SNOW DEPTH INFORMATION AND MITIGATION BEFORE AVALANCHES

SIMBA

Manufacturing Status Review

Presenters

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SPONSORS:

COPPER MOUNTAIN

Smead Aerospace
UNIVERSITY OF COLORADO BOULDER

Overview

Project Purpose

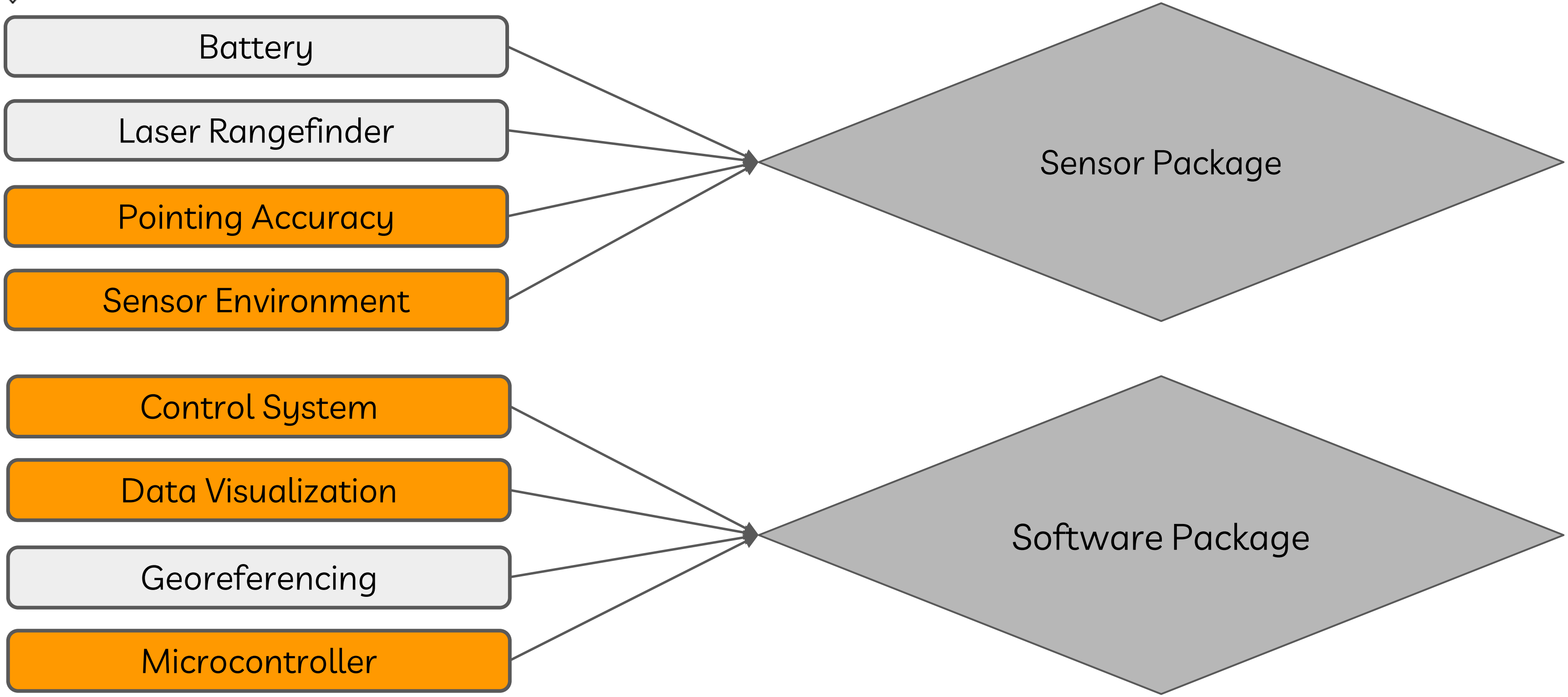
The Problem: Avalanche Mitigation

- Currently
  - Deep pits in avalanche prone areas
  - Dangerous, laborious, and time consuming
- Our system provides data that minimizes
  - Number of snow pits required
  - Time and effort in avalanche prone areas
- This makes avalanche mitigation safer and more efficient

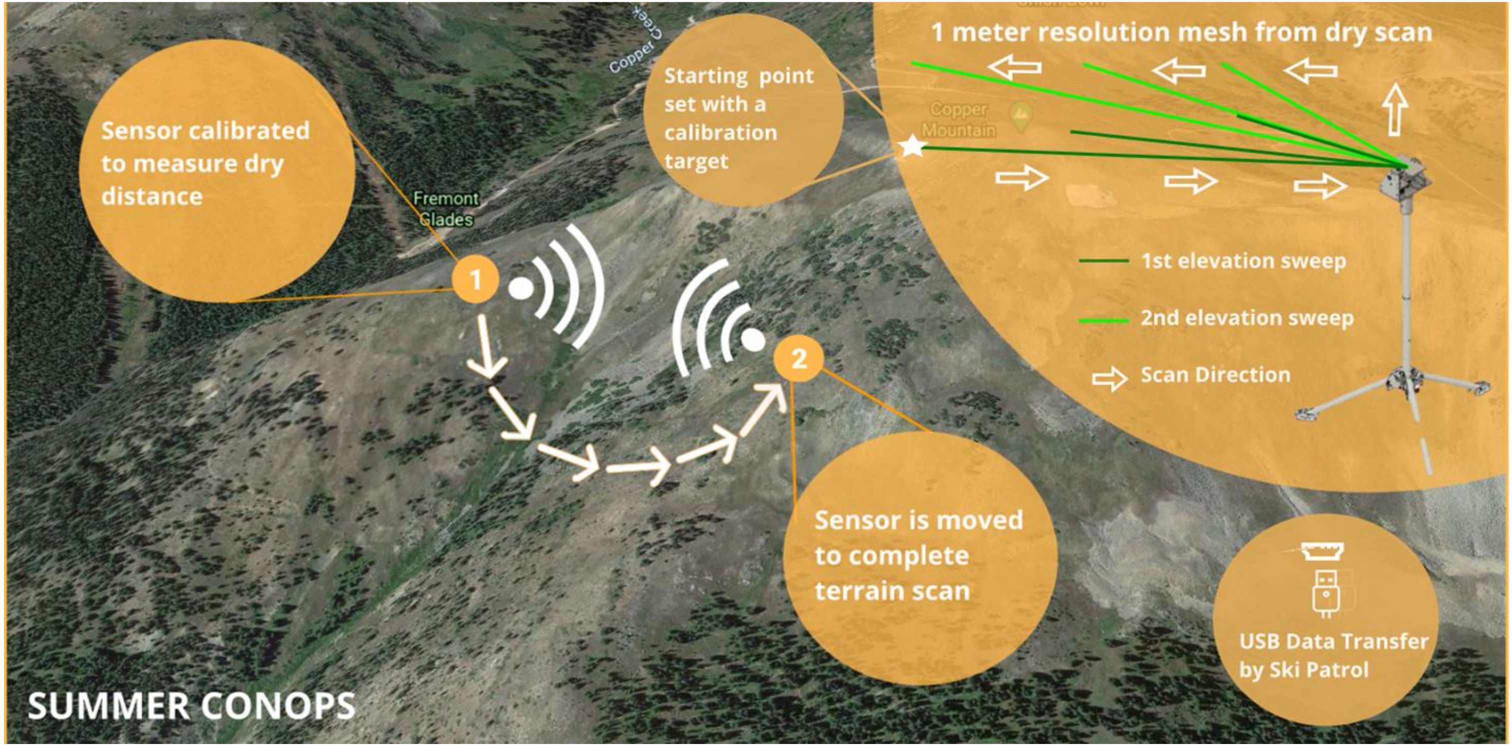
Mission Statement

- Team SIMBA shall provide a mobile snow depth measuring system to help Copper Mountain Ski Patrol mitigate the risk of avalanches.

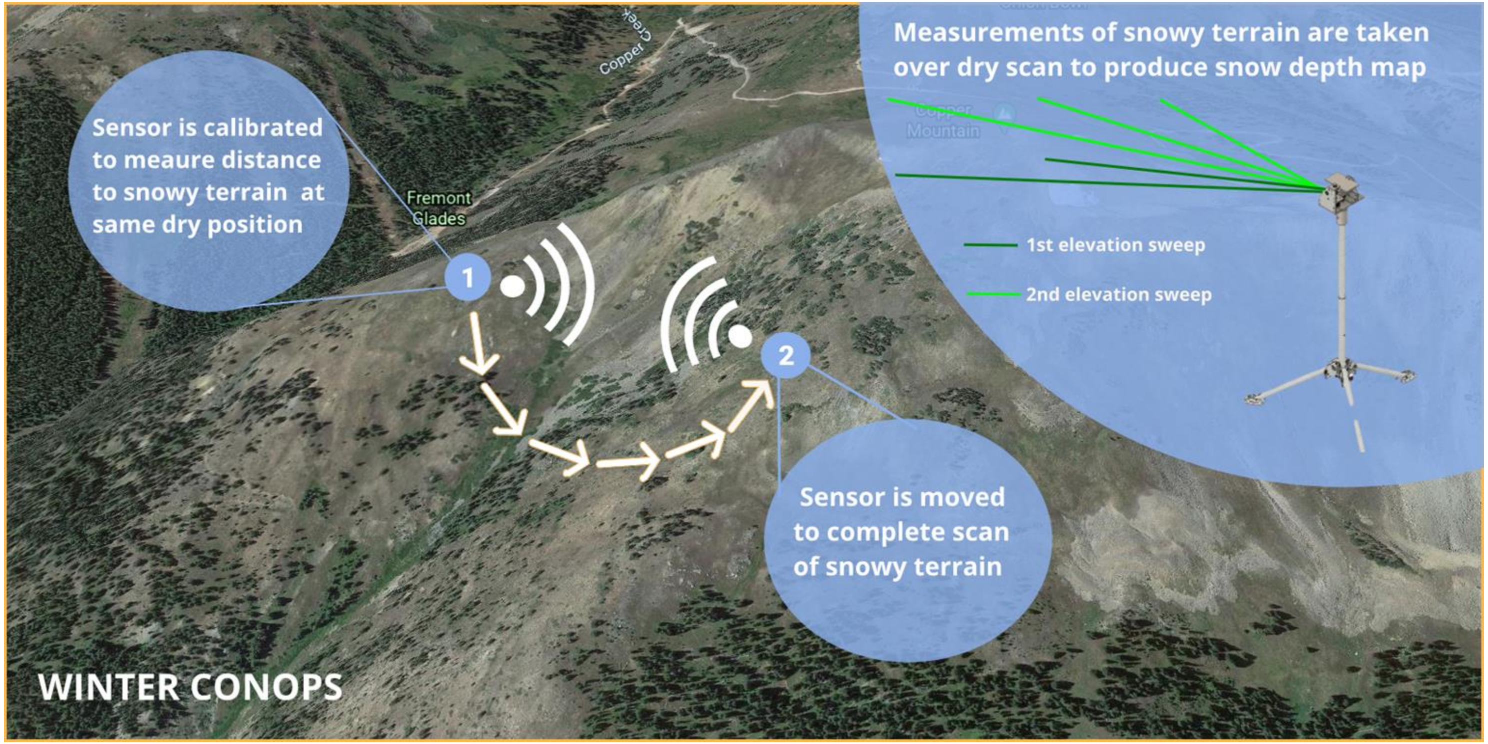
Critical Project Elements



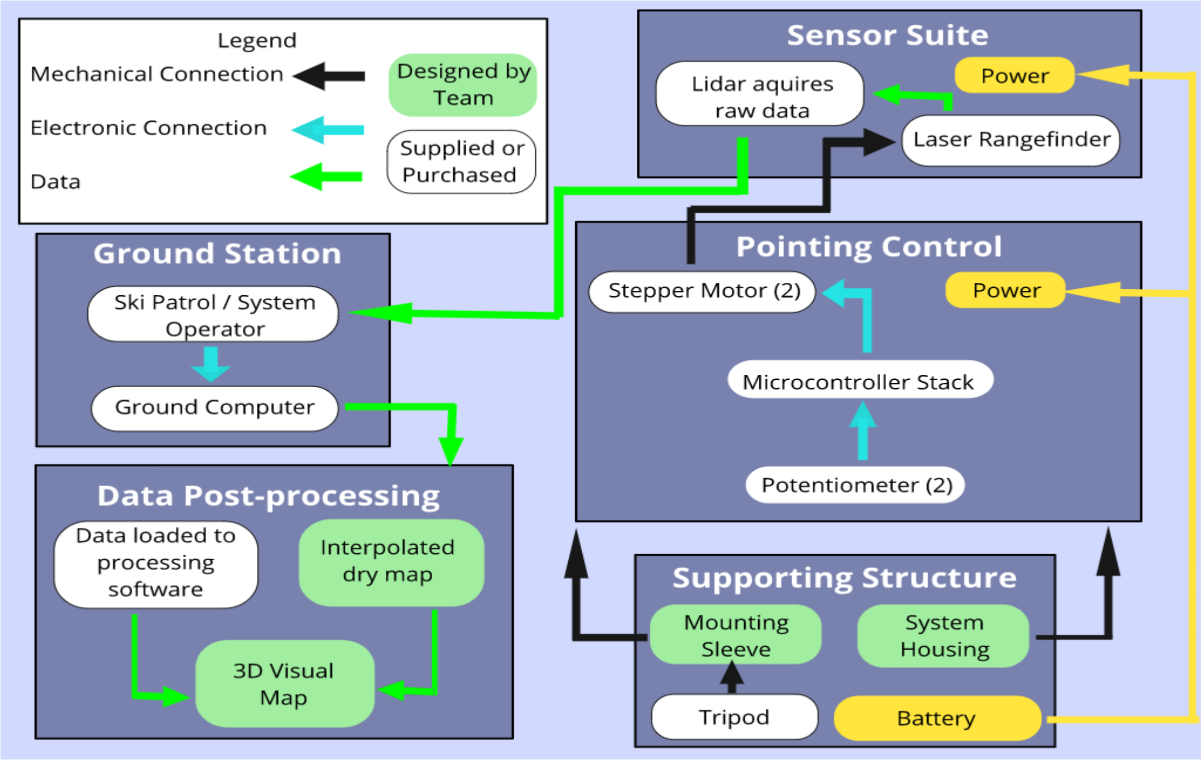
CONOPS


1 meter resolution mesh from dry scan
Starting point set with a calibration target
Sensor calibrated to measure dry distance
Fremont Glades
Copper Creek
Copper Mountain
1
2
1st elevation sweep
2nd elevation sweep
Scan Direction
Sensor is moved to complete terrain scan
USB Data Transfer by Ski Patrol
SUMMER CONOPS

CONOPS


Measurements of snowy terrain are taken over dry scan to produce snow depth map
Sensor is calibrated to meaure distance to snowy terrain at same dry position
Fremont Glades
1
2
1st elevation sweep
2nd elevation sweep
Sensor is moved to complete scan of snowy terrain
WINTER CONOPS

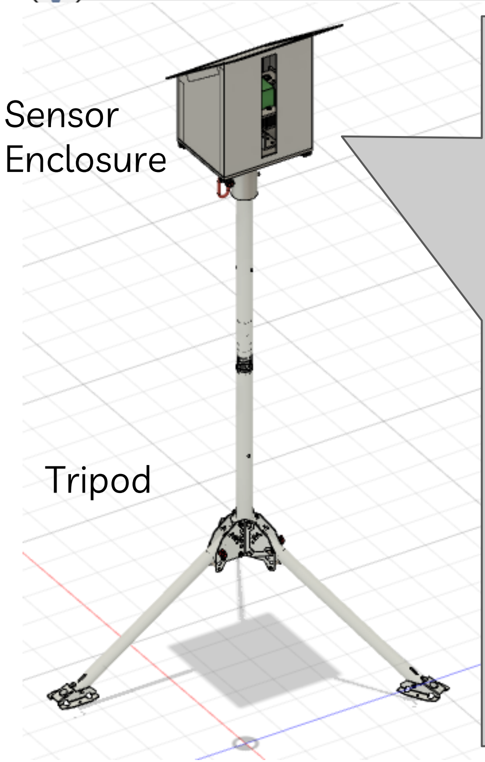
FBD

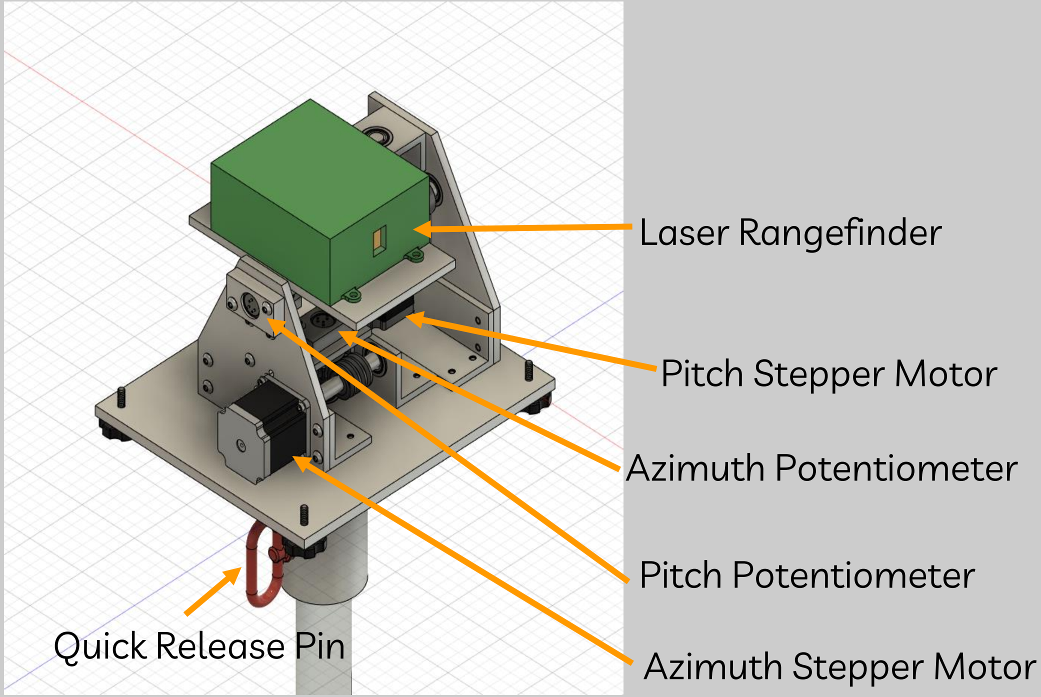

Legend
Mechanical Connection
Electronic Connection
Data
Designed by Team
Supplied or Purchased
Sensor Suite
Lidar aquires raw data
Power
Laser Rangefinder
Ground Station
Ski Patrol / System Operator
Ground Computer
Pointing Control
Stepper Motor (2)
Power
Microcontroller Stack
Potentiometer (2)
Data Post-processing
Data loaded to processing software
Interpolated dry map
3D Visual Map
Supporting Structure
Mounting Sleeve
System Housing
Tripod
Battery

Project Levels of Success

	Sensor Package	Software	Pointing Accuracy and Control	Output
1	Snow depth accurately measured within ±50 cm at 1 location at 400 m	Data of one distance measurement by sensor is saved	Laser pointing is able to be determined to 0.01 degrees. No feedback present. Motors ±1° of desired position	Compile data to form a plane to serve as origin for height measurements
2		Distance and attitude of each measurement is recorded for attitude control	Feedback is present allowing the motors to readjust as needed	Display snow depth calculated for one location
3	Snow depth accurately measured **within ±15 cm at 400m**	**Distance, attitude, time & temperature of each measurement** is recorded	Motor initial move **±0.1° of desired position. Feedback allows for ±0.01°**	Produce **map displaying snow depth**
4	Snow depth accurately measured within ±10 cm at 400 m with 1 m spatial resolution		Motor initial move ±0.01° of desired position. Feedback allows for ±0.001°	Produce topographical snow depth map to within ±10 cm

Baseline Design





Major Changes Since CDR

1. Raspberry Pi and PCB **is now mounted on the roof** instead of with the laser range finder
2. Sensor **enclosure is enlarged** to accommodate Raspberry Pi in order **to maintain full degrees of motion** in pitch
3. Sensor package will use **one battery for both wet and dry scans** instead of two separate batteries
4. Ceramic **resistors selected for conductive heating** around potentiometers

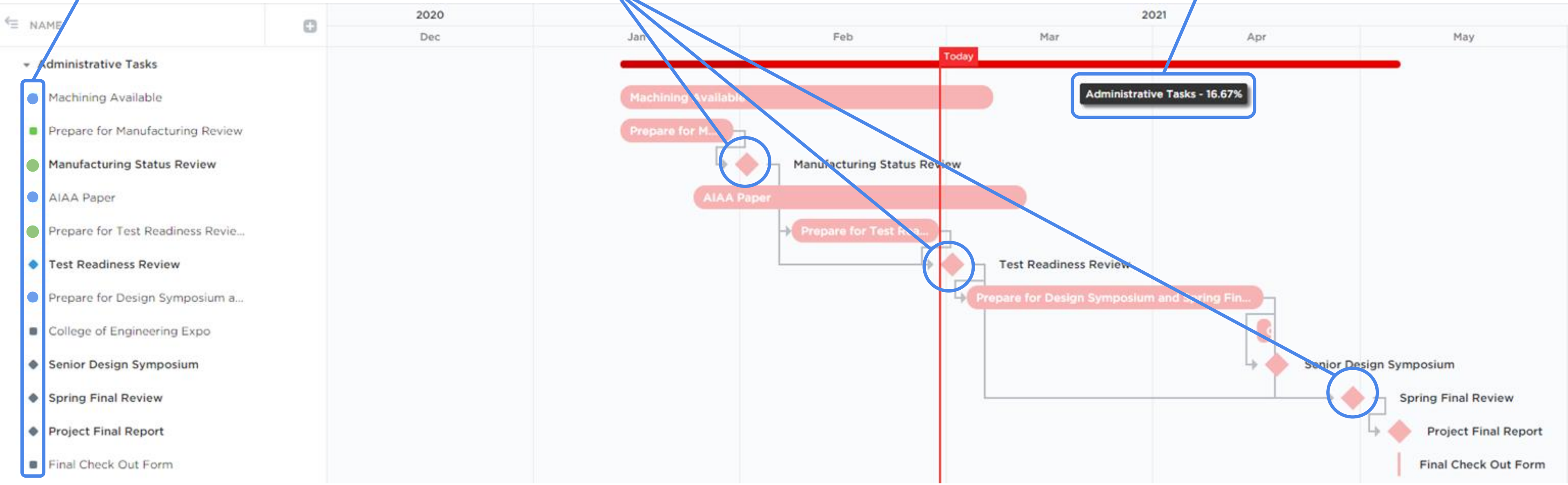
Schedule

Administrative Schedule

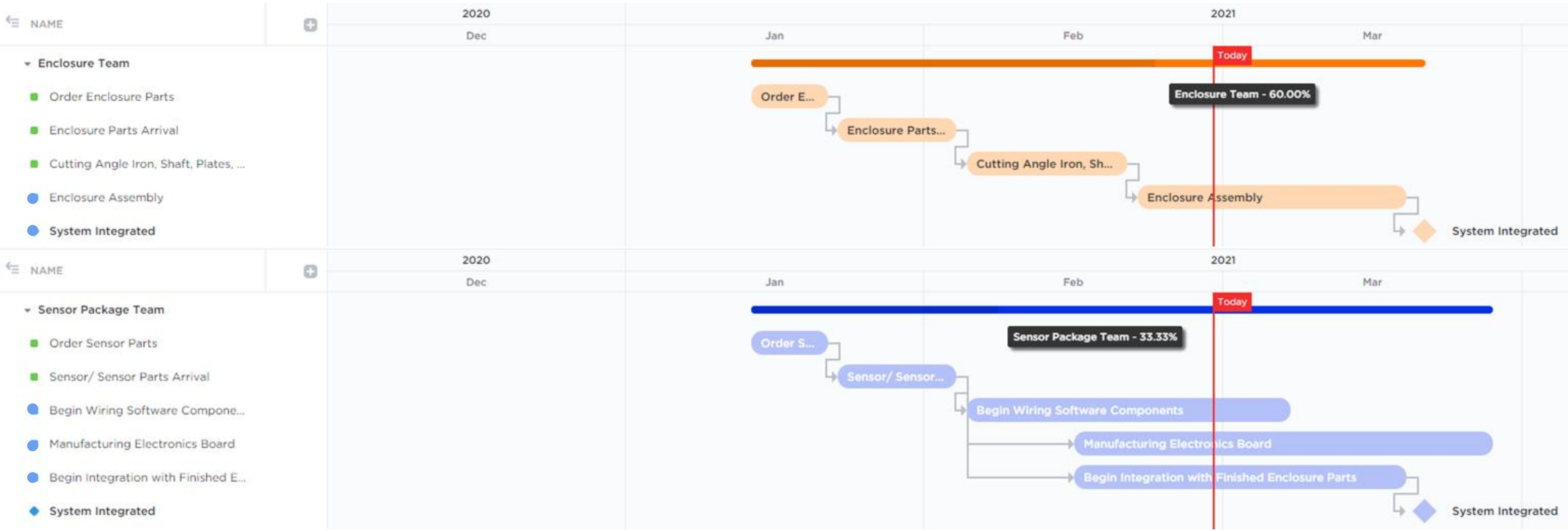
- To-do
- In progress
- Complete

Milestones

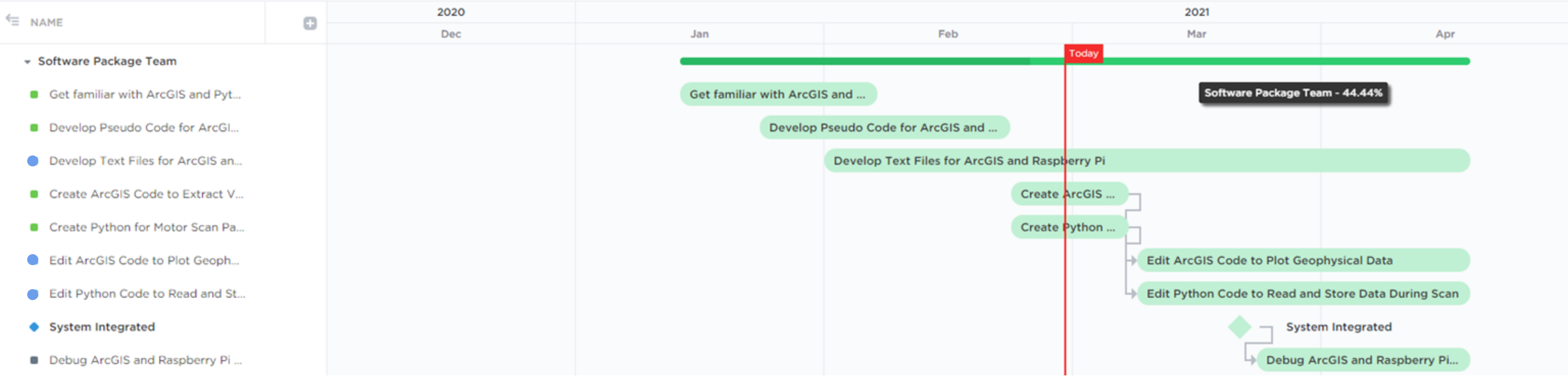
Completion Status
*Note, this represents what percentage of tasks have been completed.



Enclosure and Sensor Team Schedules

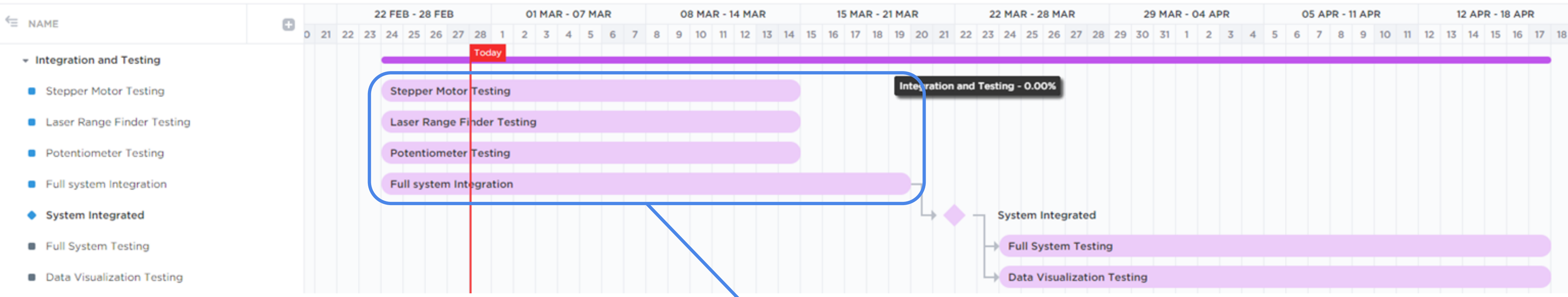


Software Team Schedules



Overview | Schedule | Test Readiness | Budget | Backups

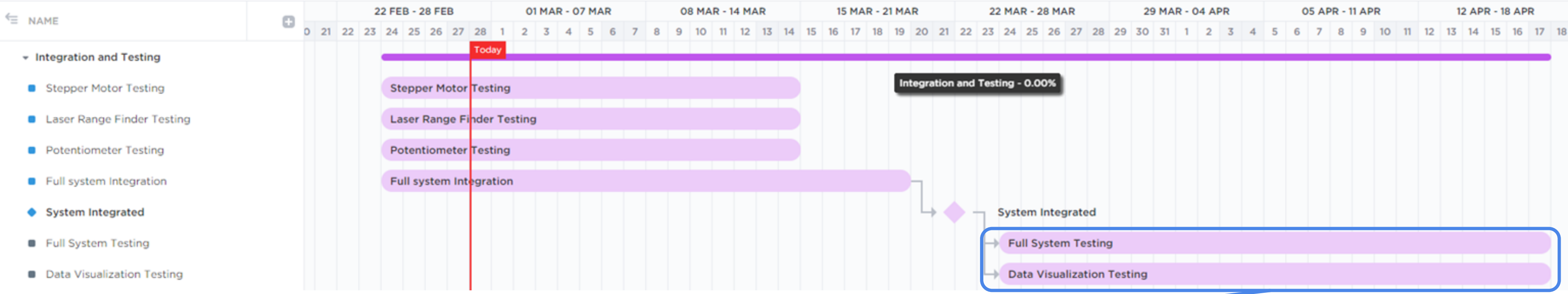
Individual Component Testing Schedule



Test Details

- Test driving **stepper motors** using the Raspberry Pi. Also test the smallest stepping size.
- Test accuracy of **laser range finder** and compatibility with Raspberry Pi .
- Test **potentiometer** accuracy while driving rotation with stepper motors.
- While testing each component, also begin partial integration.

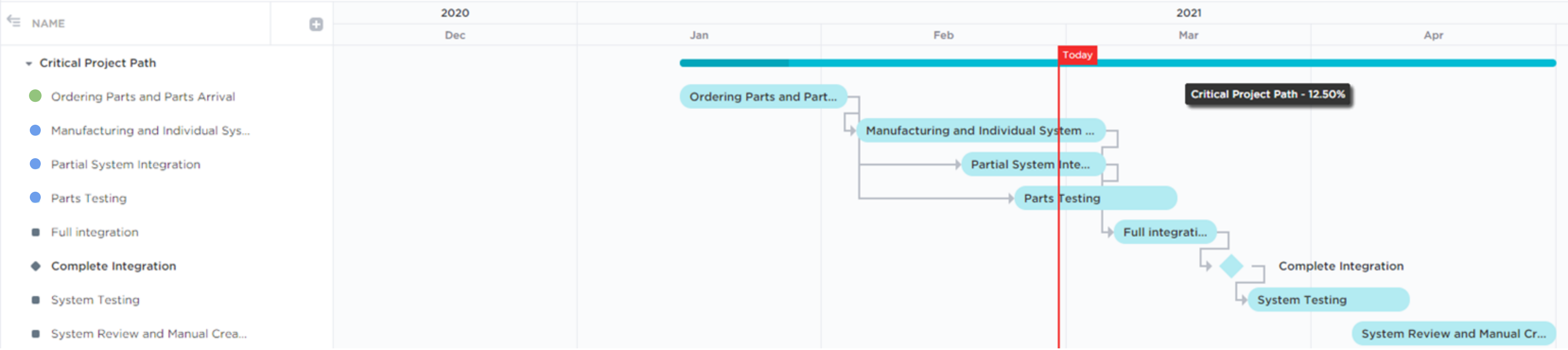
Full System Integration and Testing Schedule



Full system integration and testing details

- Full system includes enclosure, sensors, software, and hardware.
- Testing includes automated scanning tests for both the wet and dry terrain as well as calibration test.
- This also allows us to test the robustness of all software.

Critical Project Path



Test Readiness

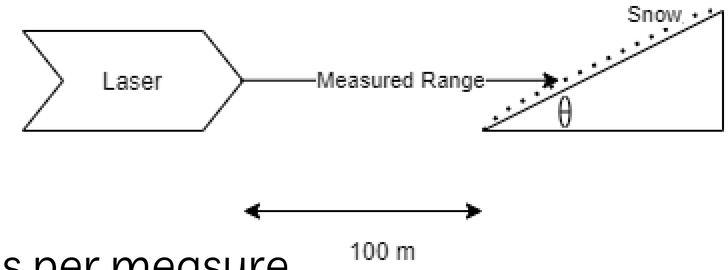
Functional Requirements

FR 1	The system shall **implement a snow depth detection system** to assist Copper Mountain ski patrol in avalanche mitigation
FR 2	The system shall be able to operate with acceptable endurance such that **data collection will occur in a reasonable amount of time**
FR 3	The system shall be able to **operate in the typical weather conditions** found on the top of Copper Mountain
FR 4	The system shall be able to **collect the required data, store the data, and transfer the data** to Copper Mountain ski patrol **through available interfaces** (Data Storage)
FR 5	The system shall **process the data collected and present snow depth data** to Copper Mountain ski patrol in the software found at their facilities
FR 6	The system shall **collect pointing data accurately** and then use that data **to control the sensor's pointing**

Laser Range Finder: Overview

What is Being Tested?	Why?	Driving Functional Requirement	Risks Reduced	Status
Range	Verify manufacturer specifications of ±4cm	FR 1	Manufacturer over-confidence	Complete
Reflectivity	Determine sensitivity against variable surfaces	FR 6	Reduce sensor errors	Complete
Incidence	Determine range of angles that can be measured before exceeding accuracy requirement	FR 6	Reduce sensor errors	In Progress
Laser Beam Halfwidth	To limit snow accumulation inside sensor environment	FR 1 FR 3	Housing interference and snow accumulation	In Progress

Laser Range Finder: Incidence



Testing Equipment/Facilities

- 100m Track; Plywood Target; Inclinometer

Testing Procedure

- Place board 100m away on track.
- Place board vertically; measure, tilt 10 degrees per measure

Expected Results vs Actual Results

Theta (vertical = 90°)	Expected Reading(m)	Actual Results(m)
80°	100.116	TBD
70°	100.240	TBD
60°	100.381	TBD
50°	100.554	TBD

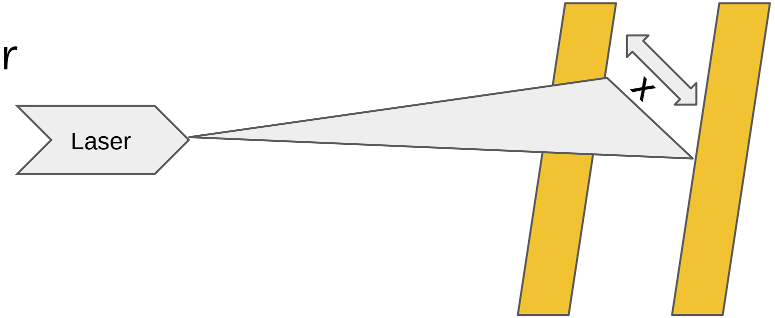
Laser Range Finder: Beam Width

Testing Equipment/Facilities

- Measuring tape; Plywood Target; Inclinometer

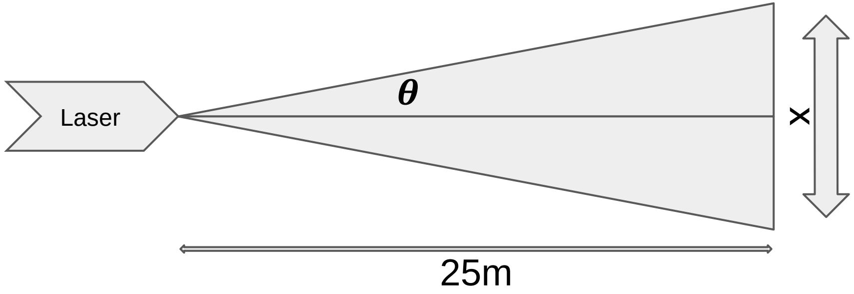
Testing Procedure

- Place two board 25m away.
- Measure in between the boards
- Slide the two boards closer together until measurement reads 25m
- Measure distance between the boards



Expected Results vs Actual Results

- Expect the boards to be only a few centimeters apart
- Actual results TBD
- θ = 2 arctan((x/2) / 25m))



Stepper Motors: Overview

What is Being Tested?	Why?	Driving Functional Requirement	Risks Reduced	Status
Demo scan pattern	We are using an Adafruit stepper driver with a non-Adafruit motor, need to be sure they interface	FR 6	Code bugs, different standards between manufacturers	Complete
Determine step size	Needs to be determined to know number of steps needed to turn a specific angle	FR 6	Exceeding desired horizontal resolution	Complete
Current draw	Improve estimate of battery lifespan	FR 3	Battery draining during a scan	Incomplete

Stepper Motors: Demo Scan

Testing Equipment/Facilities

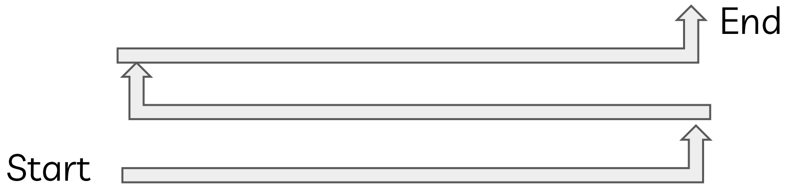
- Laser pointer, tape measure, stepper motor, platform

Testing Procedure

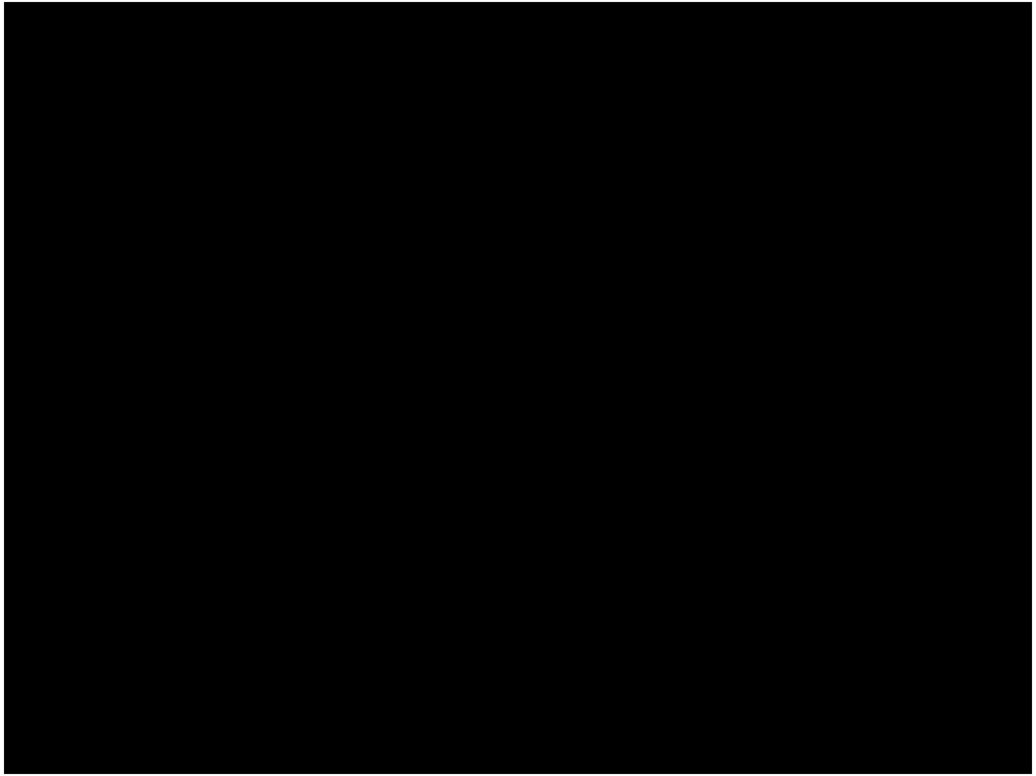
- Run demo scan code
- Attach laser pointer to sensor platform
- Trace laser’s path on whiteboard

Expected Results vs Actual Results

- Expected Results: Steps in a snaking pattern
- Actual Results: See video on next slide



Stepper Motors: Demo Scan



Stepper Motors: Step Size

Testing Equipment/Facilities

- Laser pointer, tape measure, grid paper, and stepper motor

Testing Procedure

- Attach laser pointer to stepper motor, point at paper, command smallest step, and measure laser distance moved, and distance from the paper

Expected Results vs Actual Results

- Expect less than 0.1 degree step size
- 1 step is about 0.086 degrees

Potentiometers: Overview

What is Being Tested?	Why?	Driving Functional Requirement	Risks Reduced	Status
Settling Time	The Potentiometer needs to settle in between movements to obtain accurate measurements	FR 2	Excessive settling time in scan pattern which would lead to large time per scan	Complete
Potentiometer Accuracy	The Potentiometers are the systems sole source of pointing data, which our project is highly reliant on	FR 6	Large snow depth error due to large error in pointing accuracy	Incomplete
Potentiometer Calibration	Potentiometers have systematic bias which can be negated with calibration	FR 6	Experiencing pointing error which can be mitigated	Incomplete

Potentiometers: Accuracy

Testing Equipment/Facilities

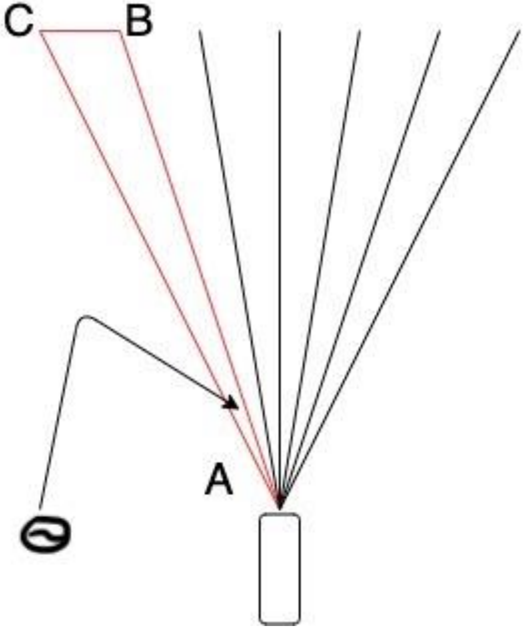
- Rangefinder
- Stepper motor
- Potentiometer
- Marker
- Raspberry Pi with monitor, keyboard, etc.
- ADC hat
- Tripod
- Measuring tape
- System enclosure
- Laser pointer
- Cell phone (to collect range finder data via bluetooth)

Testing Procedure

1. Assemble range finder, stepper motor, and potentiometers within enclosure and place on the tripod
2. Attach laser pointer onto tilting plate with the rangefinder and attach all electronics to the Raspberry Pi or ADC as needed
3. Point system at target 25m away, take range measurement and mark initial location of the laser pointer with marker
4. Step motors in 2° increments and repeat step 3 until you cover a 30° range.
5. Measure distance from initial point to each additional point using tape measure.
6. Calculate pointing angle using the law of cosine and each distance measurements
7. Compare to Potentiometer output and potentiometer accuracy model

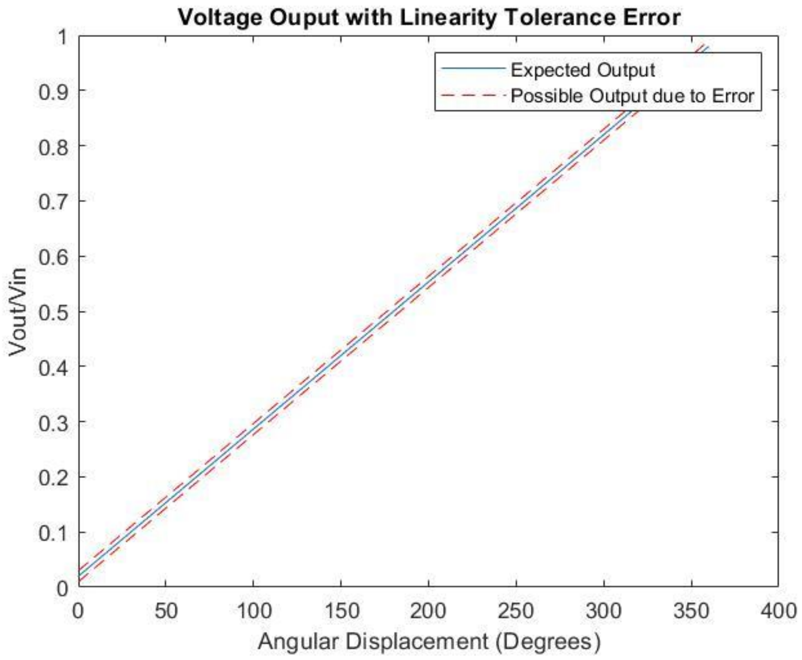
Potentiometers: Accuracy

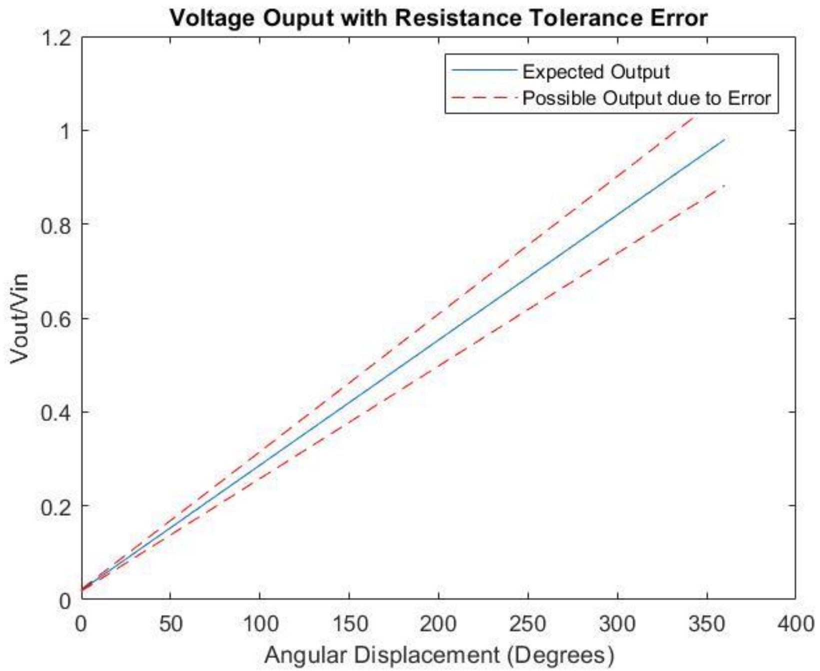
Test Setup



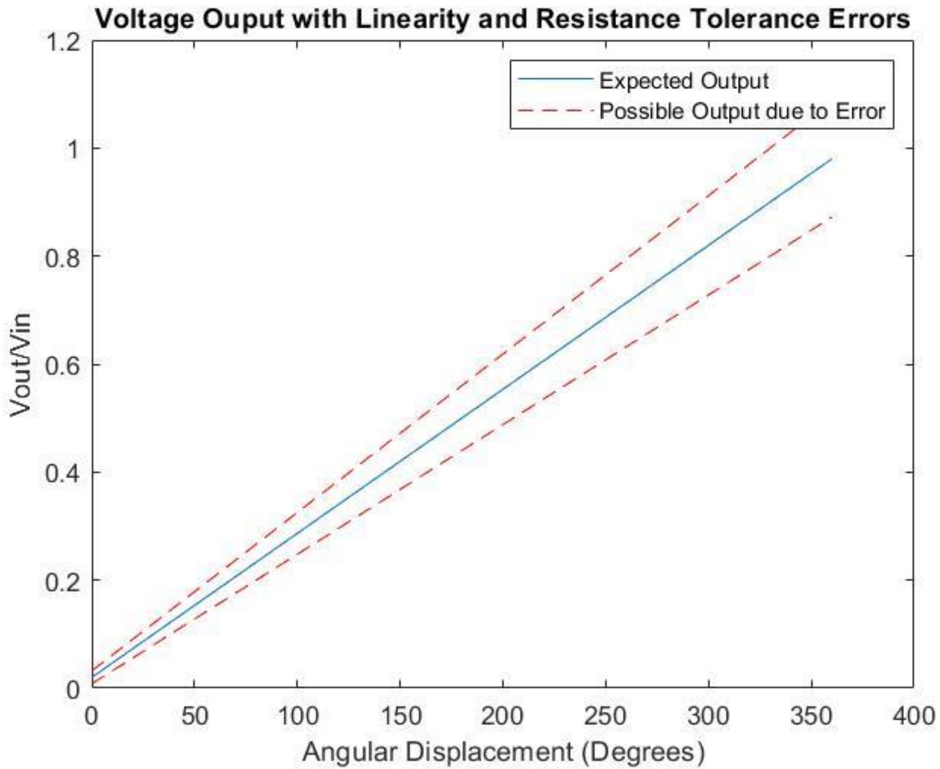
$$\theta = arccos(\frac{AC^2 + AB^2 - BC^2}{2 * AC * AB})$$

Potentiometers: Expected Results





Potentiometers: Expected Results



PCB: Overview

What is Being Tested?	Why?	Driving Functional Requirement	Risks Reduced	Status
Correct Voltage	Ensure voltages are supplied to the different components	All	Damaging sensors and other equipment	Complete
Voltage Ripple	Determine feed voltage stability for potentiometer	FR 1	Quantify potentiometer error caused by feed voltage	Complete
Thermal Switching	Ensure MOSFET switches open completely/verify circuit	FR 2	Potentiometer failure/damage due to low temperature	Incomplete
Sustained Load	Make sure PCB does not overheat with full power load	FR 7	Damage to PCB and full system failure	Incomplete

PCB: Voltage Ripple

Testing Equipment/Facilities

- Power Supply
- Multimeter
- Oscilloscope
- Dummy loads

Testing Procedure

- Use oscilloscope to determine maximum and minimum voltage output
  - Under variable loads
  - Under constant load

Expected Results vs Actual Results

- Expected -> 5V, 3V steady supply, 2.5V voltage fluctuation
- Results ->
  - 5V: 12.9kH 5.81V spikes lasting >1 microsecond
  - 3V: 36.2kH 3.46V spikes lasting >1 microsecond
  - 2.5V: 368Hz 3.28V spikes lasting ~1 microsecond

PCB: Sustained Load

Testing Equipment/Facilities

- Power Supply
- Multimeter
- Dummy Loads/Actual Loads
- Infrared thermal laser

Testing Procedure

- Attach all loads to PCB and begin drawing current
- Measure PCB temperature over time until steady state temperature is achieved

Expected Results

- Expecting maximum PCB temperature ~50C in 25C room (design)
- Test has not been conducted

Data Visualization: Overview

What is Being Tested?	Why?	Driving Functional Requirement	Risks Reduced	Status
ArcGIS functionality and interfacing	Ensure ease-of-use	FR 5	User needing to debug code	Complete
ArcGIS geodata processing	To ensure that data can be overlaid	FR 5	Reduces risk of not being able to communicate data to user	In progress
ArcGIS geodata analysis and processing	To ensure that data can be analyzed and overlaid	FR 5	Ensures that code can extract data and plot it	Incomplete

Data Visualization: Testing Procedure

*Most critical test can only be completed after full system integration.

- Only equipment required for test is a computer to run ArcGIS.
- No facilities are need.
- Examples of current progress:

CoordinateExample

Edit View Insert Cell Help ArcGISPro

Run Code

```
In [*]: #Import packages to be used
import arcgis
import matplotlib.pyplot as plt
import numpy as np
import csv
import os

from arcgis.gis import GIS

# Create definitions
# Variables and text file names
gis = GIS()
lat = []
lon =[]
alt = []
file = 'ExampGridCoords.csv'
os.chdir('/')
os.chdir('users\Adam\Documents\CU Boulder\Spring 2021\ASEN4028DesignPracticum\ArcGIS\MyProject')
#print("widgetnbextension: ",widgetsnbextension.__version__)

In [*]: # Pull data from file
with open(file) as csv_file:
    csv_reader = csv.reader(csv_file, delimiter=' ')
```

1	Coordinate
2	4788722.415455 -11817089.623411 3618.75
3	4788721.610932 -11817090.219592 3618.47
4	4788720.948762 -11817090.70117 3618.47
5	4788720.259229 -11817091.149913 3618.13
6	4788719.767144 -11817090.424481 3617.99
7	4788720.600712 -11817089.934147 3618.47
8	4788721.24667 -11817089.510905 3618.39
9	4788722.016237 -11817088.972208 3618.75
10	4788721.580149 -11817088.296699 3618.39
11	4788720.827683 -11817088.826846 3618.39
12	4788720.186377 -11817089.305687 3618.05
13	4788719.468114 -11817089.810182 3617.99
14	4788718.972171 -11817089.091919 3617.57
15	4788719.852898 -11817088.578874 3618.05

StationInfo - Notepad

File Edit Format View Help

```
Inital Geolocation Values
LocationLetter A
StationLatitude 39.4645946 # Degrees
StationLongitude 106.1552998 #Degrees
EstimatedElevation 3574.53 #m
```

Whole System Integration: Overview

What is Being Tested?	Why?	Driving Functional Requirement	Risks Reduced	Status
Calibration	To test the calibration software	FR 1	To ensure repeatable data retrieval for dry and wet scans	Incomplete
Operational Scanning Time	To test the time it takes for a wet and dry scan	FR 2	Reduce the time spent in avalanche zones	Incomplete
Outdoor Campaign	Test all components simultaneously	ALL	Prove system success in design environment	Incomplete

Whole System: Calibration

Testing Equipment/Facilities

- Fully assembled system
- Ground Control Point
- Open space with measurable distances

Testing Procedure

- Place GCP at known distance away
- Initiate software to find GCP

Expected Results

- Software is expected to find GCP with a searching grid of 1 degree by 1 degree

Whole System: Operational Scanning Time

Testing Equipment/Facilities

- Fully assembled systems
- Timer
- Indoor locked room

Testing Procedure

- Setup system indoors
- Step through both axes of motion and record the time
- Perform both wet and dry scanning algorithm

Expected Results

- Set and forget performance
- Complete scan patterns without crashing, running out of battery or other system failure
- The dry scan should take roughly 1 day to complete
- The wet scan should take roughly 2-3 hours to complete
- This test has yet to be done

Whole System: Outdoor Campaign

Testing Equipment/Facilities

- Fully assembled systems
- Open space with sloped terrain(TBD)

Testing Procedure

- Set up system outdoors in variable elevation environment
- Perform a dry scan of representative area with variable elevation
- Perform a wet scan of representative area after snowfall
- Measure snow depth at various locations using probes
- Visualize terrain digitally and compare

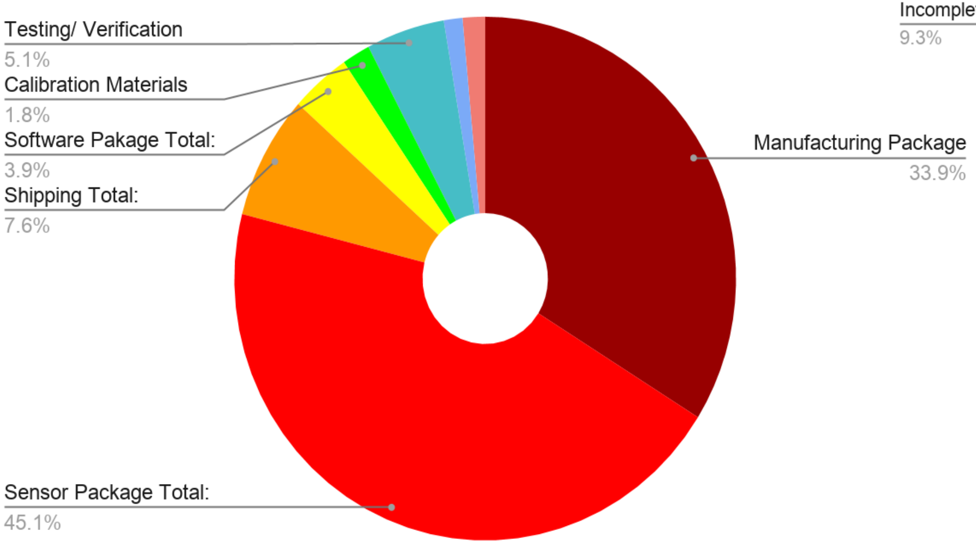
Expected Results

- Produce accurate 1m by 1m resolution map of a 400m radius half circle terrain with significant elevation variation (dry scan)
- Complete scan patterns without crashing, running out of battery or other system failure
- Copy over all data into ArcGIS
- Successfully interplate high resolution map to determine snow depth form wet 6m by 6m scan
- Determine if snow depth is within 10-15 cm

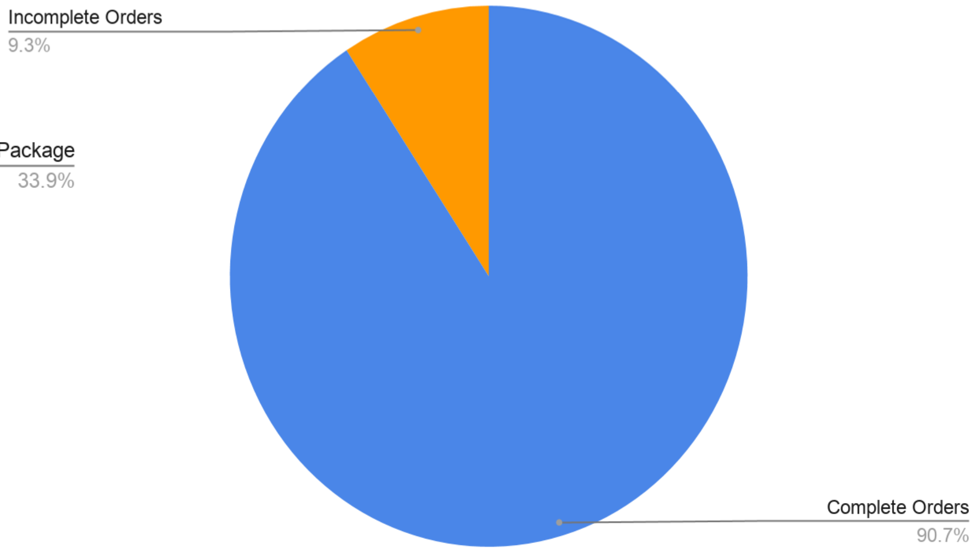
Budget

Current Budget Status

Estimated Budget by System



Purchases Completed



Current Budget Status

Purchases Completed *currently in our possession	Purchases Incomplete *waiting for testing completion	Remaining Budget
• PAB Board • Potentiometer • Stepper Motors • Enclosure equipment • Raspberry Pi • Raspberry Pi hats • Electronic components • Tripod • ClickUp	• Battery • *Laser pointer • *Avalanche probe • *Calibration sign • *Reflectors	$746.54
Total spent = $4,253.46	Allocated funding = $578 Unallocated funding = $168.69	

* There are currently no expected lead times for these items .

Backups

Laser Range Finder: Range

Testing Equipment/Facilities

- 100m Track
- Plywood Target
- Tape measurer

Testing Procedure

- Place board 100m away on track.
- Measure the track with tape measurer for exact length
- Take measurement from Laser Range Finder

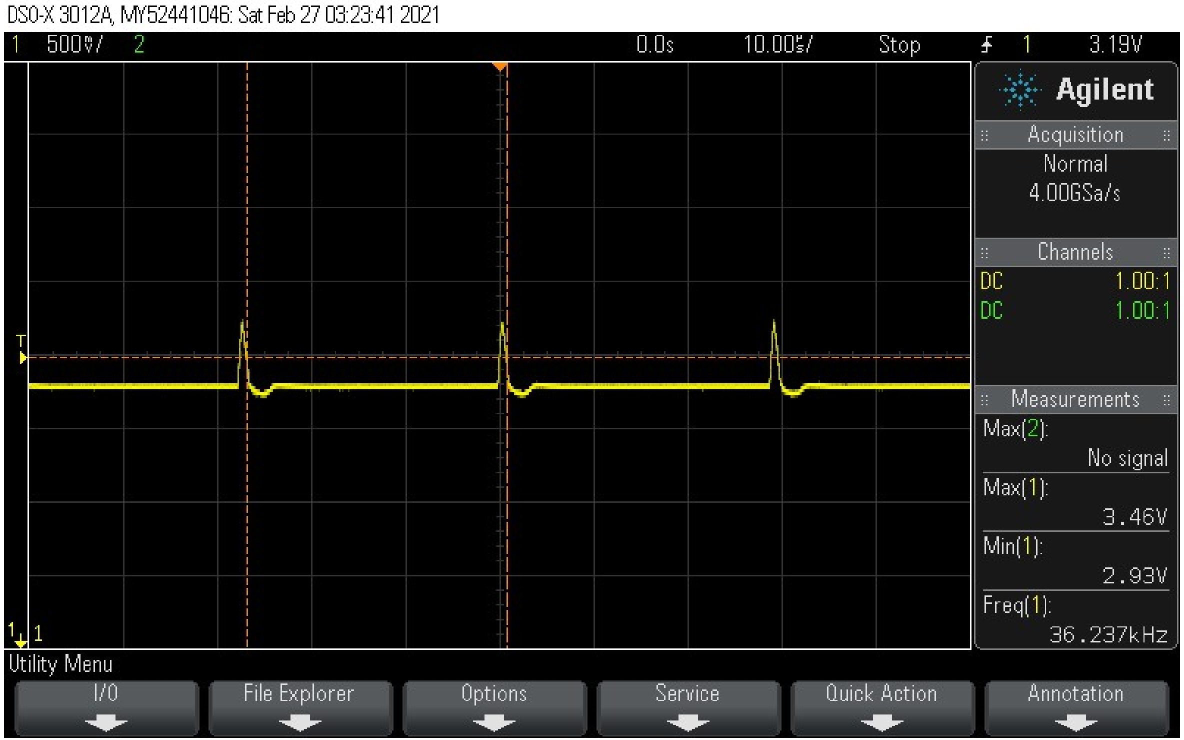
Expected Results vs Actual Results

- Assumed length of track: 100m; Actual Length of track: 99.95m
- Measured: 100.09m; Expected(with 10 degree tilt): 100.06m
- 3cm error

5V Ripple

DSO-X 3012A, MY52441046: Sat Feb 27 03:21:14 2021

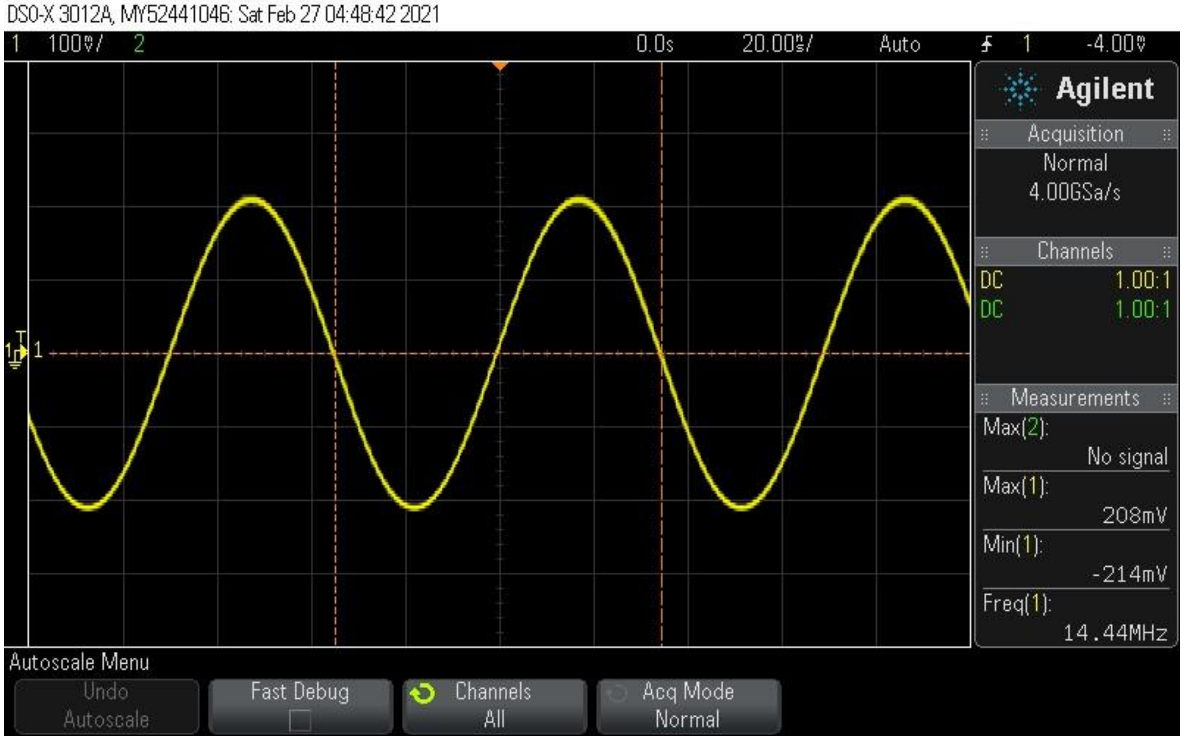
3V Ripple


DSO-X 3012A, MY52441046: Sat Feb 27 03:23:41 2021
1 500mV/ 2
0.0s 10.00us/ Stop
1 3.19V
Agilent
Acquisition
Normal
4.00GSa/s
Channels
DC 1.00:1
DC 1.00:1
Measurements
Max(2):
No signal
Max(1):
3.46V
Min(1):
2.93V
Freq(1):
36.237kHz
Utility Menu
I/O
File Explorer
Options
Service
Quick Action
Annotation

2.5V Ripple


DSO-X 3012A, MY52441046: Sat Feb 27 03:25:53 2021
1 500mV/ 2
0.0s 1.000ms/ Stop
1 2.90V
Agilent
Acquisition
Normal
100MSa/s
Channels
DC 1.00:1
DC 1.00:1
Measurements
Max(2):
No signal
Max(1):
3.28V
Min(1):
2.50V
Freq(1):
367.97Hz
Autoscale Menu
Undo Autoscale
Fast Debug
Channels All
Acq Mode Normal

Potentiometer Electrical Settling Time



Potentiometers: Thermal

Testing Equipment/Facilities

- Infrared Thermometer
- Assembled Structure

Testing Procedure

- After structure assembly, attach ceramic resistors at selected locations
- In room temperature environment, power the resistors
- Supply 5W to each resistor
- Measure surface temperature at various locations
- Comparison with thermal model steady state

Expected Results vs Actual Results

- Expected range of surface temperature is $31^{O}C$ to $51^{O}C$

Stepper Motors: Current

Testing Equipment/Facilities

Testing Procedure

- Apply a moment equal to the holding torque of the system (~0.1Nm) and see how much power is drawn holding the static load. Next, begin cycling the motor at 6.7 deg (10m distance, 1m apart) and record the power draw. Next, do cycles at 0.1 deg and record power draw. This quantifies what the power draw necessary will be over the course of a scan.

Expected Results vs Actual Results

- Multimeter

Stepper Motors: Demo Scan

Testing Equipment/Facilities

- Stepper motors
- Stepper Driver
- Power Supply
- Raspberry Pi w/ monitor, keyboard, etc.

Testing Procedure

Expected Results vs Actual Results

PCB: Thermal Switches

Testing Equipment/Facilities

- Power Supply
- Multimeter
- Arduino/Raspberry Pi

Testing Procedure

- Attach the microcontroller to the controlling gates on the MOSFETs
- Supply 12V to the board and 5V to the MOSFETs
- Measure resistance across the source and drain

Expected Results

- Since Vgs=1V, the resistance from source to gate should be very low (milliohms or less)
- Test has yet to be conducted

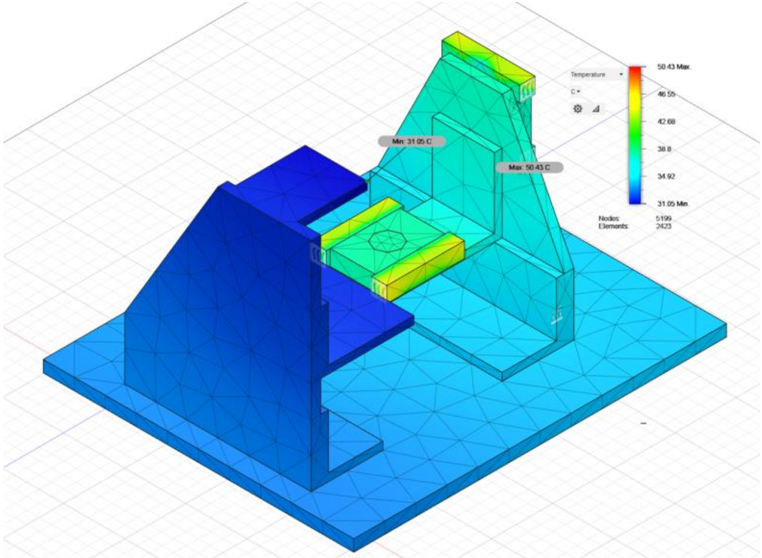
Thermal Model - Room Temperature

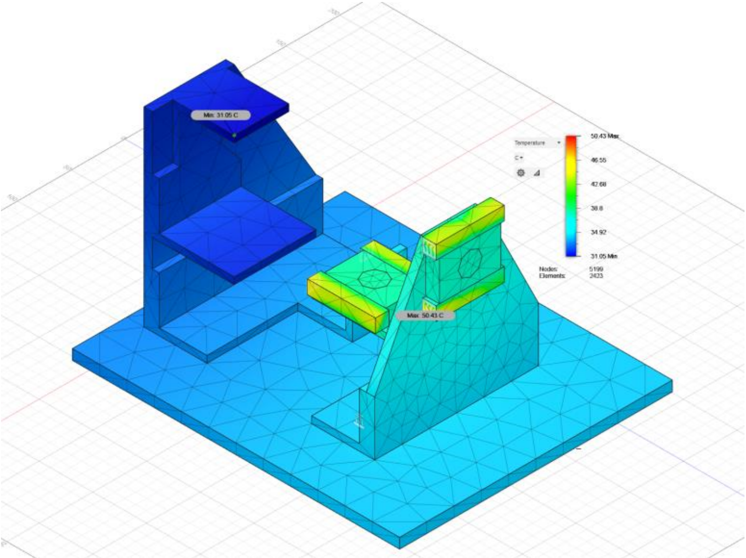
Input parameters:

- 5 W (m^2 K) convection
- 5 W heat per resistor
- Ambient temperature 20 C

Results:

- Minimum temperature 31C
- Maximum temperature 50C





Serial Connection: Overview

What is Being Tested?	Why?	Driving Functional Requirement	Risks Reduced	Status
RS-232 hat interfaces with Pi	Make sure Pi and hat interface as expected	FR 6	Manufacturing errors	Complete
Send and receive test with rangefinder	Determine if rangefinder can accept commands from Pi and Pi can receive data back from rangefinder	FR 6	Not able to autonomously receive data from rangefinder	Incomplete

Serial Connection: Interface

Testing Equipment/Facilities

- RS-232 hat
- Raspberry Pi w/monitor, keyboard, etc.

Testing Procedure

- Setup the serial hat and Raspberry Pi
- Check if serial hat is connected via the **ls /dev** command

Expected Results vs Actual Results

The expected result matches the actual result: both RS-232 ports show up on the list of connected devices under the names ttySC0 and ttySC1

Serial Connection: Send/Receive

Testing Equipment/Facilities

- Rangefinder
- RS-232 hat
- Raspberry Pi w/monitor, keyboard, etc.
- RS-232 cable

Testing Procedure

- Test sending RUN command to rangefinder
- Test sending STOP command to rangefinder

Expected Results vs Actual Results

We have run into a delay with this test: the manufacturer misreported the connector type on the rangefinder. We have ordered an adapter to correct this issue, but waiting on its arrival.