Manufacturing Status Review

SPECTROM

Scientific Platform for the Exact Control of Thermally Regulated Optical Mechanisms

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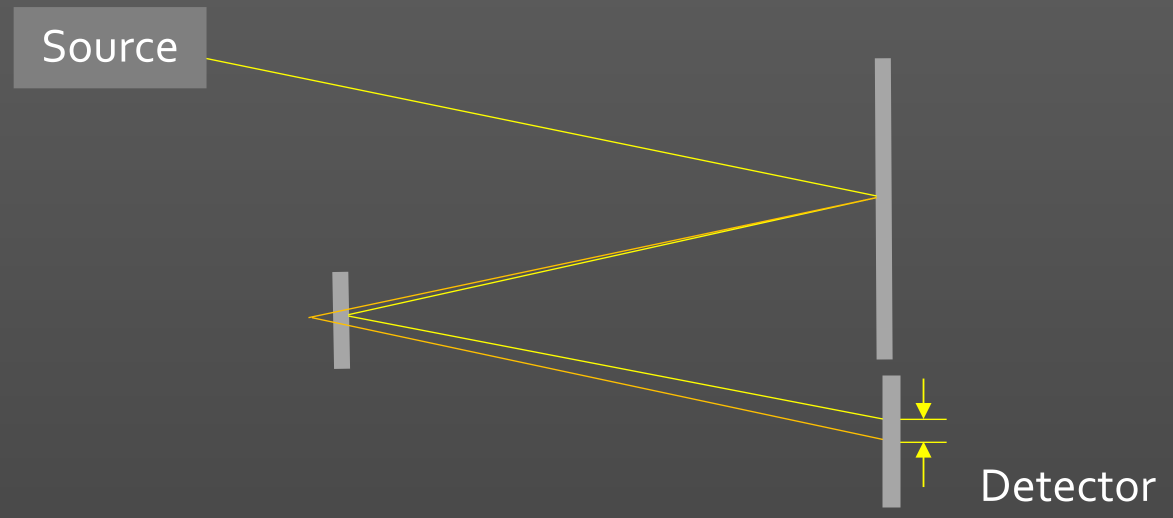
Customer: Ball Aerospace & Technologies Corp.
Joe Lopez

Advisor: Bob Marshall

Project Purpose

- Maintaining precise alignment of optical instrumentation

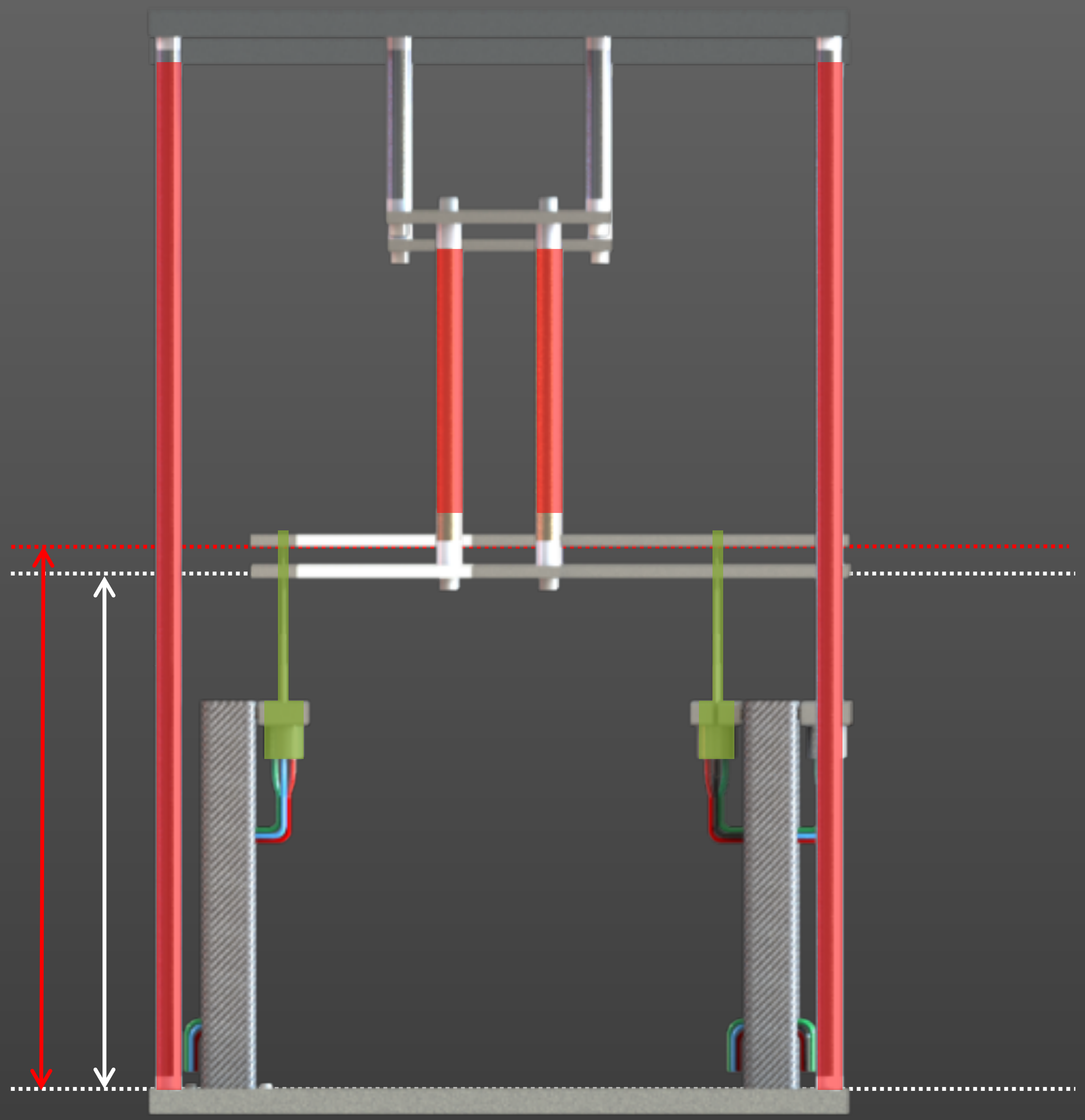


- Optical bench costly carbon fiber composites
- Reduce cost by using aluminum frame
- Thermal expansion for active control mechanism

Project Statement

Design, integrate, and verify precision, of an **active control system** that utilizes **thermal expansion** to adjust the **alignment** of spacecraft optical instrumentation. This system will correct for misalignment introduced by thermal expansion of an **aluminum optical bench**.

Concept of Operations



1. The test bed is heated to induce alignment error between two planes.

2. Alignment error is measured by the Alignment Measurement System (AMS).

3. Heating is applied to the Alignment Correction System (ACS) to maintain alignment of the two planes.

4. Displacement and temperature data are recorded and stored by the electronics package.

Critical Project Elements

Critical Project Elements	System Solution
Active control of plane alignment using expansion of a high CTE material	Alignment Correction System (ACS)
Accurate measurement of plane alignment in three-axes	Alignment Measurement System (AMS)
Introduction of controlled thermally induced alignment error	Test Bed
Thermal control and measurement of heated elements	Electronics Package

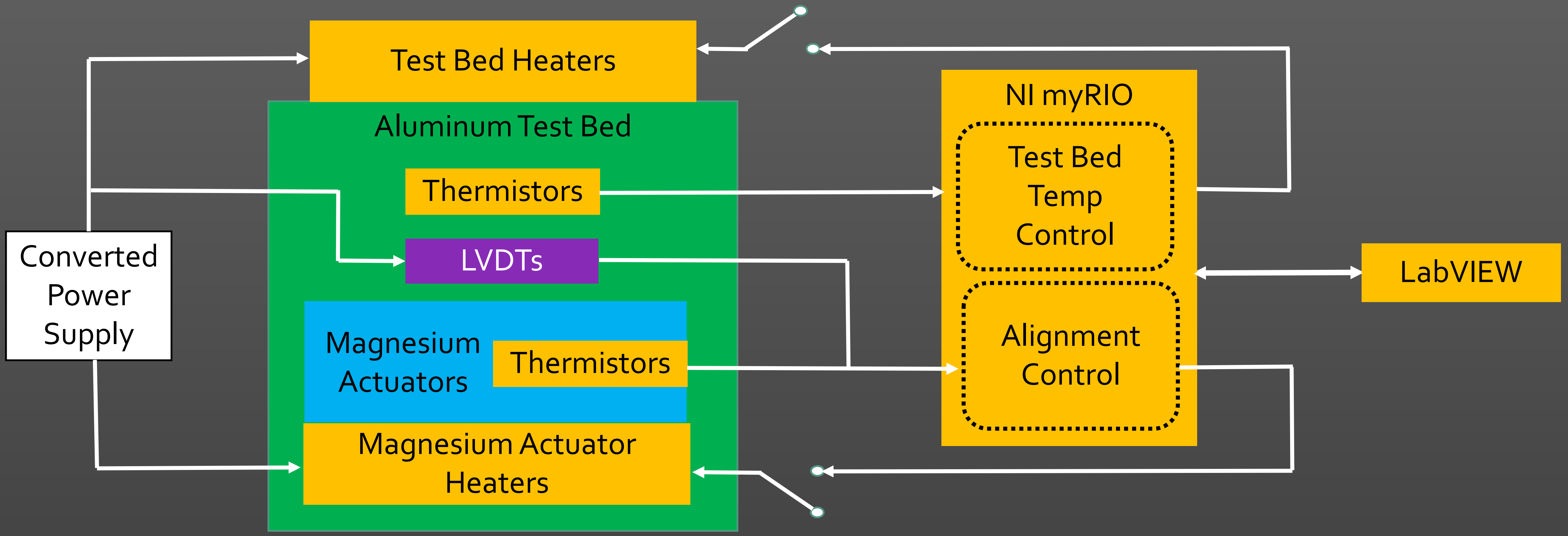
Levels of Success

	Test Demonstration Unit (TDU)	Alignment Correction System (ACS)	Alignment Measurement System (AMS)	Electronics Package
Level 1	• Induce > 100μm of plane alignment translation error over $\Delta T = 10K$	• Correct plane alignment to within ±2 μm of original position within 120 seconds	• Measure translation displacement of two planes with 1.75 μm accuracy	• Heater control to enable translation correction within ±2 μm
Level 2	• Induce customer-provided temperature profile to within 0.5 K at all times • Know temperature of actuators to within ± 0.3 K at all times	• Maintain plane alignment within ±2μm for 95% of the test bed heating profile		• Active temperature control using thermistor feedback • Record time, position and temperature data for duration of testing
Level 3	• Induce > 50 μm rotational displacement over ΔT of 10 K starting from 296.15 K	• Maintain plane alignment within ±2 μm and ±20 μrad for 95% of the test bed heating profile	• Measure translation and rotation displacements to ±1.75 μm and ±15.3 μrad accuracy	• Record, and display real-time position and temperature data at a rate of at least 1 measurement per second

Overview | Schedule | Manufacturing | Budget

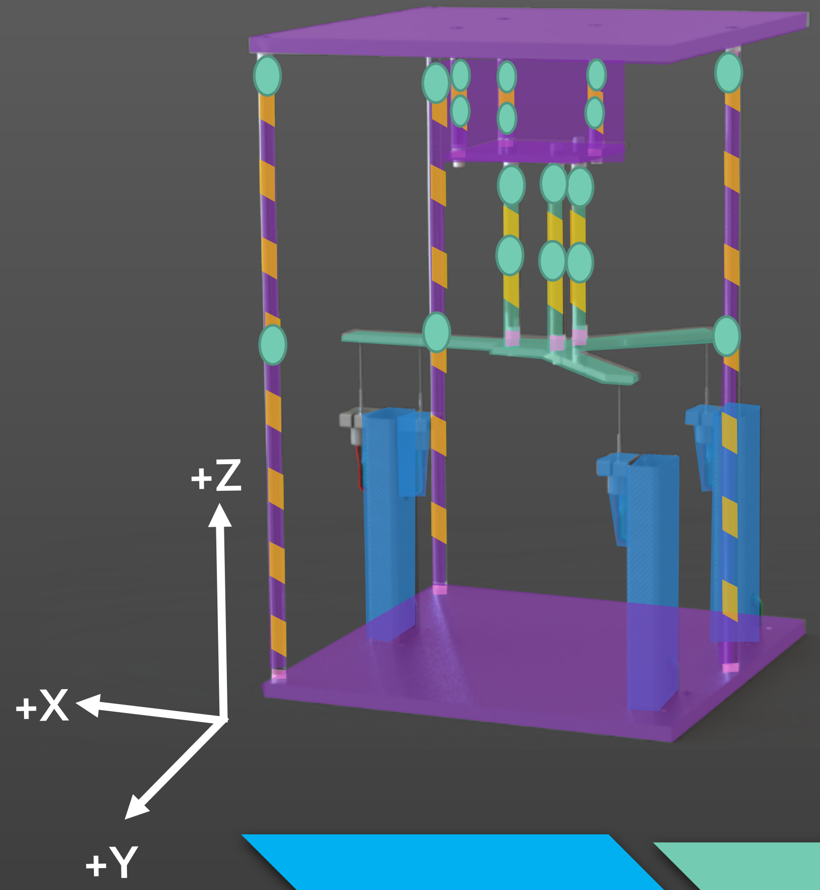
Functional Block Diagram

AMS | ACS | Test Bed | Electronics



Design Overview

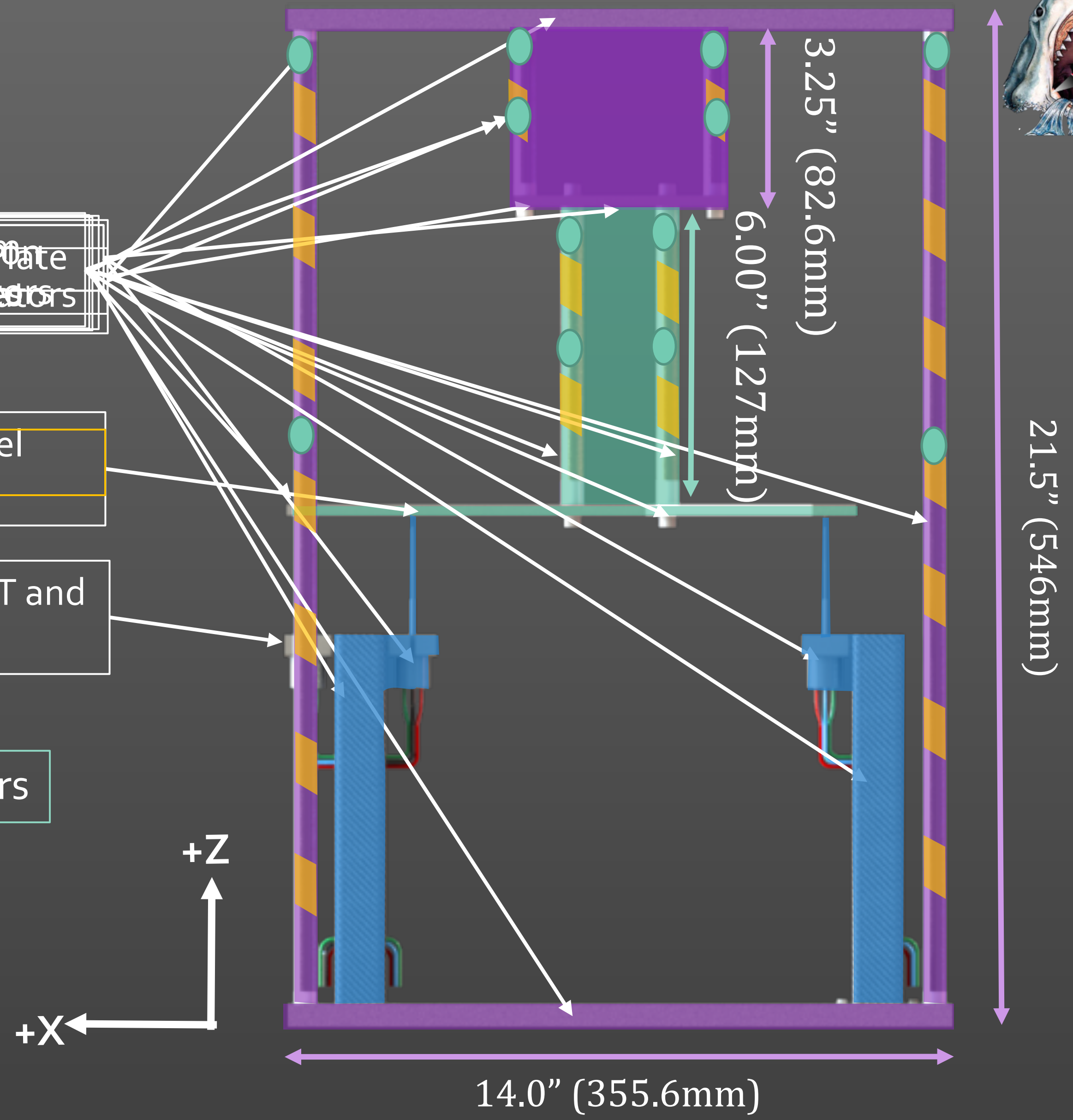
Alignment
Test Bed
Measurement System
Correction System



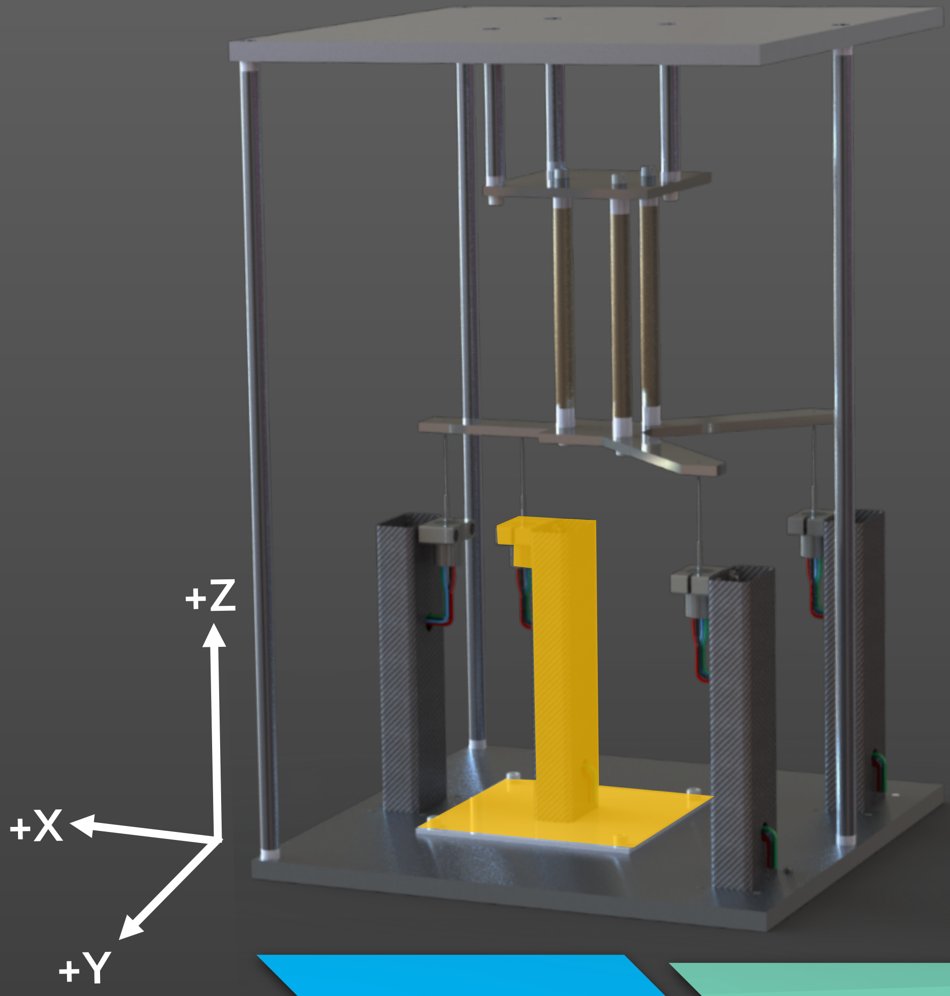
Stainless Steel
Heaters
"Exocore"

Verification LVDT and Support

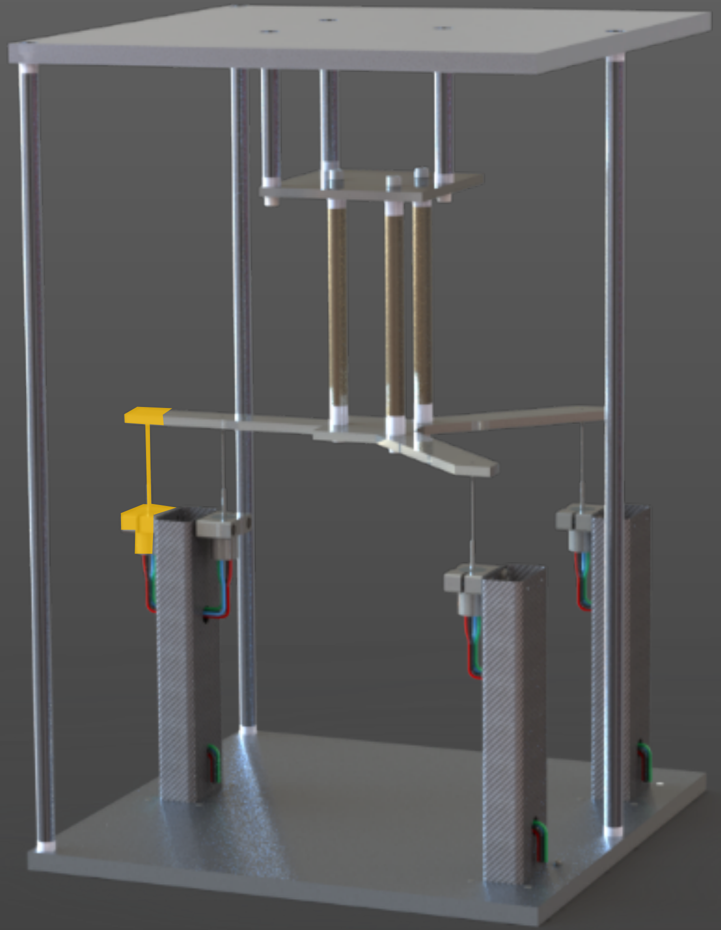
Temp Sensors



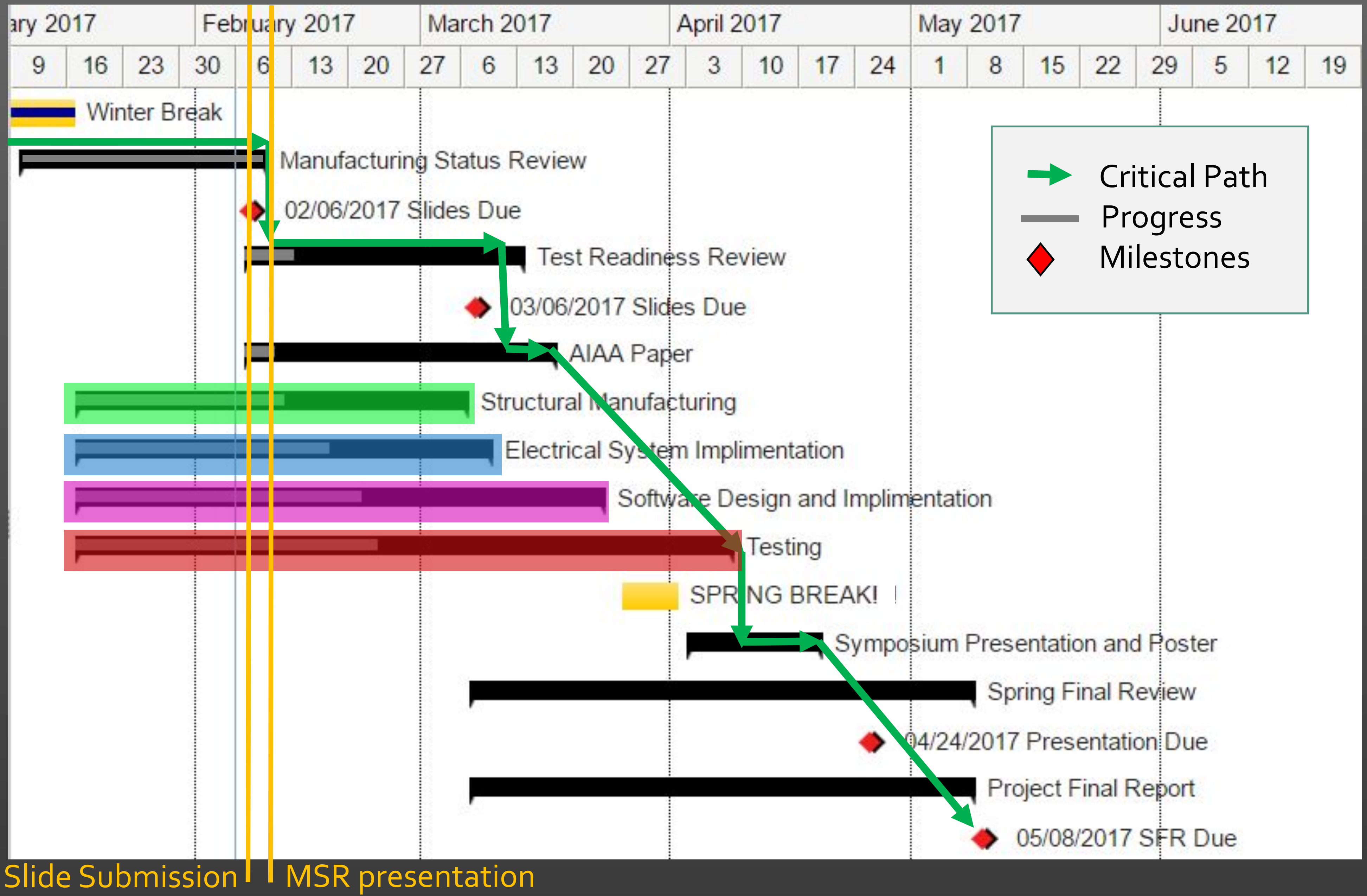
Design Updates



- Expansion of Exocore
- Relocation of 4th LVDT



Overview



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February 2017
March 2017
April 2017
May 2017
June 2017
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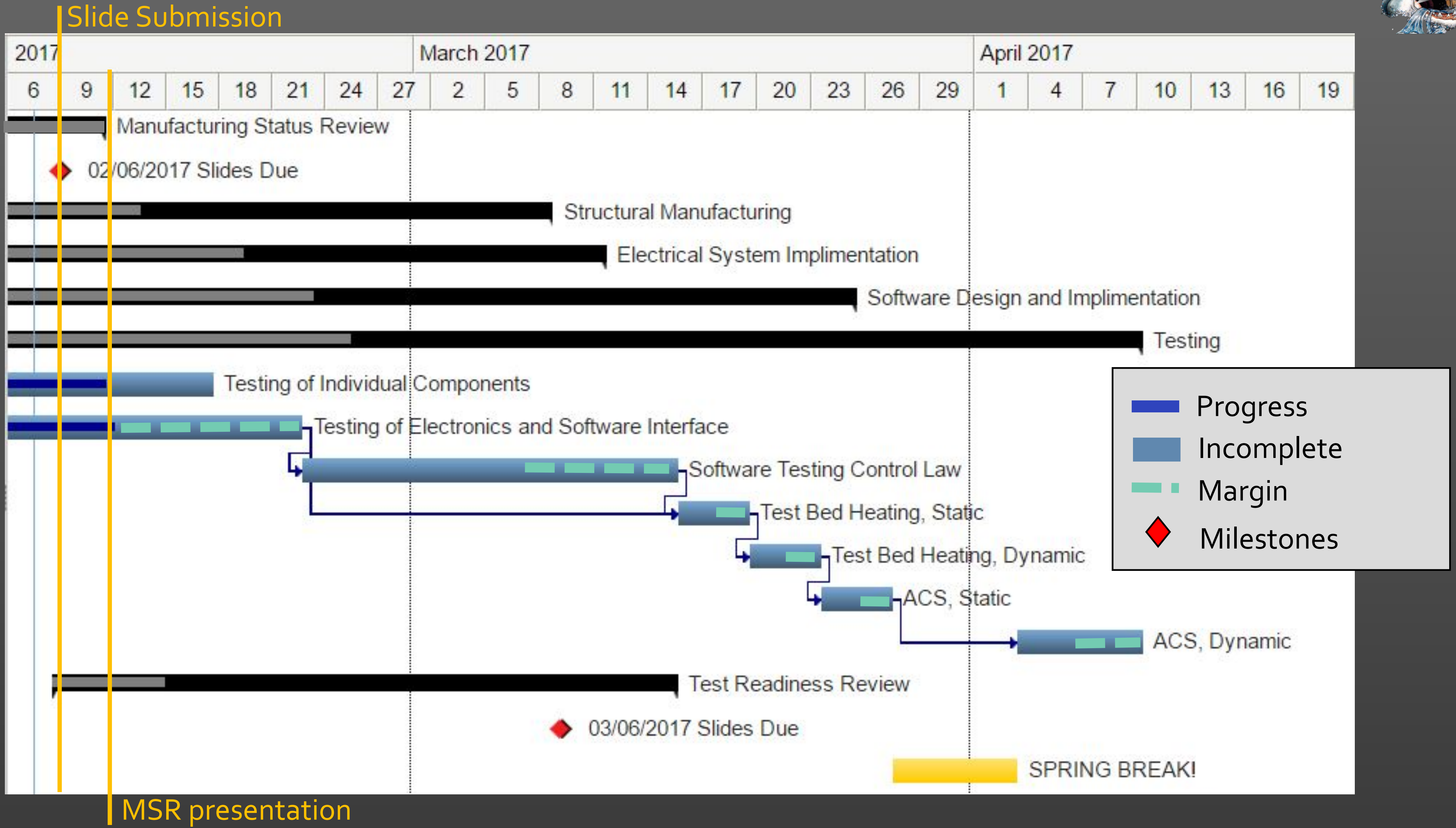
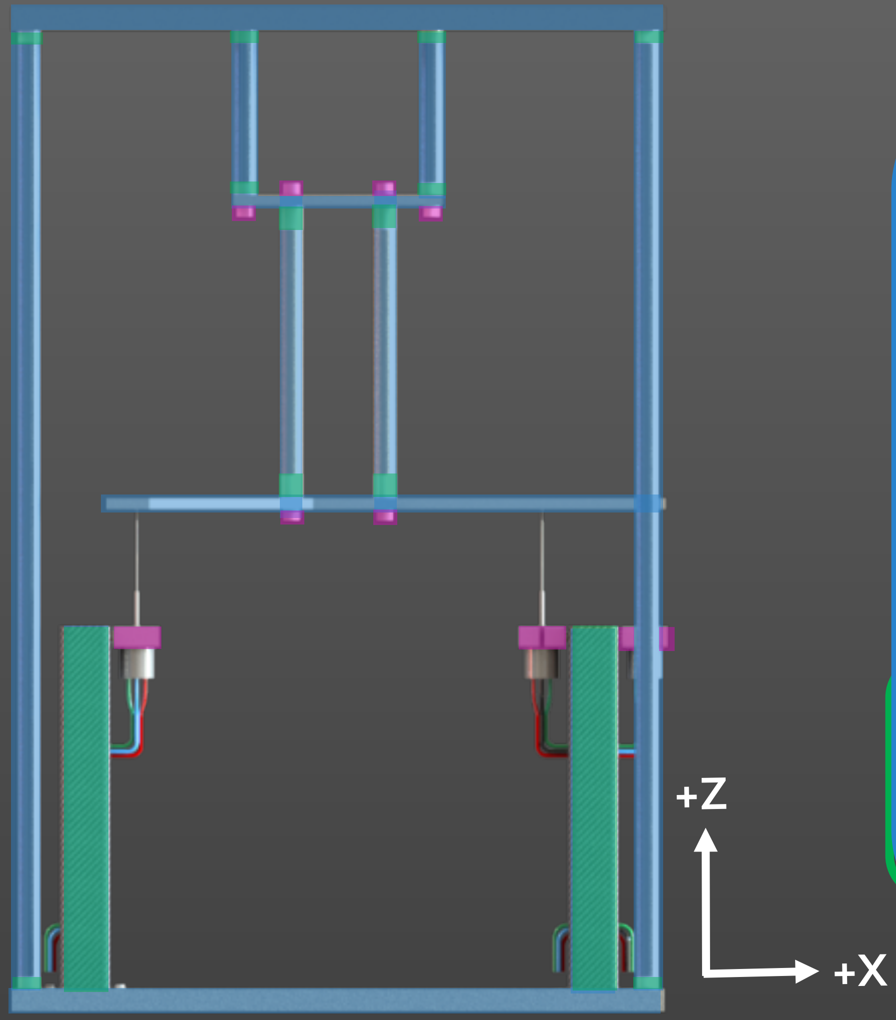
Winter Break
Manufacturing Status Review
02/06/2017 Slides Due
Test Readiness Review
03/06/2017 Slides Due
AIAA Paper
Structural Manufacturing
Electrical System Implimentation
Software Design and Implimentation
Testing
SPRING BREAK!
Symposium Presentation and Poster
Spring Final Review
04/24/2017 Presentation Due
Project Final Report
05/08/2017 SFR Due
Critical Path
Progress
Milestones
Slide Submission
MSR presentation

Testing Schedule



Manufacturing

Structure Manufacturing

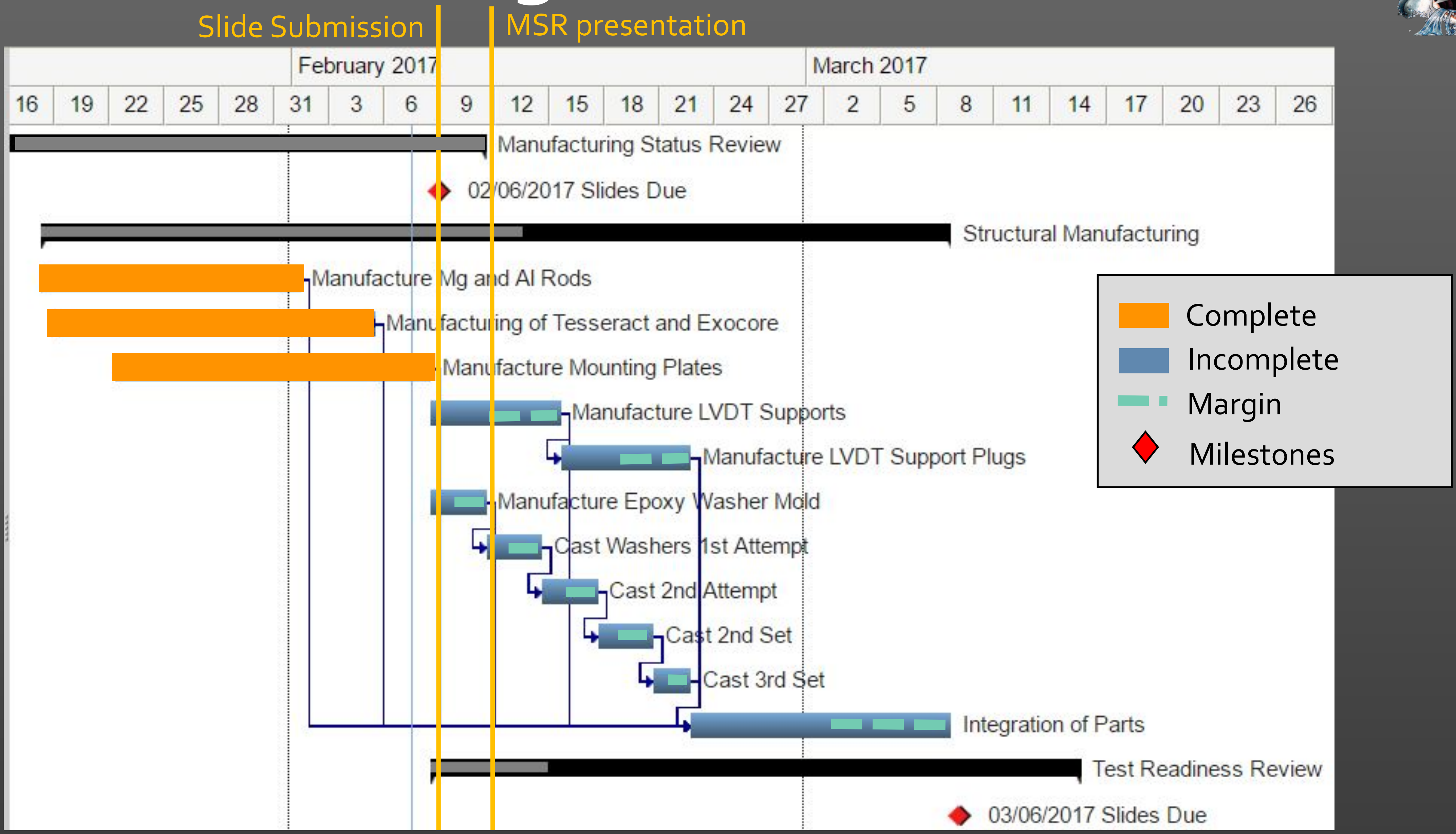


Manufactured Components	Purchased Components
~~Top mounting plates~~	LVDT mounting clamps (x4)
~~Bottom mounting plate~~	Fasteners (x18)
~~Aluminum actuators (x6)~~	
~~Magnesium Actuators (x3)~~	
~~Exocore~~	
~~Tesseract plate~~	
Carbon fiber supports	
Epoxy washers	
Carbon fiber plugs	

Manufactured

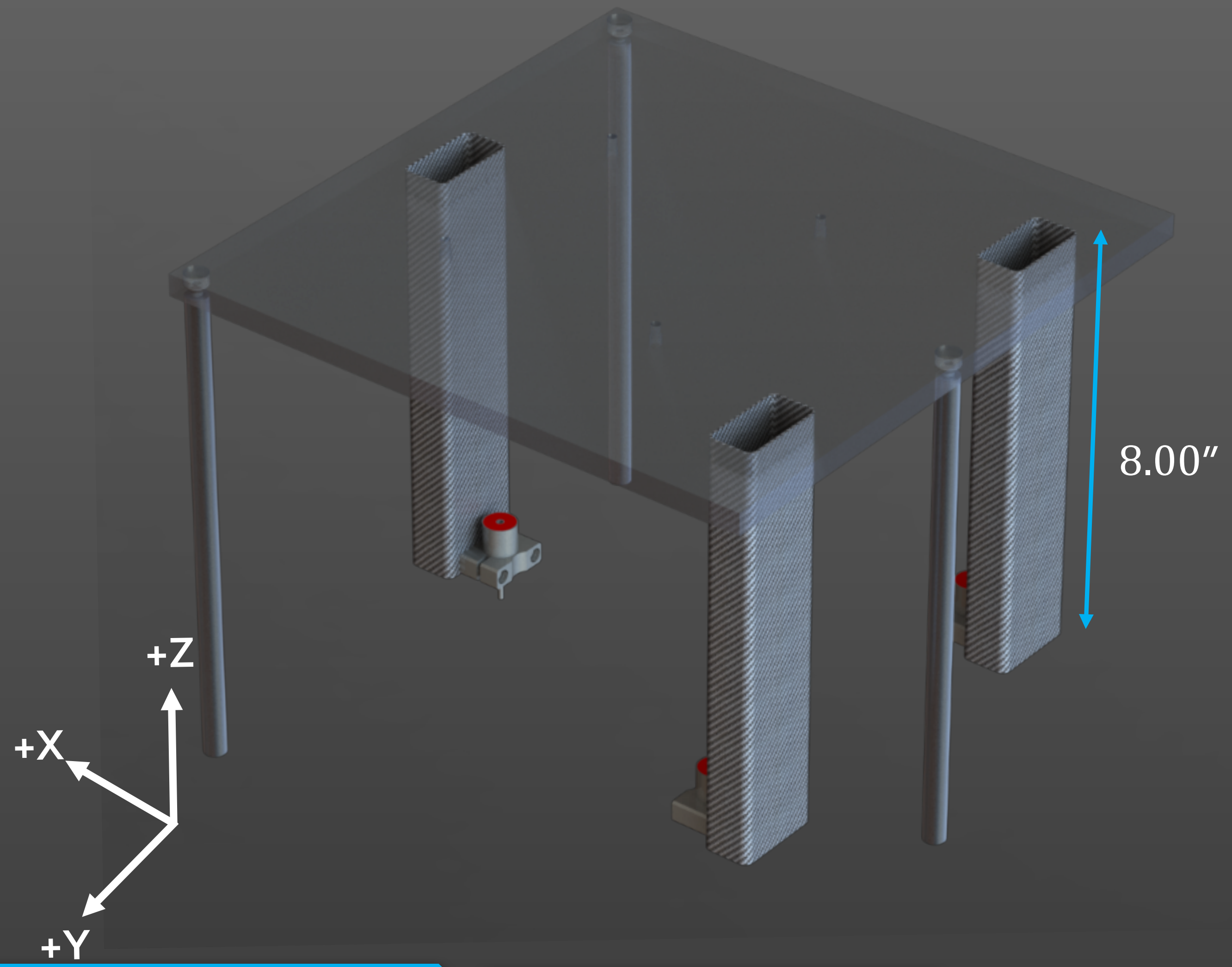
Not Manufactured

Manufacturing Schedule



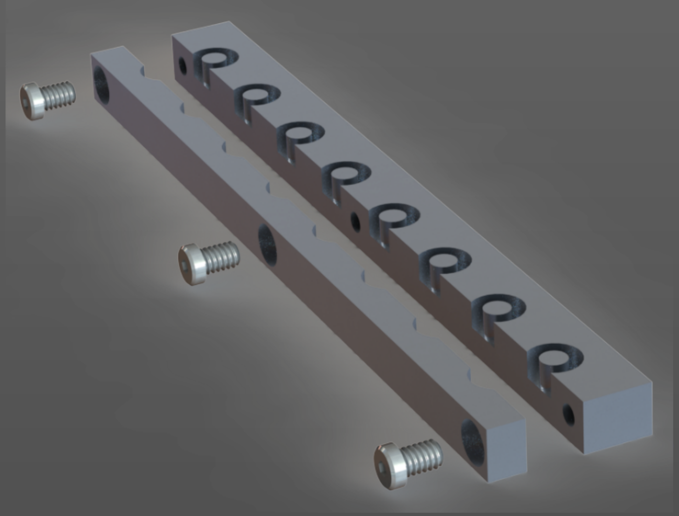
Manufacturing: Carbon Fiber Rods

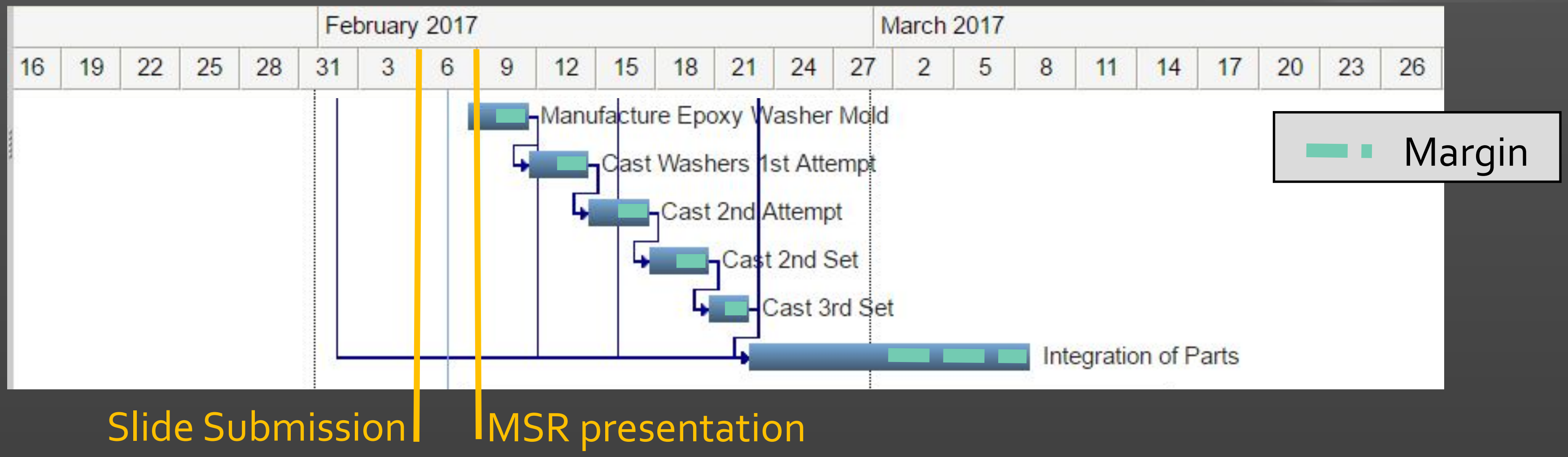
- Carbon Fiber Supports
  - Will be manufactured using purchased bit on machine shop end mill
  - Safety Considerations:
    - Breathing masks worn for manufacturing
    - Shop vac held to collect dust



Manufacturing: Epoxy Washers

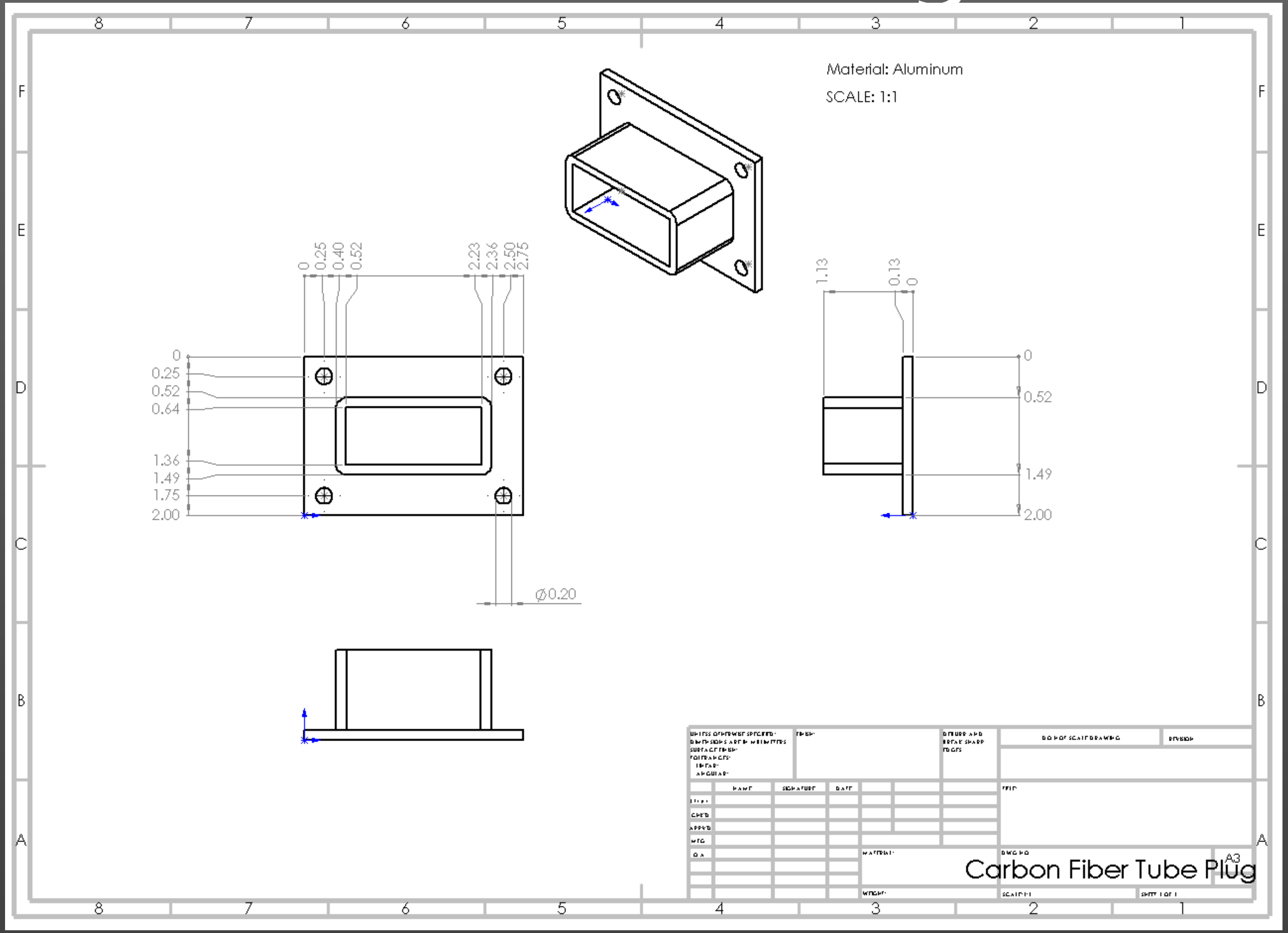
- Epoxy Washers
  - Cast washers, mold needs to be manufactured
  - Casting may require multiple iterations to ensure useable washers



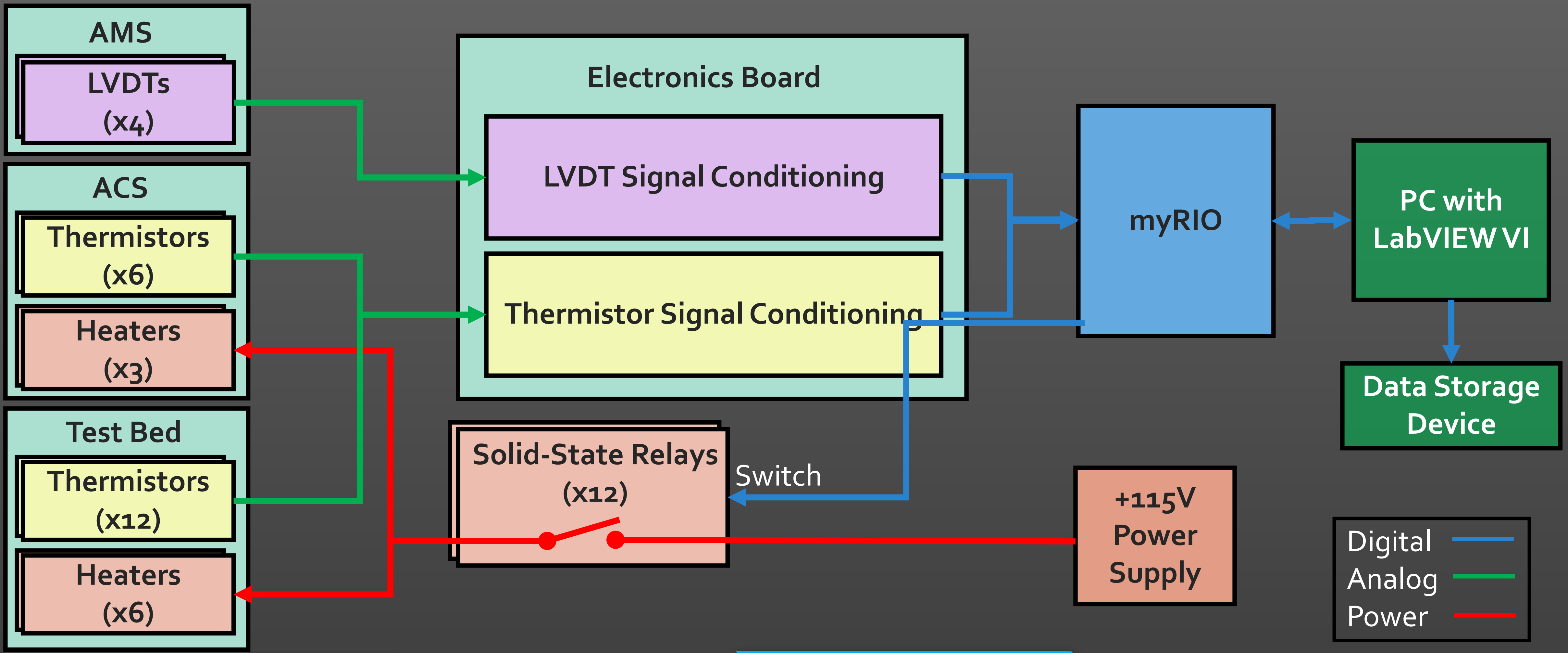


Manufacturing: Carbon Fiber Rod Plugs

- Plugs:
  - Tight tolerance component for ensuring slip fit with carbon fiber tubes
  - Each plug custom machined
    - Potential variation of carbon fiber tube shape
    - Machined to enable desired 5 thou layer of epoxy between support and plug
  - Manufacturing pushed until carbon fiber supports complete



Electronics Package CONOPS



Electronics Package Status

AMS
- LVDTs (x4)

ACS
- Thermistors (x6)
- Heaters (x3)

Test Bed
- Thermistors (x12)
- Heaters (x6)

Electronics Board
- LVDT Interface PCB
- Thermistor Interface PCB
- Solid-State Relay PCB

myRIO

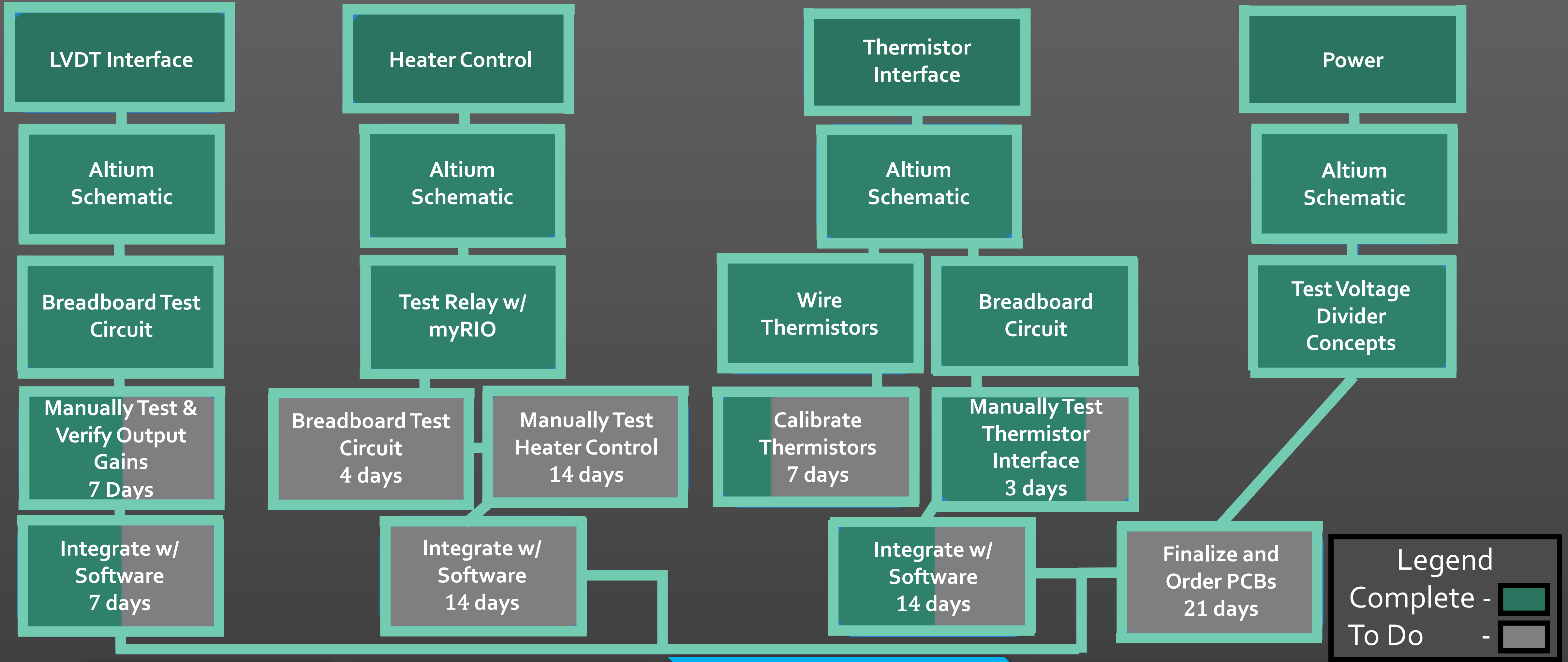
PC with LabVIEW VI

Data Storage Device

+115V Power Supply

Acquired/Built -
In Development -
Need to Order -

Electronics Package Status

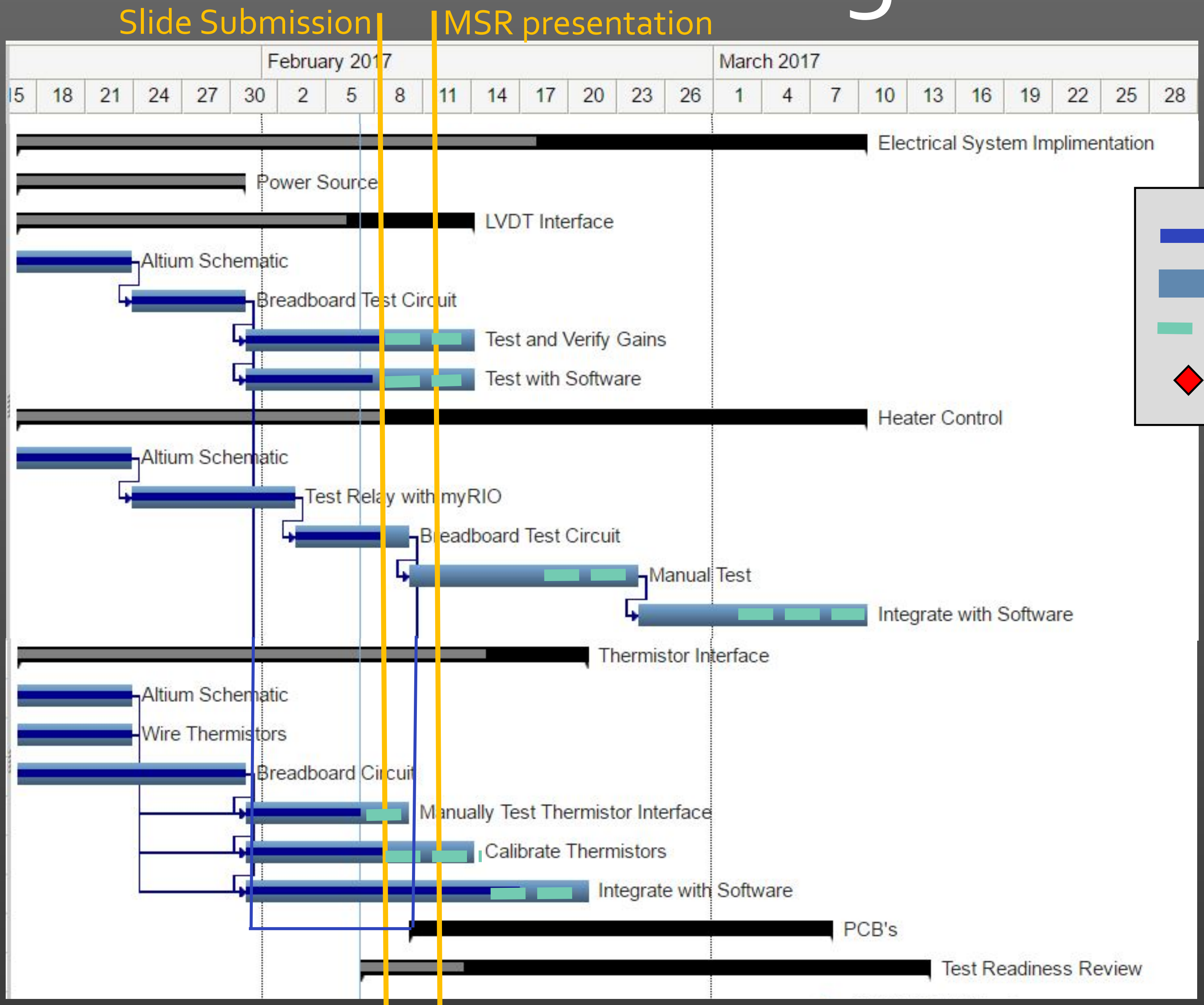


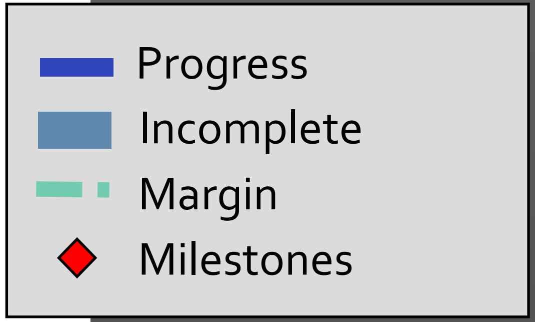
Overview | Schedule | Manufacturing | Budget

Manufacturing Electronics: Possible Complications

- Thermistor Calibration
  - Require precise knowledge of R_{sense} and R_{therm} for each thermistor
  - Will hand measure each R_{sense} and use an ice bath to determine each R_{therm}
- LVDT Output Gains
  - Requires high gain resistor precision for accurate LVDT output
  - Will build in extra resistor pads to PCB design for gain adjustment
- Relay Integration
  - Each relay requires 2mA activation current, which each myRio DIO line must be able to supply
  - Will test current output through each relay with all outputs on to verify

Electrical Manufacturing



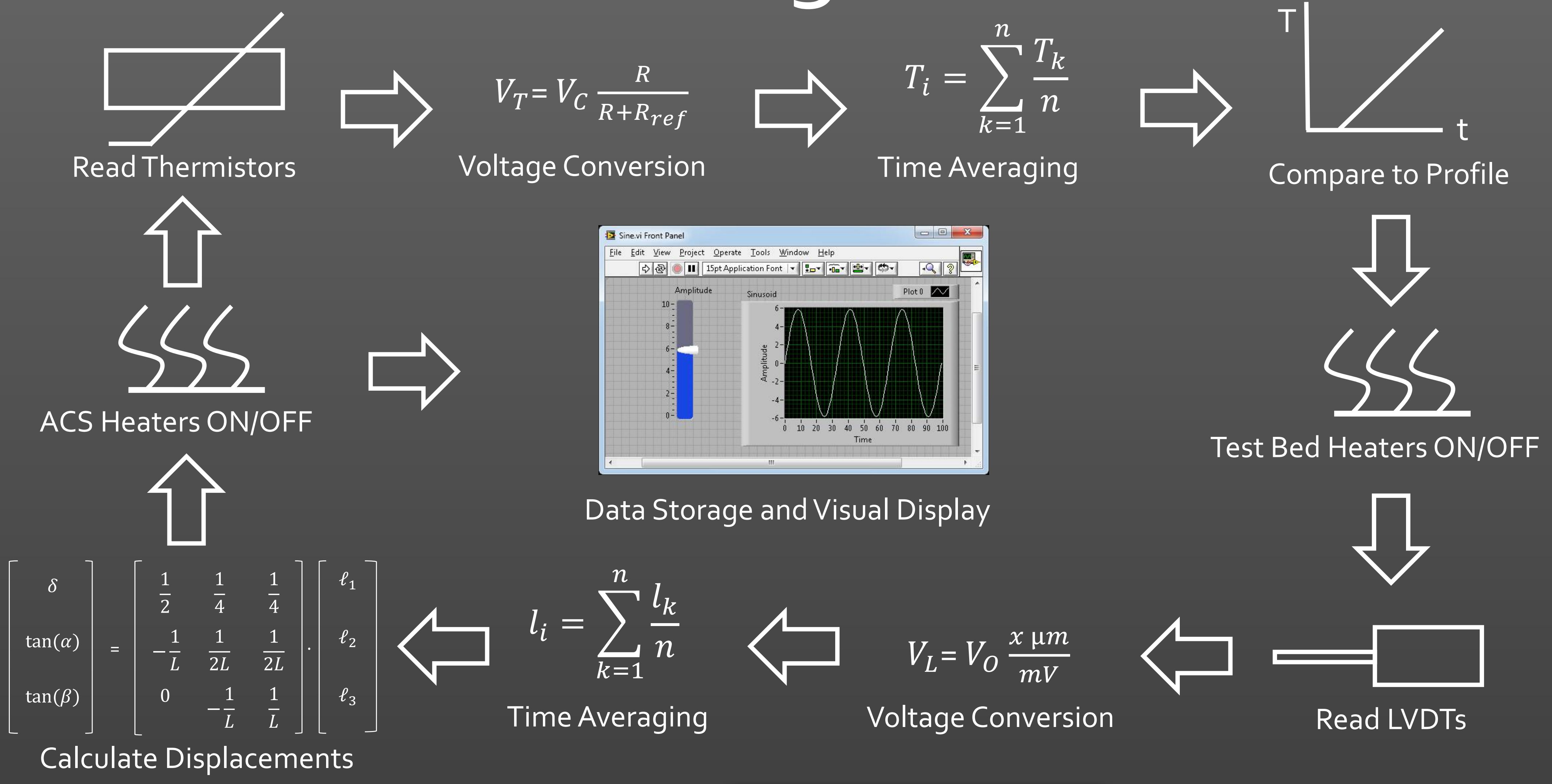


Software Overview

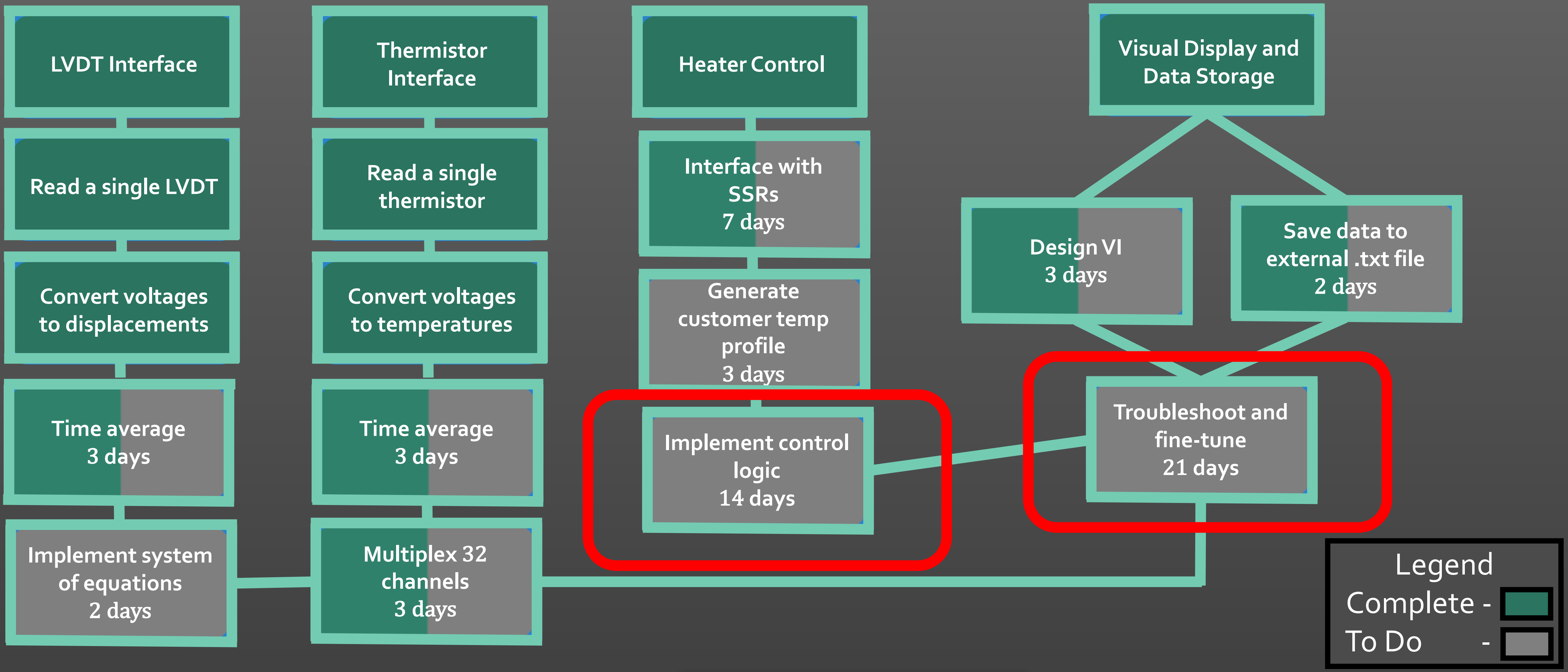
- Software designed and implemented through LabVIEW
- Four distinct development areas:
  - LVDT Interfacing
  - Thermistor Interfacing
  - Heater Control
  - Data Display/Storage

Software validated through component tests. Test data will be compared to predicted MATLAB results.

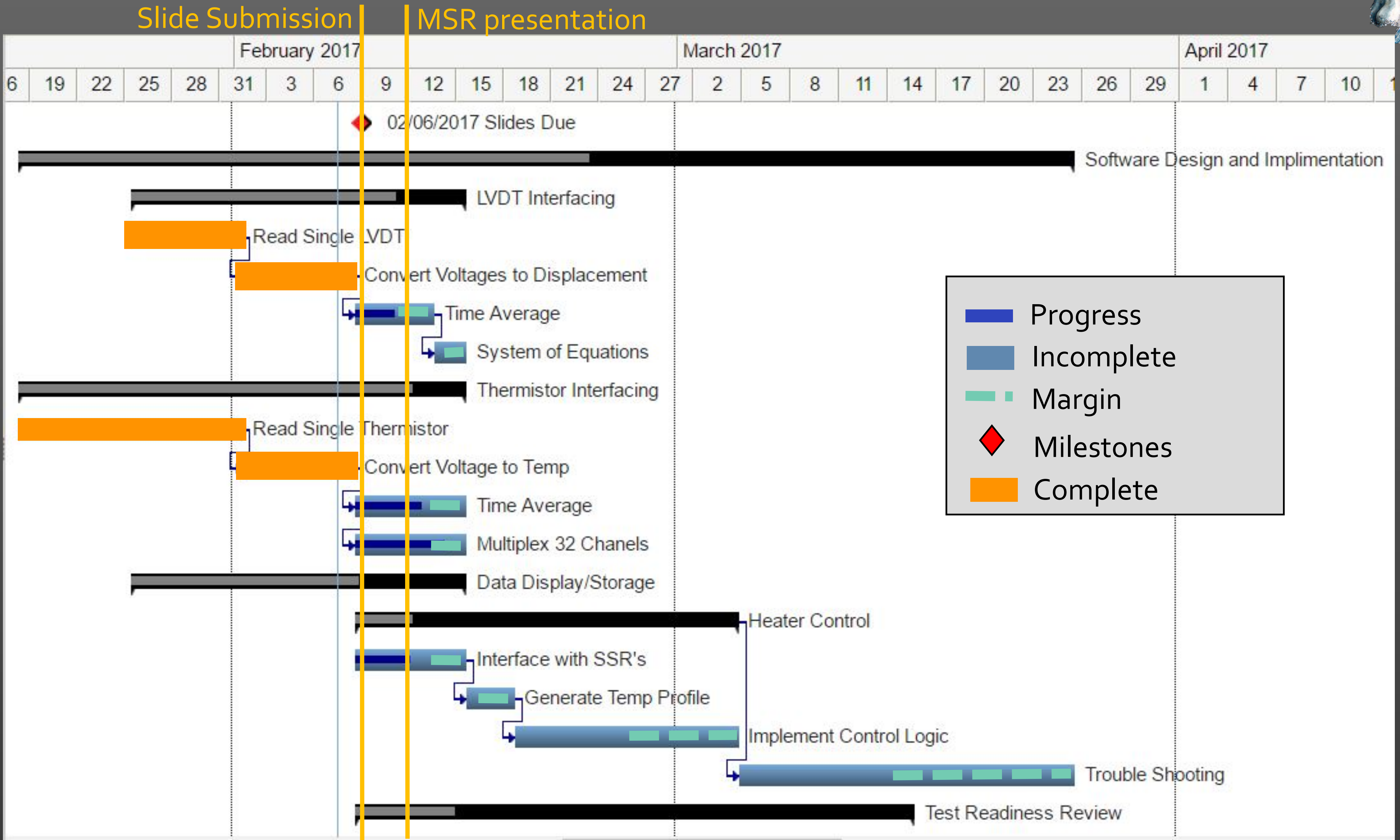
Software Flow Diagram



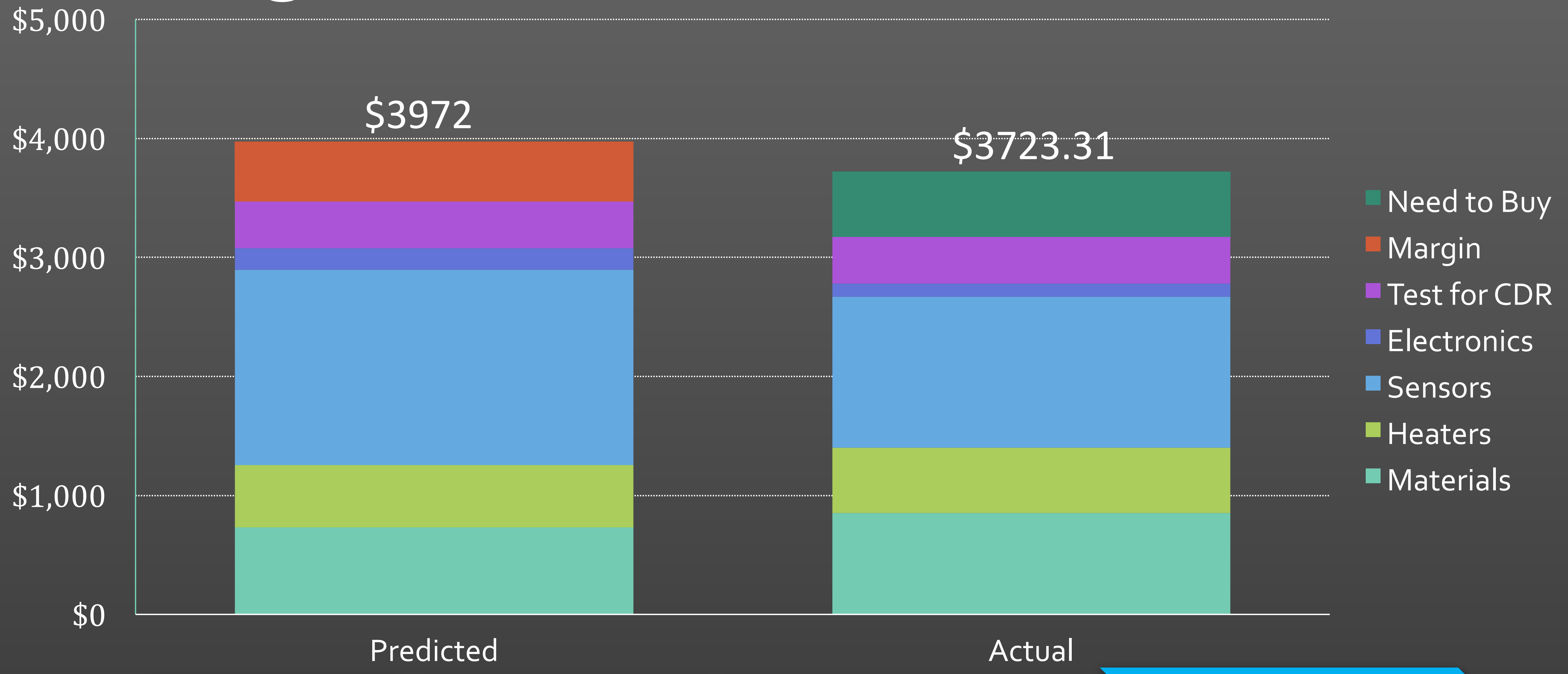
Software Status: LabView



Software Schedule



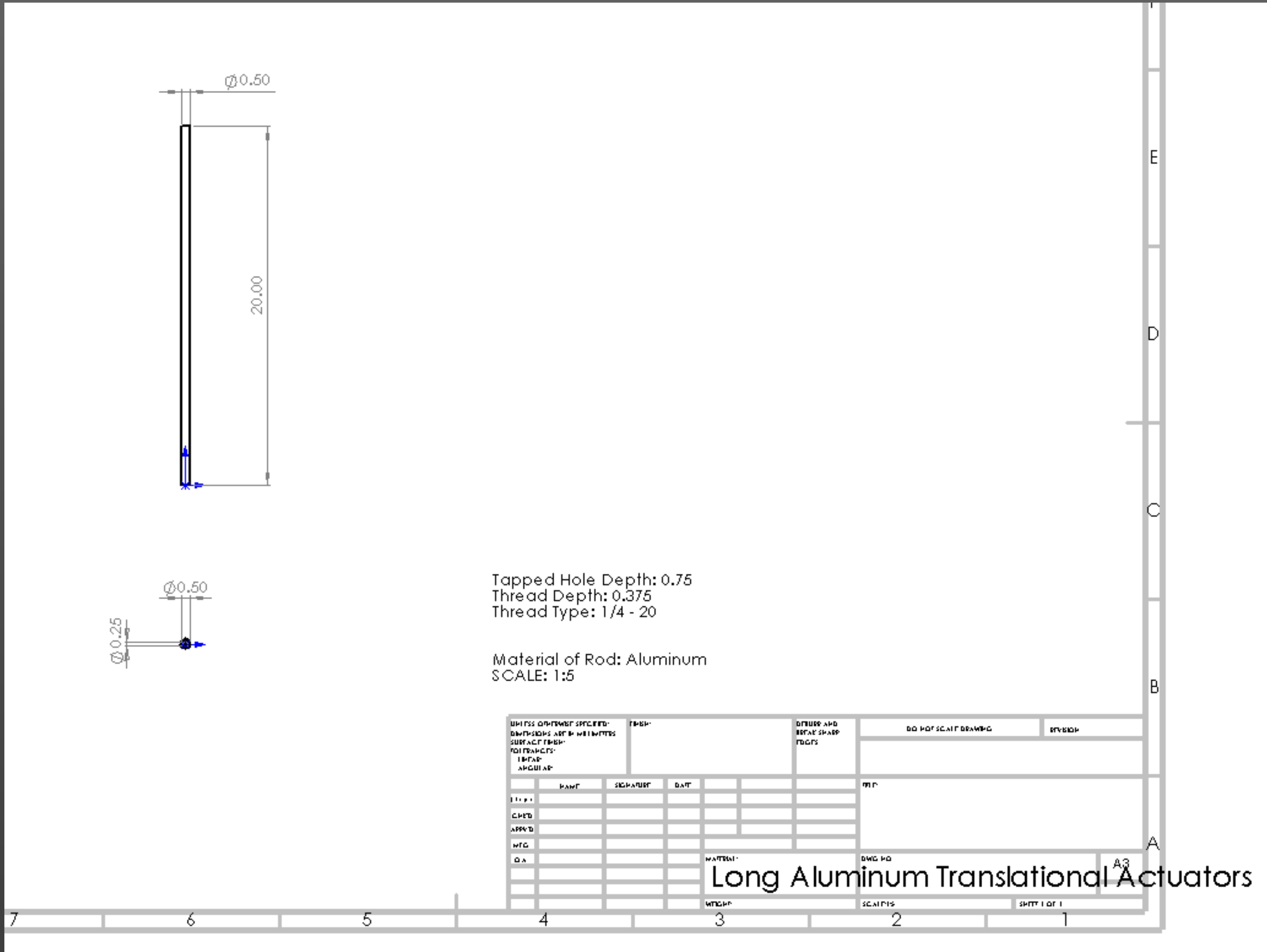
Budget


$5,000
$4,000
$3,000
$2,000
$1,000
$0
$3972
$3723.31
Predicted
Actual
Need to Buy
Margin
Test for CDR
Electronics
Sensors
Heaters
Materials

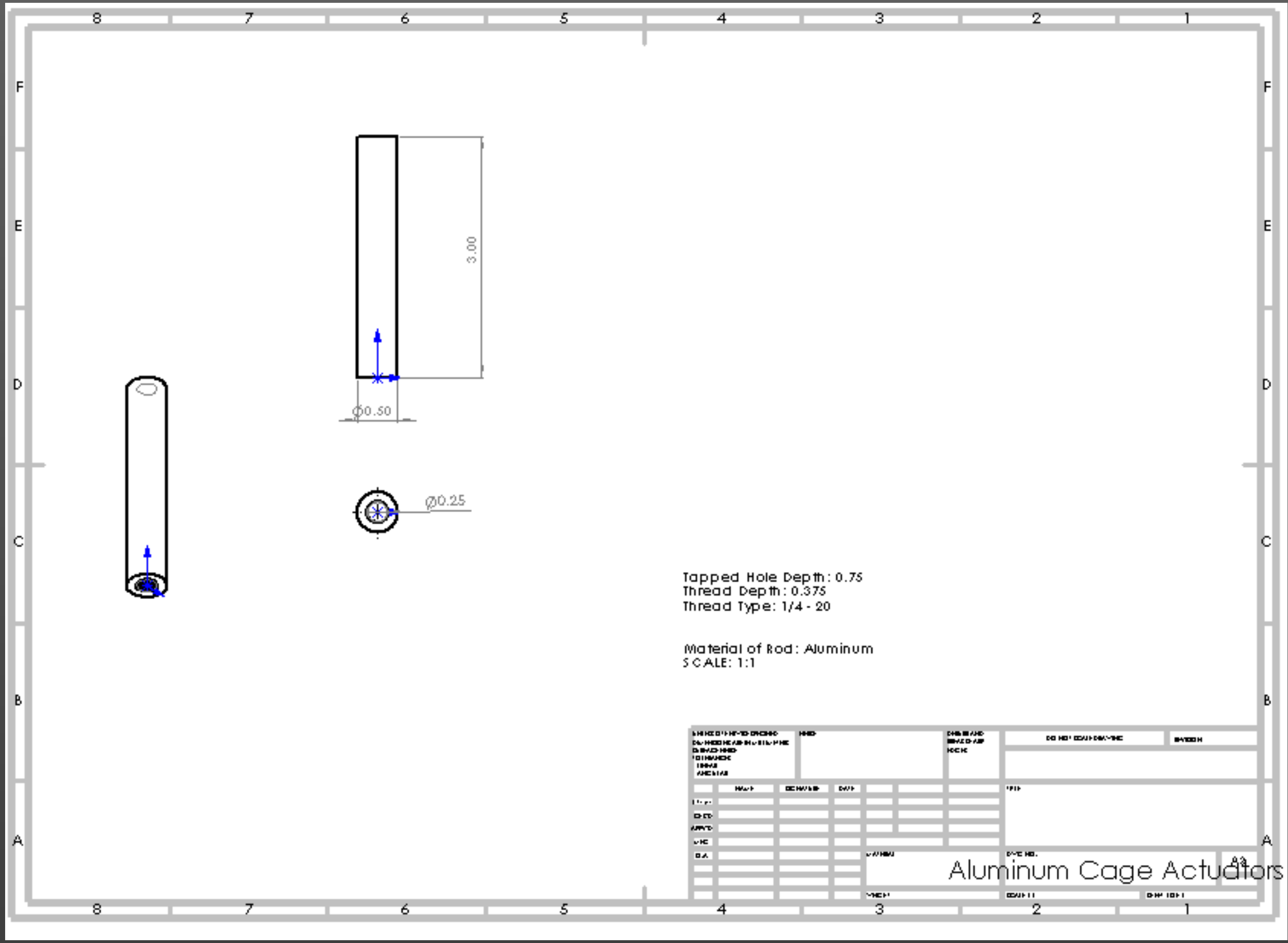
BACKUPS

Drawing Package

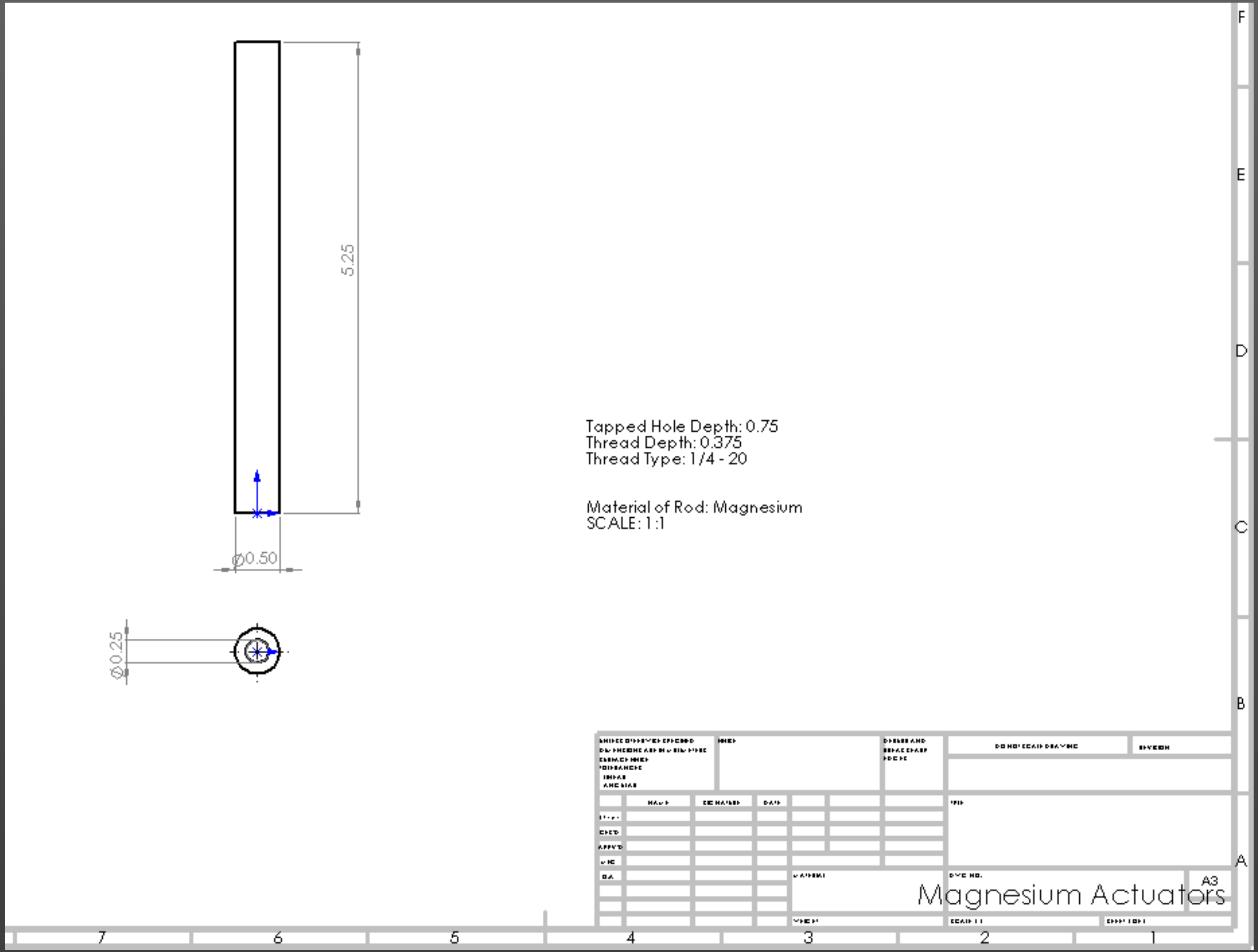
Mechanical Drawings: Long Aluminum Actuators



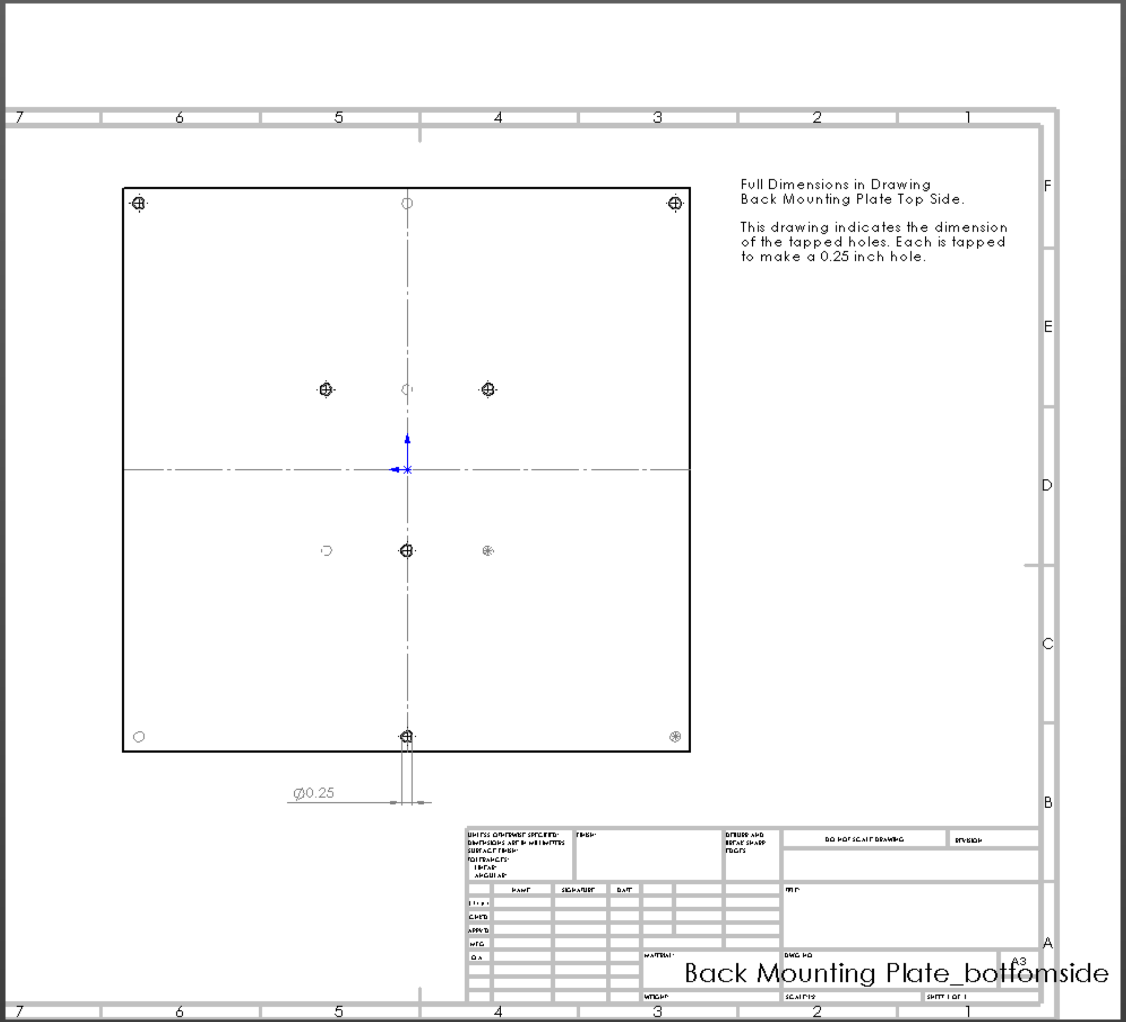
Mechanical Drawings: Aluminum Actuators

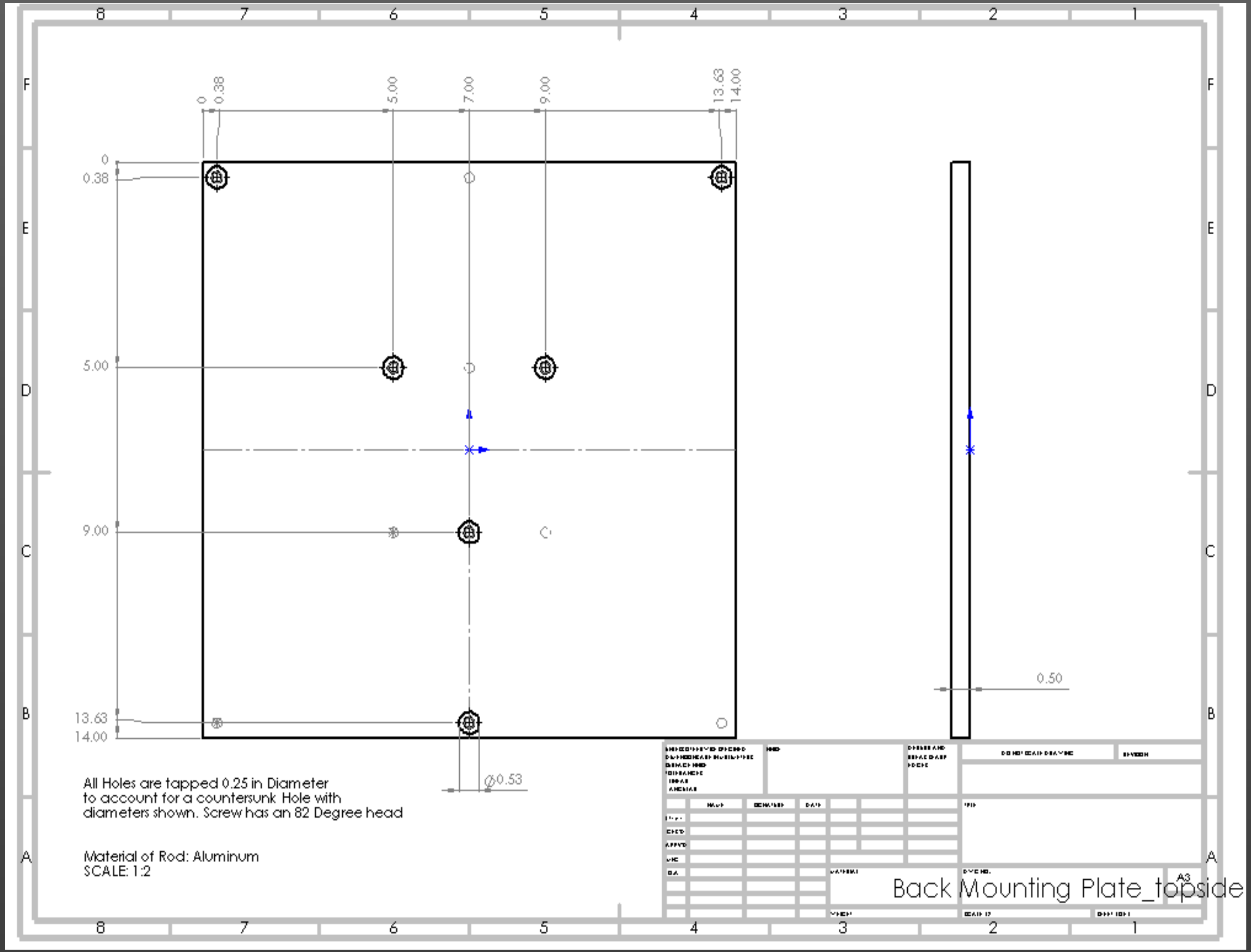


Mechanical Drawings: Magnesium Actuators

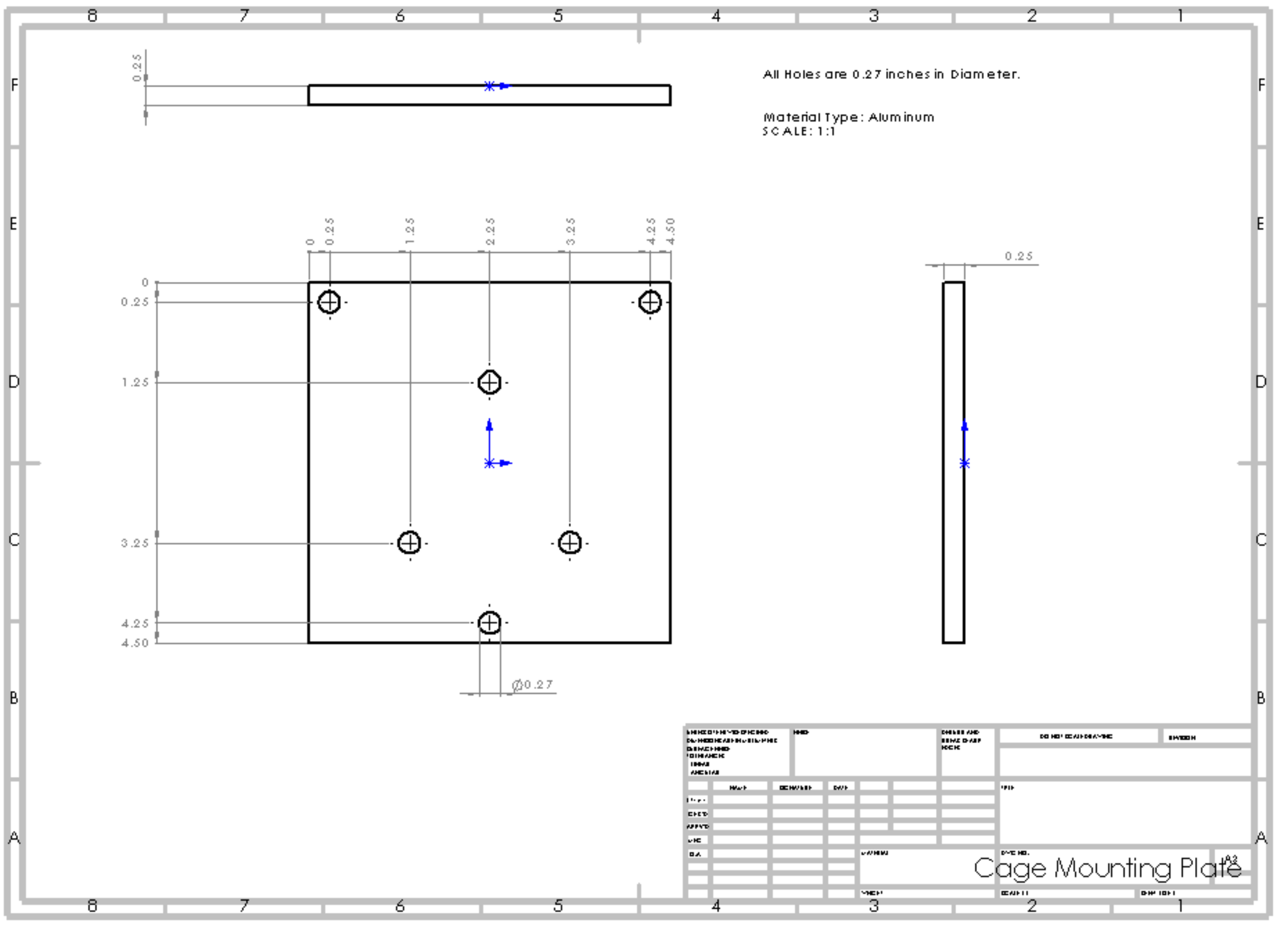


Mechanical Drawings: Back Mounting Plate

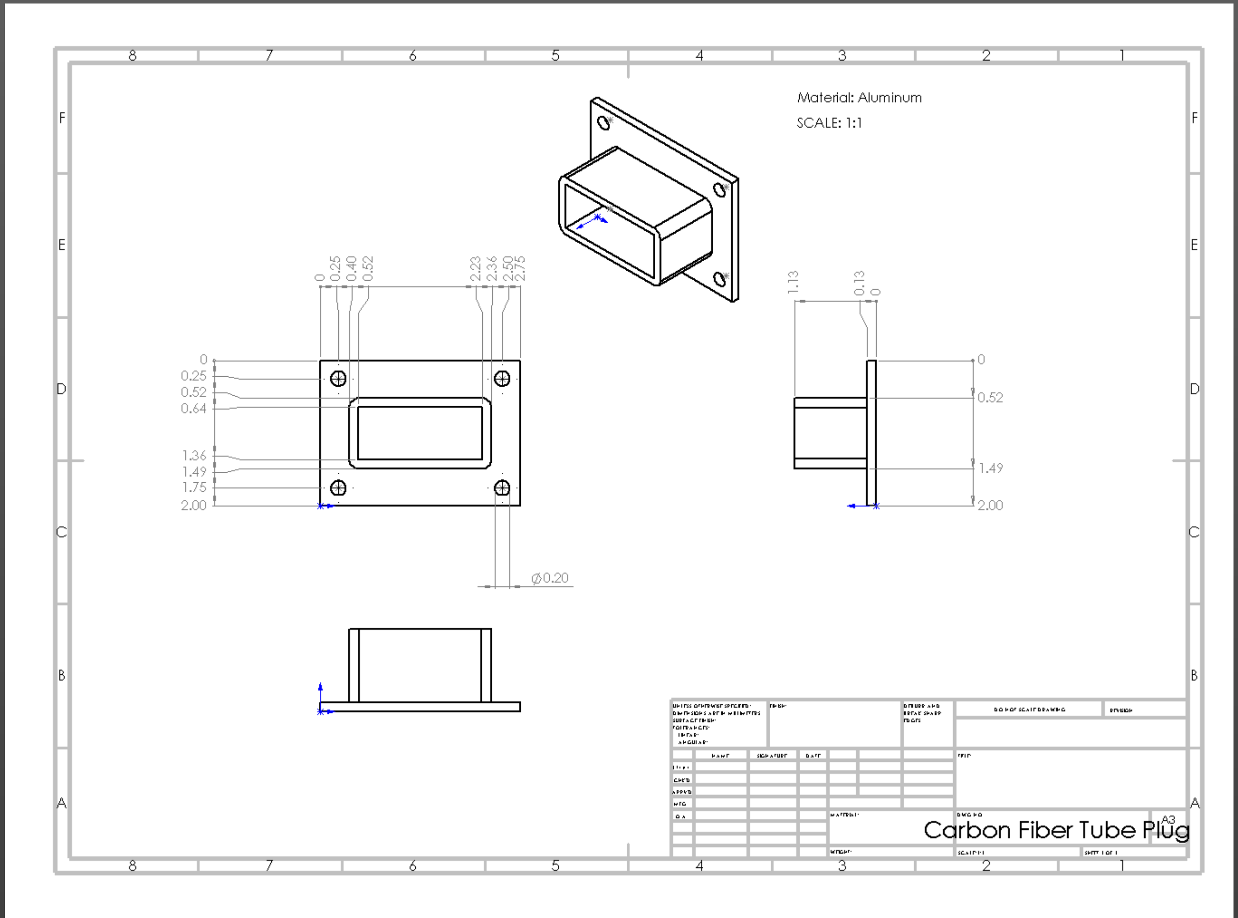




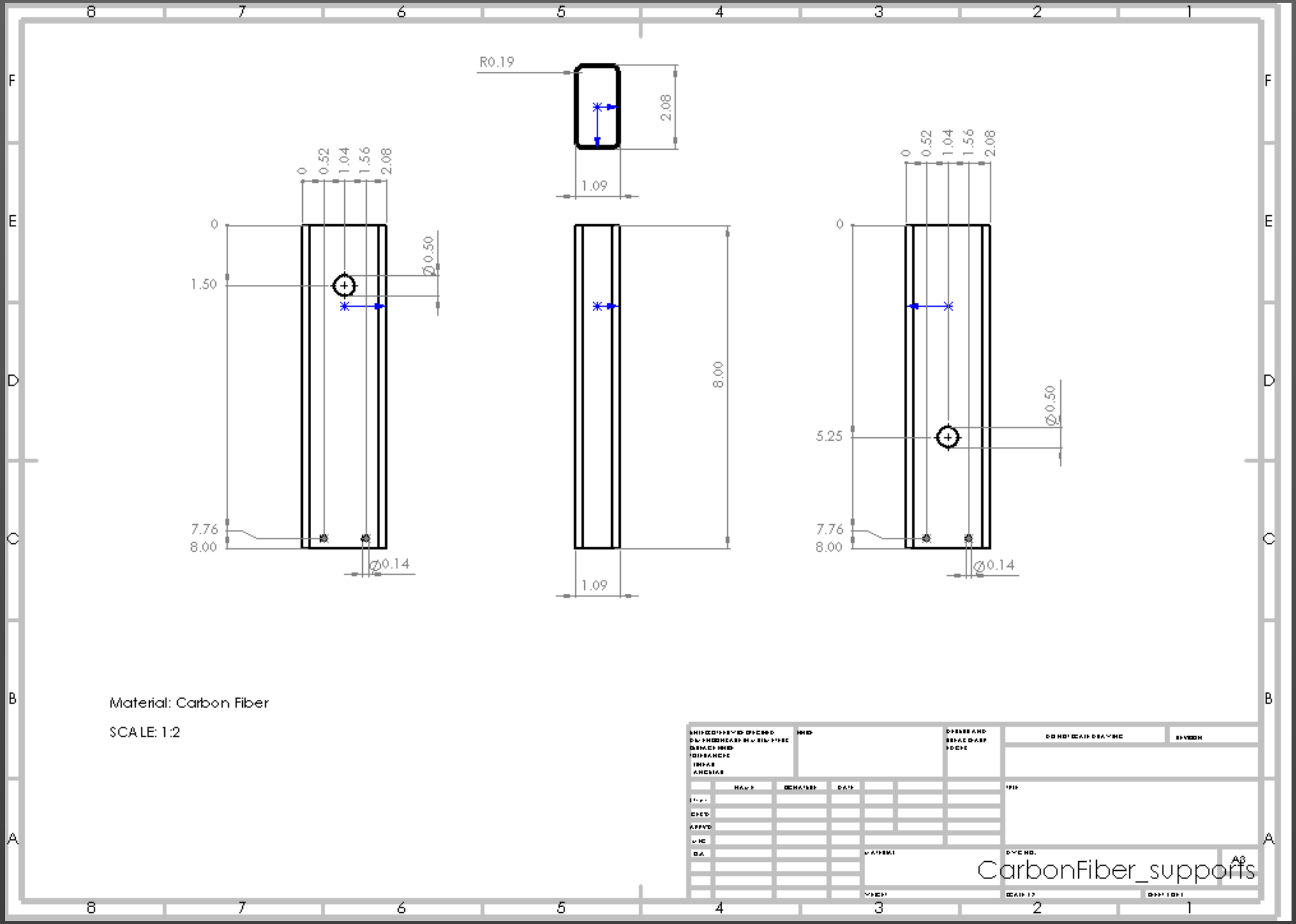
Mechanical Drawings: Tesseract



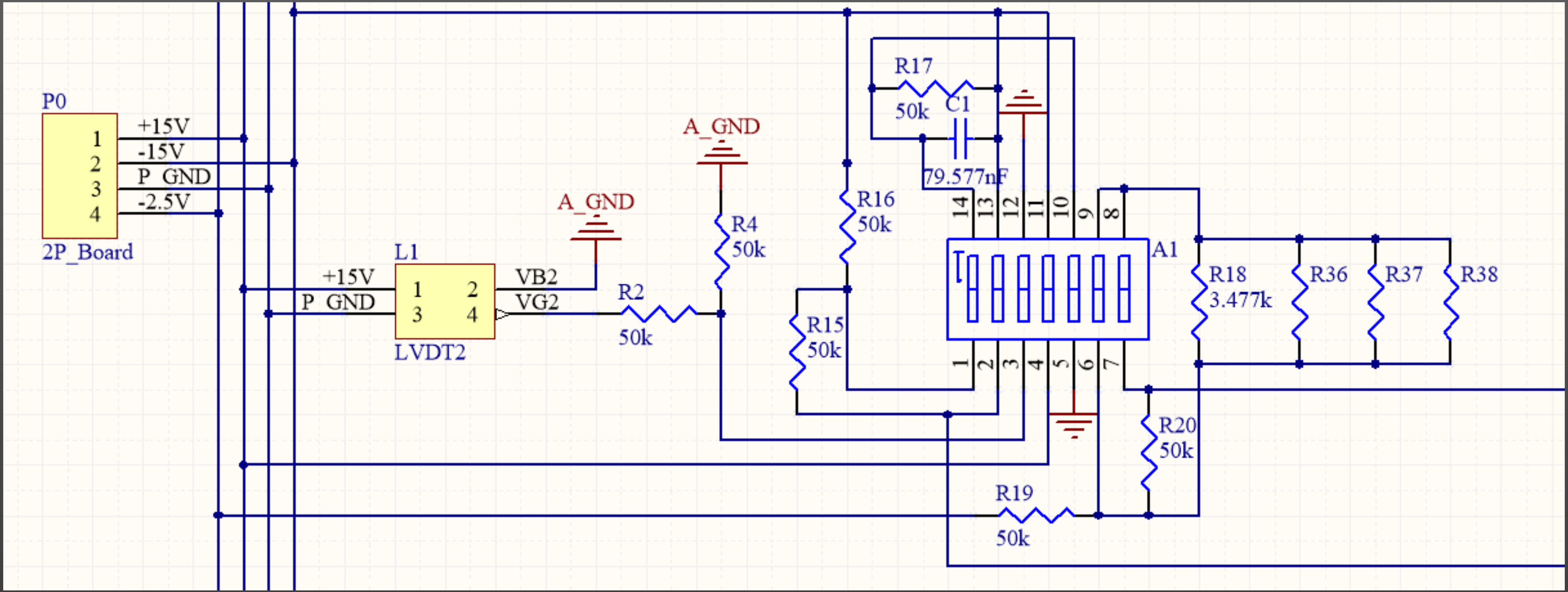
Mechanical Drawings: Carbon Fiber Plug



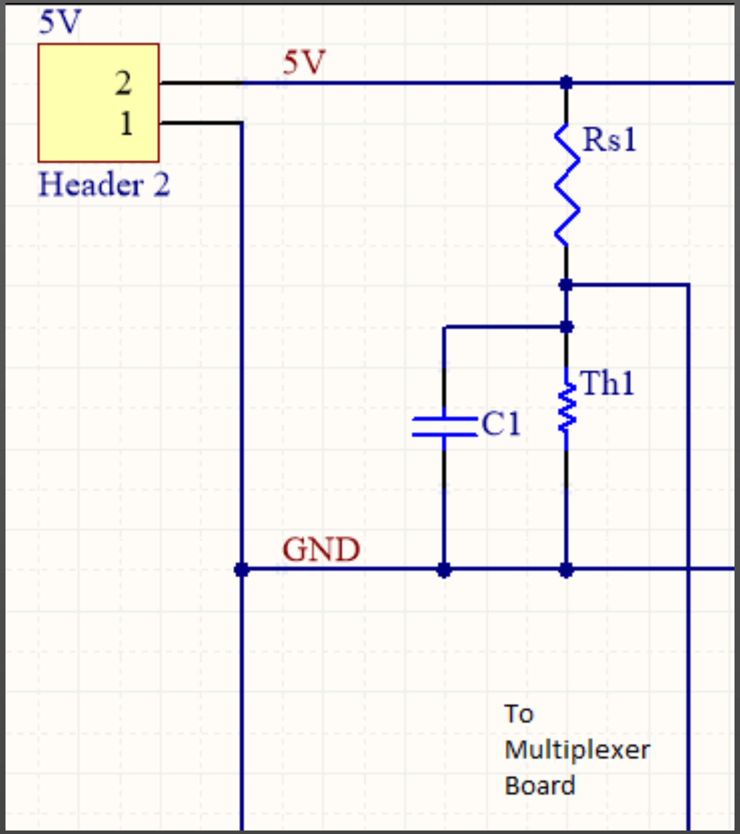
Mechanical Drawings: Carbon Fiber Supports



LVDT PCB Schematic



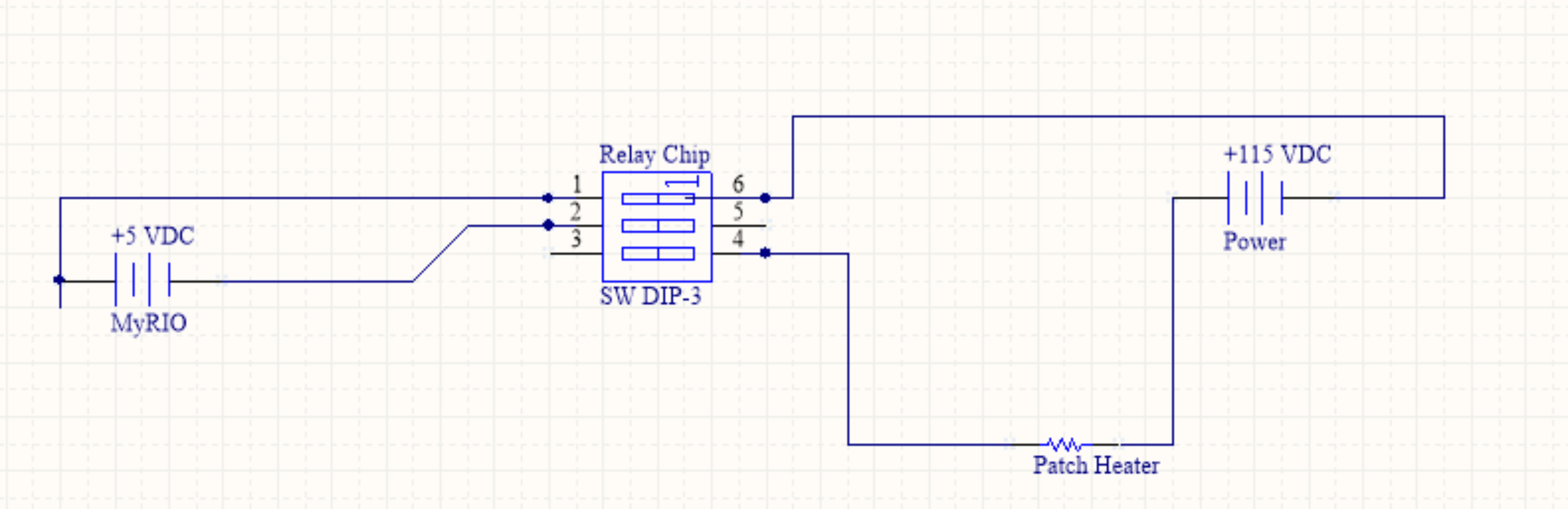
Thermistor Schematic



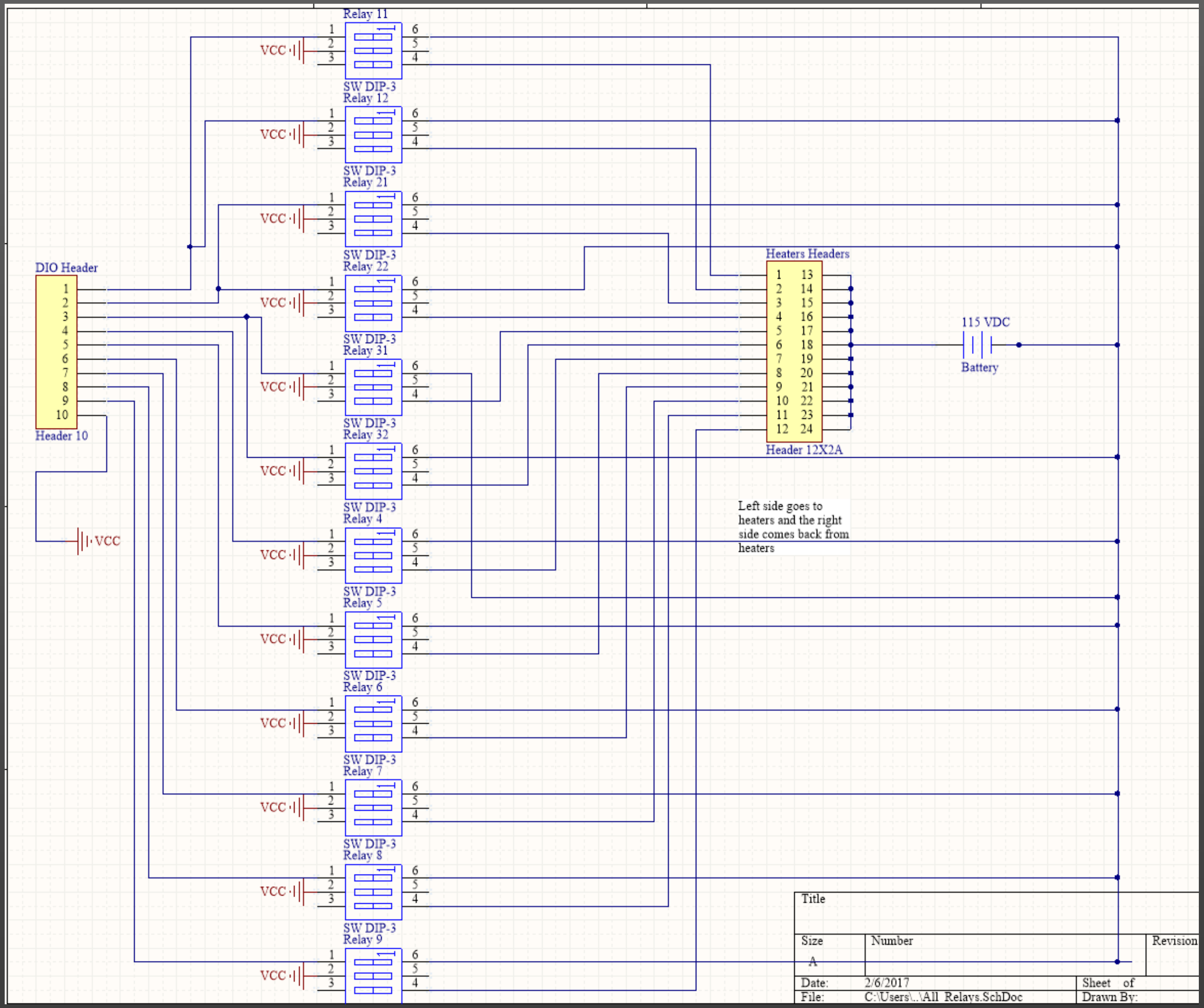
Repeats 18x

Multiplexer
& myRIO
Interface

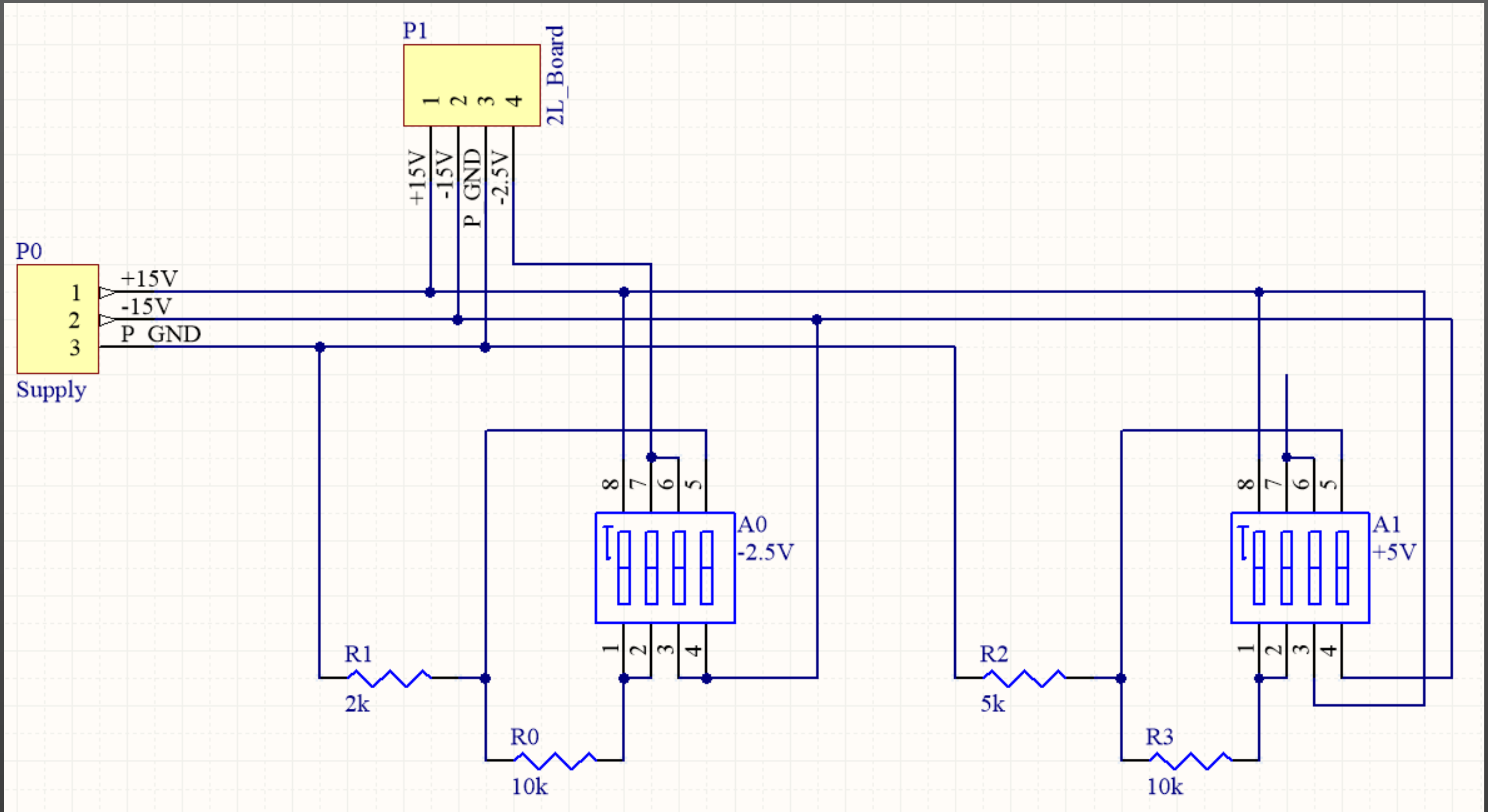
Single Heater Control Schematic



All Heaters Control Schematic



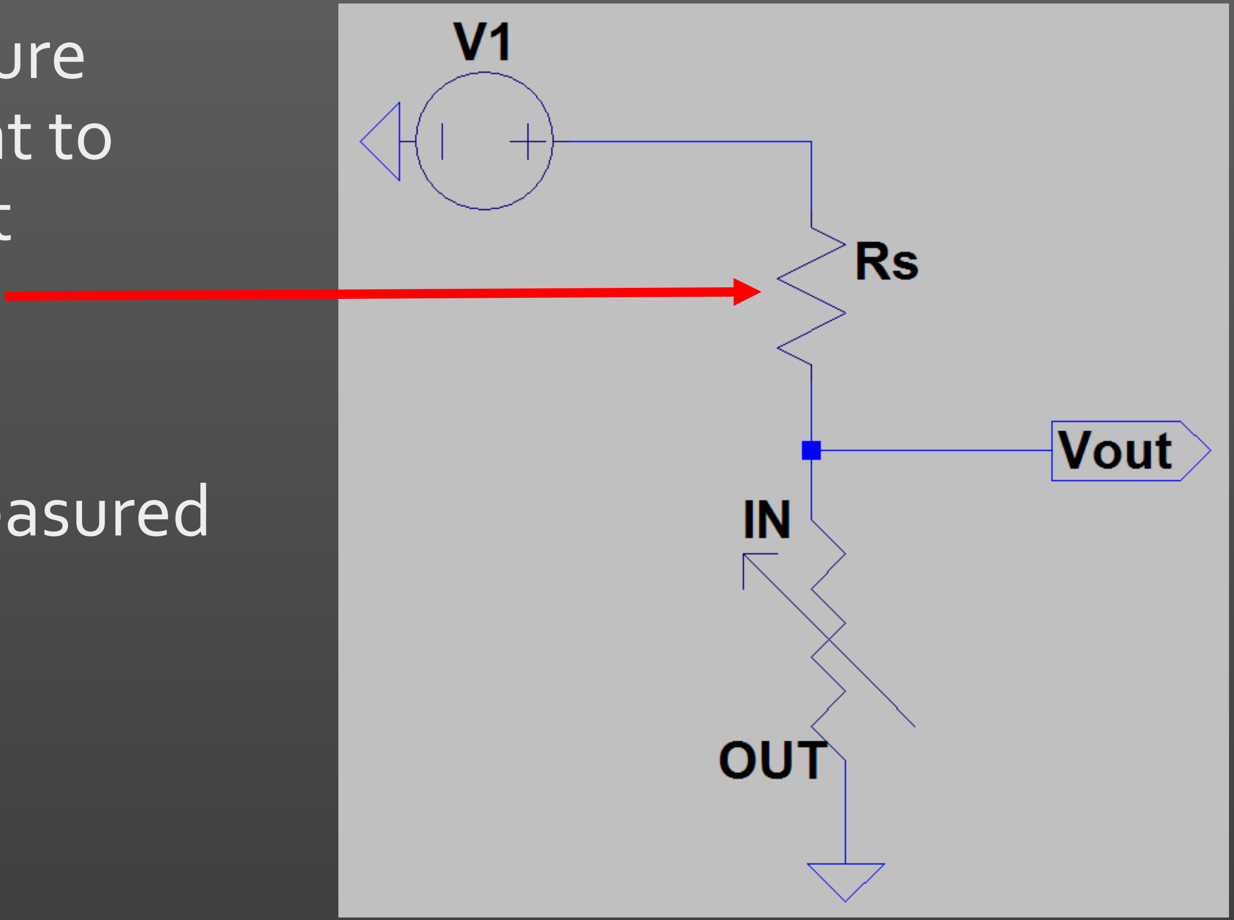
Power Board PCB Schematic



Thermistor Calibration 1

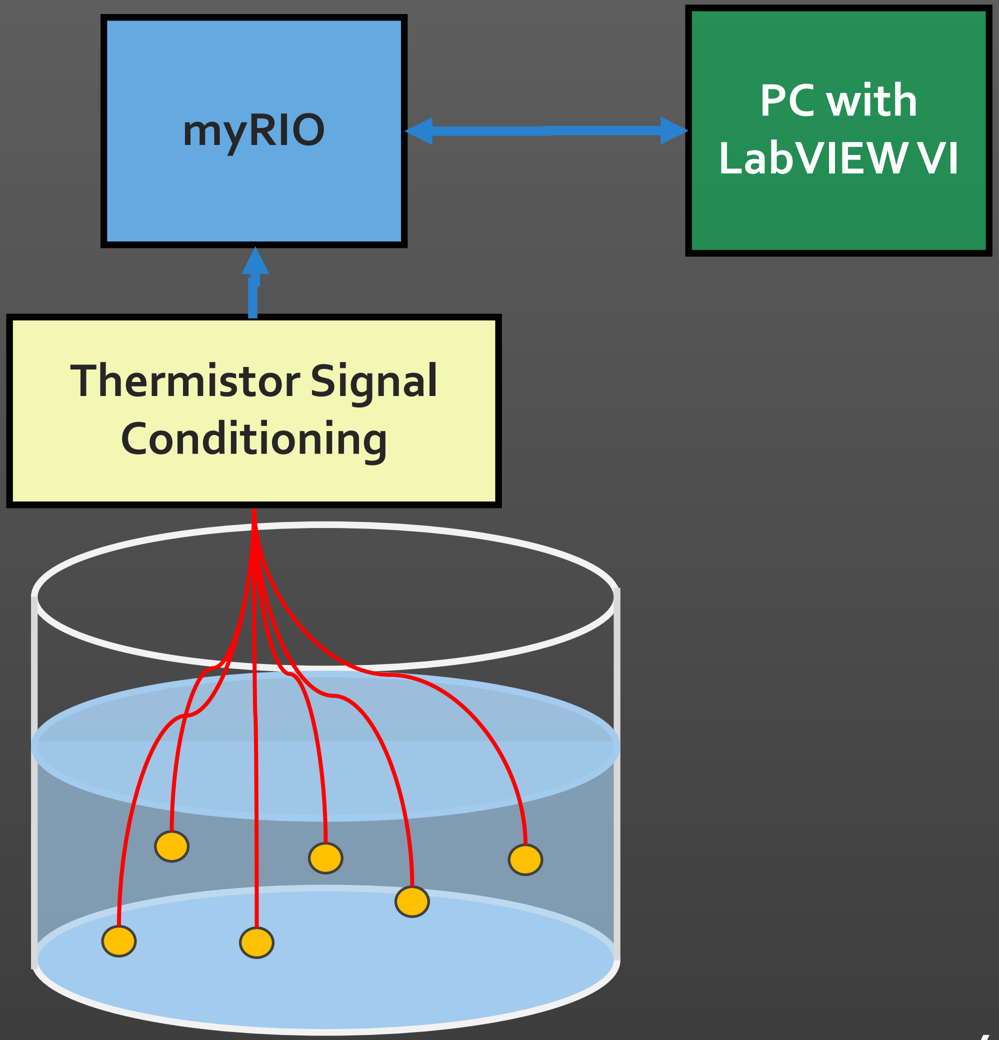
- For accurate temperature readings, it is important to know R_{sense} with great certainty (1 ohm)

- R_{sense} value will be measured and recorded for each thermistor in the chain

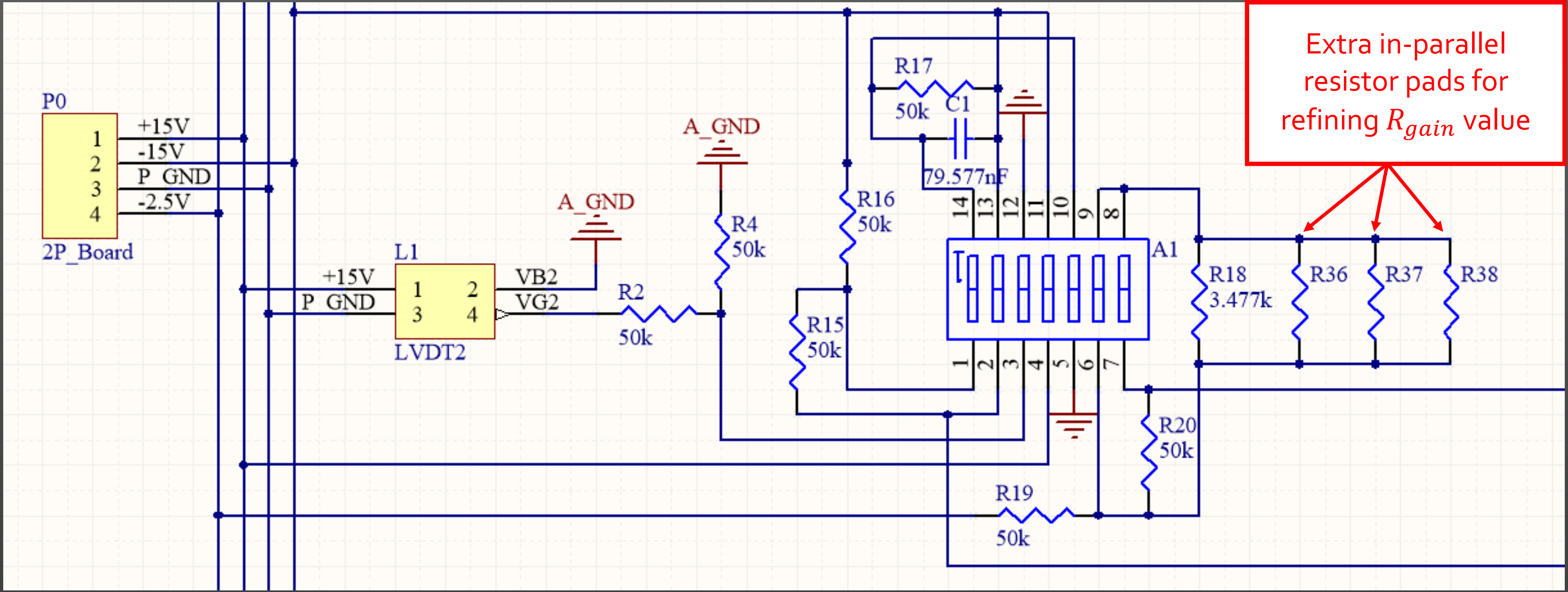


Thermistor Calibration 2

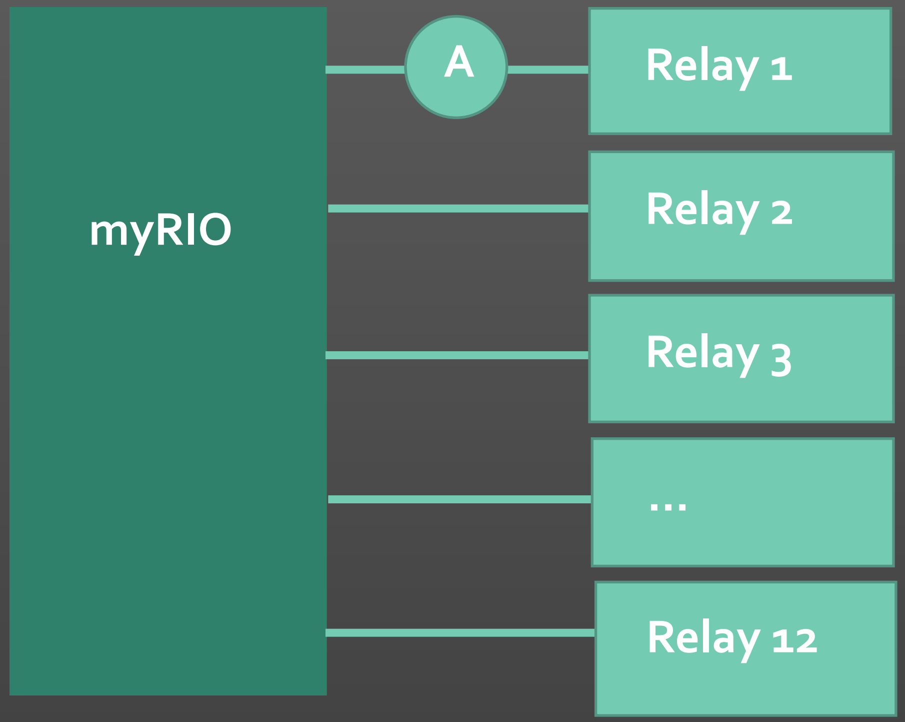
- Each R_{therm} will be slightly different than advertised, so each thermistor must be fine tuned
- Thermistors will be put in a closed off de-ionized ice water bath (known $0°C$ reference)
- Special LabVIEW code will record each thermistor measurement and determine the refined R_{therm} value
- These refined values will be stored in a data file for future reference



LVDT R_{gain} Refinement



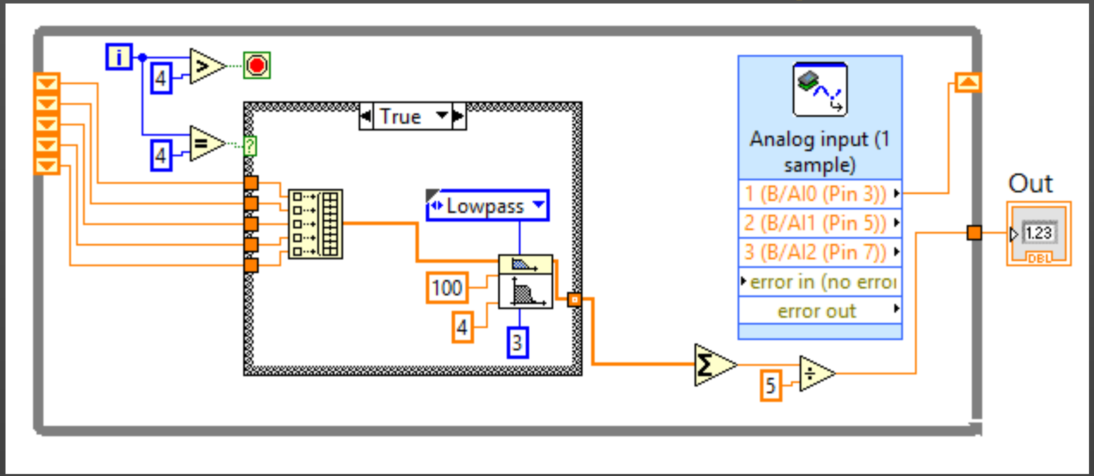
Relay myRIO compatibility



- Need at least 2mA activation current for each relay
- Plug Ammeter in series with one relay and measure correct output
- Can be taken as current for each DIO line

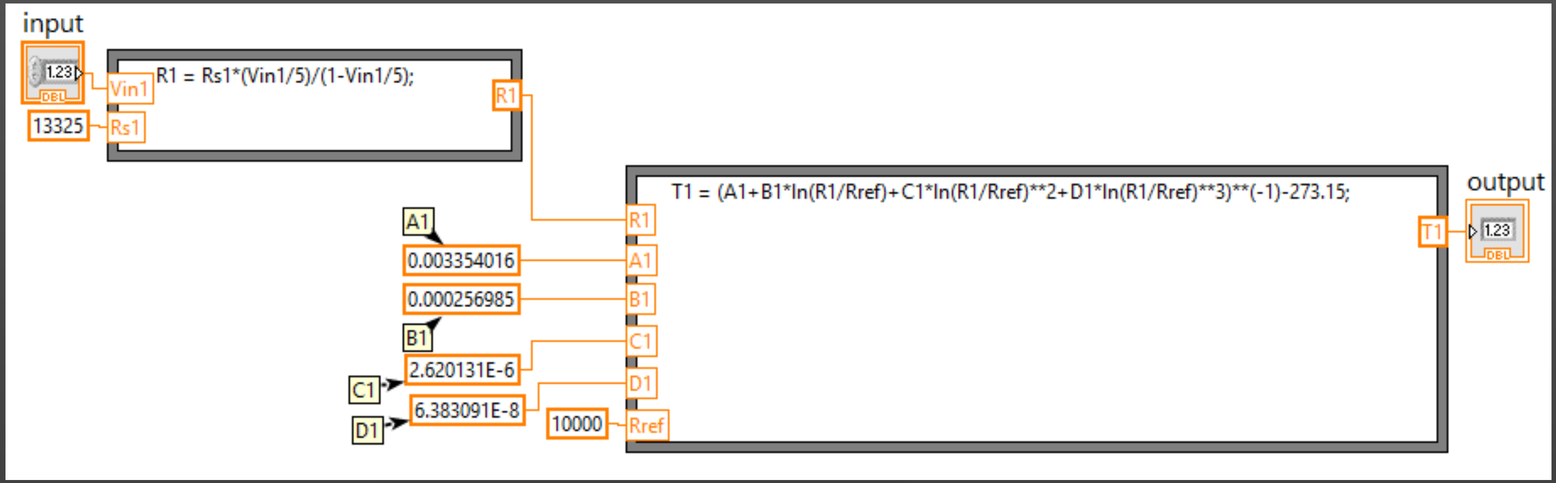
Software: LVDTs

1. Read a single LVDT and get meaningful data √
2. Convert voltages to displacements √
3. Time averaging √
4. Implement system of equations for linear/rotational displacements



Software: Thermistors

1. Read a single thermistor and get meaningful data √
2. Convert voltages to temperatures √
3. Time averaging √
4. Multiplex 32 signals

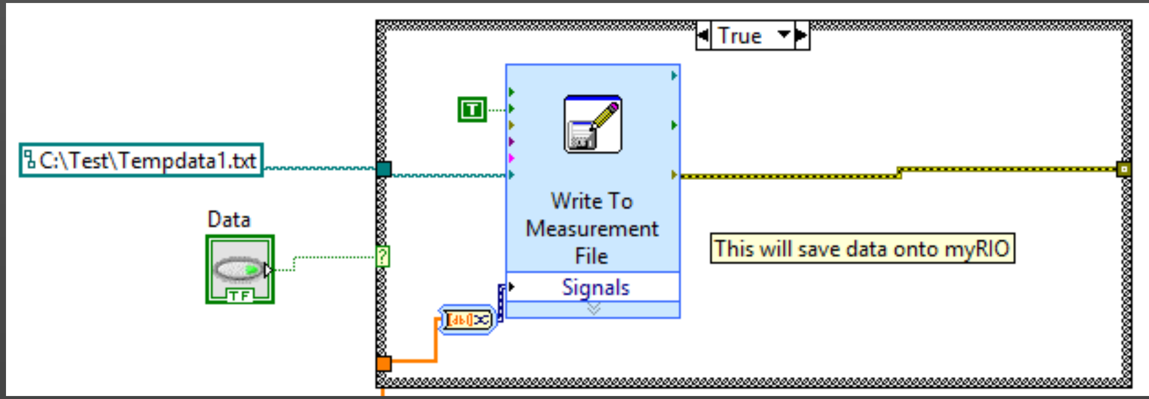


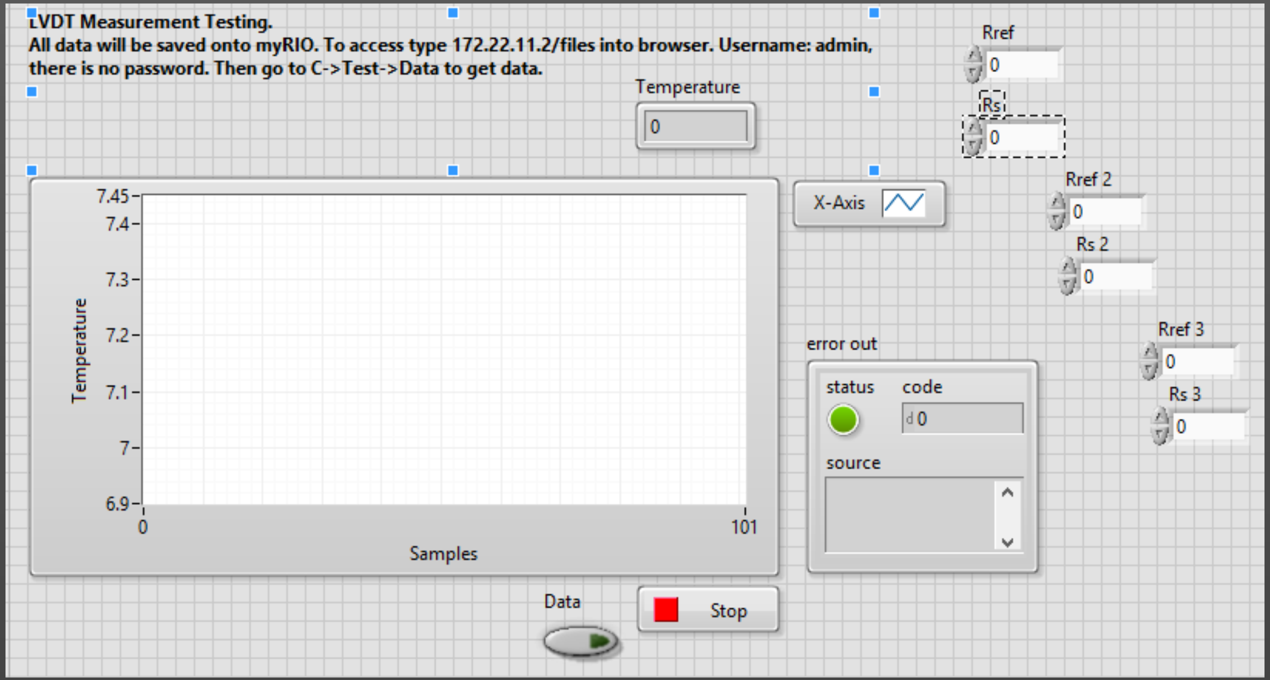
Software: Heater Control

1. Generate customer-provided temperature profile √
2. Interface with SSRs √
3. Implement control conditionals

Software: Data Display/Storage

1. Save all data in external .csv file
2. Design VI





Budget: Test for CDR

Item	Cost
Al Rods	$ 43.98
Mg Rods	$ 38.44
Test Heater	$ 55.00
Demo Board	$ 155.49
16 bit ADC	$ 14.95
Bread Boards	$ 54.75
Total:	$ 406.59

Budget: Materials

Item	Cost
Carbon Fiber Rods	$ 144.45
Screws	$ 143.72
Plates and Shims	$ 502.05
Epoxy	$ 63.45
Total:	$ 853.67

Budget: Electronics/Sensors

Item	Cost
Extender cable for myRio	$ 24.74
Relays	$ 86.57
Total:	$ 111.31

Item	Cost
LVDTs	$ 1,238.40
Thermistors	$ 29.05
Total:	$ 1,267.45

Budget: Electronics/Need to Purchase

Item	Cost
Extender cable for myRio	$ 24.74
Relays	$ 86.57
Total:	$ 111.31

Item	Cost
Carbon Fiber Drill bit	$ 25
New Relays	$ 225
PCBs	$ 300
Total:	$ 550