Lockheed Martin Low-Cost F-35 Simulator

Senior Design Team 514

Will Rickles

Meet the Team

Jonah Gibbons
Electrical & Manufacturing Engineer

Laiken Kinsey
Test Engineer & Project Manager

Francisco Lopez
Mechanical & Product Design Engineer

Branden Pacer
Mechanical Engineer & Gimbal Design

Will Rickles
Mechatronics Engineer

Emelia Rodriguez
Research Engineer

Will Rickles

Sponsor and Advisor

LOCKHEED MARTIN

Andrew Filiault

Mechanical Engineer, B.S.

JSF F-35 Pilot Training and Training Infrastructure Systems

FAMU-FSU College of Engineering

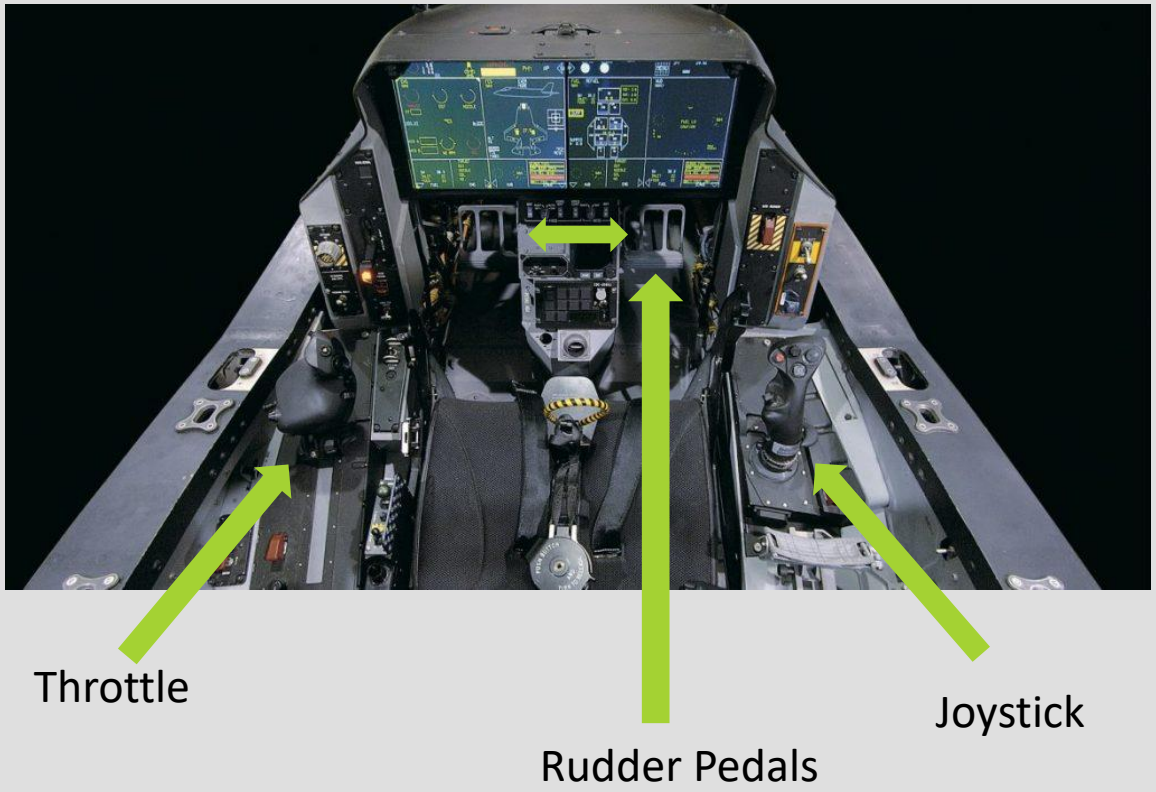
Brandon Krick

Mechanical Engineer, Ph.D.

Associate Professor

Will Rickles

Project Objective



The objective of this project is to create F-35 flight controls that integrate with Lockheed Martin's simulator software to be used in the pilot training program.

Will Rickles

3D Printed Cockpit and Desktop Simulator

- Pilots train in simulators to develop muscle memory and learn the unique operating procedures of the aircraft

Full Scale Simulator

3D Printed Cockpit

Desktop Simulator

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Rudder Pedal System

- Rudder Pedal System (RPS): Controls the jet rudders, nose wheel steering and rear wheel brakes
- Initially developed by a previous senior design team, we will integrate this RPS with minor modification

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HOTAS System

- HOTAS: Hands on Throttle and Stick
- Throttle: Controls the thrust from the jet engine
- Stick: Controls the pitch and roll axes of the aircraft
- Aspects of the HOTAS from previous senior design team will be incorporated in our version

Throttle

Stick

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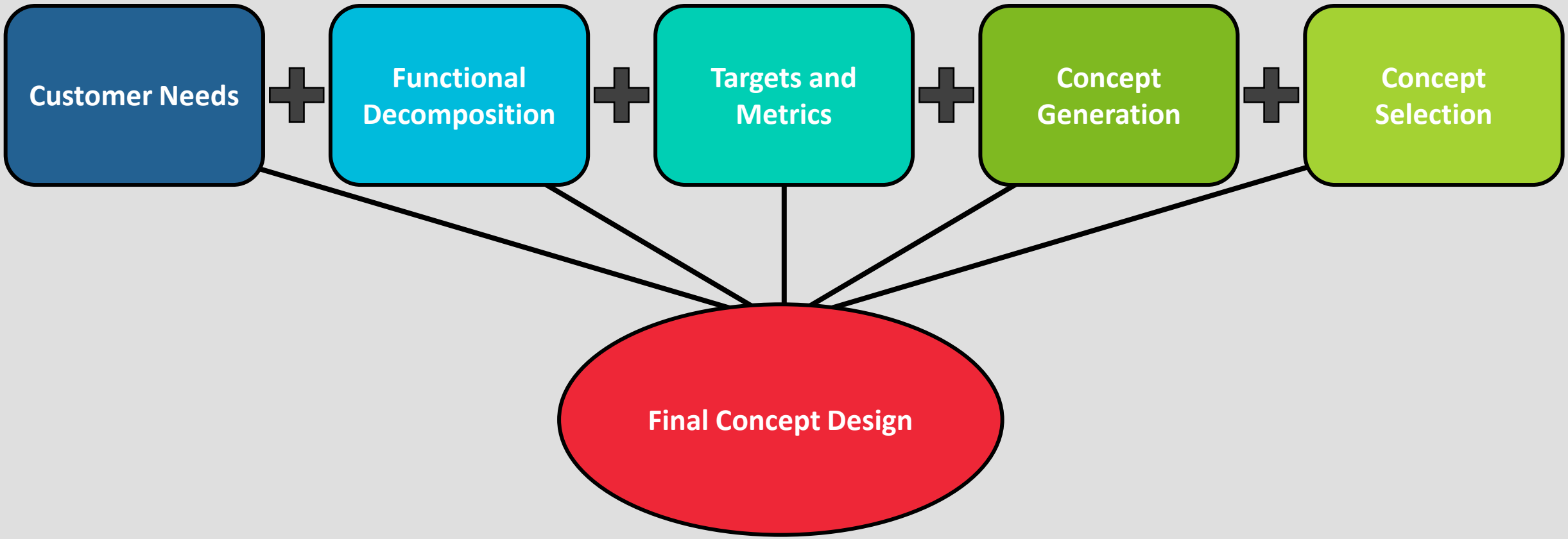
Design Process



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Customer Needs

- Integration between the RPS, HOTAS and Prepar3D
- Able to simulate take-off, perform flight maneuvers, and reasonably attempt landing
- Each subsystem costs should be less than $1000 for our project
- Compatible with both a standard desk and a 3D printed F-35 cockpit

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Key Goals

Create finished, working prototype

Integrate physical sub-systems into the simulation software

Keep manufacturing costs low

Design for use in desktop or cockpit training models

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Flight Control Functions

Pilot Interface

- Controls closely mimic F-35 look and feel
- Mechanic parts will withstand repeated use

Communicate to Software

- Controller position awareness
- Negligible input delay
- Simulated jet accurately responds to control inputs

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Critical Targets

Cost

- Each new sub-system less than $1000

Latency

- No more than 20ms delay from input

Compatibility

- 3D printed cockpit and standard desk

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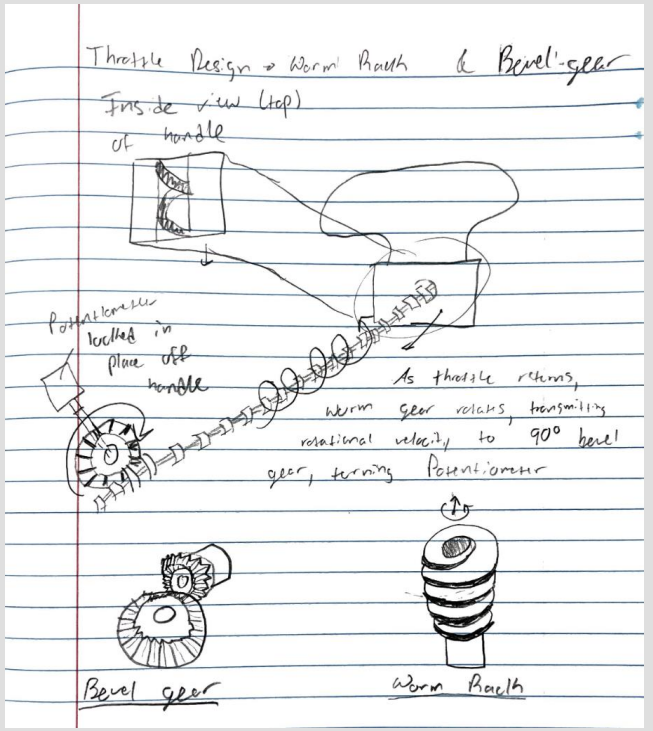
Additional Targets

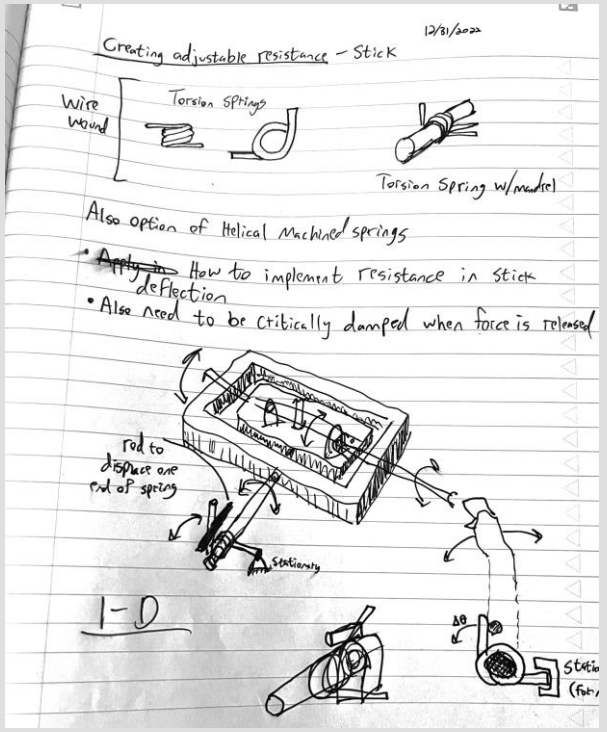
Individual components < 35 pounds	Joystick deflection 13 degrees in all directions	Throttle travel 6 inches
Operates 1 hour without defect	No more than 15 lbf required to move RPS	HOTAS withstands applied 7.5 lbf

Will Rickles

Concept Generation

- Joystick:
  - Multiplane gimbal
  - Ball joint
  - Linkages
- Throttle:
  - Rack and pinion gears
  - Belt system
  - Worm and bevel gear
- RPS:
  - Upgrade electronics
  - Keep previous electronics system

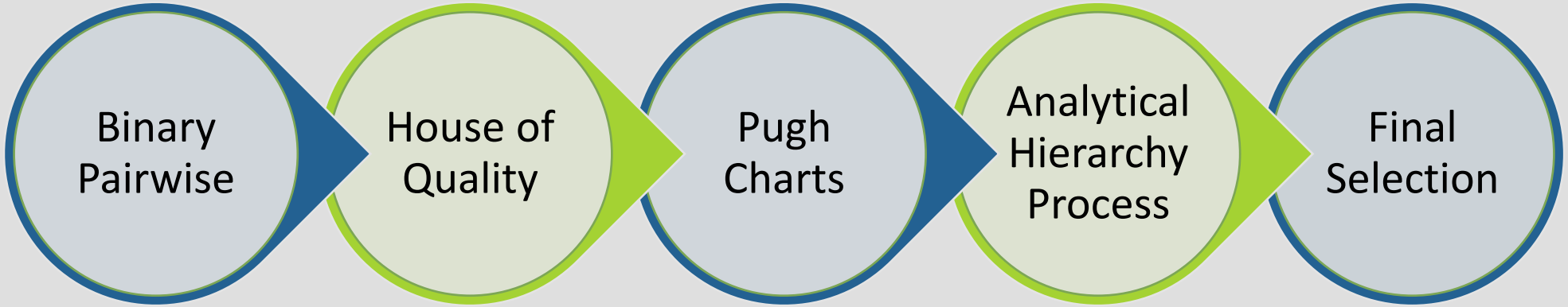




Preliminary Sketches

Emelia Rodriguez

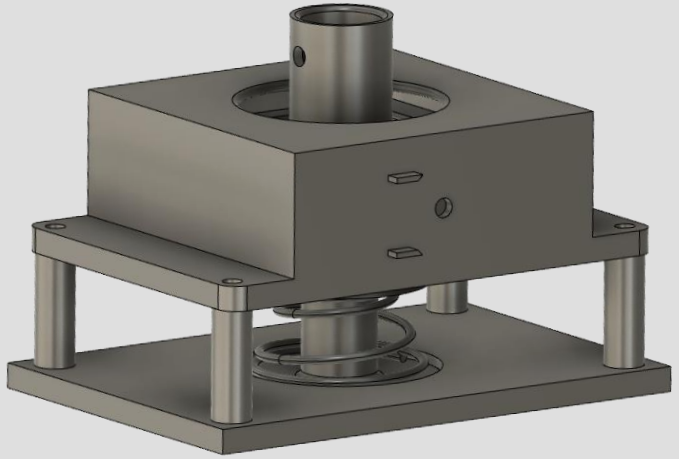
Concept Selection Process

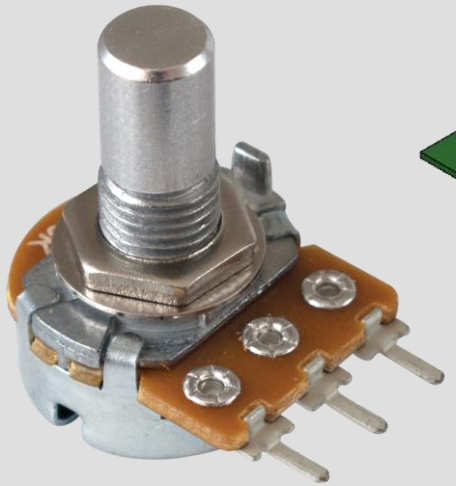


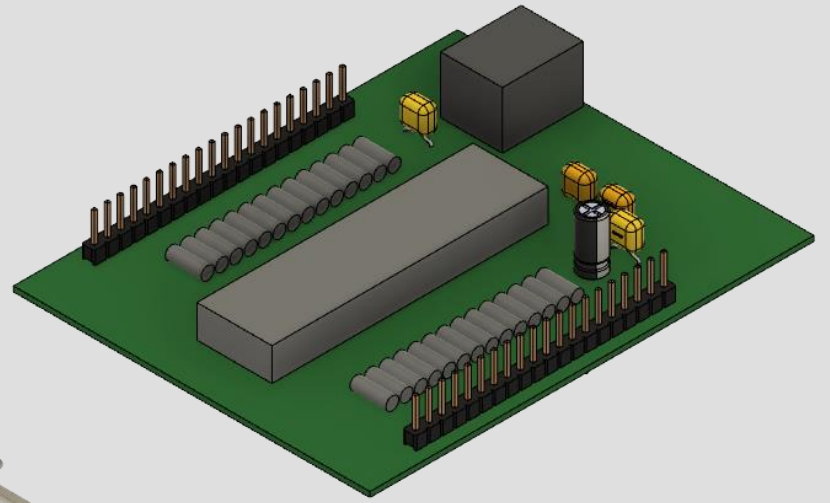
Emelia Rodriguez

Final Design Selection

- Stick: 2-axis gimbal, rotary sensors, custom USB microcontroller
- Throttle: linear square rail, rack and pinion with rotary sensor, custom USB microcontroller
- Rudder Pedal System: updated rotary sensors, custom USB microcontroller







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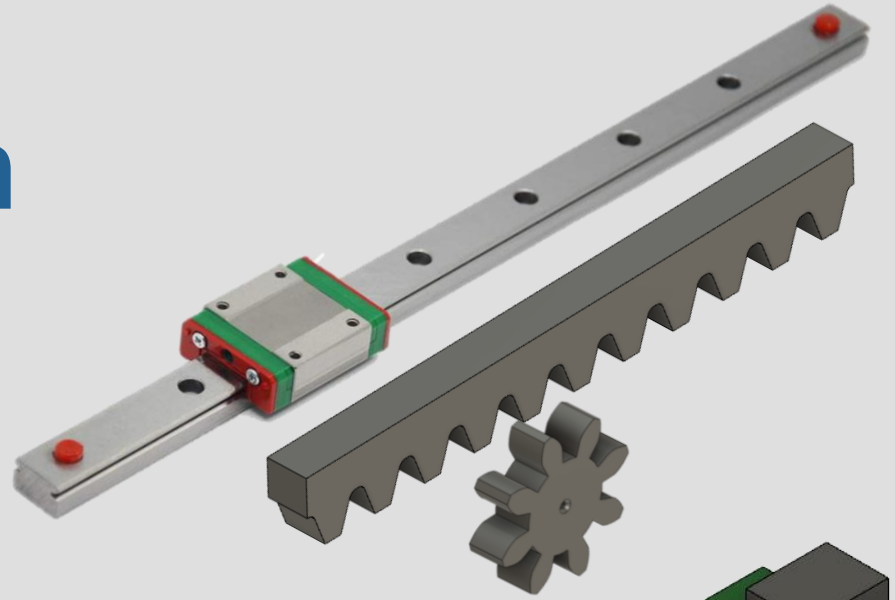

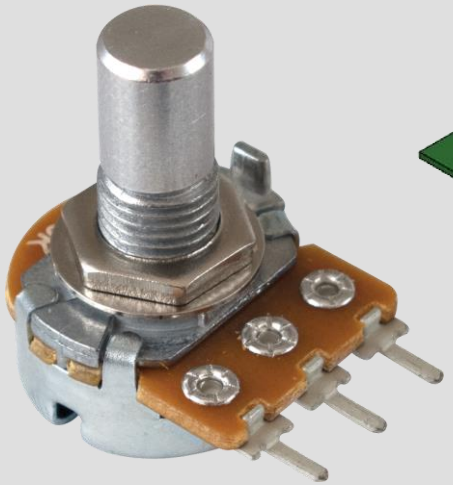

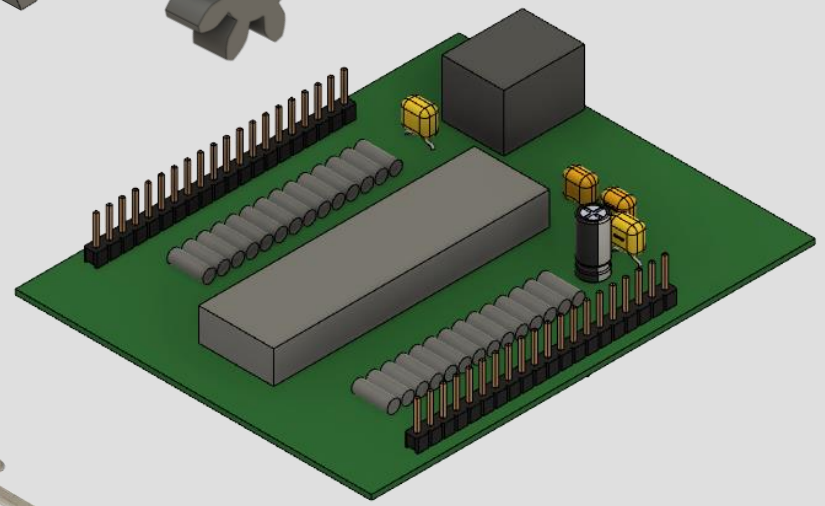

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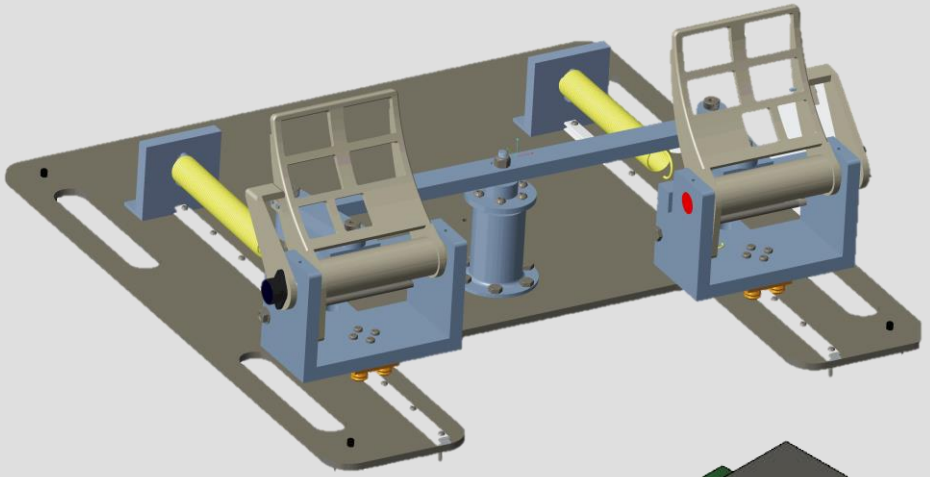
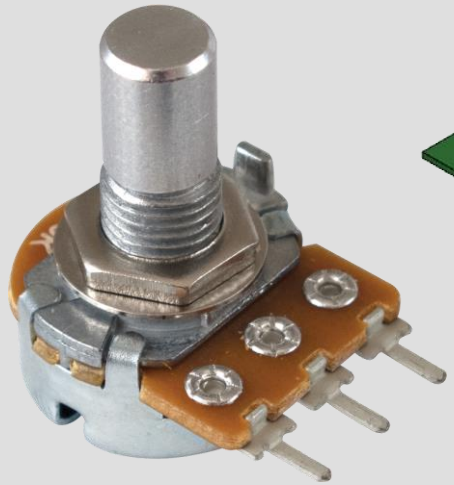
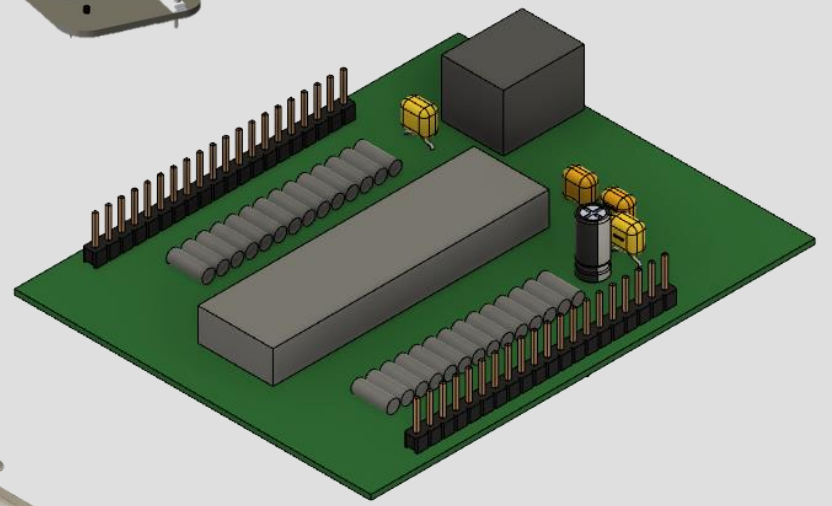






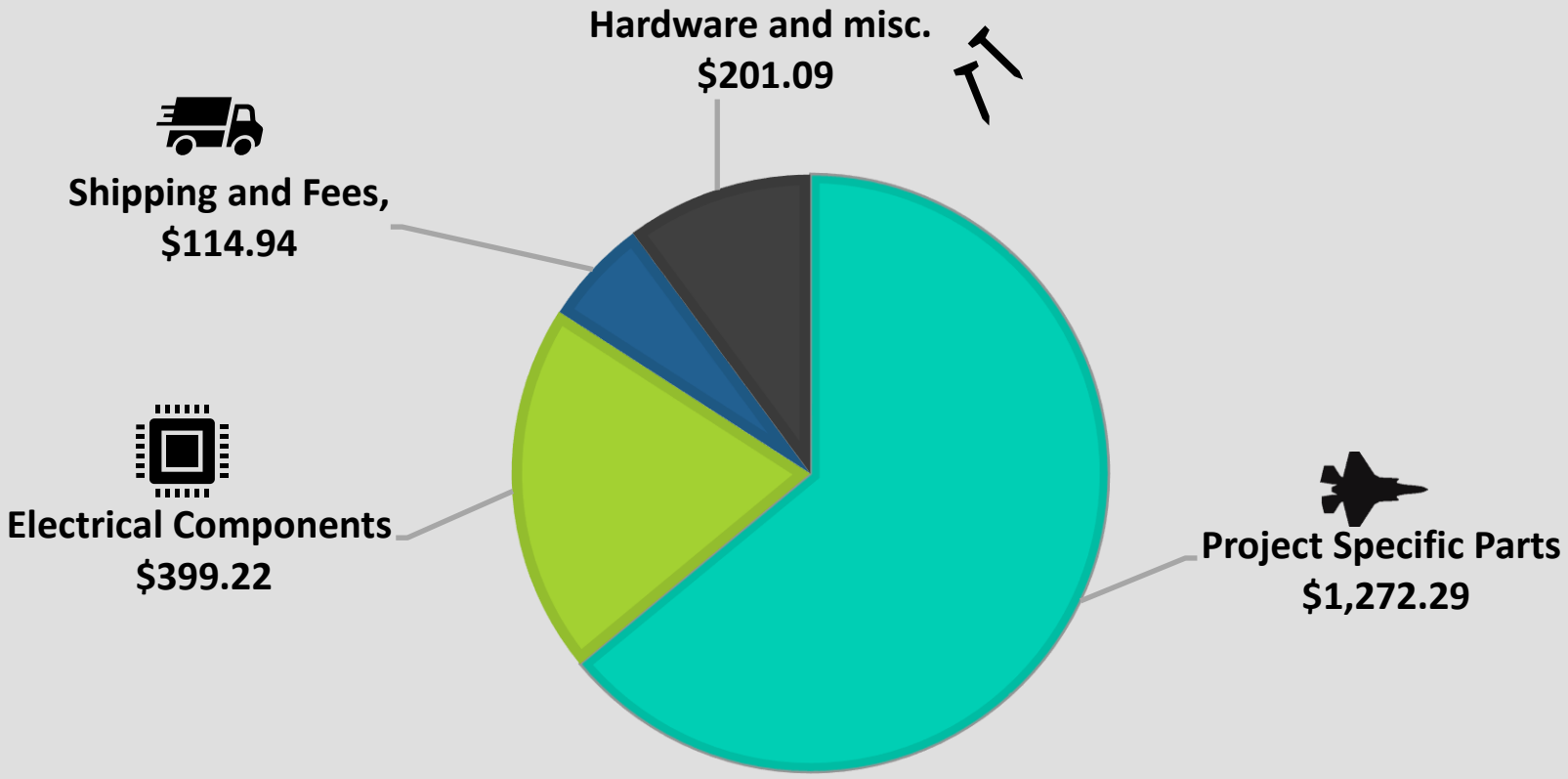
Emelia Rodriguez

Materials Update

- All parts have arrived
- Currently, we are using parts already available for simple and non-specific applications
  - Single push buttons
  - Wires
  - Wire management
- Newly designed caps made for alternate buttons without caps

Emelia Rodriguez

Budget Update

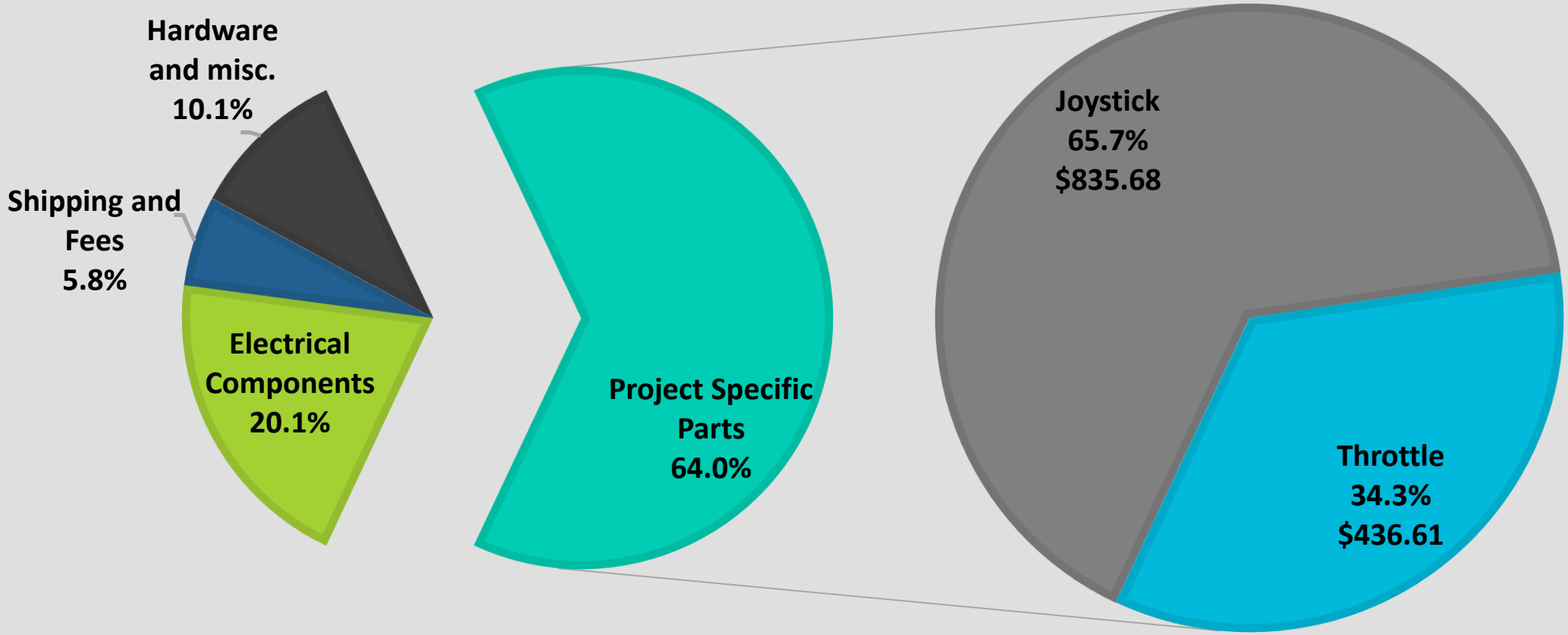


TOTAL COST TO DATE:
$1987.54
99.38% OF OVERALL BUDGET

Project Specific Parts	: 64.0%
Electrical Components	: 20.1%
Shipping and Fees	: 5.8%
Hardware and misc.	: 10.1%

Emelia Rodriguez

Budget Update



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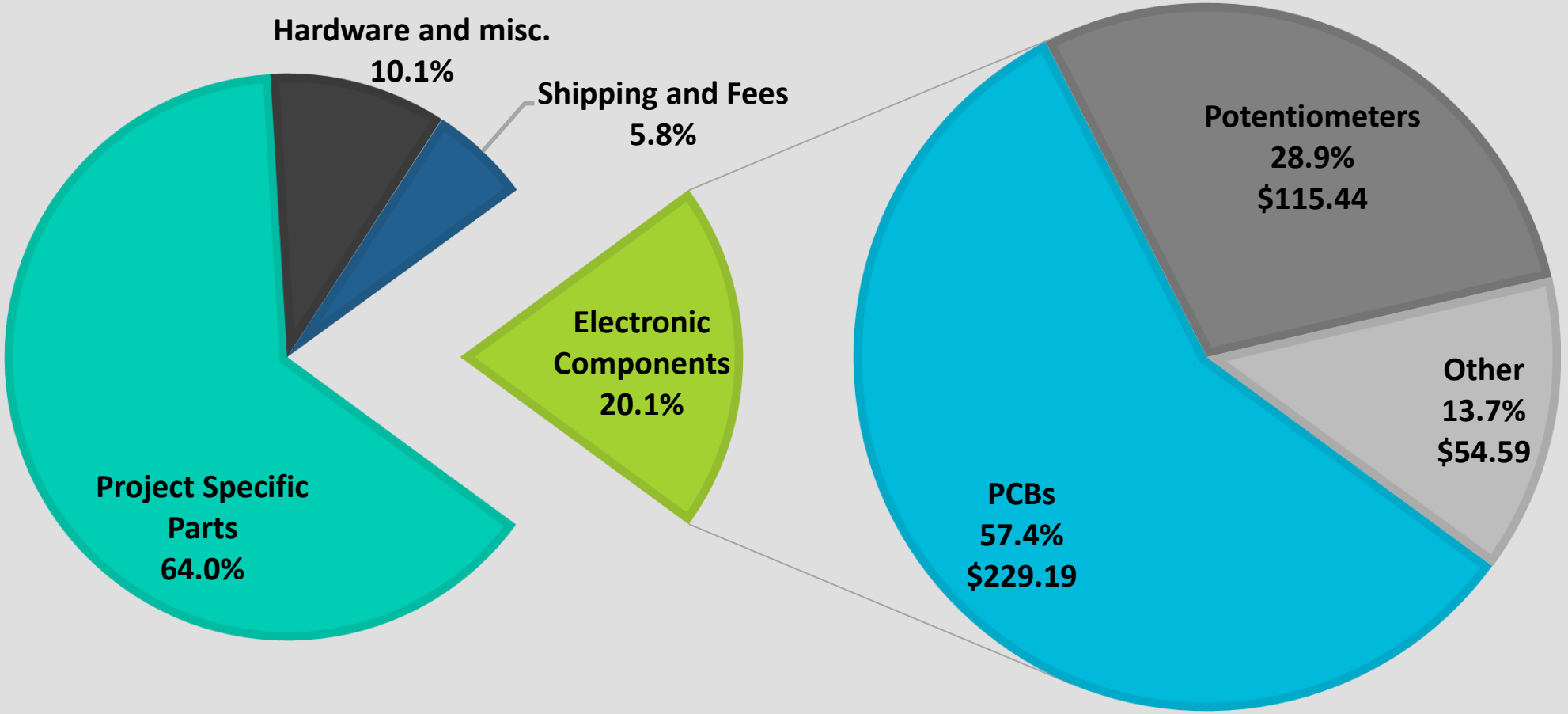
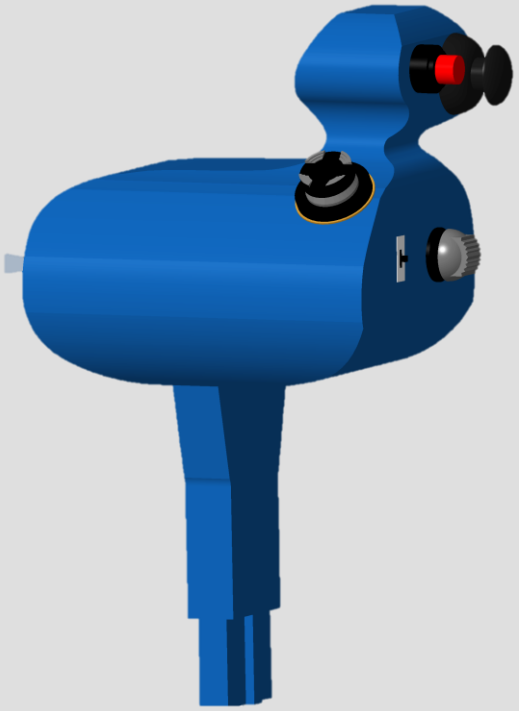
Budget Update

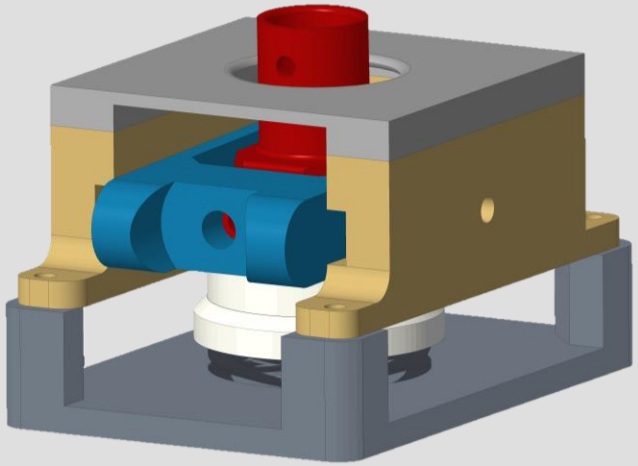


Emelia Rodriguez

Creating CAD Designs



Throttle

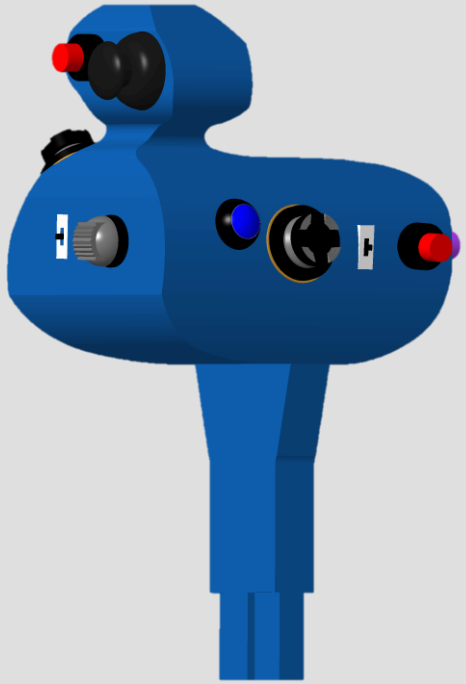


Joystick Gimbal

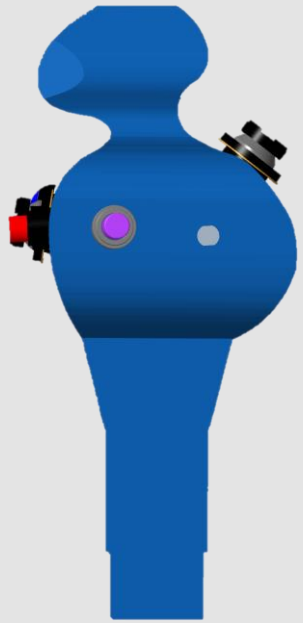
Joystick

Francisco Lopez

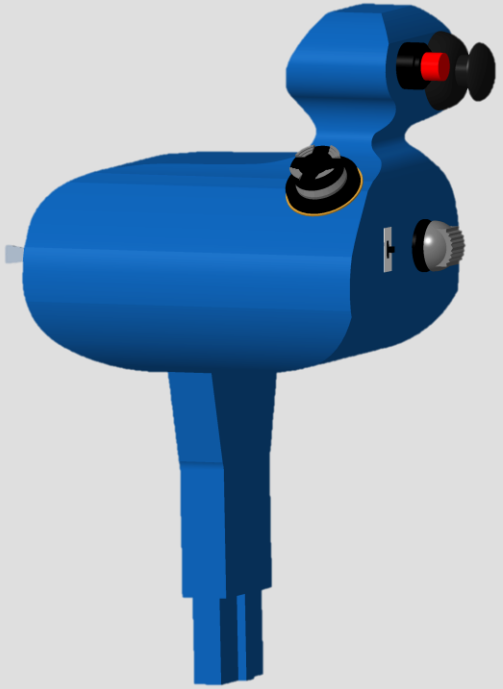
Throttle



Back/rear



Left side

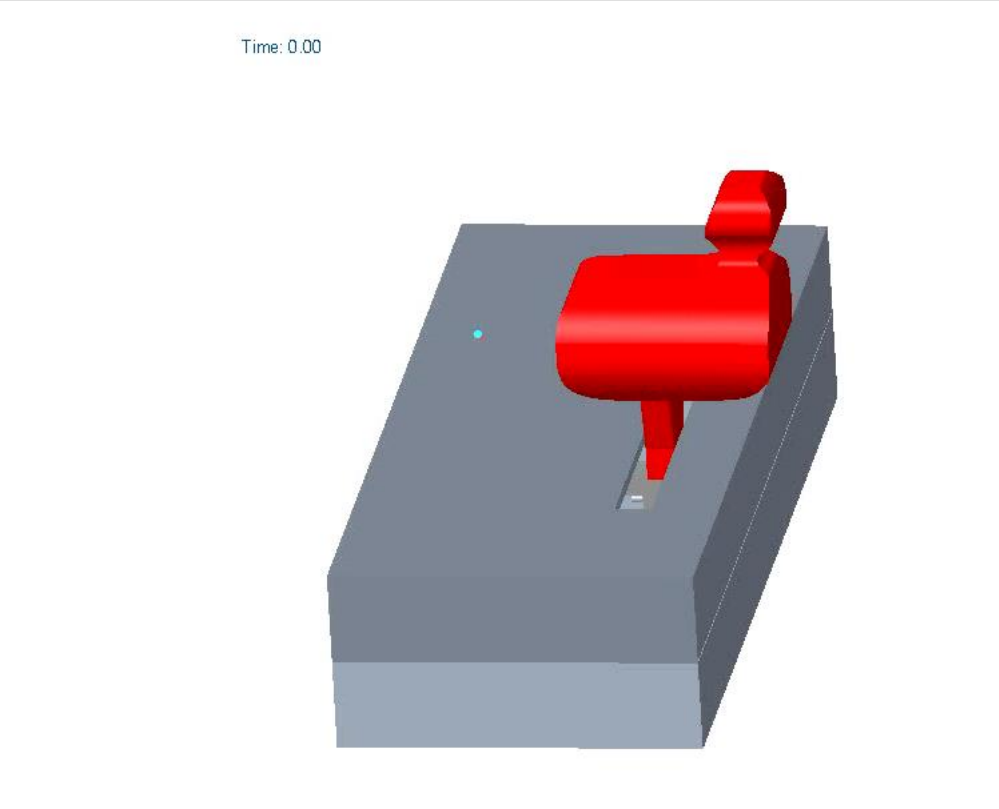


Front

Francisco Lopez

Throttle Prototype

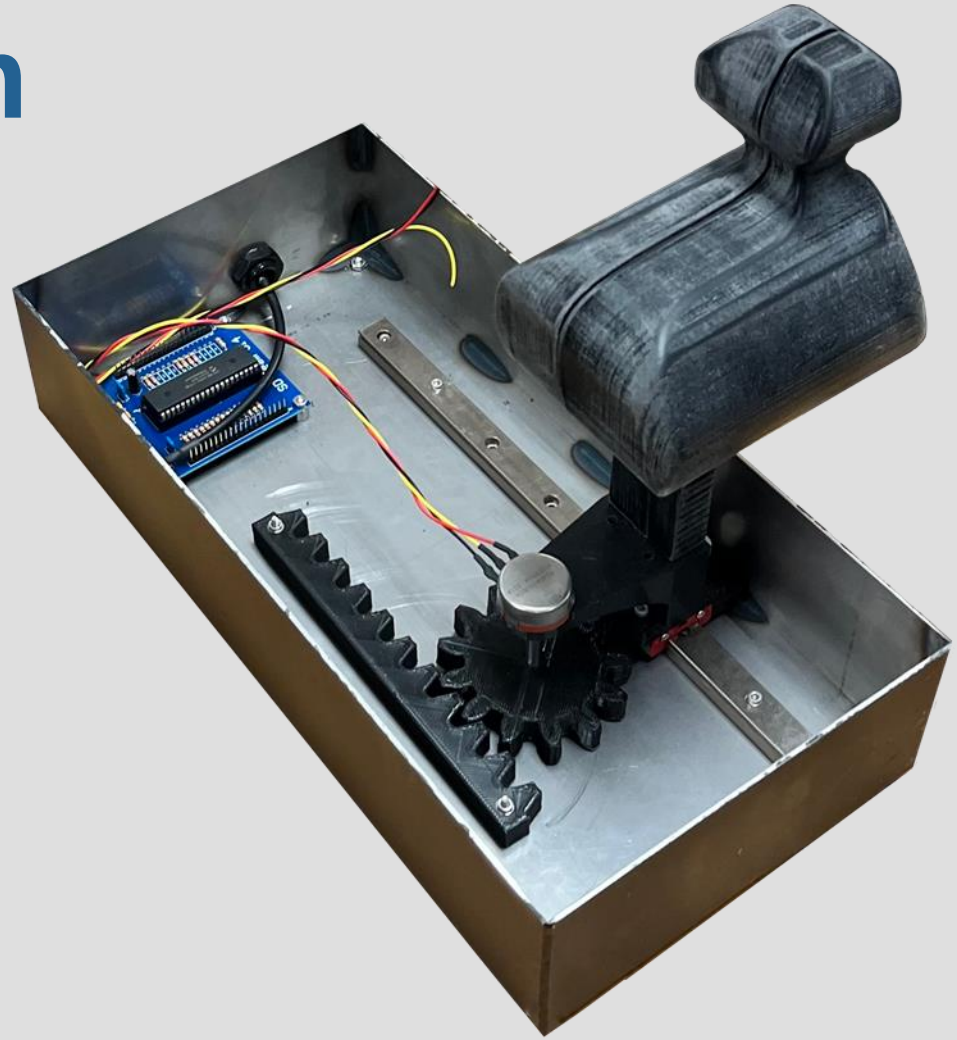
- Rack and pinion utilized to sense linear displacement
- Nylon screw in slider attachment provides adjustable resistance



Francisco Lopez

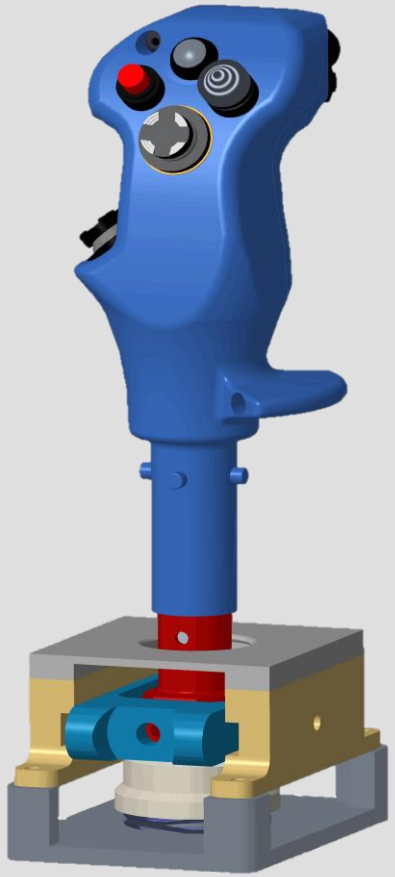
Throttle Mechanism

- Prototype Results
  - Rack and pinion are 3D printed
  - Welded steel enclosure with a removable lid
  - Gear teeth have minimal slop



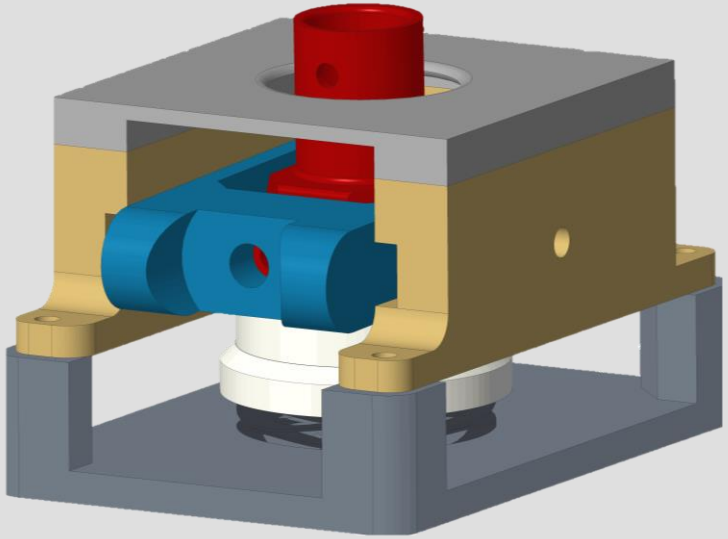
Francisco Lopez

Joystick Assembly



Branden Pacer

Joystick Mechanism

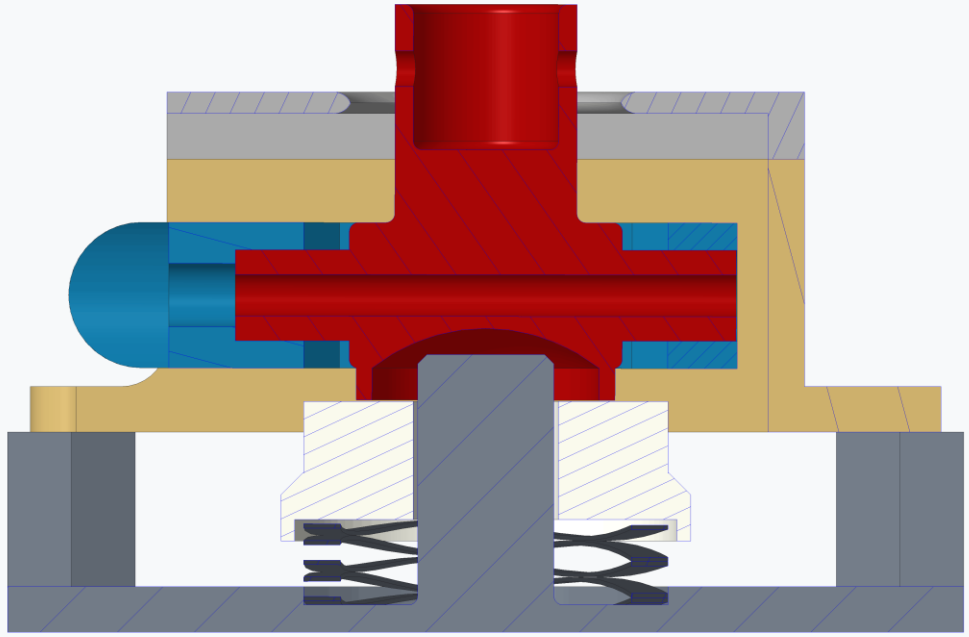


- Gimbal allows motion within target angle of deflection.
- Single wave spring provides joystick resistance.
- Wave springs reduce overall height of stick

Branden Pacer

Joystick Mechanism

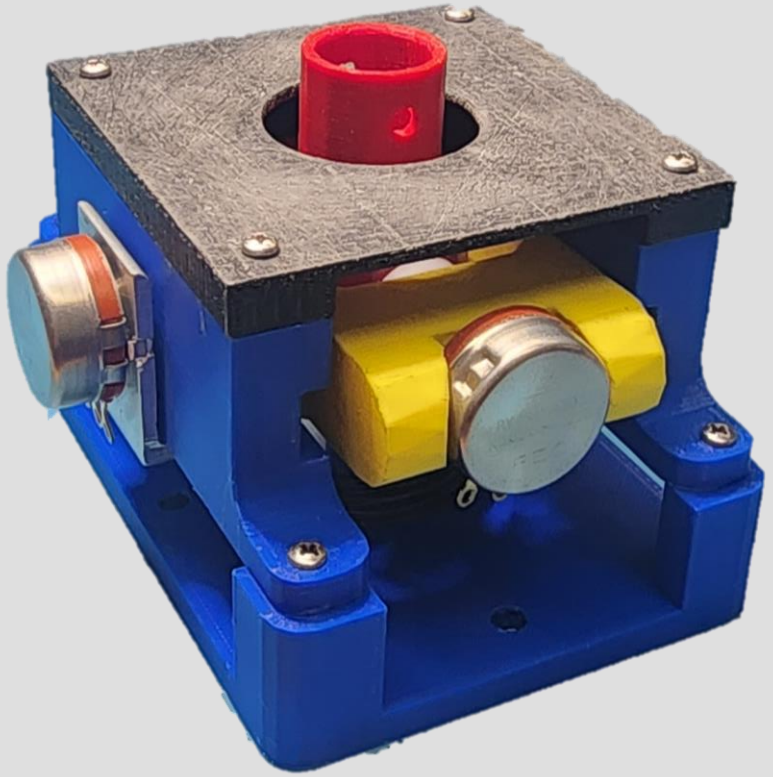
- Challenges creating smooth joystick control
  - Contact surfaces
  - Spring force and deflection
  - Integrating large potentiometers
  - Centering of gimbal



Branden Pacer

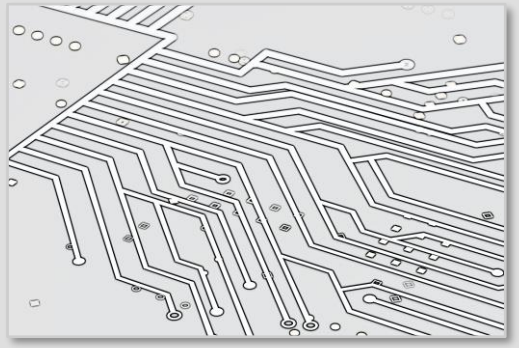
Joystick Mechanism

- Results:
  - Reasonably smooth
  - Does not create distraction
  - Potentiometers have plenty of wire clearance
  - Options available for increased resistance as future feature



Branden Pacer

Electrical Design



Constraints

- Lots of buttons, switches, and rotary sensors need to connect to the simulator
- Communication must be fast
- Compatible with lots of computers
- Requested not to use Arduino as previous teams did

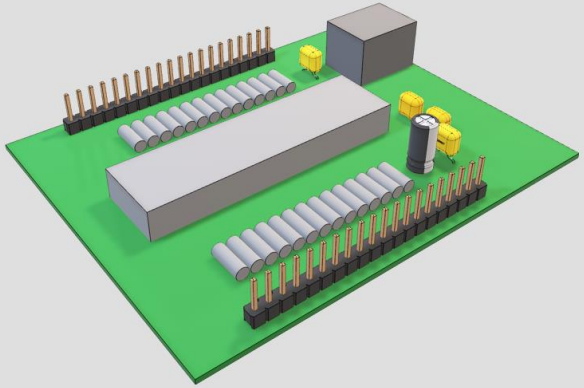
Signals

- Joystick:
  - 10 buttons, multi-position switches.
  - 2 rotary sensors.
- Throttle:
  - 12 buttons, multi-position switches.
  - 4 rotary sensors.
- Rudder Pedal System:
  - 3 rotary sensors.

Jonah Gibbons

Solution

- PIC microcontroller:
  - 40 pins to use
  - 13 analog-to-digital channels
  - Powered by USB port
  - Cheap
- Custom firmware:
  - Code written specifically to process our signals and transmit them efficiently over USB
- Custom printed circuit board:
  - Built to match our exact needs for circuit components



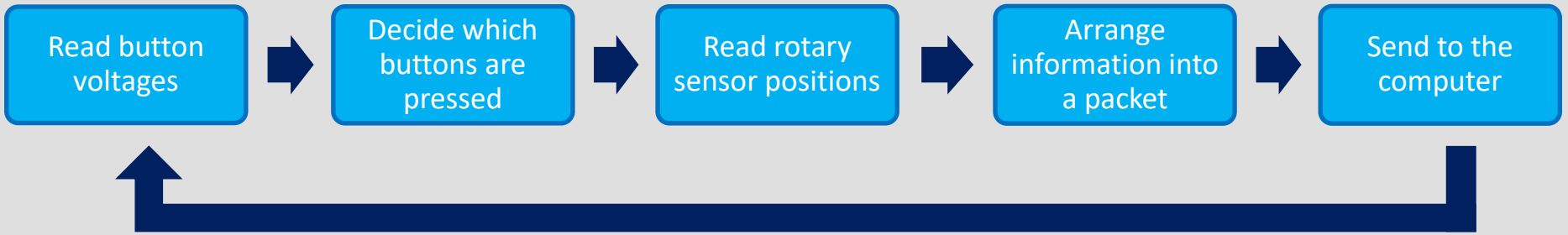
Jonah Gibbons

Universal Serial Bus (USB)

- Designed to be plug-and-play solution for any electronic device
- Capable of high-speed data transfer
- Generic drivers are standard on computers now

Jonah Gibbons

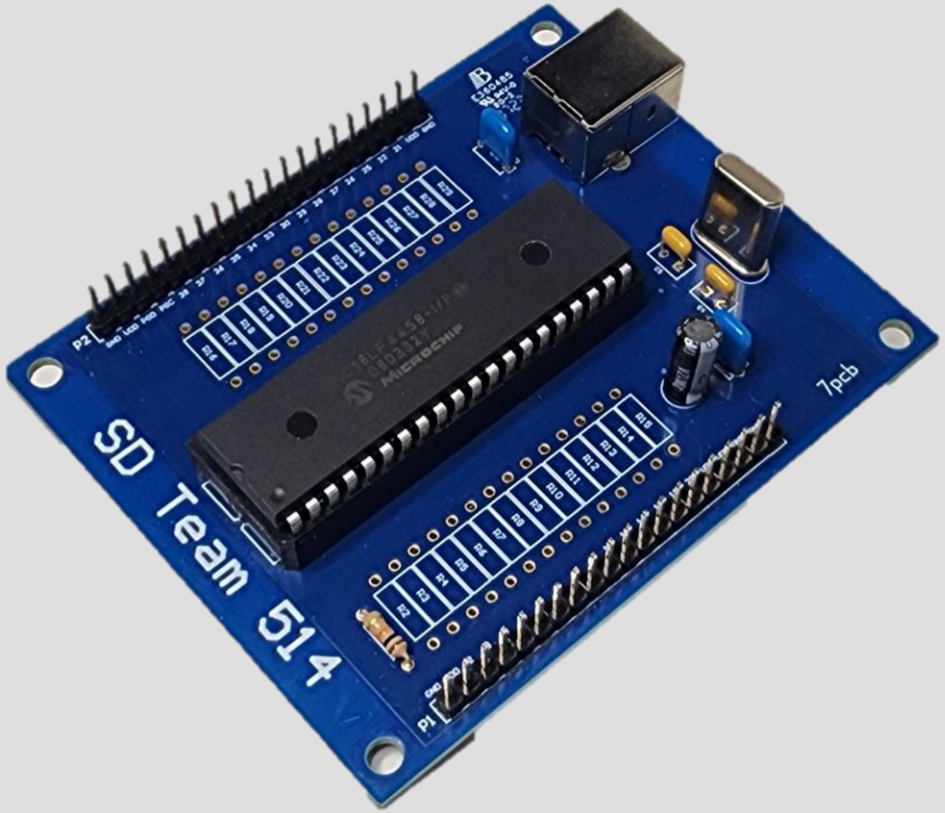
Firmware



- 732 lines of code not including USB header files
- Written and compiled using Microchip's MPLAB X software

Jonah Gibbons

Custom Printed Circuit Board



Creating our own PCB board from scratch allowed us to design it for our exact needs.

Jonah Gibbons

Custom Printed Circuit Board

- 5-layer design
  - Separate signal layers
  - Sandwich traces between ground planes to reduce signal noise
- Same layout used for all 3 controllers

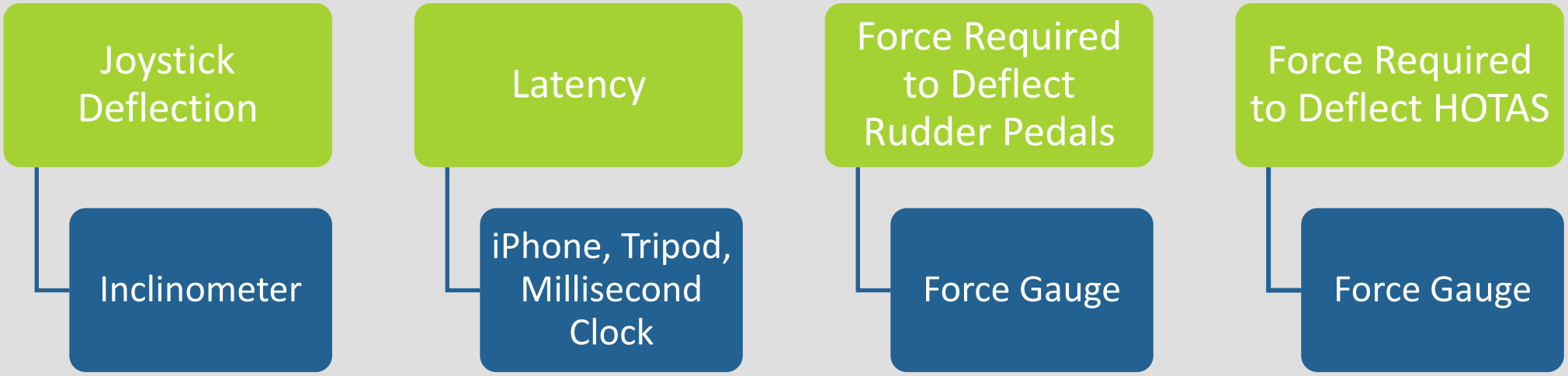
Jonah Gibbons

Prototype Build

- The final prototype is nearly ready for delivery
  - Touchups, detail-work
  - Mechanisms are finalized and being tested
  - Firmware receiving update
- RPS retrofitted with new potentiometers
- Grips sanded smooth and everything painted

Jonah Gibbons

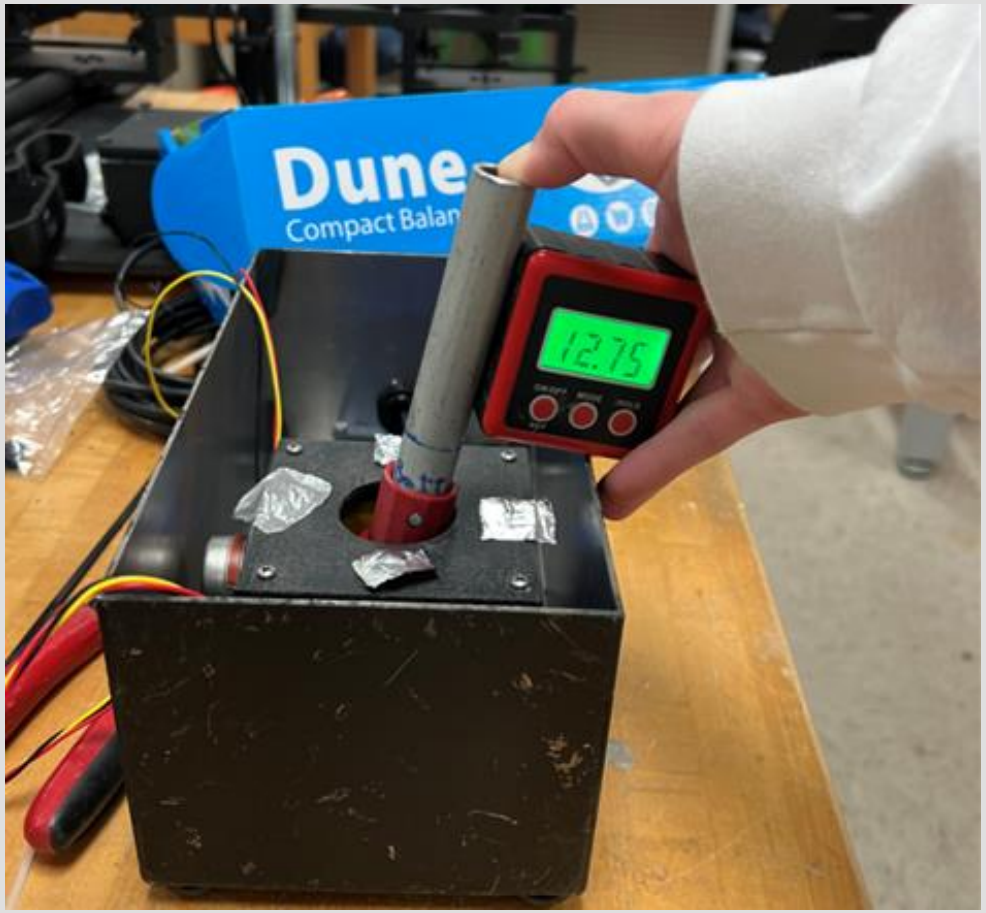
Methods of Validation



Laiken Kinsey

Joystick Validation

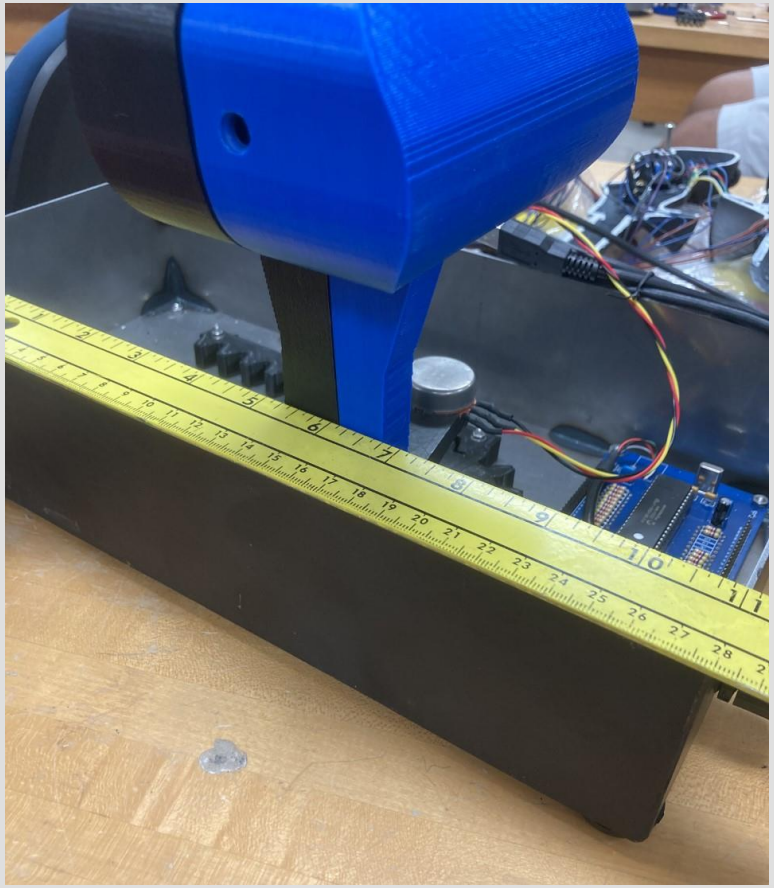
- Angle of deflection
  - **Goal: 13°**
  - North: 12.7°
  - South: 13.9°
  - East: 14.7°
  - West: 13.3°
- Resistance to deflection
  - **Goal: <7.5 lbf**
  - Pitch: ### lbf
  - Roll: ### lbf



Laiken Kinsey

Throttle Validation

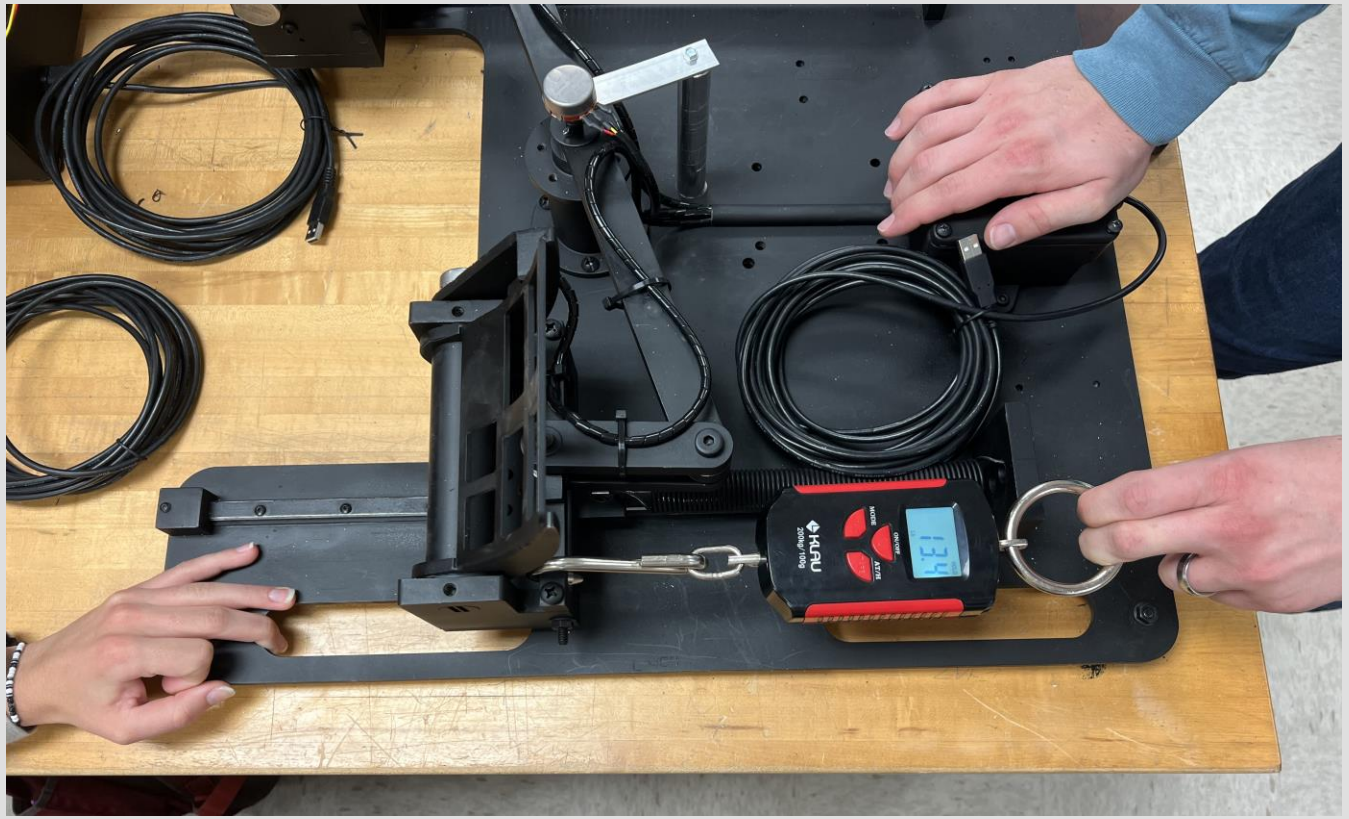
- Travel Distance
  - **Goal: 6 inches**
  - Distance: 6.06 inches
- Resistance to motion
  - **Goal: <7.5 lbf**
  - Resistance: ### lbf



Laiken Kinsey

RPS Validation

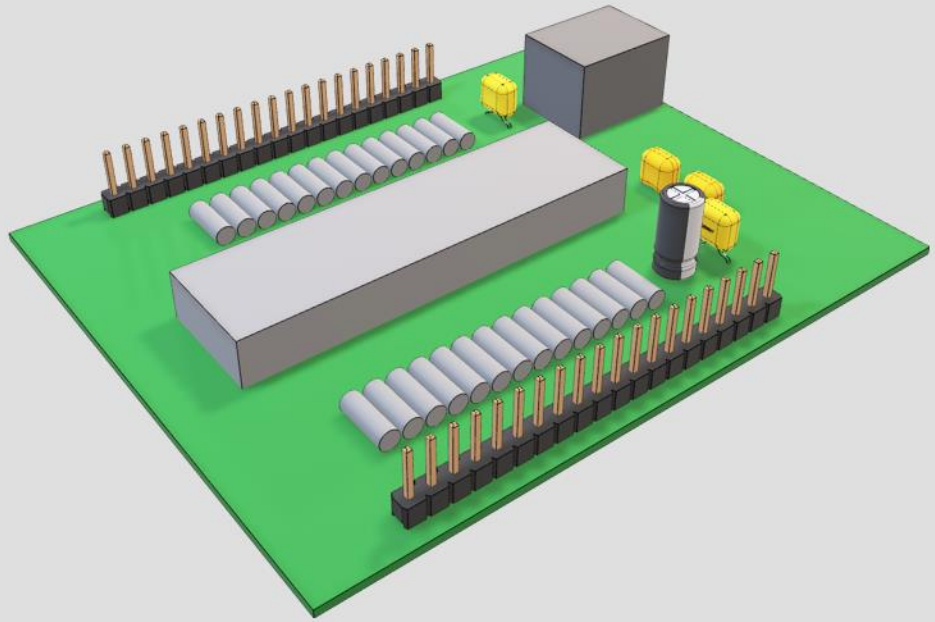
- RPS Weight
  - **Goal: <35 lbs**
  - Weight: 25 lbs
- Force of deflection
  - **Goal: <15 lbf**
  - Left pedal: 11.2 lbf
  - Right pedal: 13.5 lbf



Laiken Kinsey

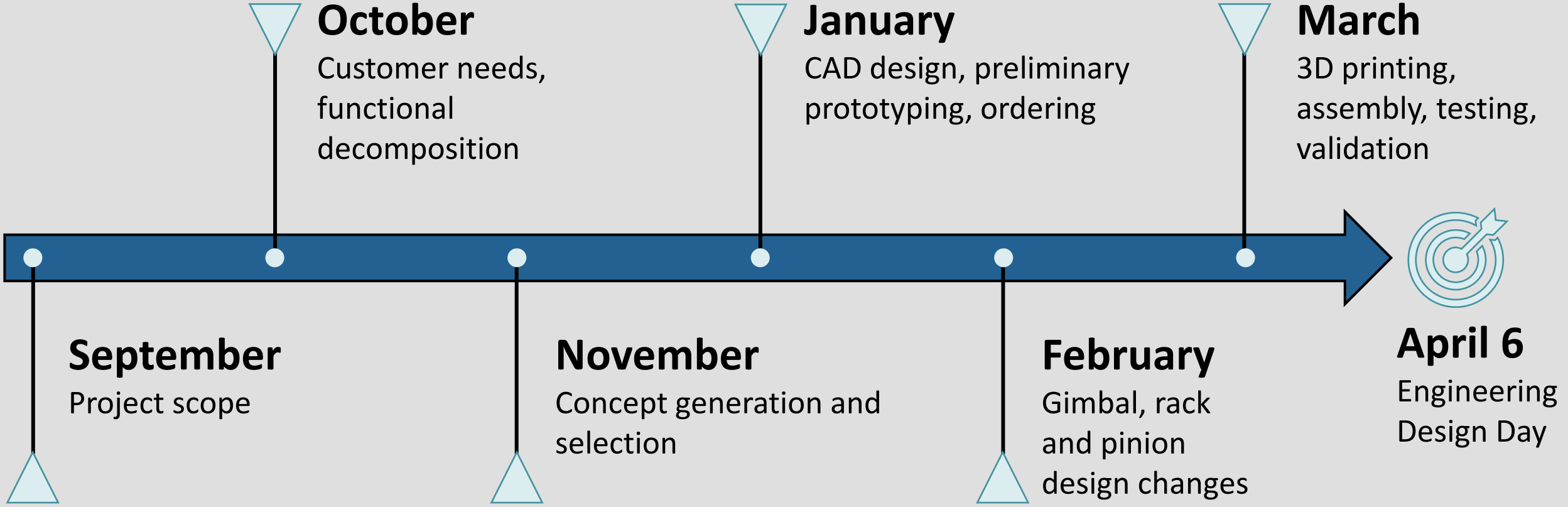
PCB Validation

- Electric Test Report
  - **Test voltage - 250 V**
  - **Test current - 100MA**
  - **Conductive Resistance - 20 Ohms**
  - **Insulation Resistance - 20 M Ohms**
- Solderability Test Report
  - **245 +/- 5 °C for 3-5 seconds**
- Thermal Stress Test Report
  - **288 +/- 5 °C for 10 seconds**



Laiken Kinsey

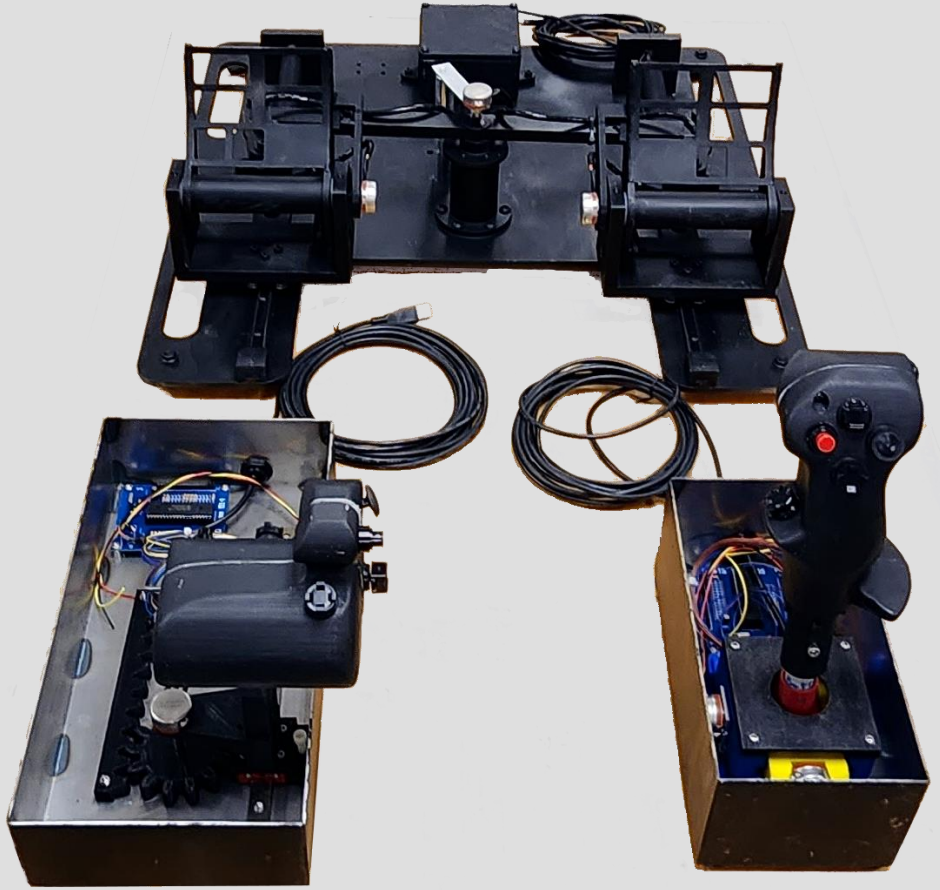
Project Timeline



Laiken Kinsey

Summary

- Objective
  - Create F-35 controls for low-cost simulation training
- Targets
  - Working desktop prototype created within $2000 limit
- Design
  - Two subsystems built new, RPS improved
- Outcome
  - We have readings from each subsystem, but not completed a flight test yet



Laiken Kinsey

Lessons Learned

Be sure to assemble prototypes early so there is ample time for adjustments or redesigns

Defend your ideas but remain flexible and open-minded toward necessary changes

With multiple iterations, version control is essential when collaborating on parts with teammates

Joining 3D prints together can be tricky, so plan for wide tolerances and other ideas like hardware

Parts lock up, wear out, and break, so budget for maintenance as well

Keep tabs on everything. Having a broader project awareness speeds everything up

Laiken Kinsey

Questions?

- Design Team
- Budget
- Project Objective
- Customer Needs
- Background
- Functions
- Targets
- Validation
- Final CAD
- Concept Selection
- Project Timeline
- Electronics

Laiken Kinsey