



# ELEVATE

The Retrofittable Standing Desk Converter

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# standing desk

*noun*

a desk that can be used to work comfortably while sitting or standing



\$9.5 billion market size by 2028<sup>[1]</sup>  
50% expected growth<sup>[1]</sup>



Improves posture<sup>[2]</sup>  
Reduces neck and shoulder pain<sup>[3]</sup>  
Improves vitality<sup>[3]</sup>  
Reduces stress<sup>[2]</sup>



Increases productivity<sup>[3]</sup>

# The Problem

Adjustable standing desks offer physical and mental health benefits.<sup>[3]</sup> However, currently, there exists a barrier to entry for potential standing desk customers: the only two options are to buy a whole new standing desk or a tabletop standing desk converter. The former option generally costs upwards of \$350<sup>[4]</sup> and weighs 110 lbs. on average<sup>[5]</sup>, while the latter option is clunky, uses space inefficiently, and is manually operated.



Expensive



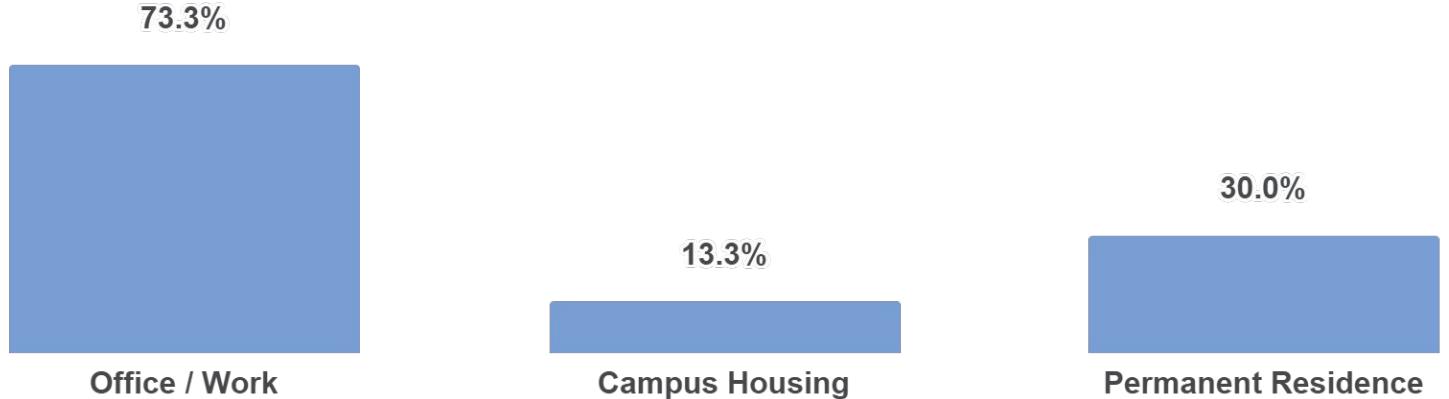
Lack of Portability



Space Inefficient

# The Market

## Where College Students Use Standing Desks



Office / Work

Campus Housing

Permanent Residence

**50%**  
of college students have used  
standing desks

**86.7%**  
of college students who have  
used standing desks DO NOT  
use a standing desk on campus

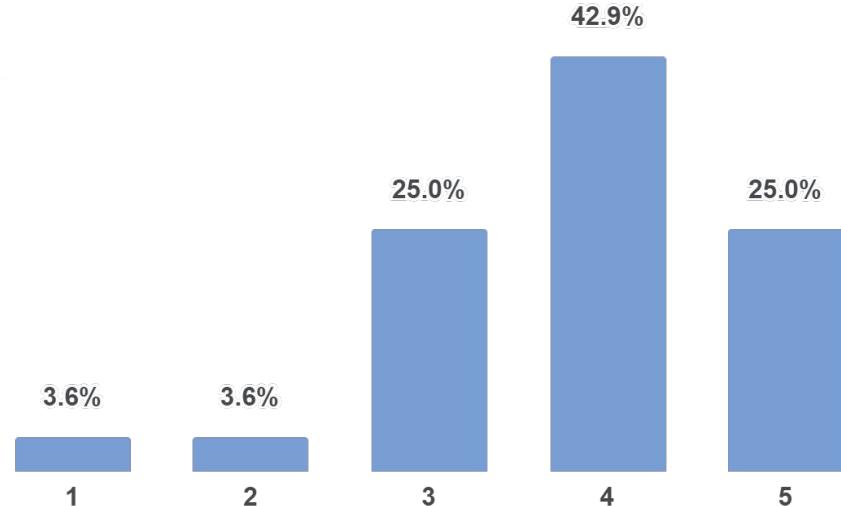
**45%**  
of college students have used  
true standing desks

# The Competition

## The True Standing Desk



Aesthetics Rating of True Standing Desk

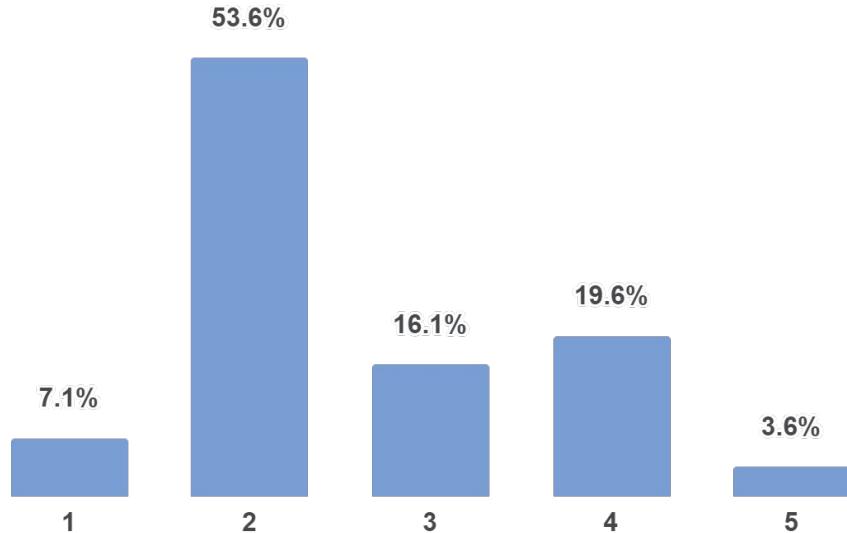


# The Competition

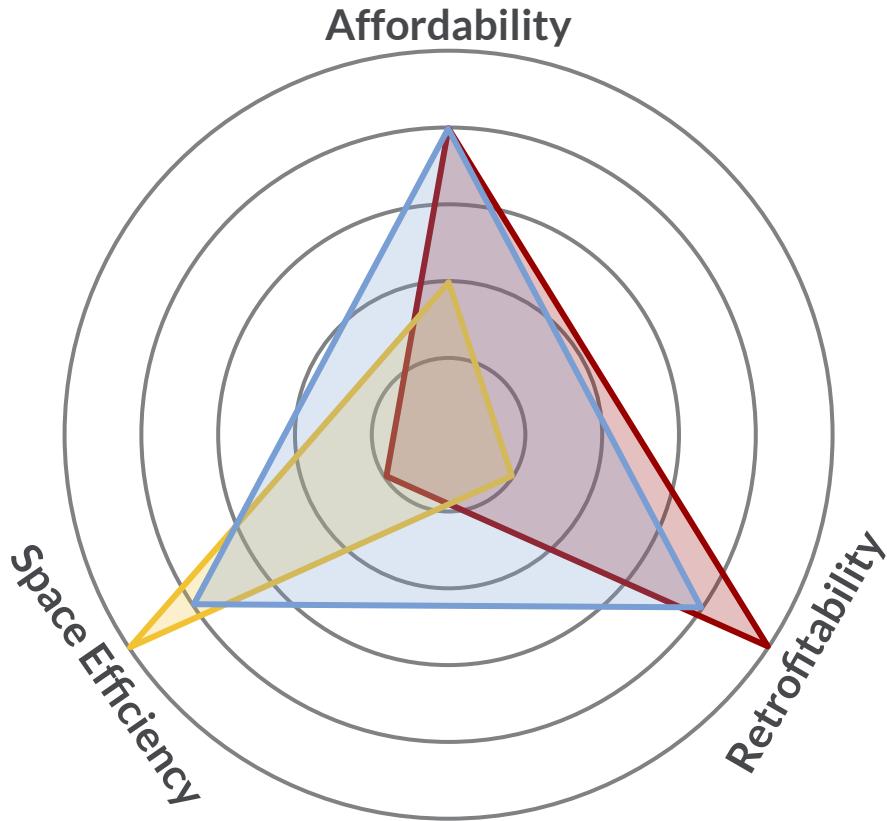
## The Standing Desk Converter



Aesthetics Rating of Standing Desk Converter



# Competition Comparison



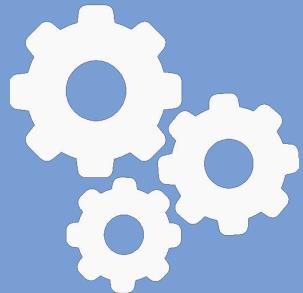
— ELEVATE



# Our Customers

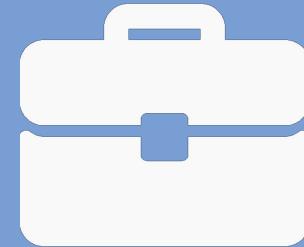


**Business Owners**  
and other employees  
and employers who  
have a budget and are  
looking for lower cost  
solutions



## Artists

and other individuals  
who are looking for a  
retrofittable solution  
to keep their current  
setup



**College Students**  
and other individuals  
who do not have a  
permanent desk setup  
and are looking for a  
portable solution

# System Characteristics



**Functional**  
300lb at  $\frac{1}{2}$ " / sec  
1.5' adjustability



**Affordable**  
< \$250



**Reliable**  
Load cycling  
IP62 rating  
UL consumer  
product ratings



**User-Friendly**  
Portable  
Space efficient  
Easy to install  
Intuitive



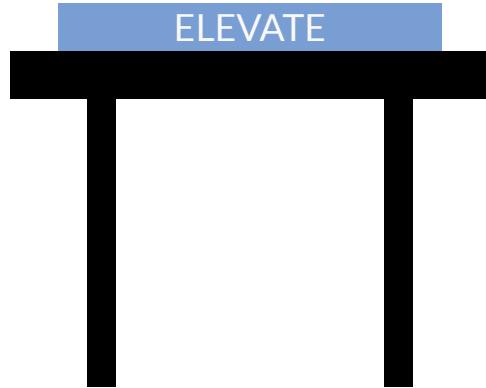
**Universal**  
Works for  
majority of desks



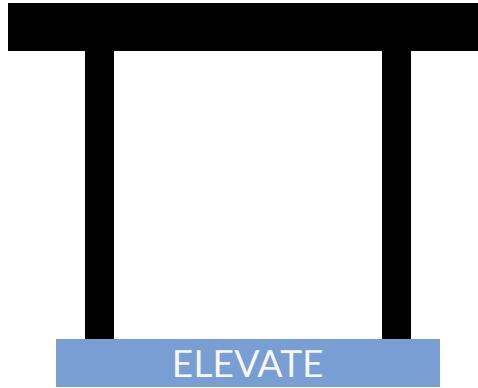
**Safe**  
No backdriving  
Rigid  
Stable

# Concept Selection

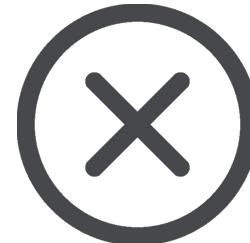
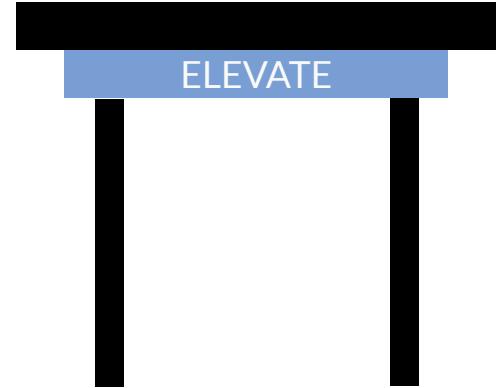
On Desk



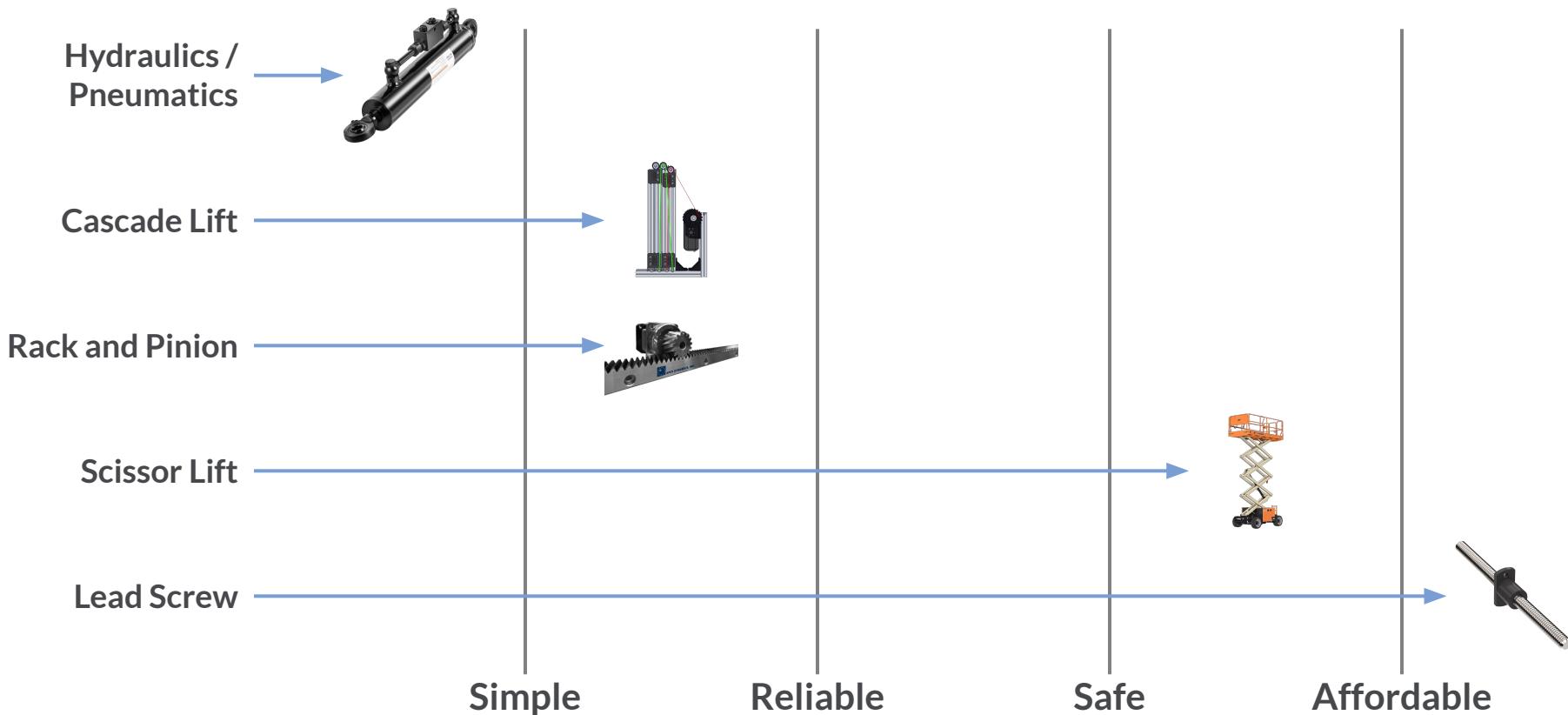
Under Legs



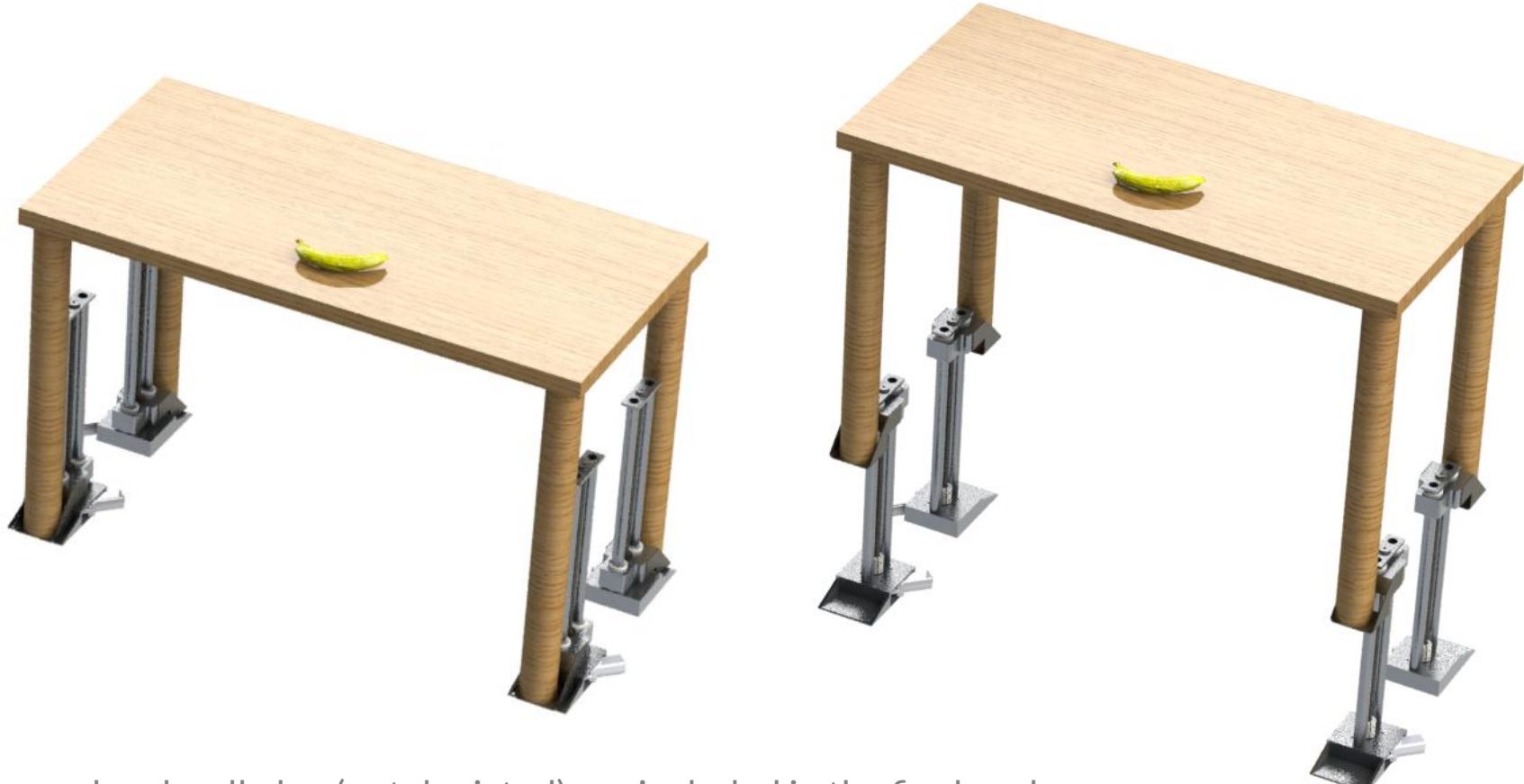
Under Desk



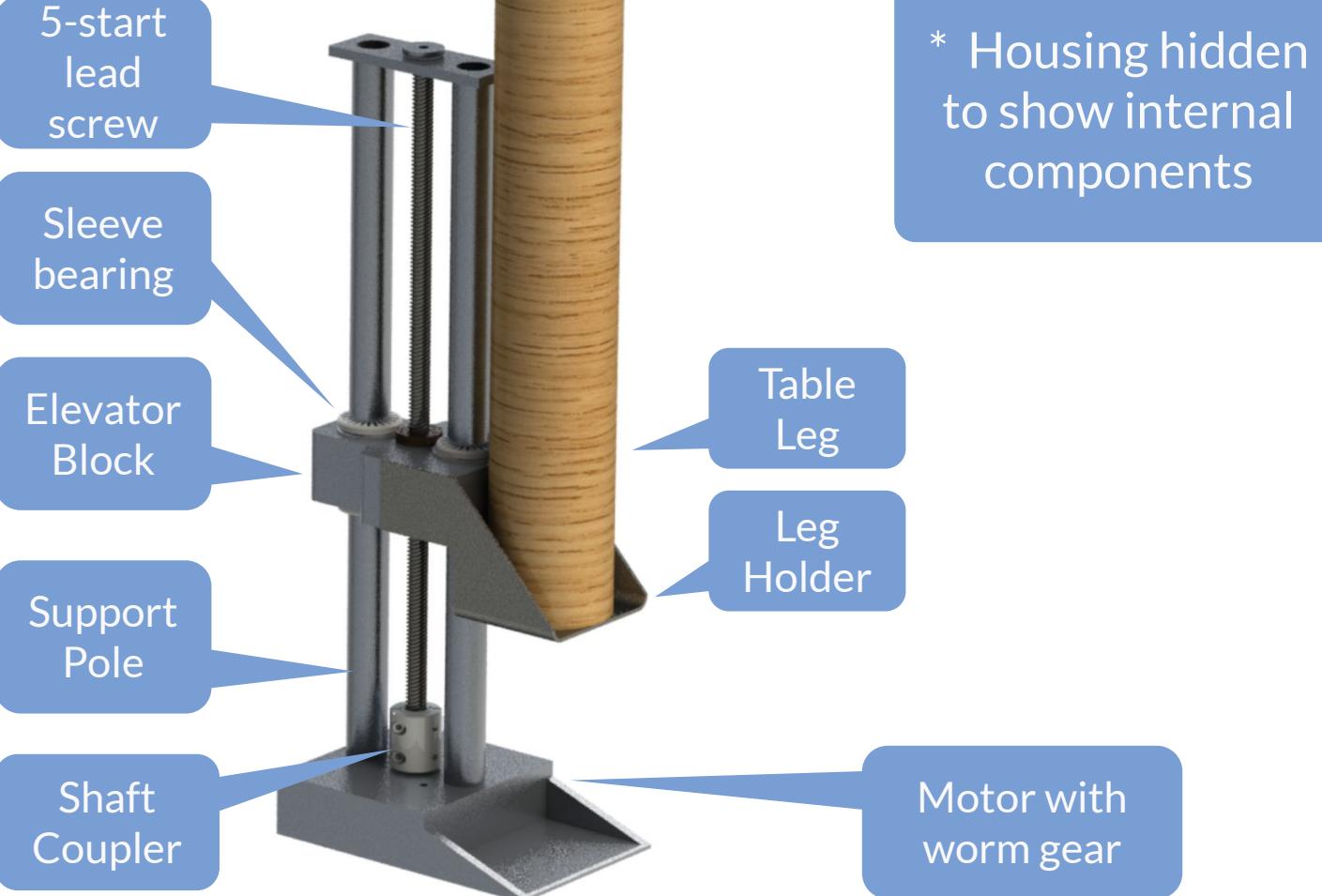
# Linear Actuation Mechanism Selection



# Elevate Final System Form



Desk panel and wall plug (not depicted) are included in the final package



5-start  
lead  
screw

Sleeve  
bearing

Elevator  
Block

Support  
Pole

Shaft  
Coupler

Table  
Leg

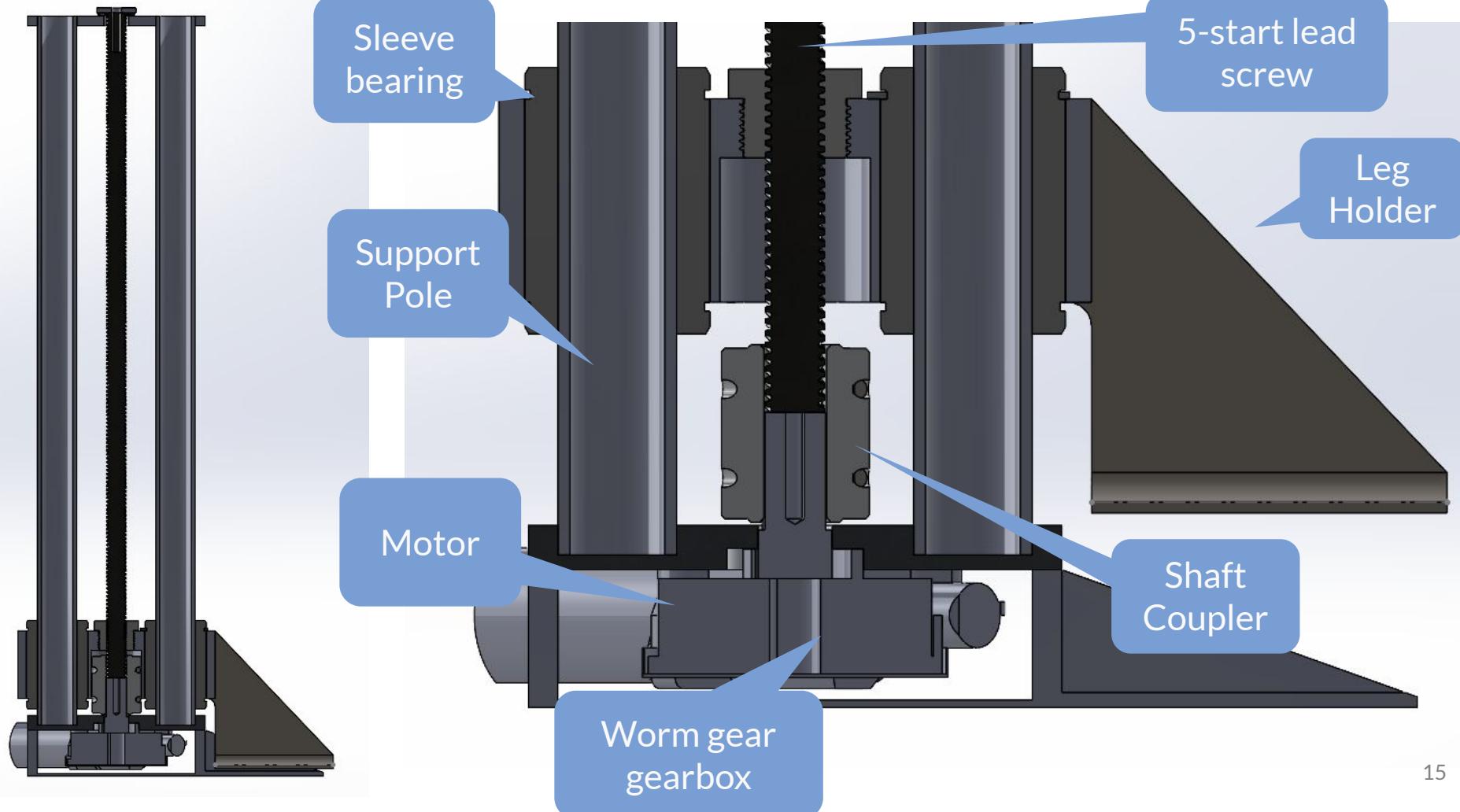
Leg  
Holder

\* Housing hidden  
to show internal  
components

Motor with  
worm gear

# Our Advantage

ELEVATE	Standing Desk Converter	True Standing Desk
Volume (in <sup>3</sup> )	30" x 20" x 8"	30" x 20" x 6" <sup>[6]</sup>
Weight (lb)	50	50 <sup>[6]</sup>
Cost (\$)	250	300 <sup>[6]</sup>
Retrofittable	Yes	Yes
Space Efficient	Yes	No
Easy to Install	Yes	Yes
		No



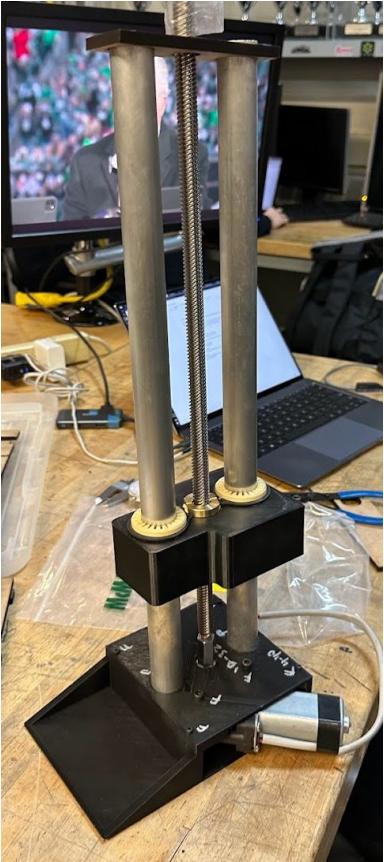
## Leg Attachment Method

- Inspiration taken from ski boots
- Ratchet mechanism adjustable to different leg widths
- Padding adjustable to different leg geometries



# Physical Form Updates

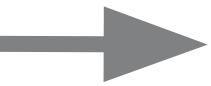
Pre-beta



Hall-Effect  
Encoder + Mount

Aluminum  
Top Plate

1 month



Beta



Custom  
Coupler

Taller pole support

Purpose-Made  
Slide Rails

future

Machined  
Aluminum,  
Welded &  
Threaded

V1



Foot  
Holder

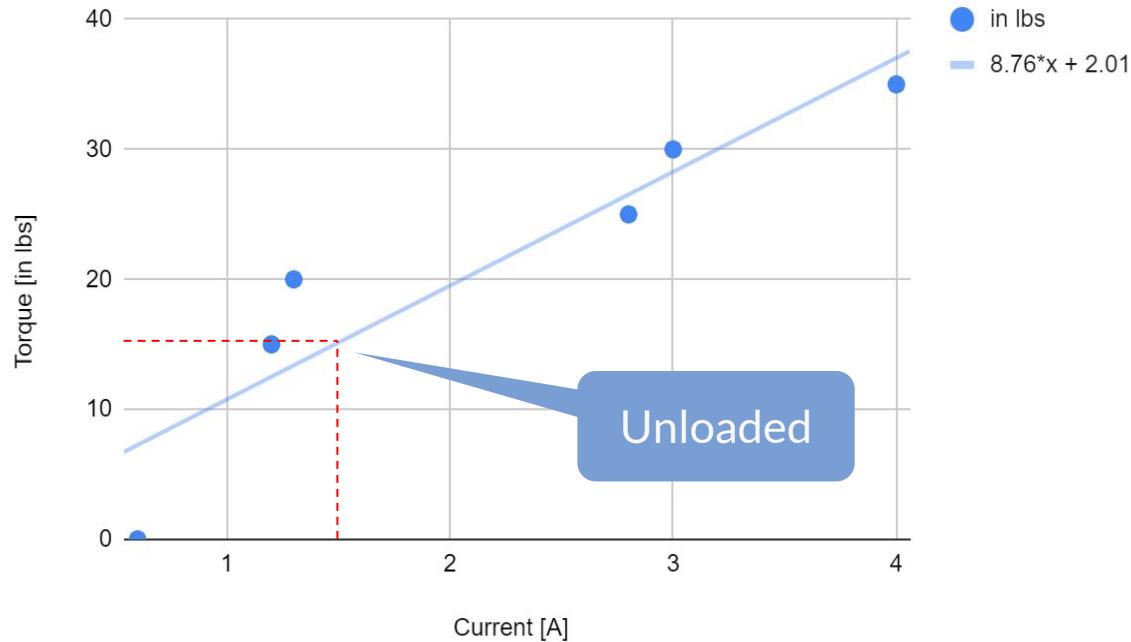


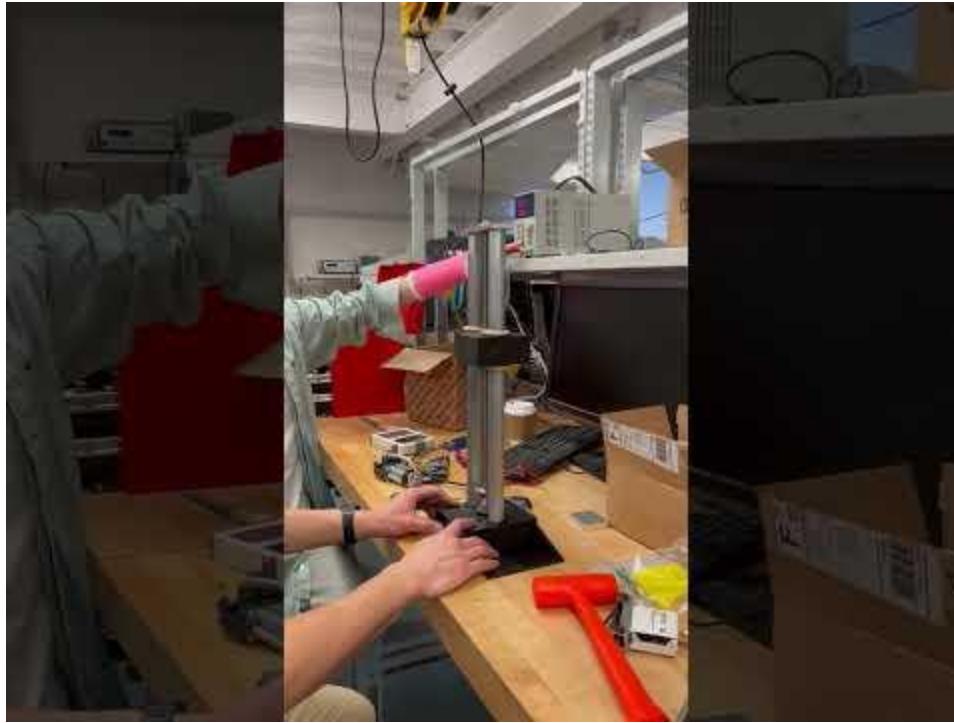
## First Prototype Findings

- **Mechanical:** functional, but can improve
  - High unladen torque due to assembly friction
  - Solution: purpose-built slide poles and machined block
- Electrical: functional, should refactor into PCBs
- Software: functional
  - Could use PID tuning
- Overall architecture is feasible

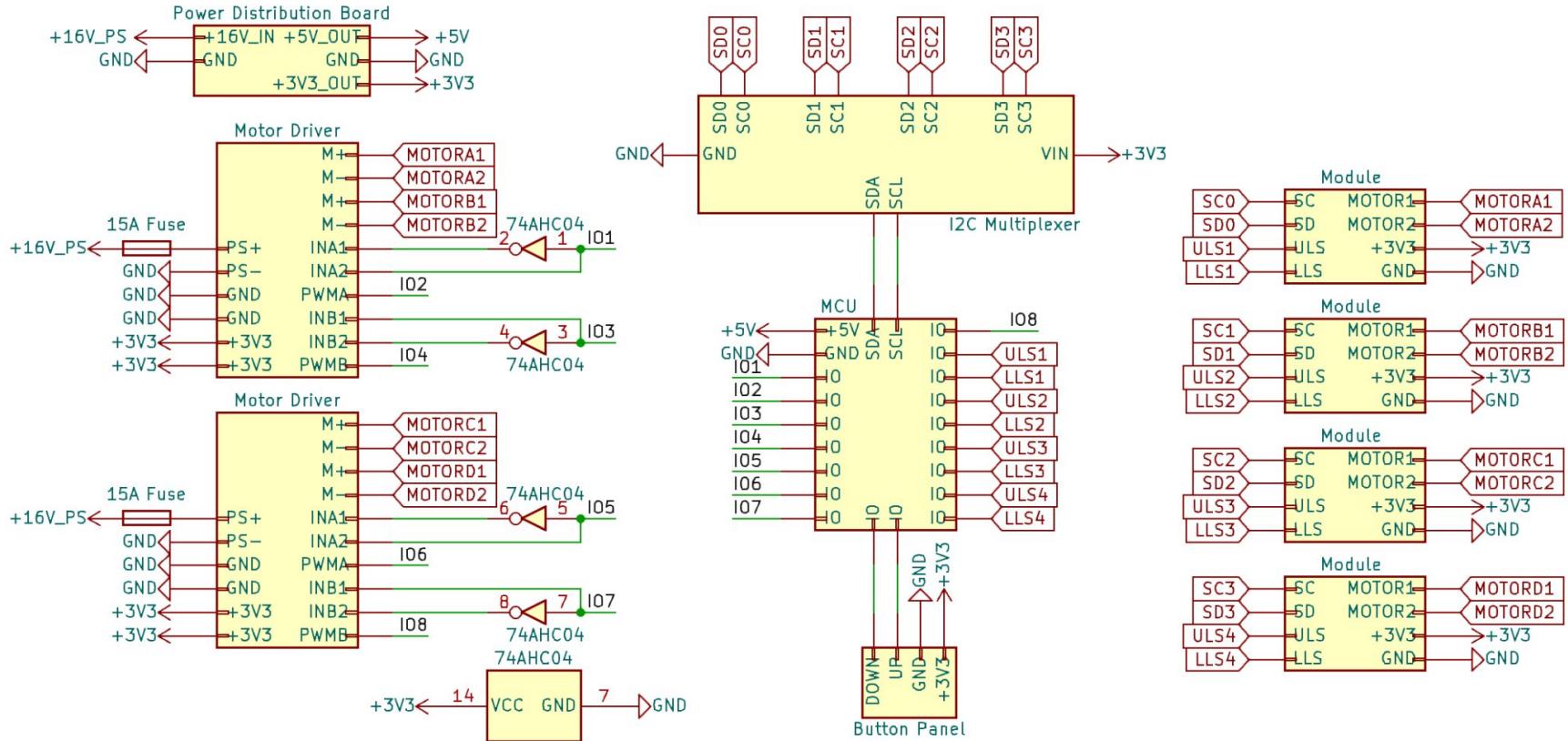
## First Prototype Findings

12V Motor Current - Torque

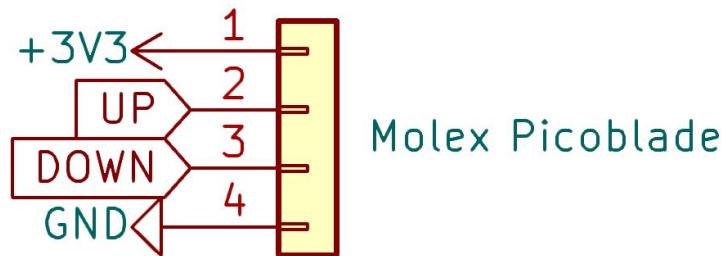
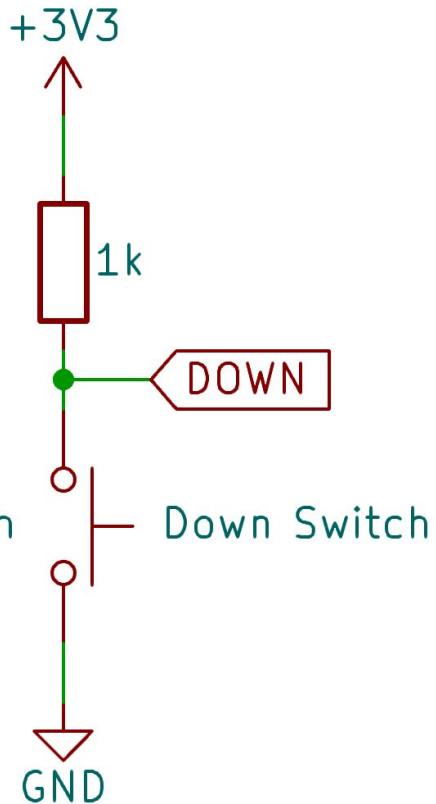
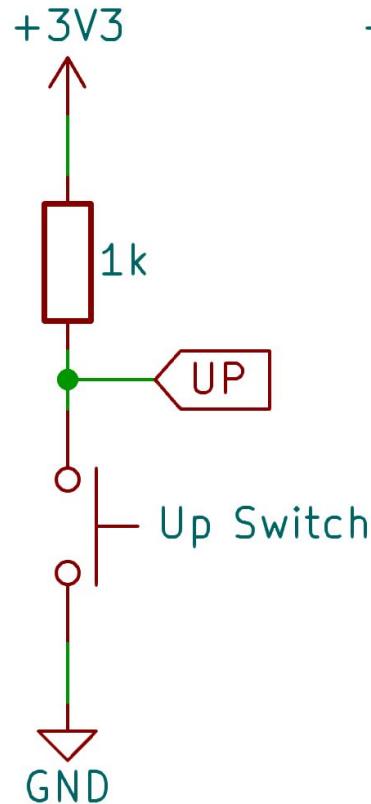




# Electrical Architecture



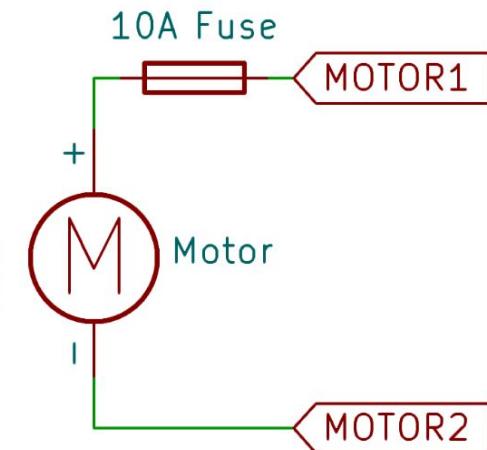
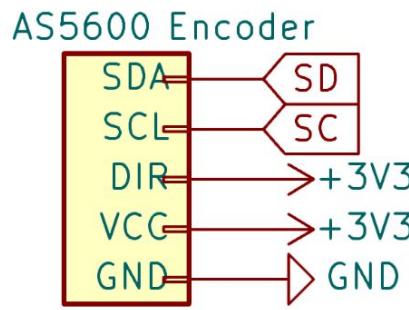
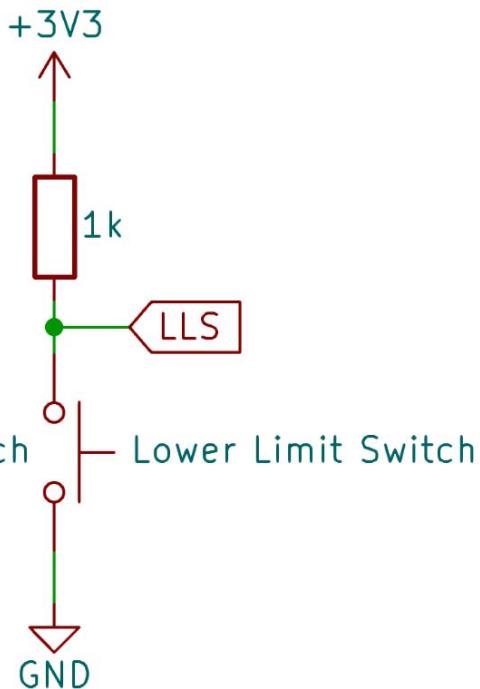
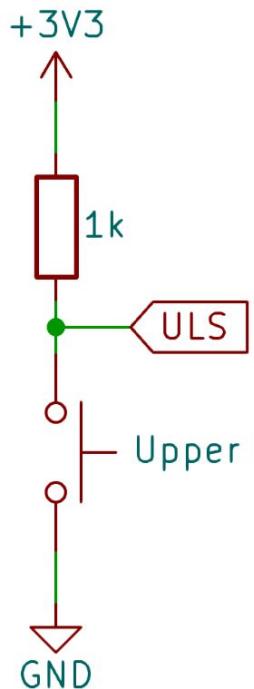
# Button Panel Circuit



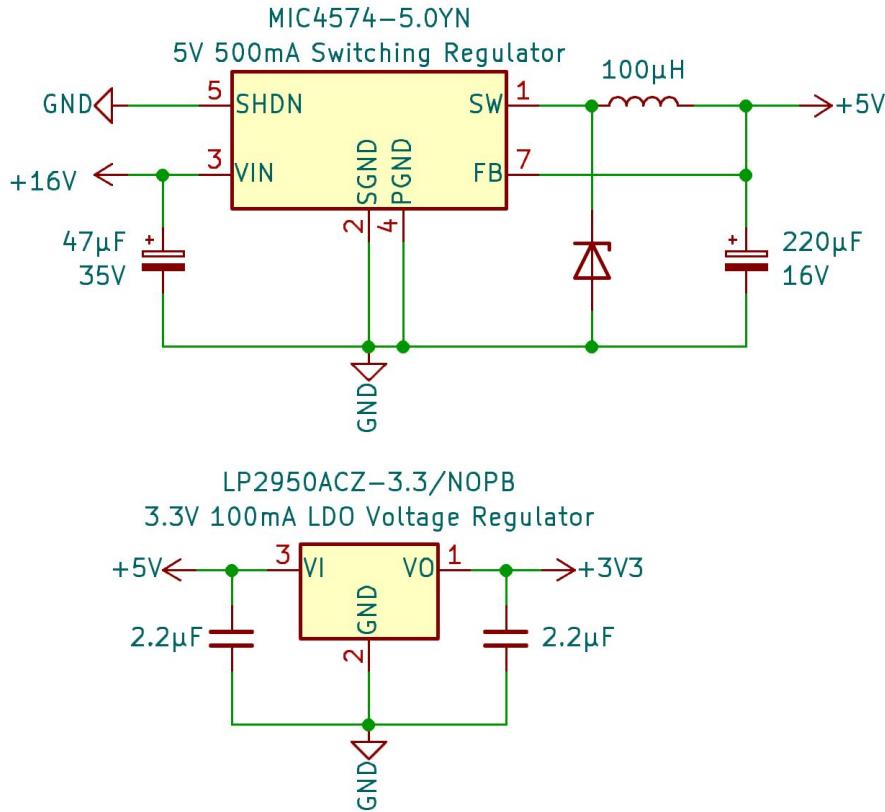




# Leg Module Circuit



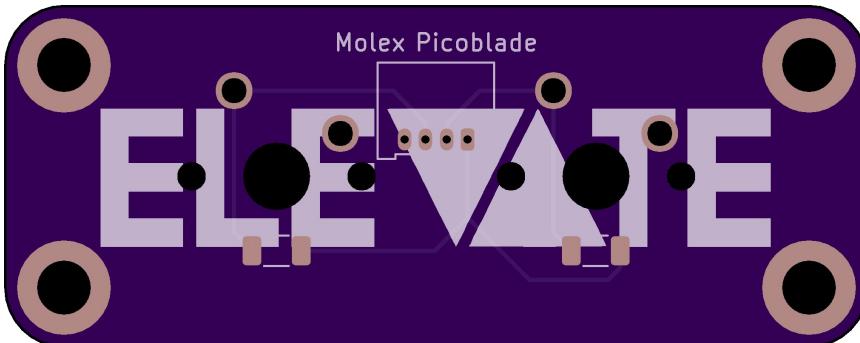
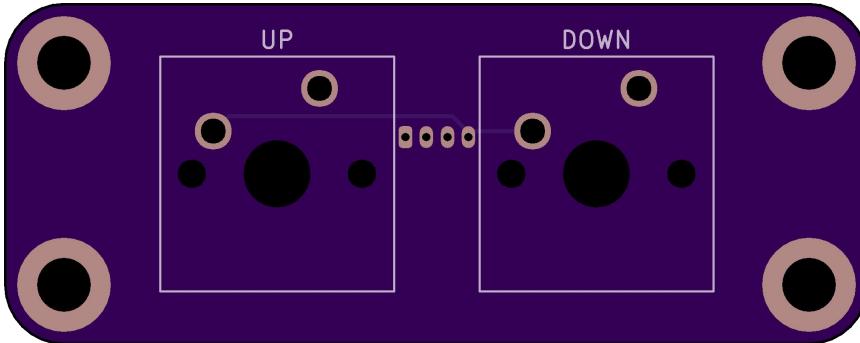
# Power Distribution Circuit



- Motors are “rated” for 12V
- 16V fixed power supply is for motors
  - Higher voltage is necessary for controls algorithm
  - Current is limited by software and fuses for overcurrent protection
- 5V is for powering ESP32 MCU
- 3.3V is for all logic

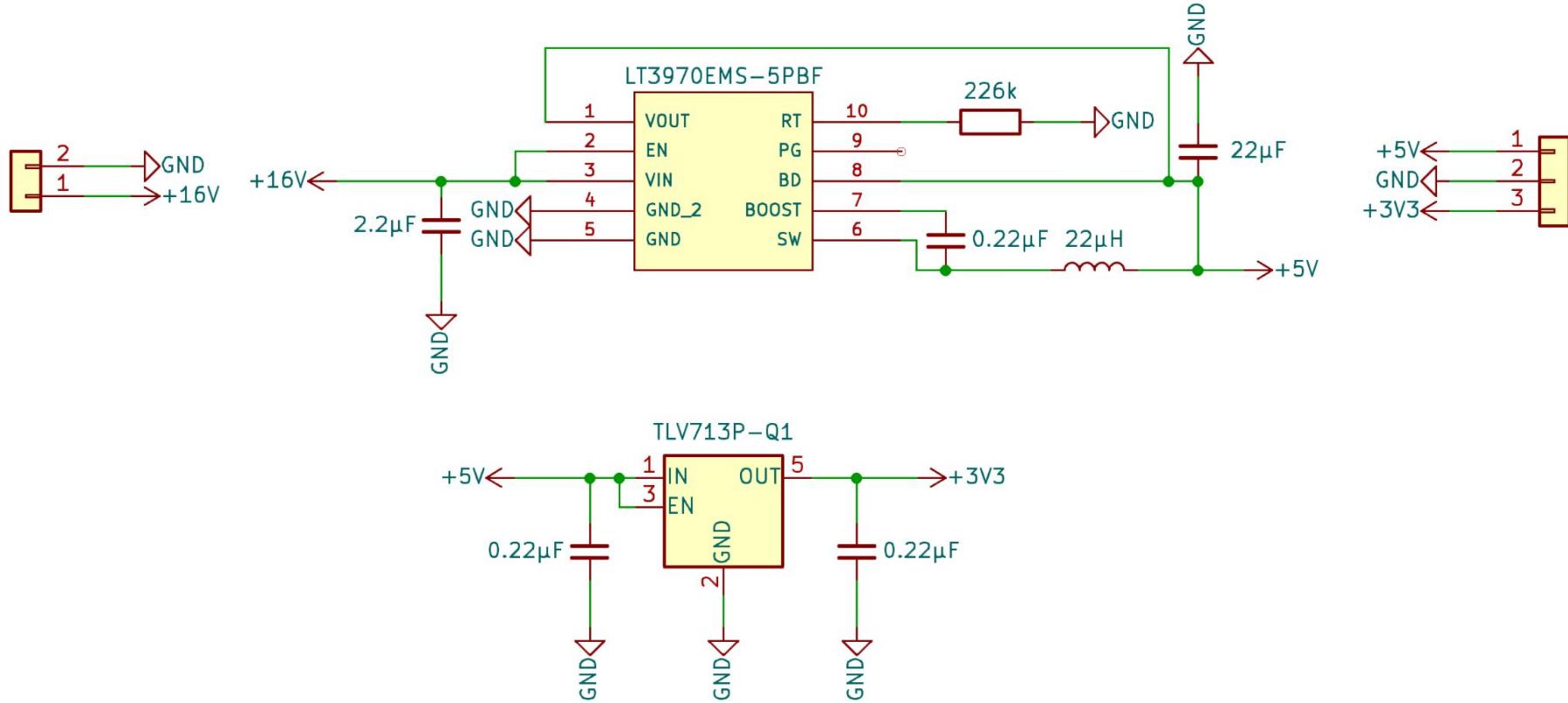
# PCB Manufacturing

## Button Panel

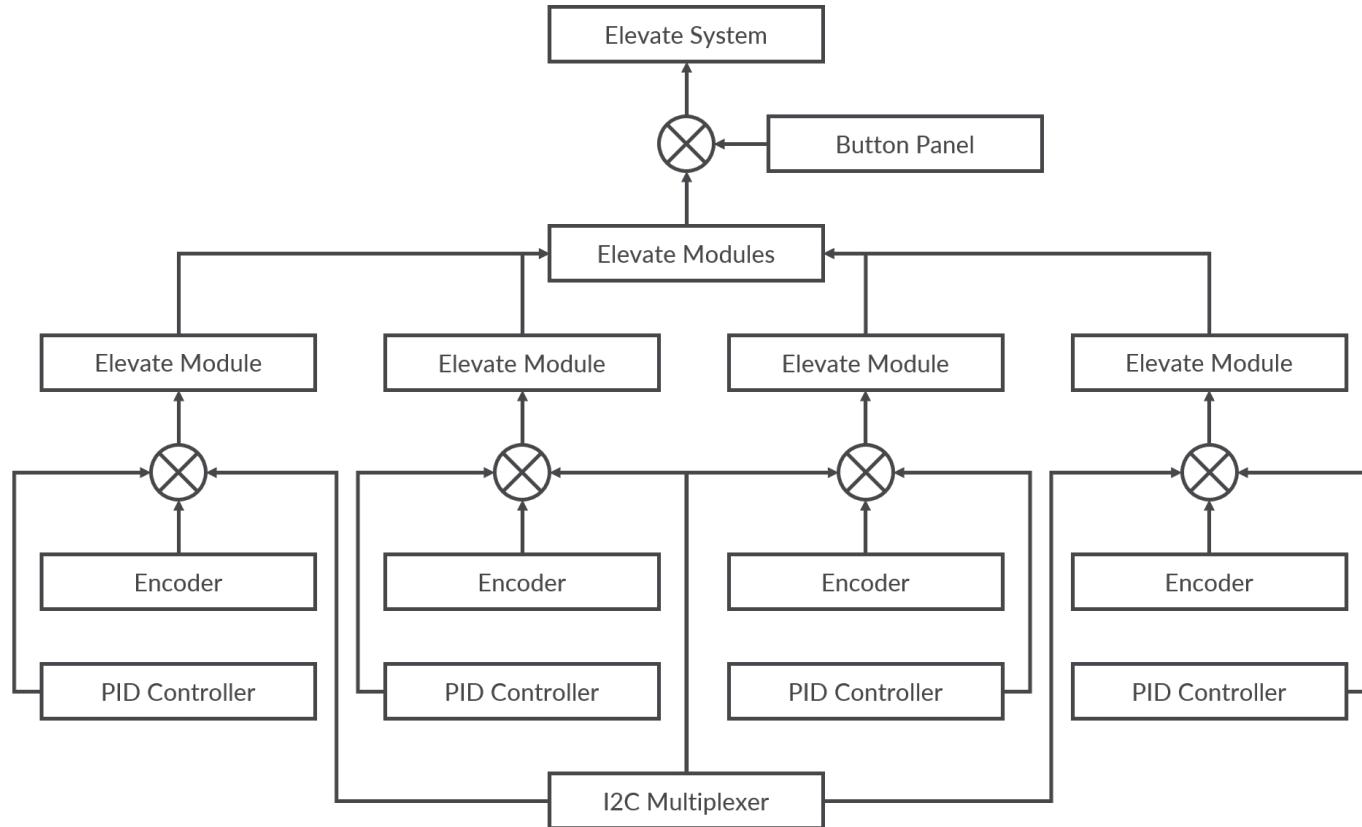


- Current plan is to prototype circuits on breadboards
- Button panel PCB is to confirm that we are capable of PCB design
- Highest priority is validating power distribution circuit and manufacturing PDB with SMD components

# SMD Power Distribution Circuit

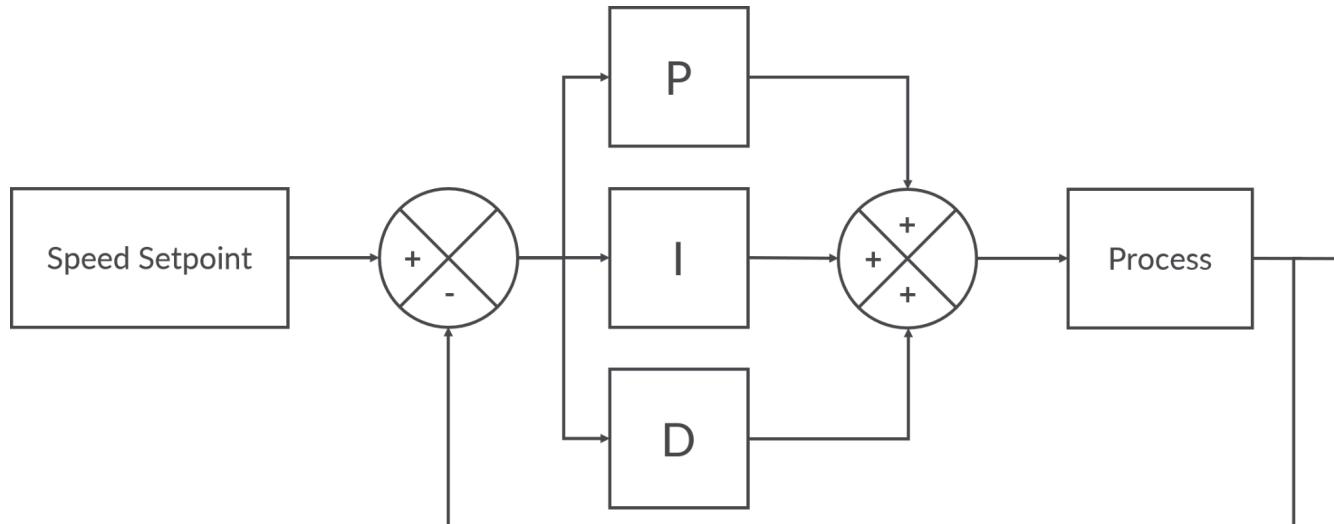


# Software Architecture



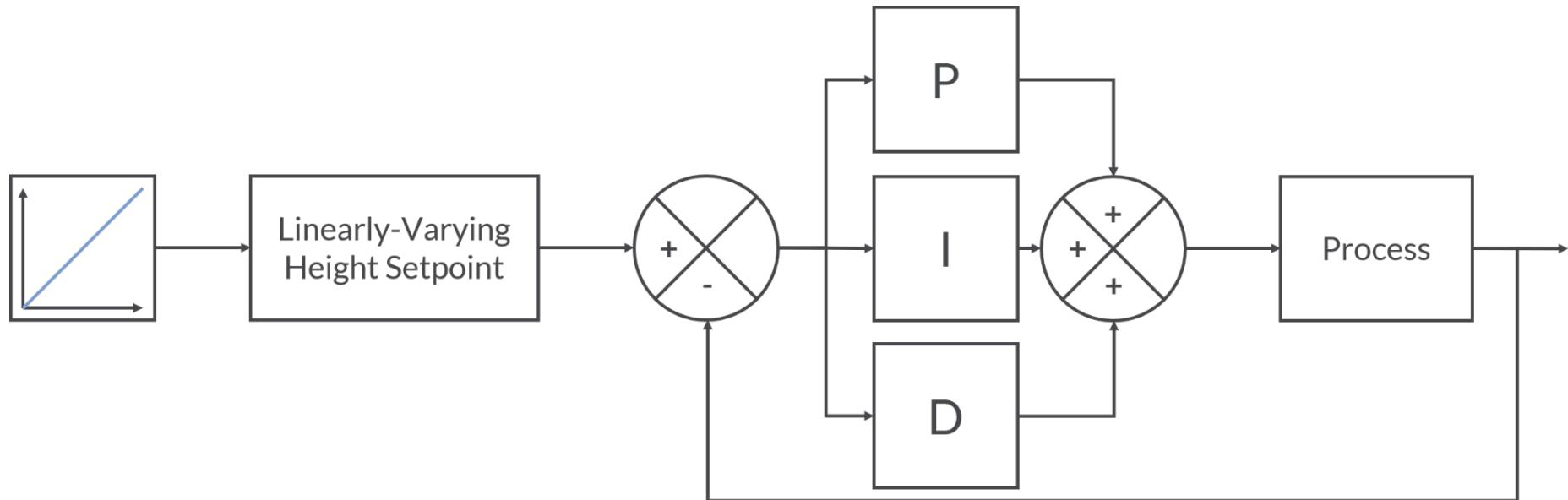
# The Control System Problem

- With the same voltage, the motors move at slightly different speeds
- Both speed and height need to be identical for all motors

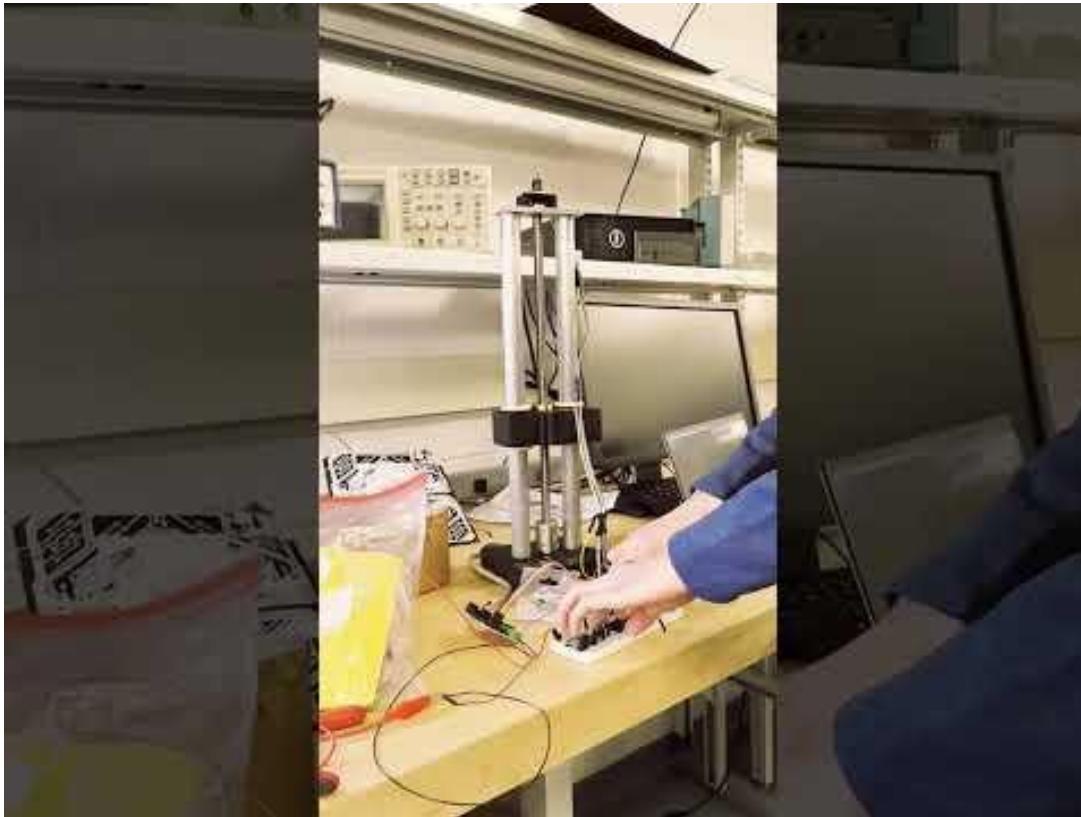


Naive Control System

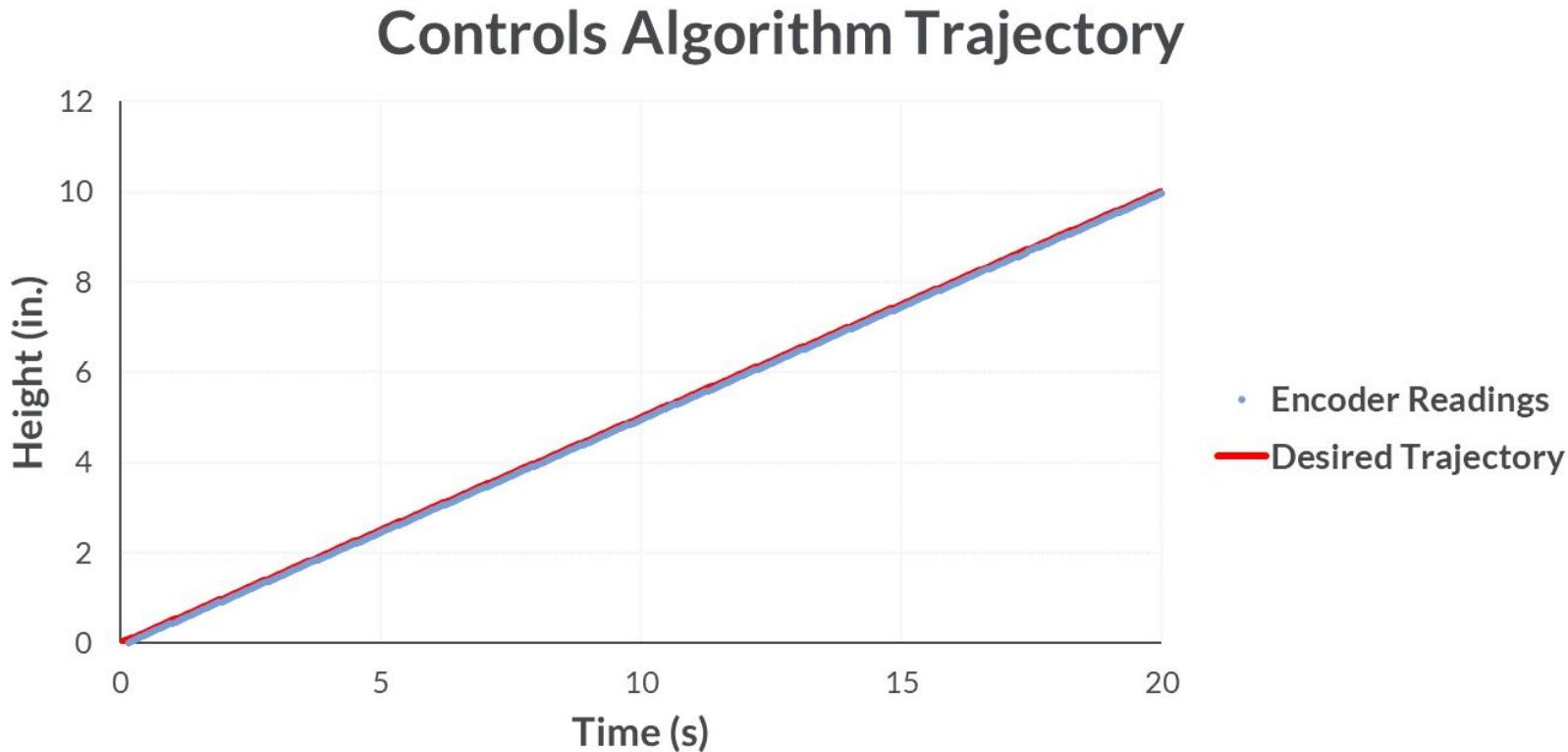
# Improved Control System



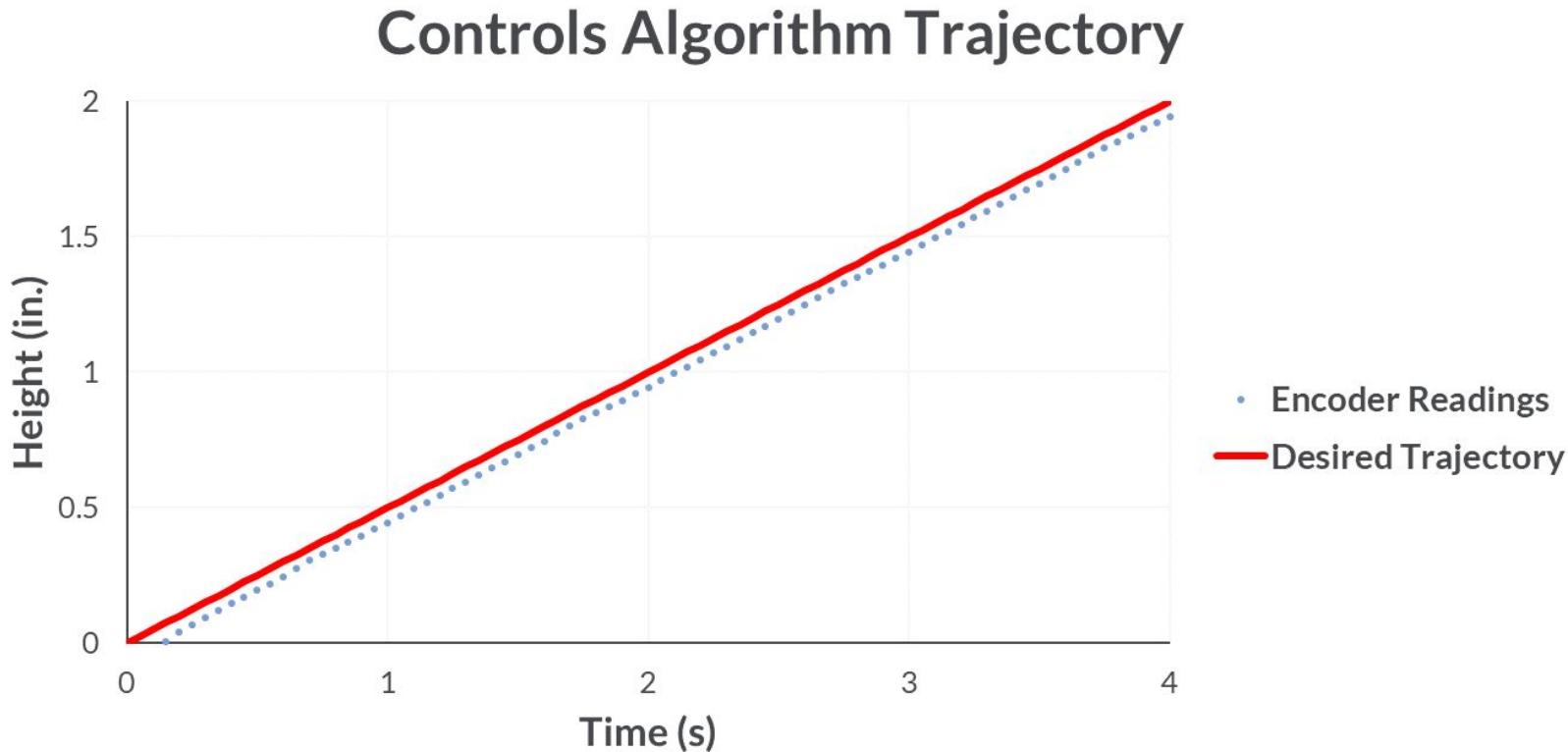
# PD Control System in Action



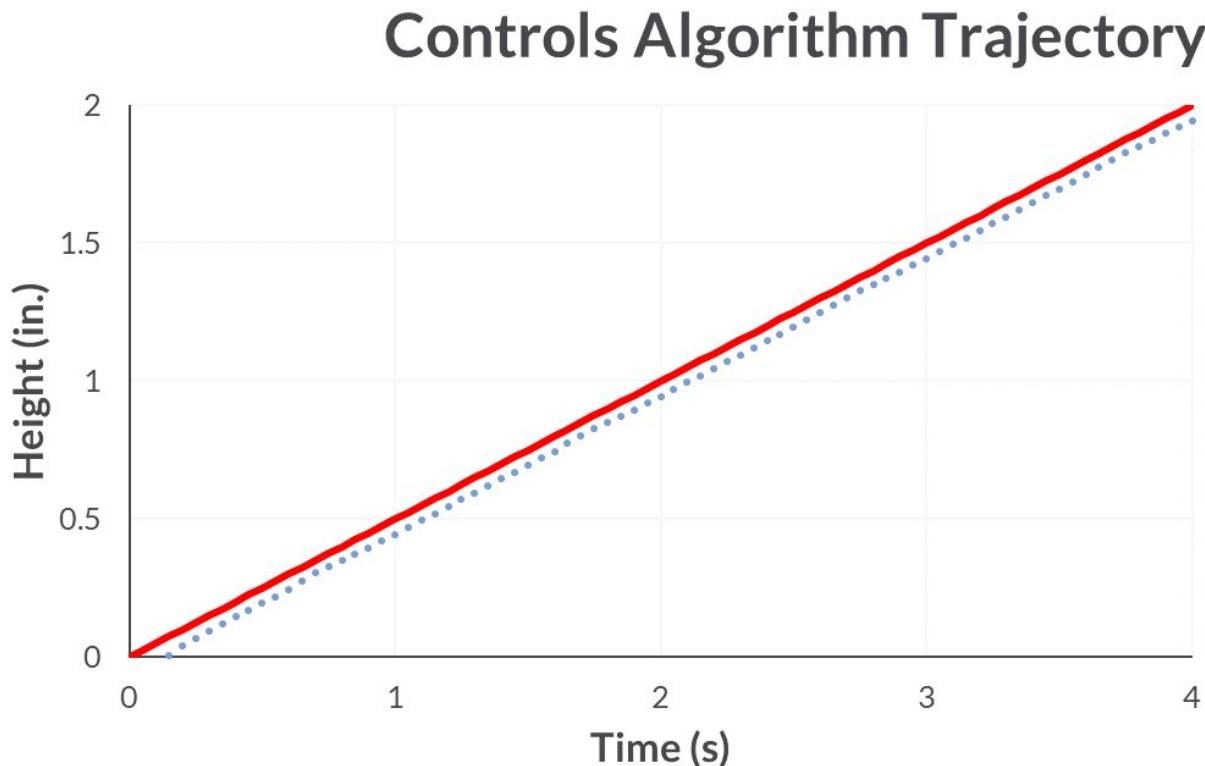
# Control System Validation - PD



# Control System Validation - PD

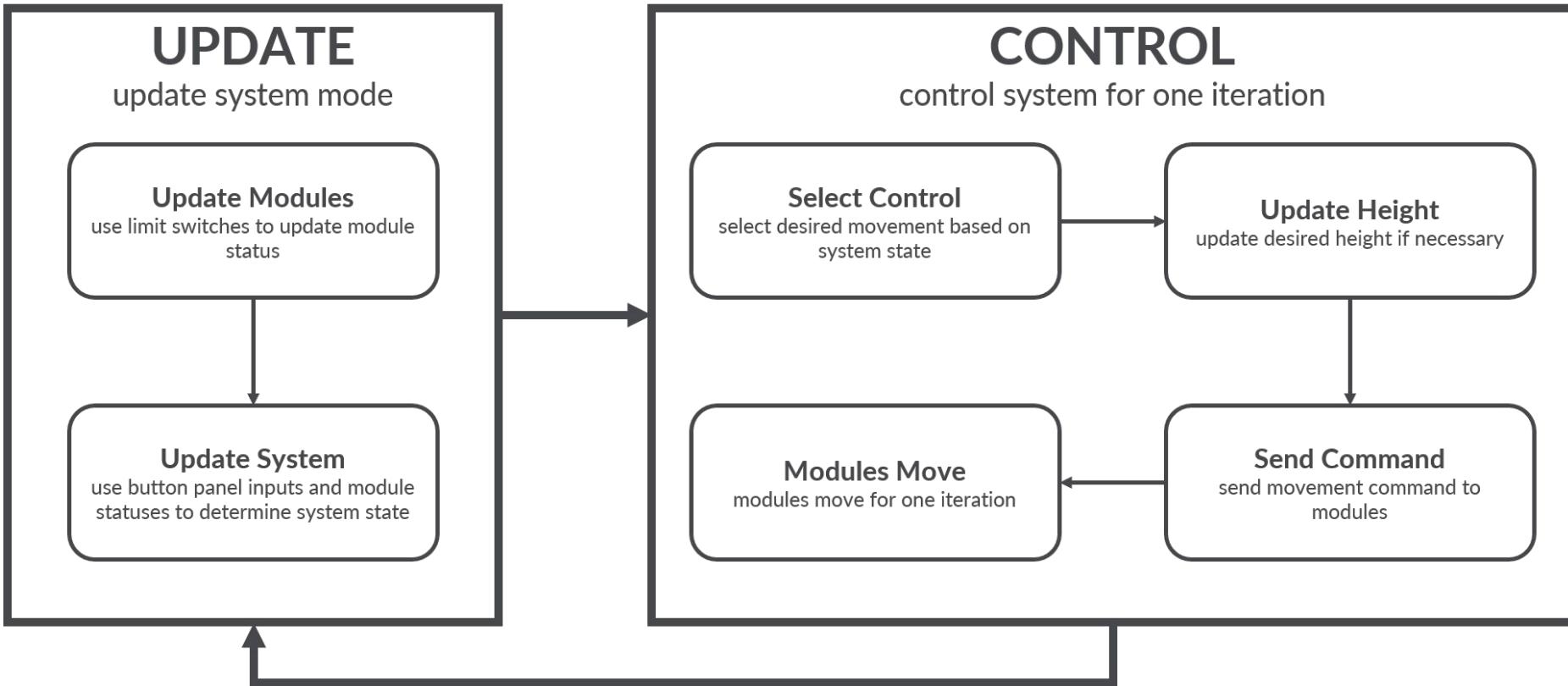


# Control System Validation - PD

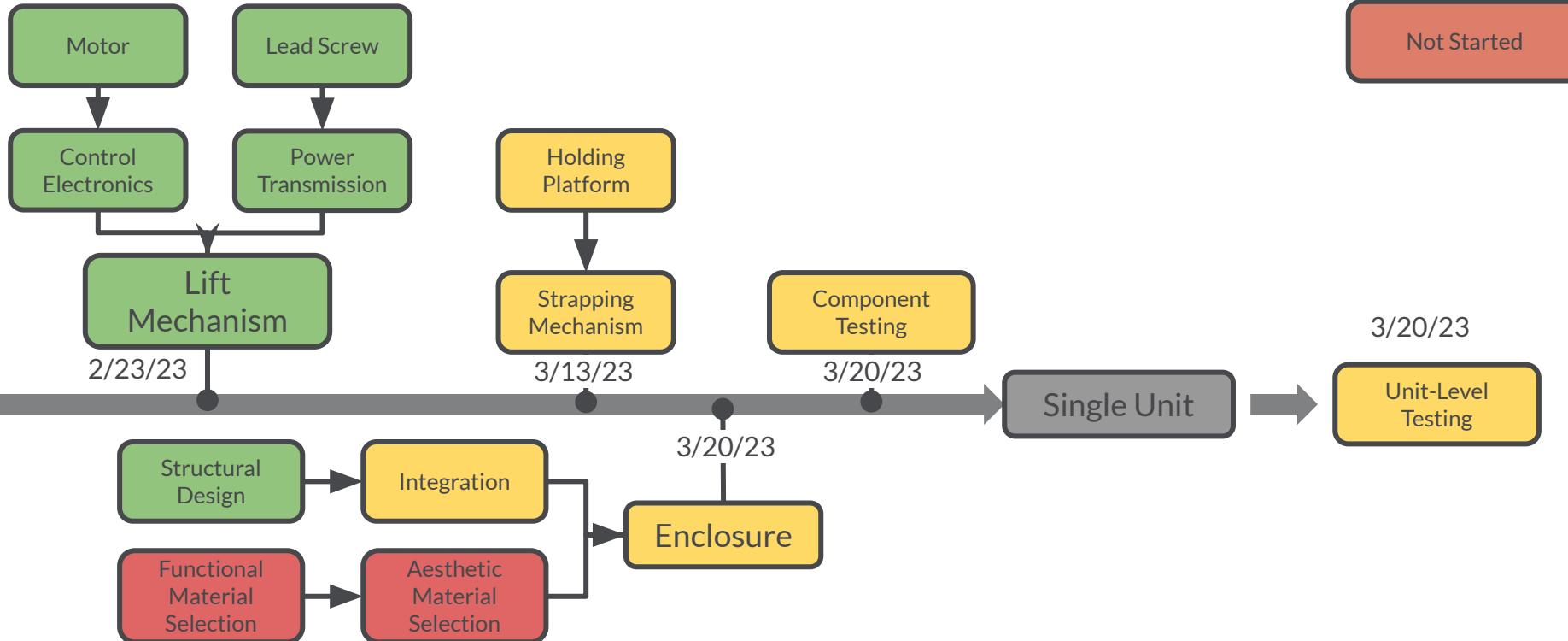


**Conclusion**  
Add Integral Term

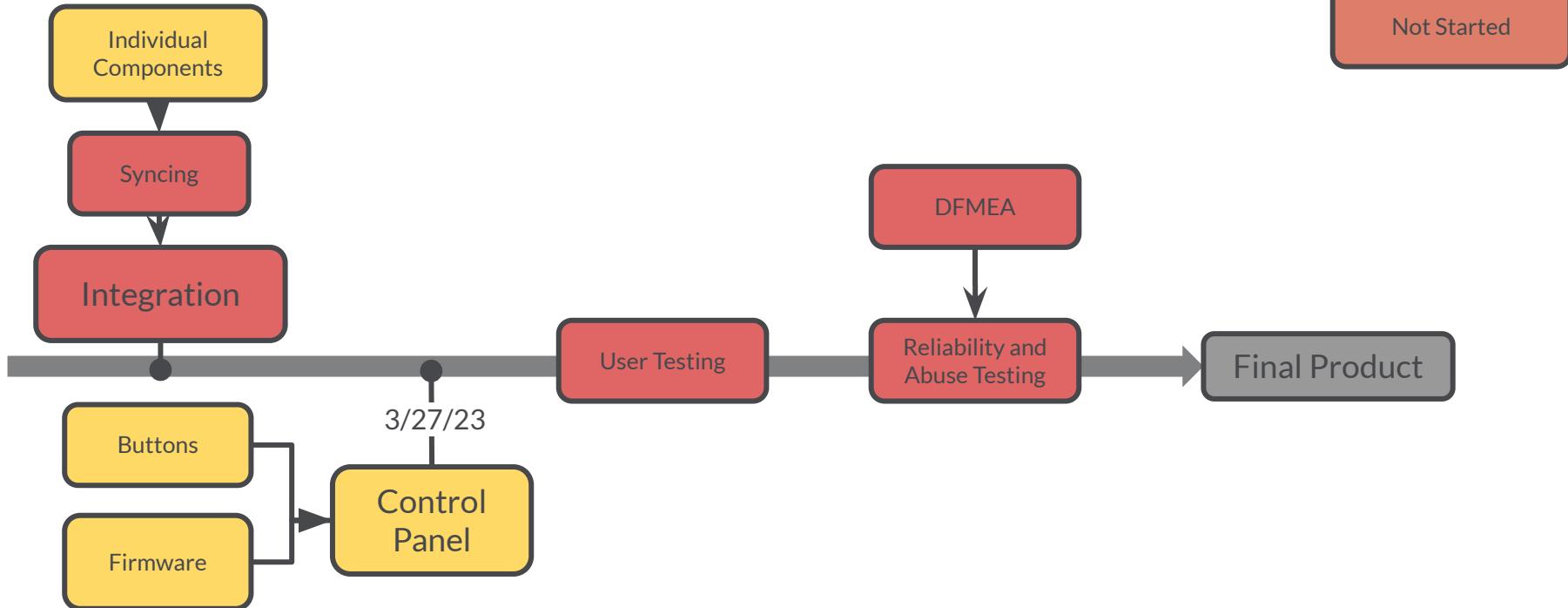
# Software Control Scheme



# Our Timeline



# Our Timeline



# Founders



**Darrion Chen**

Design & Manufacturing

MEAM



**Jonathan Lee**

Electrical & Software

MEAM & ROBO



**Griffin Addison**

Design & Prototyping

MEAM & ROBO

# Advisors



**Joah Kim**  
Team Advisor



**Bruce Kothmann**  
Faculty Advisor



**Philip Sieg**  
Team Advisor



**Graham Wabiszewski**  
Senior Design Professor



**Alex Ge**  
EE Consultant

# References

## Slide 2

- Credence Research, "Standing desks market by product type (fixed standing desk, mechanically adjusted desk, electrically adjusted desk, converter standing desk) by end use (household, commercial) by distribution channel (Online by type (standard (fixed) standing desks, mechanical adjustable standing desks, electrically adjustable standing desk, converter standing desk), by application (corporate office, education, residential, healthcare, manufacturing) - growth, future prospects and competitive analysis 2016 – 2028," *Market Research Reports*. [Online]. Available: <https://www.credenceresearch.com/report/standing-desks-market>. [Accessed: 25-Feb-2023].
- Autonomous, "Does a Standing Desk Benefit Psychological Health?," *autonomous*, 15-Jul-2021. [Online]. Available: <https://www.autonomous.ai/ourblog/psychological-benefits-of-a-standing-desk>. [Accessed: 25-Feb-2023].
- J. Ma, D. Ma, Z. Li, and H. Kim, "Effects of a workplace sit-stand desk intervention on health and productivity," *International Journal of Environmental Research and Public Health*, vol. 18, no. 21, p. 11604, 2021.

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- G. Knighton, "How much does an electric standing desk cost in 2022," *BTOD*, 30-Mar-2022. [Online]. Available: <https://www.btod.com/blog/standing-desk-cost/>. [Accessed: 19-Feb-2023].
- Sharon, "How heavy are standing desks? – it's more than you think!," *Work at Home Accessories*, 08-May-2022. [Online]. Available: <https://workathomeaccessories.com/how-heavy-are-standing-desks/>. [Accessed: 19-Feb-2023].

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6. "Cooper standing desk converter," *Fully*. [Online]. Available: <https://www.fully.com/cooper-standing-desk-converter.html>. [Accessed: 19-Feb-2023].
7. "Jarvis bamboo standing desk," *Fully*. [Online]. Available: <https://www.fully.com/standing-desks/jarvis-adjustable-height-desk-bamboo.html>. [Accessed: 19-Feb-2023].

# Photo Credits

## Slide 1

- <https://medium.com/halting-problem/local-engineer-refuses-to-work-without-a-standing-desk-fa3c0ef7a2a4>

## Slide 2

- <https://www.autonomous.ai/ourblog/psychological-benefits-of-a-standing-desk>
- <https://www.flaticon.com/free-icons/growth>
- <https://www.flaticon.com/free-icons/health-care>
- <https://www.flaticon.com/free-icons/efficiency>

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- <https://www.flaticon.com/free-icons/money-sign>
- <https://www.flaticon.com/free-icons/briefcase>
- <https://www.flaticon.com/free-icons/mess-chaos>

## Slide 5

- <https://www.fully.com/jarvis-adjustable-height-desk-bamboo.html>

## Slide 6

- <https://www.fully.com/cooper-standing-desk-converter.html>

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- <https://www.flaticon.com/free-icons/safety>

## Slide 10

- <https://www.flaticon.com/free-icons/close>
- <https://www.flaticon.com/free-icons/correct>

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- <https://www.amazon.com/VEVOR-Hydraulic-Cylinder-Retracted-Extended/dp/B08MDRLMLD>
- <https://docs.revrobotics.com/duo-build/linear-motion-kit/three-stage-cascading-lift>
- <https://apexdynamicsusa.com/precision-rack-and-pinion.html>
- <https://www.bigrentz.com/equipment-rentals/scissor-lifts/rough-terrain/32-ft-rough-terrain-scissor-lift>
- <https://www.helixlinear.com/Products/Lead-Screws/Lead-Screw-Nuts-/Heavy-Load-Lead-Screw-Nuts/Lead-Screw-Nut-Heavy-Load-HLC063118R~HLC063118R>

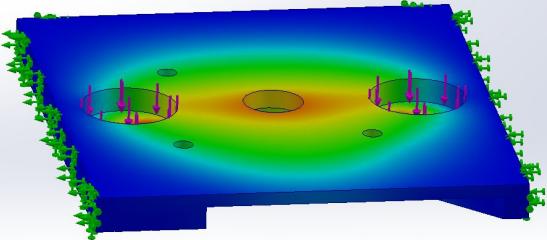
# Linear Actuation Mechanism Selection

	Lead Screw	Hydraulics	Pneumatics	Rack and Pinion	Scissor Lift	Cascade Lift
Cost	✓	✗	✗	✓	✗	✓
Reliability	✓	✗	✗	✗	✓	✗
Complexity	✓	✗	✗	✓	✗	✗
Resolution	✓	✗	✗	✓	✓	✓
Packaging	✓	✗	✗	✗	✗	✓
Safety	✓	✗	✗	✗	✓	✗

# Design, Engineering, Prototyping

URES (mm)

9.895e-01
8.851e-01
7.869e-01
6.884e-01
5.901e-01
4.917e-01
3.934e-01
2.950e-01
1.967e-01
9.895e-02
1.000e-30



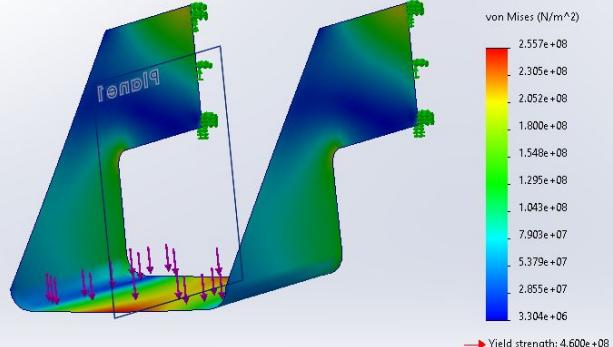
URES (mm)

2.710e-02
2.439e-02
2.169e-02
1.897e-02
1.626e-02
1.355e-02
1.084e-02
8.119e-03
5.420e-03
2.710e-03
1.000e-30

**Baseplate**  
Stiffness-limited part

Front Plane

**Lead Screw**  
Stiffness-limited  
part



von Mises (N/m<sup>2</sup>)

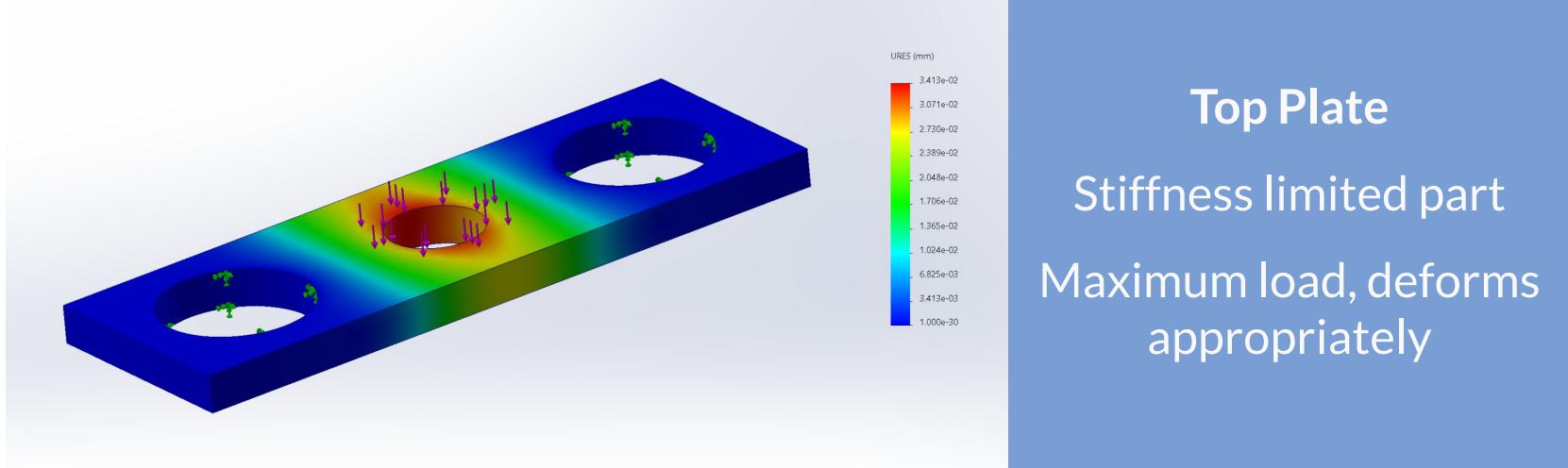
2.557e+08
2.305e+08
2.052e+08
1.800e+08
1.548e+08
1.295e+08
1.043e+08
7.903e+07
5.379e+07
2.855e+07
3.304e+06

Yield strength: 4.600e+08

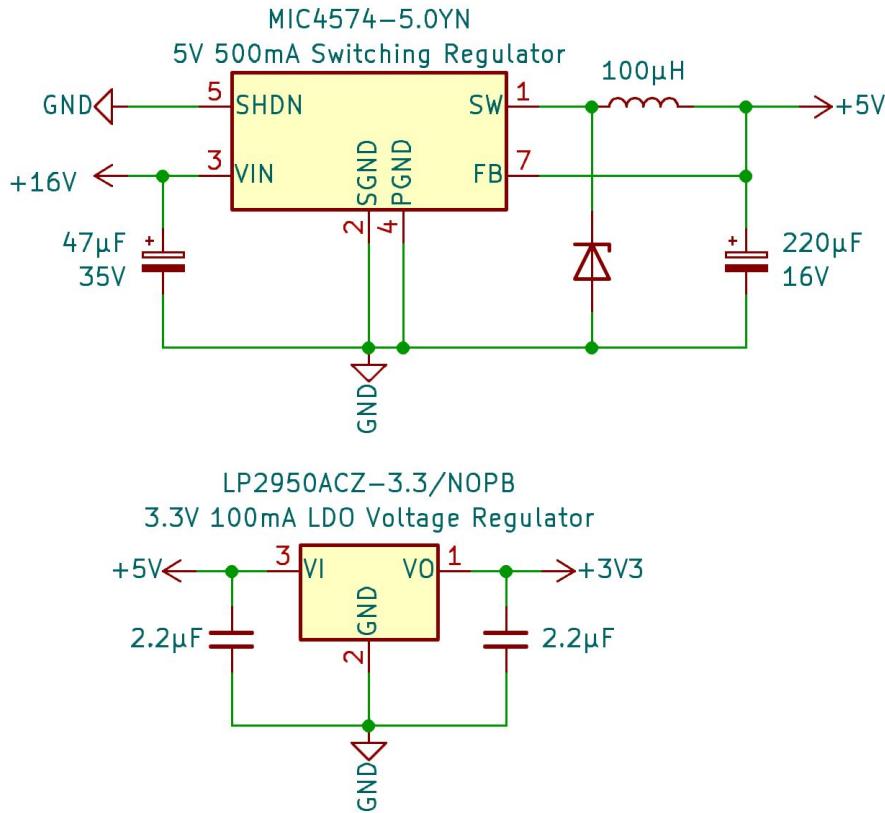
**Leg Holder**  
Strength-limited part

Load about  $\frac{1}{2}$  of yield  
strength. Fatigue not a  
worry

# Design, Engineering, Prototyping



# Power Distribution Circuit Explained



- Technically, 16V is required only for the motors and 3.3V can be used to power all other electronics and logic
- This circuit is designed with production in mind
- The ESP32 development board has a built in 5V to 3.3V LDO, but a production board would not
- To power the ESP32 and logic, a clean 3.3V source is required
- Switching regulator is efficient but noisy
- This circuit takes advantage of high efficiency switching regulator to reduce voltage and then uses an LDO linear regulator to produce a clean 3.3V source

# Current Requirements

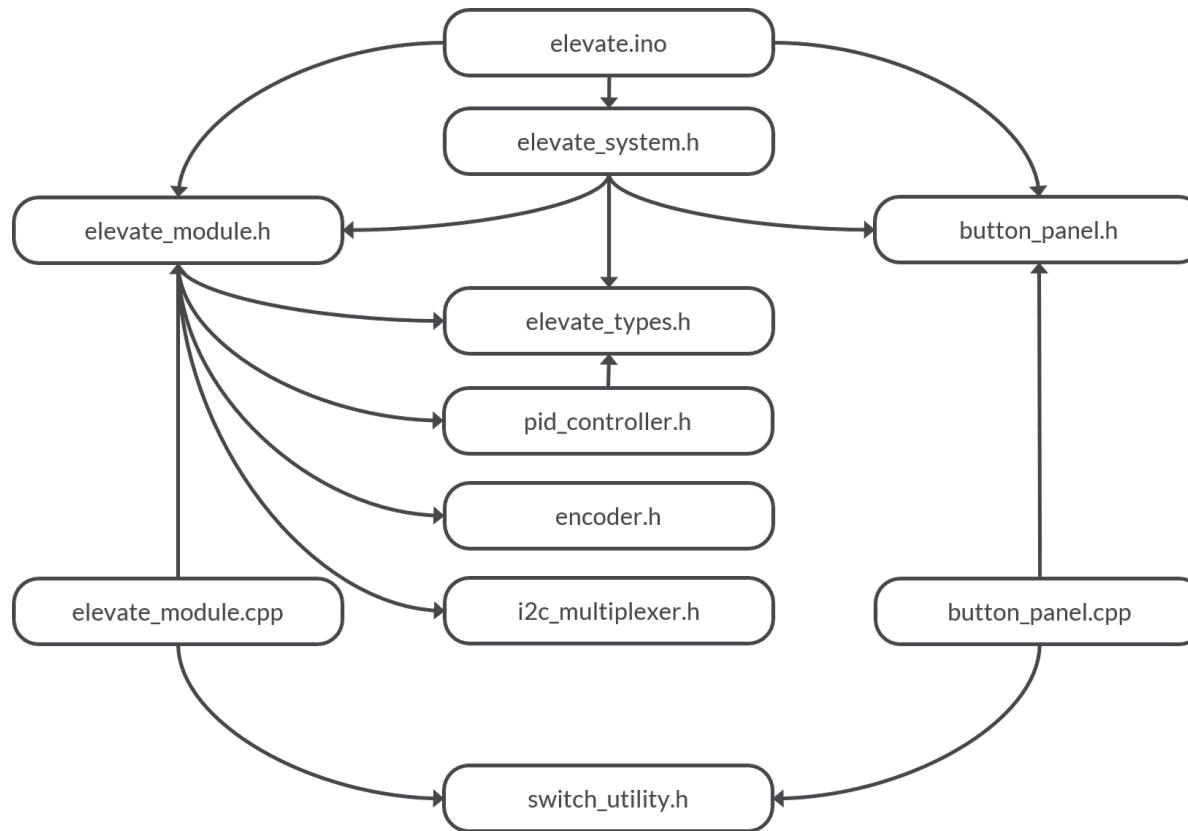
## 3.3V Electronics

Component	Max Current (mA)	Quantity
I2C Multiplexer	0.035	1
Hex Inverter	0.04	1
Switches	3.3	10
AS5600 Encoder	6.5	4
Motor Drivers	10	2
<b>Total</b>	<b>79.075</b>	

## 5V Electronics

Component	Max Current (mA)	Quantity
LDO Regulator	150	1
ESP32	120	1
<b>Total</b>		<b>270</b>

# Software Dependency Graph



# Software Statistics

- 17 files
- 1279 lines of code
- >80% self-written