Impedance Control for Robotic Assembly

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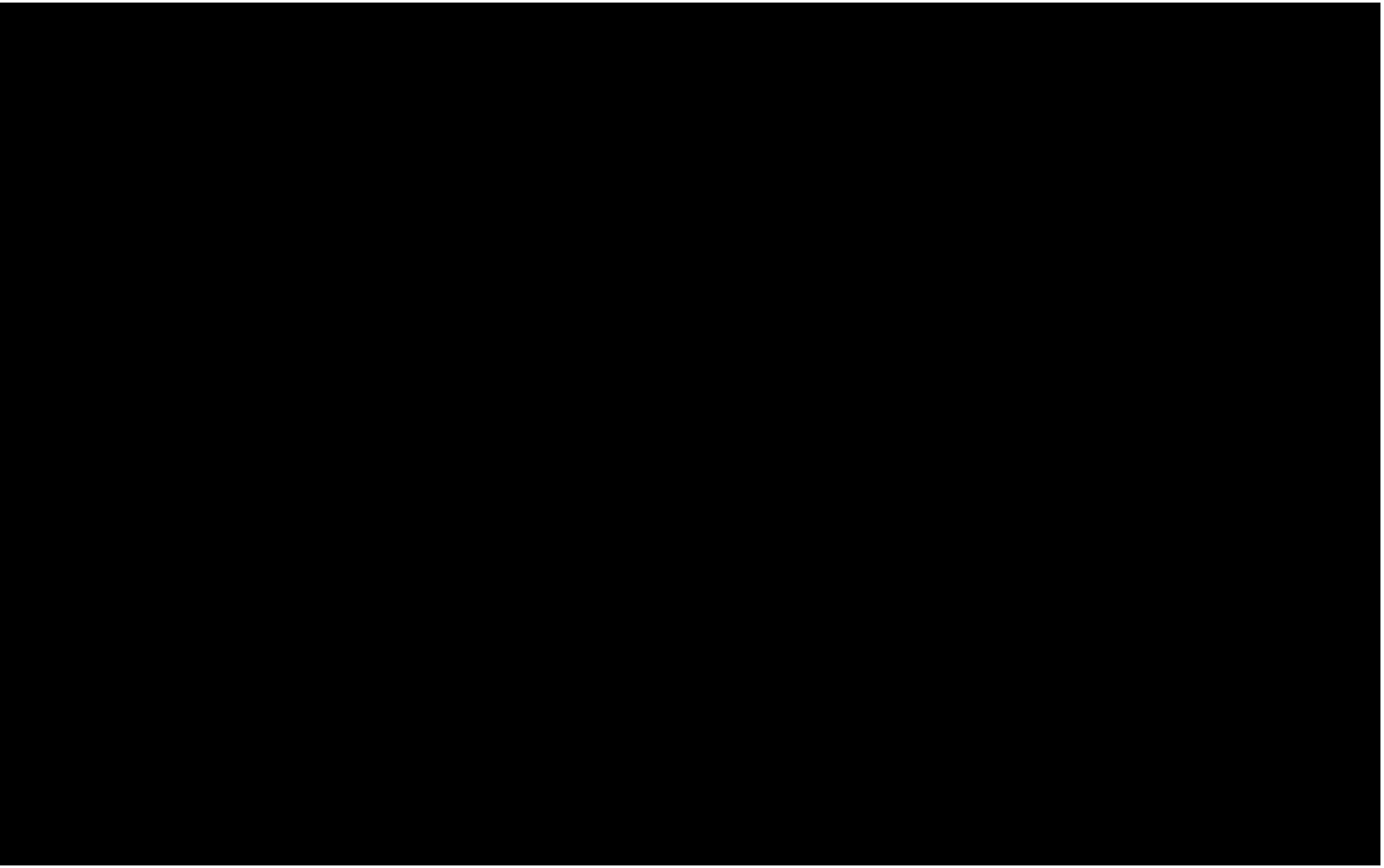
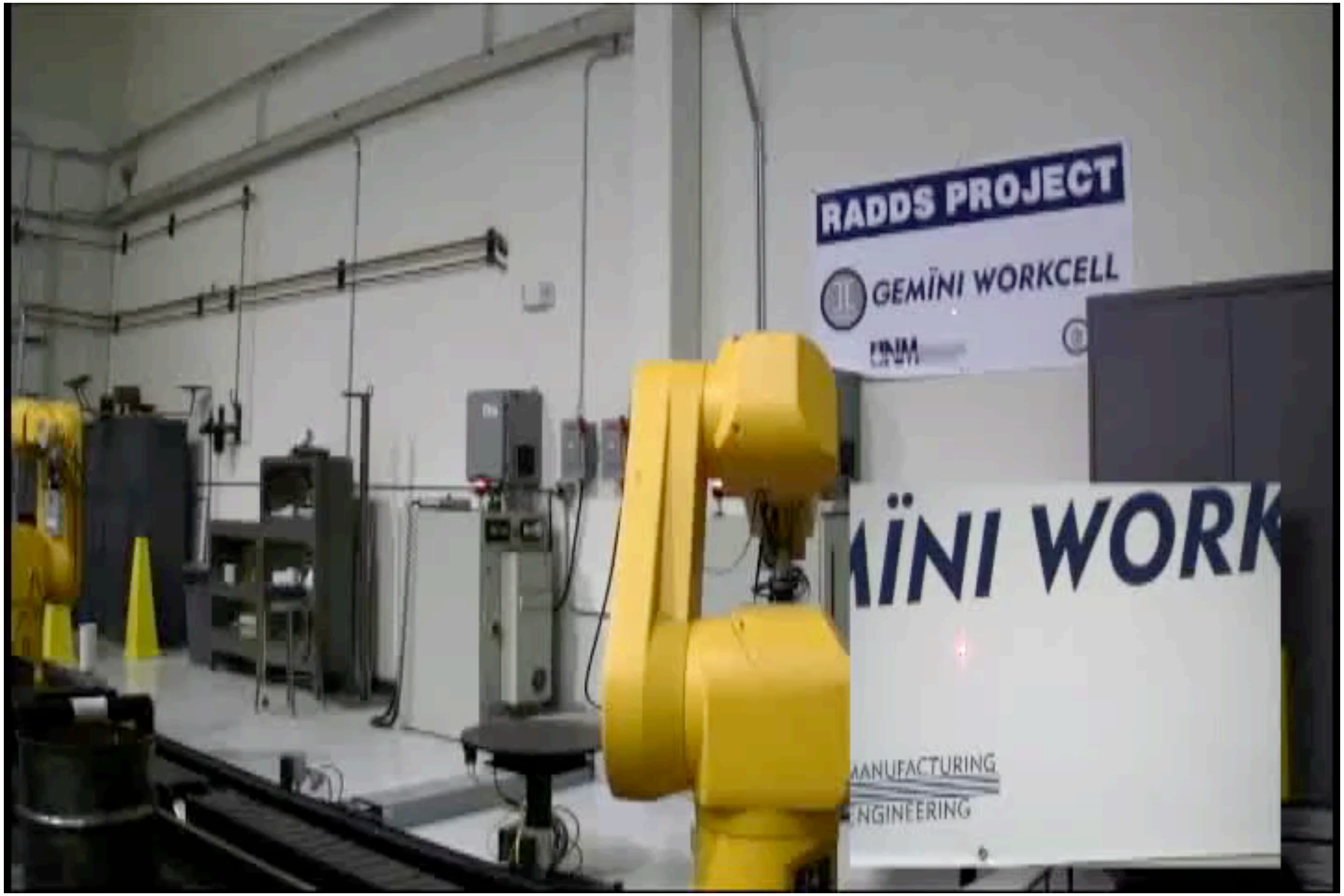
Topics

- Swing Free Control
- Laser Tag
- Impedance Control
- Peg and Hole Assembly - jamming/wedging
- Real-time Control to Prevent Jamming and Wedging
- Assembly using Attractive Regions
- DARPA demos
- Conclusions

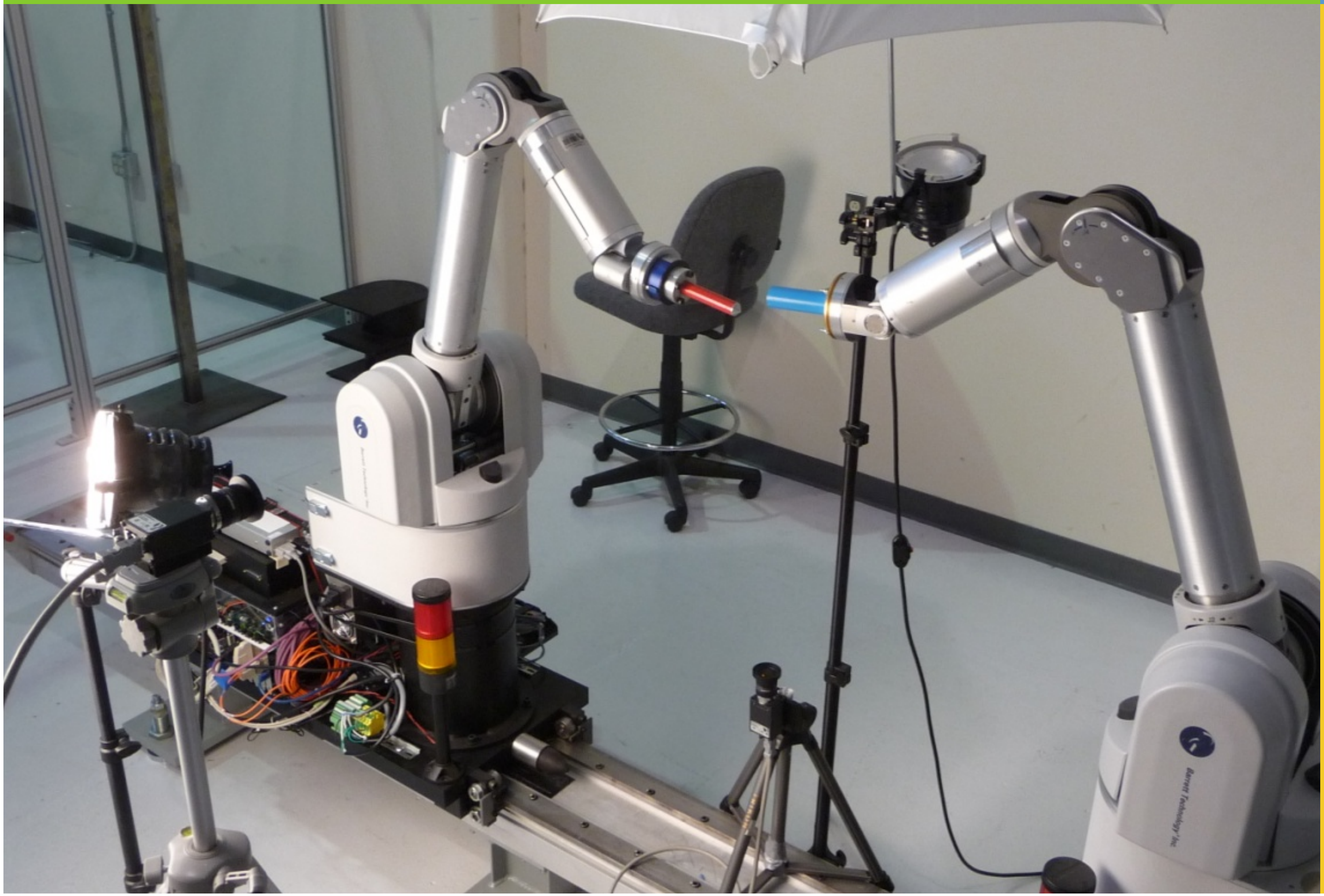
Swing-Free Trajectory



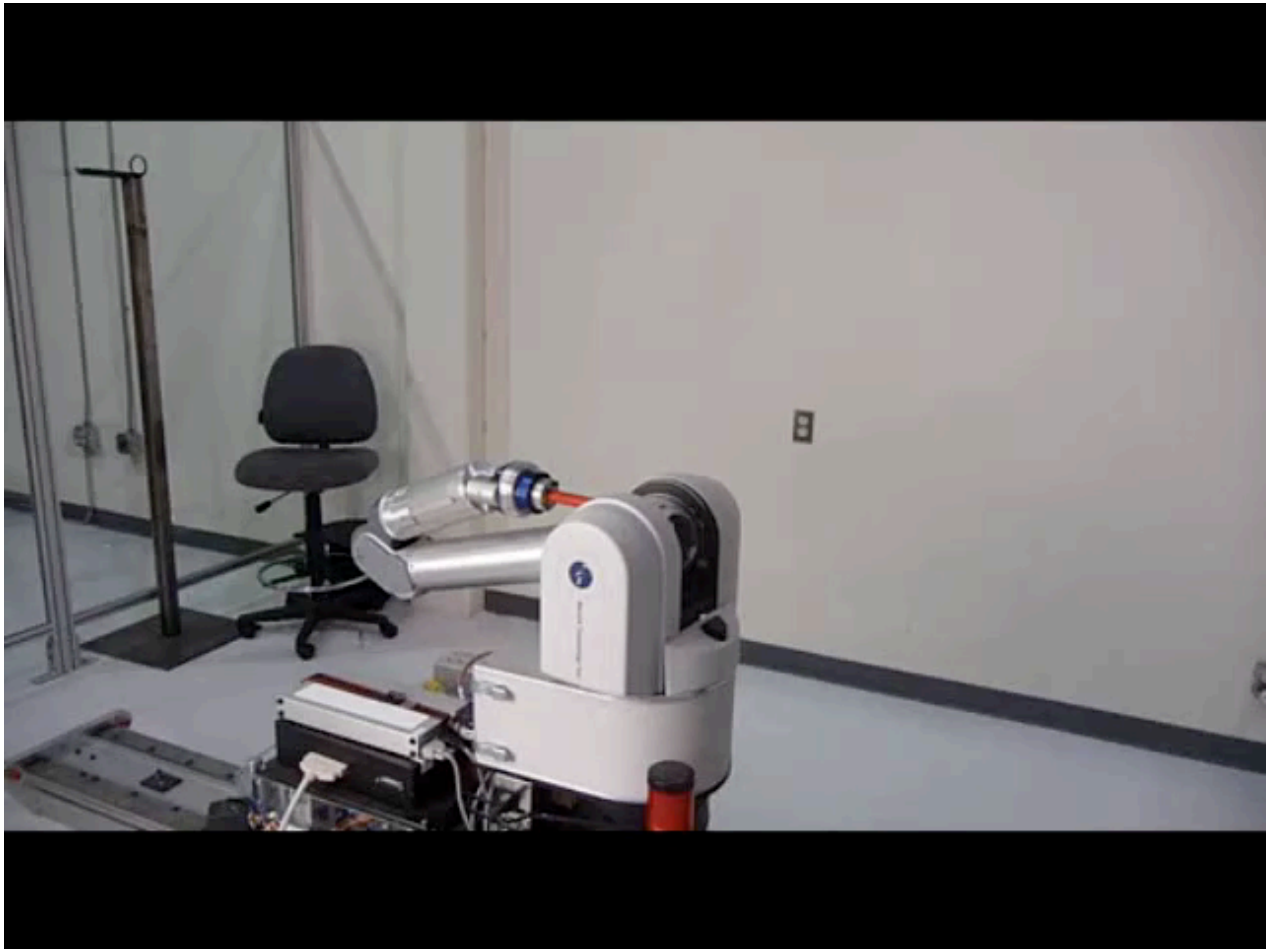
Laser Tag


RADDS PROJECT
GEMÏNI WORKCELL
ÏNI WORK
MANUFACTURING
ENGINEERING

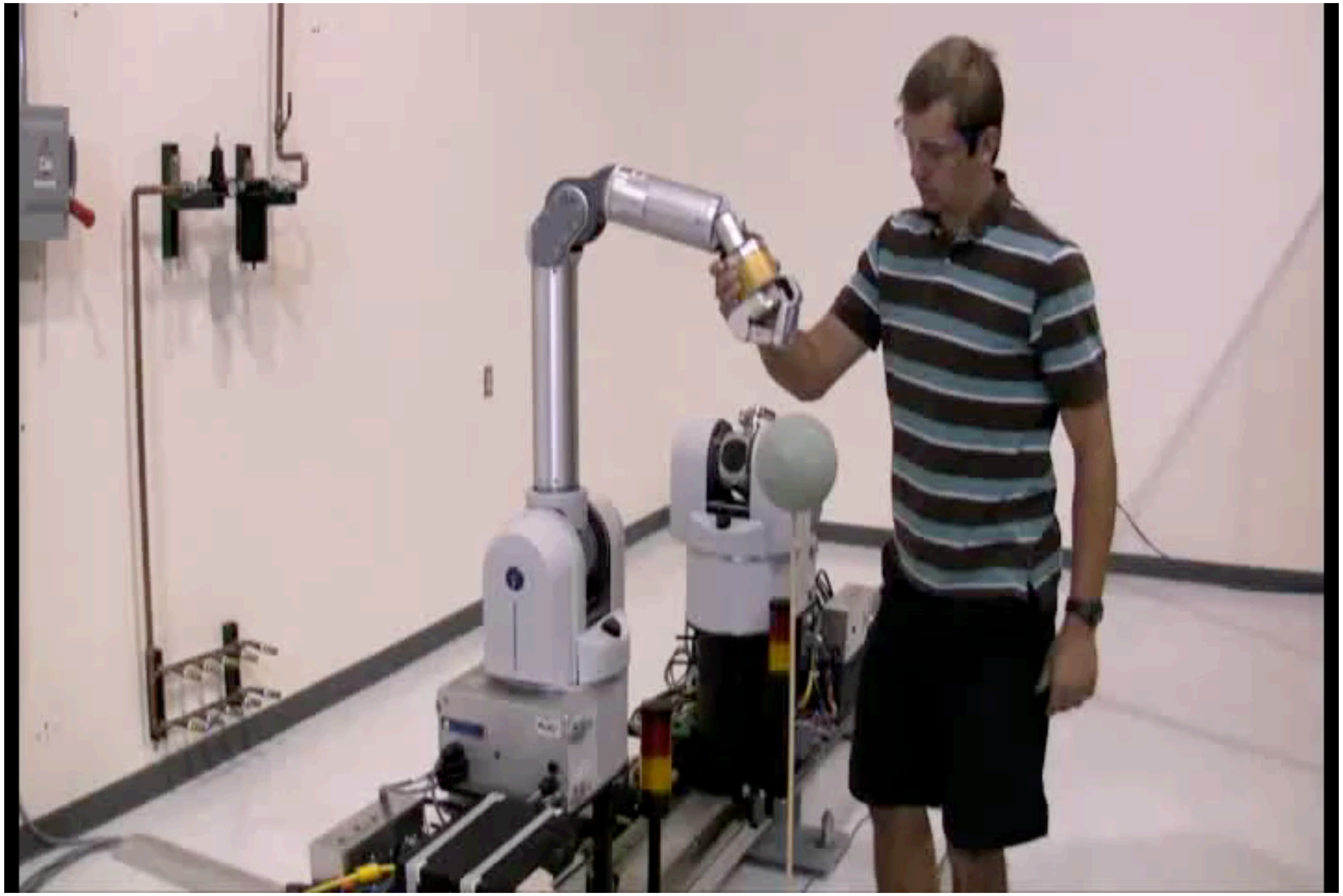
The Lab



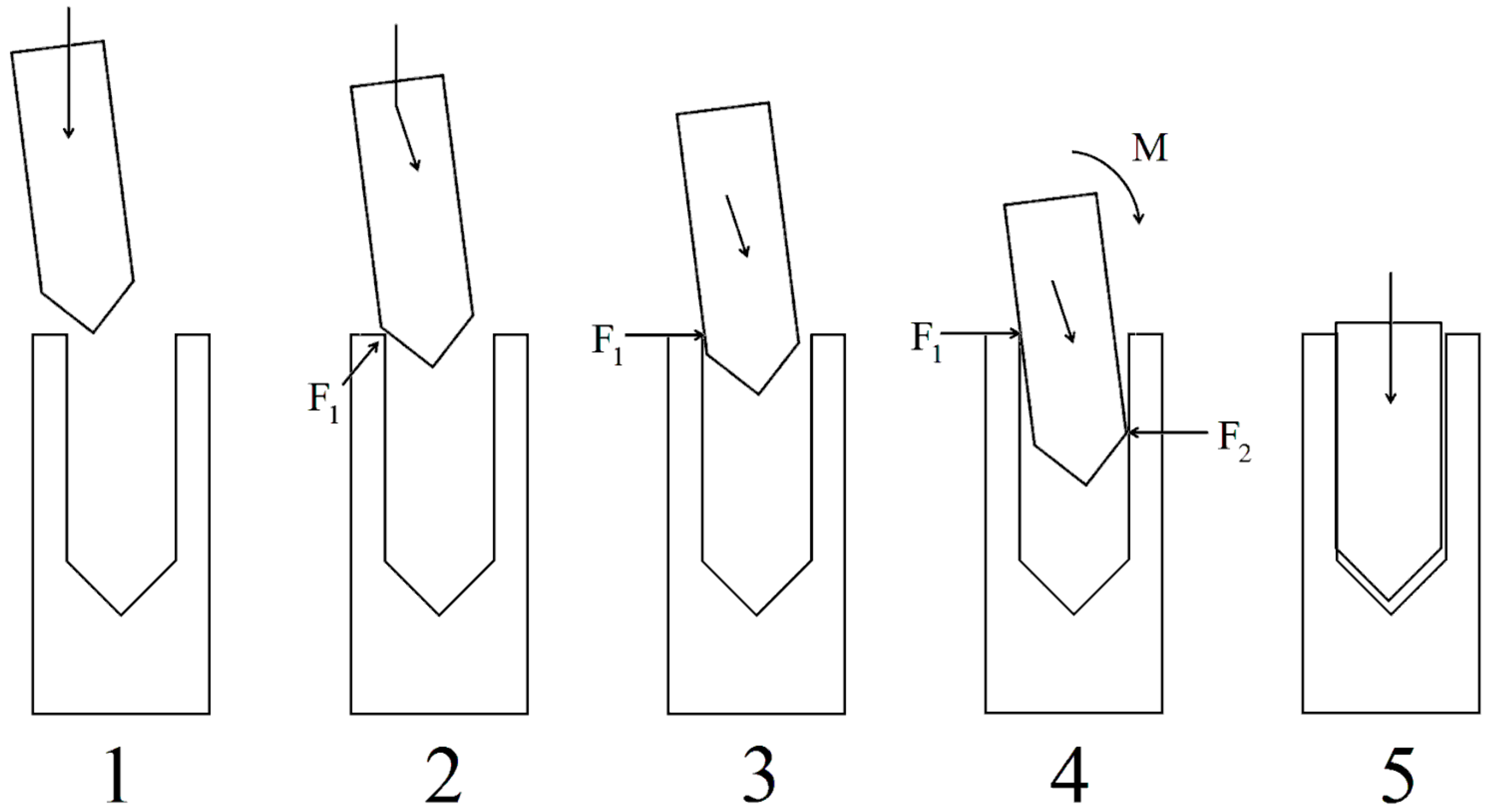
Impedance Control Concept



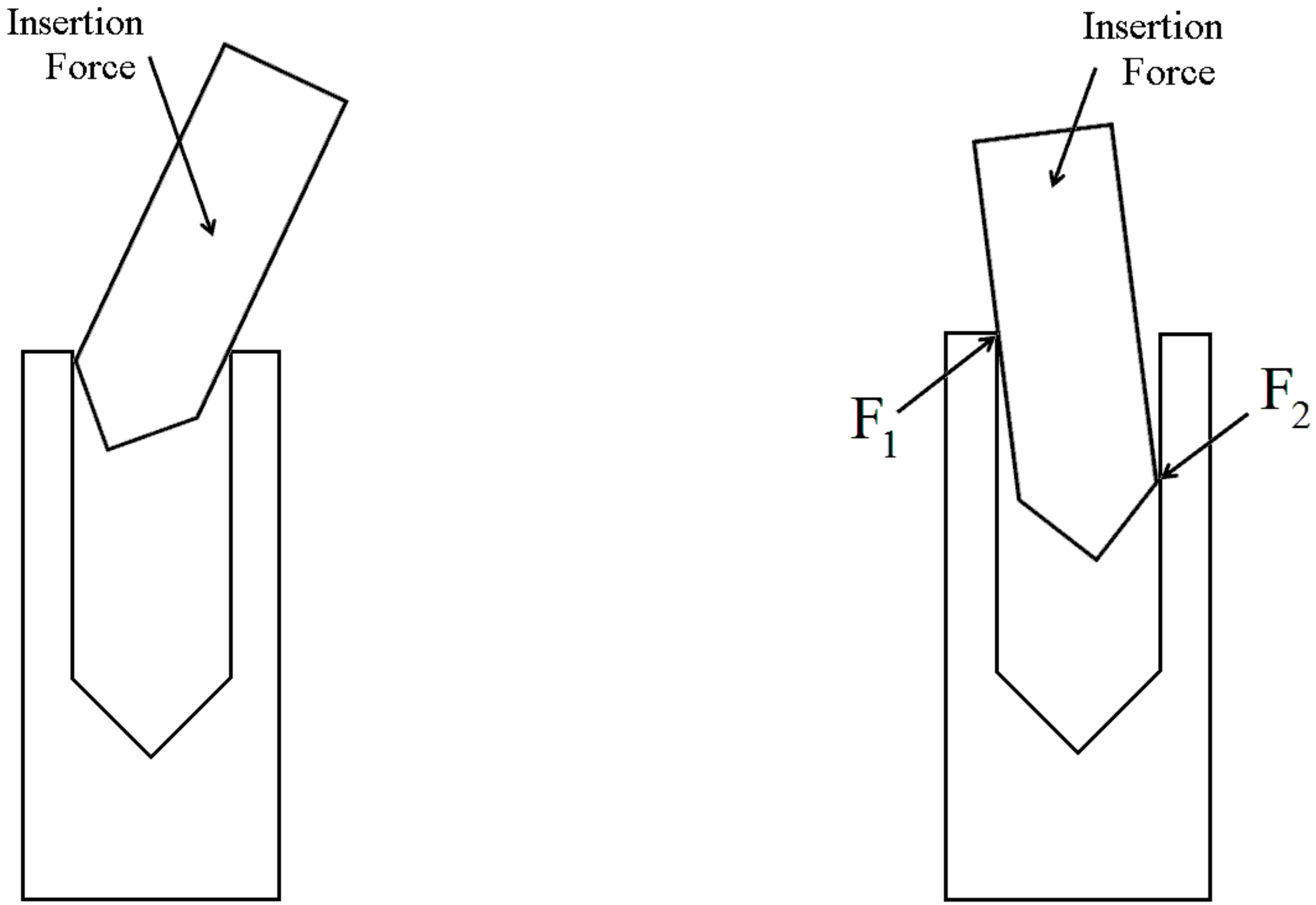
Impedance Control - Sphere Avoidance



Peg in Hole Assembly



Jamming and Wedging



Chamfer Crossing Analysis

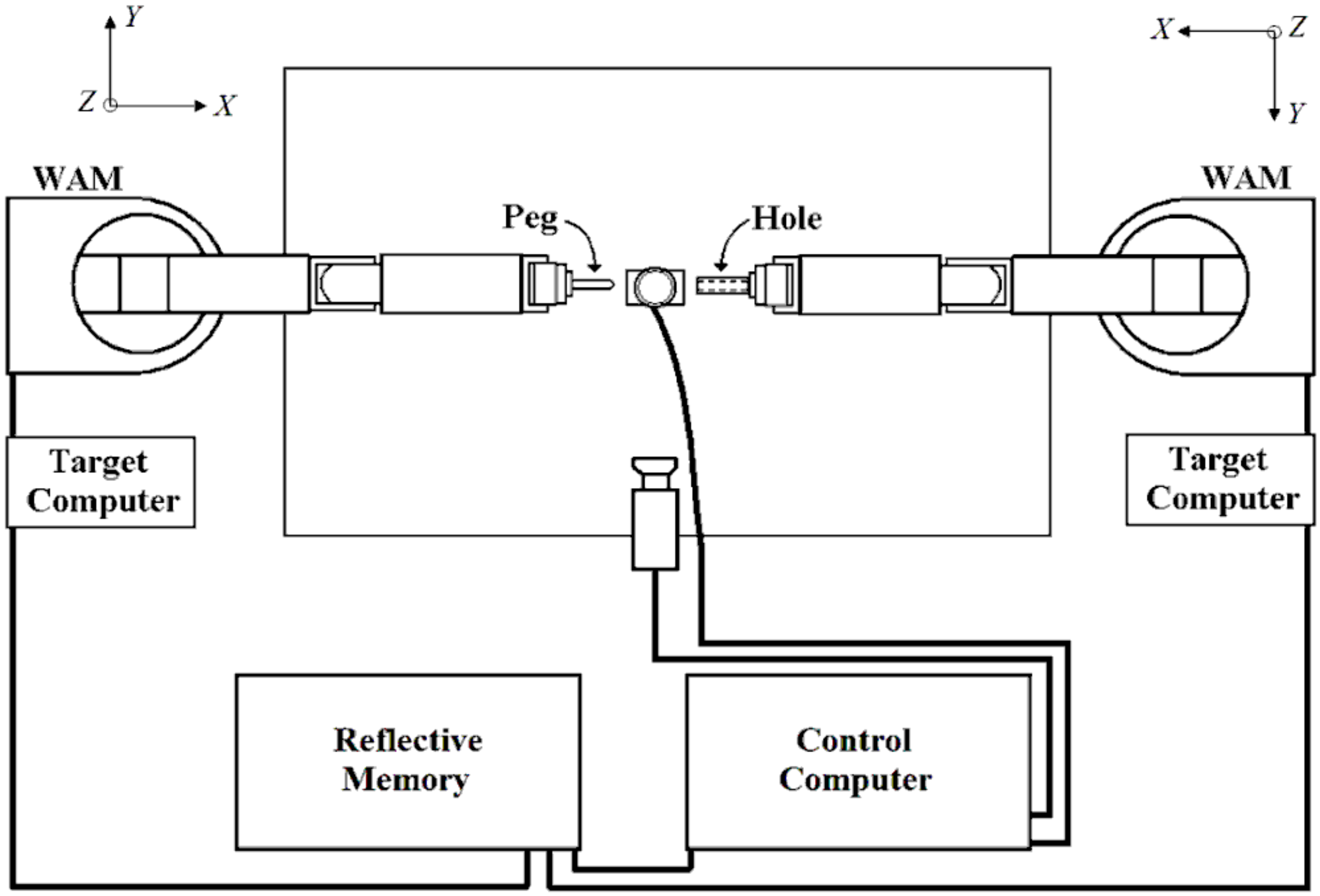
$$F_z = \frac{K_x K_\theta \left(\cos\left(\frac{\pi}{2}-\alpha\right)+\mu\sin\left(\frac{\pi}{2}-\alpha\right)\right)\left(\frac{z}{\tan\left(\frac{\pi}{2}-\alpha\right)}\right)}{\left(K_x L^2 + K_\theta\right)\left(\sin\left(\frac{\pi}{2}-\alpha\right)-\mu\cos\left(\frac{\pi}{2}-\alpha\right)\right)-K_x L r\left(\cos\left(\frac{\pi}{2}-\alpha\right)+\mu\sin\left(\frac{\pi}{2}-\alpha\right)\right)}$$

$$F_x = \frac{-K_x K_\theta \left(\frac{z}{\tan\left(\frac{\pi}{2}-\alpha\right)}\right)\left(\sin\left(\frac{\pi}{2}-\alpha\right)-\mu\cos\left(\frac{\pi}{2}-\alpha\right)\right)}{\left(K_x L^2 + K_\theta\right)\left(\sin\left(\frac{\pi}{2}-\alpha\right)-\mu\cos\left(\frac{\pi}{2}-\alpha\right)\right)-K_x L r\left(\cos\left(\frac{\pi}{2}-\alpha\right)+\mu\sin\left(\frac{\pi}{2}-\alpha\right)\right)}$$

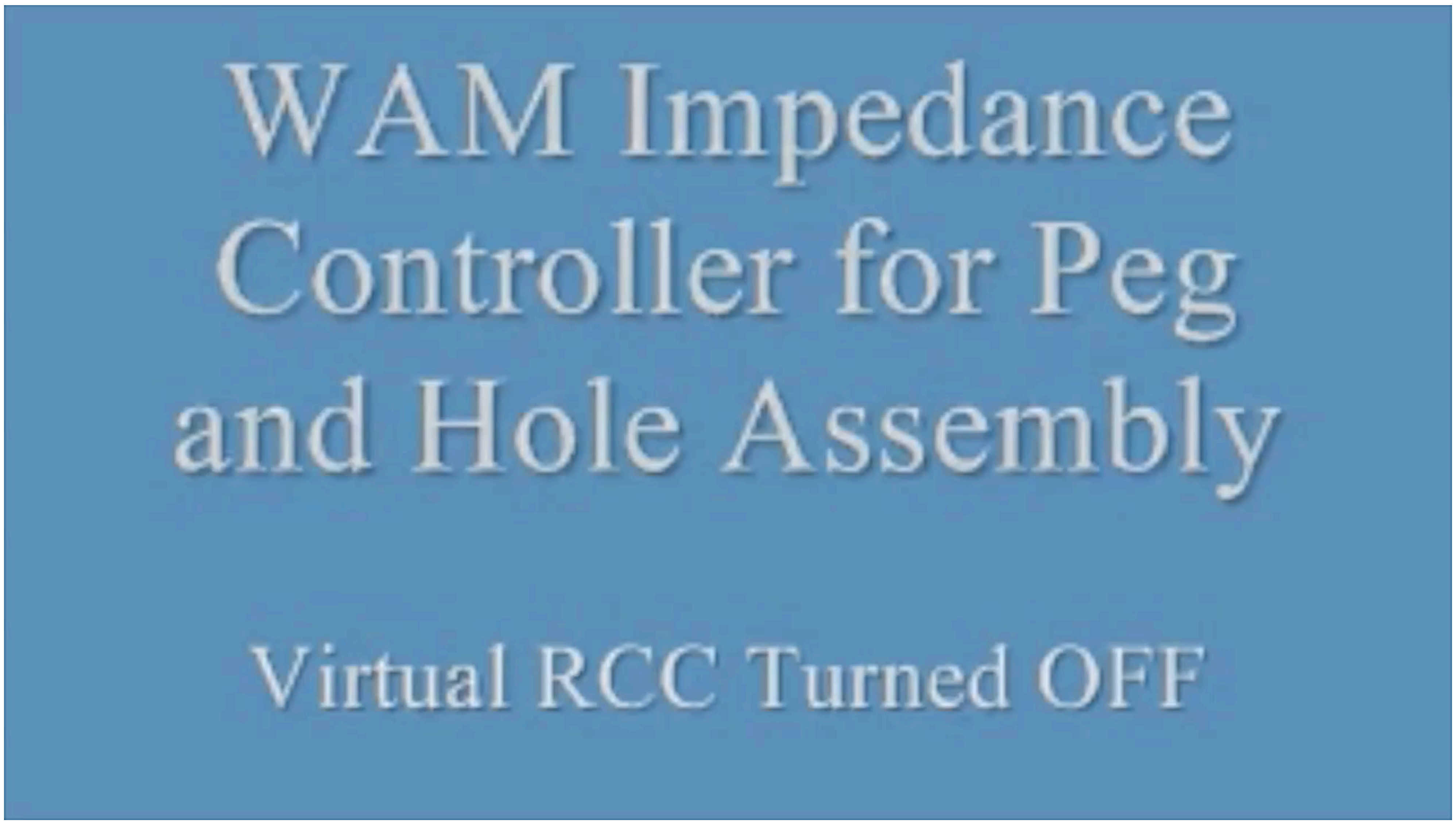
$$M = \frac{K_x L K_\theta \left(\frac{z}{\tan\left(\frac{\pi}{2}-\alpha\right)}\right)\left(\sin\left(\frac{\pi}{2}-\alpha\right)-\mu\cos\left(\frac{\pi}{2}-\alpha\right)\right)}{\left(K_x L^2 + K_\theta\right)\left(\sin\left(\frac{\pi}{2}-\alpha\right)-\mu\cos\left(\frac{\pi}{2}-\alpha\right)\right)-K_x L r\left(\cos\left(\frac{\pi}{2}-\alpha\right)+\mu\sin\left(\frac{\pi}{2}-\alpha\right)\right)}$$

$$-\frac{K_x K_\theta \left(\frac{z}{\tan\left(\frac{\pi}{2}-\alpha\right)}\right)\left(L\left(\sin\left(\frac{\pi}{2}-\alpha\right)-\mu\cos\left(\frac{\pi}{2}-\alpha\right)\right)-r\left(\cos\left(\frac{\pi}{2}-\alpha\right)+\mu\sin\left(\frac{\pi}{2}-\alpha\right)\right)\right)}{\left(K_x L^2 + K_\theta\right)\left(\sin\left(\frac{\pi}{2}-\alpha\right)-\mu\cos\left(\frac{\pi}{2}-\alpha\right)\right)-K_x L r\left(\cos\left(\frac{\pi}{2}-\alpha\right)+\mu\sin\left(\frac{\pi}{2}-\alpha\right)\right)}$$

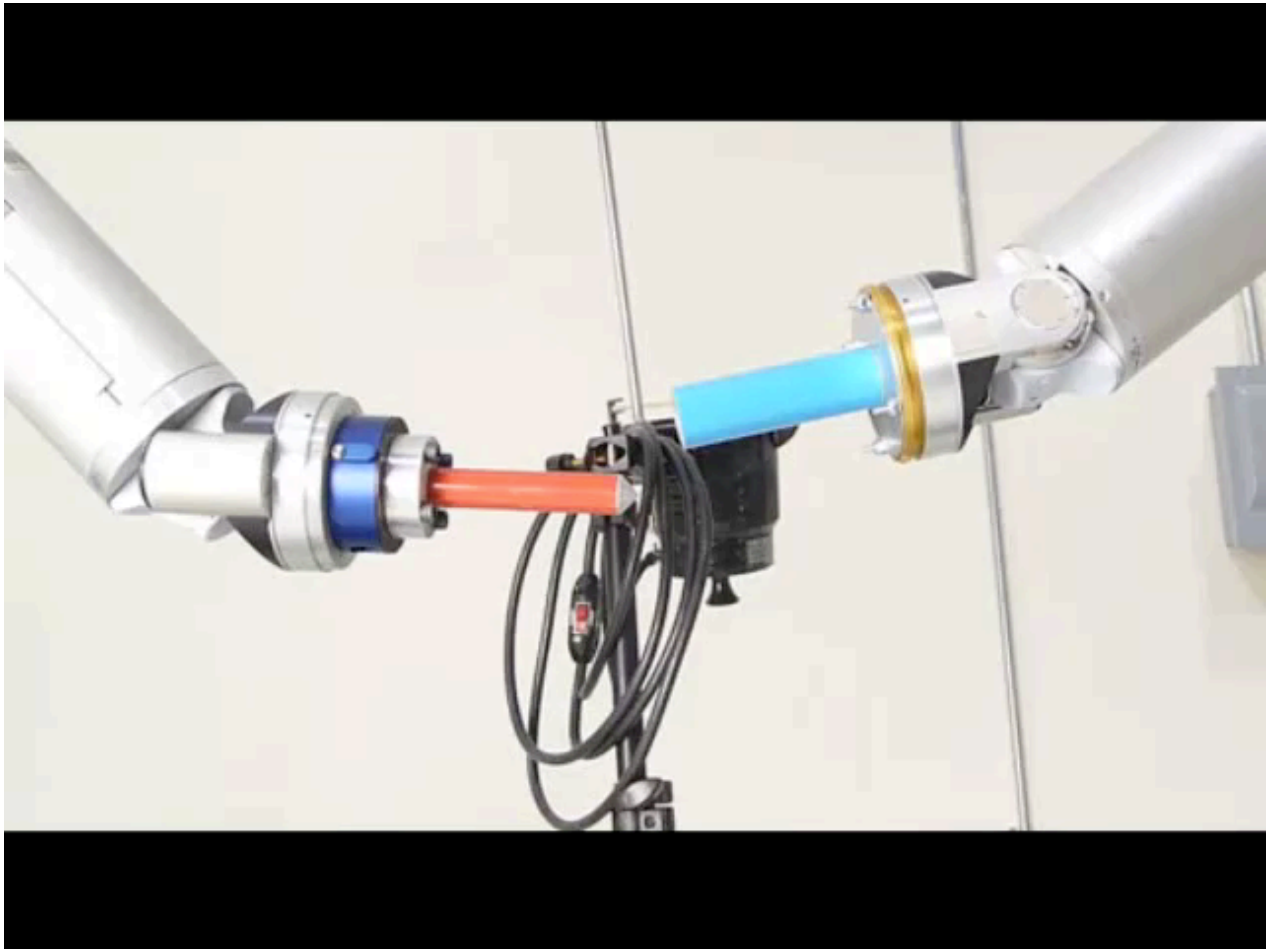
Lab Schematic



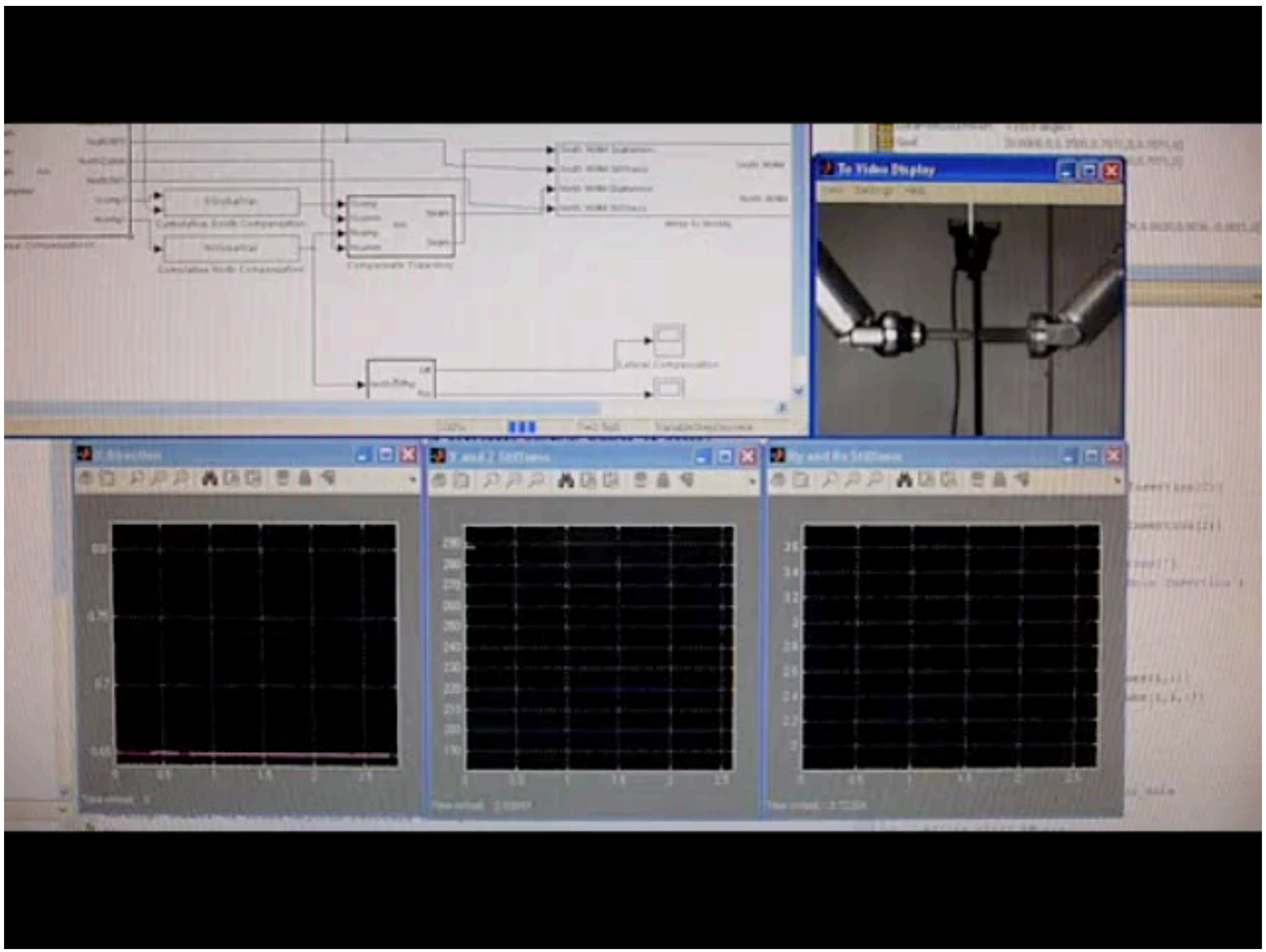
Failure Example



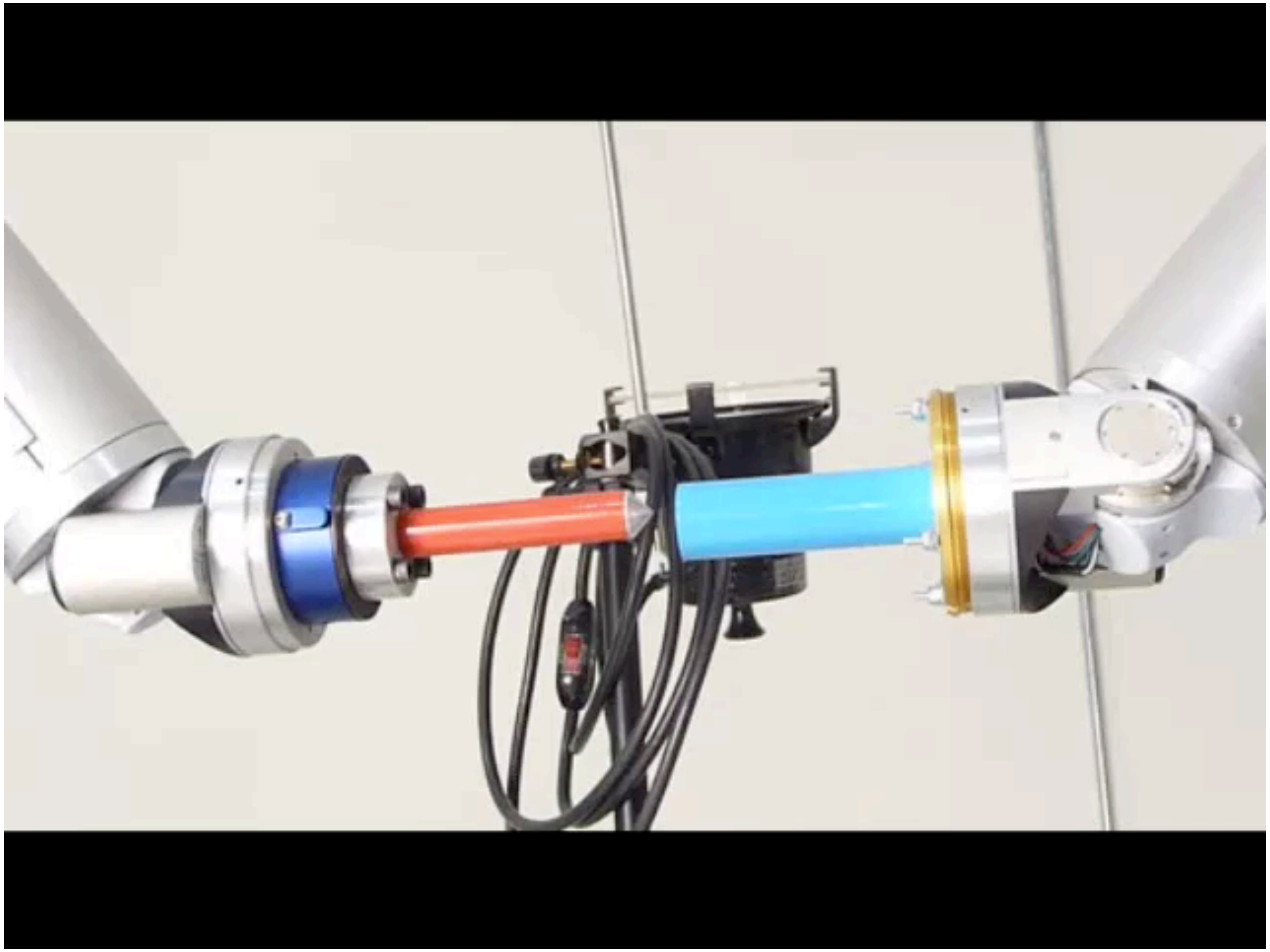
3 Second Insertion



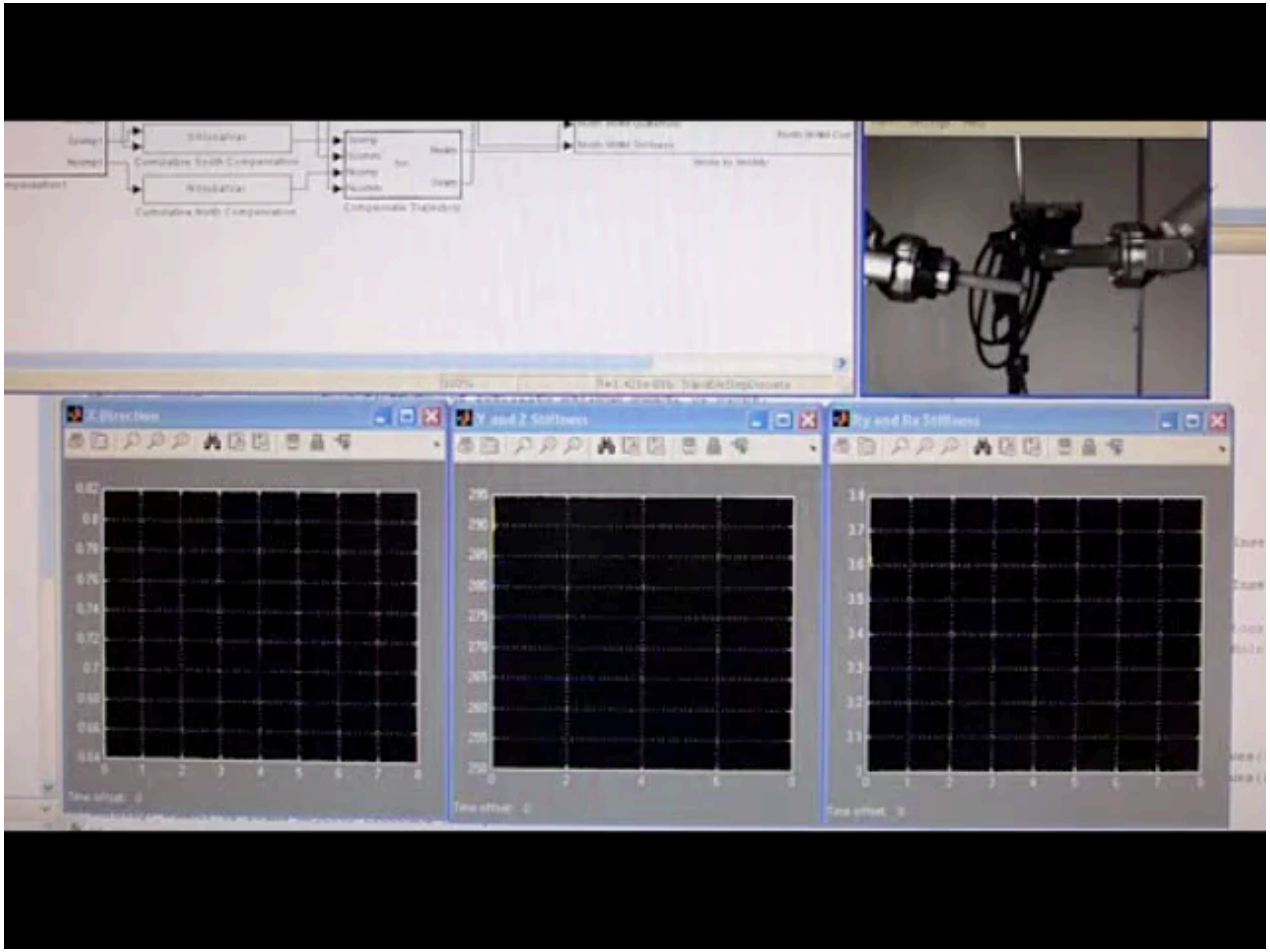
2 Seconds - No Jam



1 Second Insertion



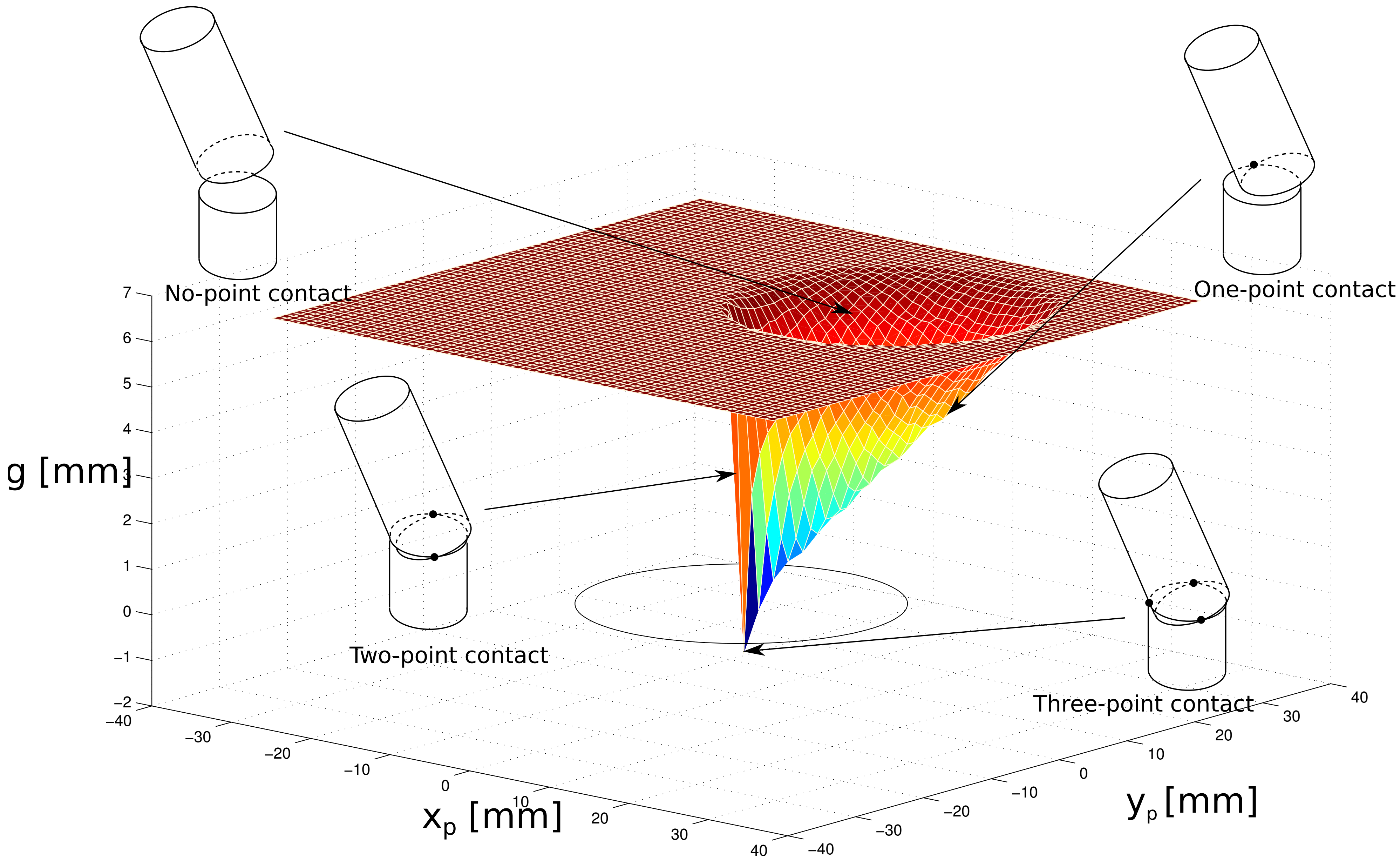
Clear Major Jam



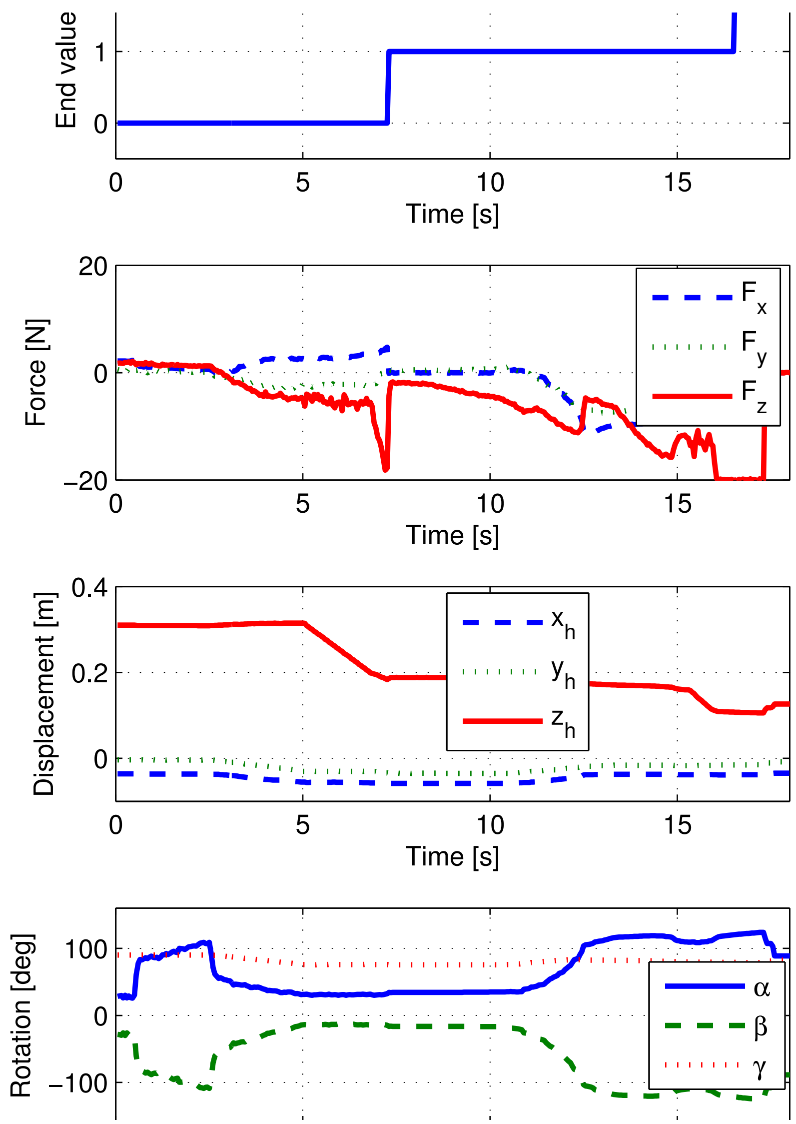
Assembly Planning

- Matteo Gilli, Politecnico di Torino
- Attractive regions + decomposition of 6-D configuration space
- Impedance controller
- Use of "events" rather than time to plan sequence

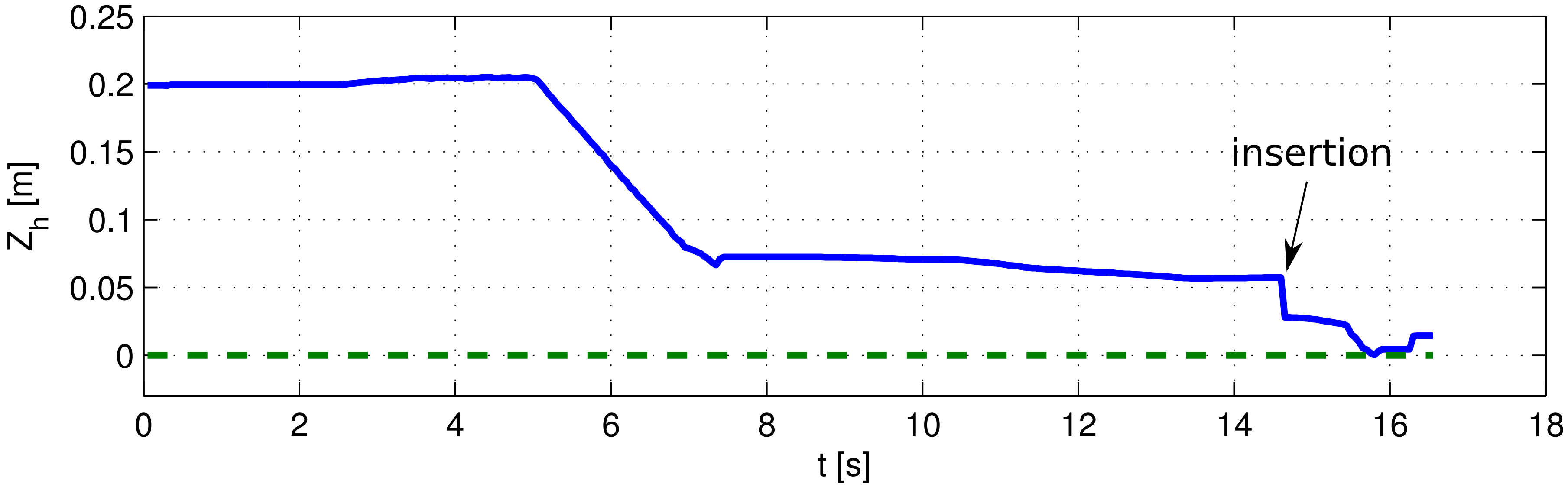
Attractive Region



States not Time

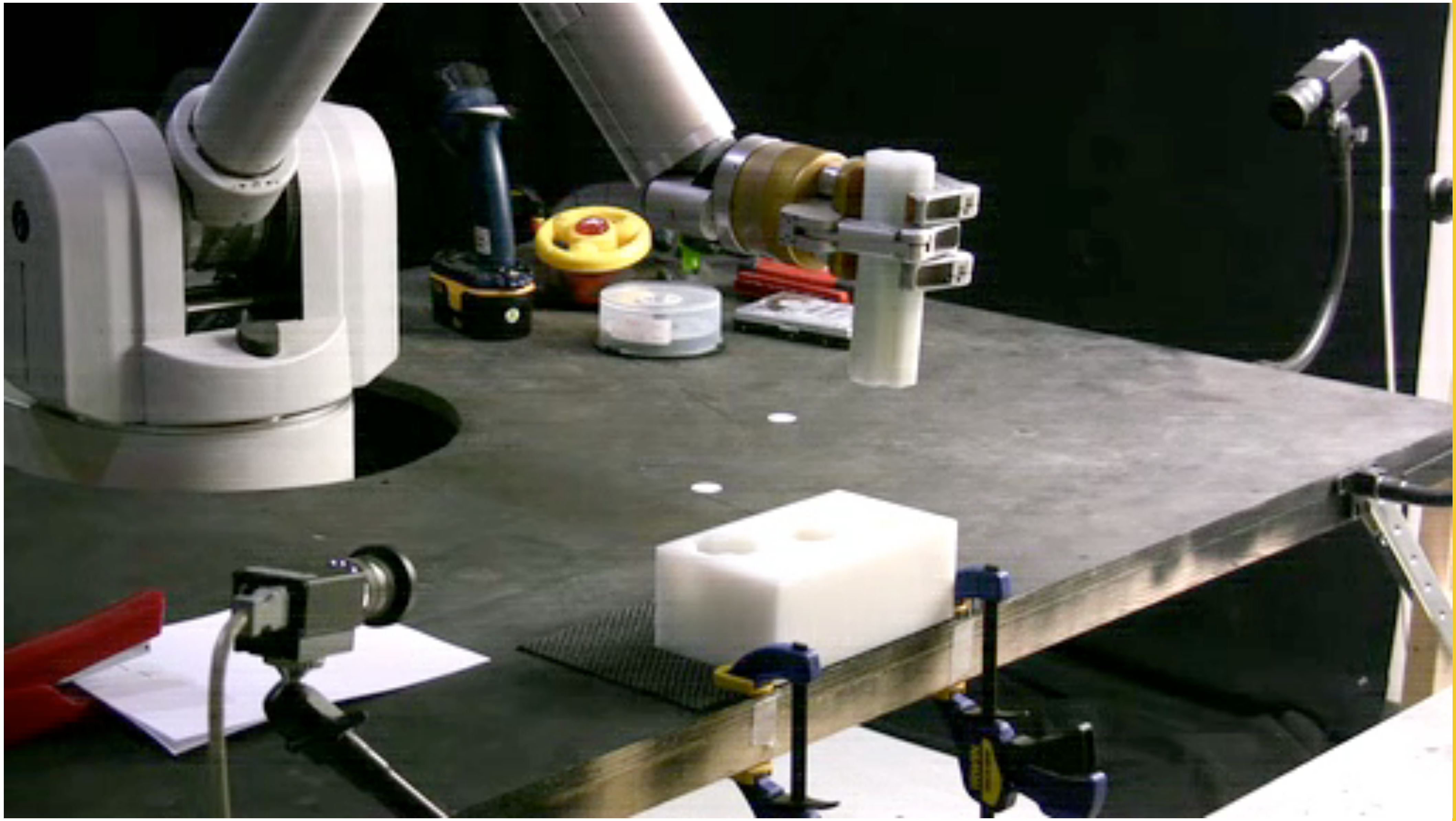


Insertion Progress

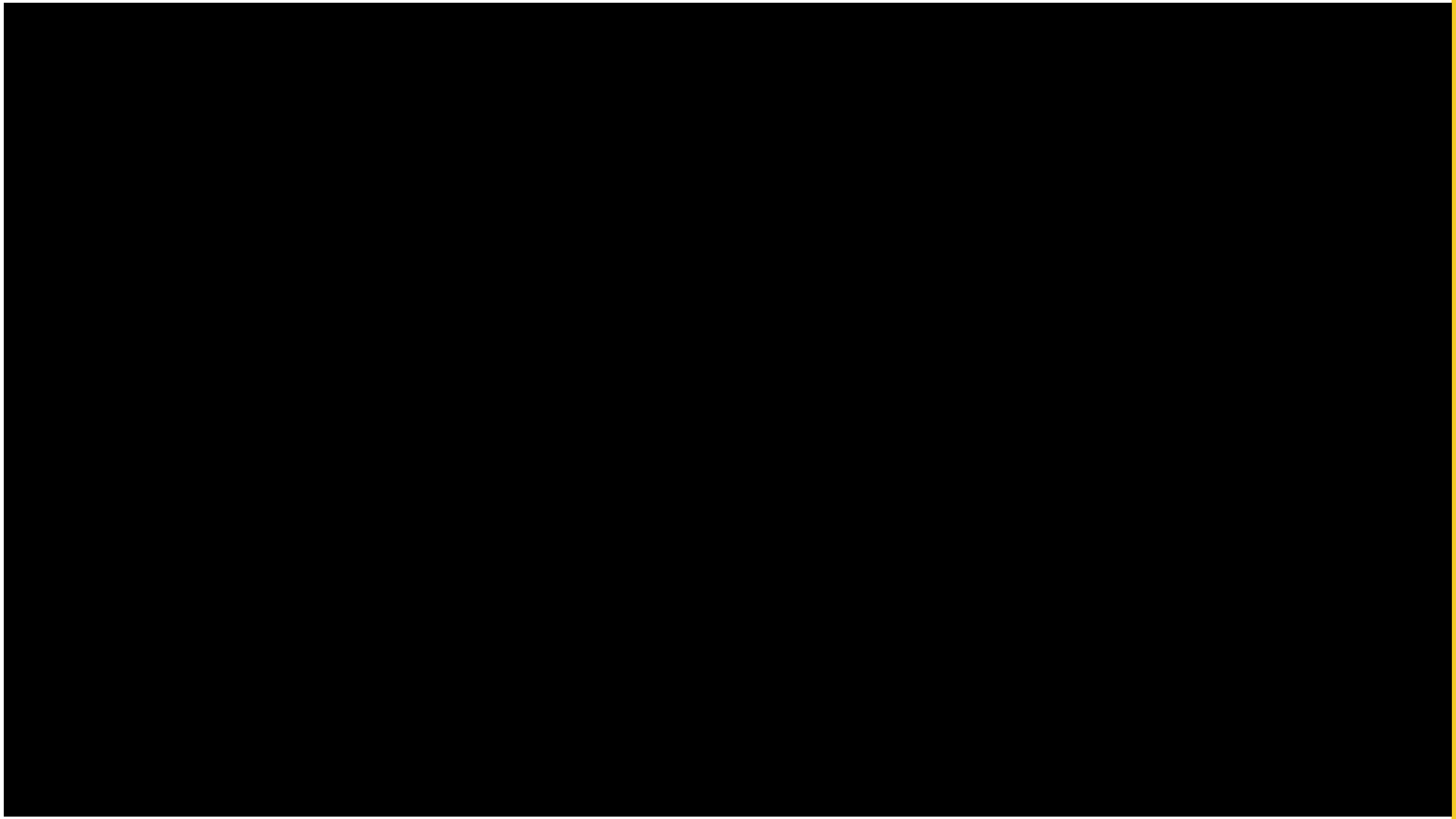


Grasp Peg

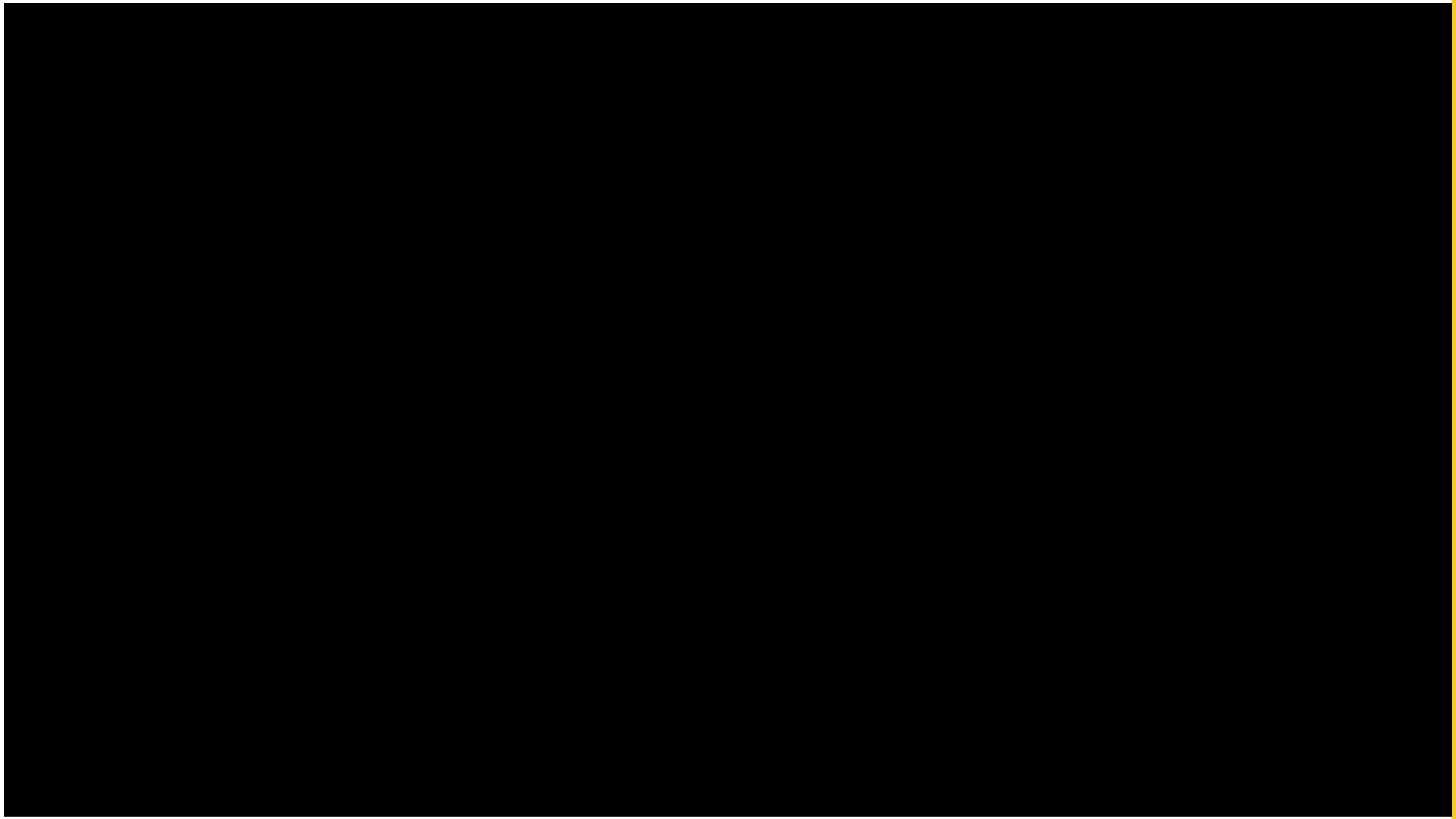
Insert Peg



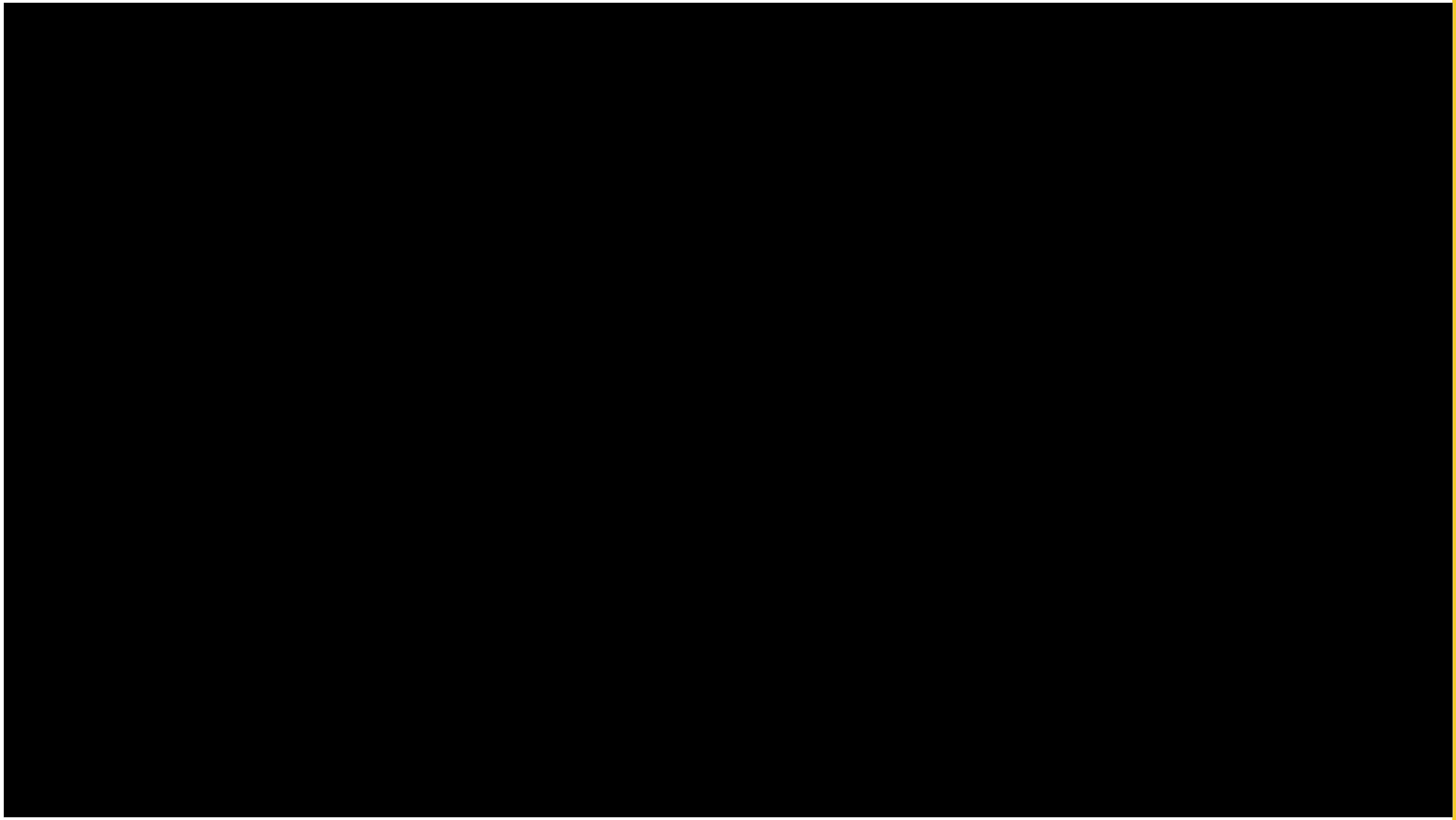
Staple and Drag



Key Insertion



Open Door



Sponsors

- DOE
  - This work is supported by DOE Grant #DE-FG52-2004NA25590 awarded to the UNM Mfg. Engr. Program. Principal Investigators are John Wood, Ron Lumia, and Greg Starr.
- NSF
  - This material is based upon work supported by the National Science Foundation under Grant No. IIS-0911133, CNS-0549563, and IIS-0329106.

Conclusions

- Non-impedance control algorithms
  - swing-free
  - laser tag
- Impedance control algorithms
  - assembly
  - staple and drag
  - key insertion
  - door opening

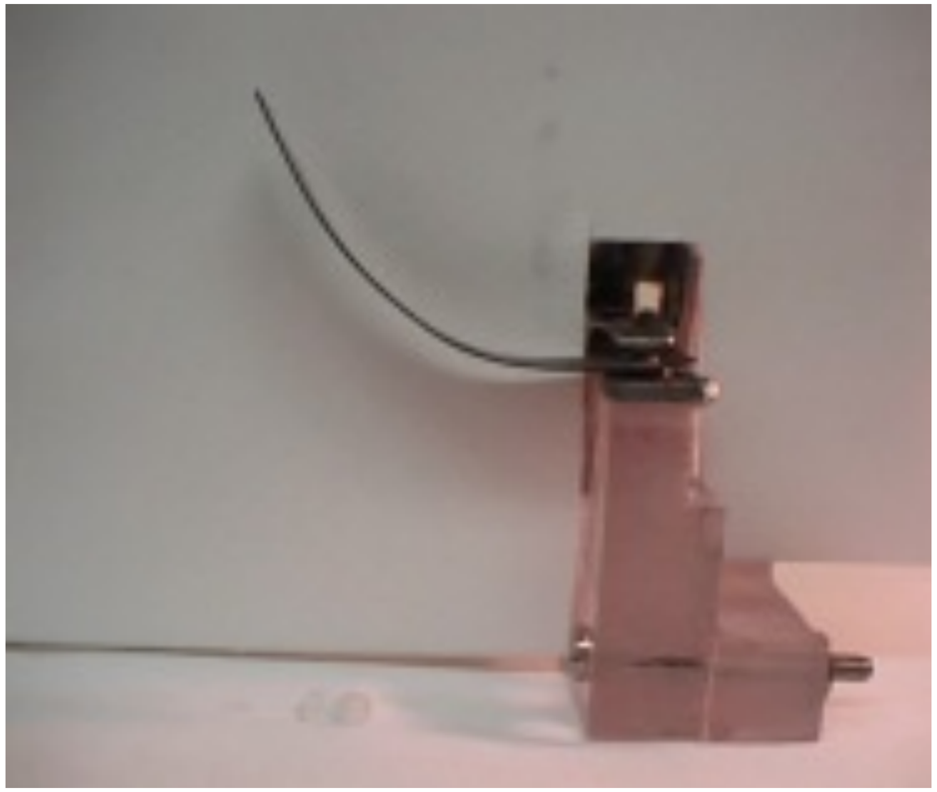
Questions

?

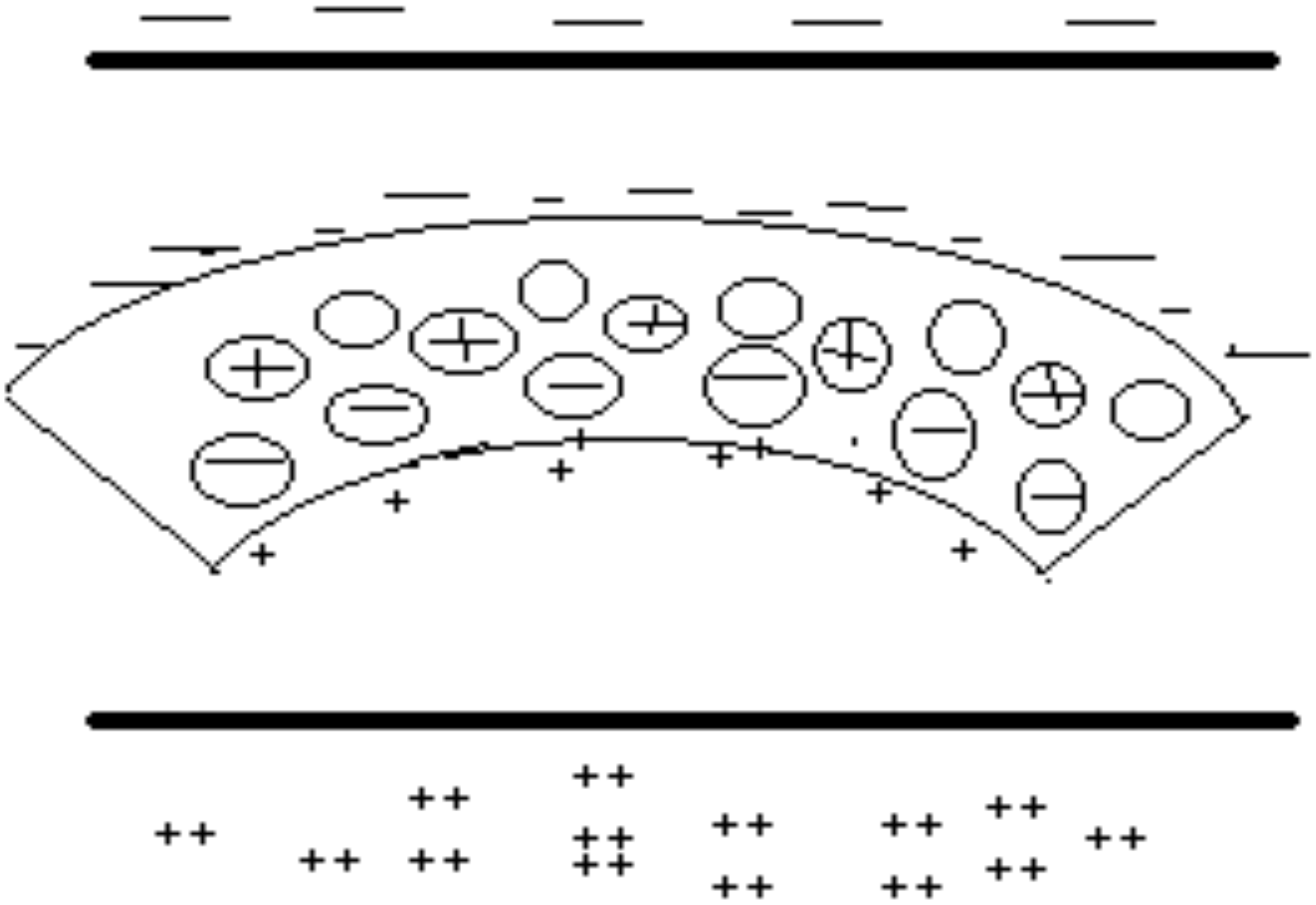
Robotics: Small

- Ionic Polymer Metal Composite (IPMC) microgrippers
- Biological applications, e.g., cell micromanipulation

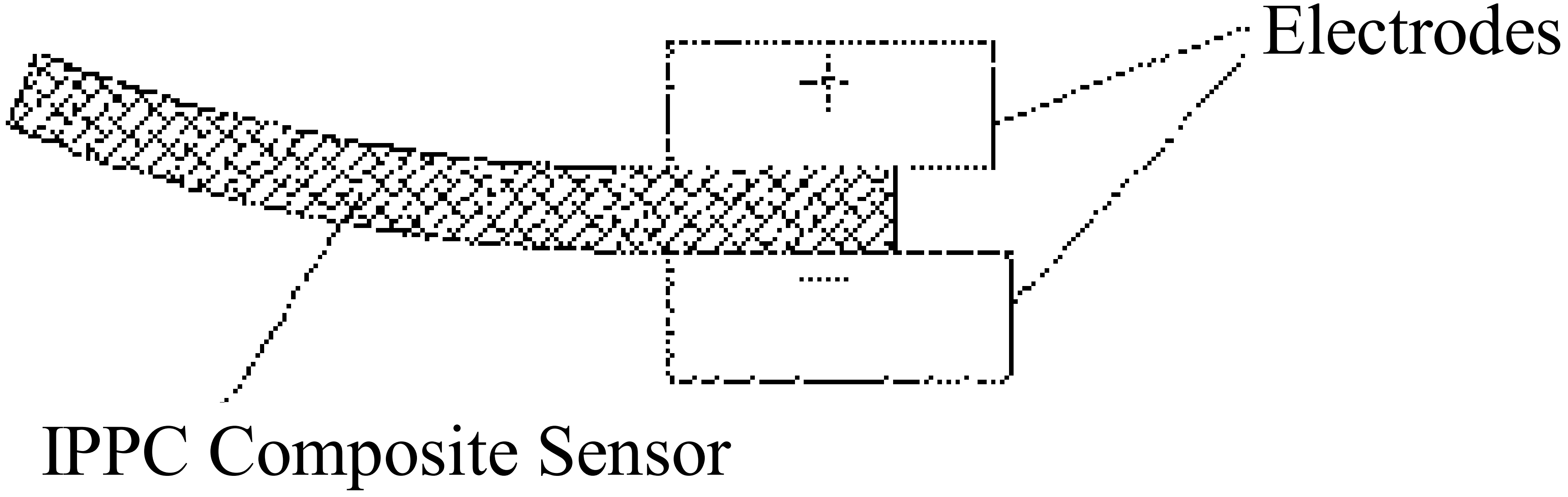
IPMC Microgrippers



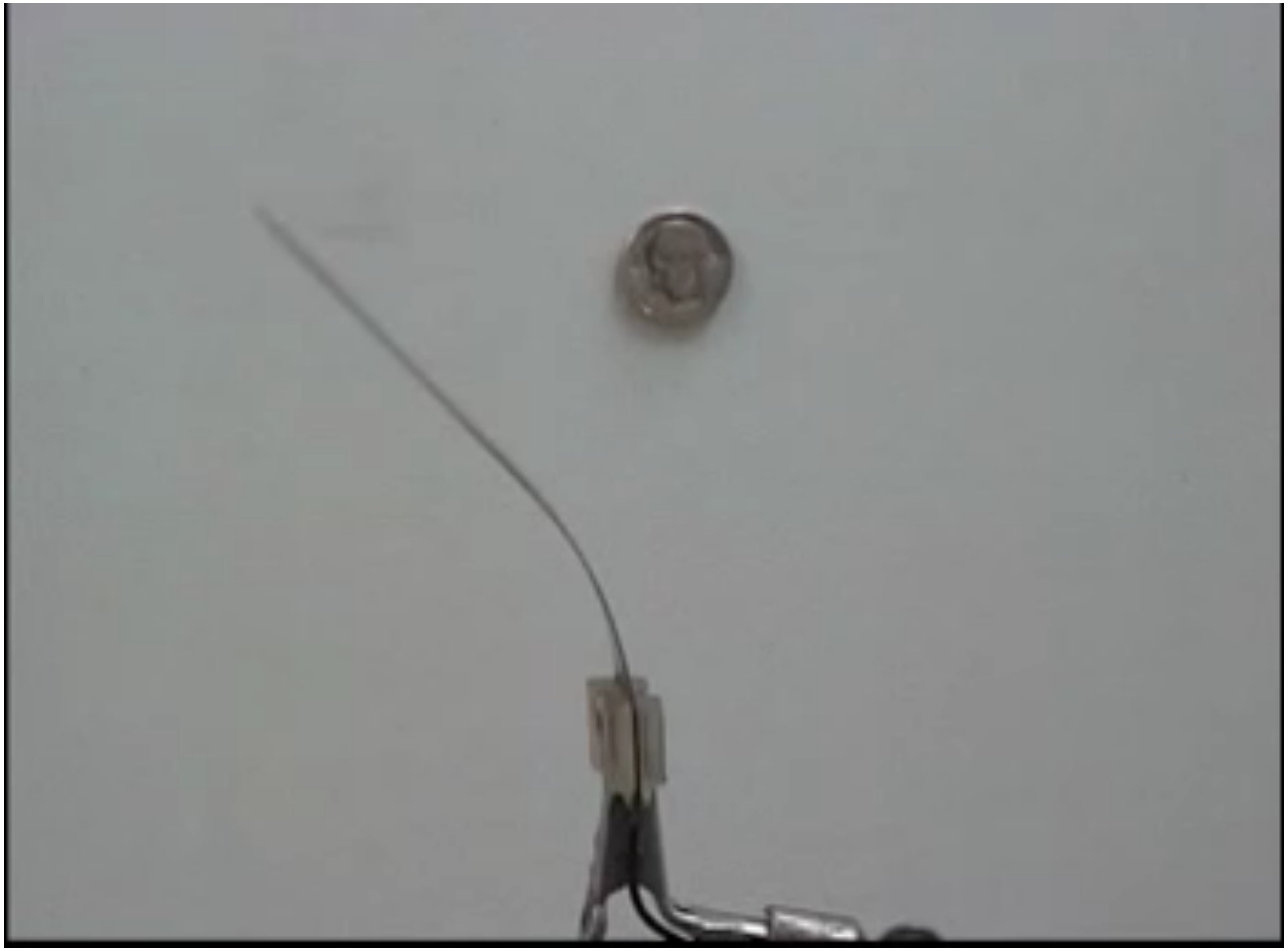
IPMC Actuators



IPMC Sensors



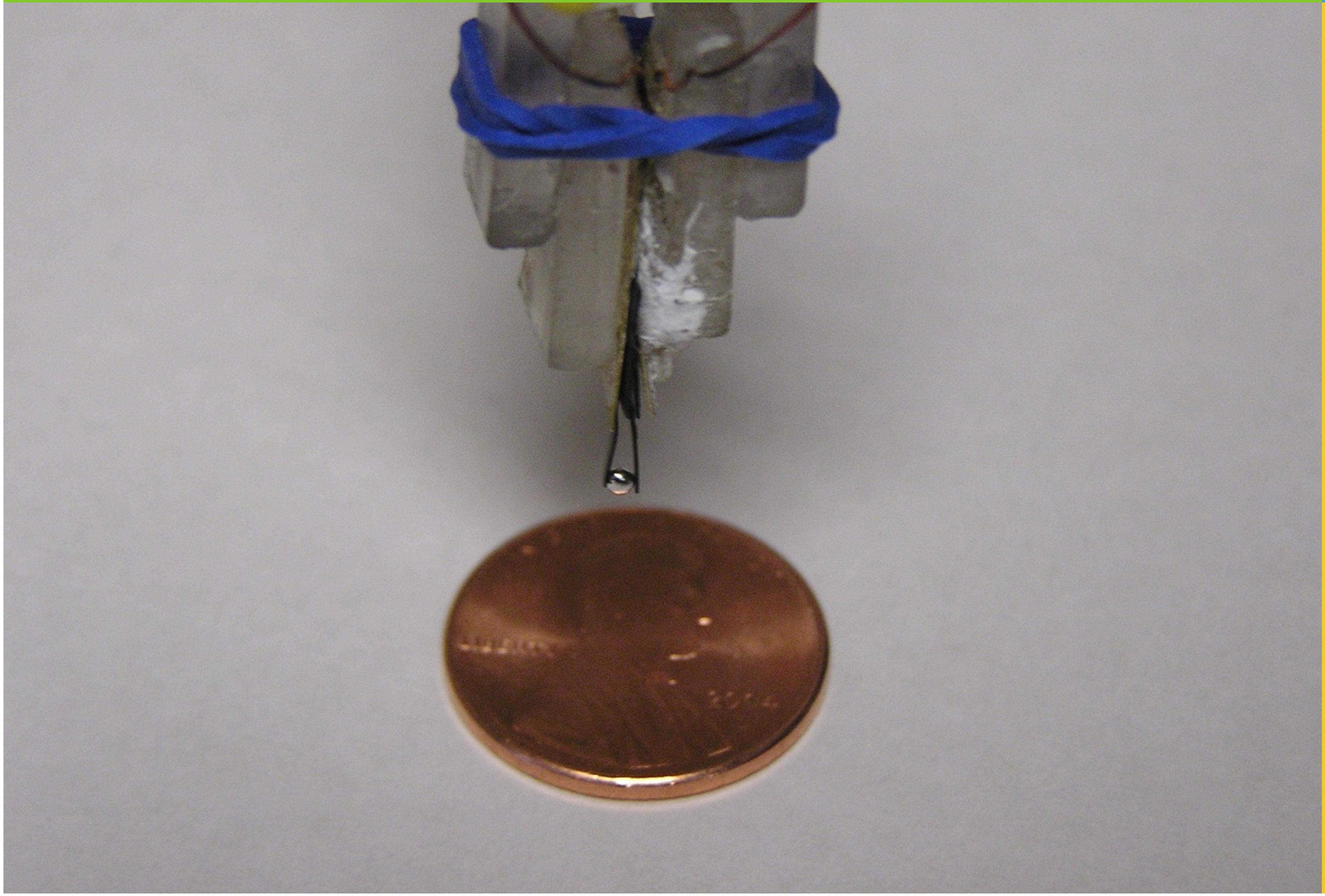
Macro-sized IPMC



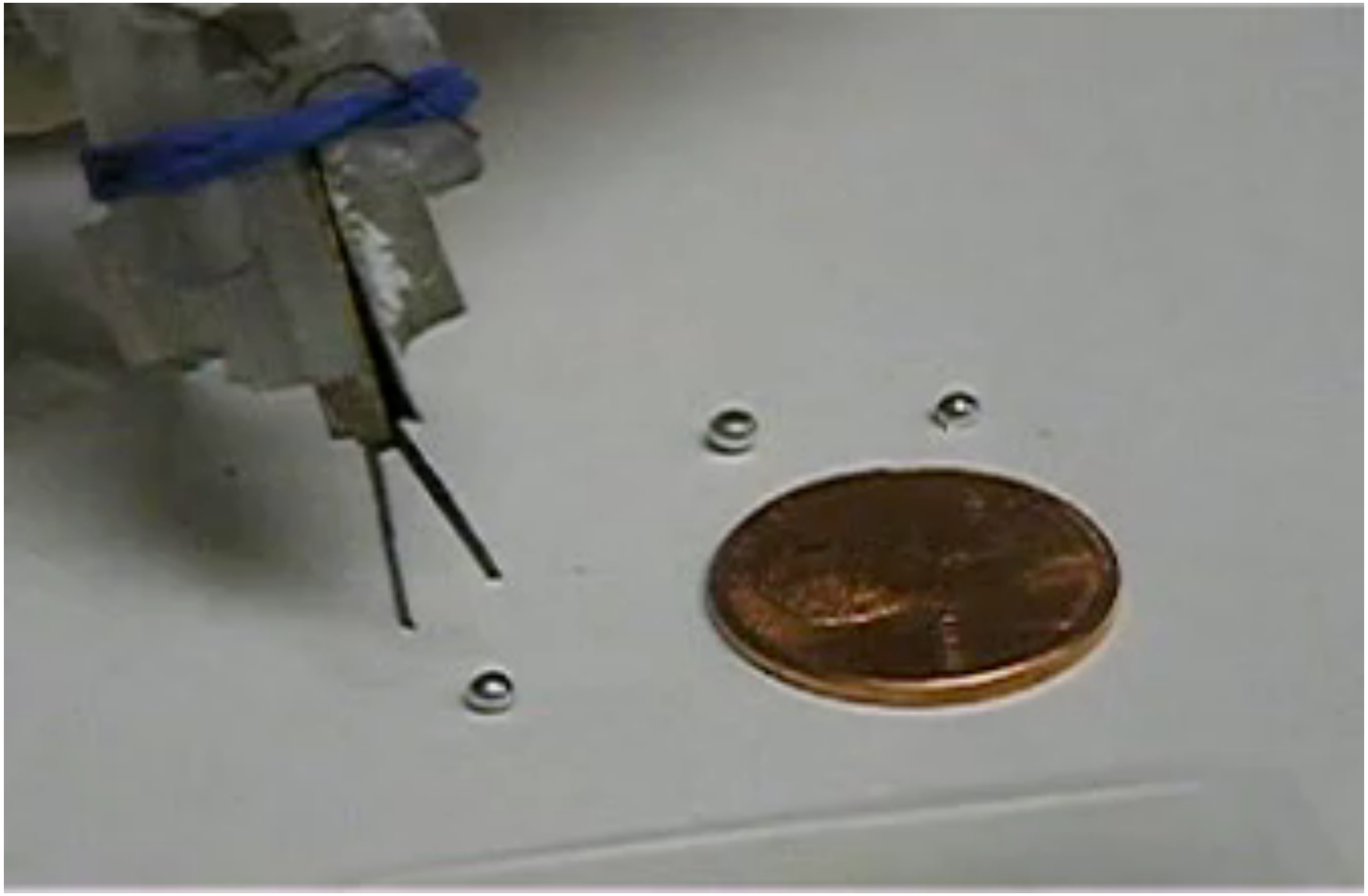
Resonance - Macro

First Microgripper

Rigid Object Micromanipulation



Rigid Object Micromanipulation



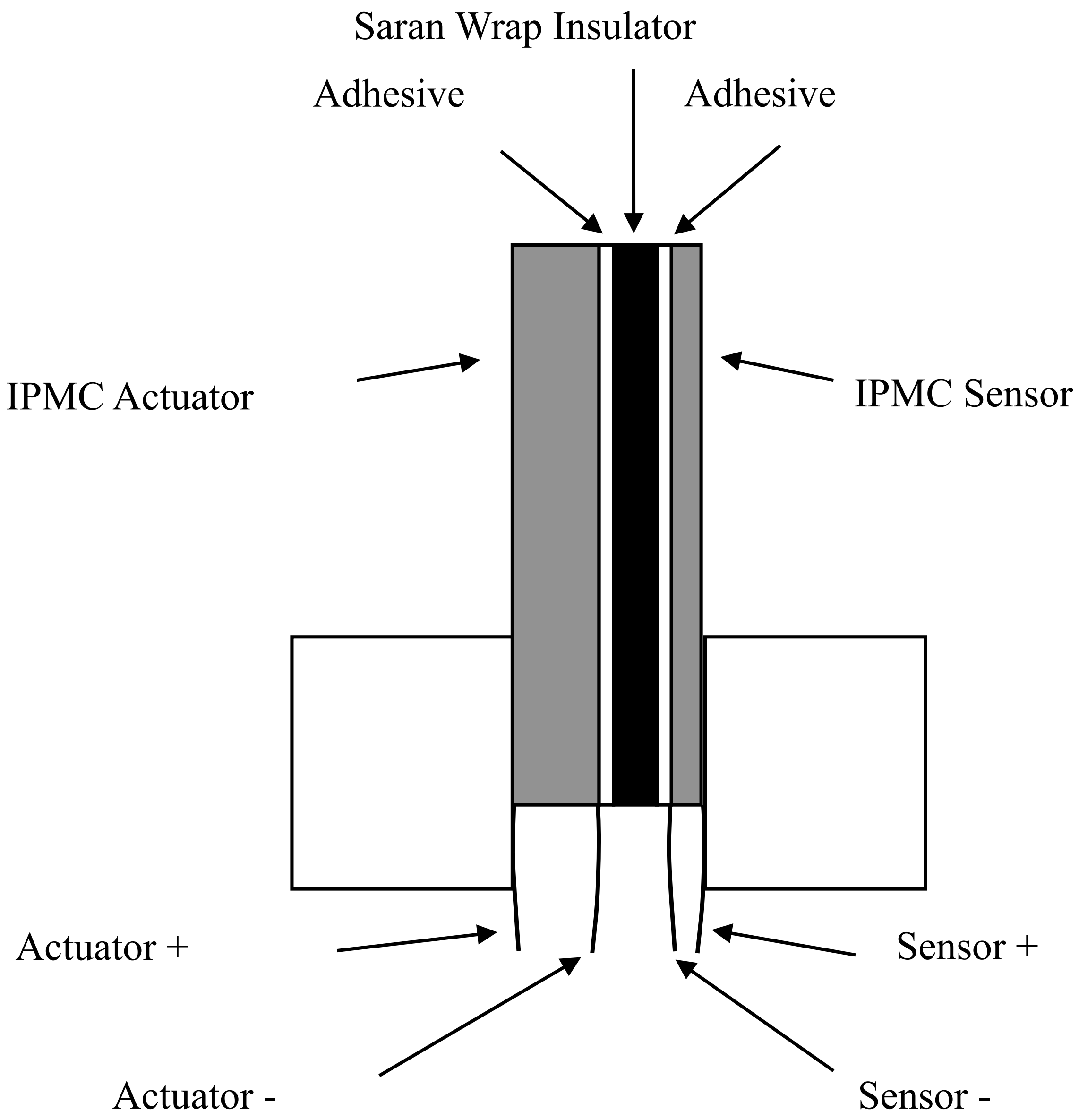
Flexible Object Micromanipulation

Microgripping: Flexible Object

IPMC Microgripper

- IPMC suited for microgrippers
  - IPMC sensor and actuator
  - IPMC weak
  - Gravity for small objects also weak
- IPMC suited to bio applications
  - Compliant - will not damage cells
  - Low voltage actuation
  - Work in dry or wet environments
    - Avoids hydrolysis in wet environments

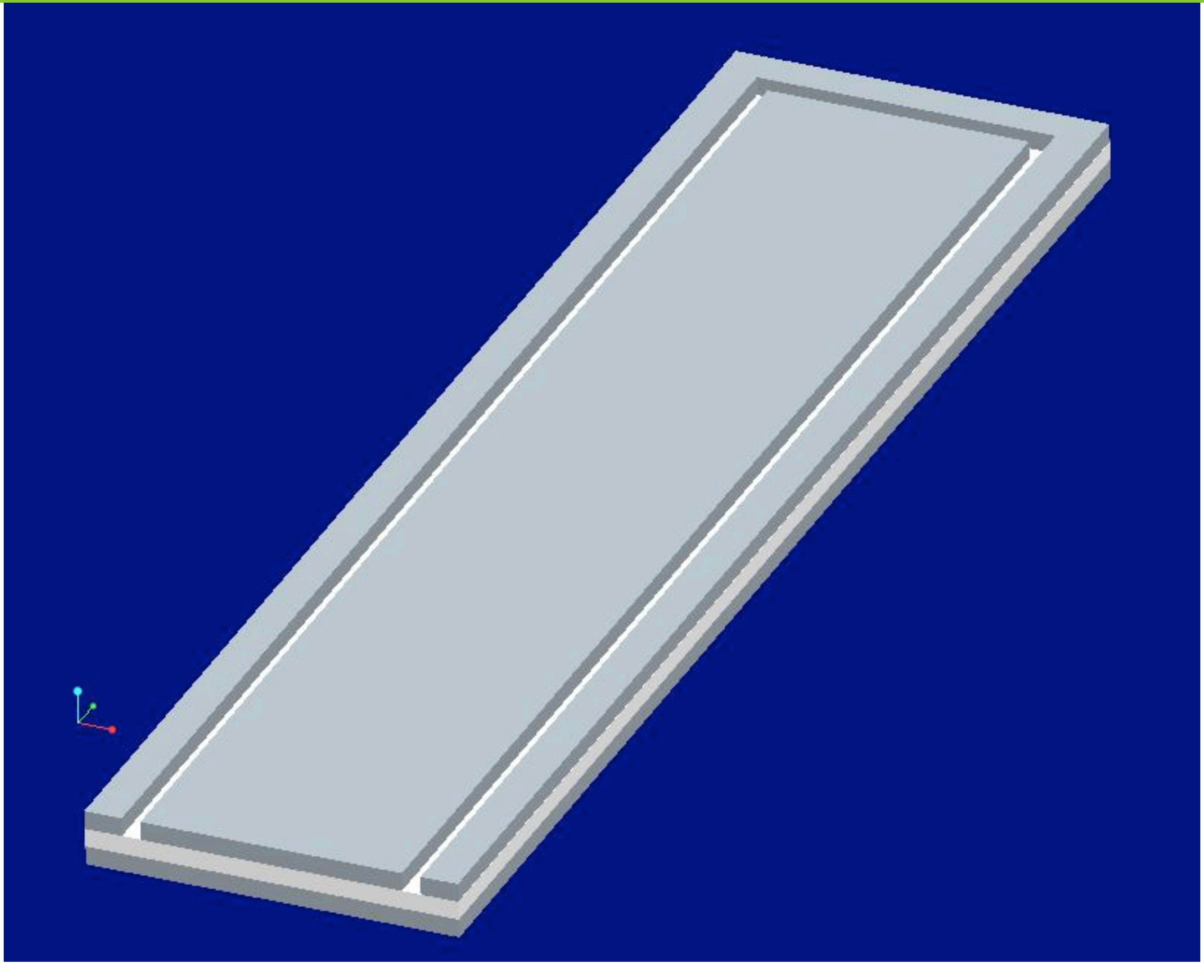
First Approach



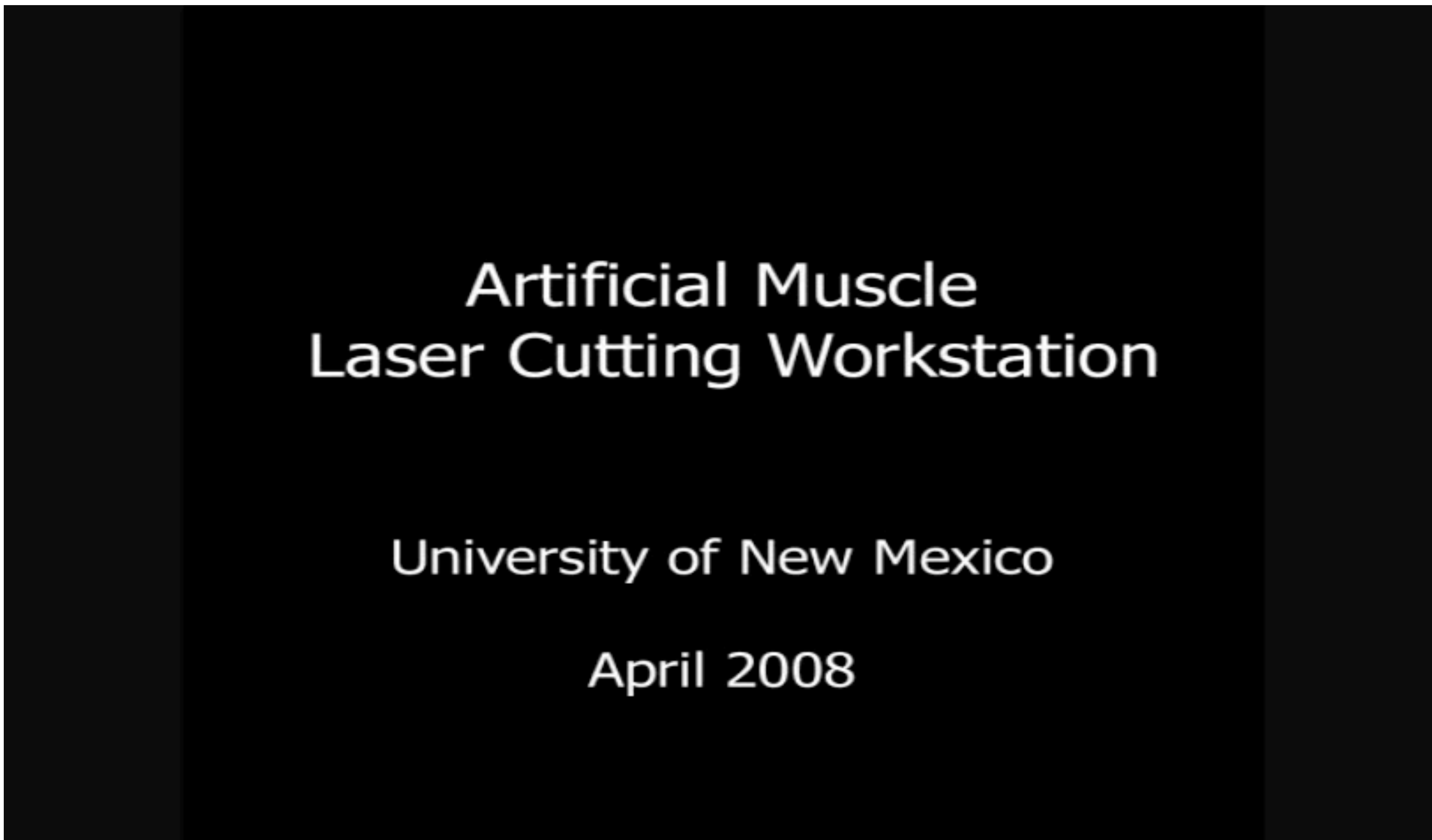
Sensing Problem

- IPMC sensing using charge works well at macro-scale
- For microgrippers
  - Small area
  - Low charge
  - Low voltage - microvolts
  - Cannot extract signal from noise

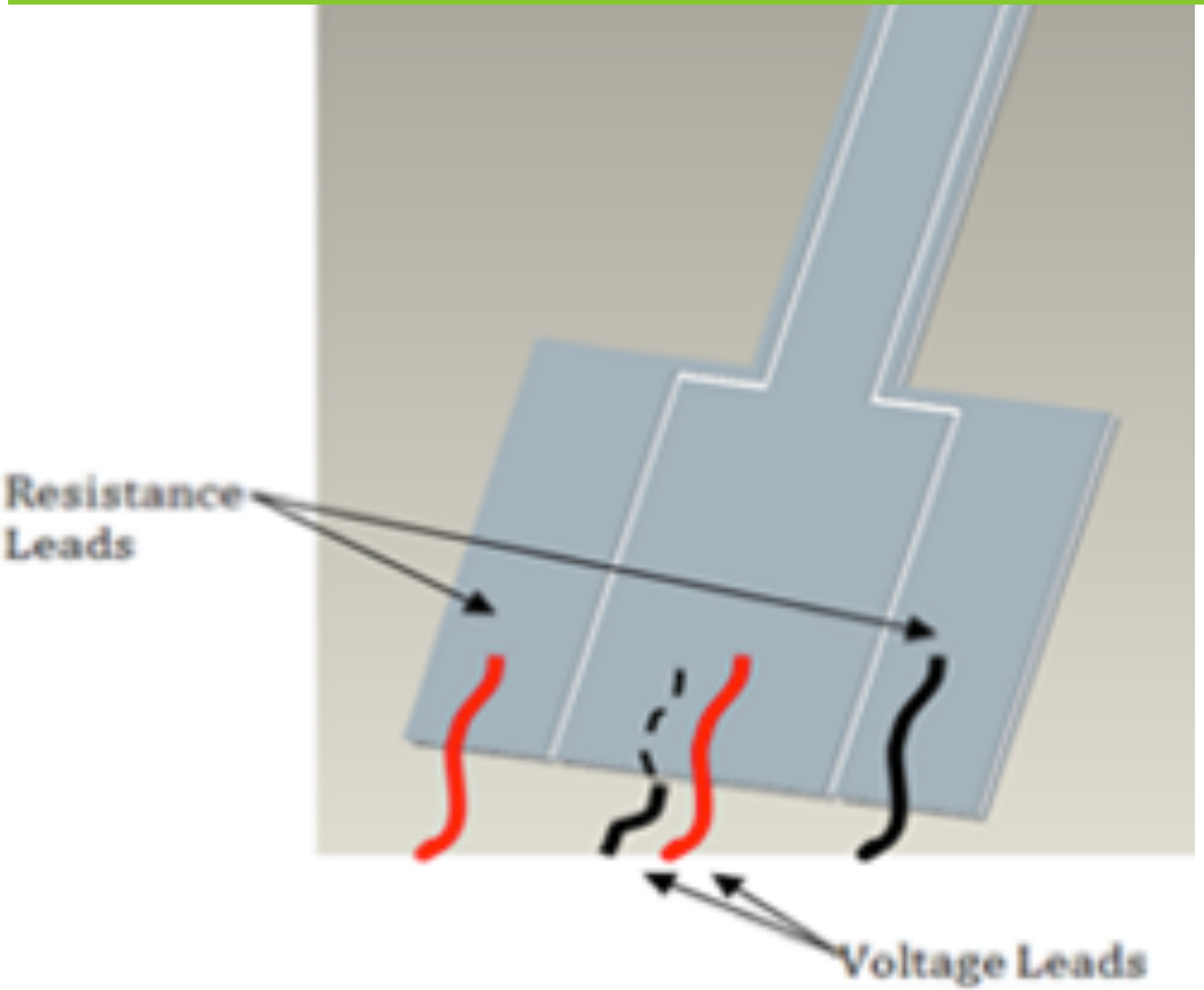
New Approach to Sensing



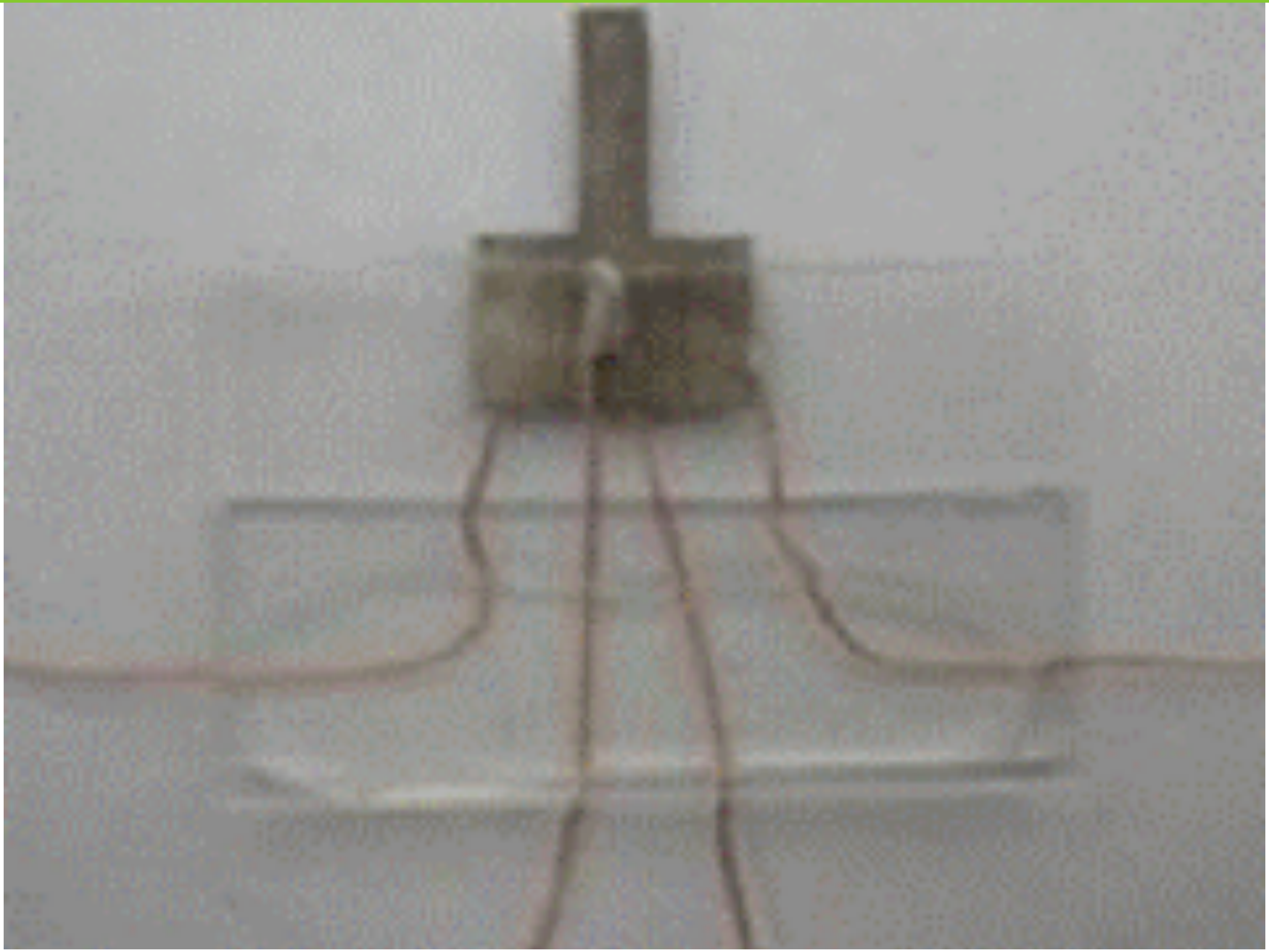
Cutting the Trench



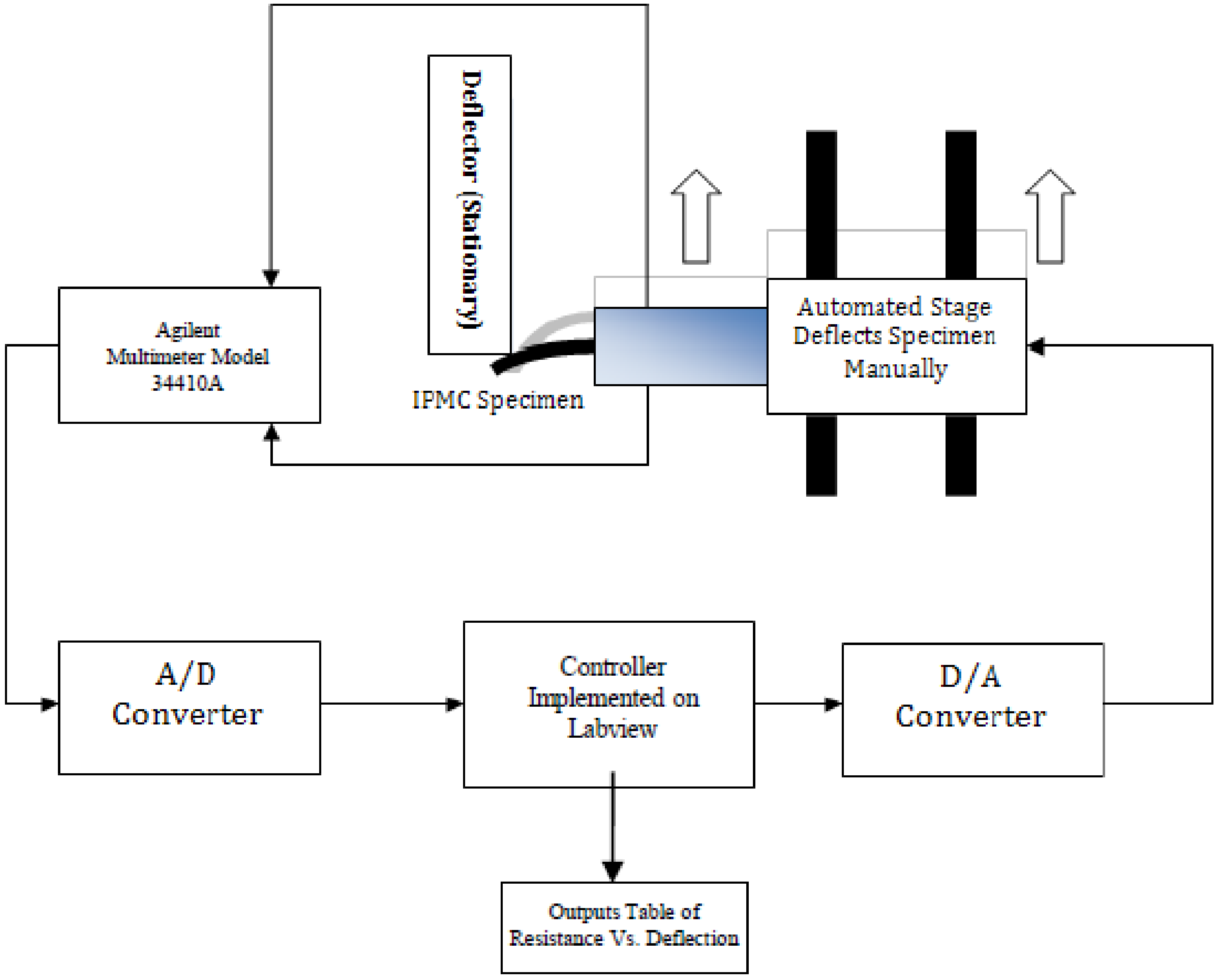
Proposed Finger



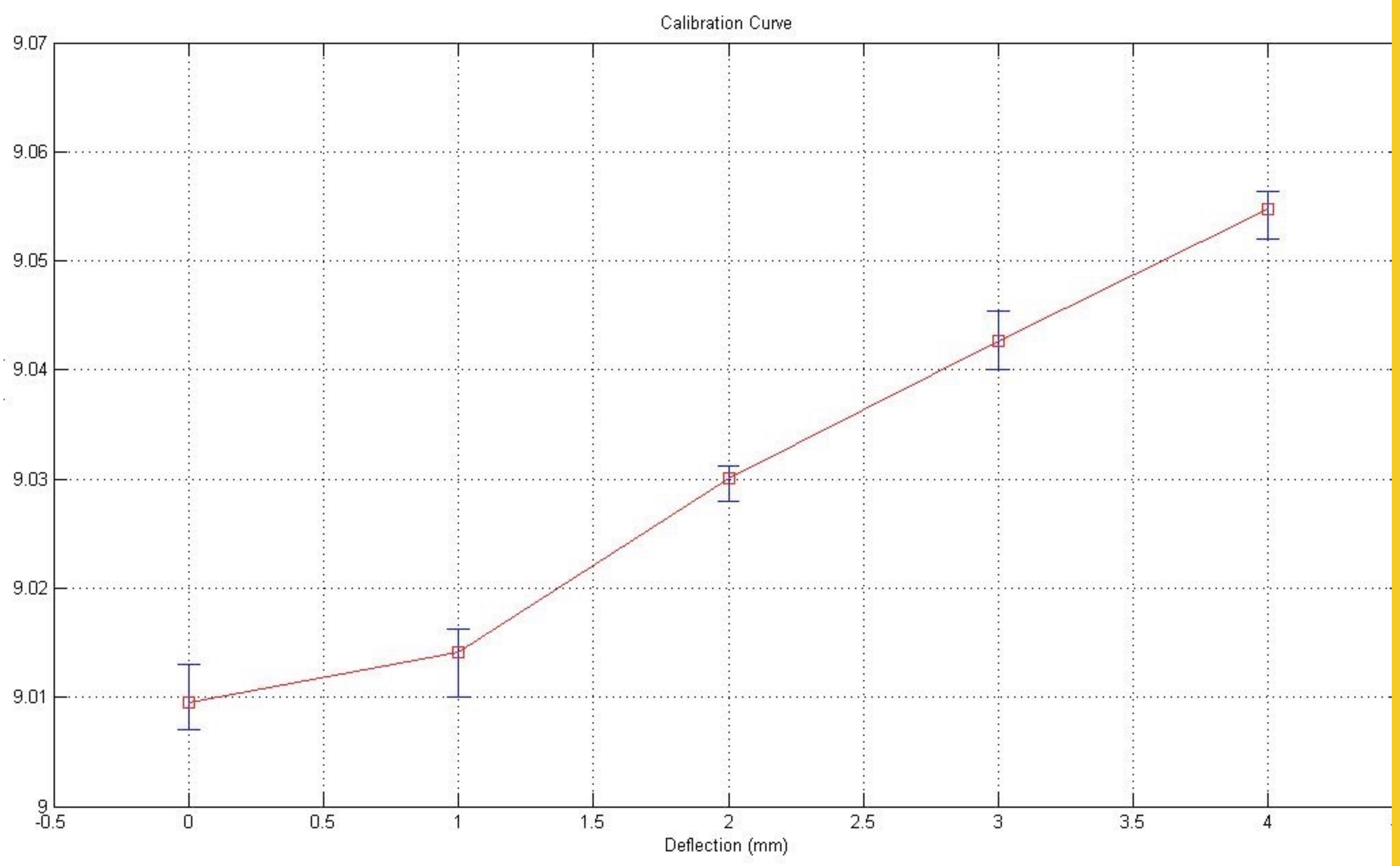
Experimental Results



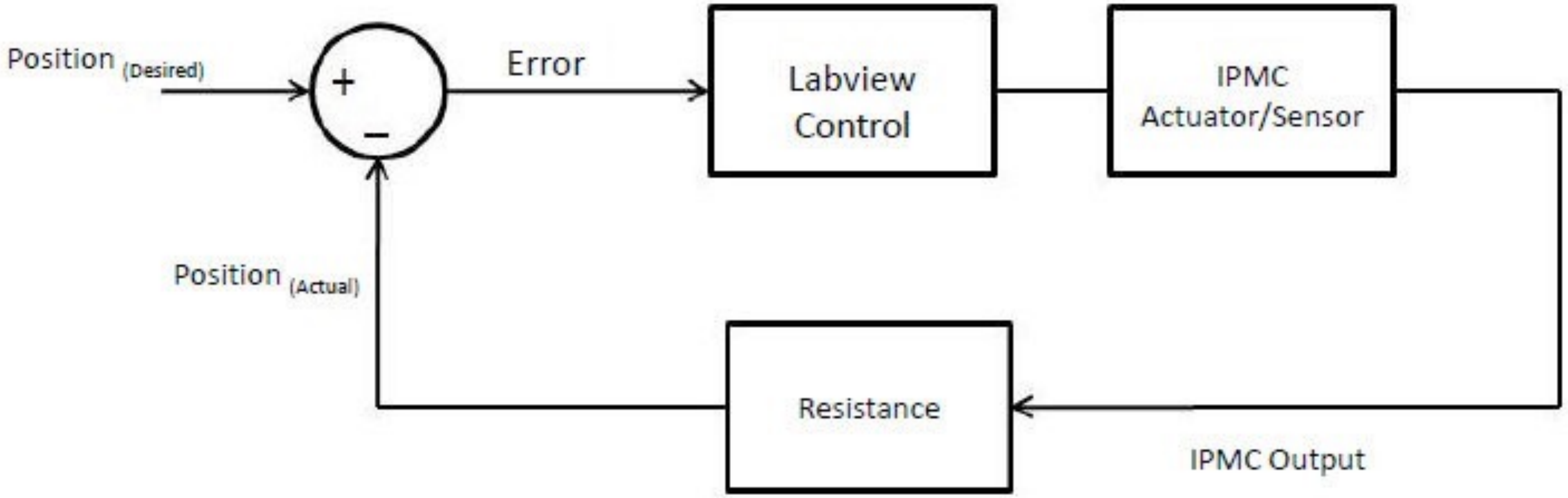
Lab Setup


Deflector (Stationary)
Agilent Multimeter Model 34410A
IPMC Specimen
Automated Stage Deflects Specimen Manually
A/D Converter
Controller Implemented on Labview
D/A Converter
Outputs Table of Resistance Vs. Deflection

Resistance vs. Deflection



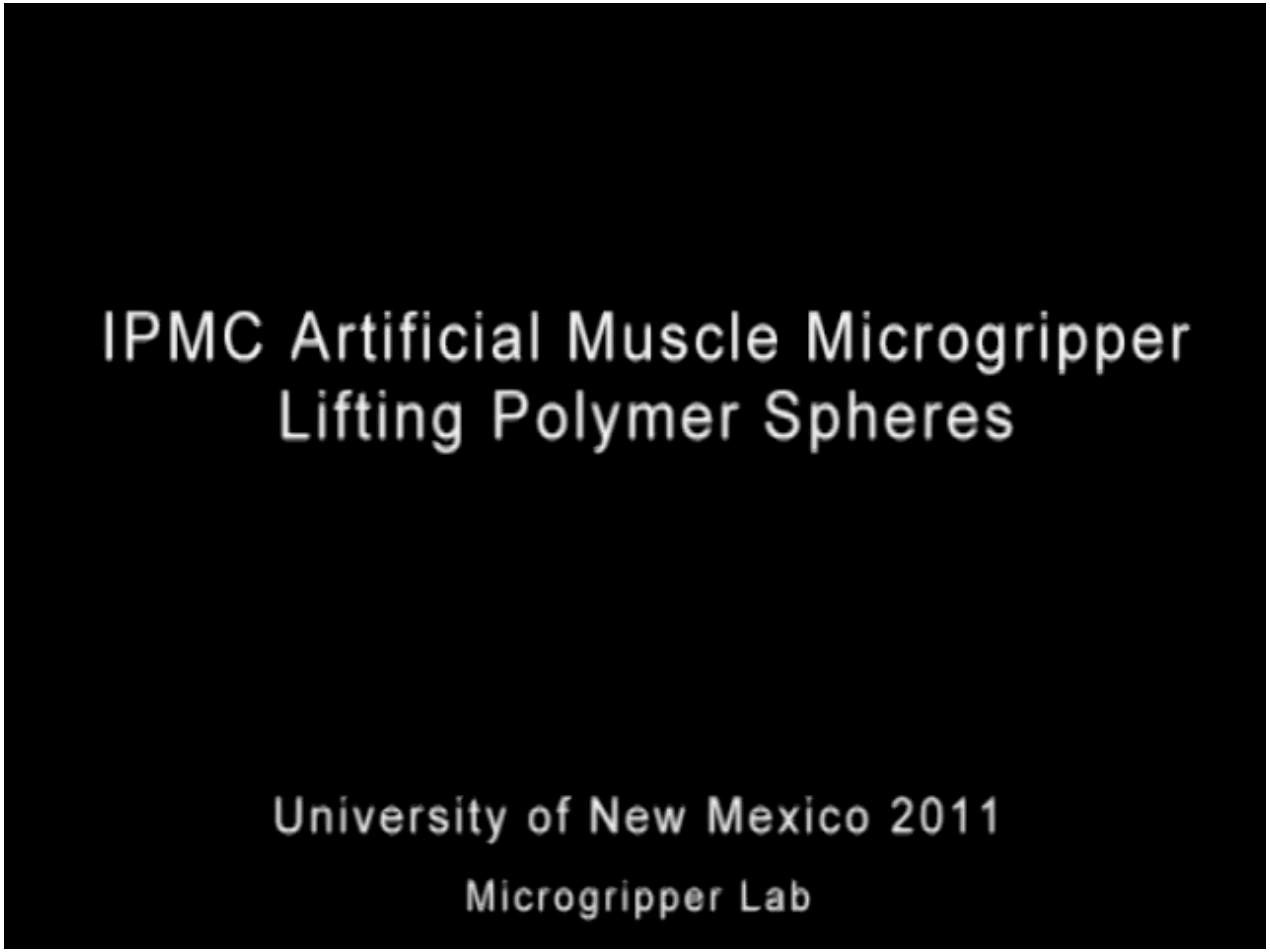
Closed Loop Controller



Results

- Open loop control
  - 0.224 mm variation
- Close loop control
  - 0.050 mm variation
  - Most of variation is transient response

Closed Loop Pick and Place



Applications

- Manipulation of flexible bio-objects
  - Suction pipette may damage cells
  - Oocytes and related bio-materials
- Manipulation of rigid objects
  - MEMS assembly

Conclusions

- Large scale robotics
  - Swing-free algorithm
  - Impedance control
  - Assembly
- Small scale robotics
  - IPMC microgripper
  - Cut trench to measure resistance to detect deflection
  - Closed loop controller for microgripper