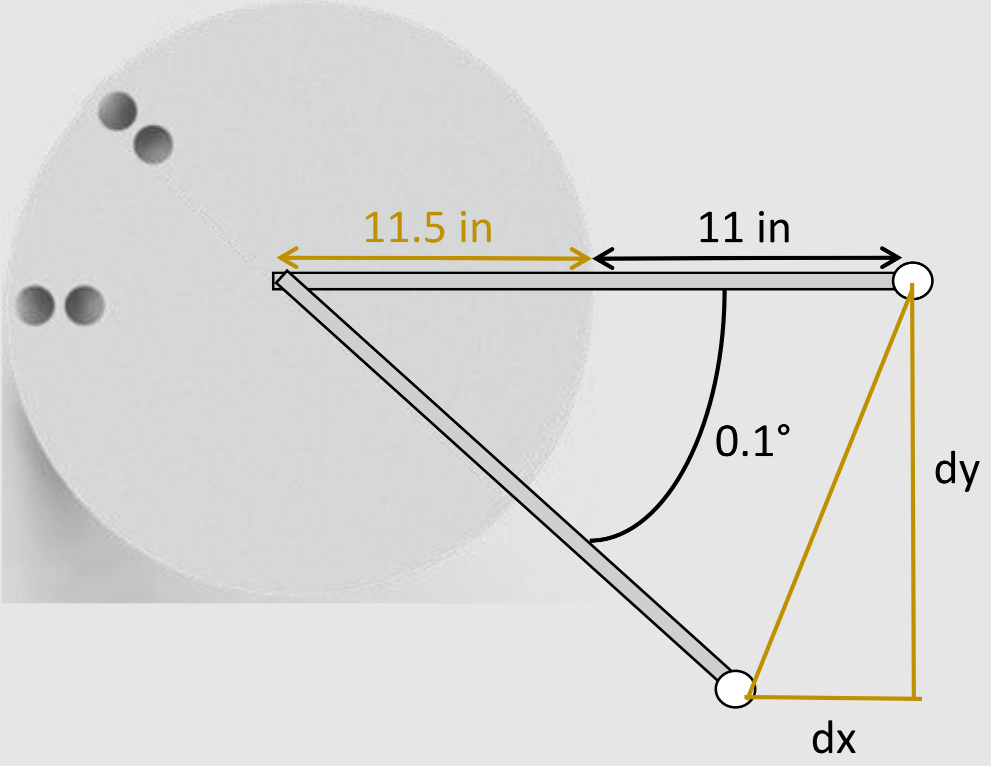


Yaw Verification Test

Main Objective: Validate **range** and **accuracy** requirements of yaw mechanism.

Requirements: **± 30°** range, **± 0.1°** accuracy.

Procedure: Connect extension arm to yaw plate to achieve needed horizontal displacement for verification in yaw using **VICON**.



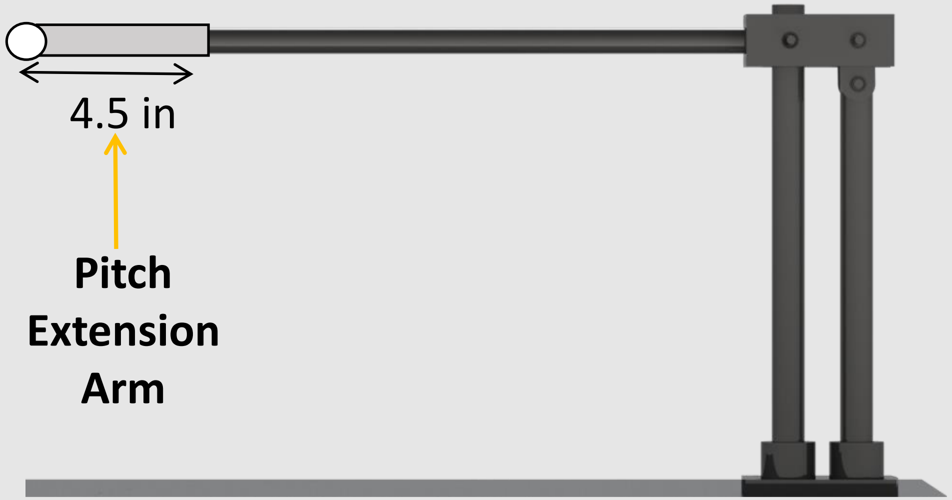
VICON Accuracy	Tip Displacement
0.5 mm	1 mm

Pitch Verification Test

Main Objective: Validate range and accuracy requirements of pitch mechanism.

Requirements: ± 30° range, ± 0.1° accuracy.

Location: Idea Forge



Procedure: Connect extension arm to sting to achieve needed vertical displacement for verification in pitch using VICON.

Provided Displacement: 1 mm per 0.1°

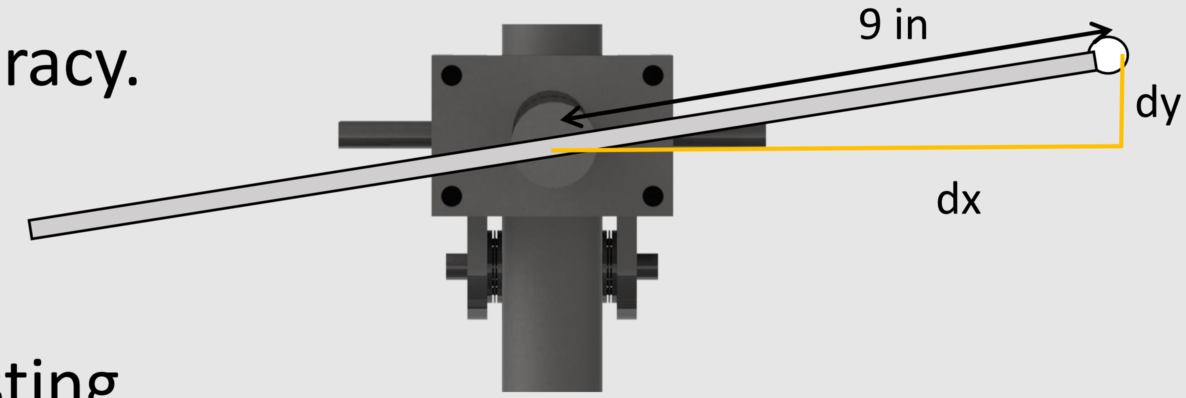
VICON Accuracy	Tip Displacement
0.5 mm	1 mm

Roll Verification Test

Main Objective: Validate **range** and **accuracy** requirements of roll mechanism.

Requirements: ± 45° range, ± 0.5° accuracy.

Location: Idea Forge



Procedure: Connect extension arm to sting to achieve needed vertical displacement for verification in roll using **VICON**. (or use VICON's 0.5° rotation accuracy)

Provided Displacement: 1 mm per 0.5°

VICON Accuracy	Tip Displacement
0.5 mm	1 mm

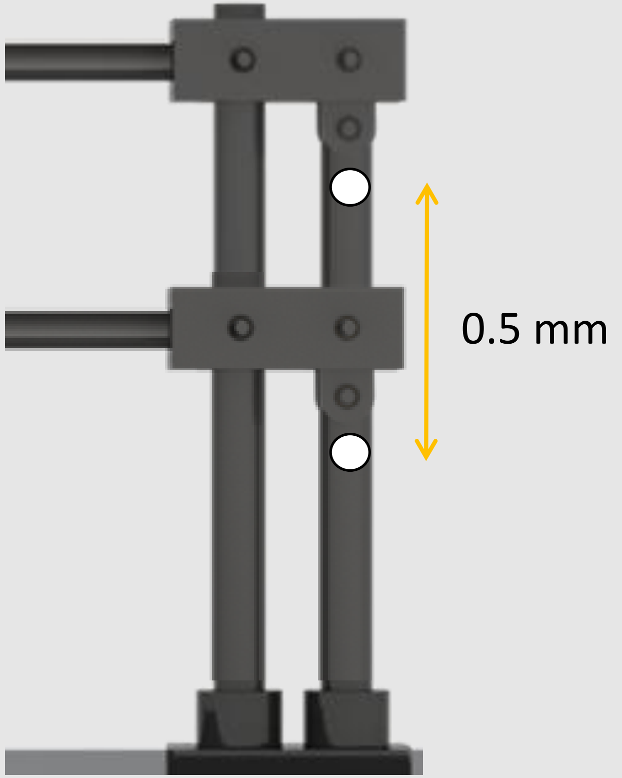
Plunge Verification Test

Main Objective: Validate **range** and **accuracy** requirements of plunge mechanism.

Requirements: ± 10 cm range, ± 0.5 mm accuracy.

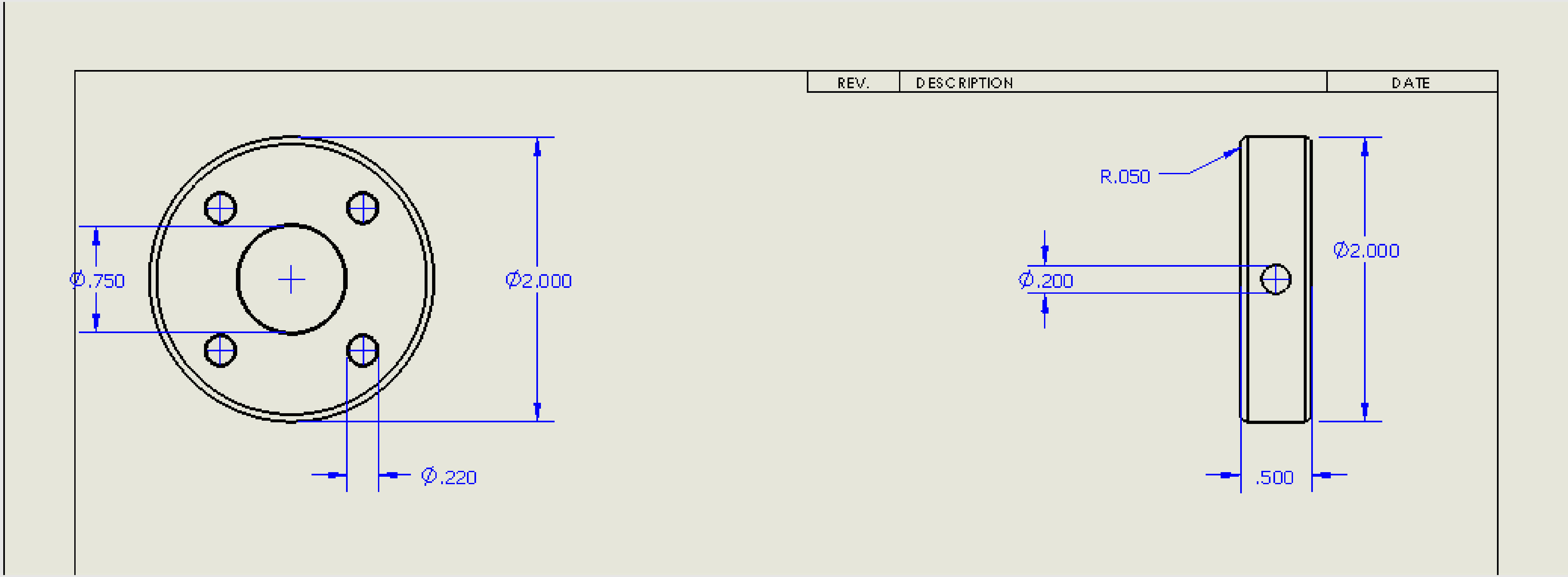
Location: Idea Forge

Procedure: Connect nodes to COMPASS, command plunge to and verify plunge requirements using **VICON**.



VICON Accuracy	Tip Displacement
0.5 mm	0.5 mm

Universal Mounting Hub



Accuracy Characterization

- Yaw can be characterized directly by incremental encoder
  - Assembly has revealed adjustments need to be made for slop
- Pitch and Plunge elements require mechanical modifications
  - Assembly of future system will allow characterization of accuracies
- Challenges:
  - Linear actuator hall effect sensor setup not expected
  - Linear actuators not to requested specifications
  - Yaw accuracy directly characterized but slop introduces control issues
  - Slop in any part of system will introduce control issues
- Goal: Characterize controllable accuracy of the system

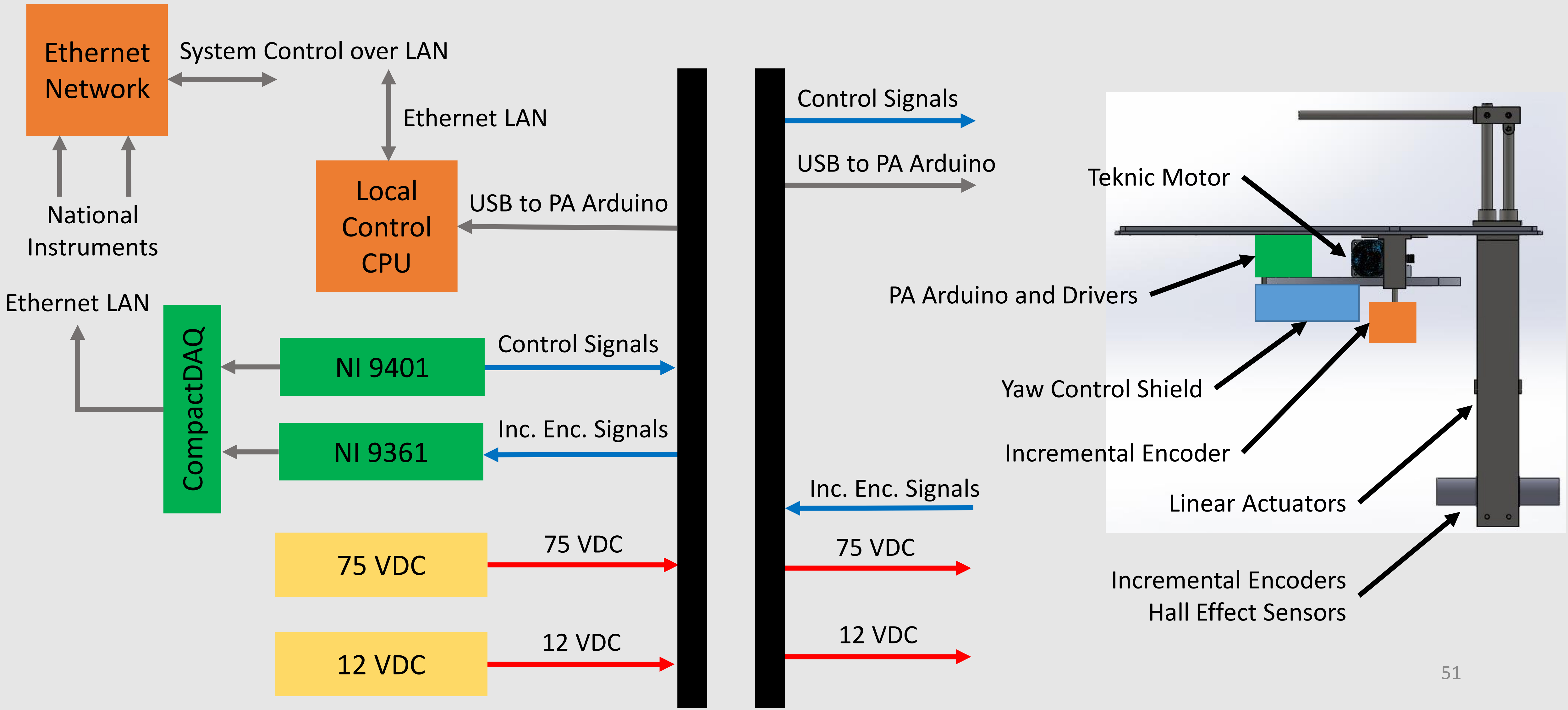
Accuracy Characterization

- Steps for characterizing system performance:
  1. Record error of incremental encoders
  2. Measure slop of assembled yaw and pitch/plunge subsystems
  3. Characterize total error through the system
  4. Characterize controllable error

Component (Yaw DOF)	Error (degrees)
Absolute Encoder	0.1°
Radial Bearing Slop	TBD with Testing
Total	0.1°

Component (P/P DOF)	Error (mm/degrees)
Linear Actuator	0.0406 mm | 0.045°
Incremental Encoder	0.00857 mm | 0.0095°
Sting Assembly Slop	TBD with Testing
Total	0.0406 mm | 0.045°

Overall System Setup



Software Scope and Status

Verified = ✓

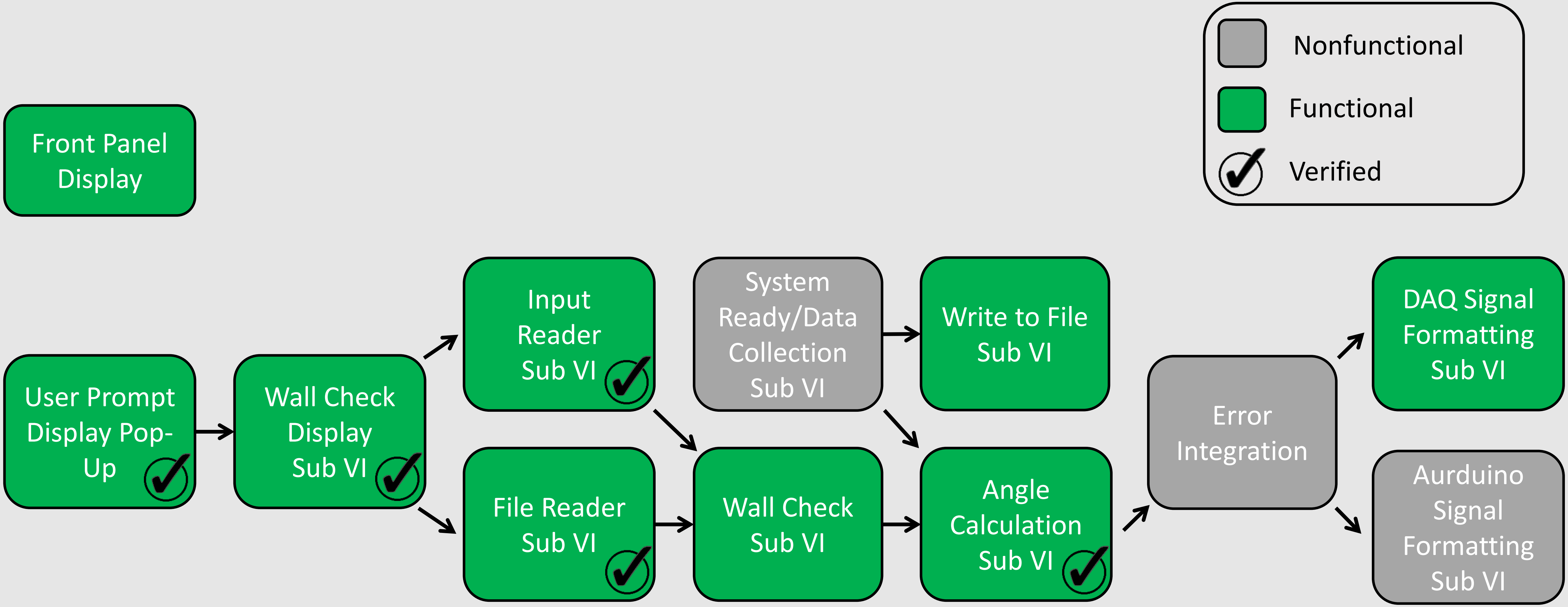
Initialization and Safety

Functionality	COMPASS VI	Status
Allow for a variable sting length	User Prompt	✓
Read a User file	File Reader VI	✓
Allow for manual inputs	Input Reader VI	✓
Prevent damage to the system, the wind tunnel and fillets	Wall Check VI Wall Display VI	✓ ✓

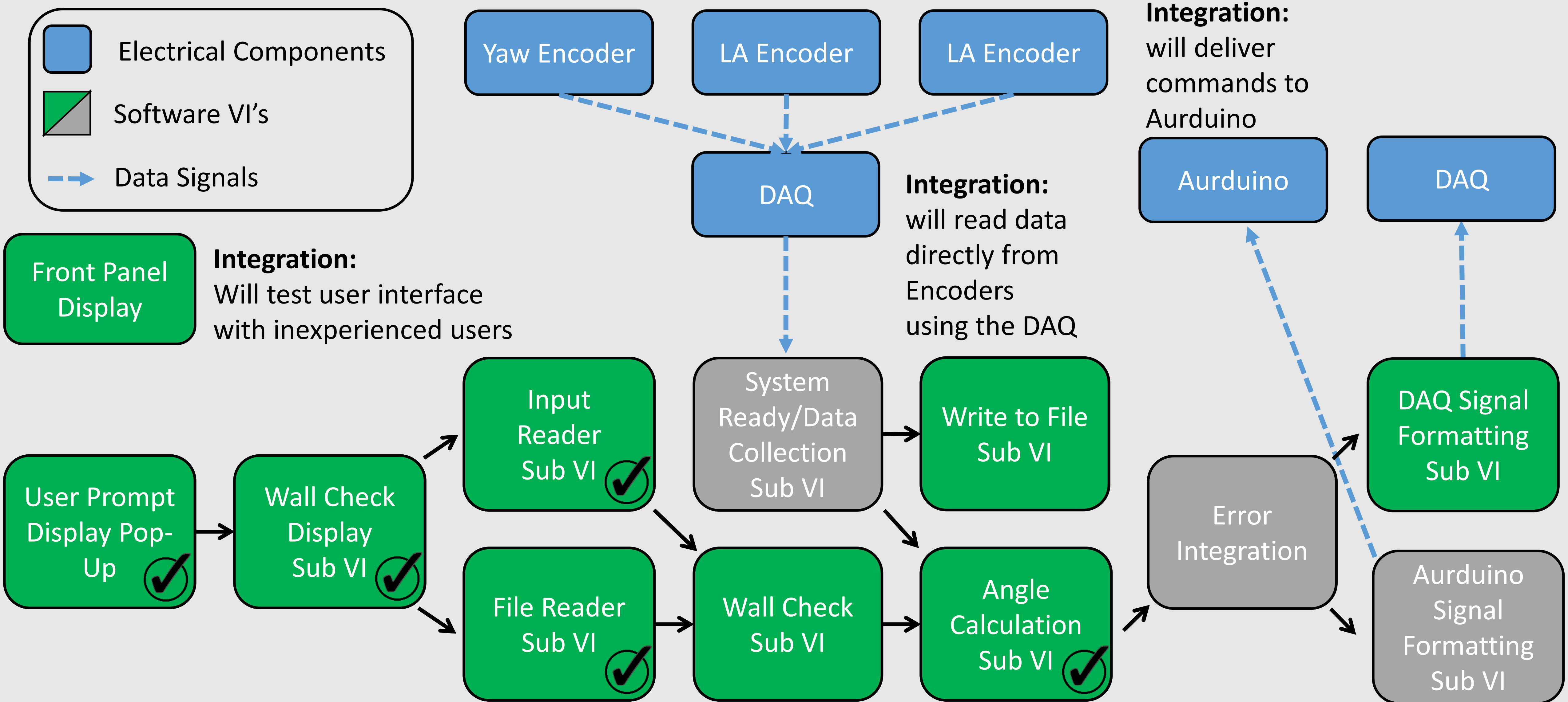
Positioning

Function	COMPASS VI	Status
Format signals to the motor	Format to DAQ VI Format to Aurduino VI	
Read position from encoders	Collect Time + Position VI	
Calculate where to position the system based on attitude	Angle Calculation VI	✓
Write position to data file and allow user to save file	Write to File VI	✓

Software Completion and Flow



Software Integration Plan



Electronics Scope and Status

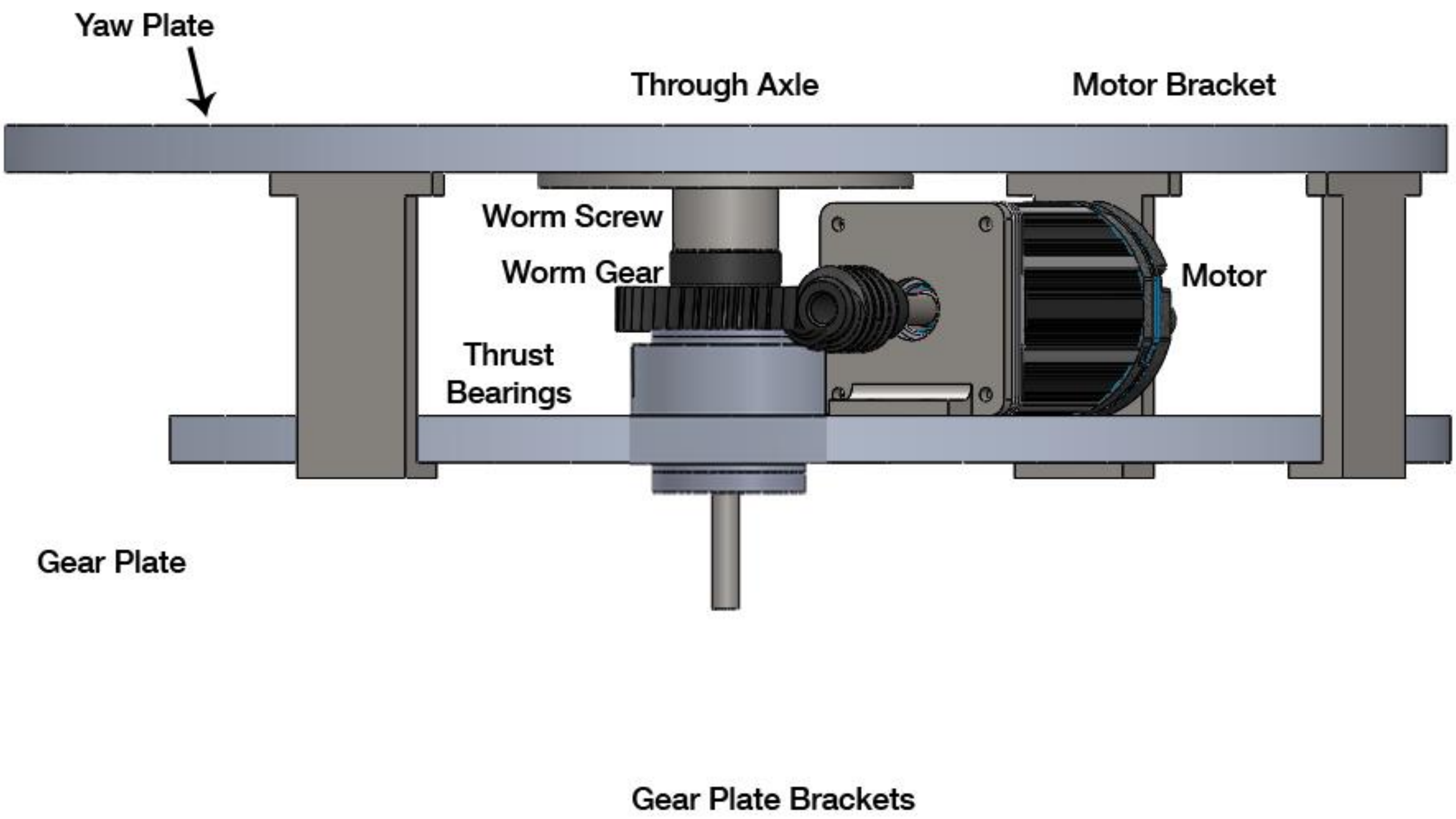
Verified = ✓

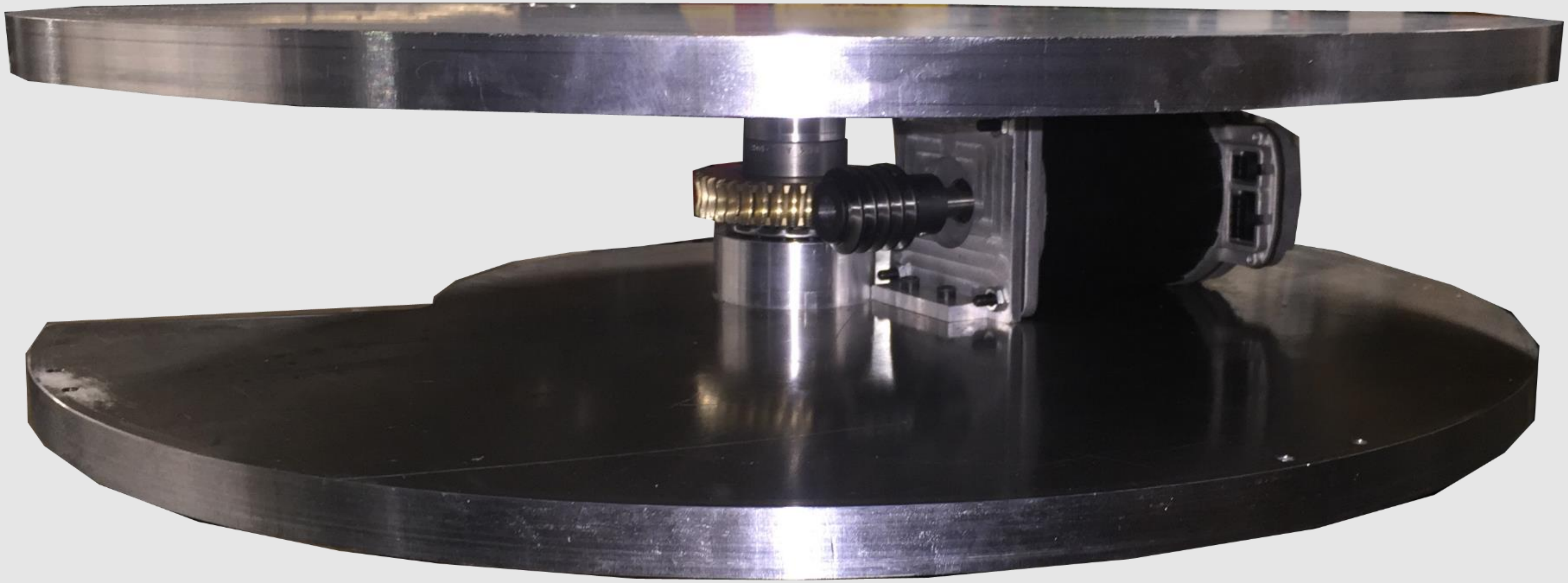
Pitch and Plunge

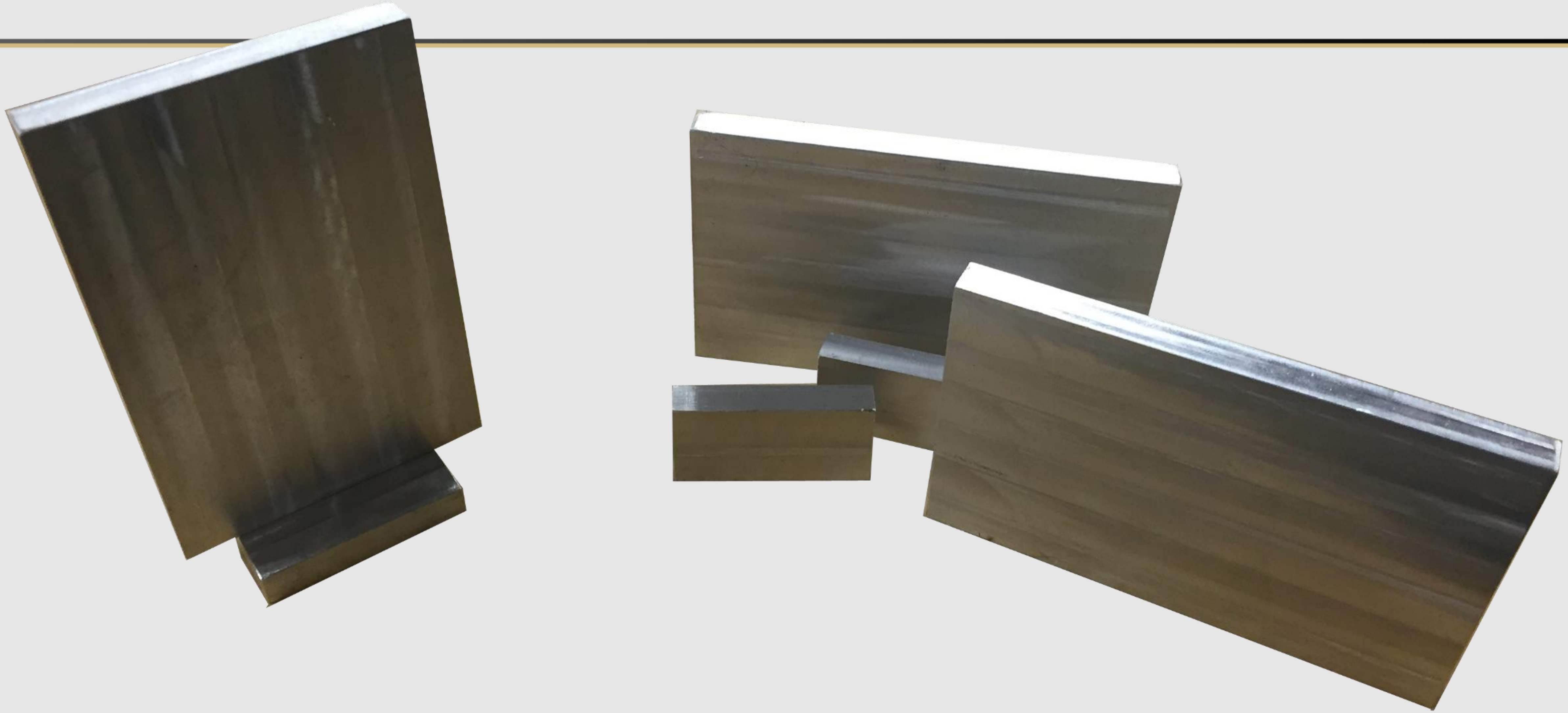
Functionality	Component(s)	Status
Powering the system	Transformers	✓
Position the system	Actuators/Hall Effect	
Feedback to LabVIEW	NI9361/Encoders	
Commanding a position	Arduinos/Motor Boards	

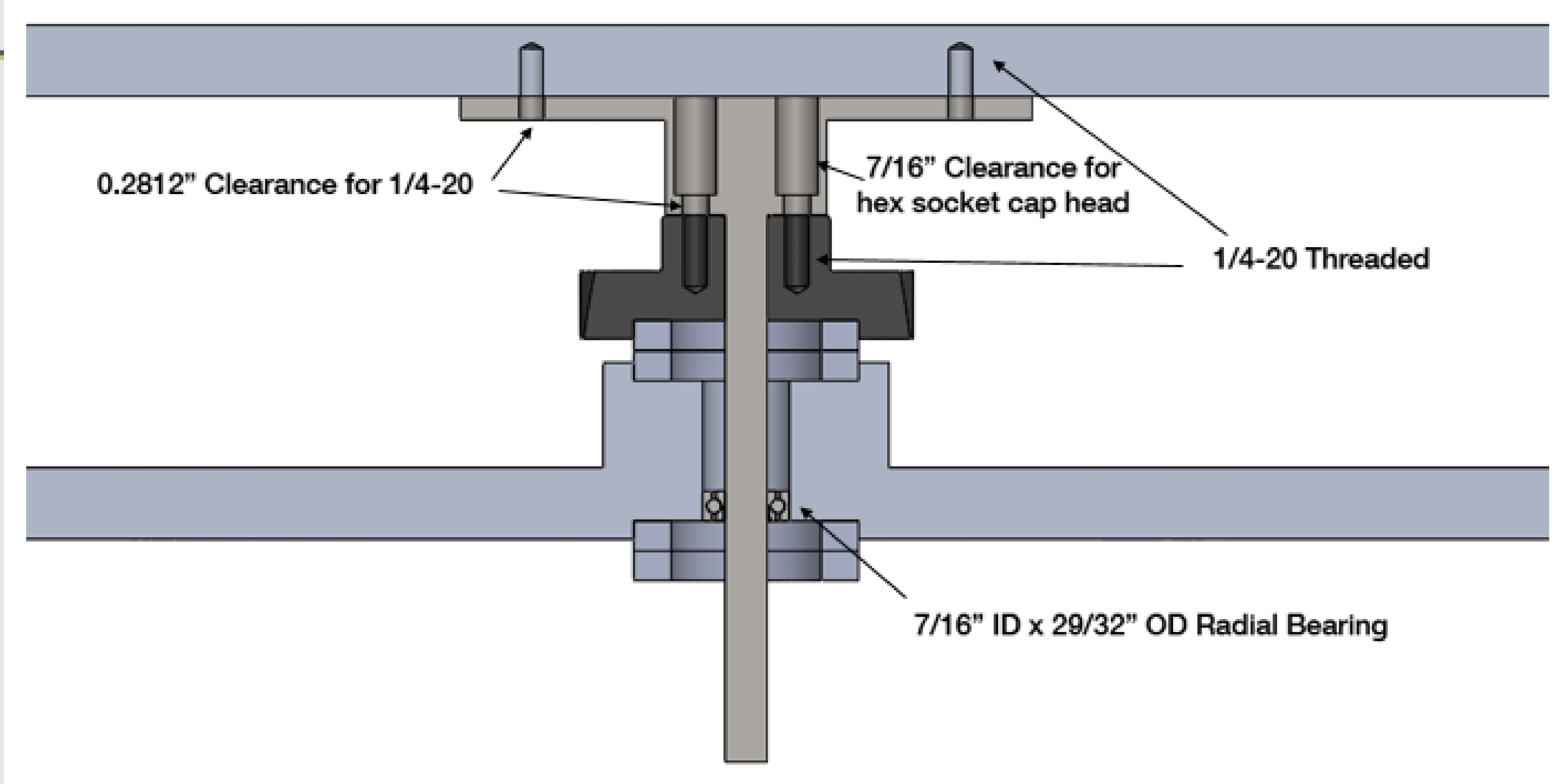
Positioning

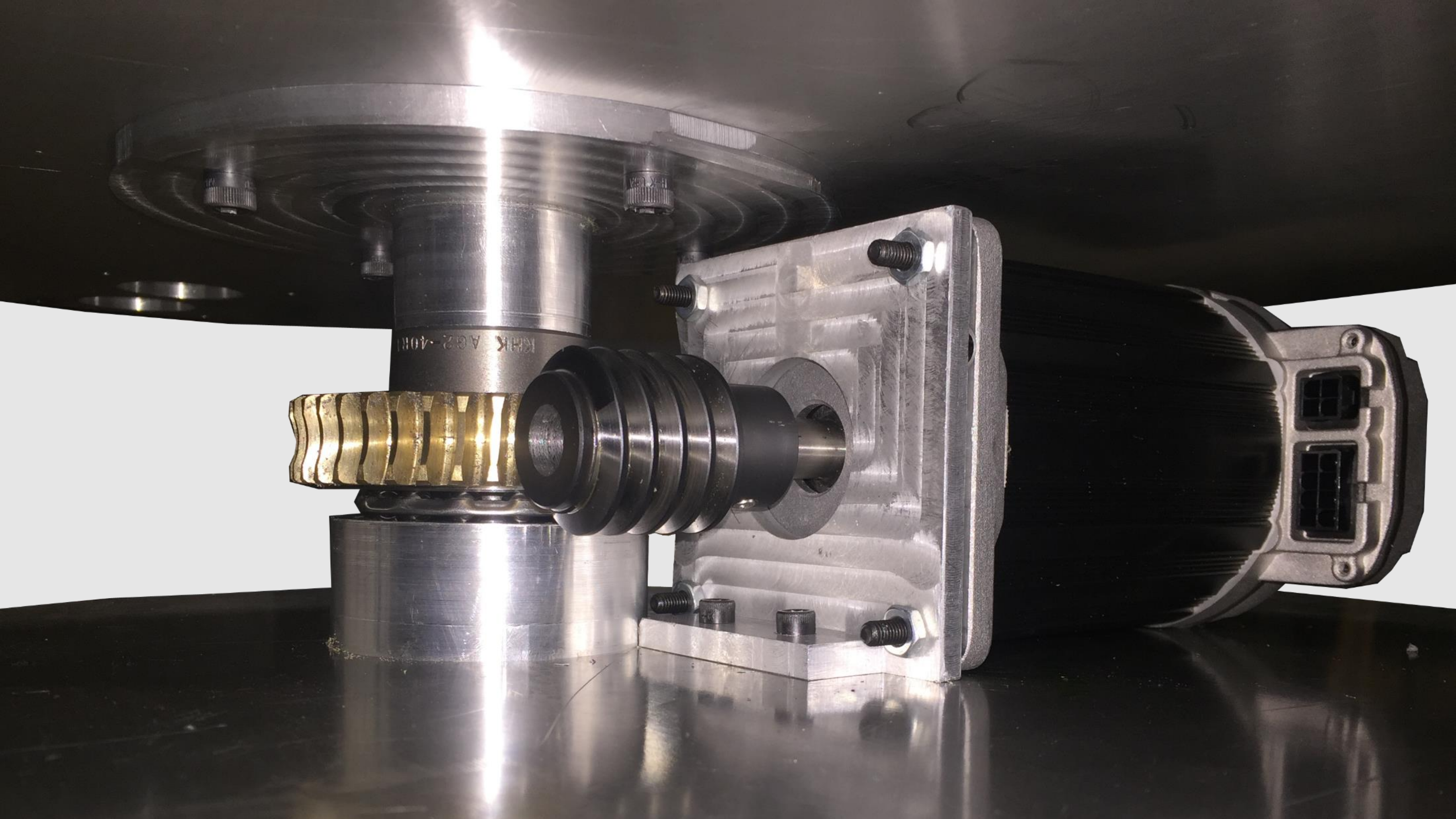
Functionality	Component(s)	Status
Powering the system	Transformer	✓
Position the system	Motor/Internal Encoder	
Feedback to LabVIEW	NI9361/Encoder	
Commanding a position	NI9401/PCB	

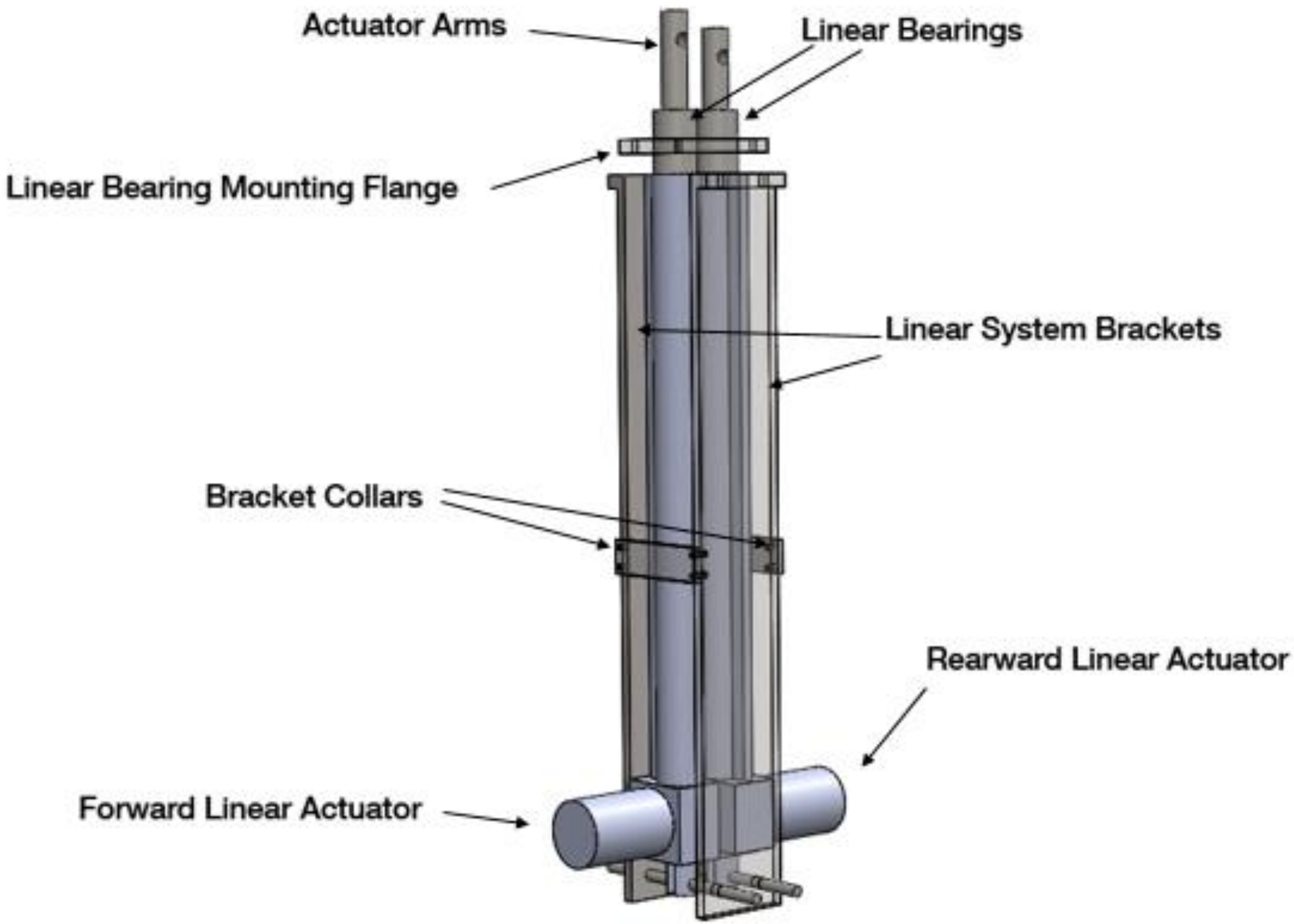

Yaw Plate
Through Axle
Motor Bracket
Worm Screw
Worm Gear
Motor
Thrust Bearings
Gear Plate
Gear Plate Brackets

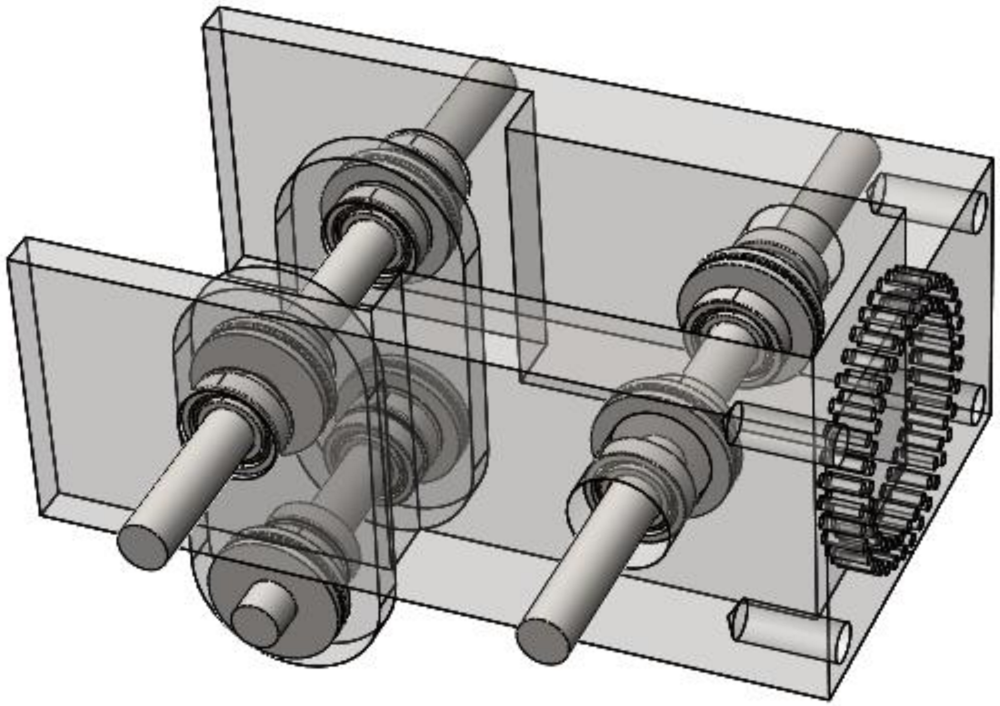





0.2812” Clearance for 1/4-20
7/16” Clearance for
hex socket cap head
1/4-20 Threaded
7/16” ID x 29/32” OD Radial Bearing




Actuator Arms
Linear Bearings
Linear Bearing Mounting Flange
Linear System Brackets
Bracket Collars
Rearward Linear Actuator
Forward Linear Actuator



Subsystem Failsafes

- Yaw DOF Subsystem
  - Software: Angle Check VI and User Input VI
  - Hardware: Motor Torque Limit with mechanical hard stop
- Pitch and Plunge DOF Subsystem
  - Software: Angle Check VI, User Input VI, no max length command input
  - Hardware: N/A
- Electrical: Power Cutoff Switch