Group 4 Project Checkpoint Presentation

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Project Goal Summary

Improve performance of the Galen Microsurgical system:

- Implement tool gravity compensation for static tools
- Implement tool gravity compensation for tools in motion
- Characterize and account for deflection

Work to Date: Summary

- Static data collection
- Static compensation model
- Results for static compensation model
- Began integrating model into robot code
- Drift analysis and characterization

Work to Date: Static Data Collection

- Designed and implemented behavior to
  - Move robot to different poses in the workspace
  - Obtain many force sensor readings at each pose
- Wrote script to parse and average output data
- Problems we ran into:
  - Raw force readings
  - Bias
    - Note: We bias the robot at its home position without any tool attached

Static Math: Setup

$$R_{bs}(0) = R_{ts}(0) = R_y(\frac{\pi}{2})R_z(\frac{4\pi}{15})$$

$$R_{bs}(\theta) = R_{ts}(\theta) = R_x(\theta_r - 3.4) * R_y(\theta_t) * R_{bs}(0)$$

$$p_{bs} = -R_{bs}(\theta) * p_{sb}$$

$$p_{ts} = -R_{ts}(\theta) * p_{st}$$

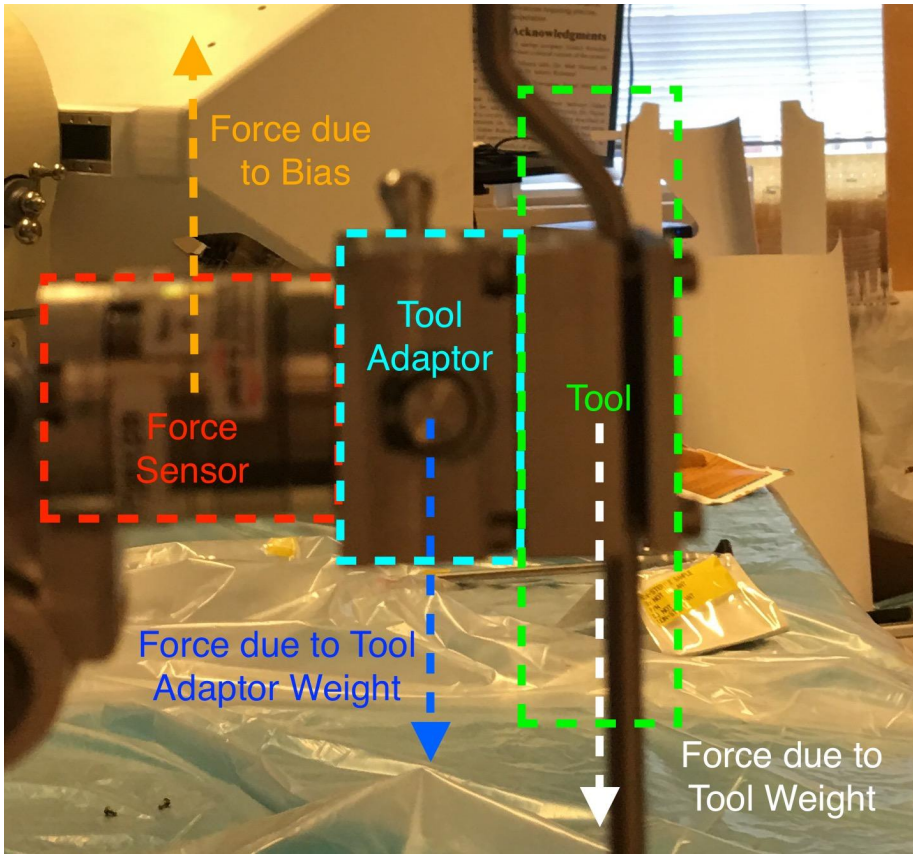
$$F_b = \begin{bmatrix} 0 & 0 & m_b g & 0 & 0 & 0 \end{bmatrix}^T$$

$$F_t = \begin{bmatrix} 0 & 0 & m_t g & 0 & 0 & 0 \end{bmatrix}^T$$

s: sensor frame

b: tool adaptor frame

t: tool frame



Static Math: Bias & Tool Regression

- Using data set with no tool attached

$$F_s = Ad^T_{g_{bs}(\theta)} F_b - Ad^T_{g_{bs}(0)} F_b$$

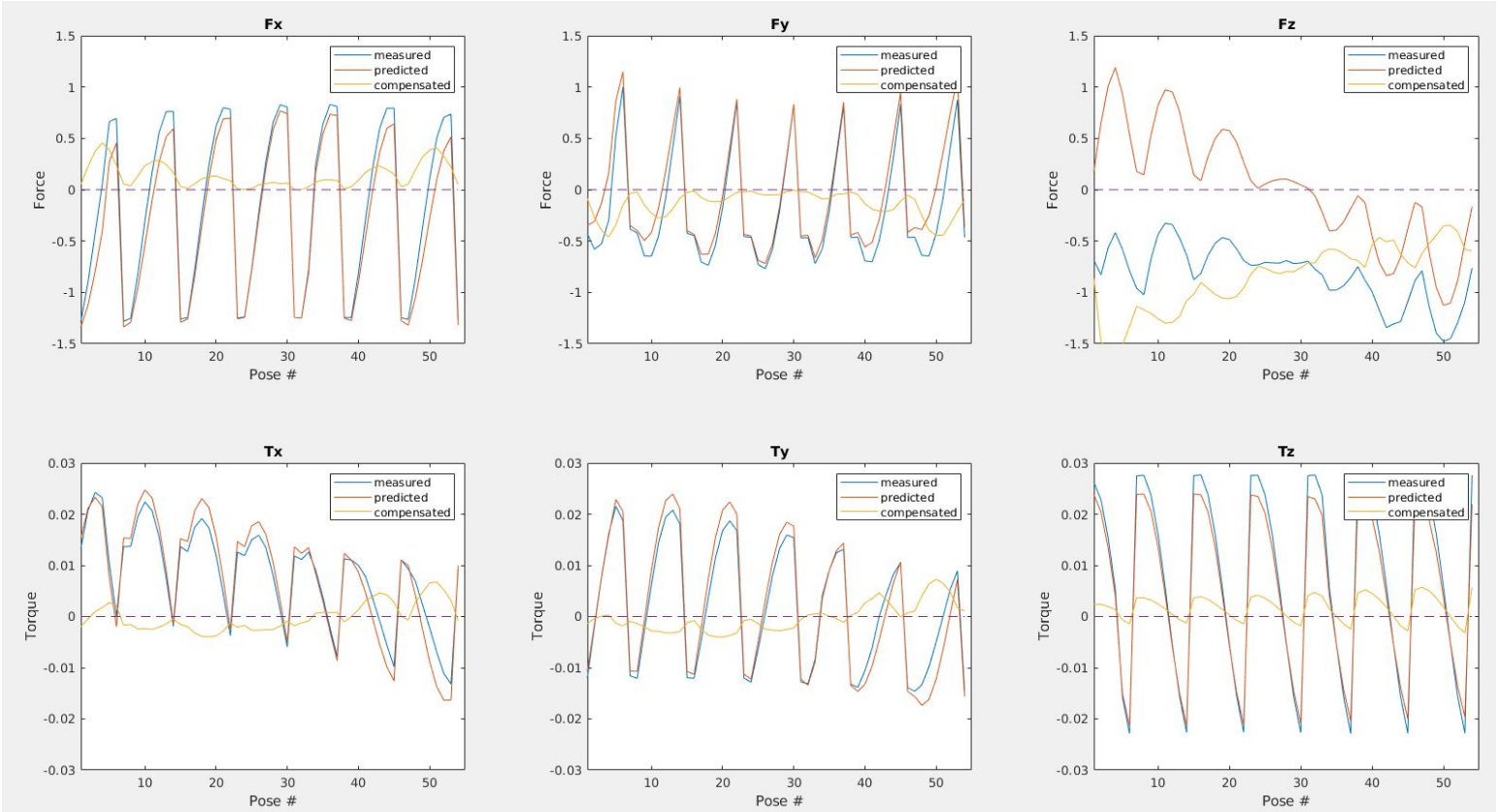
Least squares method to solve for $m_b g$ and p_{sb}

- Using data set with tool attached

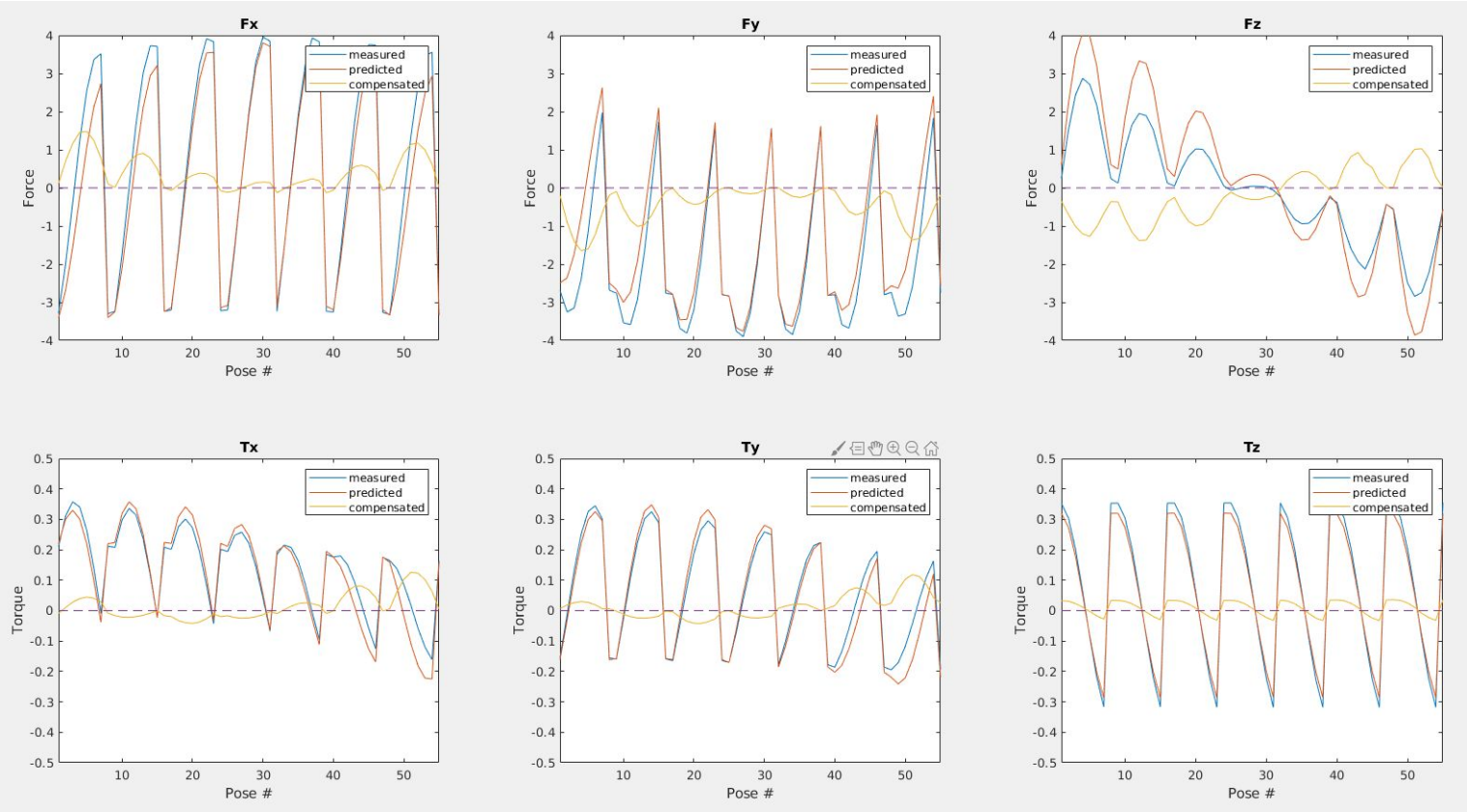
$$F_s = Ad^T_{g_{ts}(\theta)} F_t + Ad^T_{g_{bs}(\theta)} F_b - Ad^T_{g_{bs}(0)} F_b$$

Least squares method to solve for $m_t g$ and p_{st}

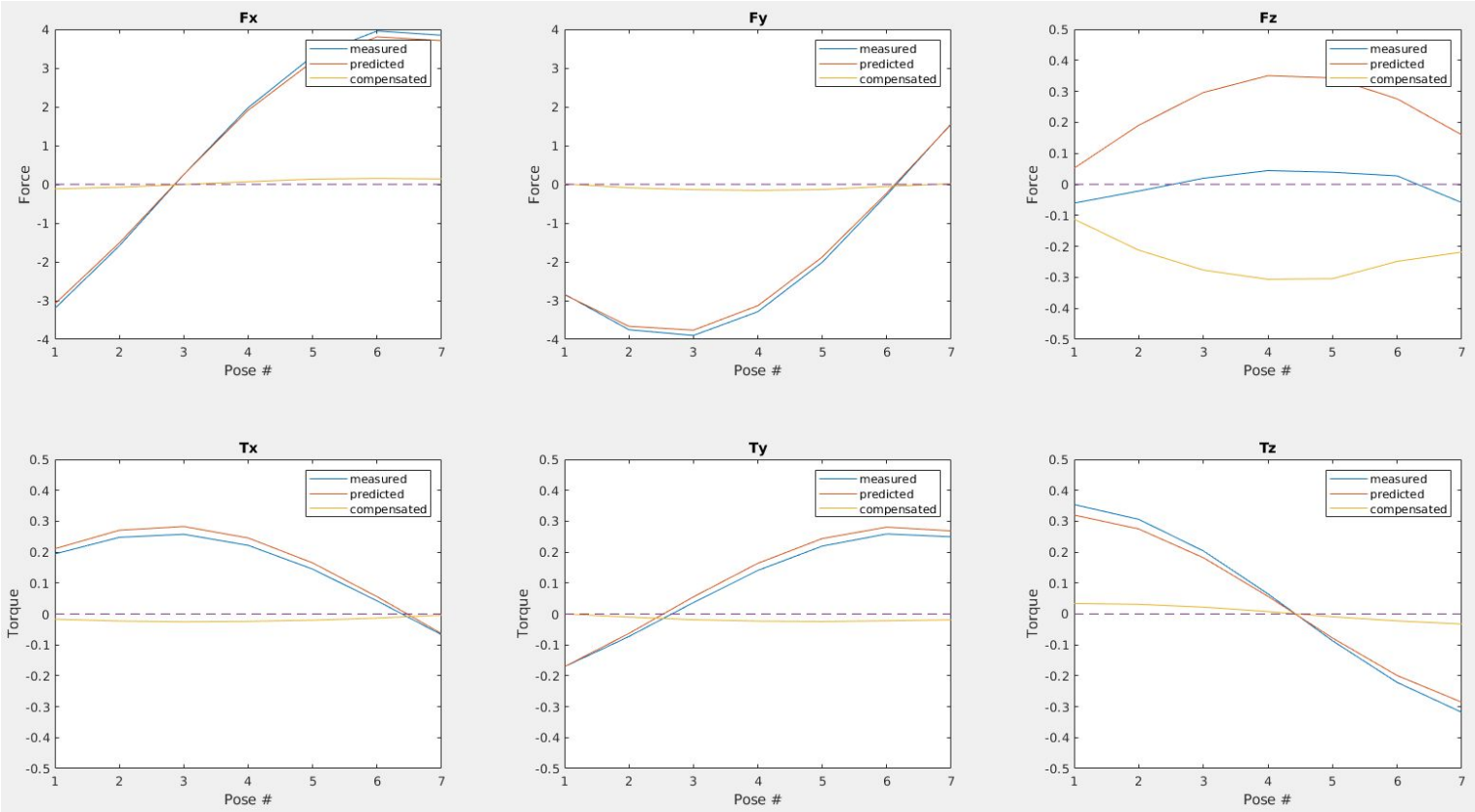
Static Results: Pointer Tool



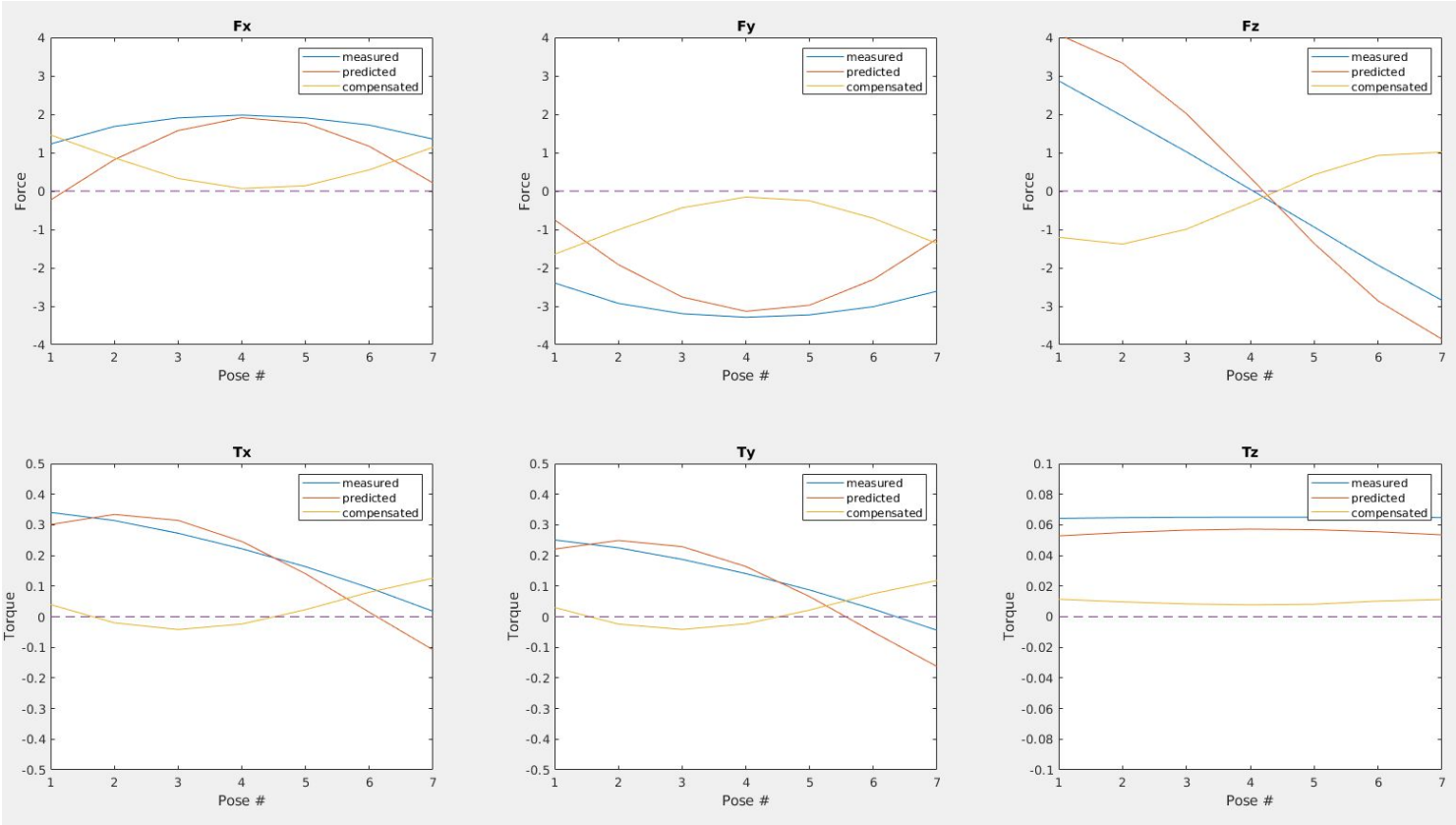
Static Results: Endoscope



Static Results: Only Roll



Static Results: Only tilt

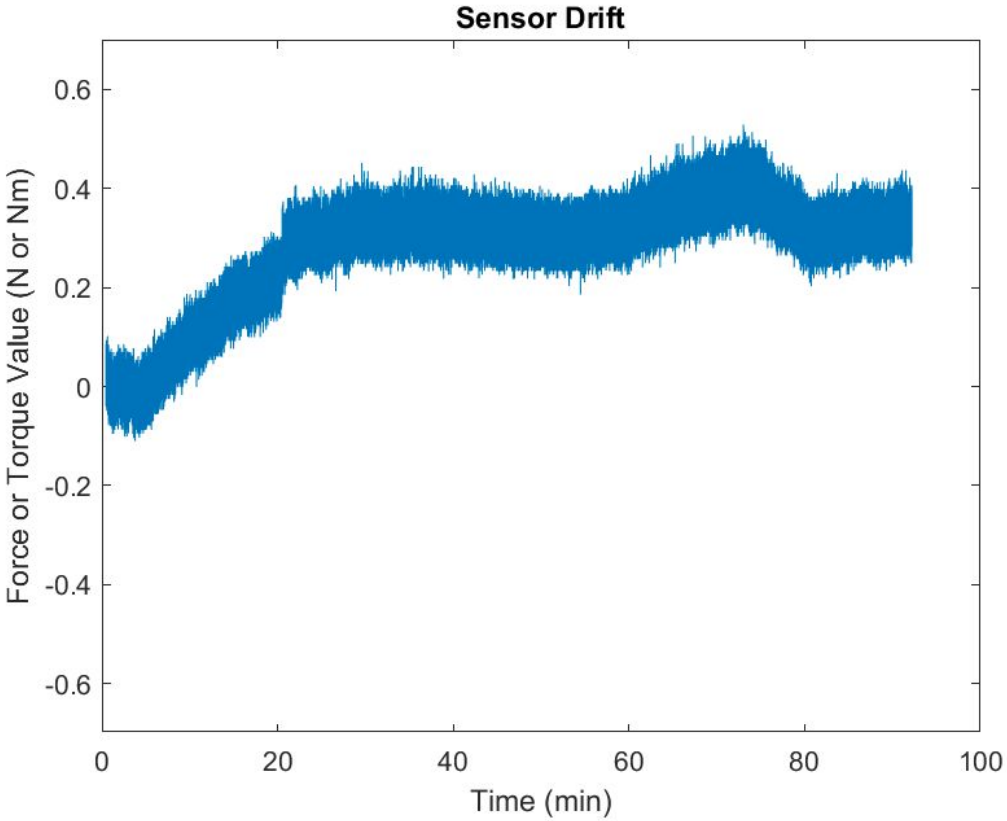


Setbacks: Summary

- Sensor Drift
- Kinematic Model Errors
- Galen Mark 2 Unavailability

Setbacks: Sensor Drift

- Noticed irregular results in z-axis force data/results
  - Seems to drift over time
- Ran data collection over the weekend
  - No tool attached, home position
  - 72 hours
- Significant sensor drift in z-axis
  - First 1.5 hours shown →
  - Note: not stable after these 1.5 hours



Setbacks: Kinematic Model Errors

- Galen found issues with the kinematic calculations that resulted in incorrect angle readings for both the mark 1 and mark 2 versions of the robot
- The company feels more comfortable with fixing the errors on the mark 1 before porting them to the mark 2
- We will need to move our code to the mark 1 for accurate readings.

Plan to deal with setbacks

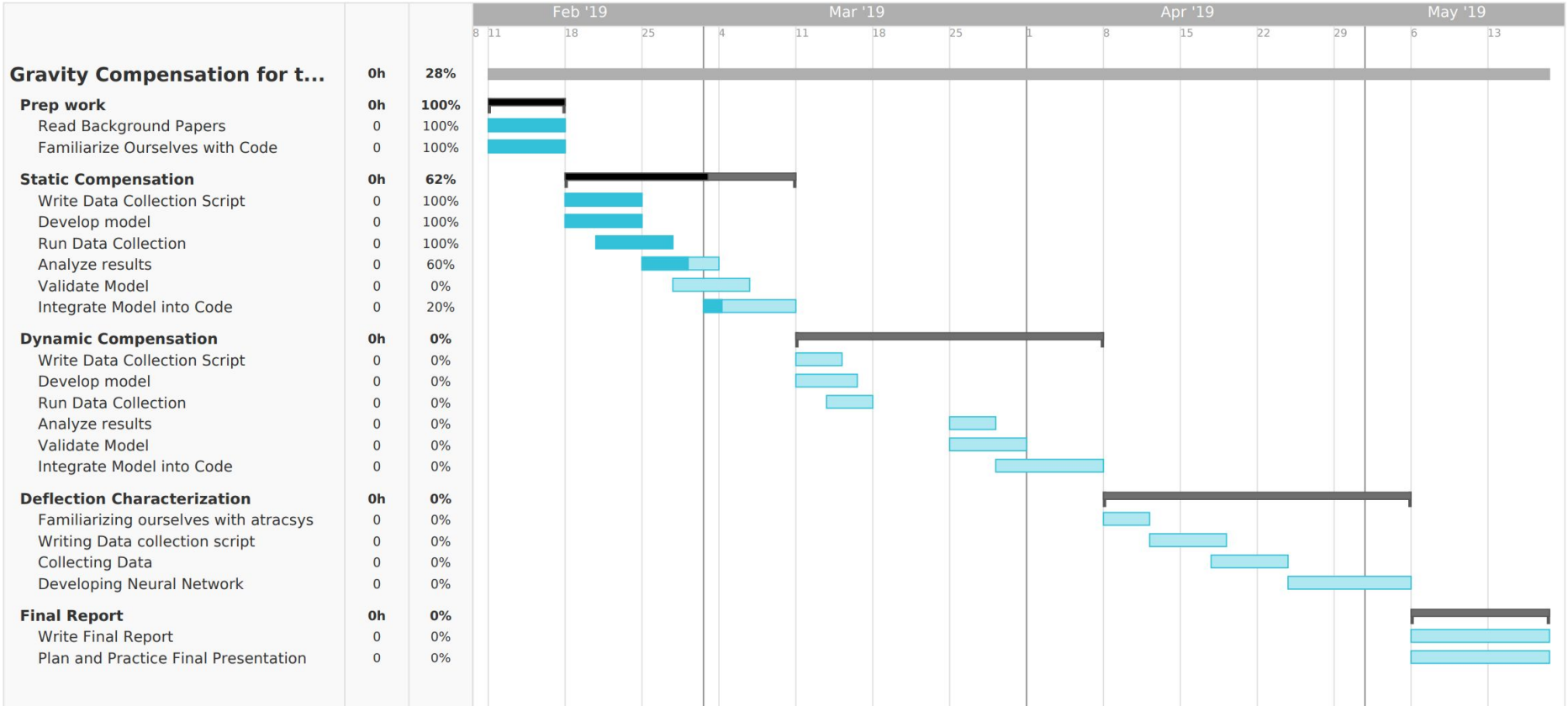
- Kinematic Model Errors →
- Sensor Drift → Move work to Galen Mark 1
- Galen Mark 2 Unavailability →

Updated Deliverables

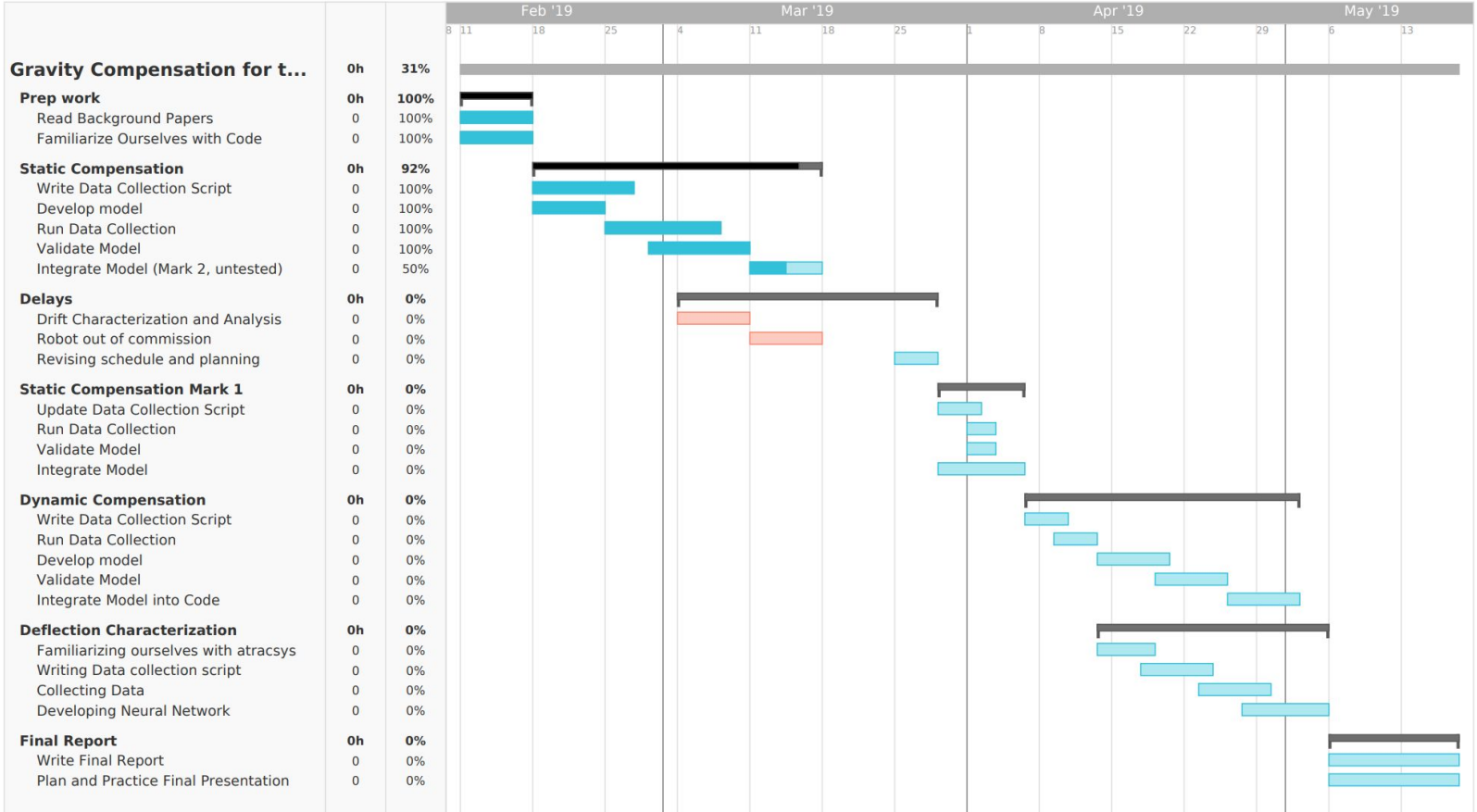
- Minimum:
  - Report with data and analysis demonstrating a model capable of predicting 6 DoF forces and torque given a tool and tool holder pose due to gravity, along with code and documentation
  - Video and data demonstrating successful integration of gravity compensation into robot control software, along with code and documentation
- Expected:
  - Report demonstrating a model capable of predicting 6 DoF forces and torque given a tool and tool holder pose due to dynamic motion, along with code and documentation
  - Video and data demonstrating successful integration of dynamic model compensation into robot control software, along with code and documentation
- Maximum:
  - Report demonstrating a model capable of predicting deflection forces at any point in the Galen workspace.

Updated Dependencies	Solution	Alternative	Date	Status
Access to Mock OR	Fill out paperwork	N/A	N/A	Resolved
Access to Galen Mark 1	Speak with Galen Commercial team about scheduling	Use Galen Mark 0	2/14	Resolved
Access to Galen Bitbucket Repository	Email Barry Voorhees	Speak to Galen Team/Dr. Taylor. Worst Case, use old LCSR repo and mark 1	2/14	Resolved
Get access or knowledge about previously used data collection on the Galen	Email Paul Wilkening	Read through code and write our own script.	2/14	Resolved
Discuss tool exchange	Speak with Dave Levi	Use Galen Mark 1	2/14	Resolved
Login Access to Galen Computers	Resolved	N/A	N/A	Resolved
Access to atracsys optical tracker	Email Dr. Taylor	Ask Dr. Taylor about alternative optical trackers	4/1	Resolved
Access to 3d Printer for tracker tool	Speak with Dave Levi about LCSR printer	Speak with Dr. Taylor about funds for Wyman printer	4/1	On-going
Access to tracker bodies	Speak with Galen Team	Use Micron tracker and print out trackers	4/1	On-going
Google Cloud Compute Credits	Email Dr. Taylor	Use our laptops to train neural nets	4/1	On-going

Old Schedule



Updated Schedule



Gravity Compensation for t...	**0h**	**31%**
Prep work	**0h**	**100%**
Read Background Papers	0	100%
Familiarize Ourselves with Code	0	100%
Static Compensation	**0h**	**92%**
Write Data Collection Script	0	100%
Develop model	0	100%
Run Data Collection	0	100%
Validate Model	0	100%
Integrate Model (Mark 2, untested)	0	50%
Delays	**0h**	**0%**
Drift Characterization and Analysis	0	0%
Robot out of commission	0	0%
Revising schedule and planning	0	0%
Static Compensation Mark 1	**0h**	**0%**
Update Data Collection Script	0	0%
Run Data Collection	0	0%
Validate Model	0	0%
Integrate Model	0	0%
Dynamic Compensation	**0h**	**0%**
Write Data Collection Script	0	0%
Run Data Collection	0	0%
Develop model	0	0%
Validate Model	0	0%
Integrate Model into Code	0	0%
Deflection Characterization	**0h**	**0%**
Familiarizing ourselves with atracsys	0	0%
Writing Data collection script	0	0%
Collecting Data	0	0%
Developing Neural Network	0	0%
Final Report	**0h**	**0%**
Write Final Report	0	0%
Plan and Practice Final Presentation	0	0%

Updated Milestones

Functional Data Collection Script	February 22nd	✓
Functional Static Prediction Model	March 4th	✓
Integrated Static Compensation	~~March 11th~~ April 4th	
Functional Dynamic Prediction Model	~~April 1st~~ April 24th	
Dynamic Compensation Integrated	~~April 8th~~ May 1st	
Deflection Data Collected	~~April 22th~~ April 24th	
Functional Deflection Model	May 4th	
Final Report/Presentation	May 16th	

Questions?