NORTHERN ARIZONA UNIVERSITY

MSMA LATERAL LOADING DEVICE

PROJECT PROPOSAL

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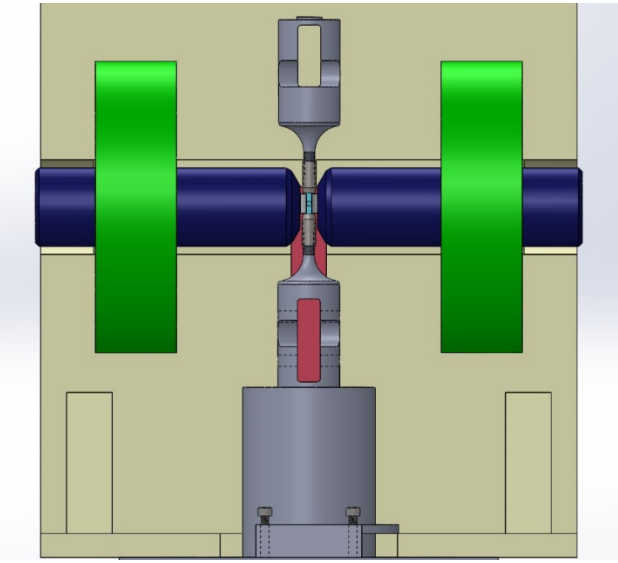
Problem Identification

- Dr. Ciocanel
  - Associate Professor at Northern Arizona University
  - Conduct research on Smart Materials
  - Wants to expand his testing process to include compressive force in the third dimension
  - Operates at room temperature in a laboratory setting

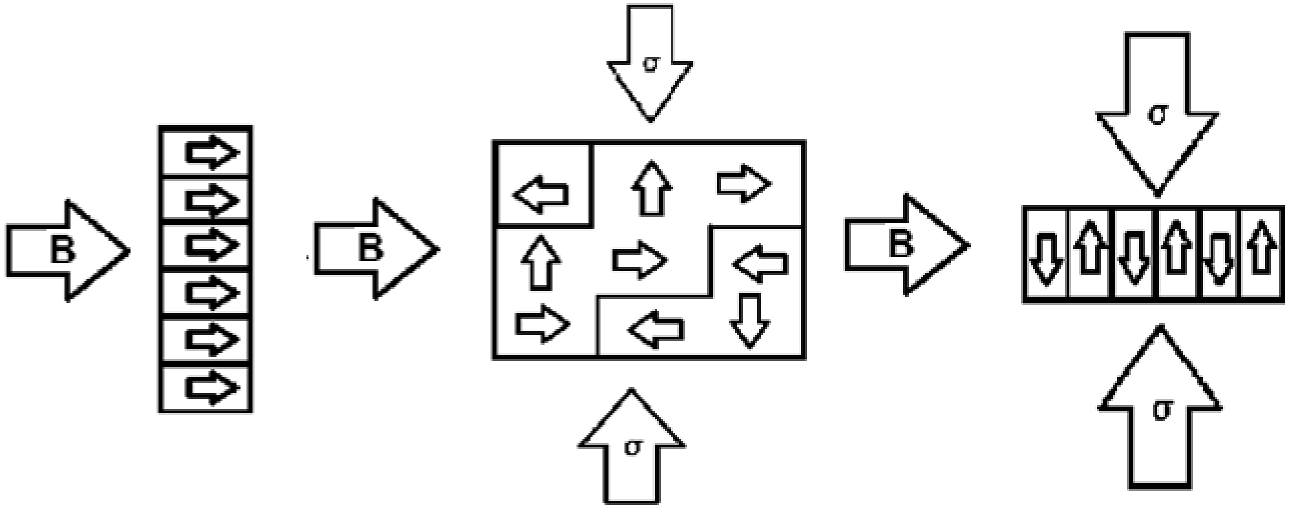
Solidworks Model of Instron Machine



Magnetic Shape Memory Alloy (MSMA)

- Ni_2MnGa
- Magnetization variant rotation
- Actuating vs. power harvesting

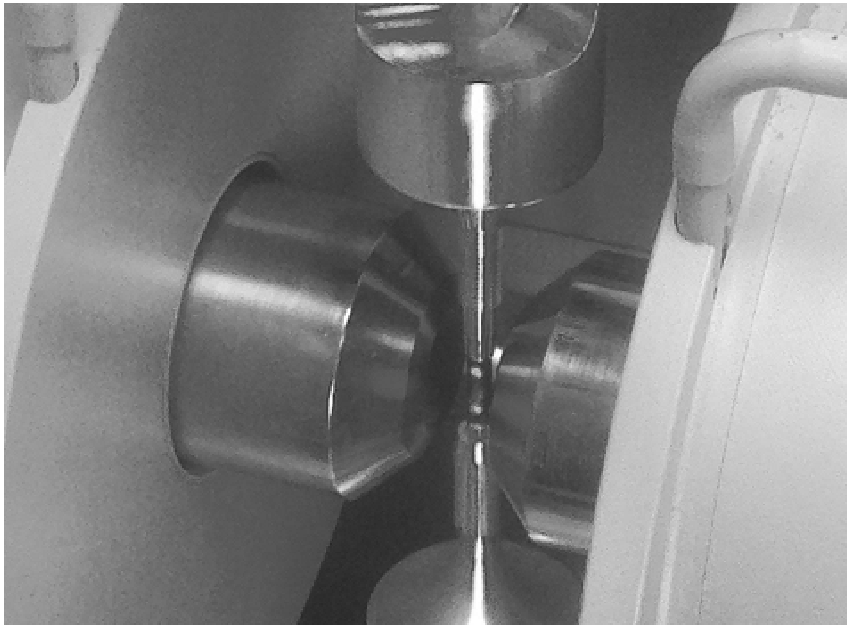
Variant Reorientation Model



Project Description

- Construction of a device capable of laterally loading up to 200 N
- Work within a $2500 budget
- Fit within 10mmx12mm area under a magnetic field
- Provide feedback control

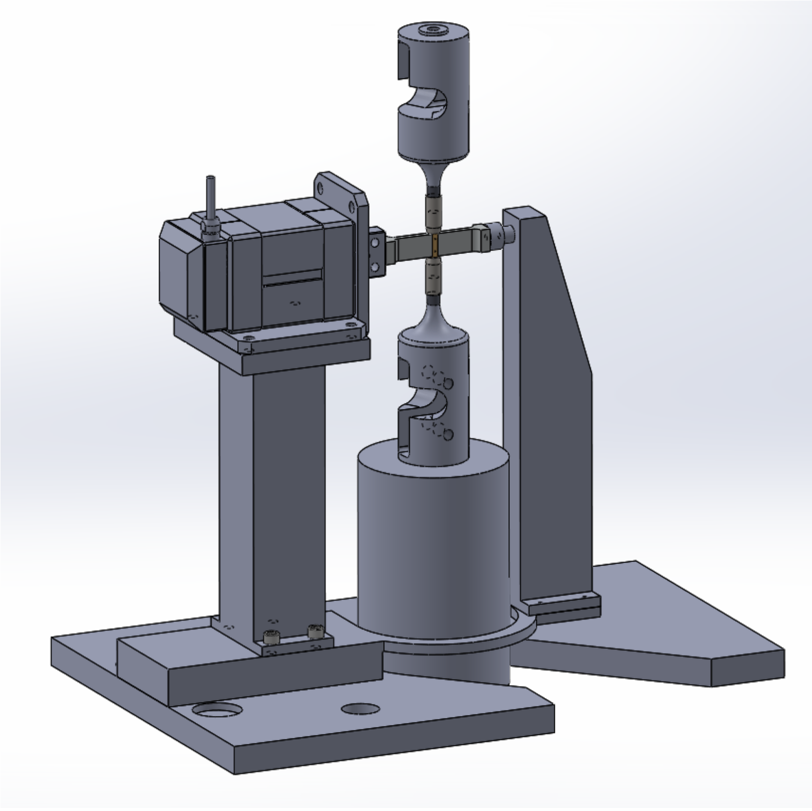
Experimental Setup for MSMA Testing



Design Concepts

- Space limitations require design to be outside 10mmX12mm area
- Similar setup so focus shifts to
  - Actuation
  - Force Sensing

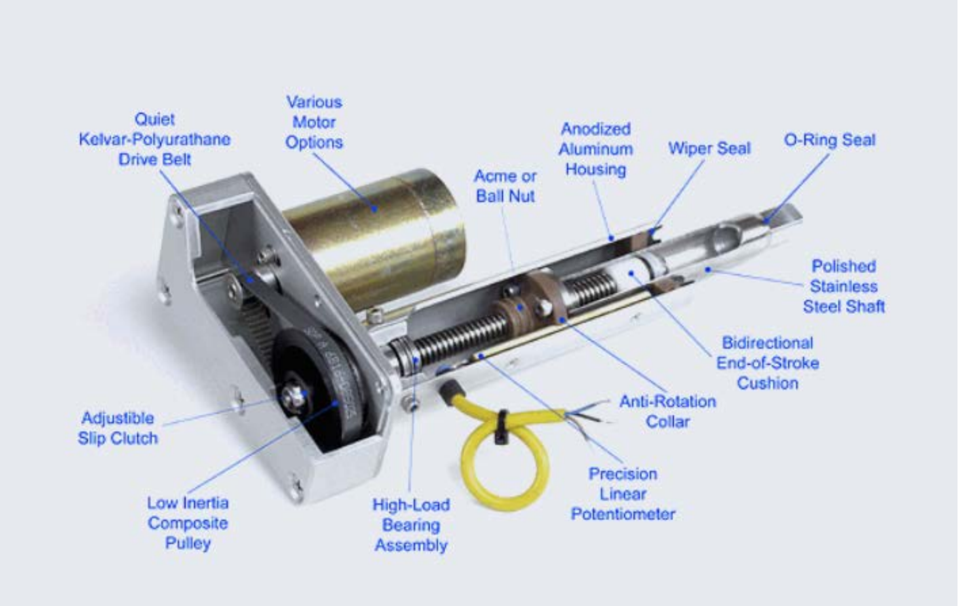
Basic System Apparatus [2][3]



Electromechanical Actuation

- Motor driven screw
- Pros
  - High precision
  - Available force feedback
- Cons
  - Large in size
  - Large operating range

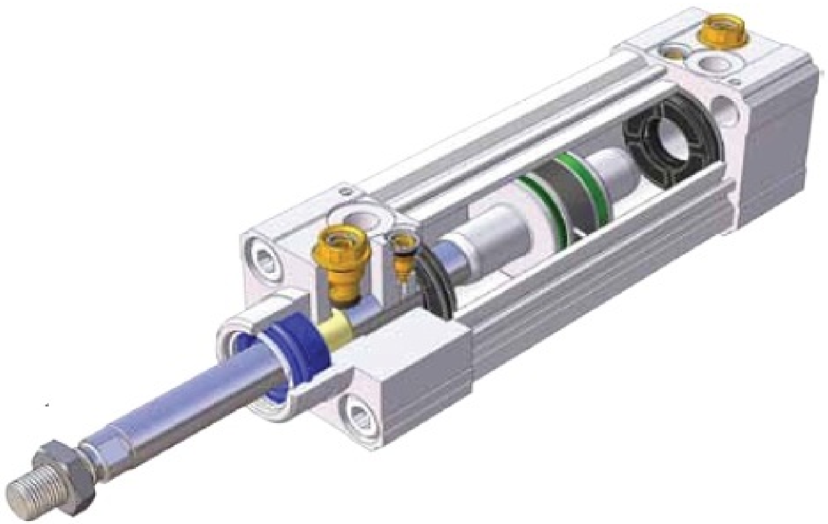
Electromechanical Actuator Design [4]



Pneumatic Actuation

- Piston cylinder or hose powered by air
- Pros
  - Fits within allowable space
  - Lower in cost
- Cons
  - Lacks precision
  - Needs compressed air

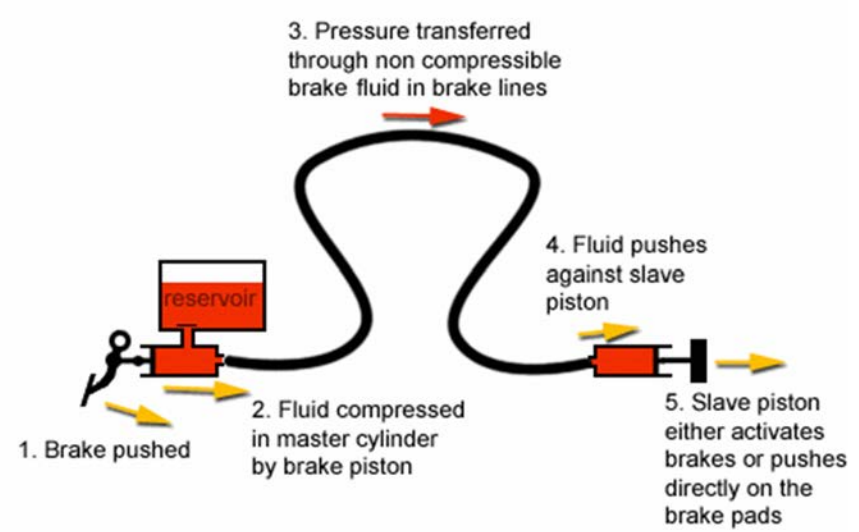
Pneumatic Actuator Schematic [5]



Hydraulic Actuation

- Computerized piston and hose or cylinder design
- A hose attached to actuators on either side of the specimen
- Pros
  - Flexible, fits in allowed space
  - Incompressible flow; finer control
- Cons
  - Less precise than electromechanical
  - Needs more components

Hydraulic Actuation Process [6]

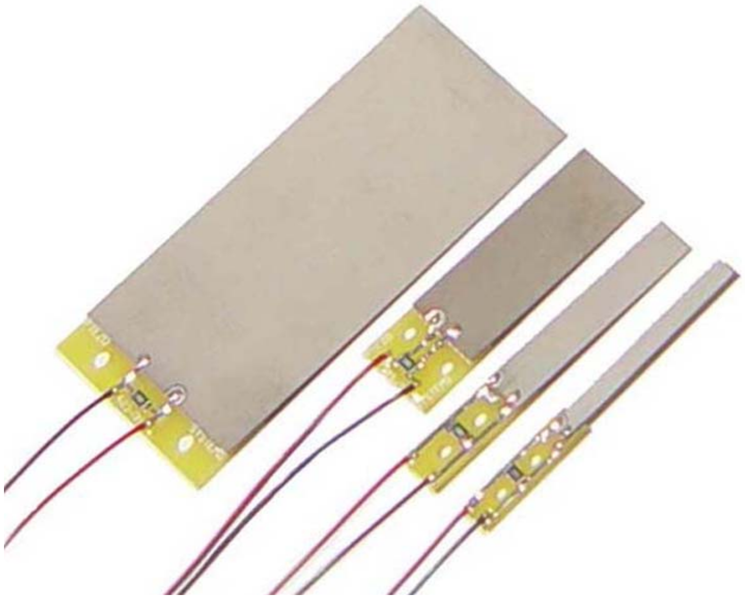


Piezoelectric Force Sensor

- Deflection outputs a voltage
  - Due to material properties

- Pros
  - Excellent sensitivity
  - Small size
- Cons
  - Fragile
  - Expensive

PZT sensor in various sizes [7]



Strain Gauge Force Sensor

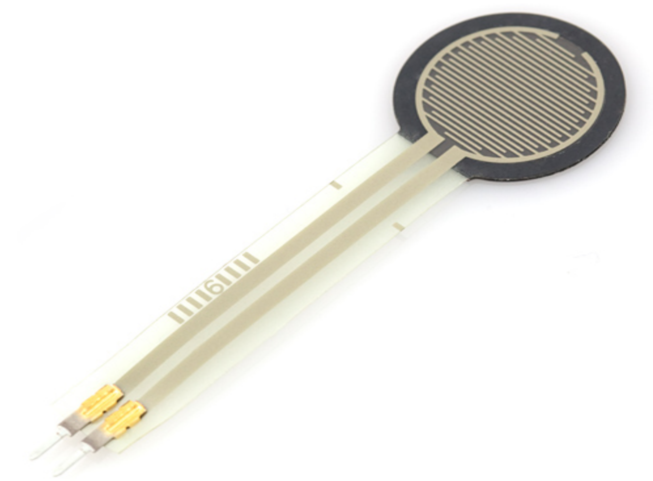
- Measures strain through voltage
- Pros
  - Low cost
  - High sensitivity
- Cons
  - Size could be an issue

Basic Strain Gauge Design [8]

Force Sensing Resistor

- Compression changes electrical resistance
- Can be setup to measure a voltage drop
- Pros
  - Inexpensive
  - High durability
- Cons
  - Low sensitivity

Basic Force Sensing Resistor [9]



Concept Selection and Decision Matrix for Actuation

- Move forward with electromechanical and hydraulic actuators
  - Client requested piezoactuators over hydraulic

	Weight	Piezoelectric	Strain Gage	Force Sensing Resistor
Sensitivity	4	8	7	4
Cost	1	4	7	9
Size	3	9	5	5
Effectiveness in a magnetic field	5	6	7	7
Durability	3	4	6	7
Total	n/a	105	103	96

Concept Selection and Decision Matrix for Force Sensing

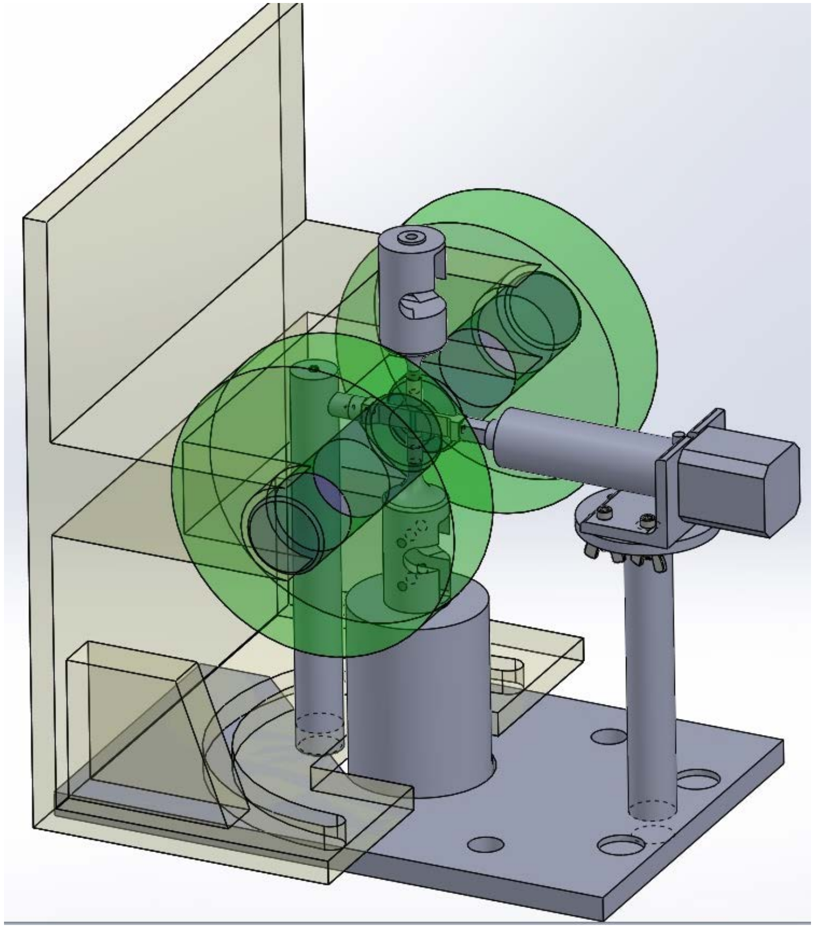
- Move forward with Piezoelectric and Strain Gauges

	Weight	Electromechanical	Hydraulic	Pneumatic
Controllability	5	9	7	4
Cost	1	3	5	3
Precision	5	6	7	3
Amount of Applied Force	2	5	8	8
Size	3	4	8	6
Total	n/a	100	115	72

Engineering Analysis

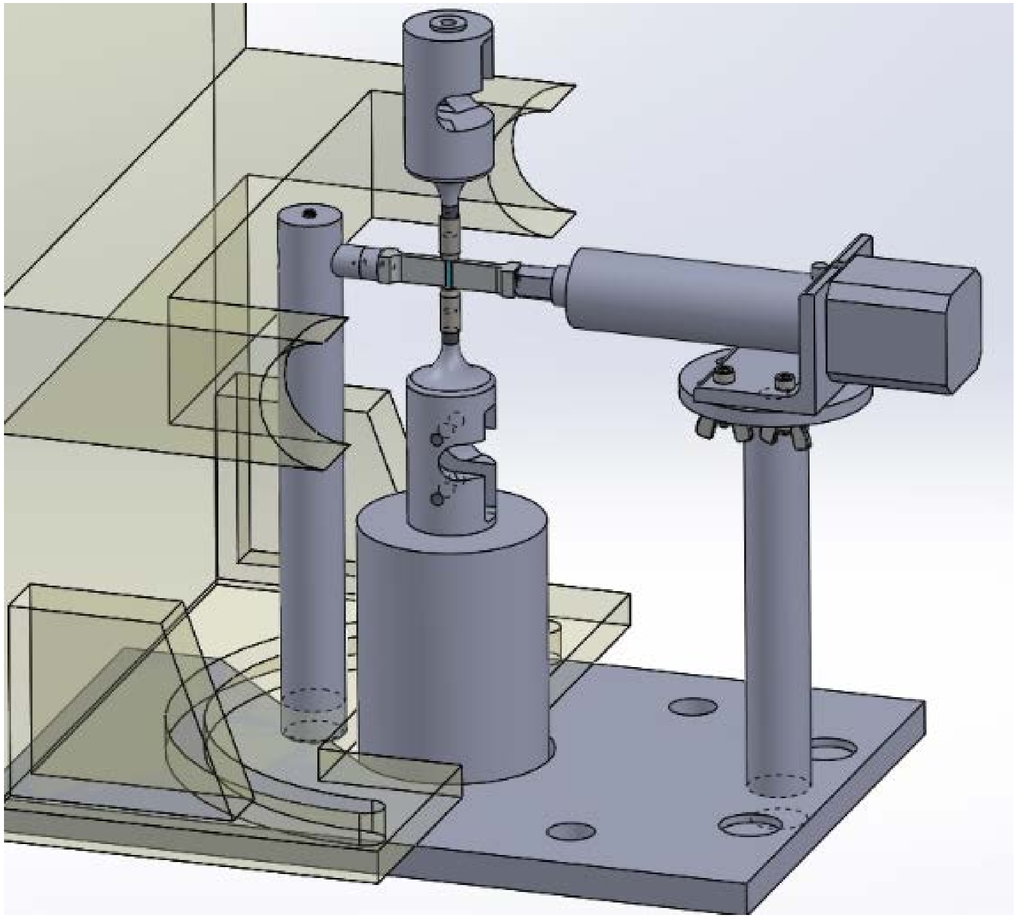
- Force Sensor [1] [5]
  - Similar size
  - Similar mounting position
  - Capable of handling fatigue
- Actuator
  - Similar forces
  - Similar cyclic fatigue
- Mounting
  - Different geometries
    - Towers, Screws

Solidworks Model of Instron Machine [2] [10]



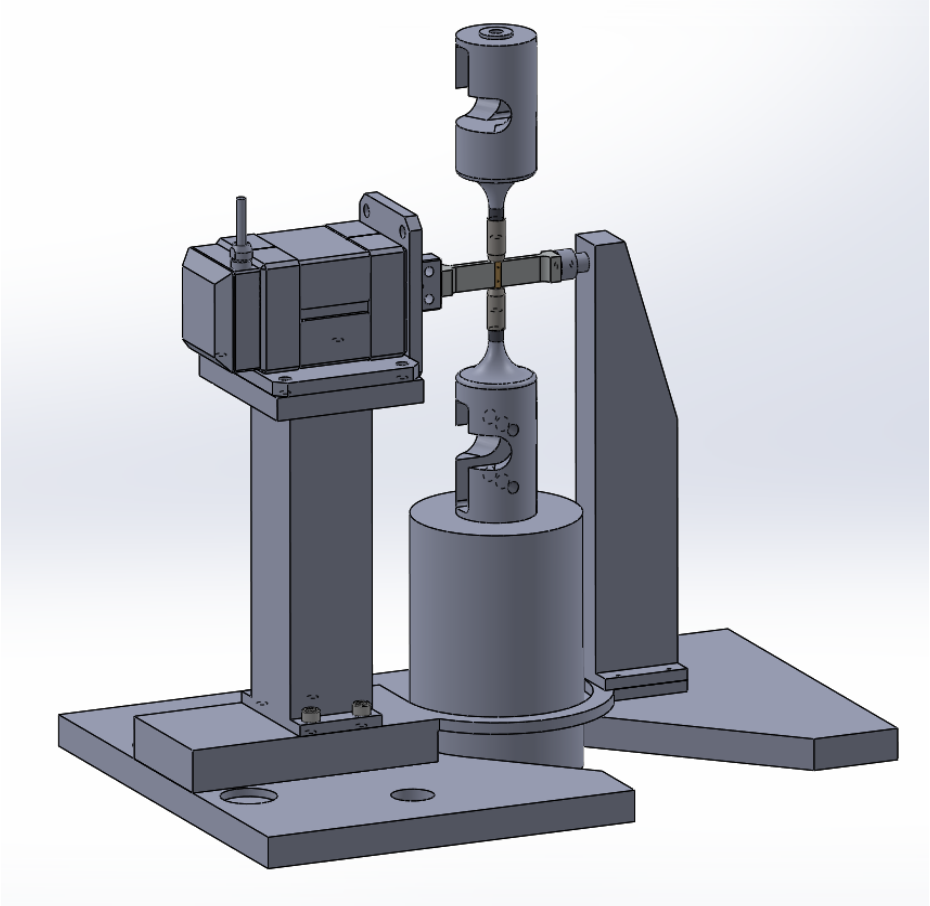
- **Electromechanical Design Setup**

Solidworks Model of Electromechanical Mounting Design [2] [10]



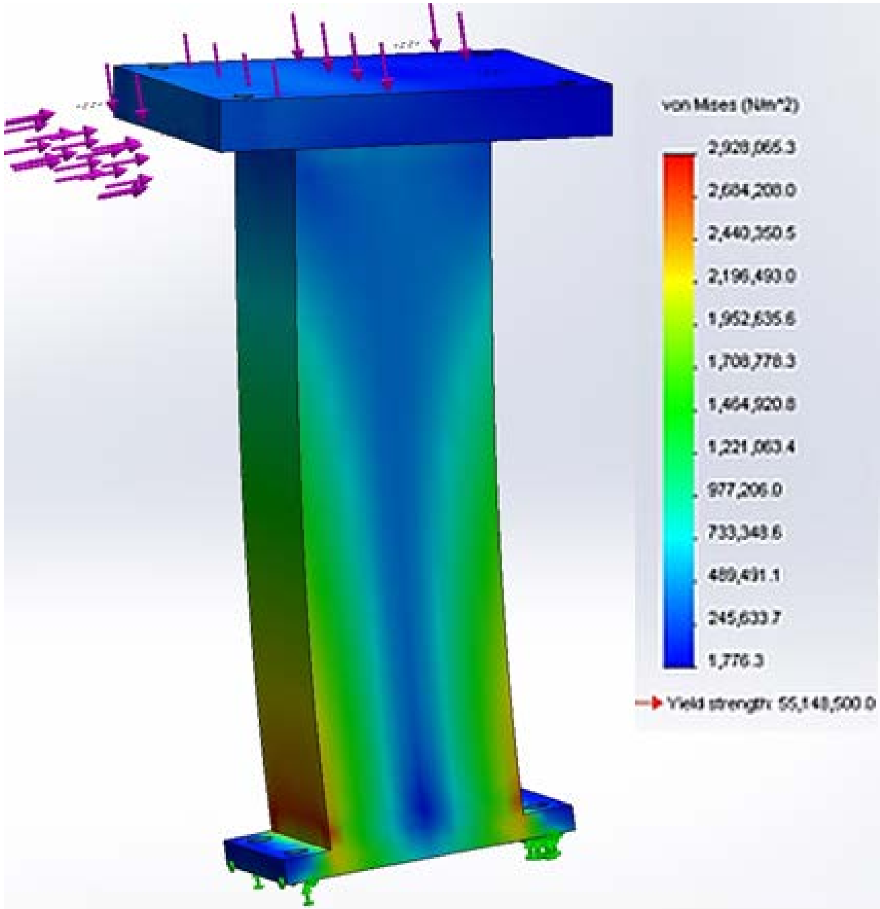
- **Piezoelectric Stack Design Setup**

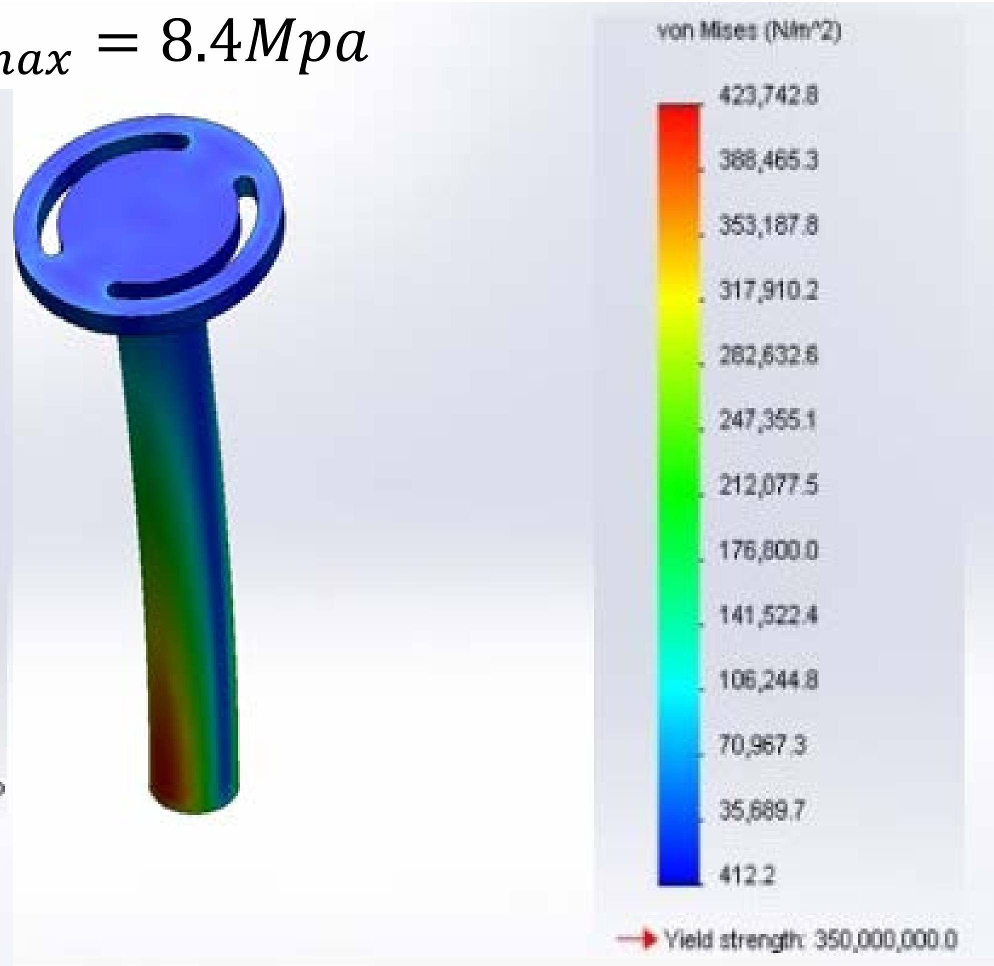
Solidworks Model of Piezoactuator Mounting Design [2] [3]



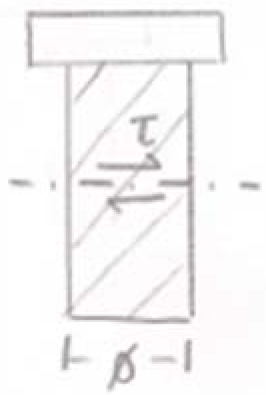
Analysis of Towers

$$\sigma_{max} = 8.4Mpa$$





By-Hand Analysis of Screws



$$\tau = \frac{F_{max}}{A} = \frac{F_{max}}{\frac{\pi D^2}{4}} \approx 70\text{Mpa}$$

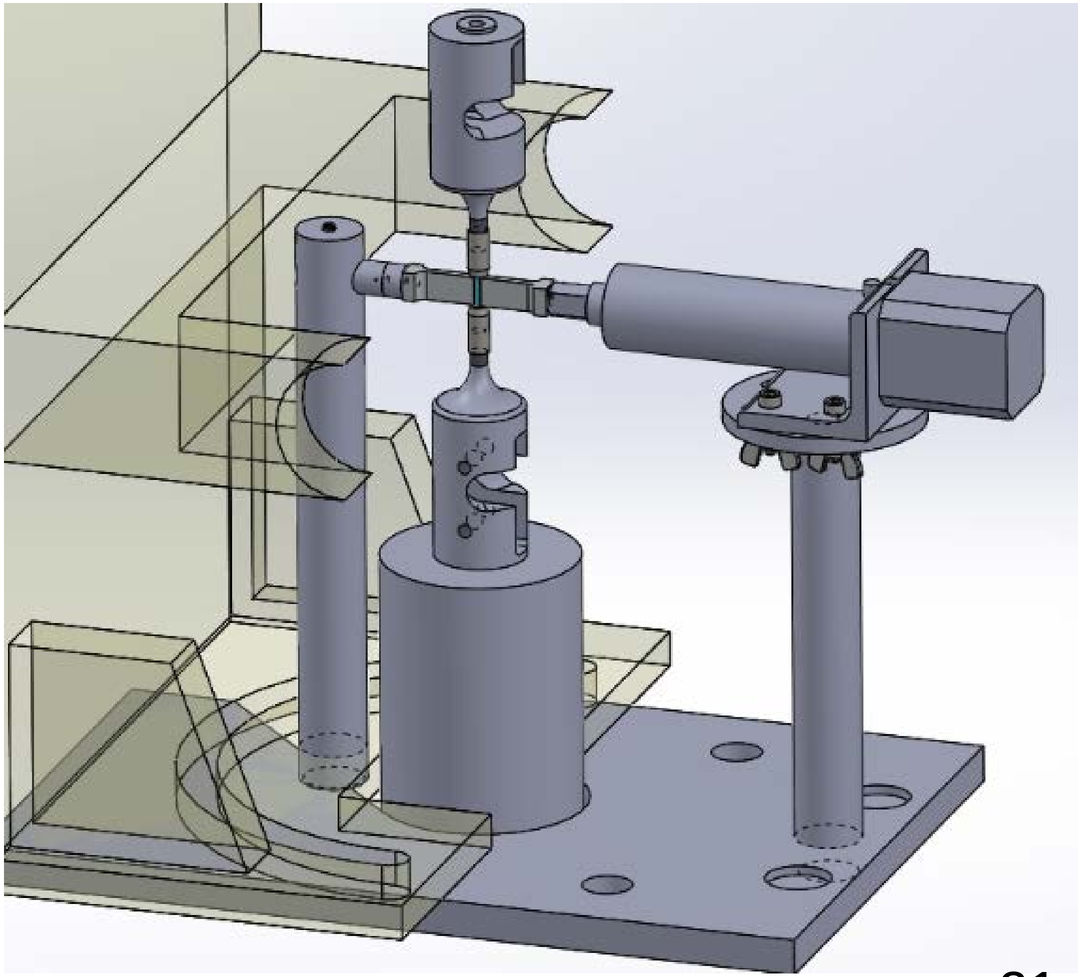
•Material Selection

- Base/Towers: 1018 Low-Carbon Steel or 6061 Aluminum Alloy
- Screws: Type 316 Stainless Steel
  - Cheap, common material
  - Yield strength exceeds maximum stress
  - Not present in magnetic field/ non-magnetic
  - Good machinability (base/towers)

Proposed Design

- Electromechanical
  - Ultra Motion Digit NEMA 17 Stepper
- Strain Gauge
  - Honeywell Model 11 load cell
- Lower costs
- Ease of manufacturing

Solidwork Model of Proposed Design [2][10]



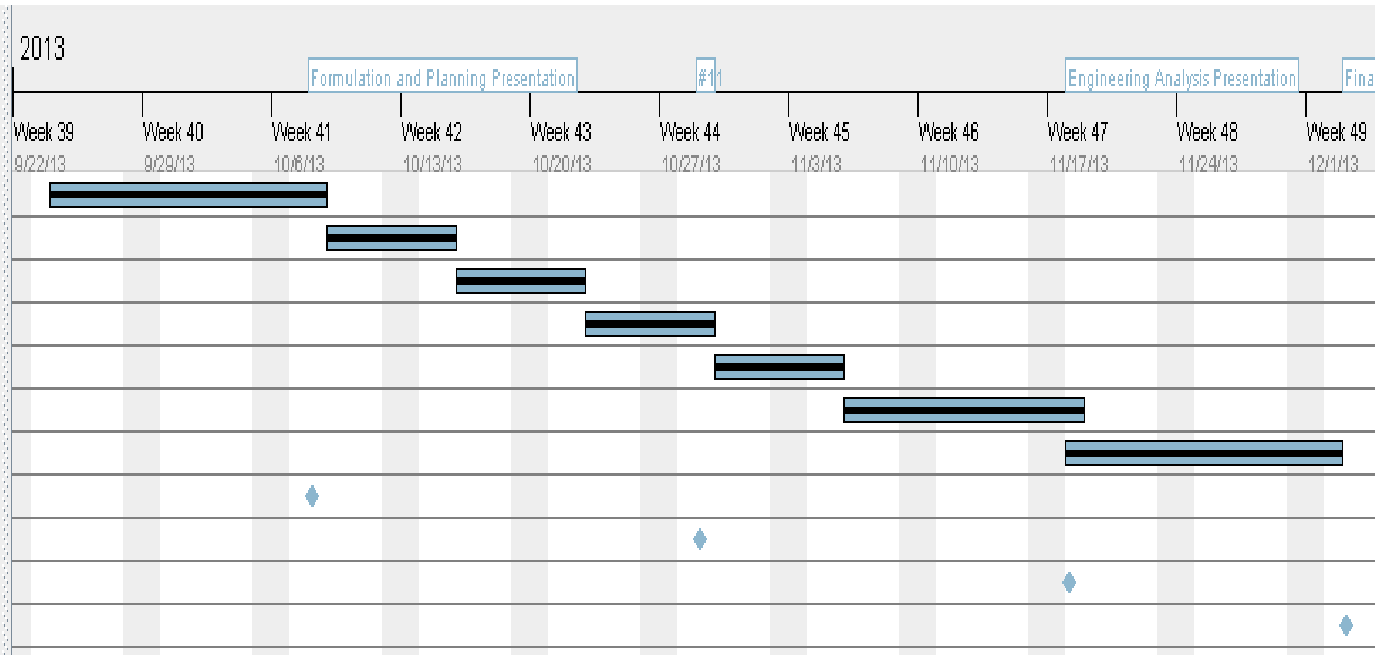
Cost Analysis

Component	Quantity	Cost
Digit NEMA 17 Stepper	1	$620.00
ST5-S Stepper Drive	1	$302.00
Model 11 Load Cell	1	$771.00
Low-Carbon Steel Rod, 1", 3' Length	1	$26.71
Low-Carbon Steel Bar, 3''-6''-1/4''	1	$7.67
Flathead Screw, 5 pack	1	$5.24
Wing Nuts, 25 pack	1	$7.21
Socket Head Cap Screw, 25 pack	1	$5.61
Set Screw, 25 pack	1	$3.76
Total Cost		**$1,749.20**

MSMA Lateral Testing

Project Timeline

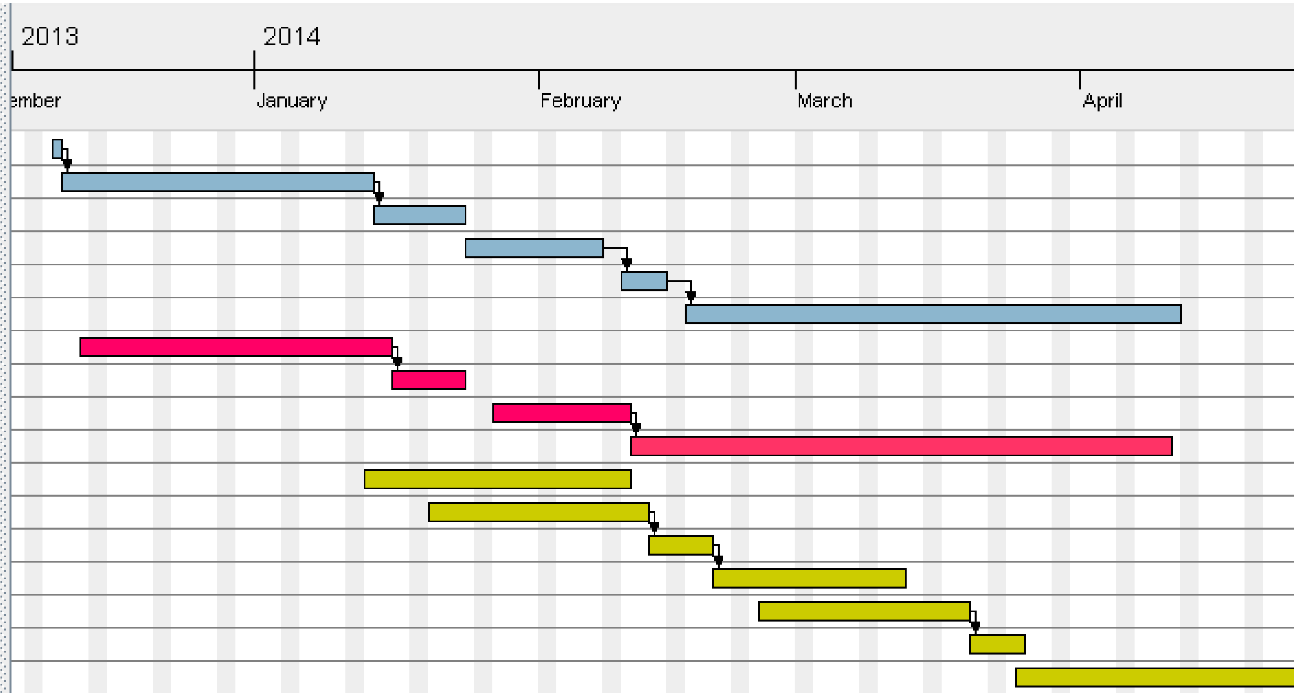
Name	Begin date	End date
Define Problem	9/24/13	10/8/13
Conduct State-Of-The-Art Resear...	10/9/13	10/15/13
Generate Preliminary Designs	10/16/13	10/22/13
Conduct Analysis	10/23/13	10/29/13
Generate Design Alternative	10/30/13	11/5/13
Analyze Alternatives	11/6/13	11/18/13
Finalize Design	11/18/13	12/2/13
Formulation and Planning Prese...	10/8/13	10/8/13
Concept Generation and Selecti...	10/29/13	10/29/13
Engineering Analysis Presentation	11/18/13	11/18/13
Final Design Presentation	12/3/13	12/3/13



MSMA Lateral Testing

New Project Timeline

Name	Begin date	End date
Final Design Completion	12/10/13	12/10/13
Initial Part Acquisition	12/11/13	1/13/14
Machining/construction	1/14/14	1/23/14
First Stage of Testing (stru...	1/24/14	2/7/14
Examination of Results	2/10/14	2/14/14
Improve Existing Features	2/17/14	4/11/14
Acquisition of Actuator	12/13/13	1/15/14
Installation of Actuator	1/16/14	1/23/14
Actuator Testing	1/27/14	2/10/14
Improvements on Actuatio...	2/11/14	4/10/14
Initial Development of Forc...	1/13/14	2/10/14
Testing of Force System	1/20/14	2/12/14
Examination of Results	2/13/14	2/19/14
Fine Tuning (Force System)	2/20/14	3/12/14
Testing of Force System	2/25/14	3/19/14
Examination of Results	3/20/14	3/25/14
Improvement of Force Syst...	3/25/14	4/24/14



Conclusion

- Must create a feedback controlled device that laterally loads a MSMA up to 200 N within a small area for under $2500.
- Initial analysis resulted in further development using electromechanical vs. Piezo actuators and piezoelectric vs. strain gauge force sensing.
- Engineering analysis was conducted to determine minimum material properties required in the fixtures.
- Final design selected to propose to client after manufacturing and cost consideration.
- Timeline for next semester has been established, and our team will begin ordering products.

•References

•[1] Leo, Donald J. Engineering Analysis of Smart Material Systems. Hoboken, NJ: John Wiley & Sons, 2007.

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•[3] "N-216 NEXLINE Linear Actuator." *PIEZO NANO POSITIONING*. Physik Instrumente (PI) GmbH & Co. KG, n.d. Web. 15 Nov. 2013.

•[4] "Ultra Motion Bug Linear Actuator." *Ultra Motion Bug Linear Actuator*. Ulta Motion, n.d. Web. 27 Oct. 2013. <http://www.ultramotion.com/products/bug.php>.

•[5] Reese, Cale, PhD. "The Ins and Outs of Single Axis Actuation." *Design World*. N.p., 1 Aug. 2012. Web. 27 Oct. 2013. <http://www.designworldonline.com/the-ins-and-outs-of-single-axis-actuation/>.

•[6] Longhurst, Chris. "Brakes - What Do They Do?" *Car Bibles : The Brake Bible*. N.p., 24 July 2013. Web. 27 Oct. 2013. <http://www.carbibles.com/brake_bible.html>.

• [7] Piezo Systems, Inc. "Piezo Systems: Quick-Mount Piezoelectric Bending Sensors, Piezoelectric Generators, Piezoceramic, PZT, Piezoelectric Transducers, Piezoelectric Actuators and Sensors, Piezoelectric Engineering, Ultrasonics, and Energy Harvesting." *Piezo Systems: Quick-Mount Piezoelectric Bending Sensors, Piezoelectric Generators, Piezoceramic, PZT, Piezoelectric Transducers, Piezoelectric Actuators and Sensors, Piezoelectric Engineering, Ultrasonics, and Energy Harvesting*. N.p., n.d. Web. 28 Oct. 2013. <http://www.iezo.com/prodbg7qm.html>.

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•[10] "The Digit." *http://www.ultramotion.com/products/digit.php*. Ultra Motion. Web. 1 Dec. 2013.

QUESTIONS?