Advanced Computer-Integrated Surgery (600.446)
Possible Projects
(Only visible to signed-up CIS 2 students)

Russell H. Taylor

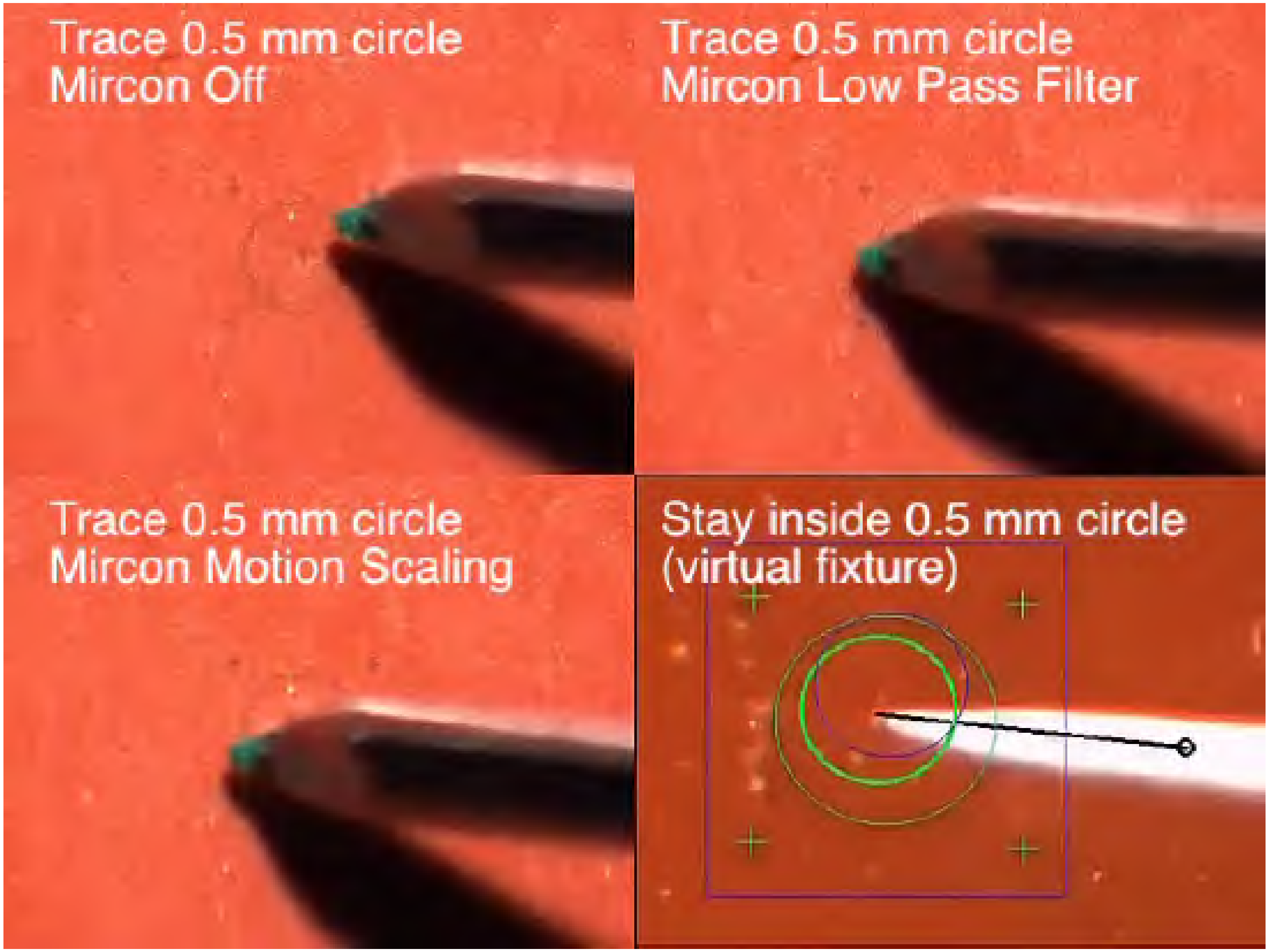
NOTE

- These are just some possible projects
- You are free to choose one, modify one of these, or propose something different on your own
- You do need to get your mentor (and me) to agree to your proposal

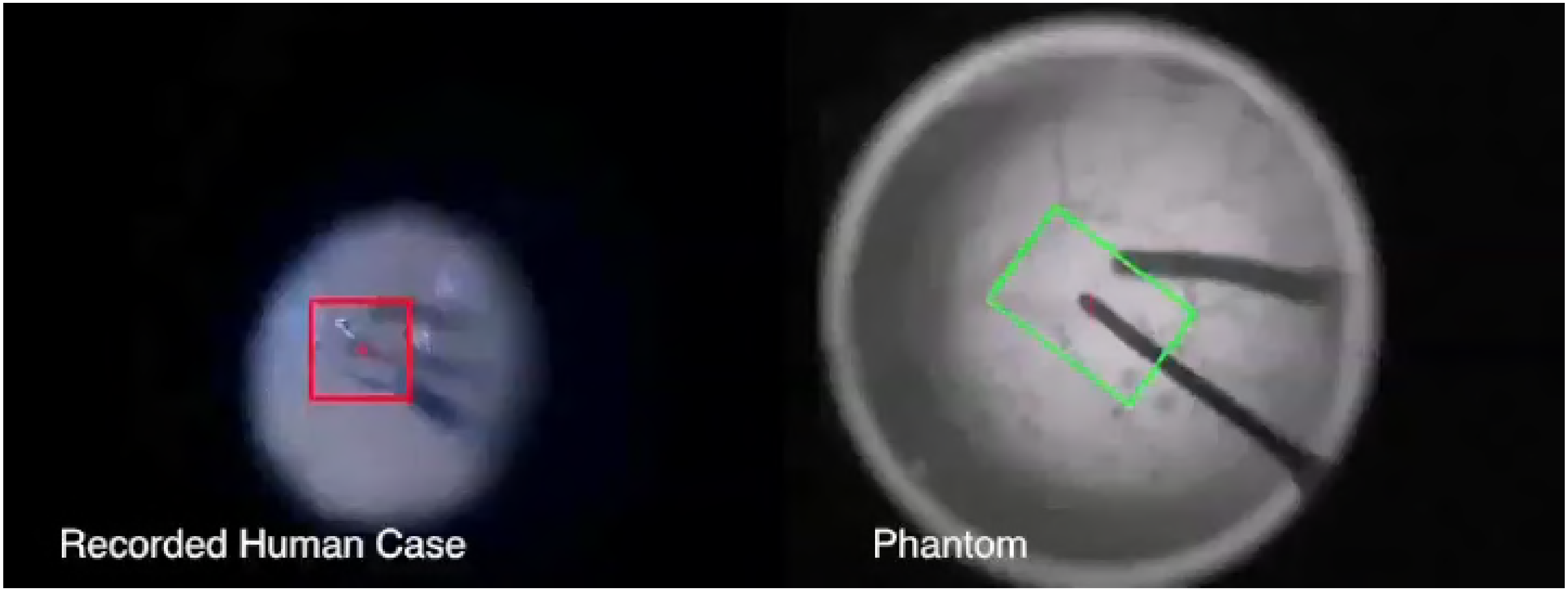
Video Overlay of MICRON range of motion

- Develop video overlay to provide surgeon with feedback indicating when MICRON is approaching motion limit
- **What Students Will Do:**
  - Interface to MICRON controller using existing code; retrieve position relative to range of motion
  - Develop video display scheme to generate appropriate warnings
  - Superimpose graphics onto video display
  - Use existing tool tracking code to track tool relative to retina
  - Update position of display based on tool position
  - Iterate with surgeon feedback
- **Deliverables:**
  - Working demonstration
- **Size group:** 1-2
- **Skills:** Computer Vision, Graphics, C++
- **Mentors:** R. Taylor, B. Vagvolgyi

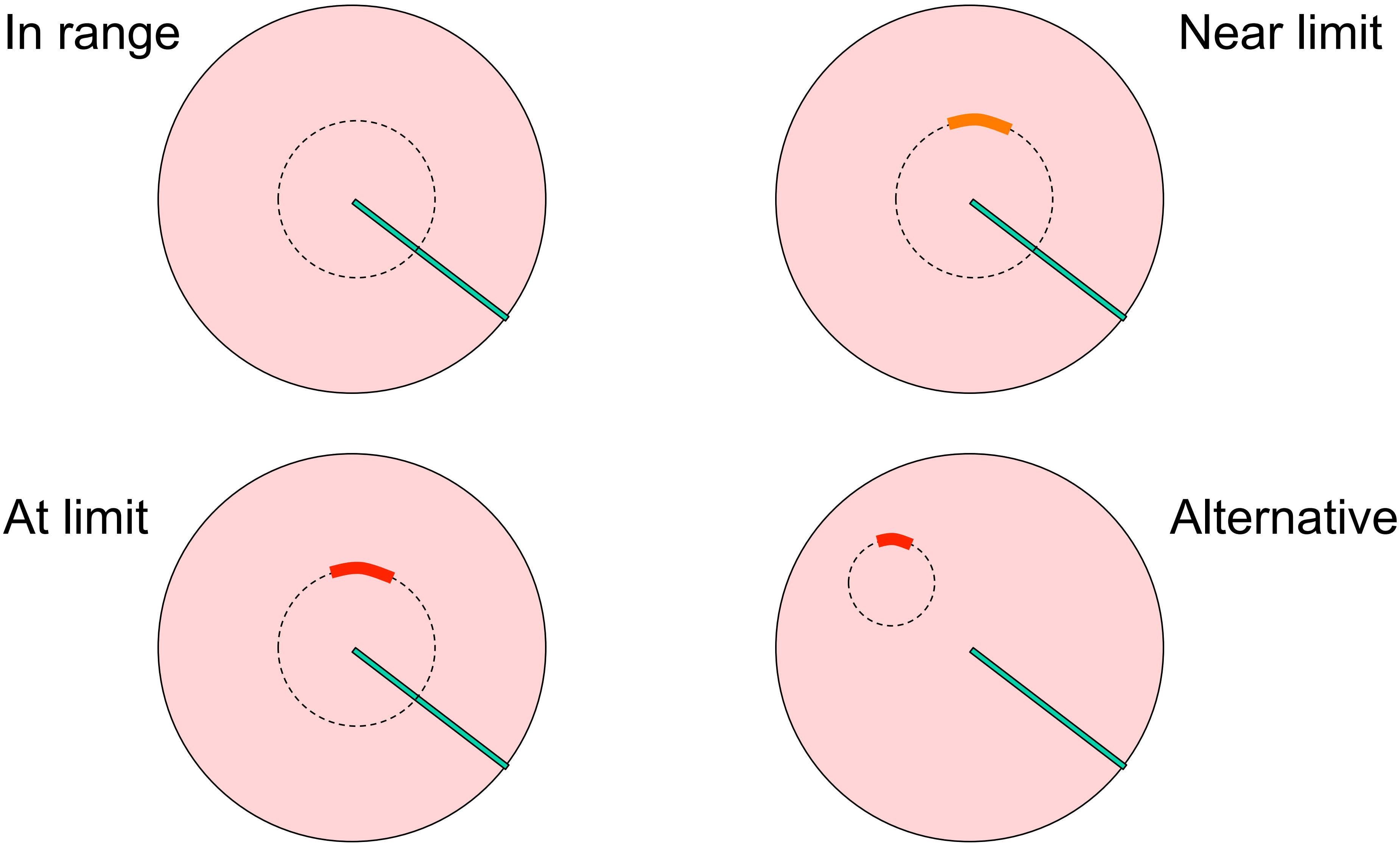
Video Overlay of MICRON range of motion



Video Overlay of MICRON range of motion



Video Overlay of MICRON range of motion



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Ultrasound Imaging of Brain Shunts

- **Goal:** Use external US probe, together with photoacoustic excitation to image brain shunts inside the skull
- **What Students Will Do:** Assemble system from existing components; take and capture images
- **Deliverables:**
  - **Minimum:** Demonstrate PA imaging of shunt in phantom brain material w/o skull
  - **Expected:** Demonstrate PA imaging through the skull of shunts with different levels of occlusion
  - **Maximum:** Monitor clearing of the shunt
- **Size group:** 2
- **Skills:** Hands-on experimentation skill; **Desirable:** Optics/ lasers experience, ultrasound experience, signal processing
- **Mentors:** Emad Boctor, Russ Taylor, [Roger Bagwell, Kevin Snook (Actuated Medical)]

Ultrasound Imaging of Ventricular Brain Shunts

Kevin Snook, Ph.D.

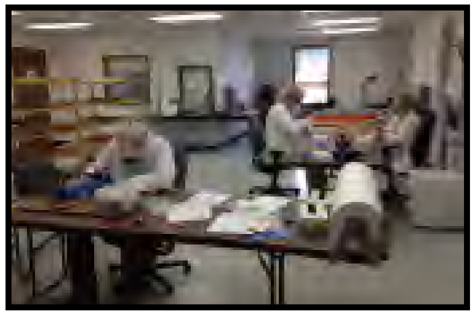
600.446 Project Presentation

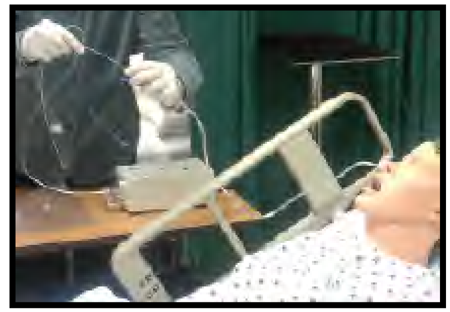
January 29, 2013

Company Background

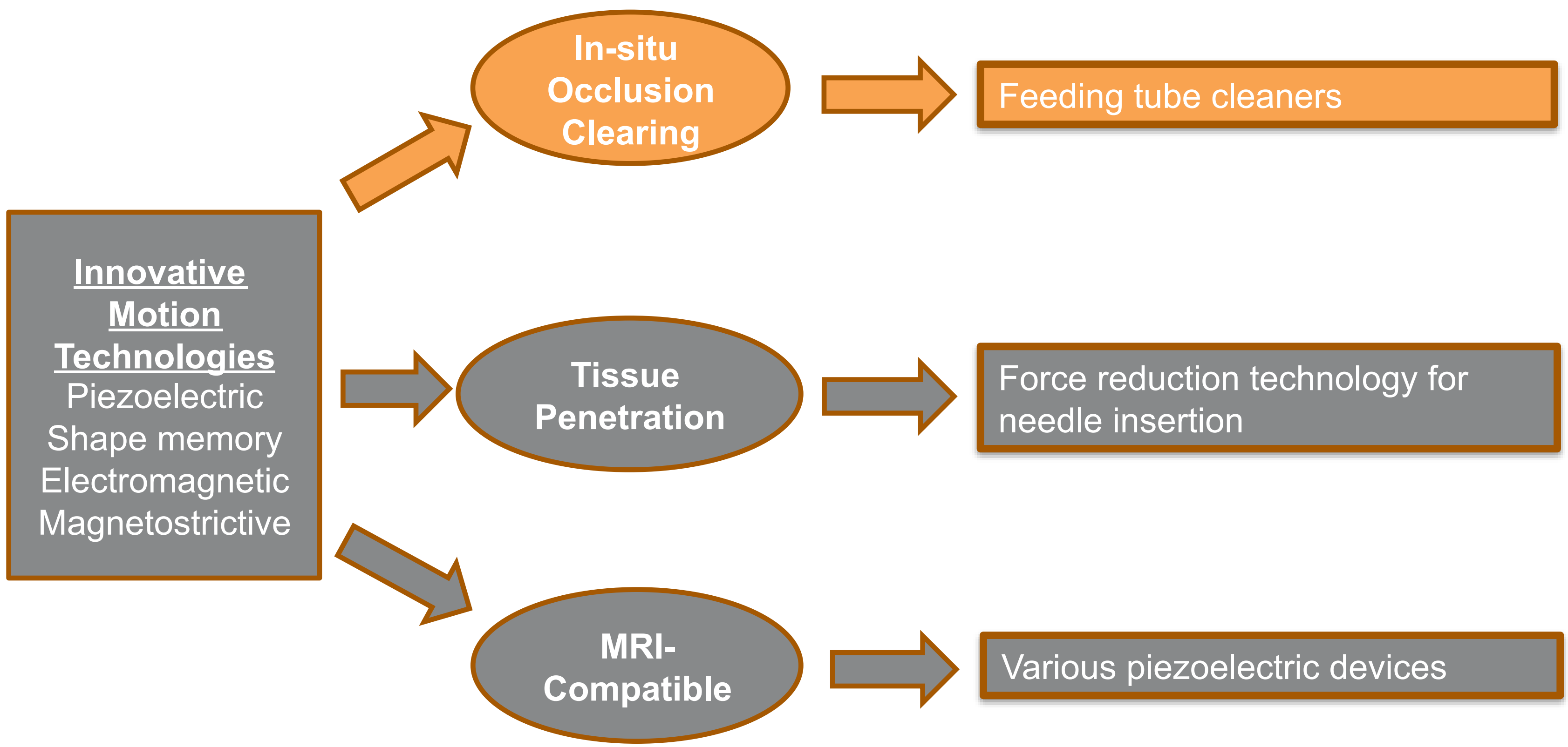
Our goal is to improve patient outcomes through development of solutions for safe and innovative medical devices.

- **Founded in December 2006**
  - Incorporating actuation into medical devices to enable new functionality
  - Located in Bellefonte, PA
- **Commercialization Focus**
  - Distribution with representatives in EU and Asia
- **9000 sq. ft. facility, 19 employees**
- **Strong Regulatory Strategy**
  - ✓ ISO 13485:2003 Medical Design and Manufacturing.
  - ✓ ISO 14971:2007 Application of Risk Management to Medical Devices.





Smart Actuation in Medical Devices



Nasogastric Tube Clearing Device

Going to Market in 80 Countries

510(k) filed !! CE Marked

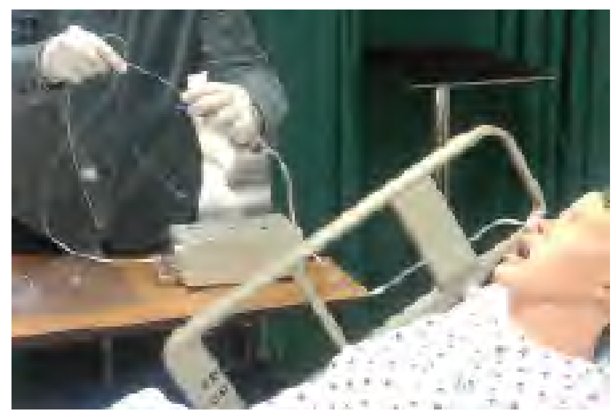
Patent Pending

In Six Focus Groups – more than 50 nurses and doctors positively reviewed the feeding tube cleaners.

- ✓ **"A lot of time savings, easy to use"** ***Conclusion of a focus group.***
- ✓ **"Innovative and easy to use,"** ***Conclusion of a focus group.***

Method	Number of Runs	Number of Runs Unclogged	Average Time to Unclog
NG-Clear™	5	5	3 minutes
Warm Water + Cola	5	3	23 minutes
Enzyme Treatment	5	4	84 minutes

Study compared Levin 12 Fr 48 inch long nasogastric tubes with clogs made from 1:1 ratio of feeding formula and fiber.



R&D, Testing and Manufacturing

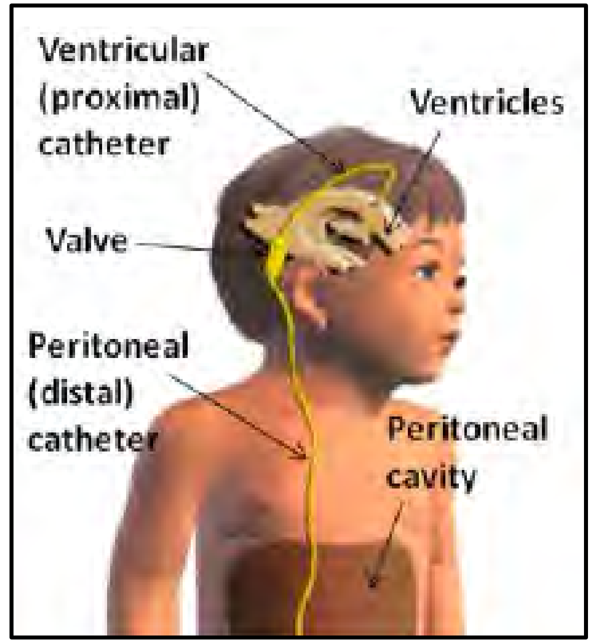
Goal – Bring capabilities in-house to accelerate development to V&V, and support small to mid-scale manufacture.

- CNC machine and mills
- Vertical machining center
- Prototyping 3D printer and mill
- Pick and place system
- Environmental chamber
- Electronic testing equipment and probes
- Force testing stands
- Controlled environment for manufacturing
- Custom fixtures and equipment to ensure quality and reduce cost




Hydrocephalus – Background

- Hydrocephalus – abnormal accumulation of cerebrospinal fluid (CSF) in the cranium due to obstruction
  - Non-communicating hydrocephalus (obstruction in ventricular system) often presents near birth
  - Pressure distends ventricles and can lead to death
- Treatment – intracranial pressure regulation through diversion of CSF via a shunt for later reabsorption



CSF shunt system for management of hydrocephalus

Procedural Background

- Neurosurgeons place shunts by
  - Making scalp incision and drilling hole in the skull
  - Passing a small catheter (1.5mm inner dia.) through the brain into a ventricle (often 3^{rd} ventricle)
  - Distal catheter placed under skin to peritoneum
- 40,000 shunt-related operations performed annually in US

Hydrocephalus - Challenge

- Unacceptably high incidence of occlusions from in-grown tissue obstructions into shunt that block CSF flow
  - ex. choroid plexus, connective tissue, neurogliosis, blood
- Failure rates are estimated to be ~40% in the first year and ~80% within 10 years
- Currently, the only accepted clinical solution for resolving obstructions is either shunt replacement or revision
  - If removal of malfunctioning shunt presents hemorrhage risk, the shunt is left and new shunt placed

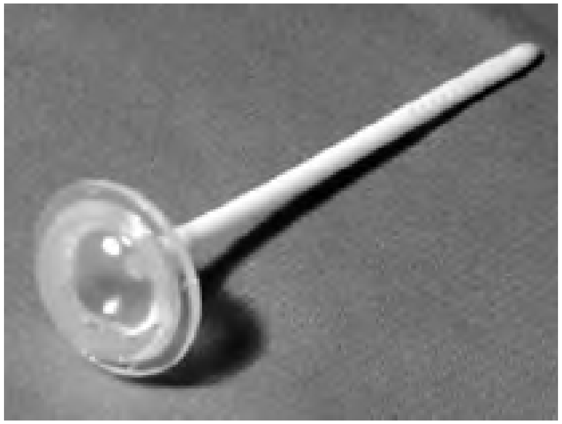
Question: *How well can we see obstructions in shunt with photoacoustic/ ultrasound imaging?*

X-ray of patient with multiple ventricular shunts

Pople I K J Neurol Neurosurg Psychiatry 2002;73:i17-i22

Imaging Goal

- We have an NSF-sponsored program for developing a system for minimally invasive clearing of brain shunts to regain patency without shunt replacement
- Imaging into the Rickham reservoir and through shunt ports could provide visualization of occlusions
- Photoacoustic imaging provides capability to distinguish tissues and fluids (ex. choroid plexus, CSF, blood)
- Ultrasound is well-characterized modality and provides real-time imaging capability



Shunt with reservoir, showing perforation holes at the tip

http://jnnp.bmj.com/content/73/suppl_1/i17.full

Background

- Goals
  - Develop system for minimally invasive clearing of brain shunts to regain patency without shunt replacement
  - Provide real-time imaging of shunt and occlusion to aid in clearing and provide extra measure of safety during procedure
- JHU role
  - Use ultrasound and photoacoustic expertise to develop system to provide visualization of occlusions in shunt and placement of clearing stem during procedure
  - Provide capability to distinguish tissues and fluids (ex. choroid plexus, CSF, blood)

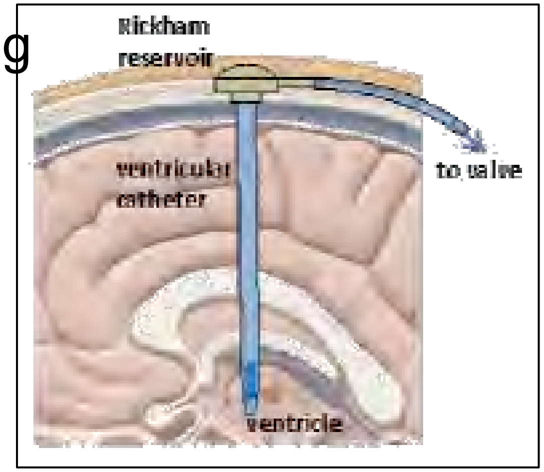


Illustration of CSF Shunt in brain.

Imaging Program

Goal: Use external US probe, together with photoacoustic excitation to image brain shunts inside the skull

What Students Will Do: Assemble system from existing components; take and capture images

Deliverables:

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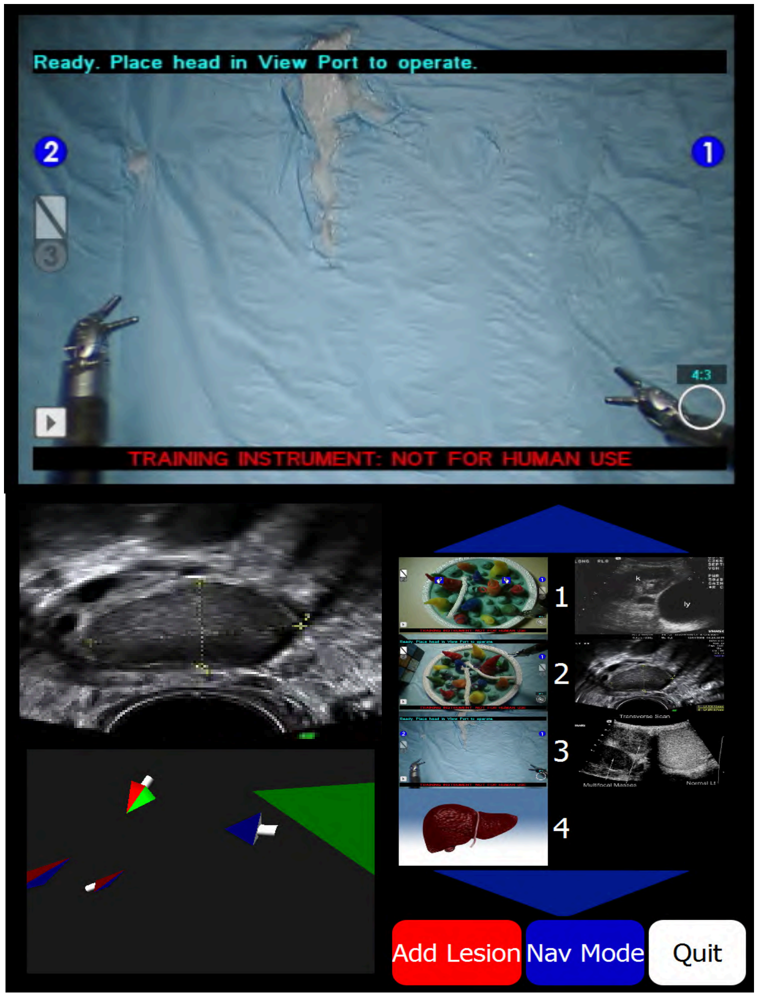
Size group: 2

Skills: Hands-on experimentation skill; **Desirable:** Optics/lasers experience, ultrasound experience, signal processing

Mentors: Emad Boctor, Russ Taylor, [Roger Bagwell (PI, Actuated Medical)]

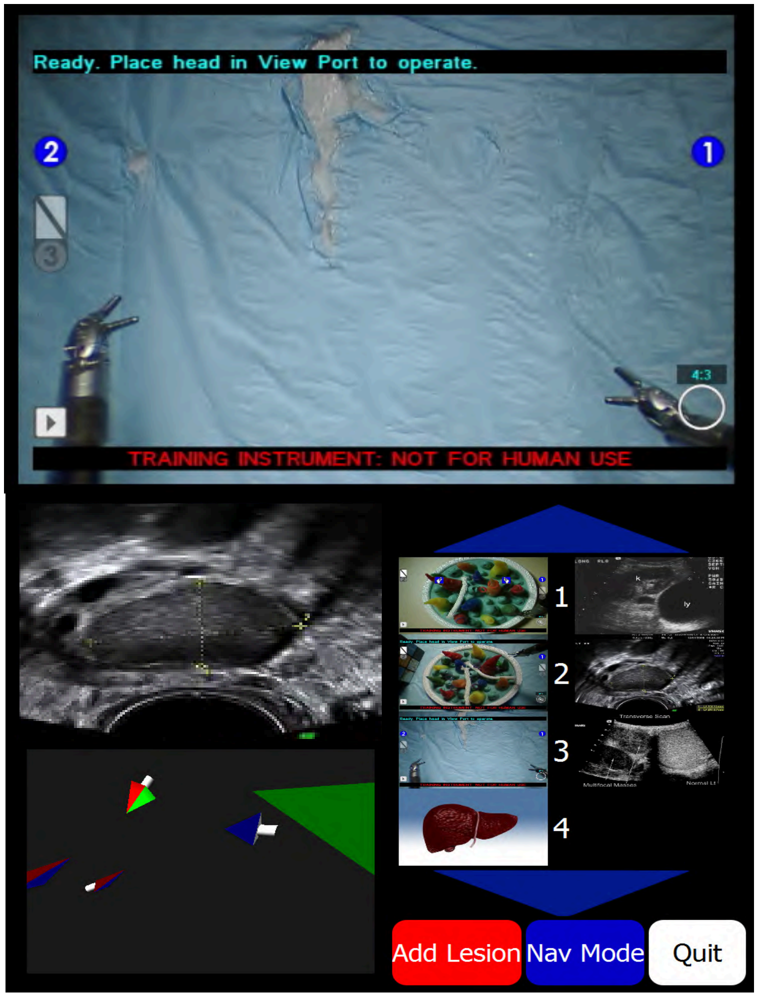
A User Interface for Data Integration during Robotic Ultrasound guided Surgery



Background: Robotic LapUS is starting to be used to guide the removal of cancerous lesions. The current process for doing ultrasound is cumbersome and requires help from additional technicians to manipulate the ultrasound images, undermining ergonomy and efficiency.

Goal: Further develope the current TilePro interface for working with real time ultrasound images from within the DaVinci console. Add additional tools to aid the doctor. Help with clinical testing and experiments.

A User Interface for Data Integration during Robotic Ultrasound guided Surgery



Minimum:

- Engineering support of clinical study
- Create a measurement tool for the Ultrasound images
- Assist in testing and deployment of the software

Expected (Some subset of):

- Create a measurement tool for the Ultrasound images
- Incorporate DICOM reader with Masters as Mice into the interface
- Use 3D fiducials with other imagery to show previously viewed areas
- Integrate segmentation software

Maximum deliverables:

- Improved and ergonomically optimized software

Group size: 1-3

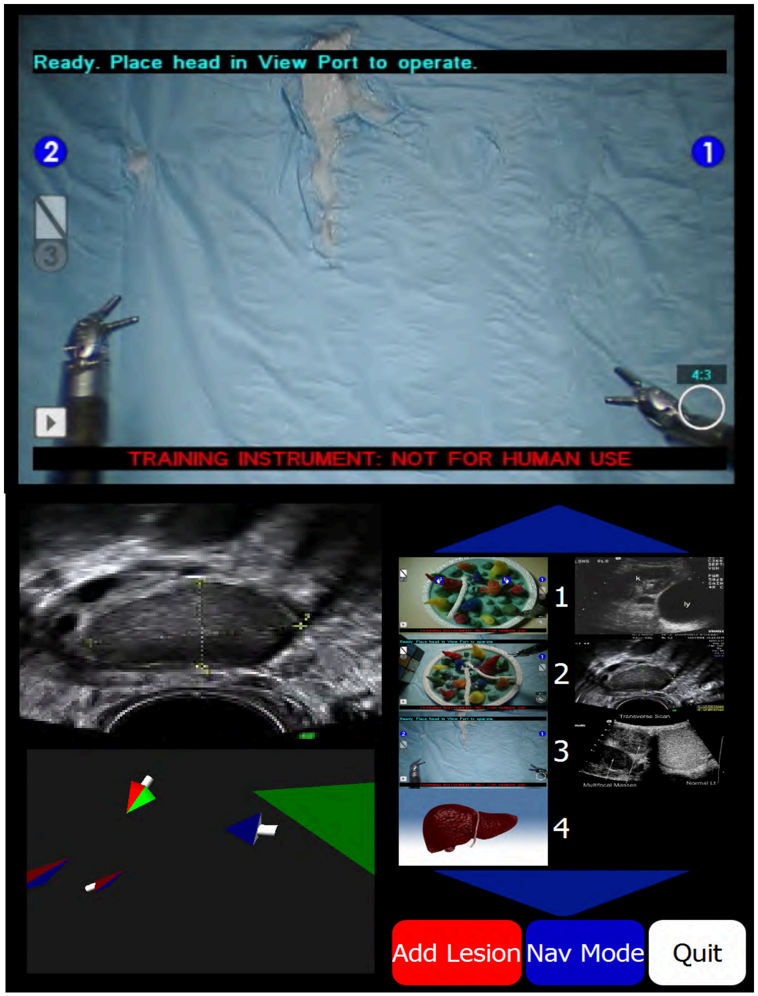
Skills: C++ (Qt and CISST are a plus)

Mentors: Clinical: Dr. Michael Choti, Theodore Katsichtis

Engineering: Prof Taylor, Anton Deguet, Colin Lea

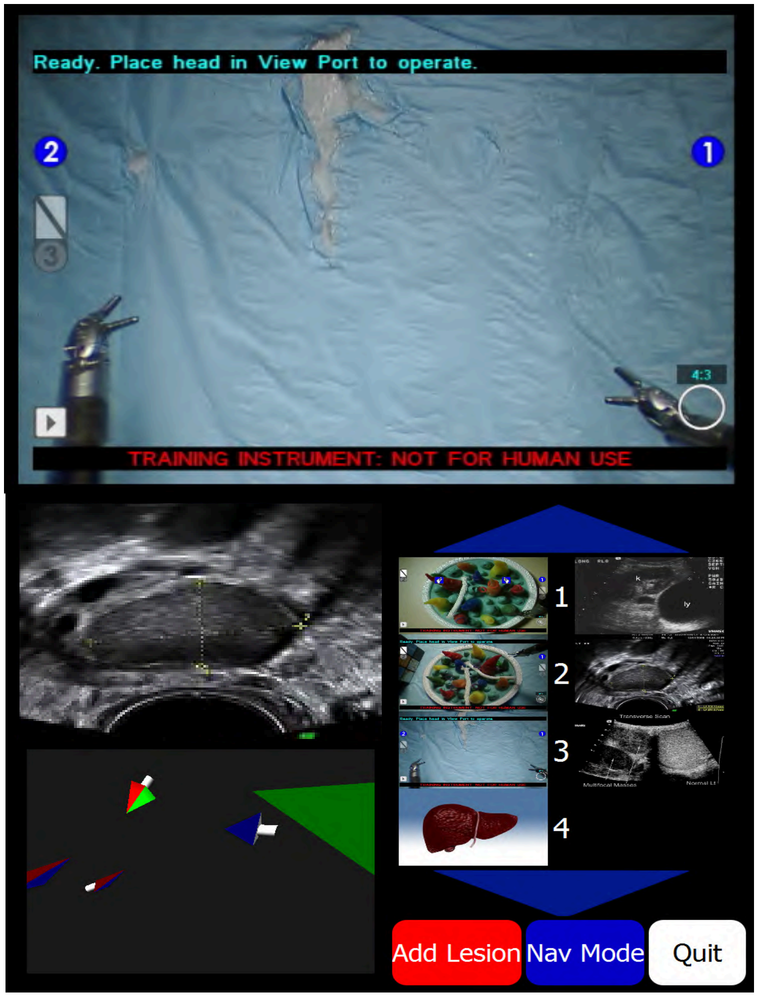
Email: colincsl@gmail.com, theokatsichtis@gmail.com

3D Visualization of Ultrasound Guidance Cues in the da Vinci Console (may combine with previous)



- **Goals**
  - This project involves converting an existing 2D image guidance interface to a 3D interface for use in a human trial of robotic ultrasound imaging using the da Vinci Surgical System
- **What Students Will Do:**
  - Implement a two-channel video pipeline for injecting stereo into the da Vinci Si console via the TilePro feature.
  - Modify image guidance widgets and features for stereo.
  - Explore new image guidance features that leverage stereo visualization.
  - Demonstrate and test the system at the medical school in preparation for a human study.
  - Participate in the IRB amendment to incorporate stereo visualization.

3D Visualization of Ultrasound Guidance Cues in the da Vinci Console (may combine with previous)



- **Deliverables:**
  - An ultrasound image guidance application that provides stereo visualization.
  - A test protocol and test results showing that the system is ready for experimental deployment.
  - An IRB amendment that incorporates changes to the existing 2D protocol.
- **Size group:** 1-3
- **Skills:** video and image processing, robot kinematics and linear algebra; graphics and GUIs.
- **Mentors:** Clinical: Dr. Michael Choti, Theodore Katsichtis, Engineering: Prof Taylor, Colin Lea, Anton Deguet

Ultrasound Elastography on DaVinci Robot

- **Goal:** Enhance ultrasound elastography capabilities on DaVinci robot, using either ISI DaVinci tool or drop-in probe
- **What Students Will Do:**
- **Deliverables:** short description or bullets
  –
- **Size group:** 1-2
- **Skills:** Computer Science, programming, image processing expertise
- **Mentors:** Names & contact info here

Ultrasound Elastography with DaVinci

(Boctor, Billings, Taylor)

Human-robotic collaboration for in-vivo detection of tumors and monitoring of therapy

(Research DaVinci Application – Not for Human Use)

Robot Assisted Ultrasound Tomography

- **Summary & Goal:** Ultrasound penetration is 15 cm maximum. In this project, we use a combination of human operated probe and a probe attached to a robotic arm, on the other side, to offer a higher image depth.
- **The final goal** is to achieve ultrasound images that could be used to generate an ultrasound tomographic scan of a soft tissue phantom (gel or animal tissue).

- **What Students Will Do:**
  Use a robotic system to enable the two aligned moving probes
- **Group Size:** 1-3
- **Skills:** Matlab, C, and C++ Programming, Robotics, Fundamentals of Serial Robots, Optical Tracking, Hand-eye Calibration, Phantom Manufacturing, Algorithms
- **Mentors:** Prof. Emad Boctor: eboctor1@jhmi.edu, Prof. Iulian Iordachita: iordachita@jhu.edu, Prof. Russ Taylor: rht@jhu.edu

Deliverables

- **Minimum Deliverables:**
  - A robotic arm should follow the position of a mock ultra-sound probe attached to a passive arm, on the other side of a cylinder, using optical tracking system

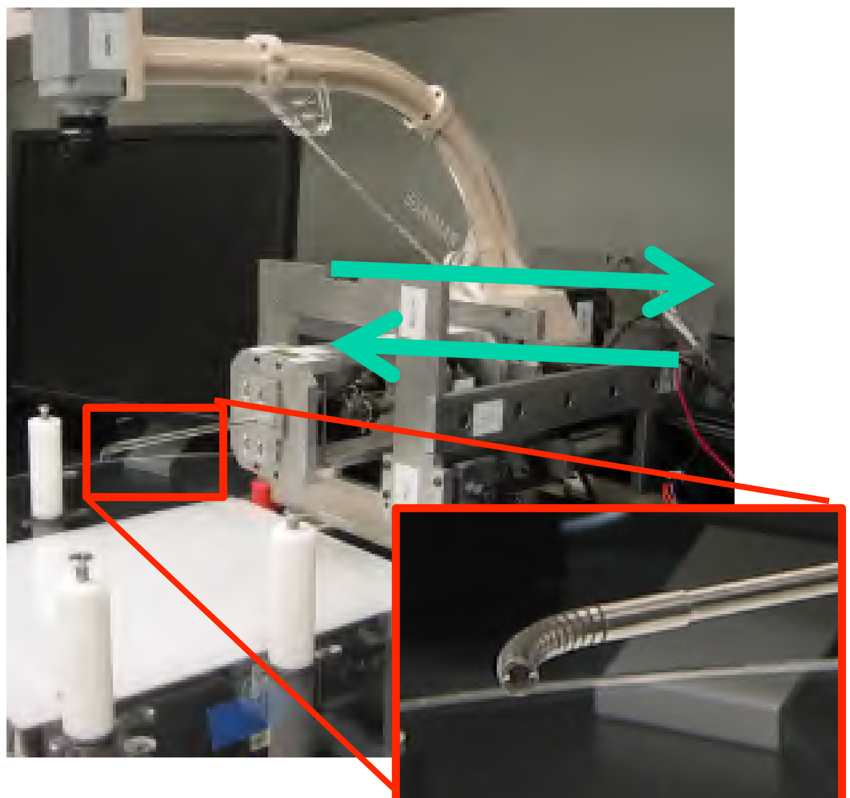
- **Expected Deliverables:**
  - The mock probes should be replaced with real ones.
  - Real data should be collected.
  - Study Energy Profile Tracking(EPT): The energy profile analysis of the ultrasound wave can replace (or be added to) the optical tracking system to (better) determine the probes’ positions. This should be thoroughly investigated.

- **Maximum Deliverables:**
  - Implement EPT and conduct its accuracy study
  - Real images shall be collected and reconstructed on a PC to display a complete real-time ultrasound image.

Hydrophone sensing of the tip of the APL Snake for Dexterous Manipulator

- *Goal:* To control the position of the tip of the dexterous manipulator using hydrophone fibers

Super intuitive and flashy user inteface



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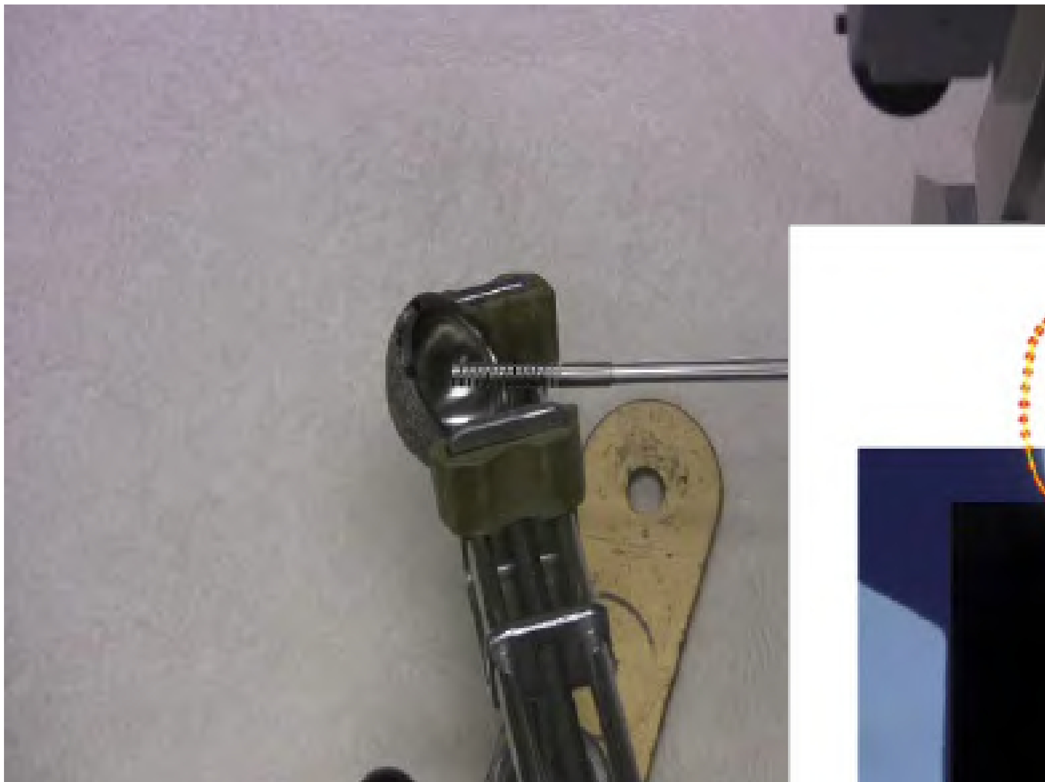
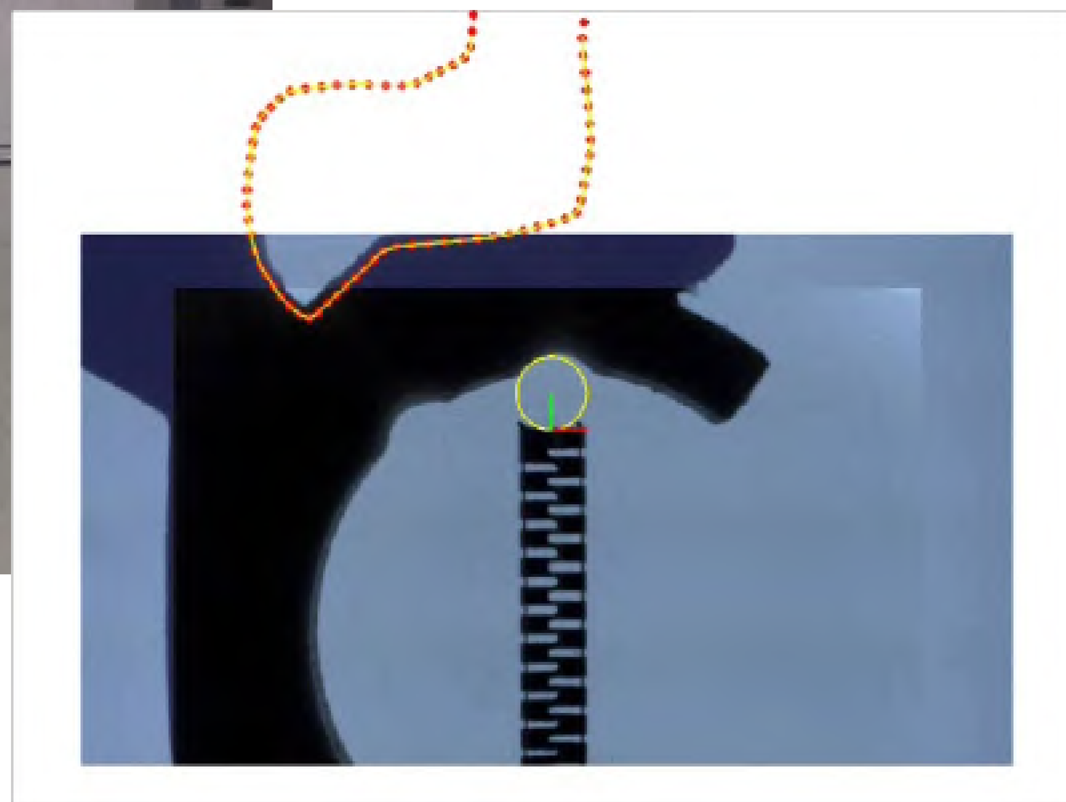
Hydrophone sensing of the tip of the APL Snake for Dexterous Manipulator

- *Background:*
  - JHU/APL in collaboration with JHU/WSE has developed a cable driven surgical manipulator initially designed for the treatment of osteolysis.
  - A basic Z-Theta stage with cable drive motors has been developed at APL to experimentally characterize the manipulator and demonstrate its capabilities.
  - The Z-Theta and manipulator can currently be user controlled using a Matlab interface via keyboard commands.
  - Drive cable tension data is available, however is not relayed to the user.

Hydrophone sensing of the tip of the APL Snake for Dexterous Manipulator





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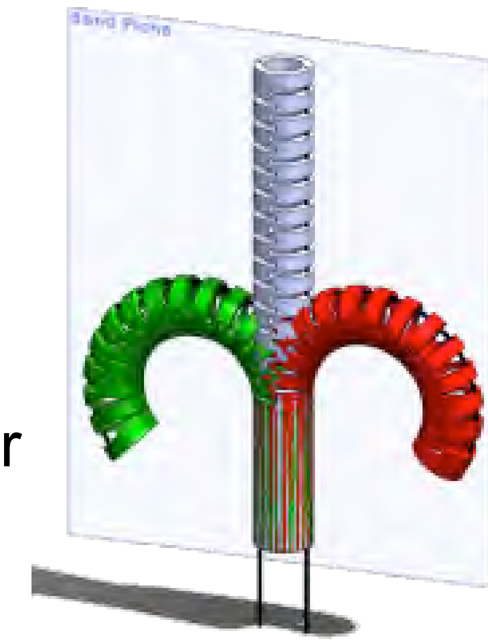
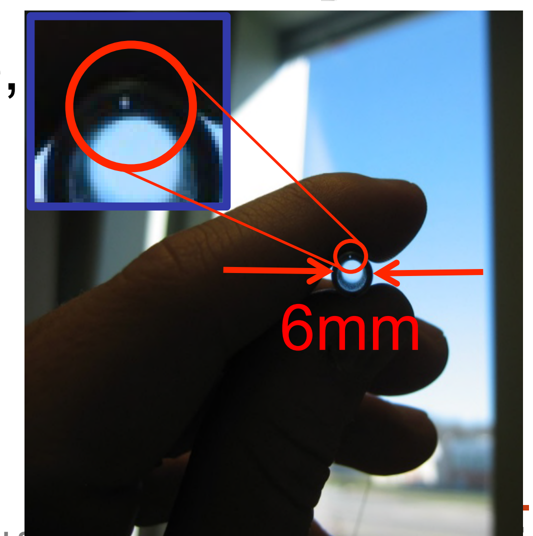
Hydrophone sensing of the tip of the APL Snake for Dexterous Manipulator



- *Deliverables (what we want):*
  - Sensing the tip of the DM using hydrophone fiber optics
  - A phantom for demonstrating the sensor performance with the DM
- *Available Hardware (what we have):*
  - Manipulator(s), Z-Theta actuation stage, PMX/DMX motor controllers, C++ and Matlab motor controller interface, Phantom



Hydrophone sensing of the tip of the APL Snake for Dexterous Manipulator

- *Size of Group:*
  - 2-3 Students
- *Skills:*
  - Experiments, Programming (C++ and/or Matlab), Basic Control Theory
- *Mentors:*
  - Emad Bactor, Mehran Armand