Presented at the COMSOL Conference 2010 Boston

A Study of Seismic Robot Actuation Using COMSOL Multiphysics

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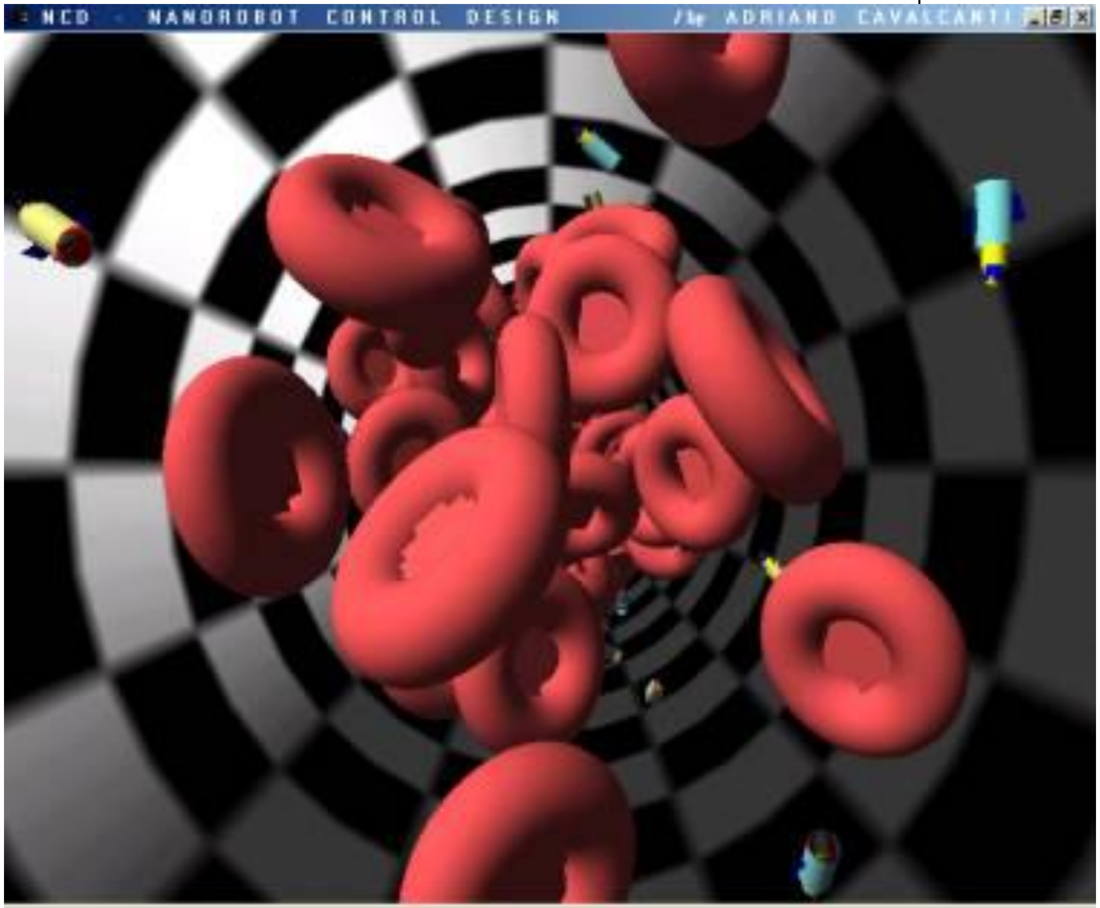
COMSOL Conference 2010

October 7, 2010

Microrobotics

- Applications in microsurgery, microassembly, and sensor swarms.



Adriano Cavalcanti, “Nanorobotics,” Nanoscience Today, September 2004, http://www.geocities.com/cbicpg/nanoscience/NST2004/nanorobots.htm

brianholmes.wordpress.com

Microrobot Power and Control

- How to power and communicate with micro robot? Use a global energy field
- Electromagnetic?
- Electrostatic?
- Vibration?

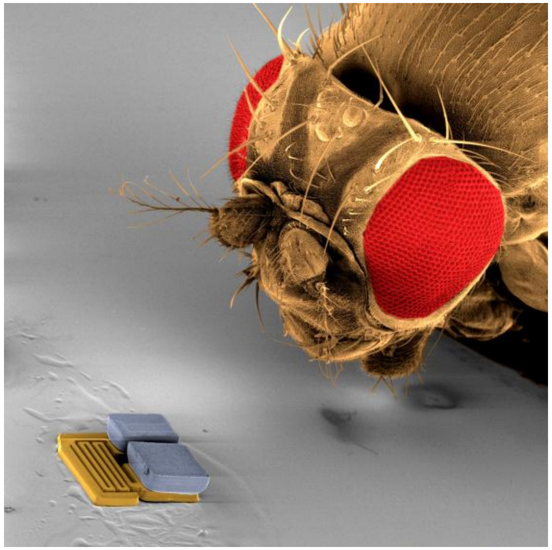


Image from Vollmers *et al.*, "Wireless Resonant Magnetic Microactuator for Untethered Mobile Microrobots," *Appl. Phys. Lett.*, 92, 144103 (2008).

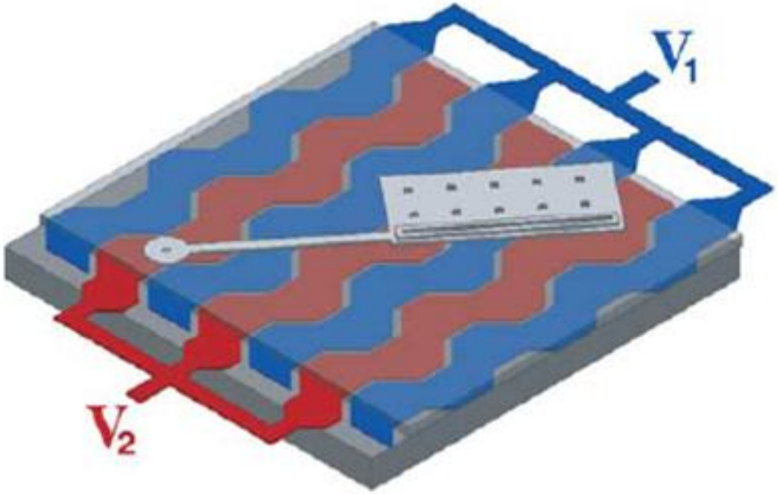
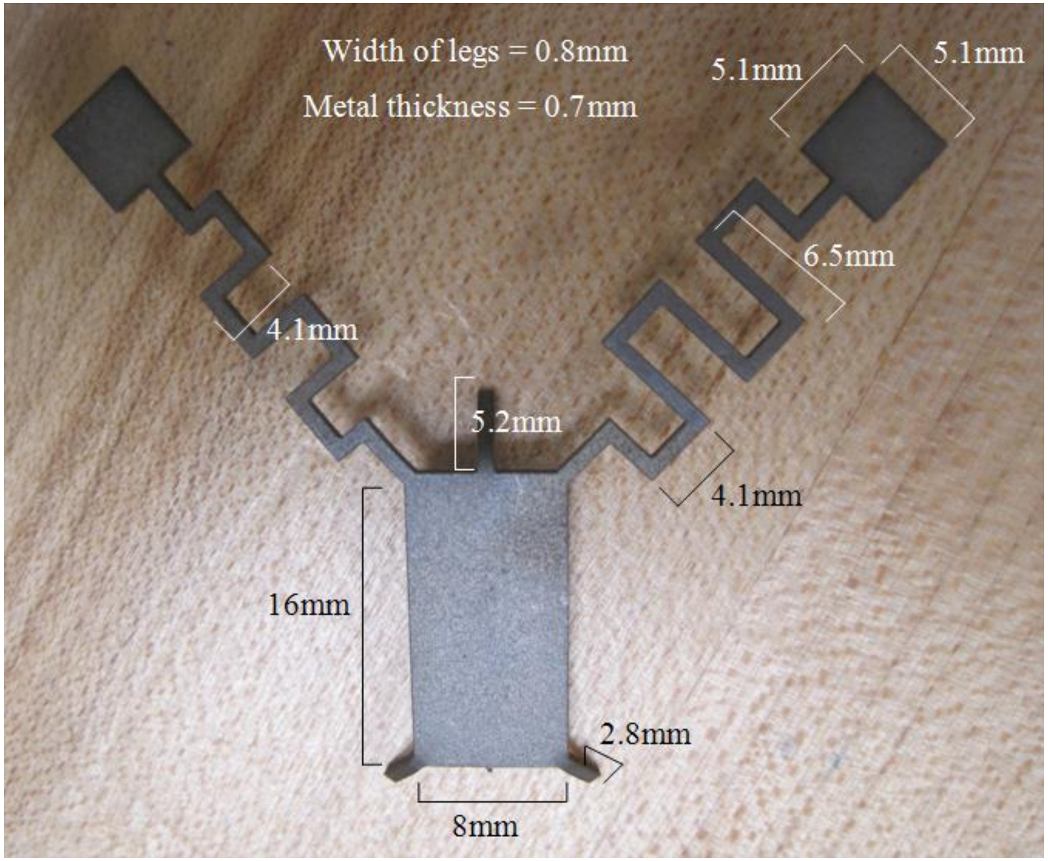


Image from Donald *et al*, "Power Delivery and Locomotion of Untethered Actuators," *J. Microelectromech. Syst.*, **12**, 947-959 (2003).

Seismic Actuation

- Why hasn't seismic actuation been more explored?
  - Surface:volume ratios go up with miniaturization
  - So friction forces dominate over inertial forces
- Then why use seismic actuation?
  - Minimally invasive.
  - "Easy" adaptation to existing ultrasonic medical equipment.
- Need to better understand physics

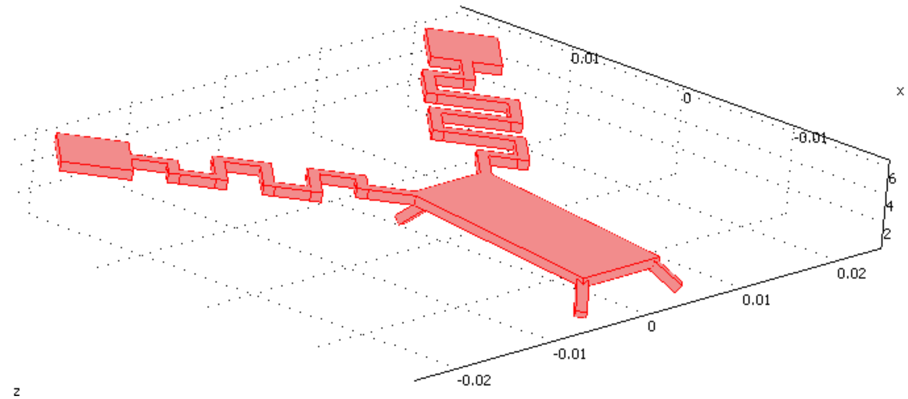
The Jitterbot: a mesoscale seismic robot

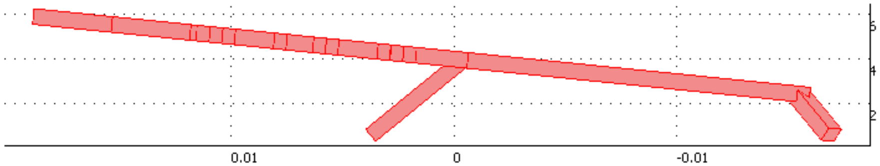


Mesoscale facilitates rapid manufacture and characterization

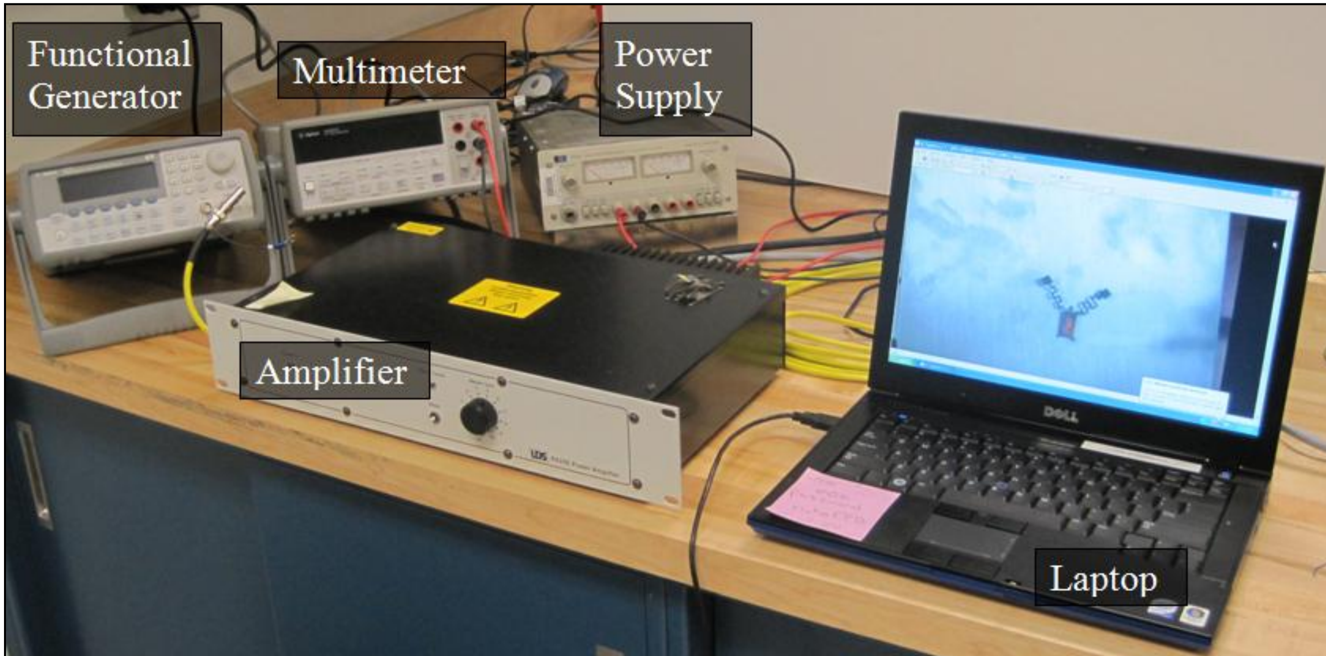
Jitterbot Features

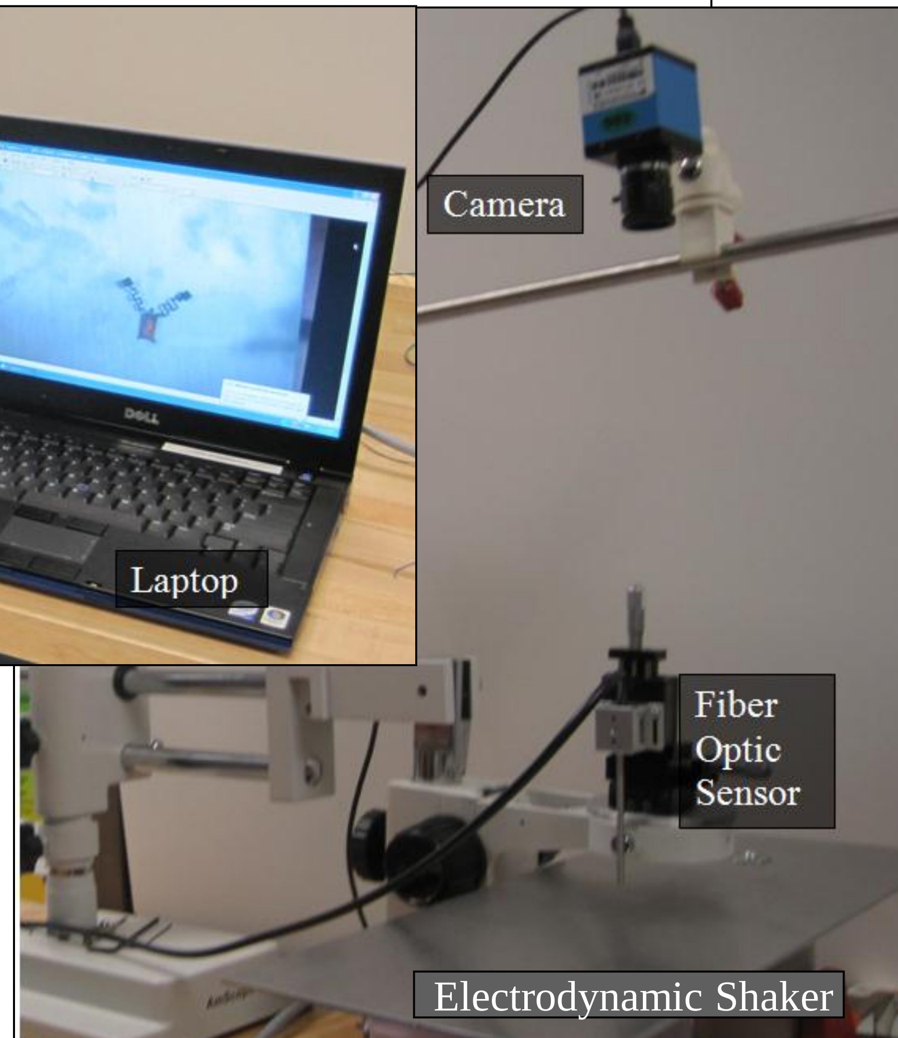
- Tripod body with two extended arms
- Body tilts backwards to facilitate transduction of vertical vibration into forward motion
- Arms designed for different resonant frequencies
- Simple mass-spring analysis used to design arms for resonance at ~140 Hz (right) and ~200 Hz (left)





Test System



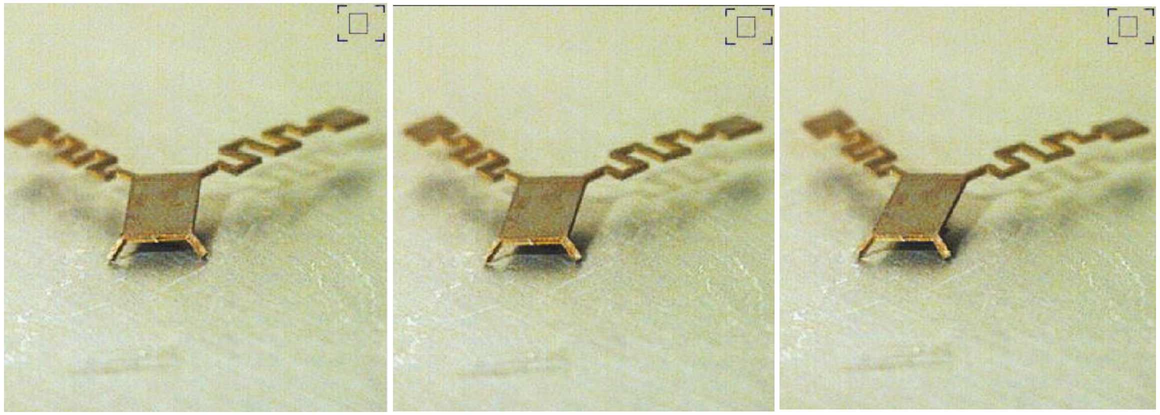


Vertical vibration field, with frequency varying from 10 to 2000 Hz

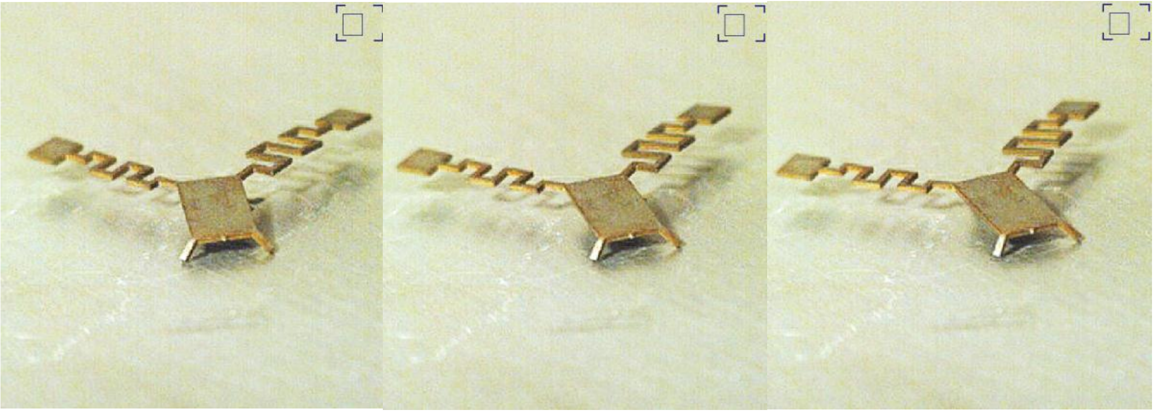
Results

- Clockwise rotation and translation at 97, 236, 810 Hz.
- Counterclockwise rotation at 1090 Hz.

810 Hz

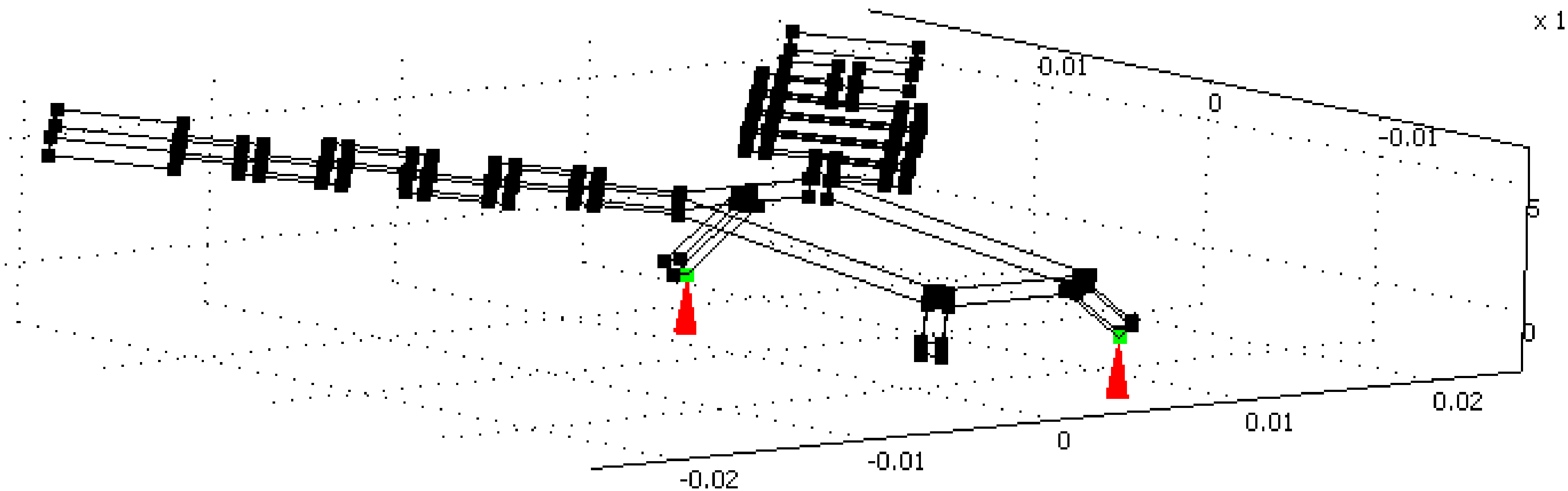


1090 Hz



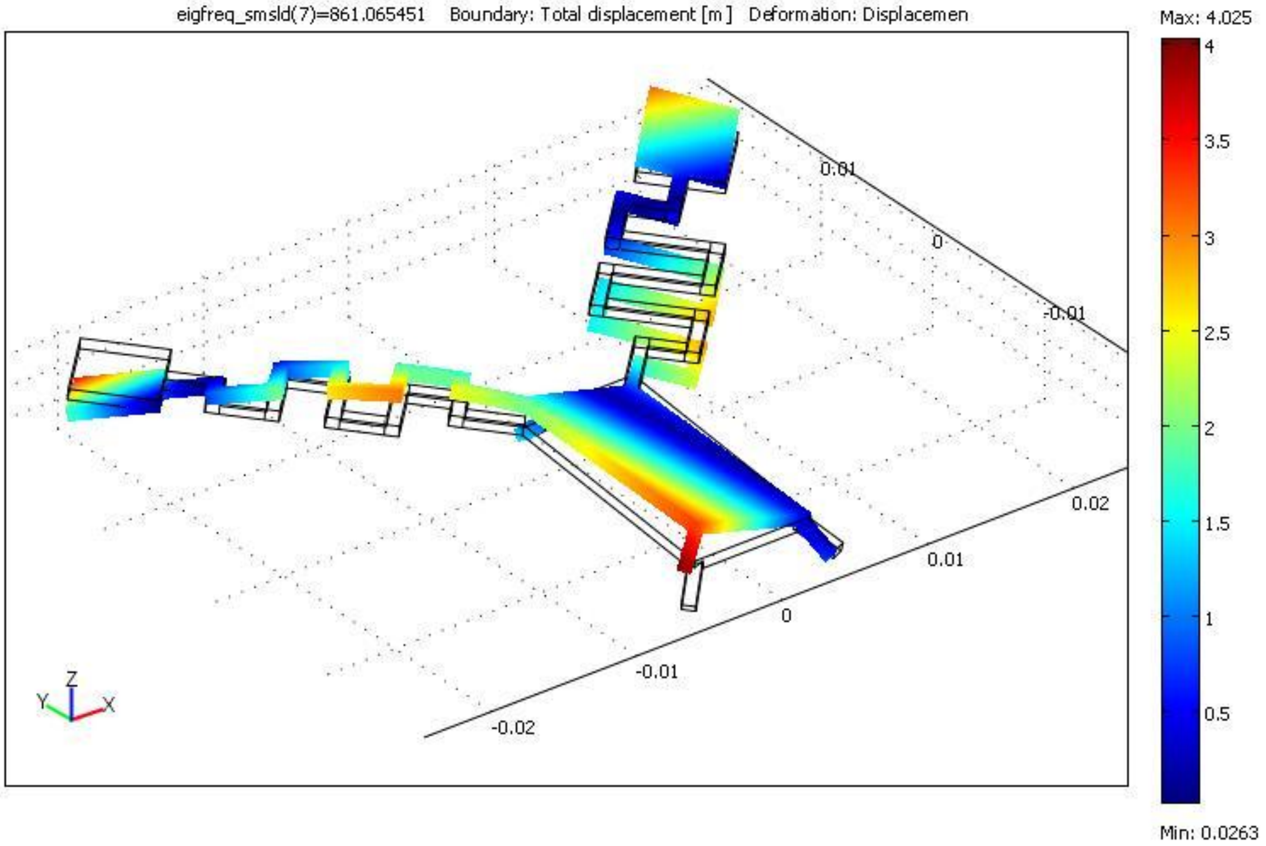
Modeling in COMSOL

- Eigenmode analysis
- Moving mesh (ALE) used to compute center of mass.
- Boundary conditions set up to allow for rocking



Eigenmode Analysis

- Eigenmodes at 320, 424, 861 and 1016 Hz
- 320, 424 and 861 Hz mode consistent with clockwise turn (CoM shifts up and to the right)

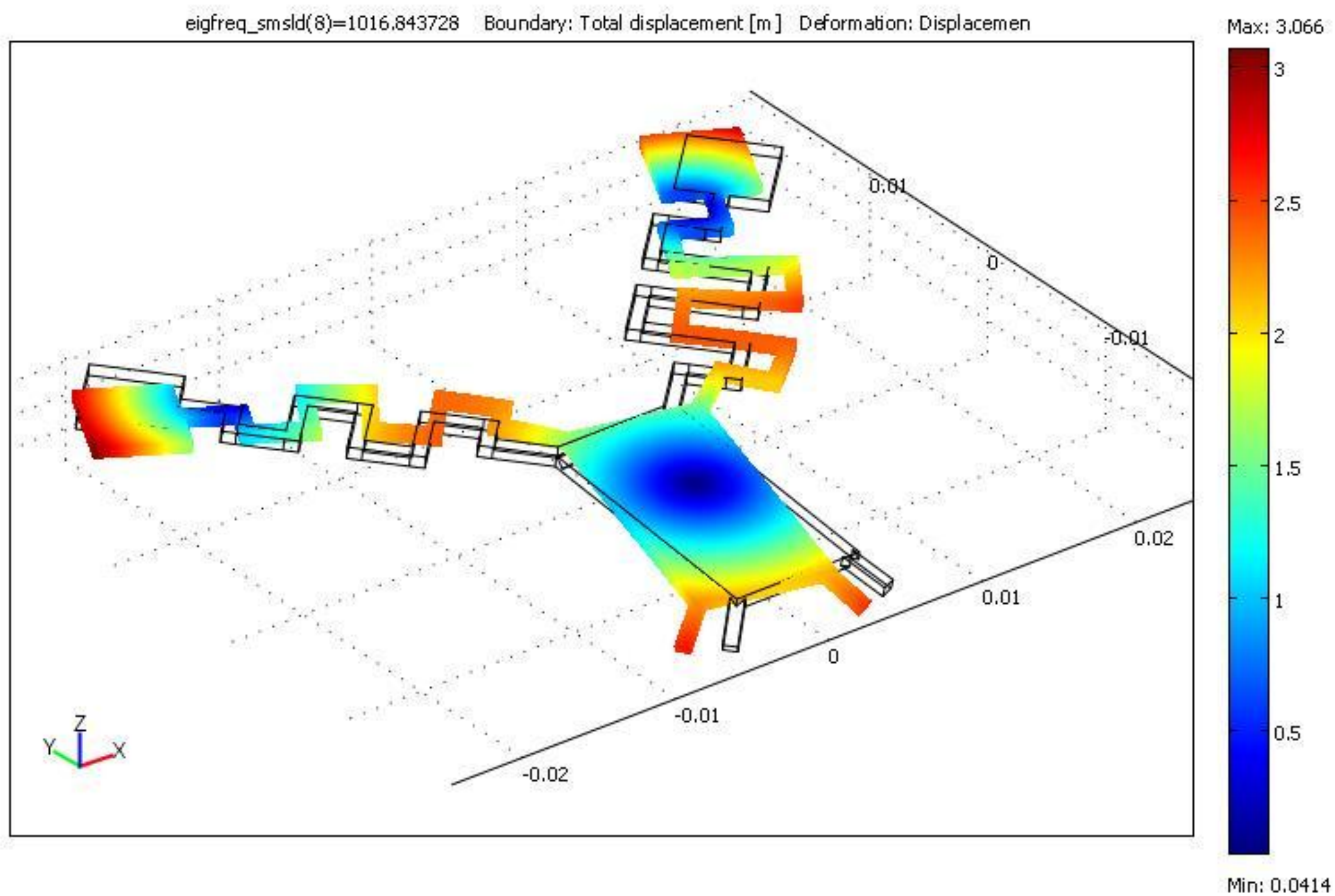


861 Hz Eigenmode

Eigenmode Analysis, cont.

- 1016 Hz mode consistent with counter-clockwise turn (CoM shifts up and to the left)

1016 Hz Eigenmode



Summary

- COMSOL makes reasonable prediction of critical frequencies.
- Rocking boundary condition essential for match.
- Future work will focus on scaling and on quantifying forces.

Experimental Frequencies	COMSOL Eigenfrequencies
97 Hz (CW)	
236 Hz (CW)	320 Hz (CW)
693 Hz (CW)	424 Hz (CW)
810 Hz (CW)	861 Hz (CW)
1090 Hz (CCW)	1016 Hz (CCW)

Acknowledgements

- Project sponsored by the Dept. of the Navy’s Program Executive Office for Integrated Warfare Systems (PEO/IWS)
- Matt Stanley, USNA Machine Shop
- Anders Ekerot at COMSOL