Robotic Endoscopic Tumor Ablation System

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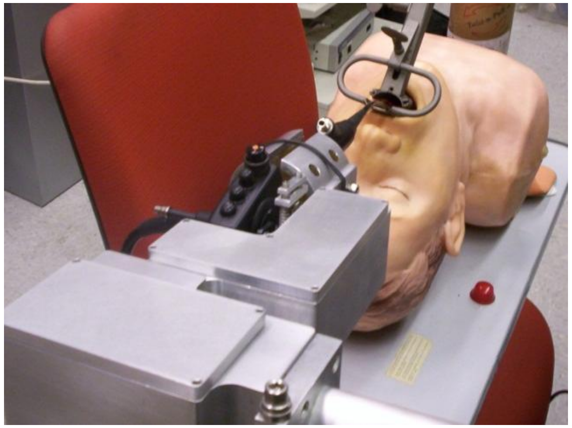
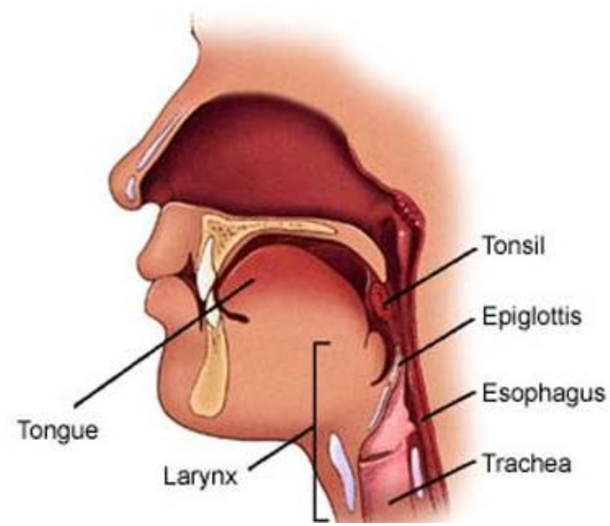
Sponsor: Dr. Jeremy Richmon



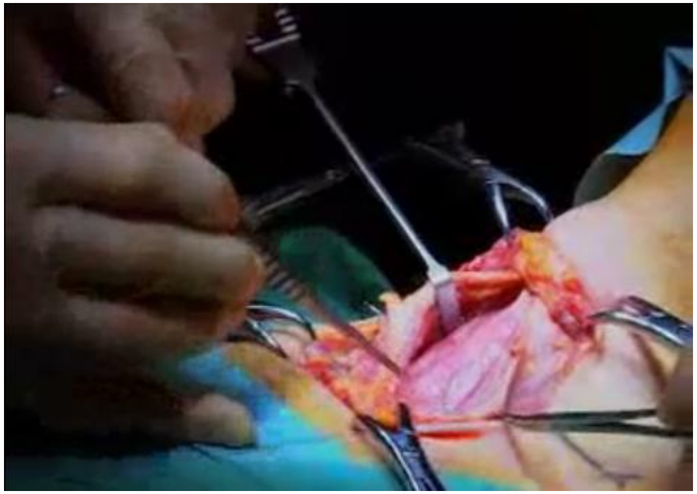
Motivation

- There are approximately 25,000 new cases of throat cancer every year in the US, resulting in approximately 6,000 deaths per year
- Radiation and chemotherapy have many undesirable side effects, especially in a sensitive and critical area like the throat
- Surgical approaches are often used to treat throat cancer



Surgical Techniques

- Types of surgical techniques in throat surgery:
  - Through incisions in the patient's neck
  - Inside the airway using an endoscope and specialized surgical tools including a cutting laser



Pros and Cons of Intra-Airway

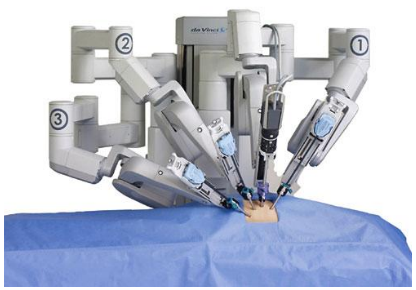
- Advantages of Intra-Airway
  - Less risk of infection
  - Less scarring
  - Smaller risk of complications (damaged vocal cord nerves, etc.)
  - Faster recovery time
- Disadvantages of Intra-Airway
  - Limited visibility
  - Limited working room

Current Intra-Airway Surgery at JHMI

- Minimum of 4 hands needed:
  - Laser and endoscope are separate instruments
  - Endoscope needs two hands to operate
  - 3rd grabbing instrument is needed
- Laser is rigid and cannot bend around corners
- Scope does not remain stationary when hands removed and is difficult to control accurately
- **Result: working environment is crowded and awkward and visibility is poor**

Problem

- Current methods for throat tumor removal require multiple surgeons, risky/expensive surgeries with general anesthesia, and unnecessarily long hospital stays
- Other devices are not specialized, too expensive or don’t have the functionality for a full system.



Goal

Design, build, and test a clinical quality prototype robotic throat tumor ablation system to aid in performing minimally invasive intra-airway surgery done potentially as an outpatient procedure under local or weak general anesthesia.

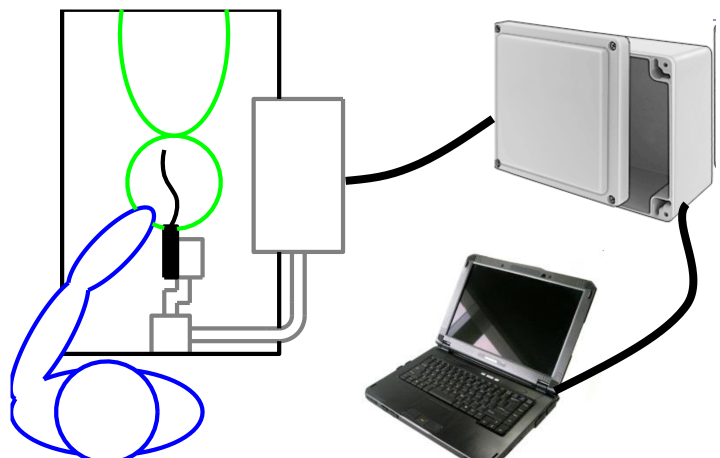
- Reduce number of hands needed
- Control all motion of endoscope
- Allow for use of one hand to control system leaving surgeon free to hold tool in other
- Have scope remain stationary with no hands

Solution

- Use a robotized endoscope with:
  - Single hand operation for laser/scope, leaving the other hand to use tissue manipulators
  - Built-in working channel for cutting laser
  - Precision movement
  - Laser and scope remain stationary when hands removed
  - Use pre-existing clinical endoscope and laser to minimize cost

Our Approach

- Design and build a 3 axis robotic assistance device
- Uses a laptop for surgeon to control system



Constraints and Design Issues

- Resistant to long term exposure to hospital grade cleaning agents
- Cannot contain any allergens or toxic materials
- Submersion proof
- Well grounded
- Should not have a lot of mass over the patient
- As few visible moving parts as possible
- Corrosion resistant seals
- All exposed metal parts must be stainless steel, aluminum, or plastic
- Robot must be able to resist bumps and minor abrasions

Deliverables

- Minimum
  - Functioning system capable of performing mock operations with phantoms
- Expected
  - System capable of performing extensive cadaver experiments demonstrating functionality of system
  - User interface able to control and adjust system
  - Extensive documentation
  - System able to pass clinical engineering standards
- Maximum
  - Image Processing and new input device

Prototype I

Hardware

- Three coreless brushed servo motors with planetary gearheads
- Integrated magnetic encoders
- Linear potentiometers for redundant sensing
- Galil Motion Controller (DMC-4030) with 20 W linear amplifiers
- Waterproof exterior
- +/-12 V isolated power supply

Current Status

- Initial proof of concept prototype using LARS completed
- Clinical prototype 1.0 completed
- This presentation covers the upgrades to transition Clinical prototype 1.0 to clinical prototype 2.0

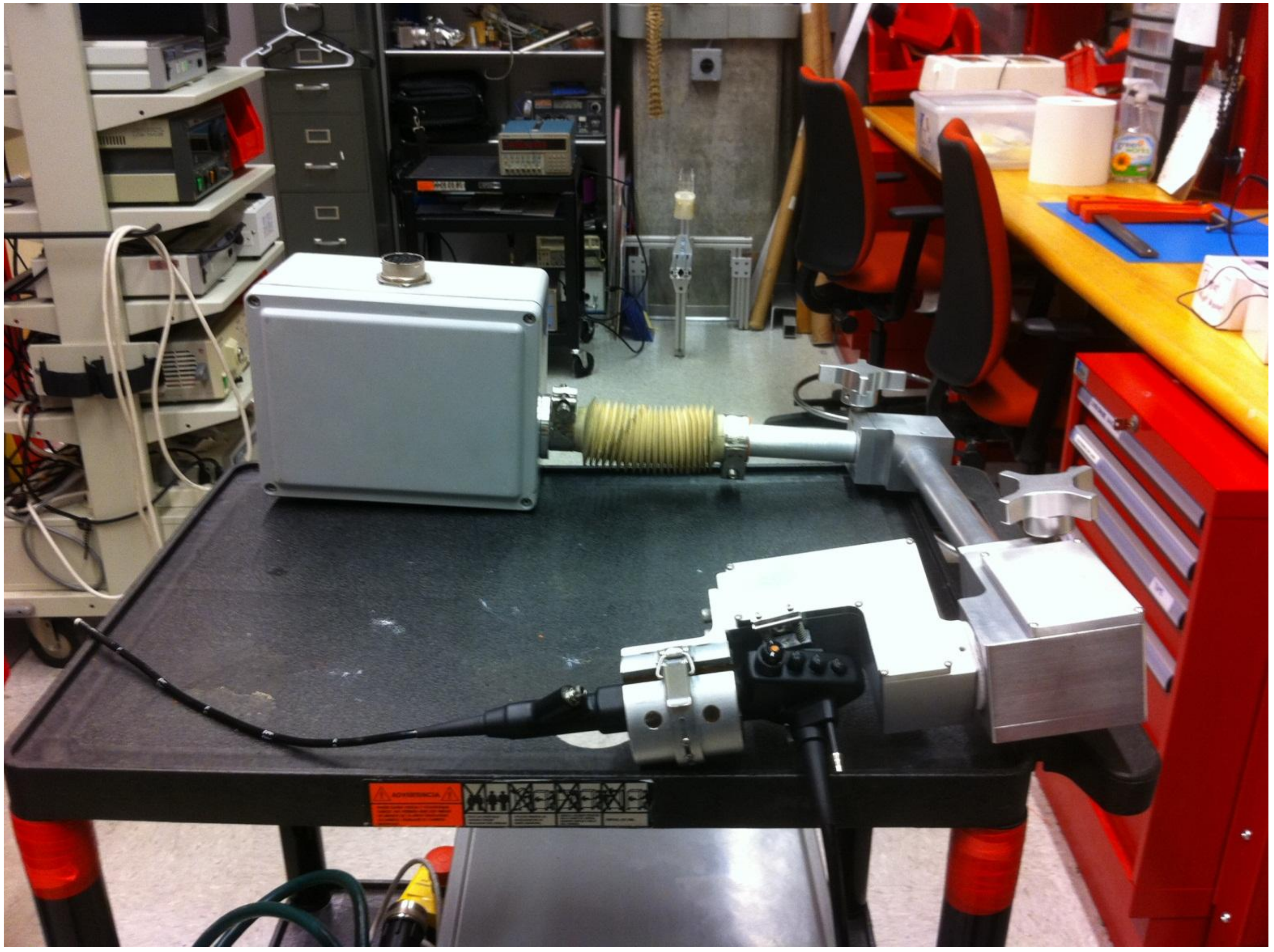
Upgrades

- Rotation stage motor/gearhead
  - More torque
  - Better control
  - Smoother, more regular motion
- Scope handle motor upgraded to fit in enclosure with scope handle manipulator
  - Eliminates mechanical cable
  - Reduces backlash
  - Frees up room for rotation stage motor upgrade

Upgrades (2)

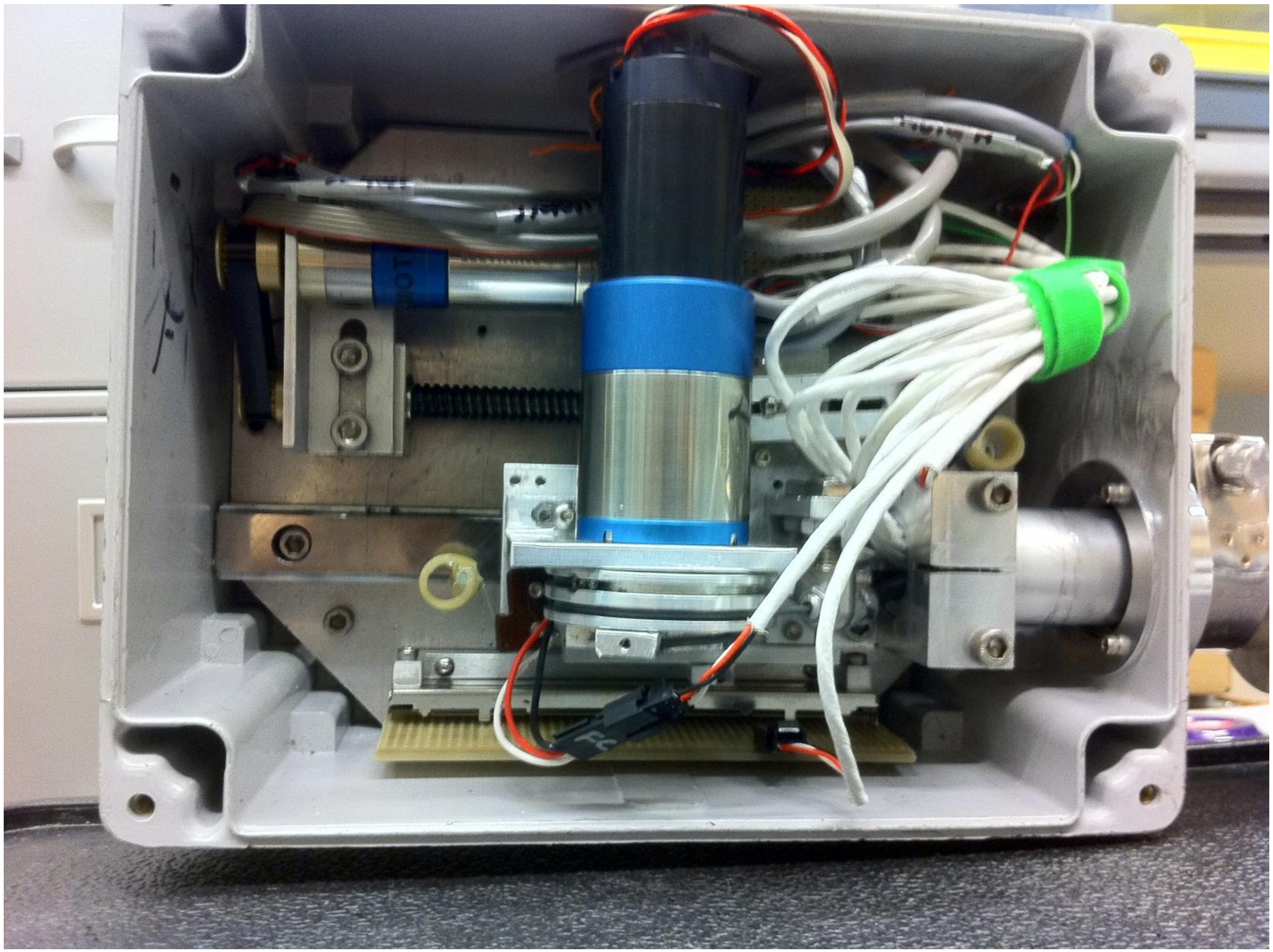
- Bicycle cable to low-stretch aircraft-grade rubber coated cable
- Use handles to adjust robot instead of wrench
- Robust locking electrical connectors
- Screw driven one-site-adjustment removable cable tensioner
- Adjustable latch for holding scope

Prototype 2.0



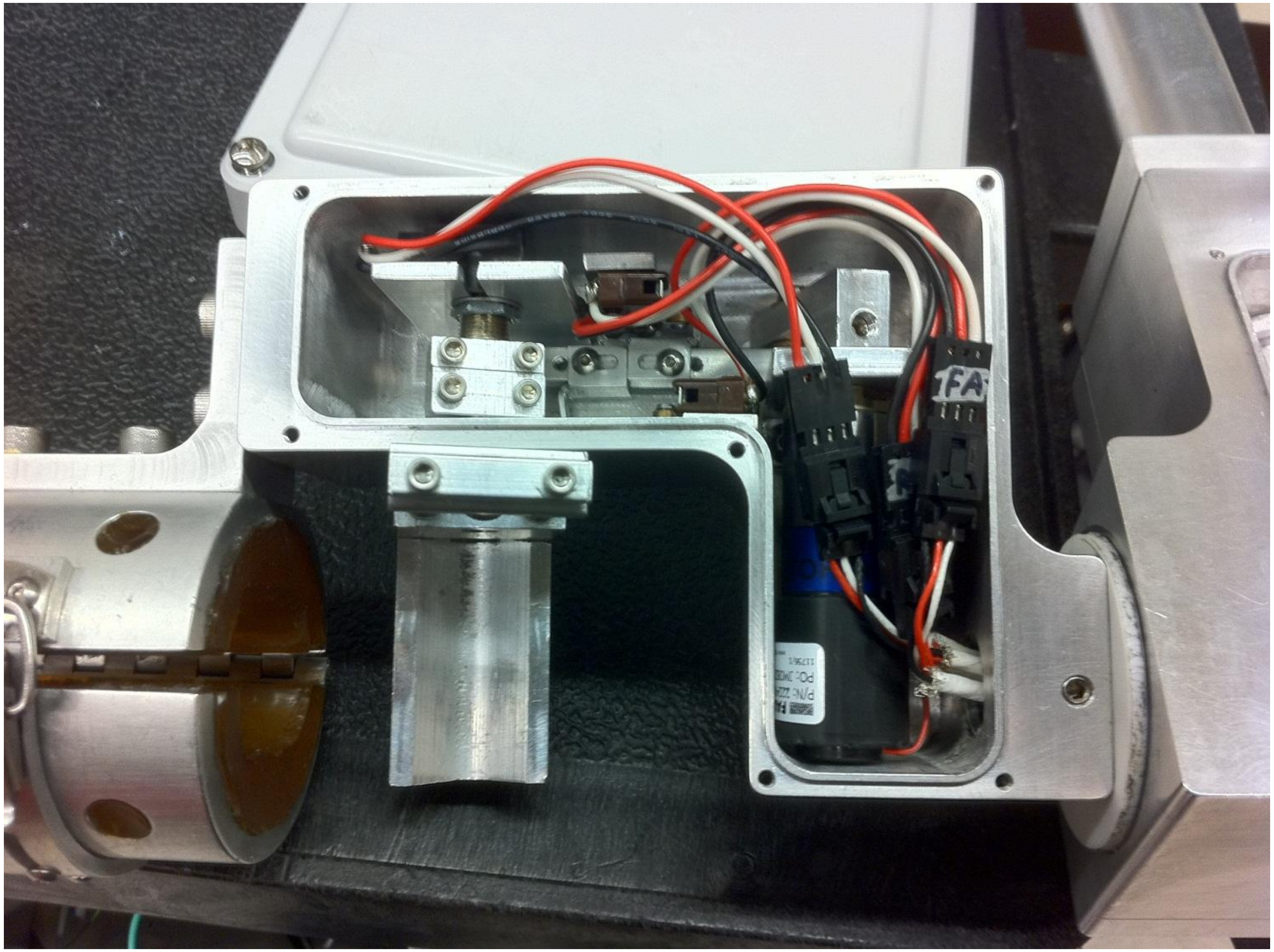
Galil Box

Translation Box



Rotation Box

Scope Box



Summary

- Parts in final robot
  - Parts machined by me: 70+
  - Parts machined by Rich: 7
- Total parts machined
  - By me: 100+
  - By Rich: 9
- Total solder connections: 300+
- Robot tested to be operable under water
- Robot tested on human cadavers and shown to improve surgical performance
- Unplug-carry-plug-play portability
- Easily accepts other comparable scopes

Future Work (Hardware)

- Arrange informal clinical engineering evaluation in preparation for IRB application
- Fine-tune pot feedback and possibly add further filtering
- Develop detailed testing and failure detection plan
- Design and build support arm for robot
- Design and build tower containing robot electronics, scope interrogator, video processing PC, and mount for robot

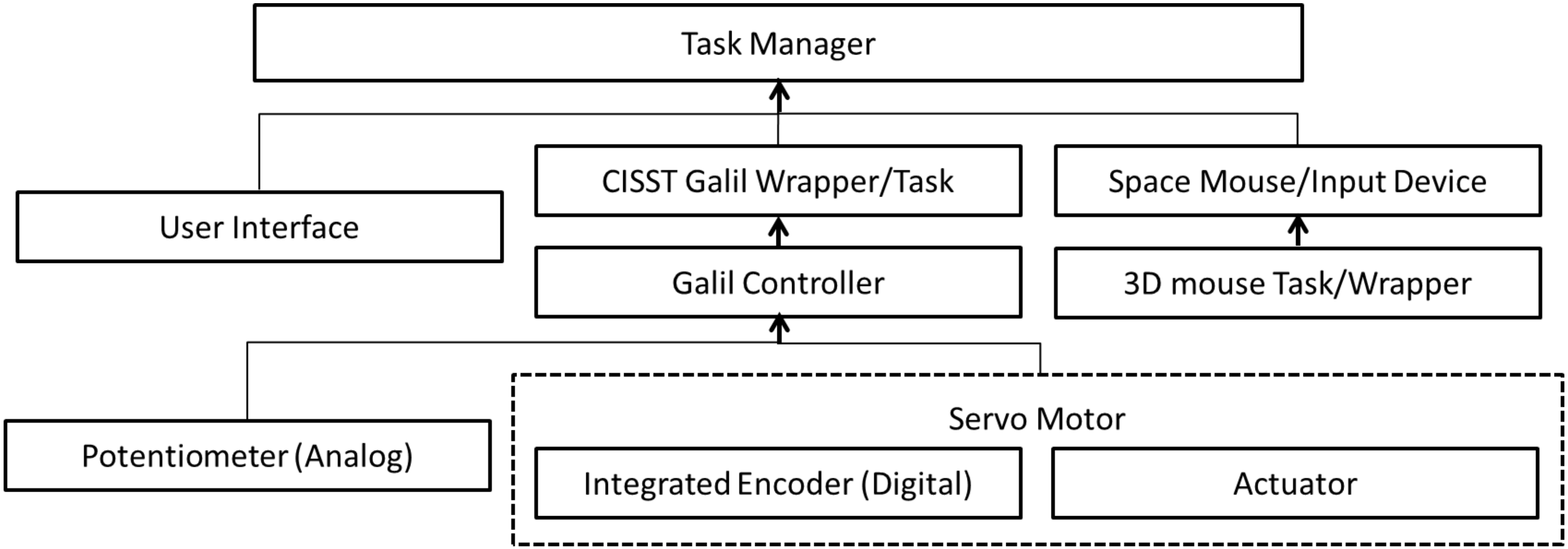
Lessons Learned

- Mechanical cables are a huge pain without a good tensioner (and a moderate pain with one)
- Gearheads have more backlash than you would like
- Using one big electrical cable is annoying for fabrication, but great to work with and well worth the investment
- Aiming for a more robust initial design with upgrades in mind is a good idea for a prototype
  - Don’t waste time repairing trivial problems
  - Transport and setup are much easier

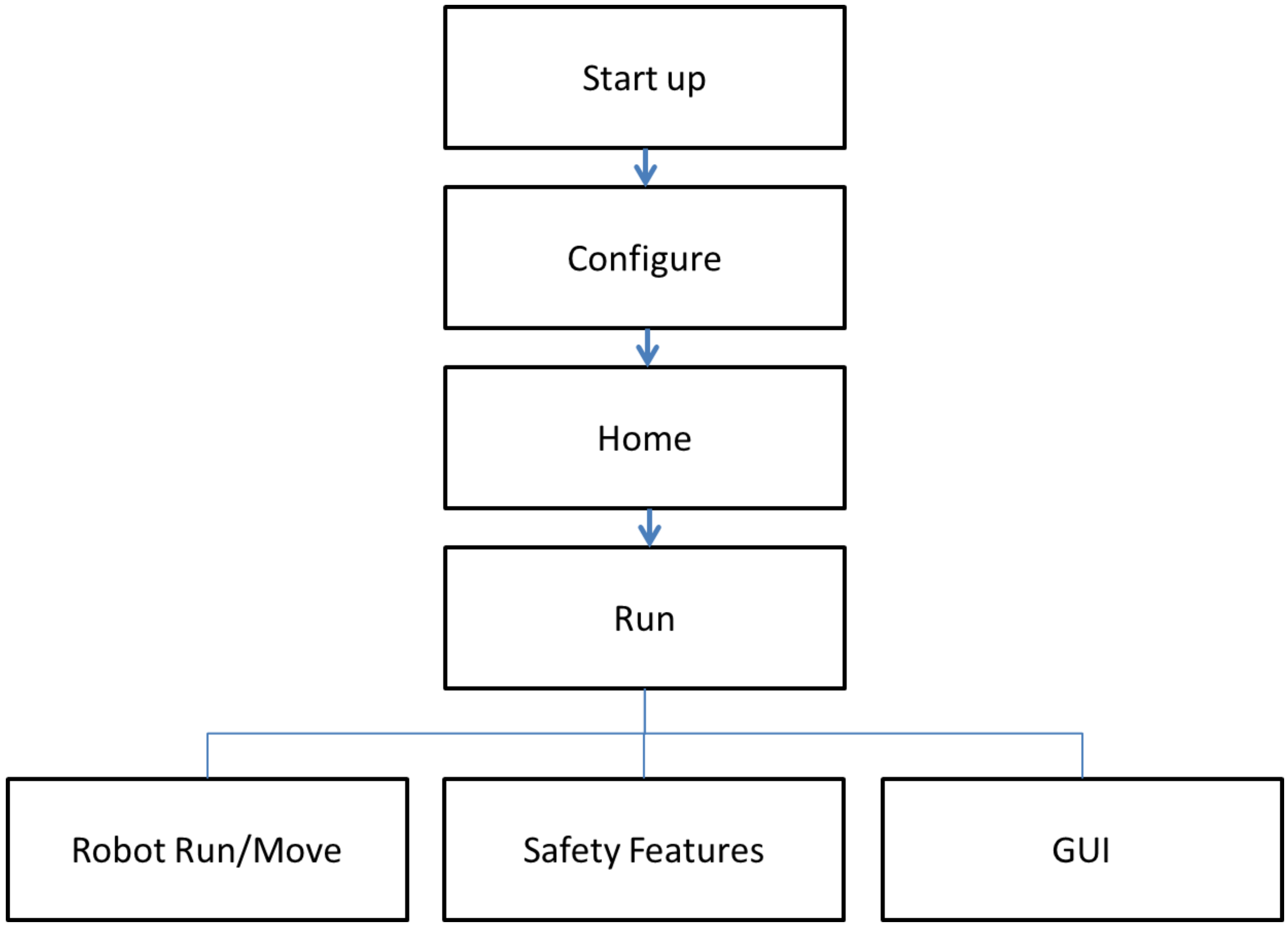
Software

- Utilizes CISST libraries
- Controls each axis of motion separately
- Contains software safety features and limits
- GUI
  - alternative way to move robot
  - adjust speed and other variables
  - visualization/debug feature

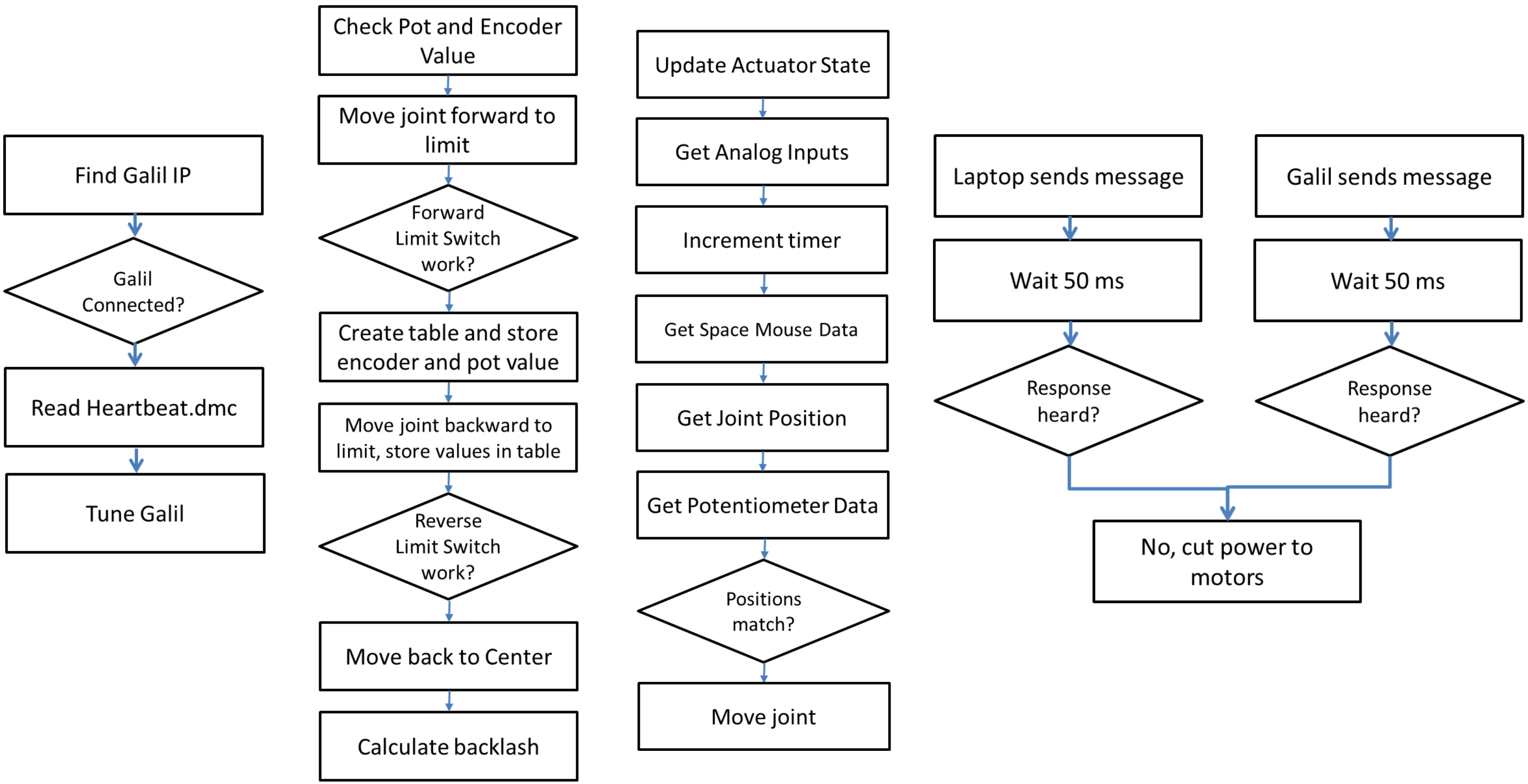
Software


Task Manager
User Interface
CISST Galil Wrapper/Task
Space Mouse/Input Device
Galil Controller
3D mouse Task/Wrapper
Potentiometer (Analog)
Servo Motor
Integrated Encoder (Digital)
Actuator

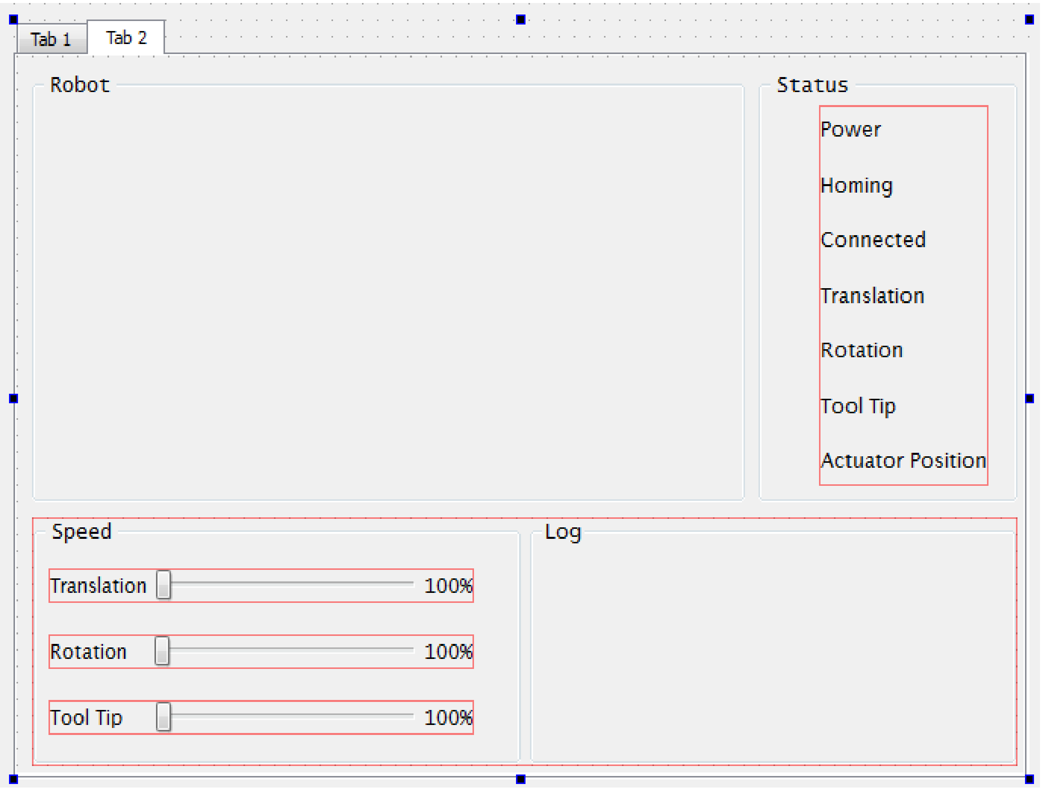
Main Program/ Functions



Tasks


Find Galil IP
Galil Connected?
Read Heartbeat.dmc
Tune Galil
Check Pot and Encoder Value
Move joint forward to limit
Forward Limit Switch work?
Create table and store encoder and pot value
Move joint backward to limit, store values in table
Reverse Limit Switch work?
Move back to Center
Calculate backlash
Update Actuator State
Get Analog Inputs
Increment timer
Get Space Mouse Data
Get Joint Position
Get Potentiometer Data
Positions match?
Move joint
Laptop sends message
Wait 50 ms
Response heard?
Galil sends message
Wait 50 ms
Response heard?
No, cut power to motors

GUI


Tab 1
Tab 2
Robot
Status
Power
Homing
Connected
Translation
Rotation
Tool Tip
Actuator Position
Speed
Translation
100%
Rotation
100%
Tool Tip
100%
Log

Testing Plan

- Clinical Engineering Standards (waterproof, grounded, chemical resistant, etc..)
- Phantom Evaluation
- Initial Cadaver Study
- Final Cadaver Study

Initial Cadaver Trials

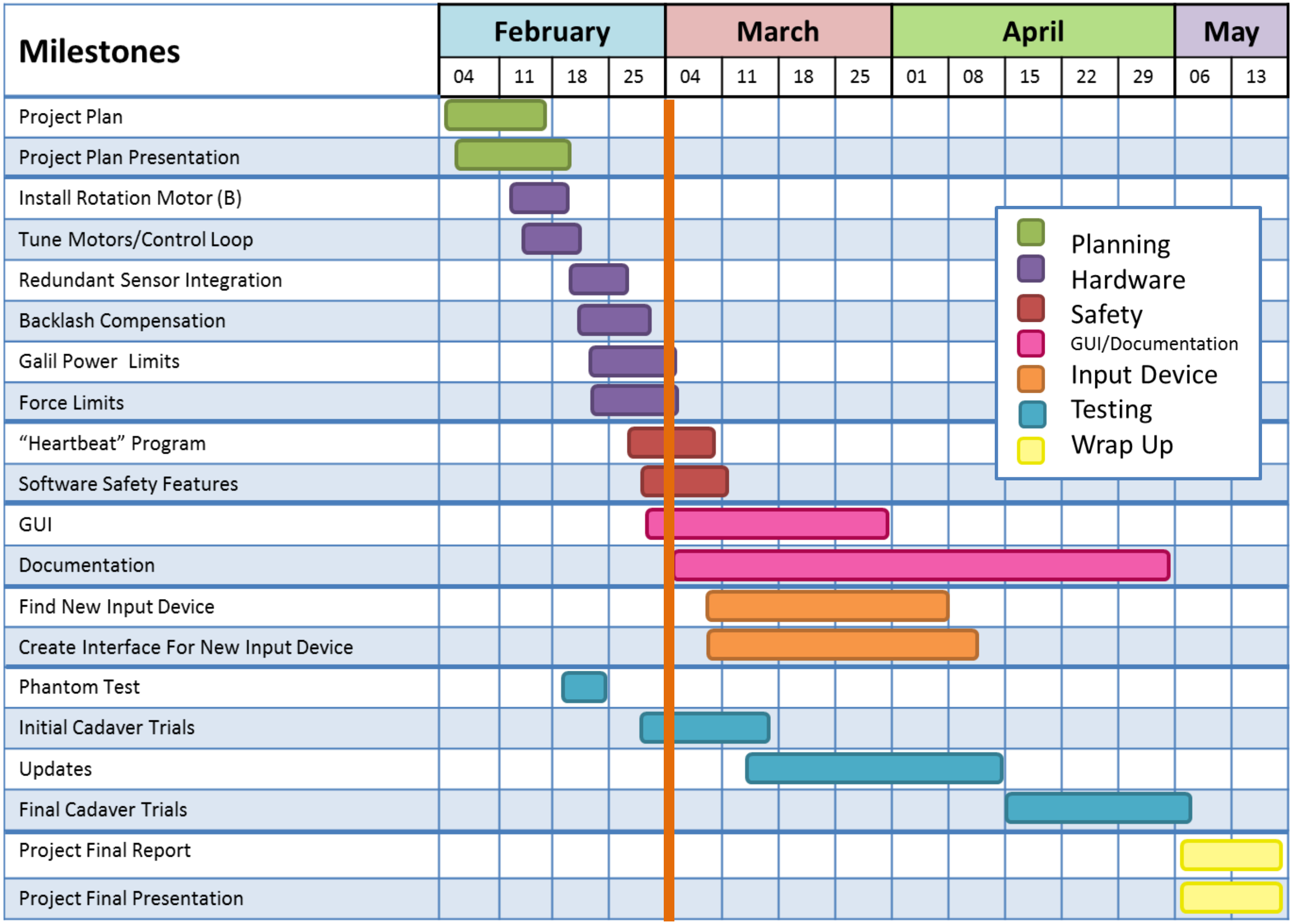
Dependencies

Dependency	Plan to Resolve	Resolve By	Affects
Cadavers Required	Have Surgeons Order	Resolved	Expected
Surgeon Feedback	Schedule Meeting	Resolved	Minimum
New Space Mouse	Order new mouse	Resolved	Minimum
New Translation Motor	Order new motor	Resolved	Maximum
Mechanical Work	Have Kevin finish	February 16	Expected
Funding	Submit budget proposal	Resolved	Maximum
New Input Device	Find an alternative or build alternative	April 1	Maximum
Electronics Equipment	Ask Dr. Taylor	March 9	Expected
QT toolkit/RobotGUI task	Talk to students in Lab	March 1	Maximum

LABORATORY FOR Computational Sensing + Robotics
THE JOHNS HOPKINS UNIVERSITY

JOHNS HOPKINS MEDICINE

Timeline and Milestones



Management Plan

- 25 hours per week on project (Liz)
- 10 hours per week on project (Kevin)
- Reassess deliverables at each milestone
- Meeting Schedule
  - Weekly meeting with Dr. Taylor
  - Monthly meeting with Dr. Richmon

Budget

Items	Budget Allocation
Scope	$22,000
Scope interrogator	$2,000
Salary (Kevin Olds)	$33,000
Hardware	$12,000
• Theta-stage	$2,000
• Z-stage	$2,000
• Motor Controller	$2,000
• Motors/Encoders	$1,500
• Misc. Shop Materials	$500
• Computer/accessories	$1,000
• Machinist Fees	$1,000
• Phantom Costs	$500
Enhancements	$2,900
Phantom Study	$925
Clinical Engineering	$2,875
Cadaver Study	$11,875
Total	**$87,575**

Questions?