Checkpoint Presentation: Robotic Endoscopic Tumor Ablation System

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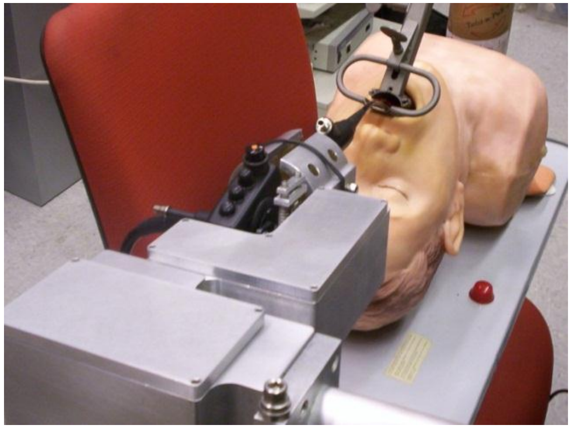
Sponsor: Dr. Jeremy Richmon



March 31, 2011

Motivation

- Approximately 25,000 new cases of throat cancer every year in the US
- Radiation and chemotherapy have many undesirable side effects
- Surgical approaches are often used to treat throat cancer
  - Through incisions in the patient's neck
  - Inside the airway using an endoscope and specialized surgical tools including a cutting laser

Problem

- Minimum of 4 hands needed
- Scope does not remain stationary when hands removed
- Control of tip is not intuitive, requires practice
- Working environment is crowded and visibility is poor
- Expensive surgeries with 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

Our Approach

- Design and build a 3 axis robotic assistance device
  - Single hand operation for laser/scope
  - Precision movement
  - Laser and scope remain stationary when hands removed
  - Use pre-existing clinical endoscope and laser to minimize cost

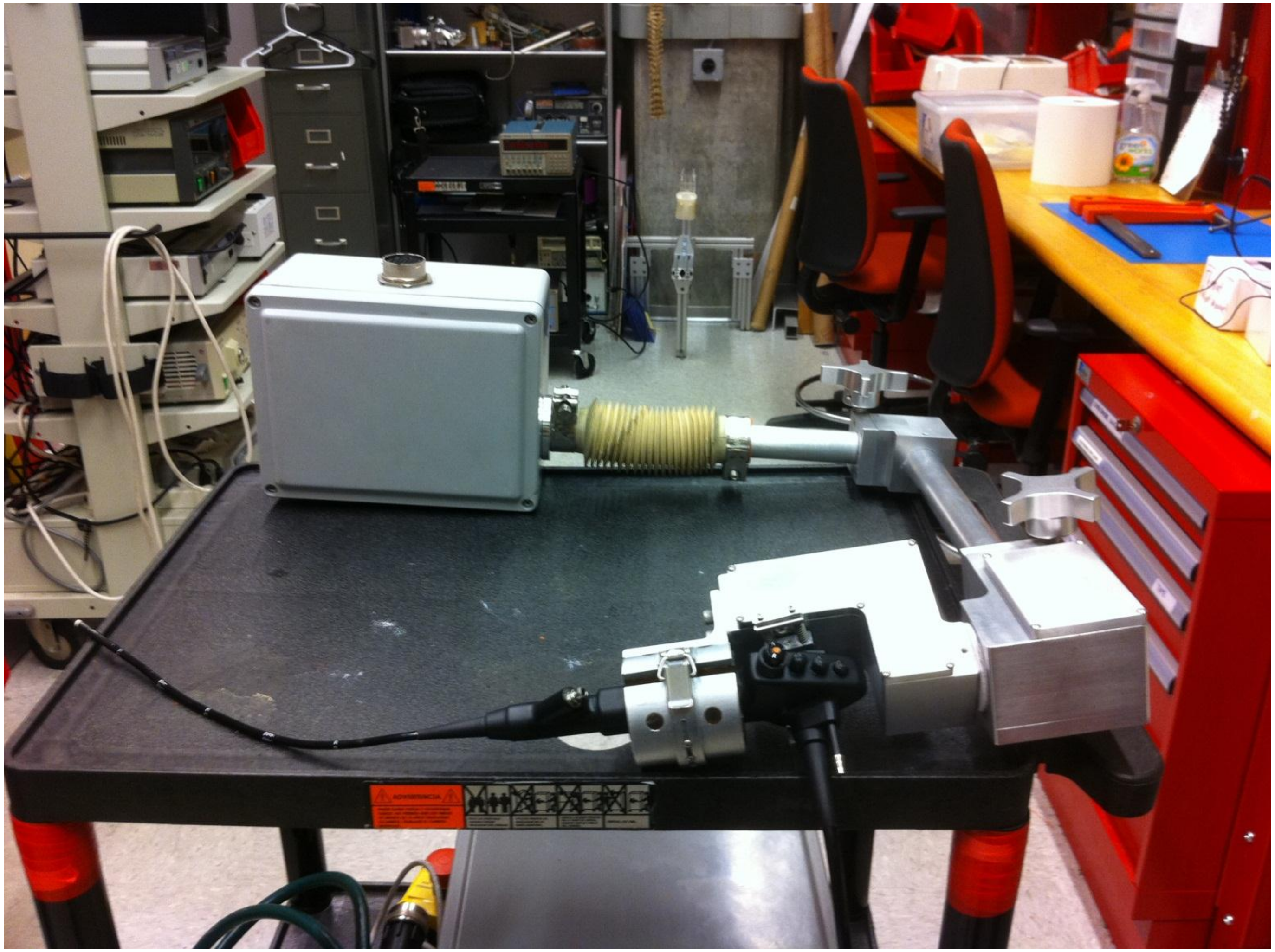
Deliverables

- 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

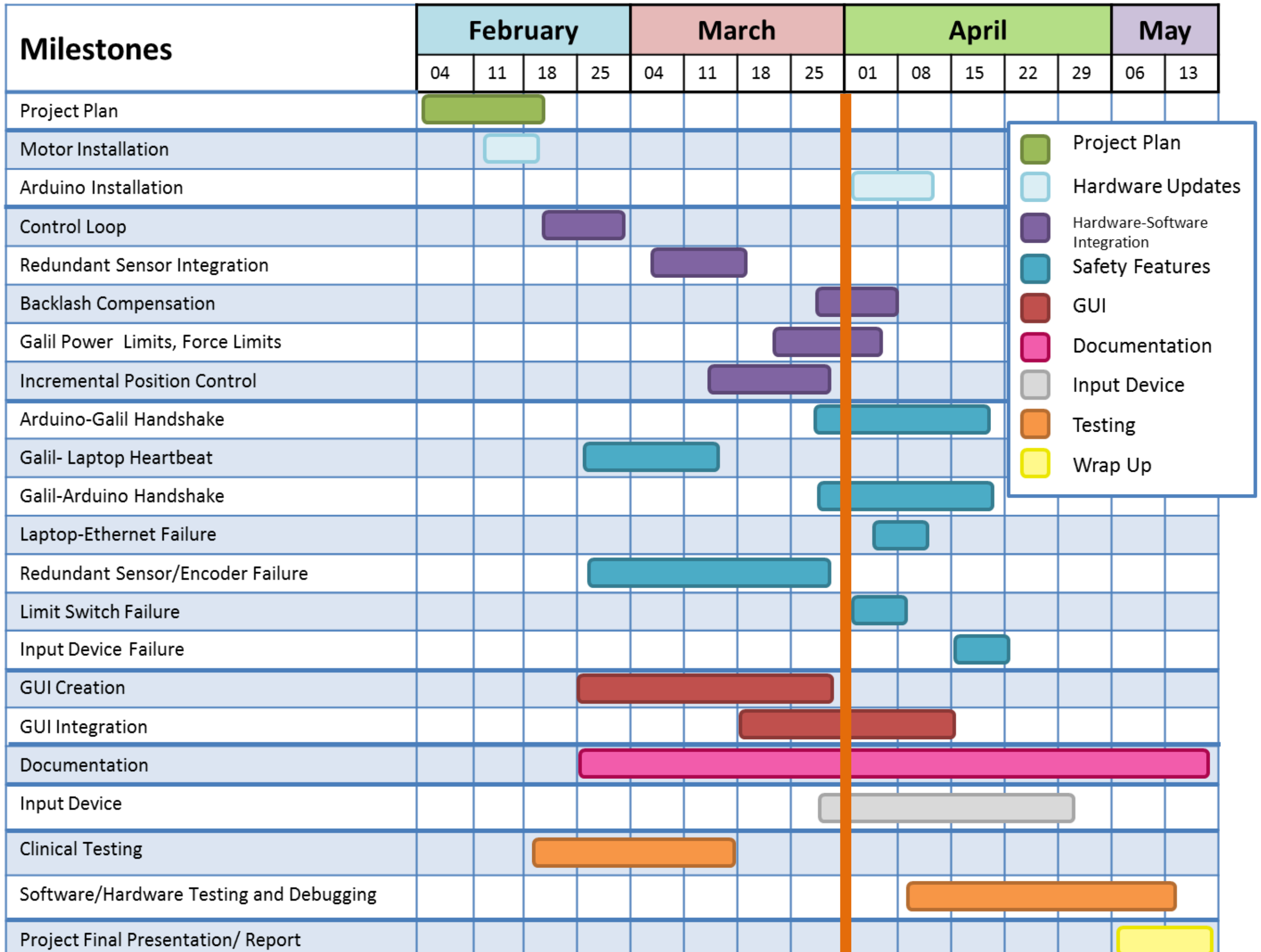
Current Status

- Completed
  - Hardware
  - Clinical Testing
- In Progress
  - Software
  - Documentation
- To Be Done
  - Testing

Prototype



Timeline



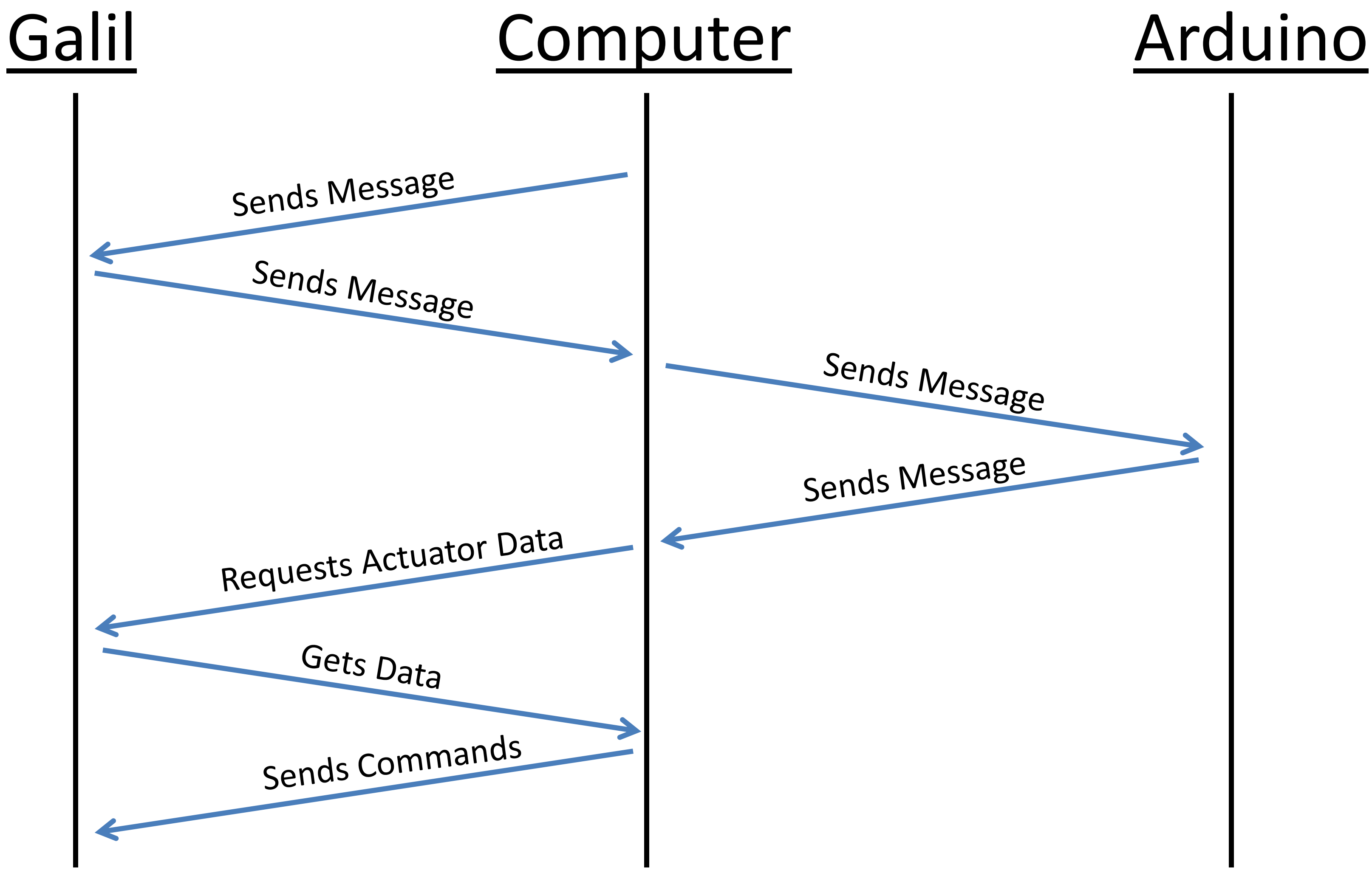
Milestones
February
March
April
May
04
11
18
25
04
11
18
25
01
08
15
22
29
06
13
Project Plan
Motor Installation
Arduino Installation
Control Loop
Redundant Sensor Integration
Backlash Compensation
Galil Power Limits, Force Limits
Incremental Position Control
Arduino-Galil Handshake
Galil- Laptop Heartbeat
Galil-Arduino Handshake
Laptop-Ethernet Failure
Redundant Sensor/Encoder Failure
Limit Switch Failure
Input Device Failure
GUI Creation
GUI Integration
Documentation
Input Device
Clinical Testing
Software/Hardware Testing and Debugging
Project Final Presentation/ Report
Project Plan
Hardware Updates
Hardware-Software Integration
Safety Features
GUI
Documentation
Input Device
Testing
Wrap Up

Initial Cadaver Trials

Software

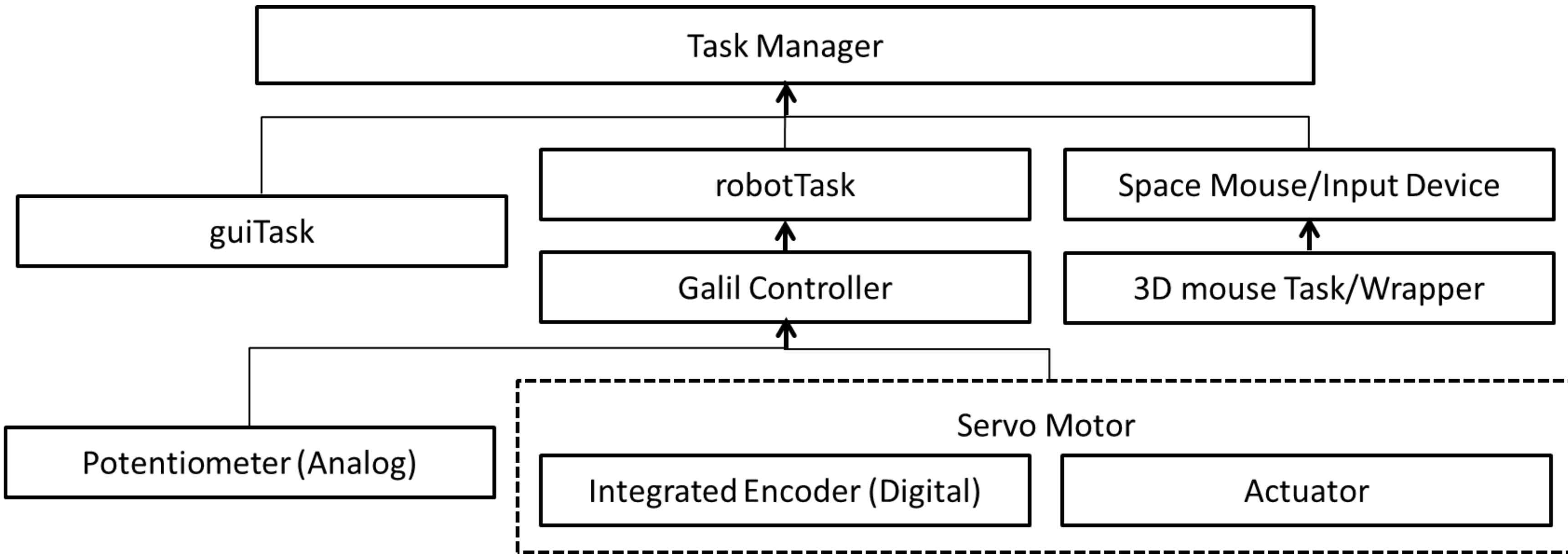
- Utilizes CISST libraries
- Controls each axis of motion separately
- Contains software safety features and limits
- GUI
  - alternative way to move robot
  - adjust speed and other variables
  - visualization/debug feature

Software

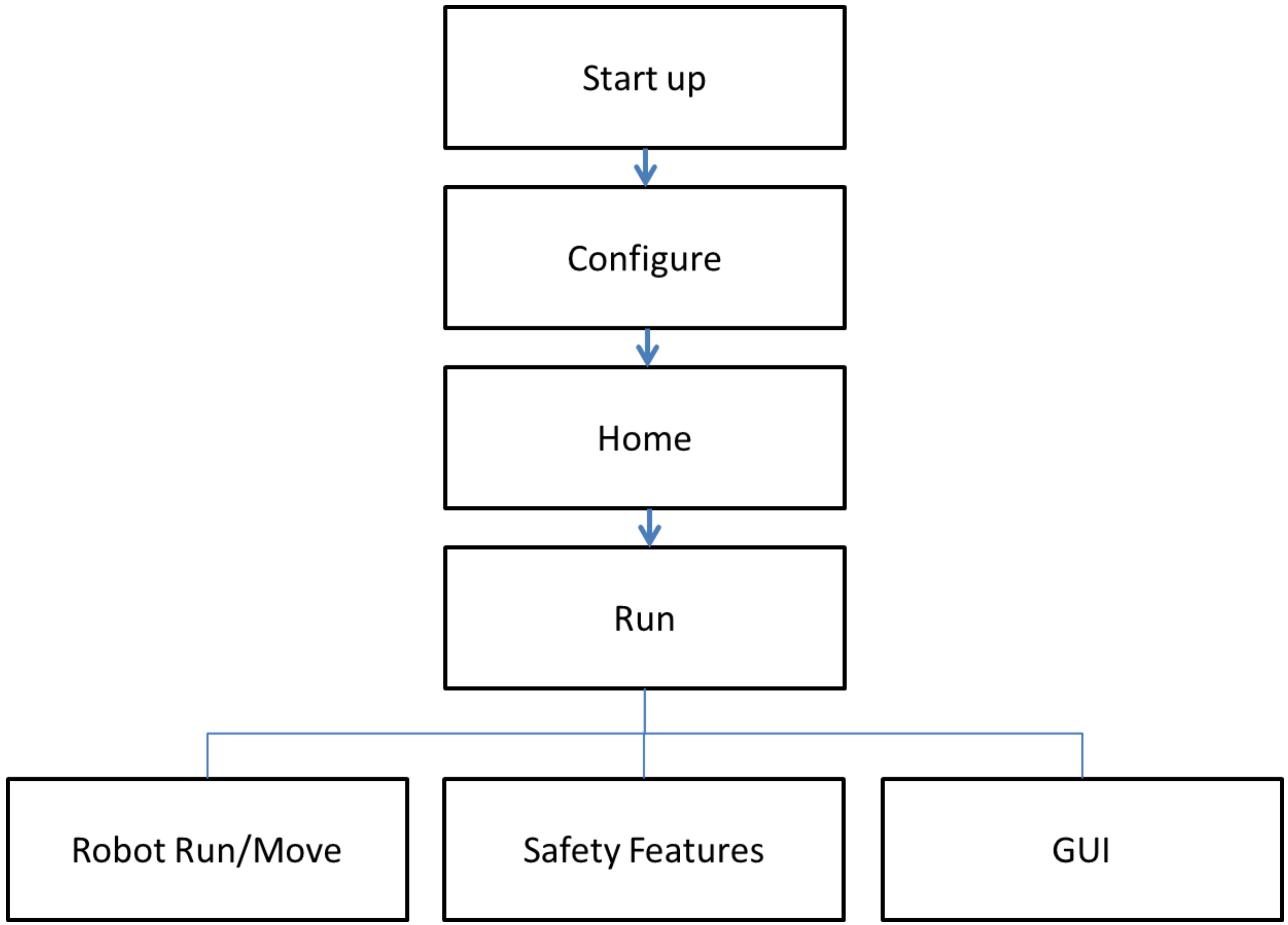


Galil
Computer
Arduino
Sends Message
Sends Message
Sends Message
Sends Message
Requests Actuator Data
Gets Data
Sends Commands

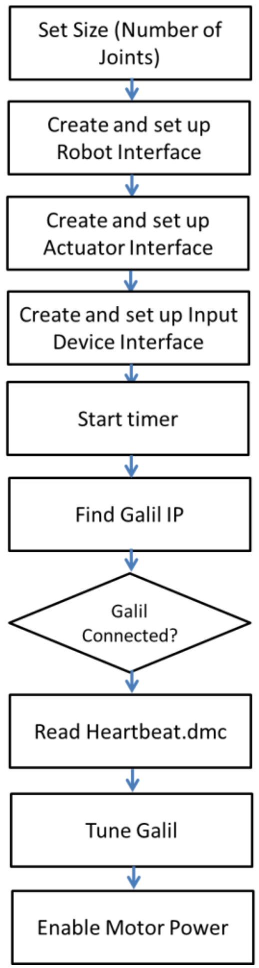
Task Overview



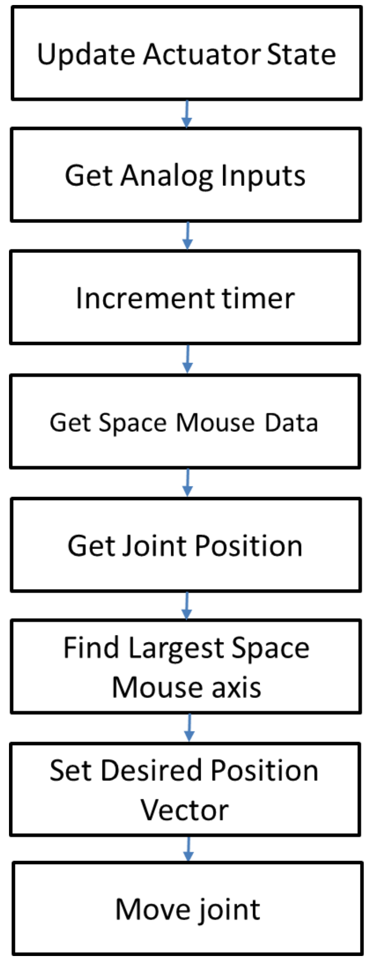
Main Program



Configure and Initialize

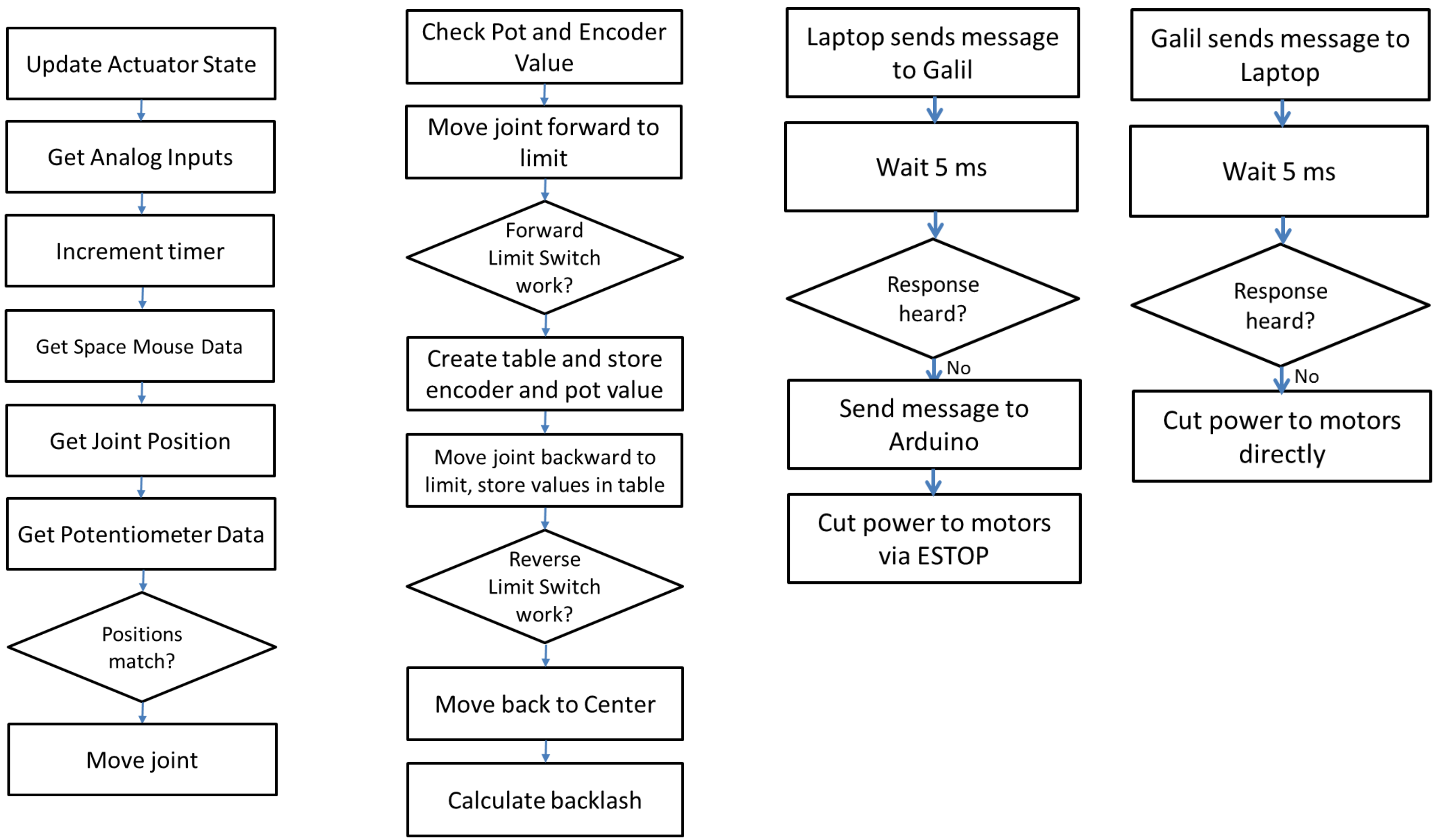


Robot Run


Update Actuator State
Get Analog Inputs
Increment timer
Get Space Mouse Data
Get Joint Position
Find Largest Space Mouse axis
Set Desired Position Vector
Move joint

Safety Features

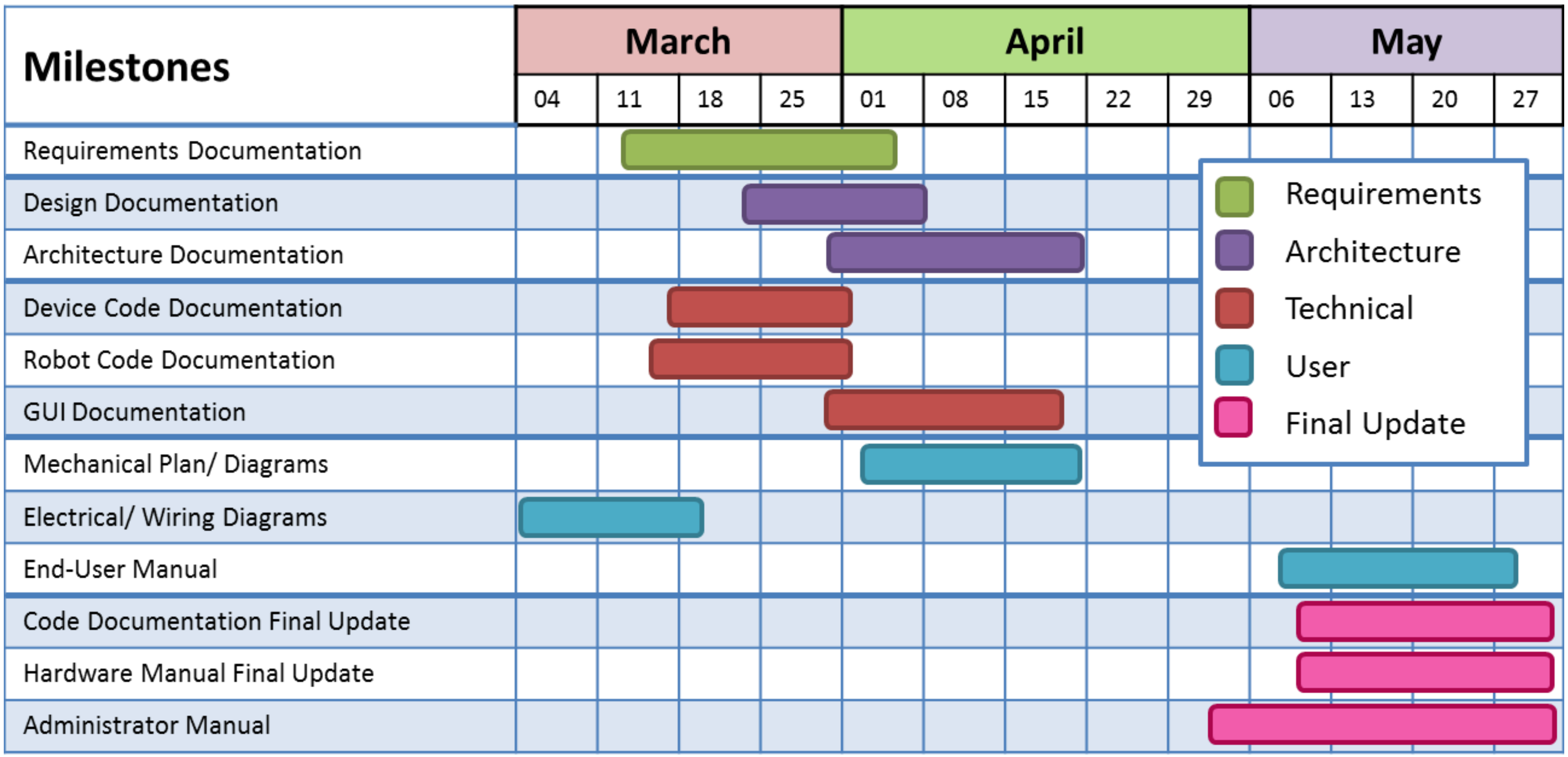
Redundant Sensing | Homing/Limit Switch | Galil Heartbeat



Input Device

- Commercial USB joysticks offer enough degrees of freedom
- Microsoft DirectInput SDK can be interfaced with C++
- Need to Integrate the SDK library into code to work with CISST libraries in order to replace Space Mouse

Documentation Plan



Requirements Documentation

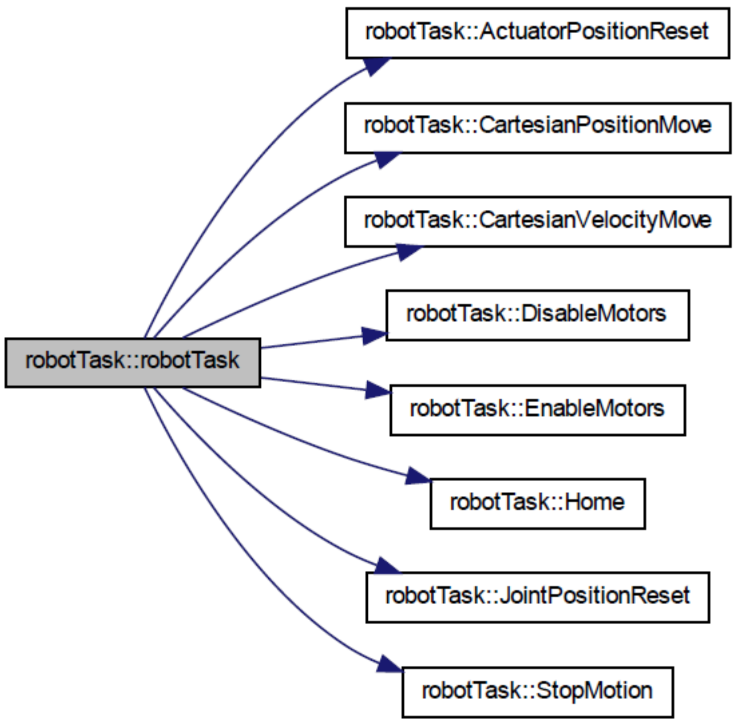
- Functional Requirements
  - Use Cases
  - UML Diagram
- Non-functional Requirements
  - Safety features to prevent failure of system
  - Extensive Documentation
- Constraint Requirements

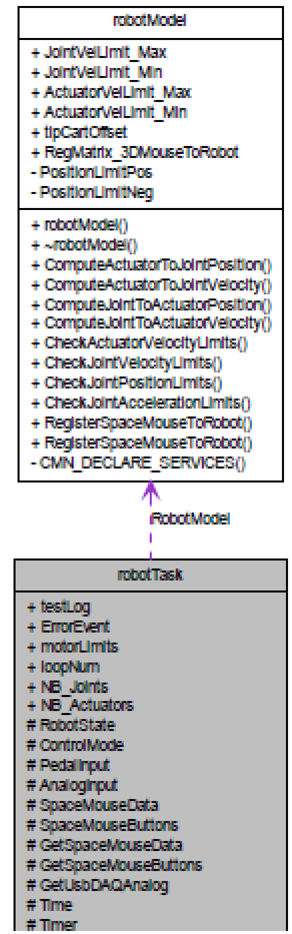
Sample Use Case

- Title: Robot Move
- Actors: Space Mouse (Input Device- Surgeon), Computer, Galil Motion Controller, Actuators
- Goal: Should take input from the Space Mouse and translate to direct movement of one axis of the robot (actuator)
- Pre-Condition: Robot Program is started and robotTask::Run() is called
- Main Path:

1) Get Digital (Encoder) Actuator Data and update states
2) Get Space Mouse Data
3) Get Analog Inputs (Potentiometer)
4) Compare Analog and Digital Inputs
   If different, cut power to the motors and show error
5) Find Space Mouse Axis with Greatest Difference from Resting Position
6) Check Sign of Desired Axis
7) Set desired Position of Axis using Appropriate Sign
8) Write to Appropriate Logs
9) Update GUI
10) Send Command to Galil to Move

Sample Diagrams





Architecture Documentation

- Design Document
- Views
  - Functional
  - Process
  - Logical
  - Design
  - Interface
  - Operational

Technical Documentation

- Use Doxygen to generate code documentation

ThroatRobot

Throat Robot

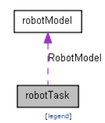
Main Page | Classes | Files | Search

Class List | Class Index | Class Members

Public Types | Public Member Functions | Public Attributes | Static Public Attributes | Protected Member Functions | Protected Attributes

robotTask Class Reference

Collaboration diagram for robotTask:



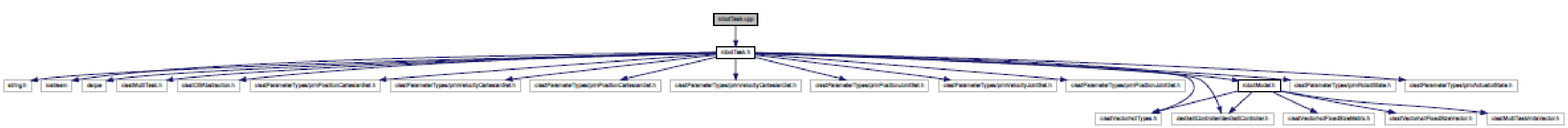
List of all members.

Public Types

enum	{ **MSG_Size** = 512 }

Public Member Functions

	robotTask (const std::string &taskName, double period)
	~robotTask (void)
void	**Configure** (const std::string &CMN_UNUSED(filename)="")
void	**Startup** (void)
void	**Run** (void)
void	**Cleanup** (void)
void	**CM_3DMouse_Direct** (void)
void	**CartesianPositionMove** (const prmPositionCartesianSet &cartPosGoal)
void	**CartesianVelocityMove** (const prmVelocityCartesianSet &cartVelGoal)
void	**CartesianPositionReset** (const prmPositionCartesianSet &newPosition)
void	**JointPositionMove** (const prmPositionJointSet &posGoal)
void	**JointVelocityMove** (const prmVelocityJointSet &velGoal)
void	**JointPositionReset** (const prmPositionJointSet &newPosition)
void	**ActuatorPositionMove** (const prmMaskedDoubleVec &posGoal)
void	**ActuatorVelocityMove** (const prmMaskedDoubleVec &velGoal)
void	**ActuatorVelocitySet** (const prmMaskedDoubleVec &velocity)
void	**ActuatorPositionReset** (const prmMaskedDoubleVec &newPosition)
void	**ActuatorStopMotion** (const prmMaskedDoubleVec &mask)
void	**ActuatorDisable** (const prmMaskedDoubleVec &mask)
void	**ActuatorEnable** (const prmMaskedDoubleVec &mask)
void	**StopMotion** (void)
void	**EnableMotors** (void)
void	**DisableMotors** (void)
void	**Home** (const prmMaskedDoubleVec &mask)
void	**SetLimit** (void)



User Documentation

- Mechanical Diagrams and Specifications
- Wiring Diagrams and Electrical Specifications
- User Manual that shows:
  – Hardware specifications
  – Software Overview and Tutorial
  – Extensive Code documentation

Failure Mode and Effects Analysis

Function	Failure Mode	Effects	Severity	Cause(s)	Occurrence rating	Current Controls	Detection Rating	CRIT (critical characterstic)	RPN (risk priority number)
Limit Switch	Connection Fails	Damage to joint and danger to patient	4	Disconnected or Power error	2	Galil Reads if Limit Switch has been triggered	2	N	16
Potentiometer	Connection Fails	Loss of redundant sensing, possible imprecision in movement	4	Disconnected or Power error	3	Read in through Galil analog input, compared to digital encoder data	2	N	24
Encoder	Connection Fails	Loss of position data, motor may run away and harm patient	7	Connection or Power error	2	Read in through Galil digital input, compared to analog pot data	1	Y	14
Motor Power	Runs Away	Joint is no longer controlled and can run into patient	8	Incorrect output from Galil	4	Galil sends power through laptop commands	2	Y	64
Motor Mechanics	Slipping	Motor causes slipping in joints	7	?	3	?	4	Y	84
Joint Jam	High Forces	Joint stops moving	7	High Forces	2	Limit Switches cut power to joint before jam	3	Y	42
Ethernet	Connection Fails	No communication between user and Robot	6	Disconnected	3	?	1	Y	18
Laptop	Crashes or Connection Fails	No communication between user and Robot	8	Program Crashes, Power Error, Computer error	5	Galil checks to see if Laptop continues to communicate	1	Y	40
Input Device	Connection Fails	No communication between user and robot via input device	5	Disconnected	2	Laptop checks to make sure an input device is detected	1	Y	10
Program	Crashes or Errors	No control to robot	8	Error in Code	6	Galil checks to see if Laptop continues to communicate	1	Y	48
Galil	Crashes or Connection Fails	No control to robot	9	?	5	Laptop checks to see if Galil continues to communicate	1	Y	45
Arduino	Crashes or Connection Fails	Possible error with Galil	3	?	5	Galil checks to see if Arduino continues to communicate	2	N	30

Testing Plan

- Clinical Engineering Standards (waterproof, grounded, chemical resistant, etc..)
- Clinical Testing
  - Phantom Evaluation
  - Initial Cadaver Study
  - Final Cadaver Study
  - IRB Application
- Hardware Testing
- Software Testing

Milestones

Milestones	Planned	Expected	On time	Delayed	Done
Motor Installation	02/20	02/20			✓
Arduino Installation	04/10	04/10	✓		
Control Loop	03/01	03/01			✓
Redundant Sensor Integration	03/21	03/21			✓
Backlash Compensation	04/08	04/08	✓		
Galil Power Limits	04/03	04/06		✓	
Force Limits	04/06	04/06	✓		
Incremental Position Control	03/28	03/28			✓
Arduino-Galil Handshake	04/16	04/16	✓		
Galil- Laptop Heartbeat	03/16	03/16			✓
Galil-Arduino Handshake	04/16	04/16	✓		
Laptop-Ethernet Failure	04/10	04/10	✓		
Redundant Sensor/Encoder Failure	04/28	04/15	✓		
Limit Switch Failure	04/09	04/09	✓		
Input Device Failure	04/20	04/20	✓		
GUI Creation	03/30	04/05		✓	
GUI Integration	04/16	04/12	✓		
Design Documentation	04/20	04/20	✓		
Code Documentation	04/18	04/01			✓
Electrical Documentation	03/20	03/20			✓
User/System Documentation	05/15	05/15	✓		
Input Device	04/30	04/30	✓		
Clinical Testing	03/10	03/10			✓
Hardware Testing	05/10	05/10	✓		
Software Testing	05/10	05/10	✓		

Dependencies

Dependency	Plan to Resolve	Resolve By	Affects
Cadavers Required	MISTIC Lab Training	Resolved	Expected
Surgeon Feedback	Scheduled Meetings	Resolved	Minimum
New Space Mouse	Order new mouse	Resolved	Minimum
New Translation Motor	Order new motor	Resolved	Maximum
Mechanical Work	Have Kevin finish	Resolved	Expected
Funding	Submit budget proposal	Resolved	Maximum
New Input Device	Find an alternative	April 6	Maximum
Documentation Review	Dr. Kazinzides	April 20	Expected
QT toolkit/RobotGUI task	Talk to Marcin, Dr. Kazinzides	Resolved	Maximum

Future Work

- Integrate Arduino
- Finish Safety Limits
- Finish final GUI Integration
- Finish Documentation
- Testing

Management Plan

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

Questions?