Uniaxial Force Plate

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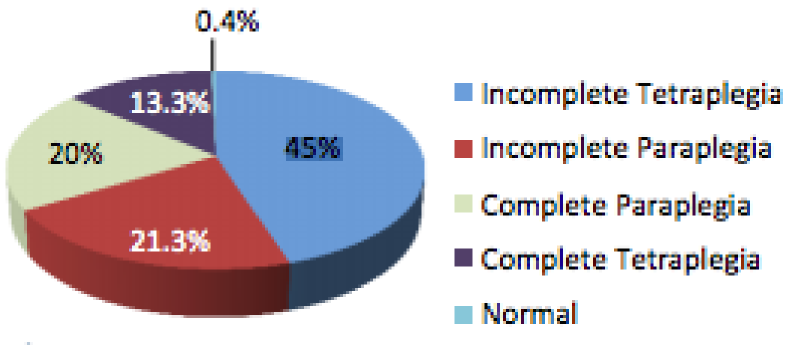
Spinal Cord Injury

Annual incidence - 54 cases/million

Approximately 300,000 persons currently

Less than 1 percent experience complete recovery



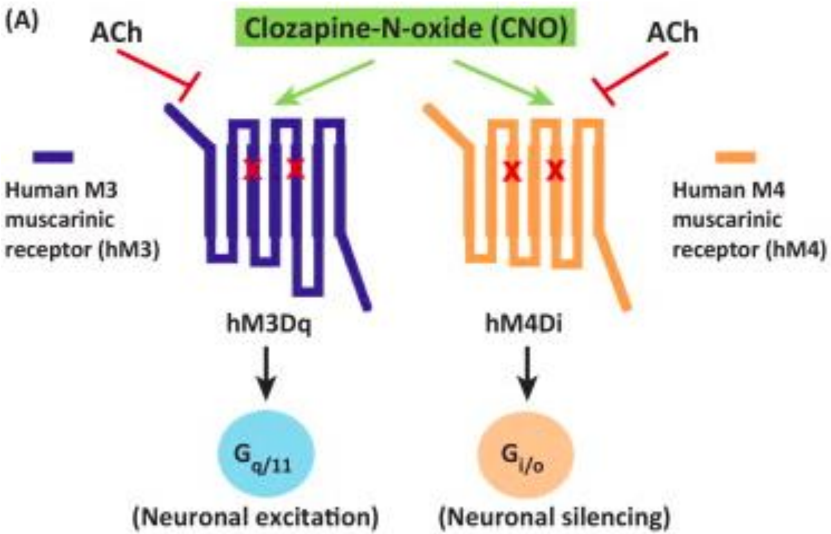
Current Research

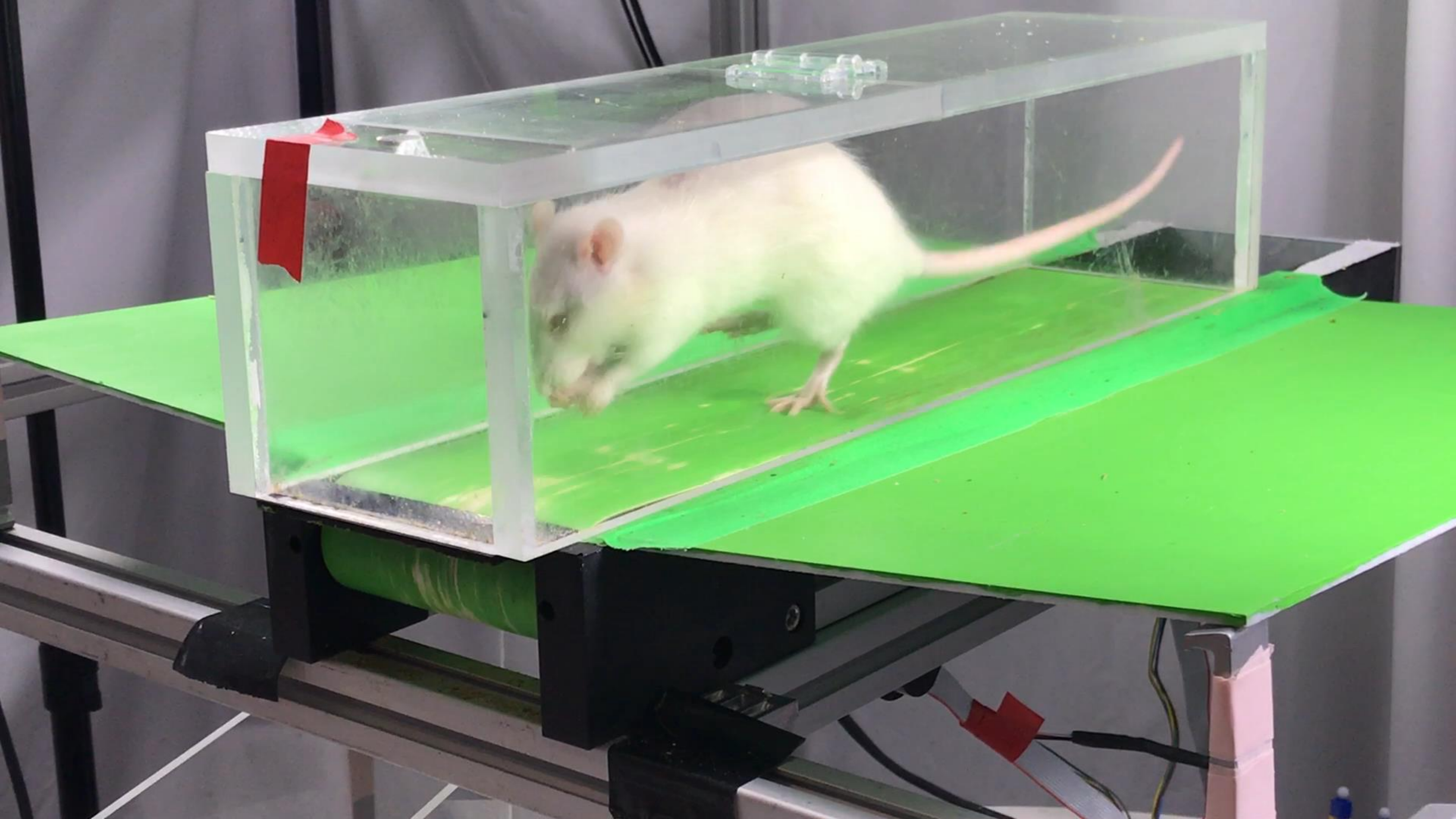
Electrical Stimulation

Optogenetics

Magnetogenetics

Chemogenetics - DREADDs





Proposed Solution – Force Plate

- Tool for kinetic analysis of rodent gait
- Appropriate for rodent model
- Cost-efficient
- Avoids inaccuracies due to loose skin

Design Requirements of force plate

Objective

- Have a linear response in the range of forces
- Reasonable operable procedure

Numerical

- Have a natural frequency> 100Hz
- Sensitive to weights as low as 0.1 N
- Carry loads up to 5 N

Technical

- Have a response independent of where the force is exerted
- Have a sufficient coefficient of safety to protect the specimen

Animal Care

Mayank Parmar

Training Inputs

Handling

- Must allow Rats to acclimate to human interaction

Environment

- Rats must acclimate to treadmill environment

Responsiveness

- Rats must be trained to respond to food reward system

Acquired Outputs

Cooperation

- Rats acclimated to protocol procedures requiring gentle handling.
- Rats have become actively comfortable in the hands of the caretaker and handler.

Performance

- Rats adjusted to being placed in the treadmill enclosure.
- At various speeds, the rats were able to maintain their speed and avoid major collisions with the enclosure.

Response to Reward System

- Rats were trained to receive food rewards after runs in order to give them incentive to perform the action.
- Food reward system proved to display the calmness of the rats on the treadmill between speed intervals

Example Training Schedule

Training Speed(cm/sec)	Run Time (sec)	Rest Time Between Intervals(sec)
16	30-60	90-120
20	30-60	90-120
24	30-60	90-120
28	30-60	90-120
32	30-60	90-120

WEEK 1

Day 1

Example Training Schedule (continued)

Training Speed(cm/sec)	Run Time (sec)	Rest Time Between Intervals(sec)
16	60-120	60-90
20	60-120	60-90
24	60-120	60-90
28	60-120	60-90
32	60-120	60-90

WEEK 1

Day 2/3

Example Training Schedule (continued)

Training Speed(cm/sec)	Run Time (sec)	Rest Time Between Intervals(sec)
16	300	60
20	300	60
24	300	60
28	300	60-
32	300	60

WEEK 2-6

Day 1-3

Questionable Aspects of Training Protocol

- Why training occurs?
- Why these specific speeds are chosen?
- Why these specific time intervals?

Mechanical Requirements for the force plate

Sensors

- What is the best method to measure force?

Geometry

- Where do we fit everything?

Material

- How do we easily manufacture the force plate?

Sensors

Bryanna Wands

Design Inputs

Sensitivity

- Must sense forces 0-5N(Zumwalt)

Linearity

- Data must show linear force versus strain relationship

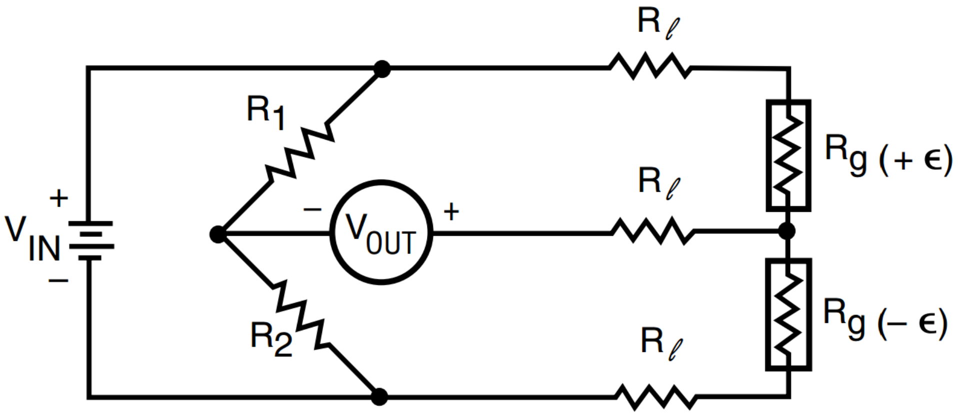
Stability

- Must be stable over time and changing conditions

Design Outputs

Strain Gauges

- Simple circuitry
- Half-bridge configuration
  - Increases sensitivity
  - Negates effects of temperature change



Evolution of Sensor Design

Force

- Piezoelectric: Voltage proportional to applied force using piezoelectric effect
- Loadcells: Manufactured sensor packages measuring compression forces

Displacement

- Hall Effect Sensors: Assembly of springs and magnets measuring the change in magnetic field due to the magnet's deflection
- Optical Sensors: Use Phototransistors to measure change in lumens due to the deflection of a LED or Laser

Strain

- Strain Gauges: Measure strain using the deformation of metal elements in a sensor

Evolution of Sensor Design

Sensors	Pros	Cons
Piezoelectric 1	• Directly Measures Force • Simple Circuitry	• Can Only measure force in Z direction • Can only measure dynamic forces
Load Cell	• Directly Measures Force	• Prohibitively expensive • Only measures force in Z direction
HES	• Displacement is linear to force • No need for opamp	• Difficult to manufacture • Difficult to avoid crosstalk
Phototransistors 2	• Not Temperature Dependent • Had Existing Drivers Available	• Difficult to Align • Impossible to implement elsewhere
Strain Gauges 3	• Proven Design • Able to Implement elsewhere	• Temperature Dependent • Strain Gauges may detach.

Evolution of Sensor Design

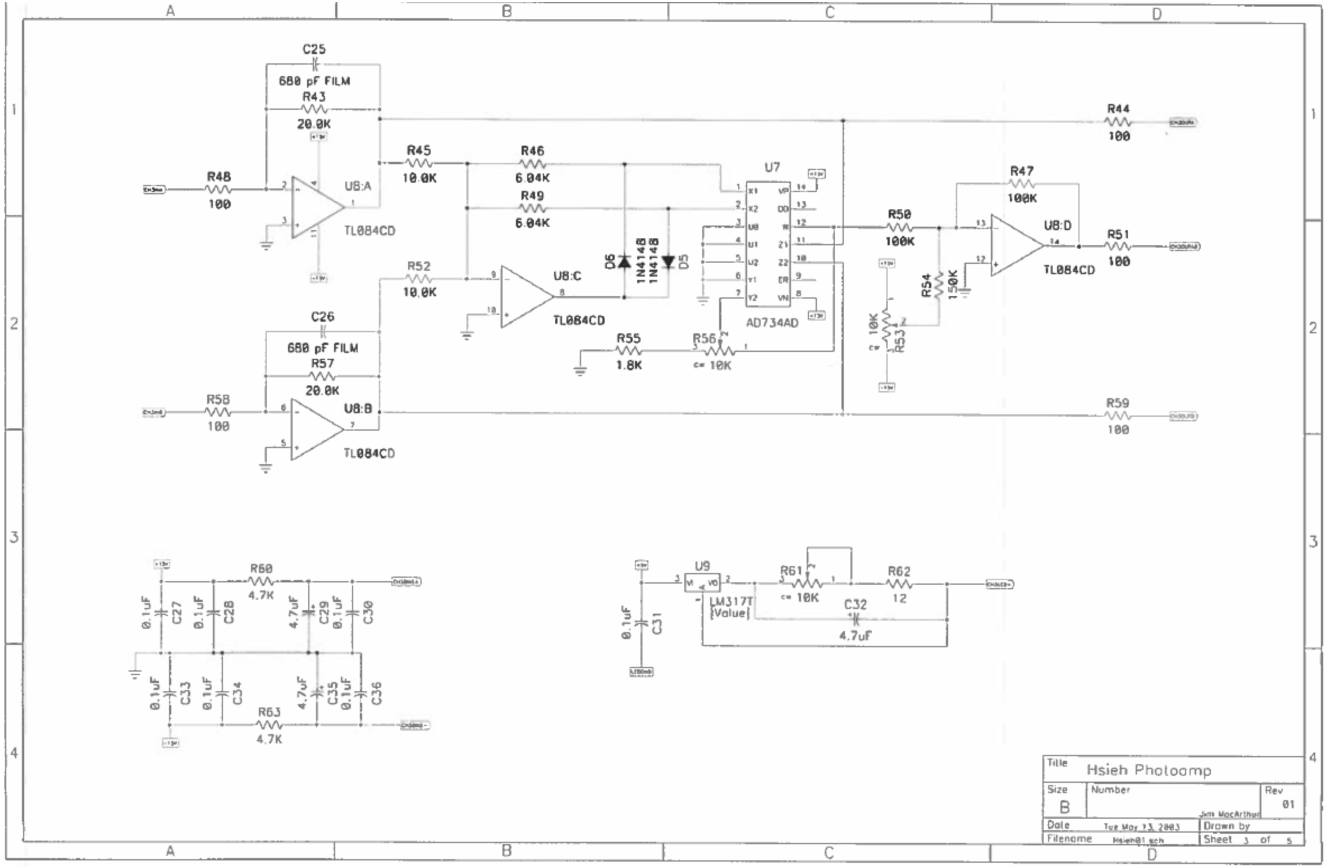
Tonia Hseih Phototransistor Driver:

Inputs(V): CH1INA, CH1INB

Outputs(V): CH1OUTA, CH1OUTB, CH1OUTAB

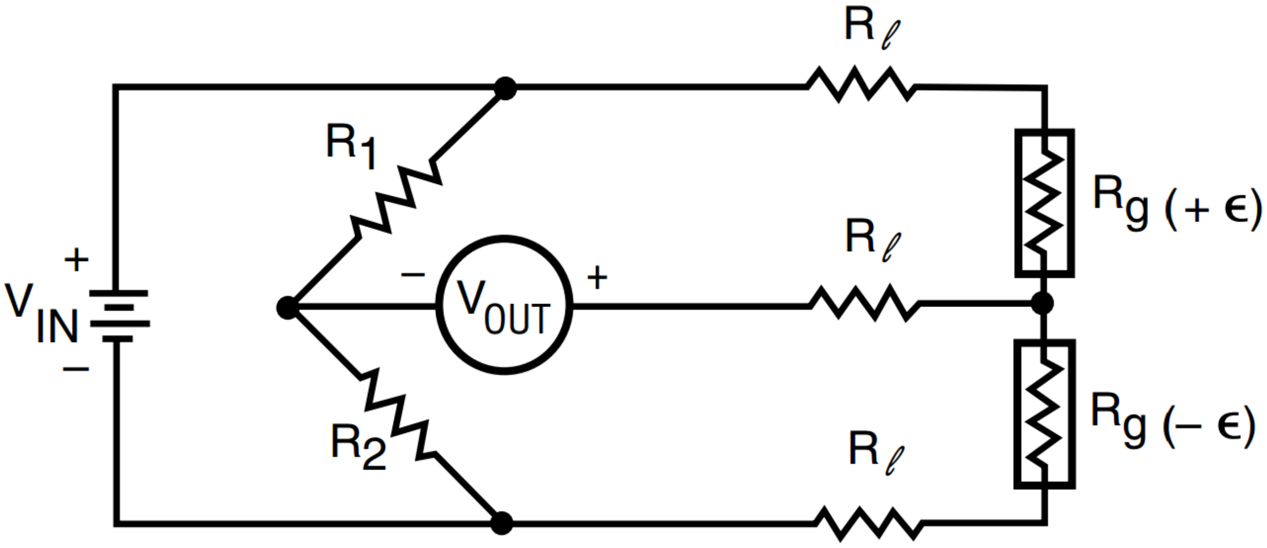
Components:

- 2 Low Pass filters amplifiers
- 15 V in
- LED Power
- BNC outputs to DAQ



Evolution of Sensor Design

- Strain Gauge Circuit
- Half-Bridge Configuration
- Measure the Voltage over R_g



Geometry & Materials

Brandon Segal

Geometry Design Inputs

Sensor Selection

- Is there adequate space?

Experiment Logistics

- Does the specimen have space to run?

Future Work

- Will future groups have the ability to add on to this work?

- SolidWorks
- Rat Sizes
- Heglund Cantilever Model
- Hseih Box Model

Evolution of Geometry

Platform

- This was theorized when developing ideas on how to incorporate piezoelectric sensors

Cantilever

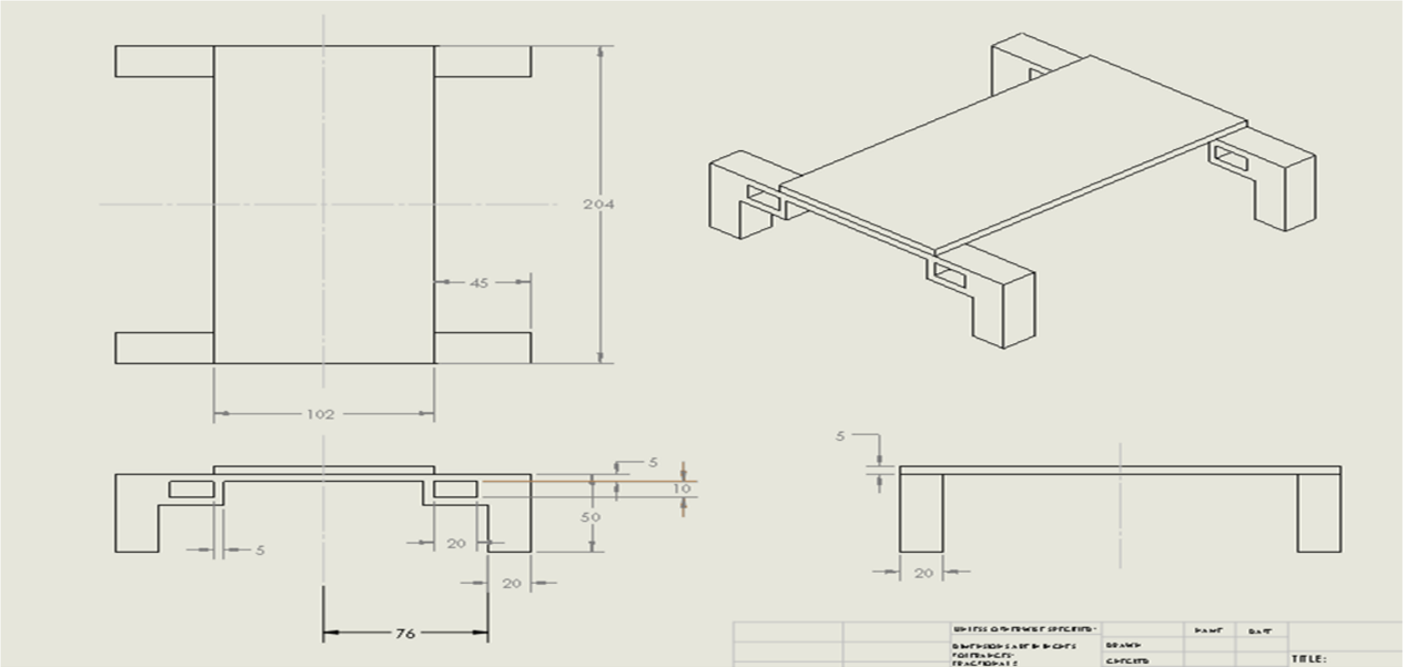
- Adaption to the Heglund model created in 1981
- Allows for multiple dimensions of force

Evolution of Geometry

The box acts as two spring blades

A fusion of Tonia Hsieh's and Heglund's Designs.

Measure strain or displacement.



Geometry Design Outputs

- Allows for sensor readings
- Proven Model
- Testable Dimensions
- Key Values can be found using basic equations
- Allows Future Work

Material Design Inputs

Strain Values

Displacement

Natural Frequency

Stress Values

- Agreed upon Force plate Geometry
- Equations to calculate key values
- Deflection.jl Code
- SolidWorks Model

Evolution of Material Choice

Copper

- Pliable and machinable metal used in highly sensitive force plates (Hsieh 2006)

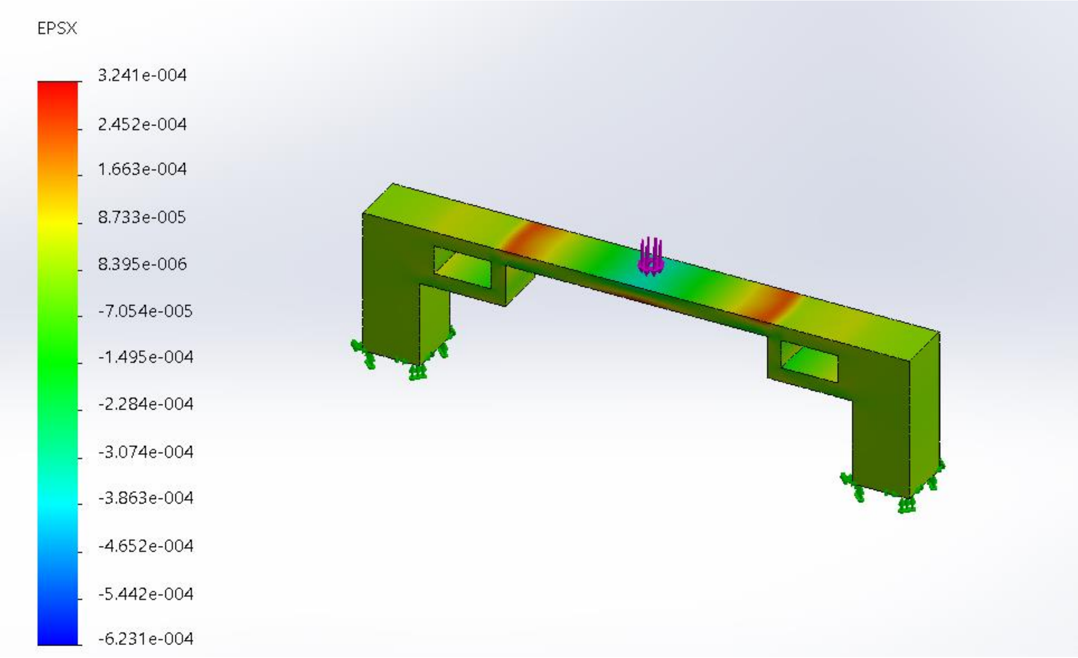
ABS Plastic

- Acrylonitrile butadiene styrene- Durable plastic available for 3D printing at Temple

PLC Plastic

- Polycaprolactone – Fragile plastic used by most 3D printers

Evolution of Material Choice



Youngs Modulus
for ABS Plastic: 2.00 GPa

Average Strain Values at Box edge (tension side): 37.5 µ

Calculated Strain Values: 36.75 µ

Material Design Outputs

Spring Blade Dimensions

- Able to finalize Solidworks dimensions
- Output results to CSV file
- Analyzed Results to pick the final dimensions

SolidWorks Simulation

- Used to validate hand calculations
- Average Values correlated within 5% of expected values
- Dimensions could hold chosen sensors

Testing of the Equipment

Follow A Similar procedure as Zumwalt

- **Static Testing** — Test linearity using multiple weights
- **Isolated Testing** — Move weights to see equal response on all legs
- **Dynamic Testing** — Test Responsivity Using Pendulum

Force Plate Operation

Lubaina Shakir

Experimental Protocol

Normal Baseline

- Healthy rats

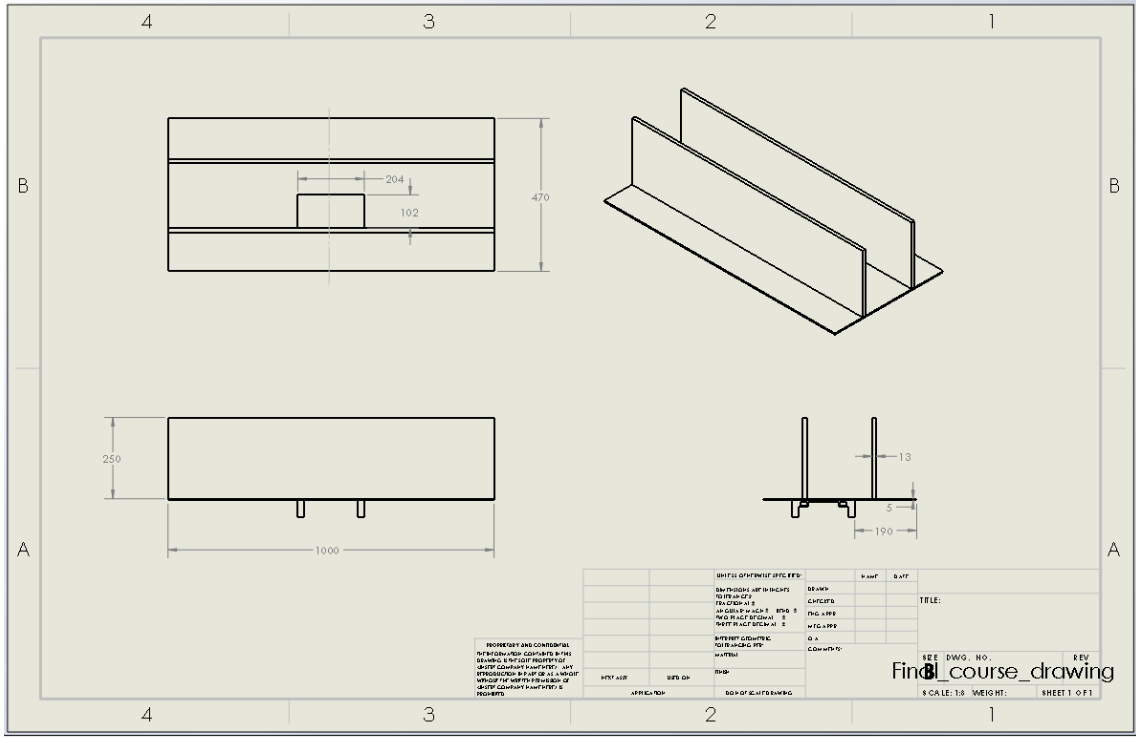
SCI Baseline

- Forces are captured after hemisection of spinal cord

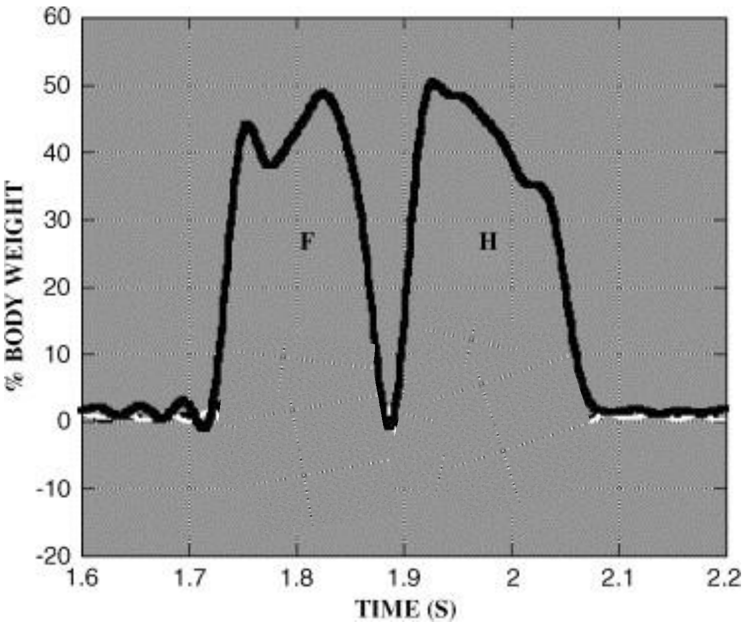
DREADDs + CNO

- Rats transfected with DREADDs constructed as per protocol
- CNO given just prior to data collection

Model for Overground Course



Data Collection Output (Theoretical)



Zumwalt (2005)

Ensuring Performance of the Equipment

Calibration

- Calibrate sensors before testing
- Zero out all 4 channels before Testing

Sensors

- Keep Sensors out of high Temps
- Determine Linearity through Dynamic and Static Testing

Structure

- Ensure that the structure is put upright as to not damage the solder

Ensuring Animal Safety

Animal Training

- Make sure all personnel are trained to handle animals

Equipment Readiness

- Ensure that Surfaces are flush with the course

Structural Integrity

- Implement a Factor of safety when choosing force plate geometries

Sustainability and Future Use

- Extra Strain Gauges will be donated to the Spence Lab
- Life of Strain Gauge exceeds 10,000,000 cycles at small loads
- The structure will remain in the Spence Lab for future teams to use as a reference
- Designs and documents will be uploaded to Github
- Make the design open source solution for small labs

Questions?