



WPI



GE Aviation

GE Aviation Tube Polishing System Major Qualifying Project

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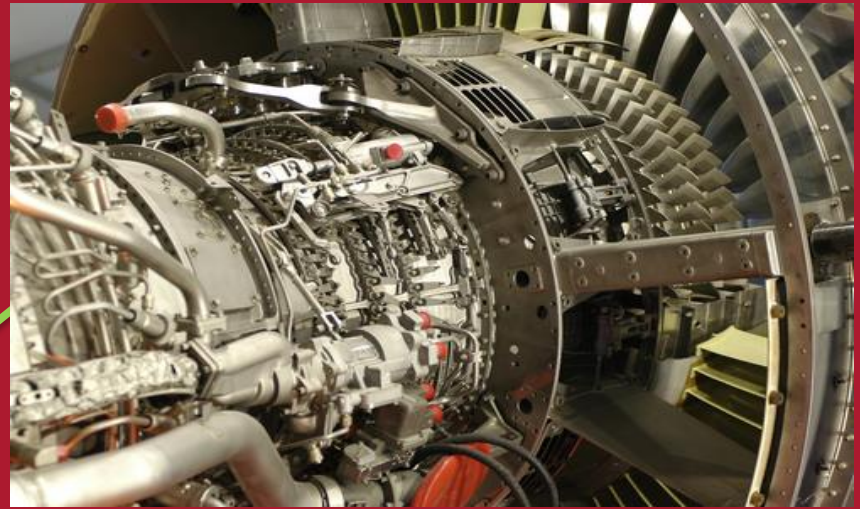
Outline

- **Introduction**
- **Project Goal**
- **Design Requirement**
- **Solution**
 - **Gripper Design**
 - **Polishing Methods**
- **Implementation**
- **Results and Conclusion**
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Introduction



Aircraft



Engine

Introduction



Introduction



Project Goal

The goal of this project is to automate the process of polishing brazed or welded areas on a tube assembly supplied by GE Aviation.

Initial Design Requirement

Grip

- A robotic gripper that can adapt to various shapes of tubes
- May not damage the tubes upon gripping
- Make use of robotic arm supplied by GE Aviation

Inspect

- Use computer vision to locate the brazed areas
- Decide if polishing is necessary

Polish

- Fully polish brazed areas on the tube assembly
- Must not damage tube, cosmetically or physically

Final Design Requirement

Grip

- **Unique gripper design for the tube supplied by GE Aviation**
- Must not damage tube upon gripping
- **Use Fanuc 200iB located in Washburn Shop**

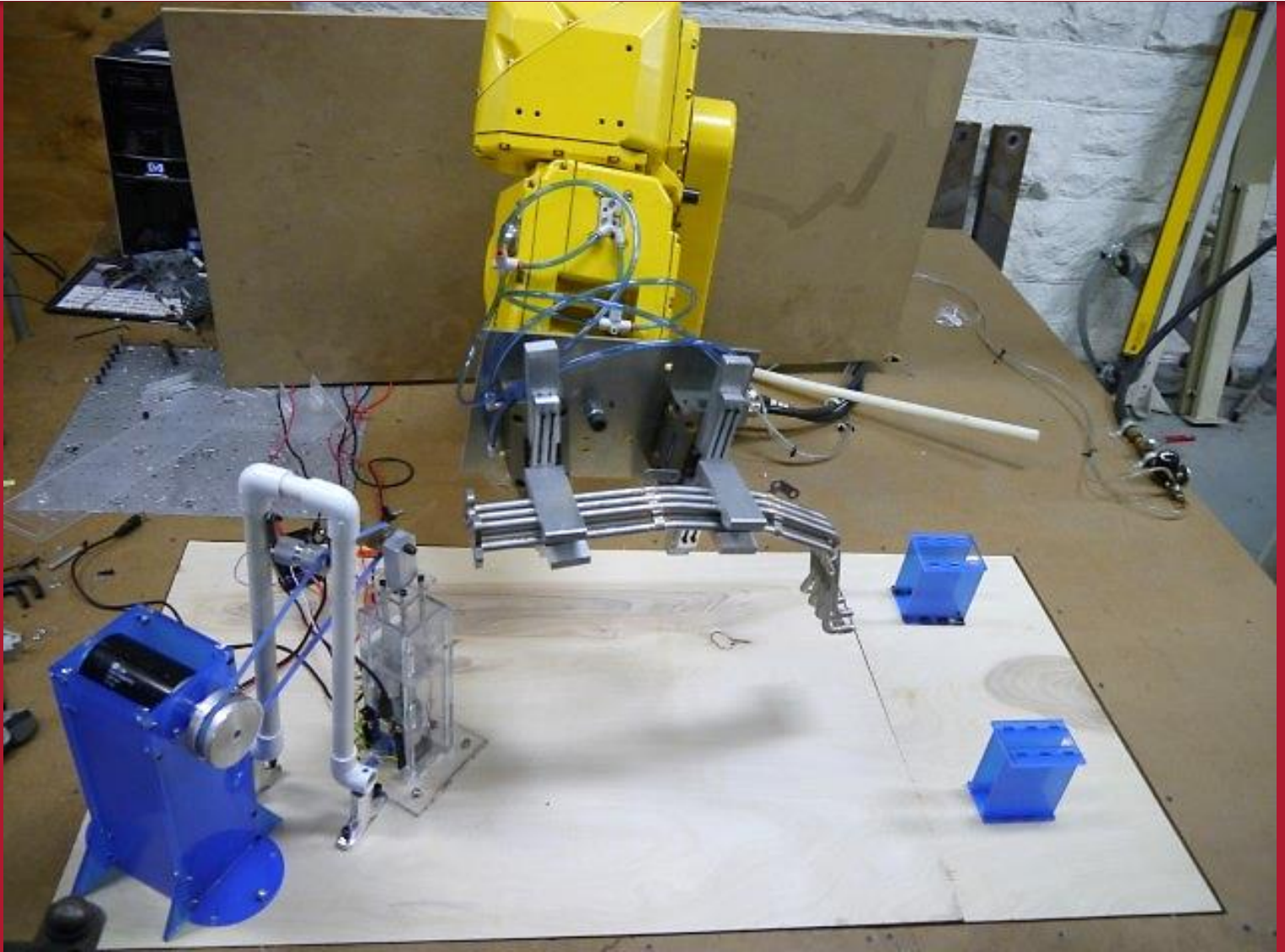
Inspect

- **Was outside of the scope for the project**
- **To be left for future MQPs**

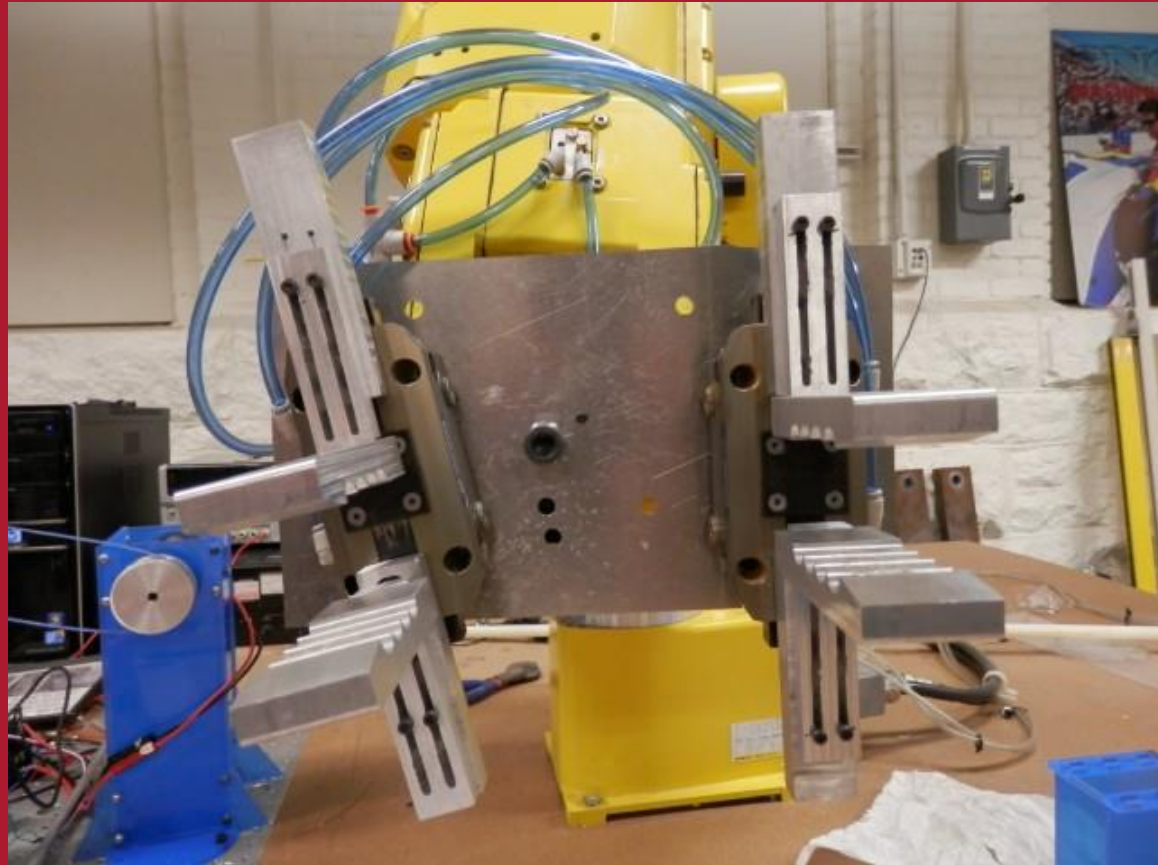
Polish

- Fully polish brazed areas on the tube assembly
- Must not damage tube, cosmetically or physically

Polishing Prototype System



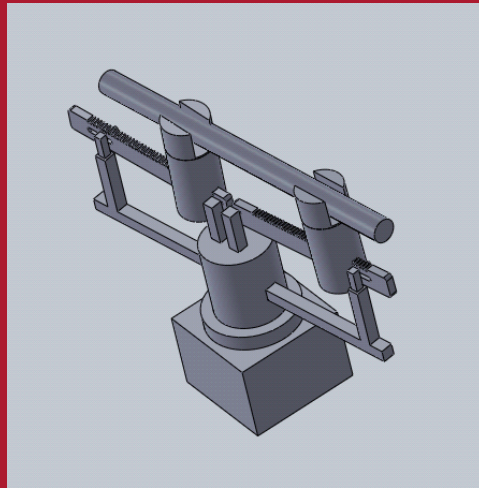
Gripper EOAT



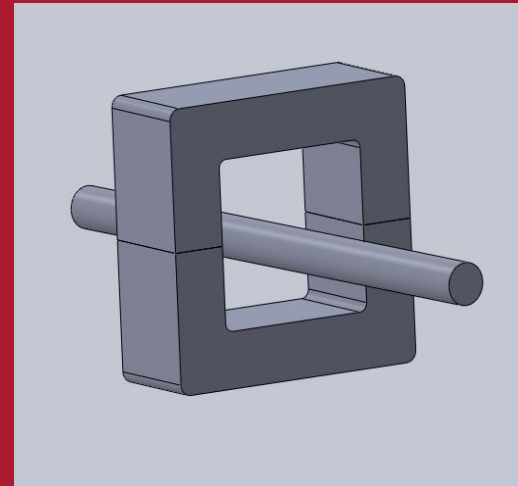
Candidate Solution – Gripper

Grip

- A robotic gripper that can adapt to various shapes of tubes
- May not damage the tubes



Gripper Base



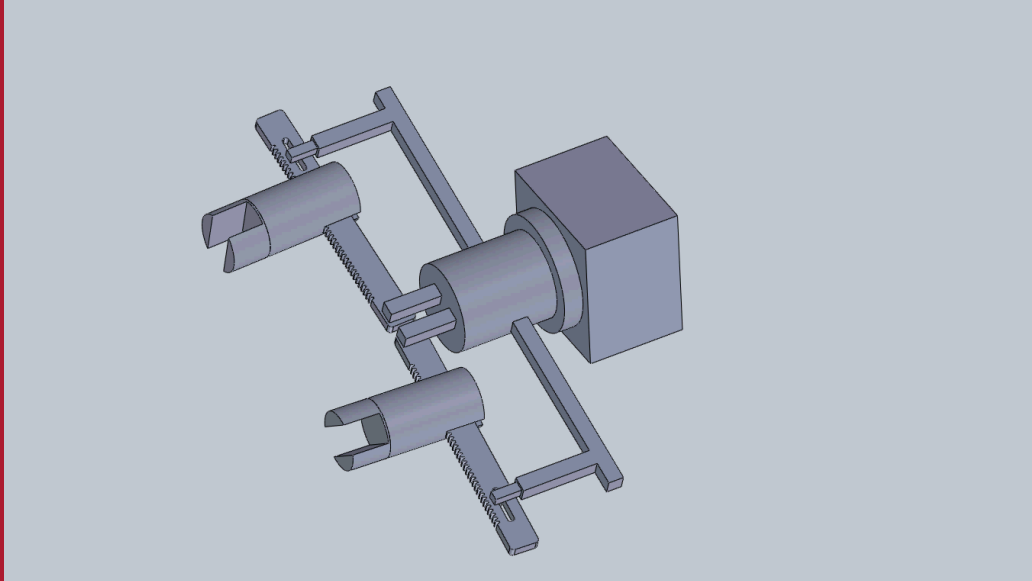
Tube Follower

Solution – Gripper Metrics

Metrics \ Methods	Gripper Base	Tube Follower
	Design Difficulty	
Programming complexity	4 Need to adapt to different tubes	2
Mechanical design complexity	3	5 Highly customized design
	Resources	
Cost (Budget)	3	4 Highly customized design
Time cost (for GE)	4 May change gripping locations	3
	Performance	
Precision	4 Harder to determine polish area	3
Desired functions absence	2	5 Cannot polish branches
Total	20	22

Candidate Solution – Gripper

Gripper Base



Pros:

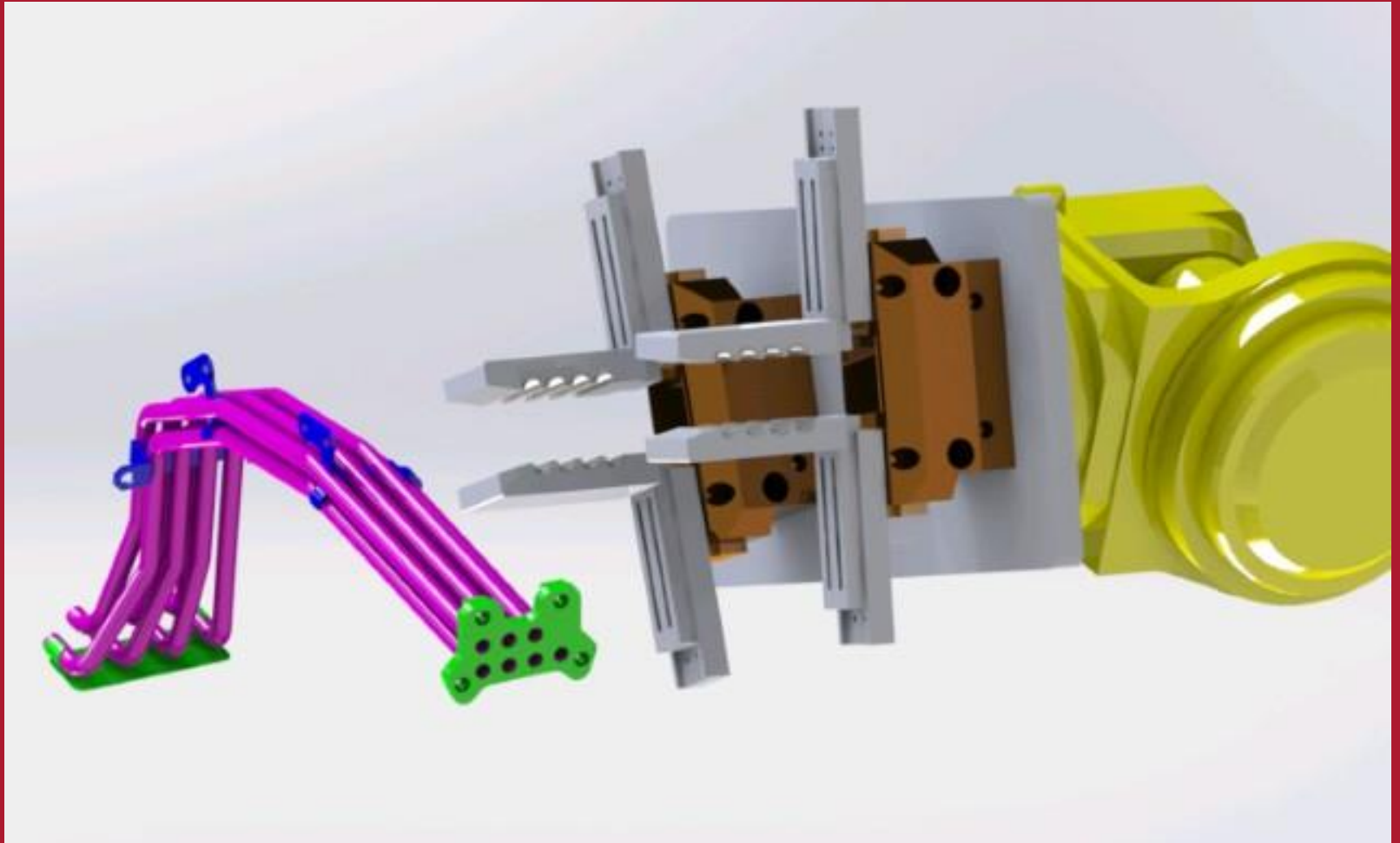
- + Capable of grabbing tubes at all different angles
- + Flexible joints adapt to different tubes
- + Interchangeable gripper fingers

Cons:

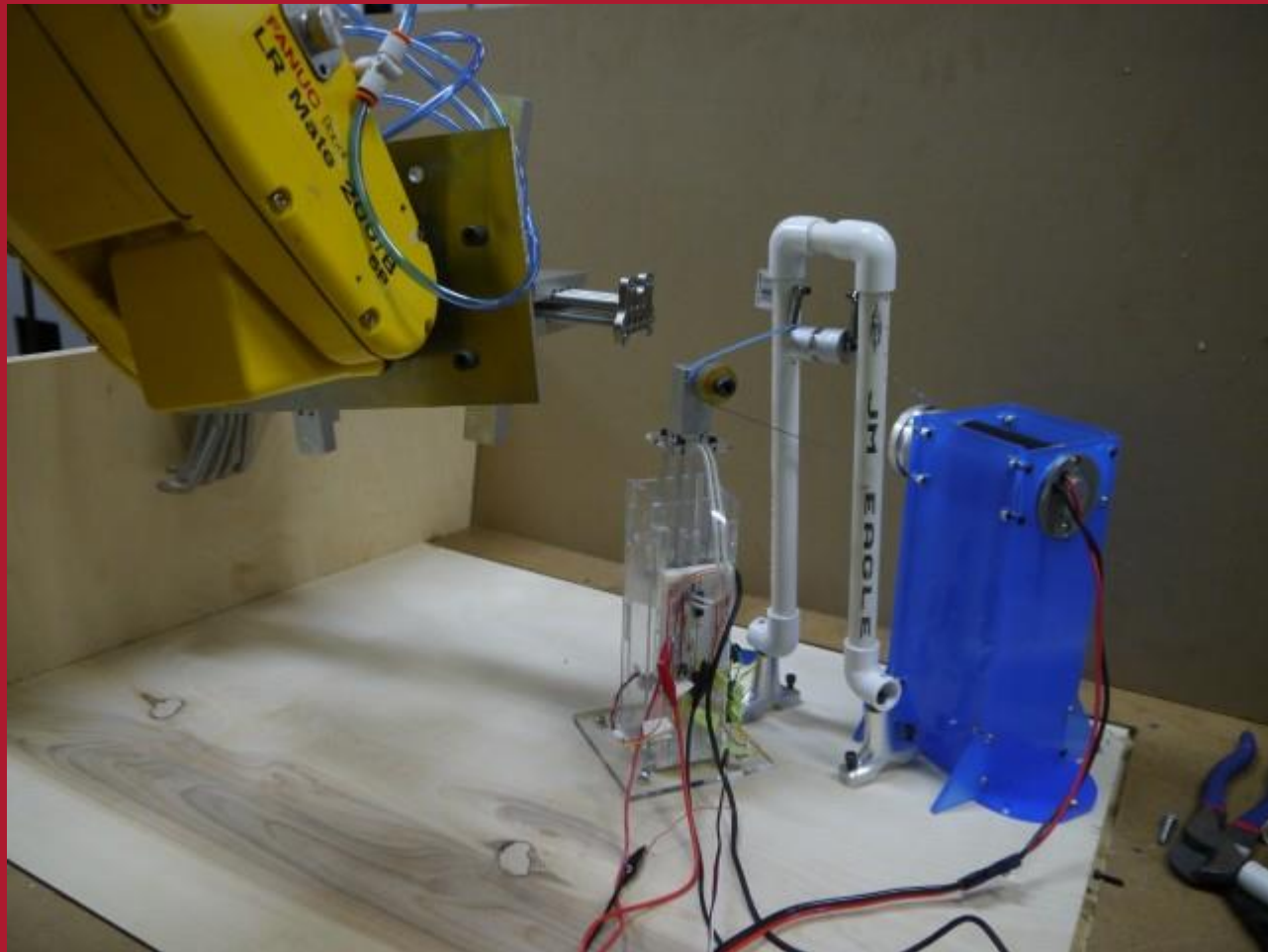
- Complex design

Gripper Base

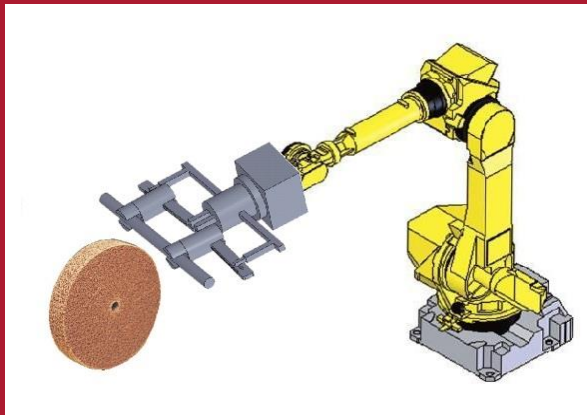
Final Gripper Design



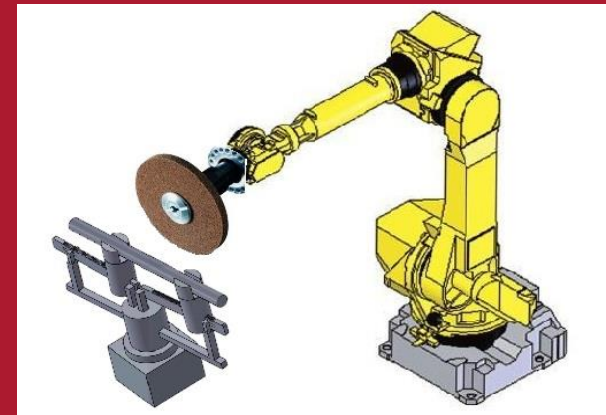
Polishing Station



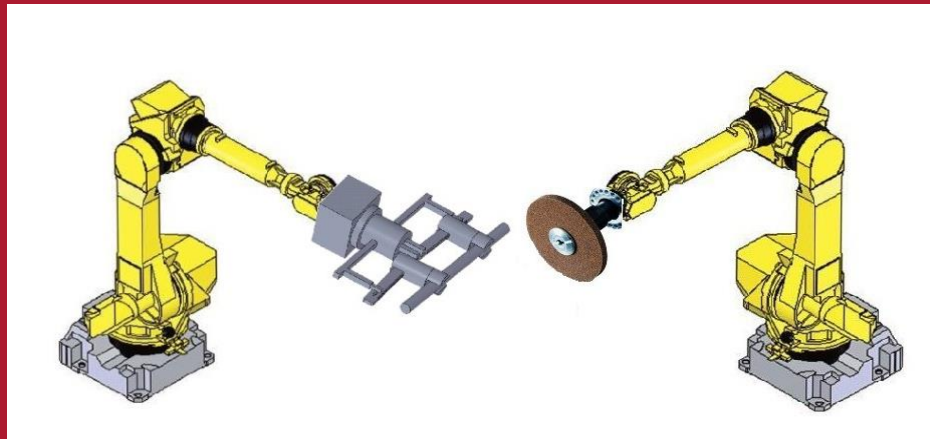
Candidate Solution – Polishing



Moving Tube, Fixed
Polisher



Moving Polisher, Fixed Tube

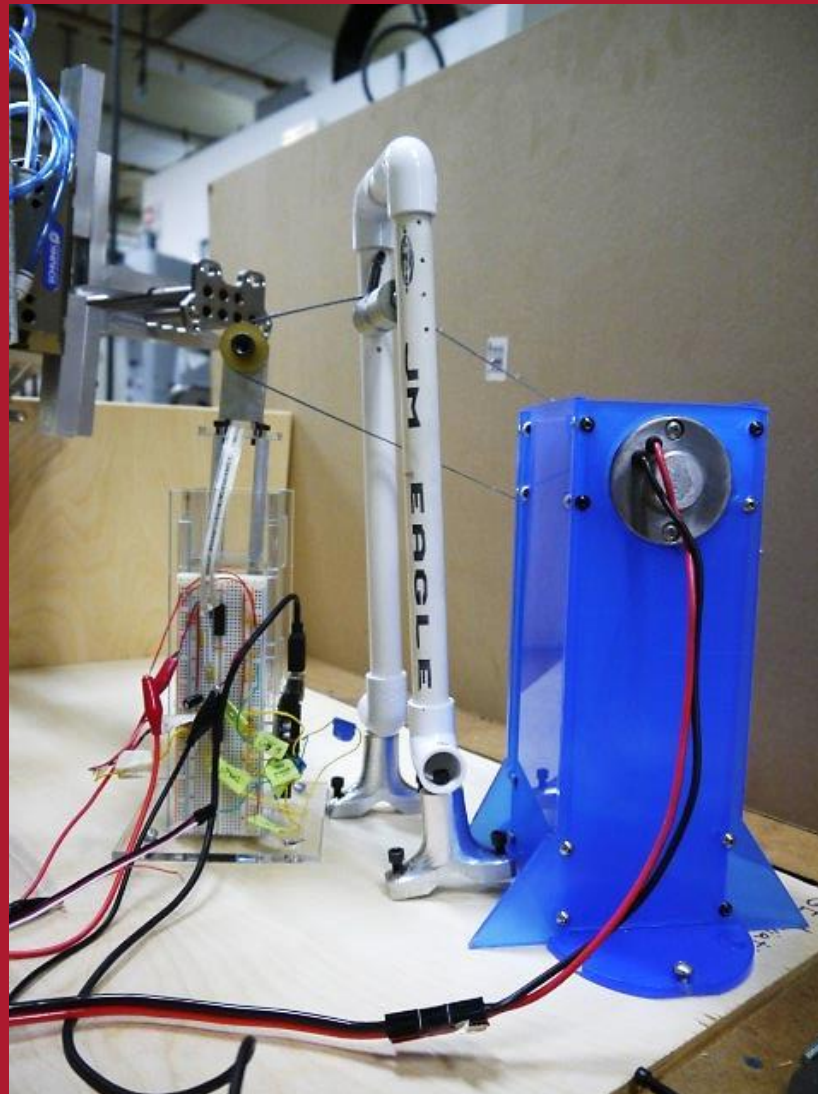


Combined: Moving Tube, Moving Polisher

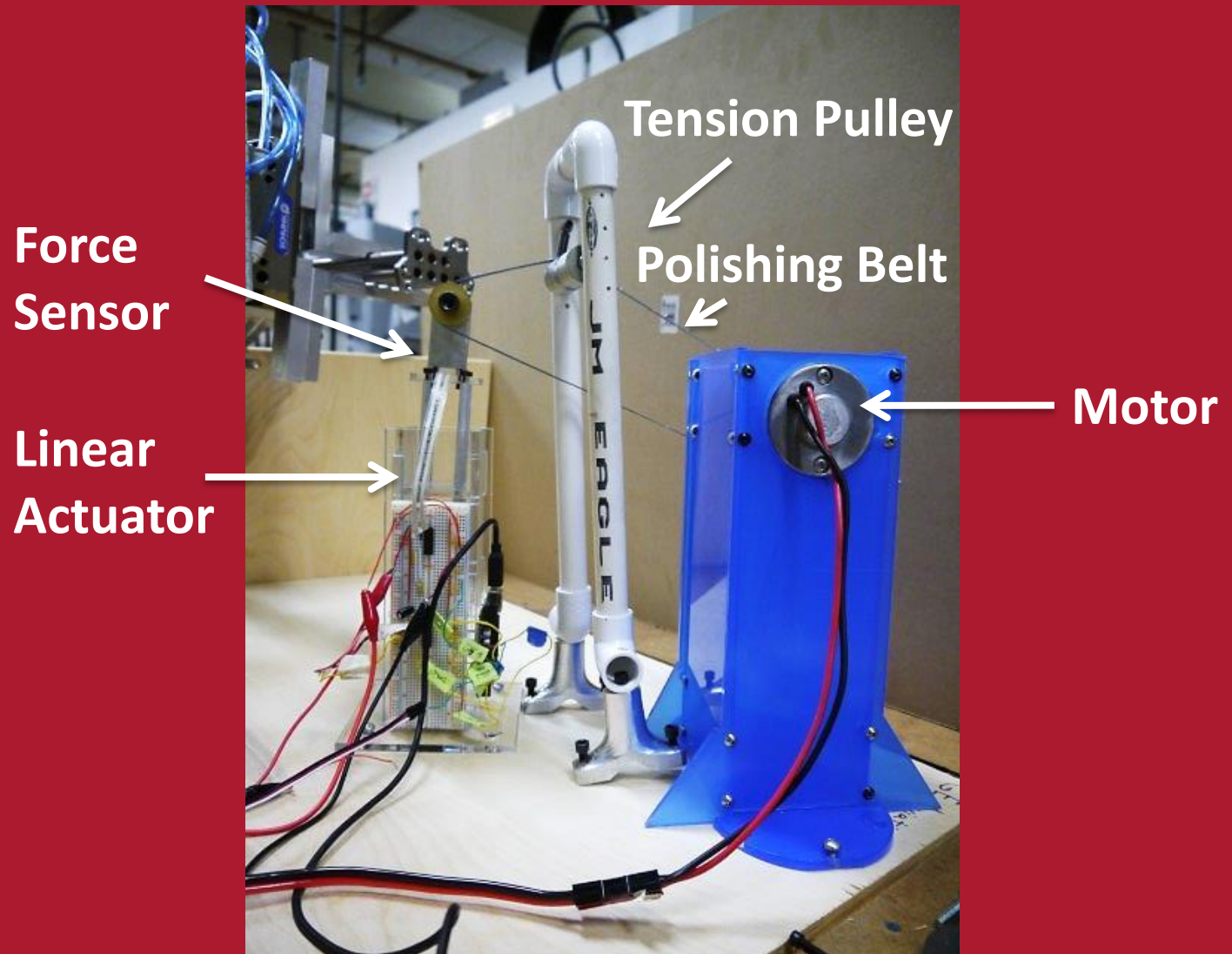
Solution – Polishing Metrics

Metrics \ Methods	Moving tube, fixed Polisher	Moving Polisher, fixed tube	Moving tube, moving Polisher
Design Difficulty			
Programming complexity	3	4 Need to pass the tube	5
Mechanical design complexity	2	3 Need to change tools	4
EOAT	3	2	4
Resources			
Cost (Budget)	2	3 Need tool changer	4
Time cost (for GE)	4	5 Need to pass the tube	3
Performance			
Precision	4 Force sensing on a more complex EOAT	3	5
Desired functions absence	2	2	2
Total	20	22	27

Polishing System



Polishing System



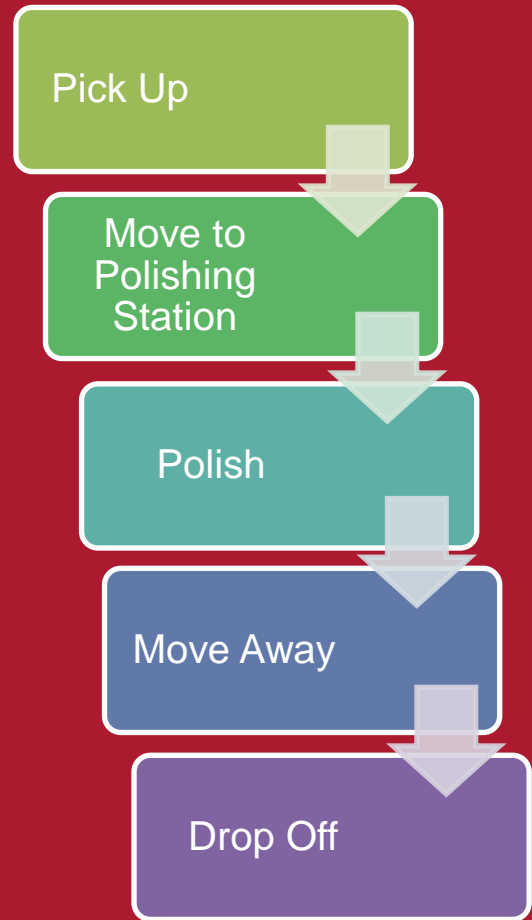
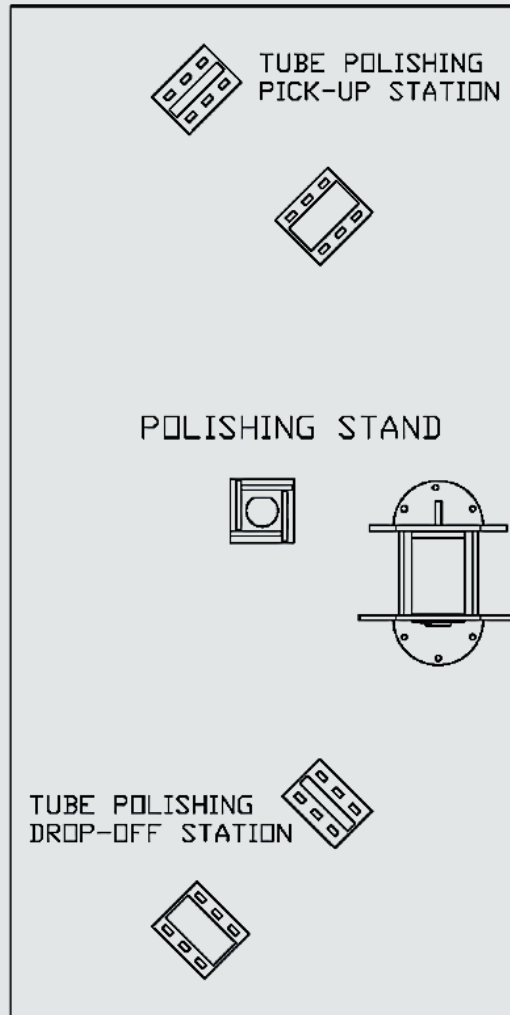
Polishing System



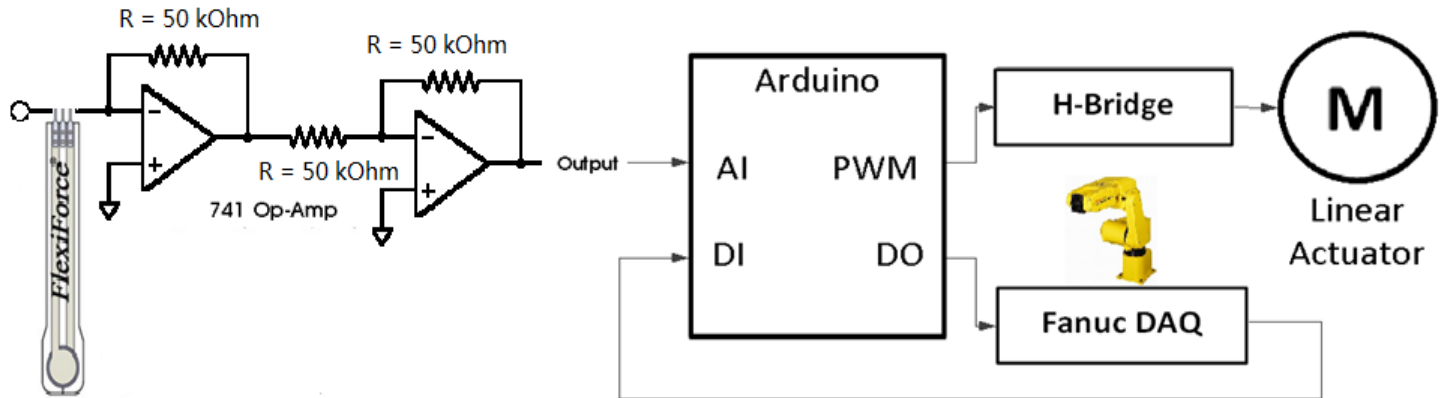
Polishing Process



FANUC 200iB
ROBOTIC ARM



Programming



- Force sensor collects data => Arduino
- Arduino generates PWM signals to linear actuator
- When desired force reached, Arduino sends signal to NI DAQ
- NI DAQ sends signal to Robot Fanuc DAQ
- Robot reacts

Results and Conclusion

- Created polishing system
- EOAT works for specific tube
- Polishing routine implements force feedback controller
- Program maneuvers tube on polisher

Future Work

- New Fanuc 710iC
- Computer vision
 - Identify welds/brazes
 - Determine the gripping positions
 - Check quality
- Built-in force sensor on the gripper
- Movable polishing finger belt to allow a finer polishing technique

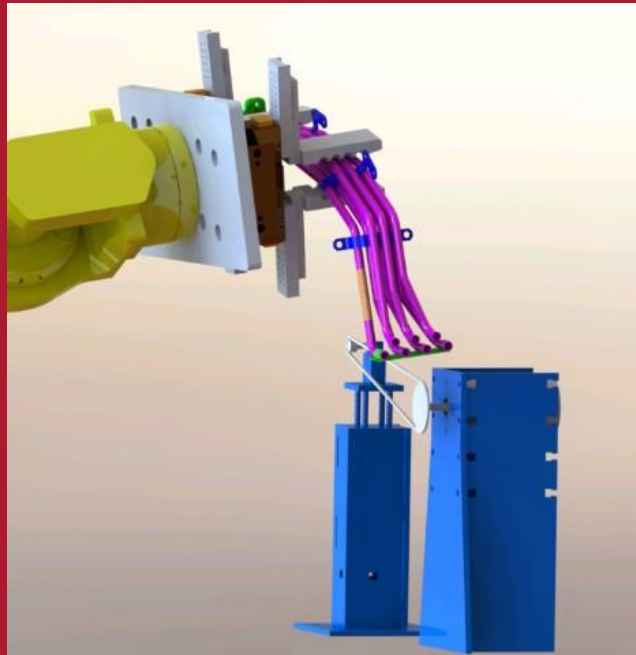
Acknowledgement

We would like to thank our project sponsor General Electric Aviation and our advisors for their support.

- Our advisors
- Robotics lab
- Washburn labs
- Higgins machine shop
- FRC Team

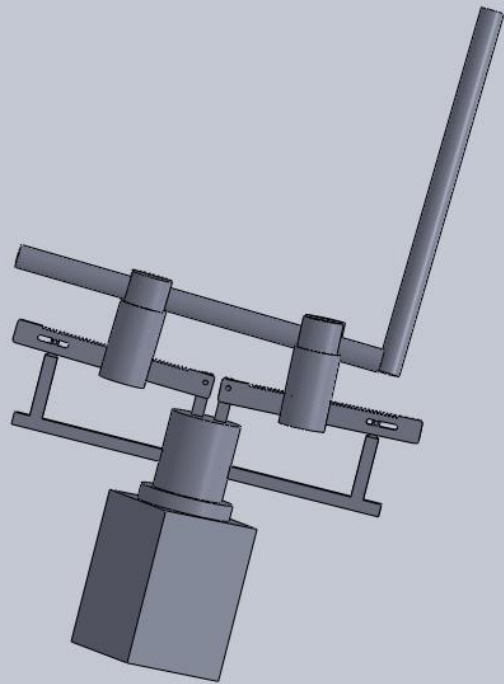
Questions?

GE Aviation Tube Polishing System Major Qualifying Project

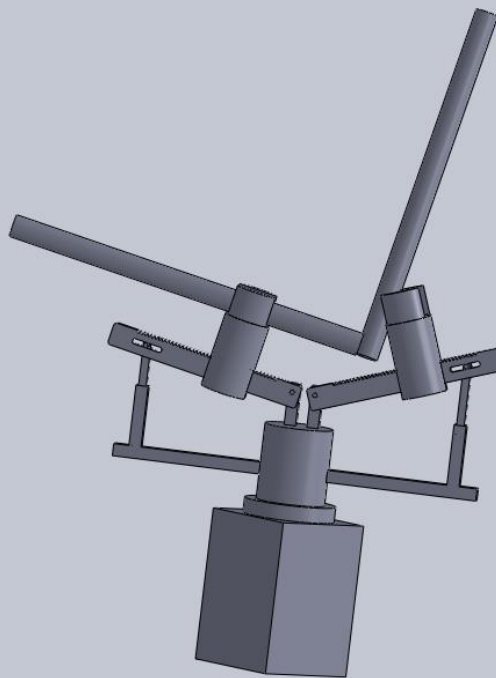


Candidate Solution – Gripper

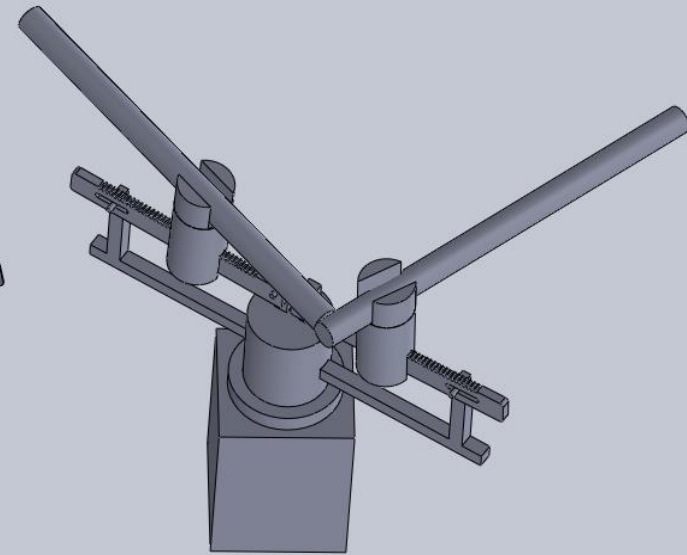
Gripper Base



Linear Tube



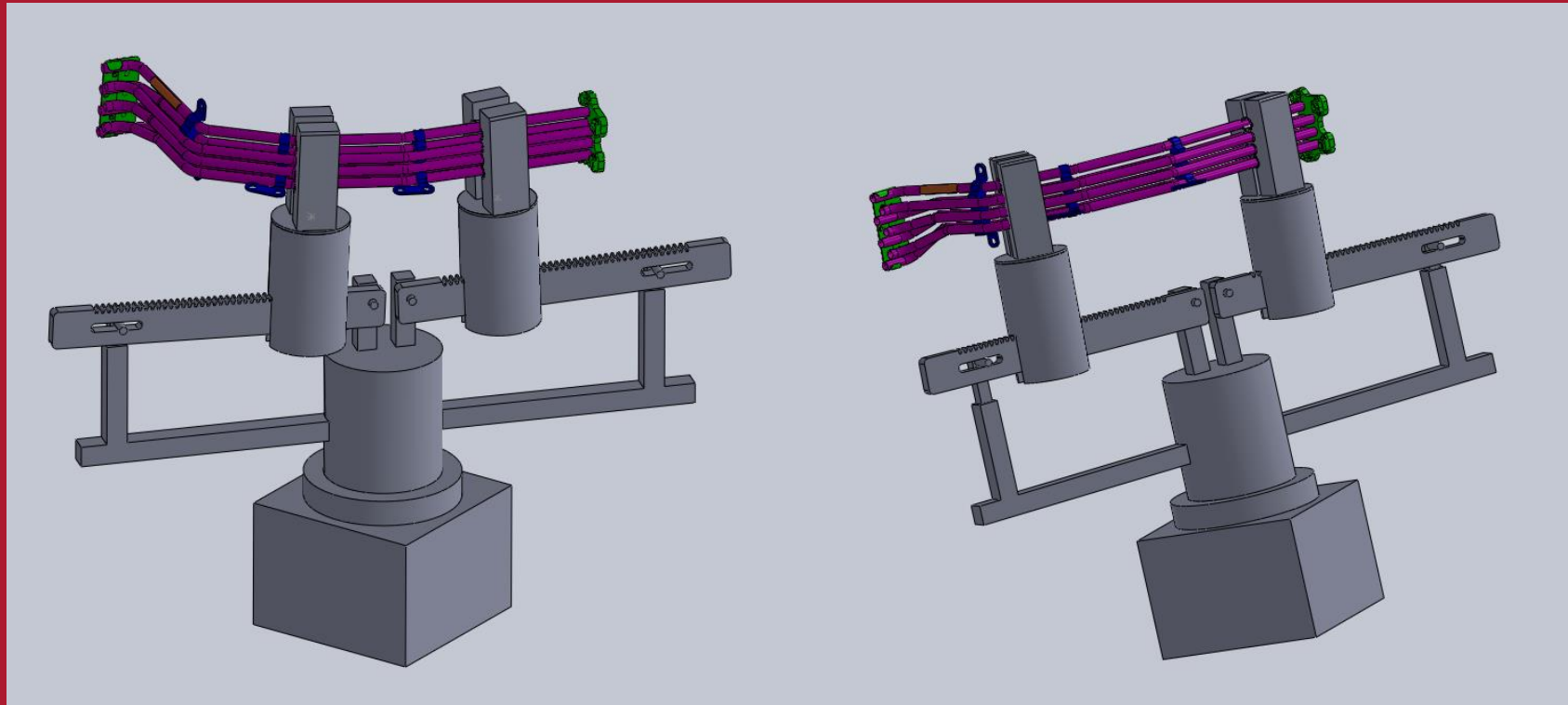
Planar Tube



Non-Planar Tube

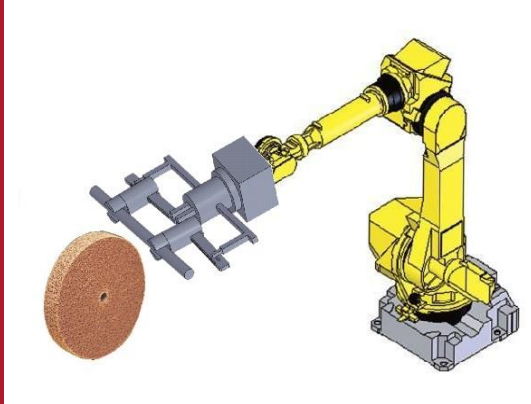
Candidate Solution – Gripper

Gripper Base



Gripping Different Positions

Polishing Comparison



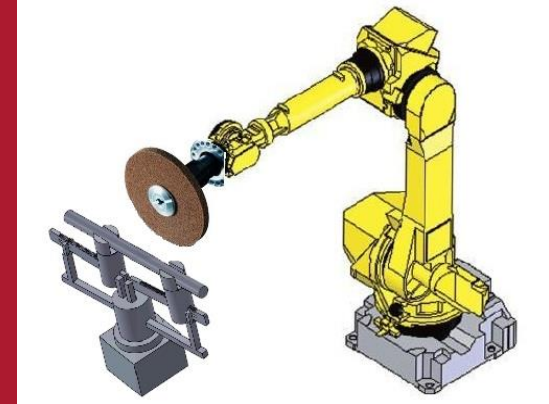
Moving Tube, Fixed Polisher

Pros:

- + No need for tool changing
- + Can pick up the tube then starts to polish immediately

Cons:

- EOAT design requires two grippers that can adapt to the tube



Moving Polisher, Fixed Tube

Pros:

- + Fewer kinematics calculations

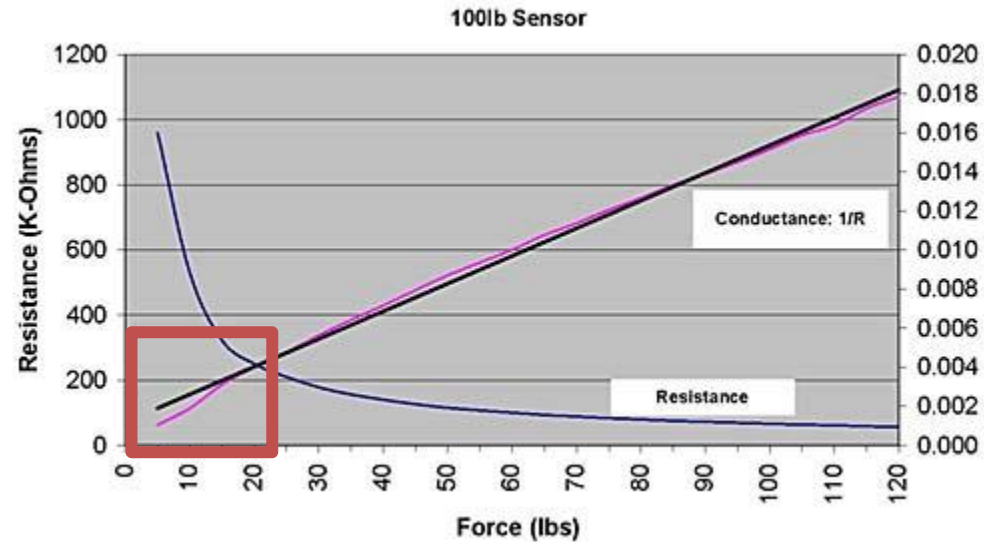
Cons:

- Need to change tools
- Need to pass the tube to the gripper base (tube fixture)

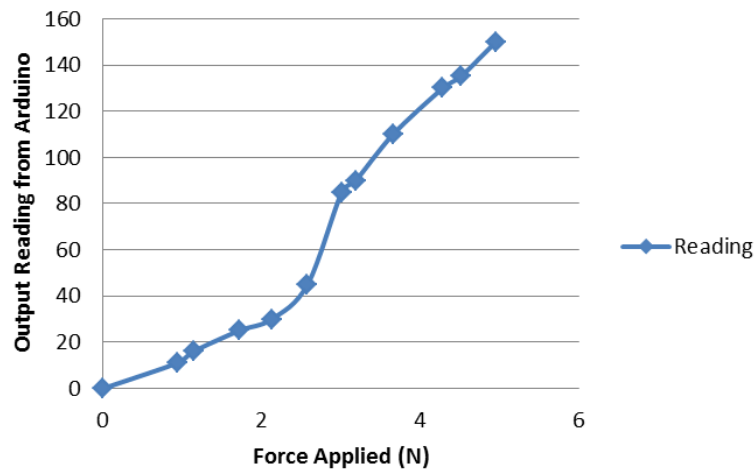
Polishing System

- Force sensor: 25lb FlexiForce
- Linear Actuator: screw mechanism driven by 12V DC motor
- Motor: CIM motor 884
- Polishing belt: 120 grit

Force Sensing



Output Reading from Arduino vs. Force Applied to the Force Sensor



GE Work Cell



GE Robot 710iC

