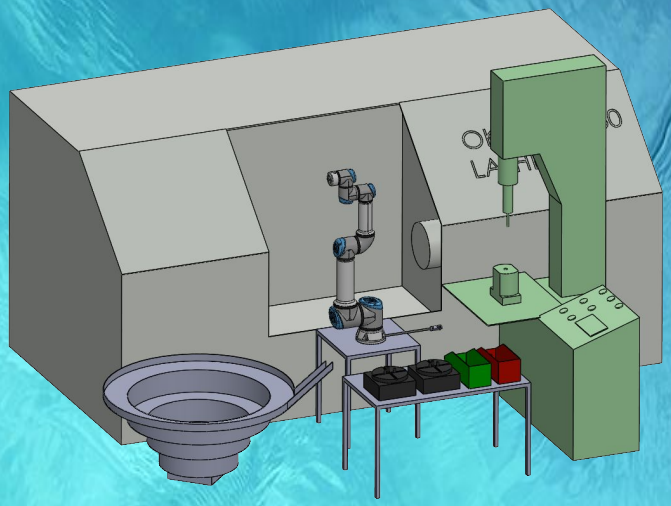
MEM/ECE 493 : Final Senior Design
Spring 2023

Automating Bolt Manufacturing



MEM 43
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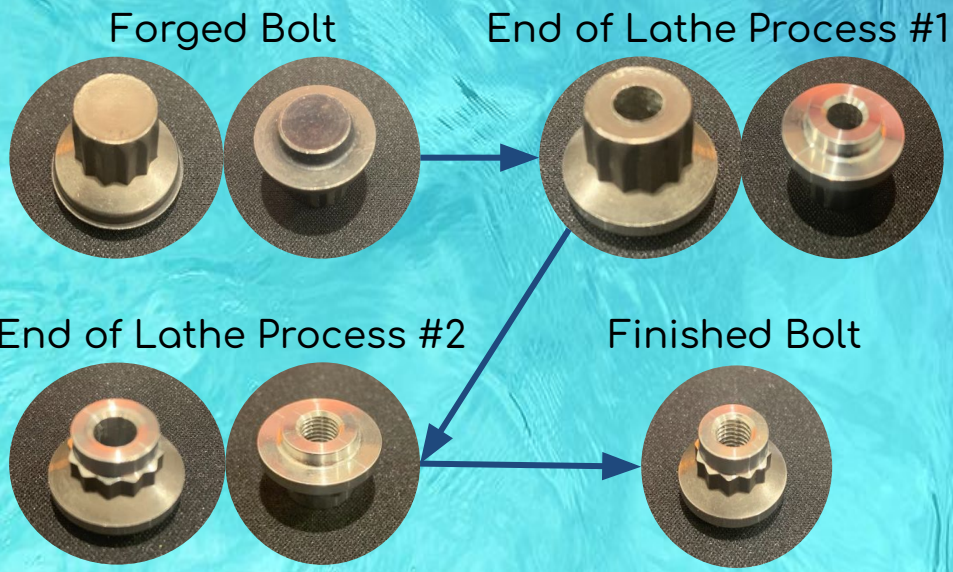
Sponsor: *B&G Manufacturing*

Introduction

- **Motivation**
  - High volume production
  - Unique manufacturing processes
  - Collaborative robot/new system
- **Stakeholder needs**
  - Save cost
  - Increase efficiency
  - Accuracy processing



Problem Statement

Process 1 → Process 2 → Process 3 → Process 4

Tumbler

Feed the small components such as bolts and nuts to automated processing

Lathe Machine

The stock part will be loaded into the lathe for rough turning the part just outside the dimensional tolerances

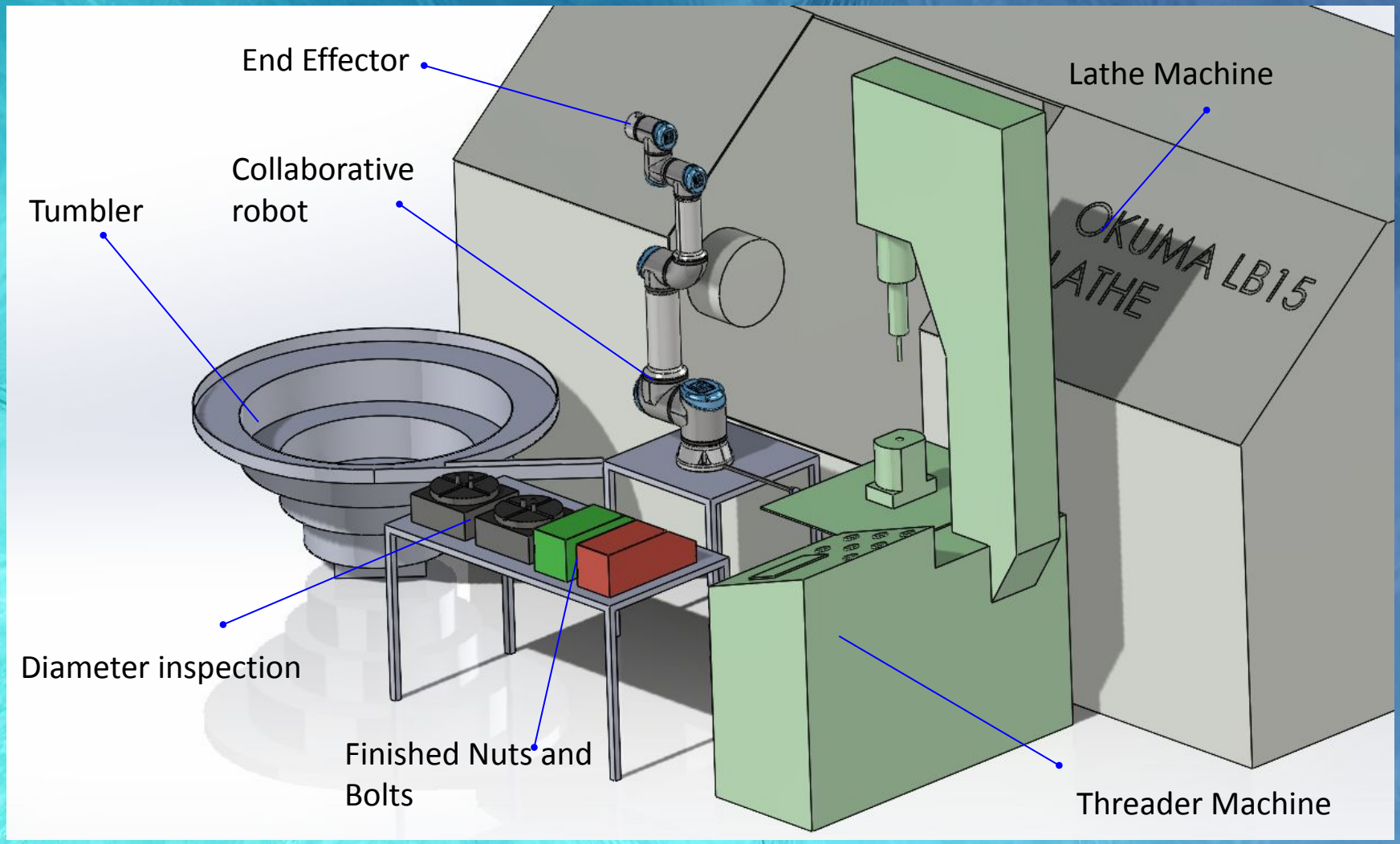
Threader Machine

Threading and inspection system process using a collaborative robot to ensure all operations are completed as efficiently as possible

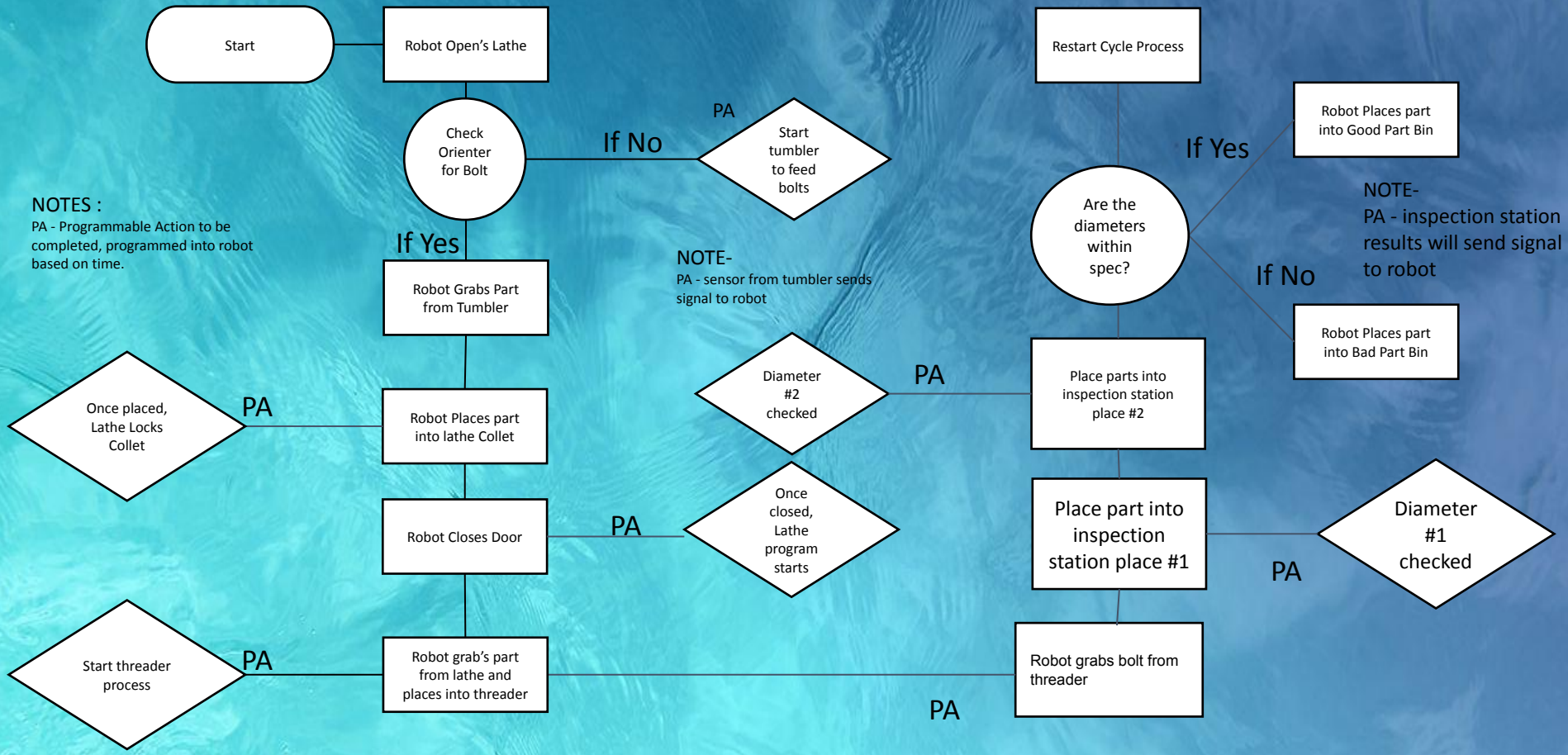
Good and Bad Part Bin

Classify good and bad parts into 2 bins.

Design Approach



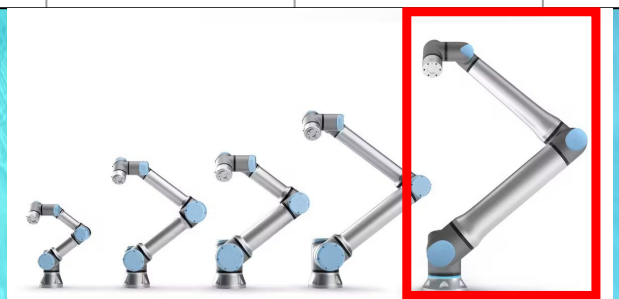
Pseudocode Flowchart



Final Design Description

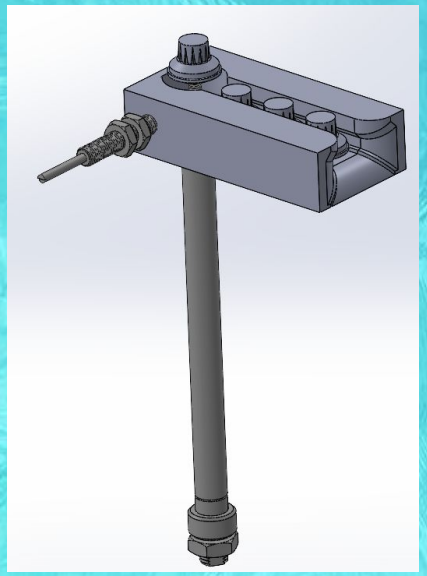
Specifications

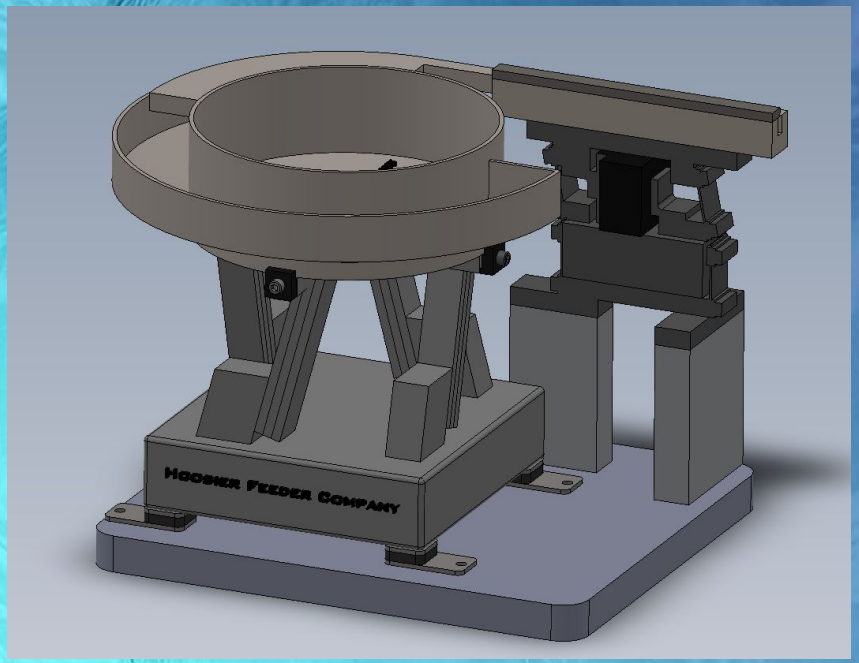
Metric No.	Metric	Units	Impact	Marginal Value	Ideal Value
1	Total Bot Travel Distance	Inches	5	19.7" - 68.9"	60"
2	Measurement Accuracy	Thousandths of an Inch	5	.0005" - .0001"	.00005" - .00001"
3	Efficiency	Parts per hour	3	20-100%	60-100%
4	Weight of Part	Oz	1	1oz - 2lb	Current Part - 2oz
5	Overall Length/Height of Part	Inches	2	0.5" - 2"	Current Part - 1.01" , 0.675”
6	Weight of Bot	Lbs	1	24.7 lb - 141.1 lb	141 lb
7	Accessibility Time	minutes	2	5 - 10 minutes	less than 1 - 2 minutes
8	Payload	lbs	1	6.6 lb - 44.1 lb	44.1 lb



Final Design Description
Standards

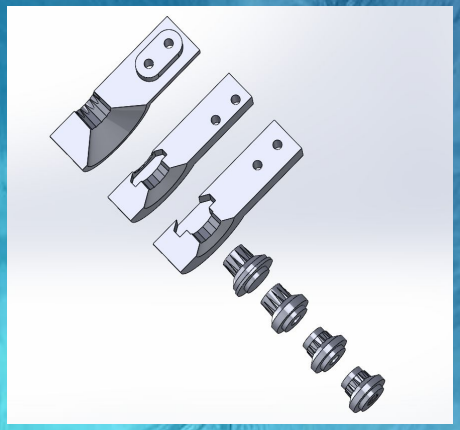
Tumbler Implementation

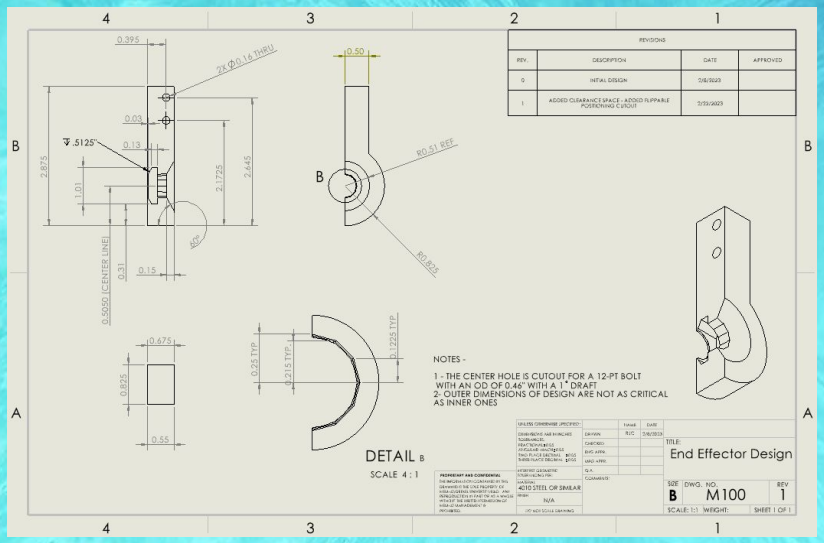




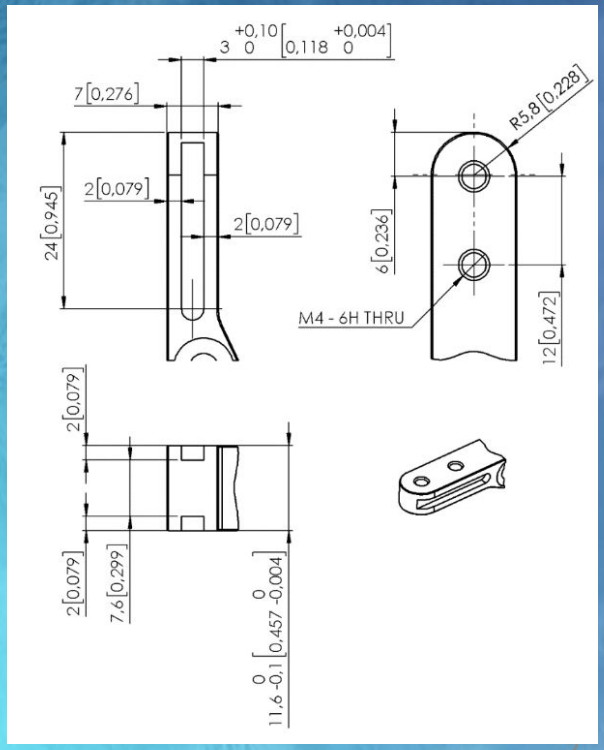
End Effector Design

R2- Gripper

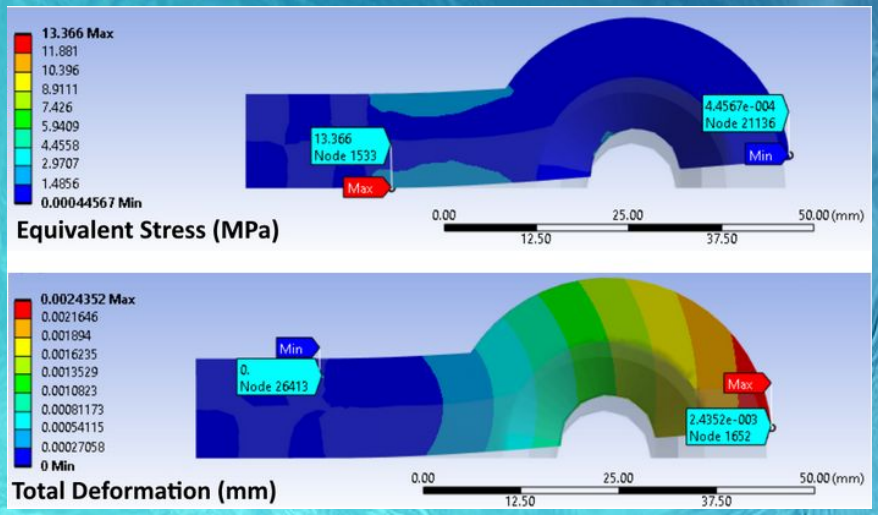


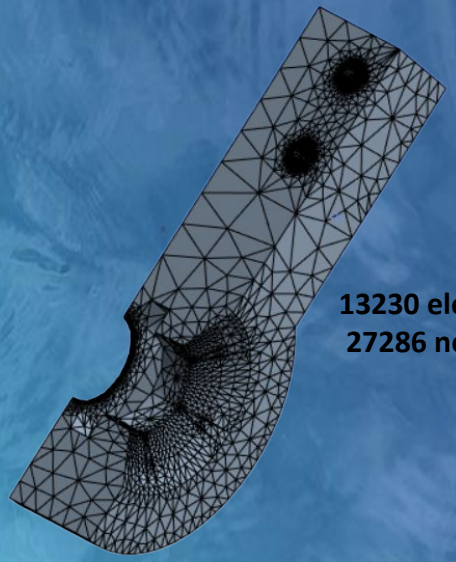


Standard End-Effector



Final Design FEA





13230 elements
27286 nodes

End Effector Materials		
Material	ABS	Steel
Cycles	18,830	18,830
Young's Modulus (MPa)	3200	200,000
Poisson's Ratio	0.37	0.30
Yield Strength (MPa)	48	250
Ultimate Strength (MPa)	74	460

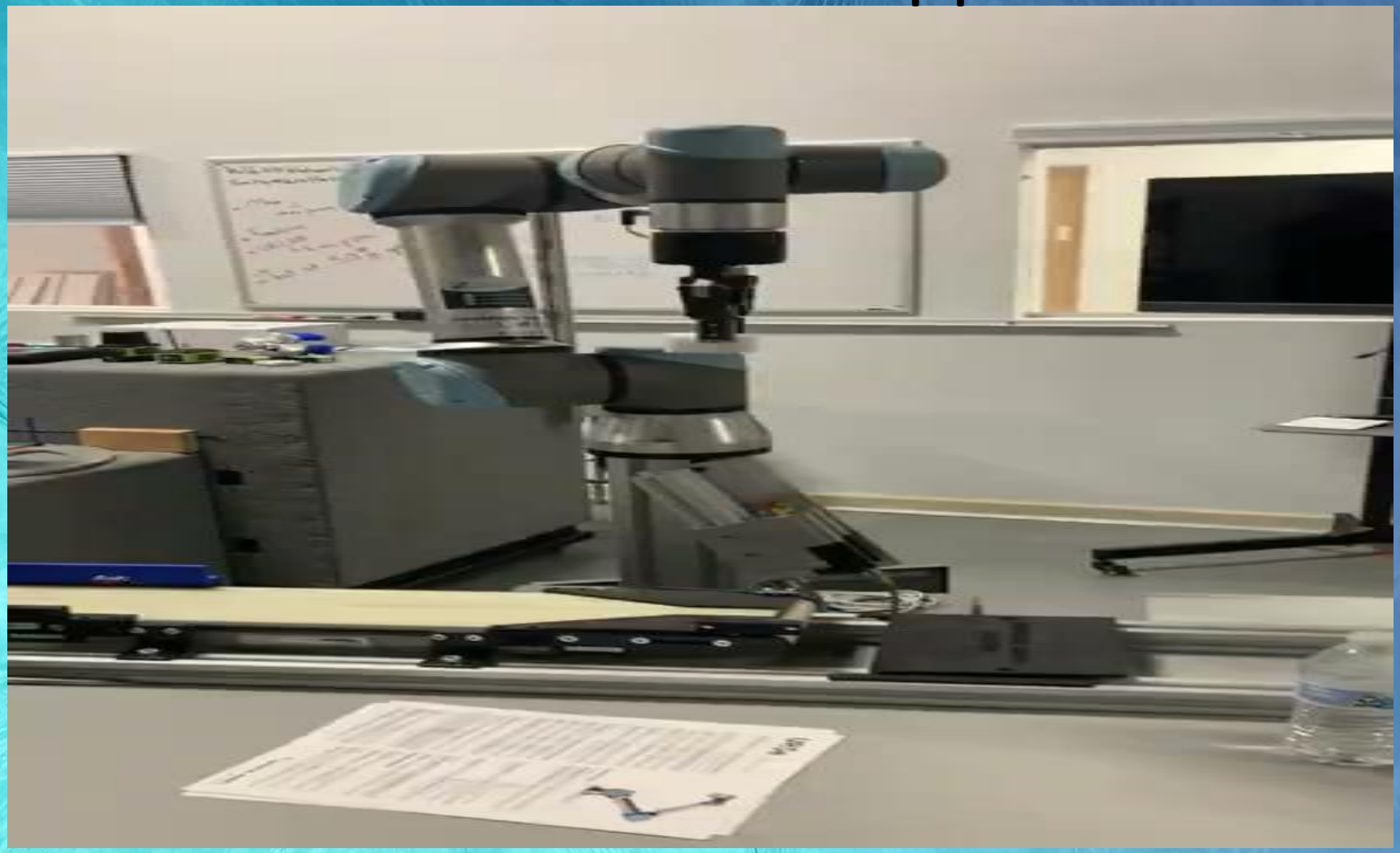
End Effector ANSYS Testing		
Material	ABS	Steel
Deflection (mm)	0.15196	0.00244
Equivalent Stress (MPa)	14.81	13.366

Final Design Description Prototypes (Continued)

Process Step	Potential Failure Mode	Potential Failure Effect	SEV	Potential Causes	OCC	Current Process Controls	DET	RPN	Action Recommended
Robot moves bolts in/out of machine	End Effector Deforms/ Widens	Attachment no longer able to lift bolt	5	Deformation caused by overuse	8	Robot allows switching gripper when max deform occurs	10	400	Print/Construct duplicate End Effector
Robot moves bolts in/out of machine	End Effector snaps at connection	Proper operation of Robot is not possible	10	Fracture caused by applied force over time	2	Maximum stress over 10K cycles below material fracture	10	200	Print/Construct duplicate End Effector
Grab part from Orienter	Arm unable to lift	Proper operation of Robot is not possible	10	Bolt being worked with is too heavy	1	Current bolt is under 1 oz	10	100	Keep manufactured bolts under max weight of 44 lbs

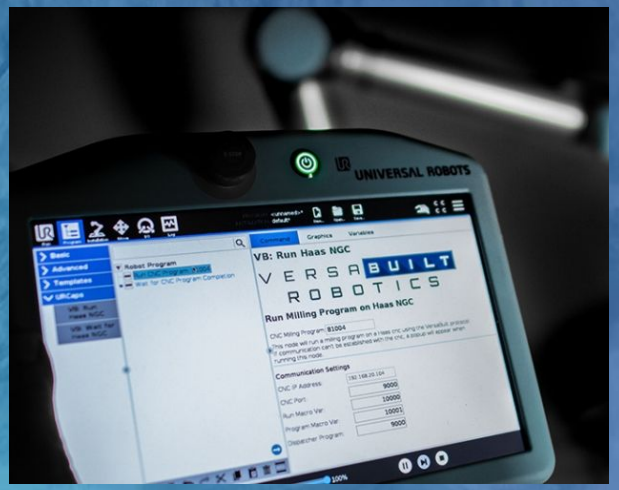
Failure Mode and Effect Analysis (FMEA)

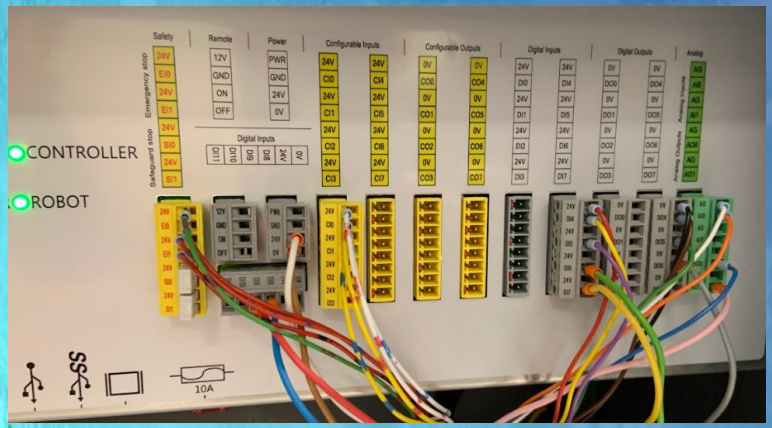
Final Design Description
Demonstration: Test Application



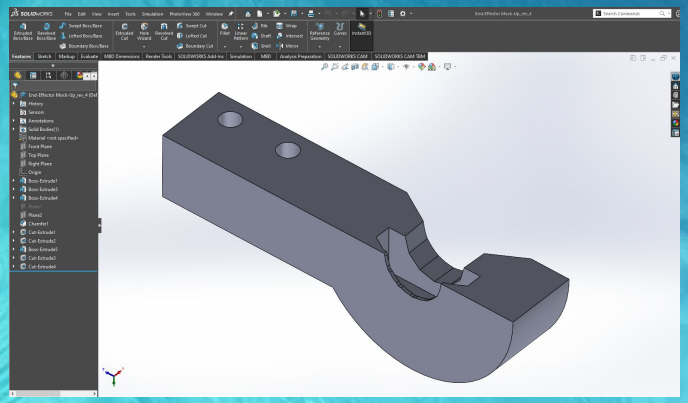
Programming/Fabrication

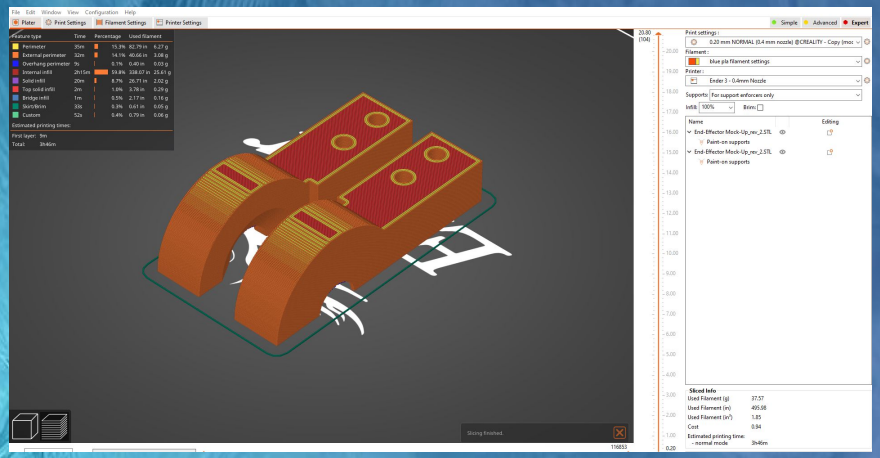
- Software
  - UI system - Polyscope
    - Robot arm speaks to all other systems in process by sending 24V signal (ex. foot pedal to lock collet when placing in bolt)
- Interactions
  - Tumbler Process
  - Lathe Process
  - Threading Process
  - Diameter Inspection

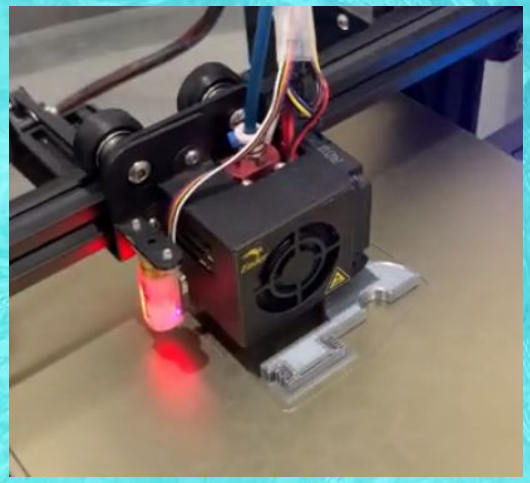


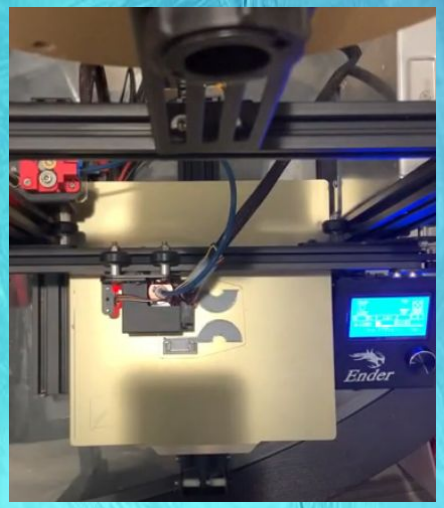


ADDITIVE MANUFACTURING FOR PROTOTYPING









RESULTS

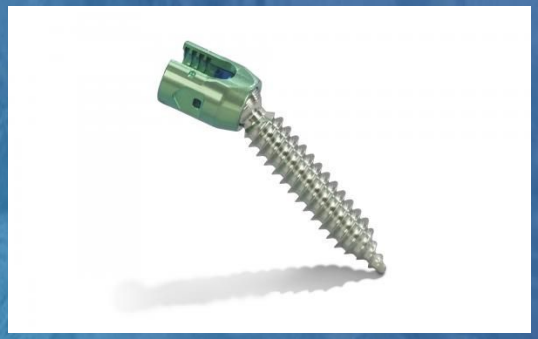
	Manual Labor (Current)	Automated System (Projected)
Efficiency (Minutes per bolt)	8.9	5.5
Batch Size (Quantity of bolts)	2690	2690
Total Time Needed (Minutes)	23941	14795
Total Time Needed (Hours)	399.0166667	246.5833333
Shifts needed to complete batch (8 hours)	49.87708333	30.82291667
Total Amount of Days to complete	50	31
Total Amount of Work Weeks to complete batch (5 Days)	10	6.2
Total Labor Cost per batch (Weeks * Worker Cost)	$16,666.67	$10,333.33
	Cost Saving's per batch ($)	Total Payback Time (Days)
	$6,333.33	364.2023416

Important Notes	Units
Worker yearly Salary ($)	$80,000.00
Worker yearly working weeks	48
Worker Weekly Cost ($)	$1,666.67
Estimated System Cost ($)	$74,406.93
Amount of Day Saving's	38.00%

Future bolts and options

Bolts and Screws

Orthopedic Implants & Components

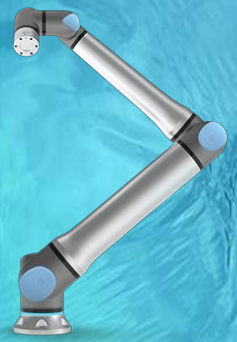


Rods, Pins, and Studs

Grinding Process?

Impact Statements

- Economic Analysis
  - Long-term cost savings to the company
  - Higher efficiency



- Environmental Analysis
  - Increased energy usage
  - Decreased errors -> less waste

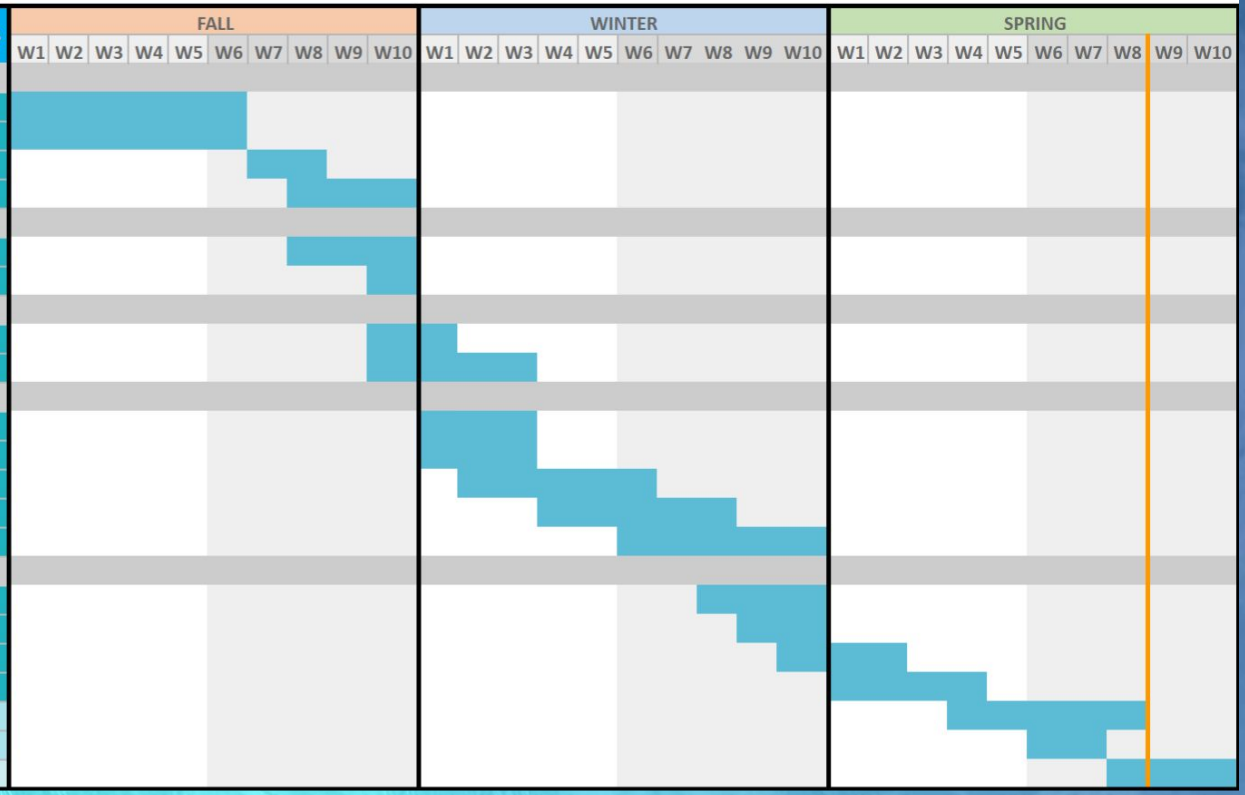
- Social Impact Analysis
  - Improve Operator Skill
  - Worker Safety
  - Unemployment low skill work

- Ethical Analysis
  - Upholding ethical standards
  - health & happiness prioritized

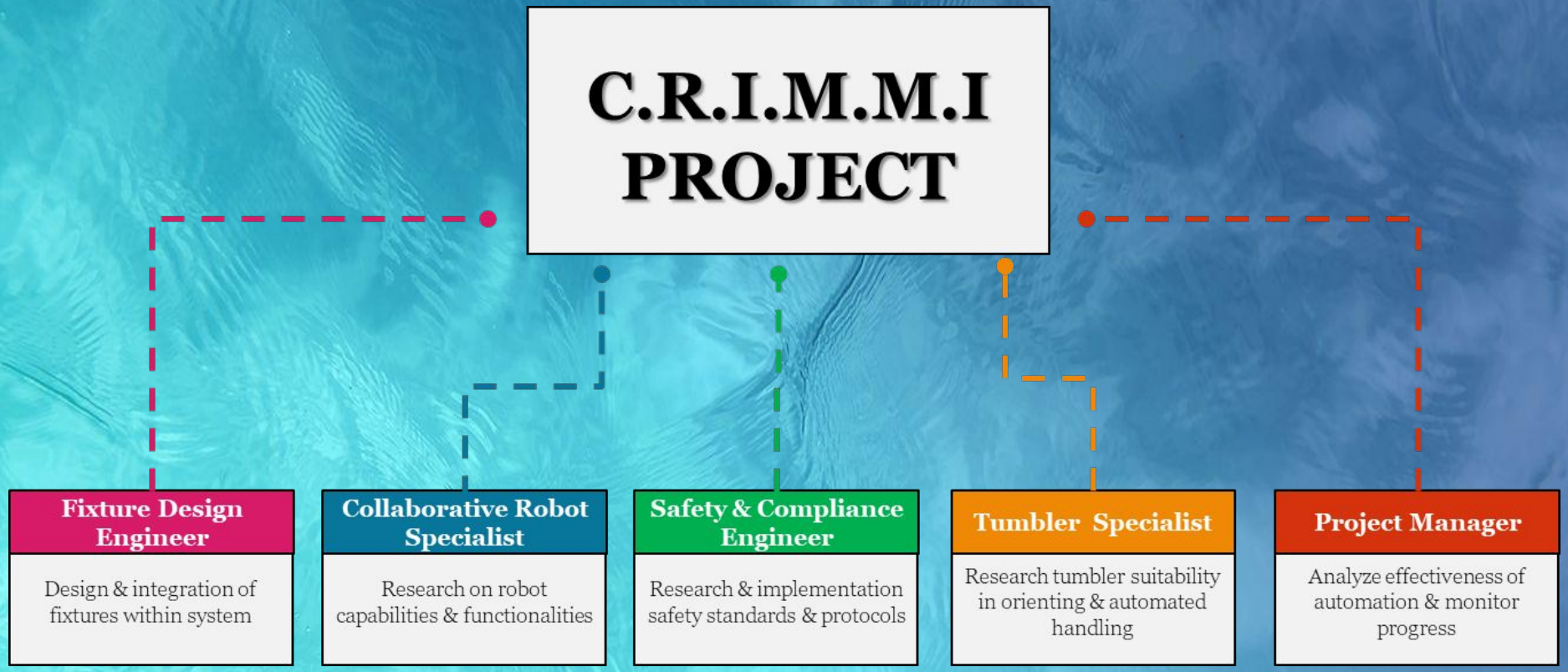
Project Management

Timeline

TASK NAME	DURATION (WEEKS)	STATUS
Milestone 1 - Project Proposal		
1.1 Project Proposal Research	6	C
1.2 Project Proposal - Draft	6	C
1.3 Project Proposal Presentation	2	C
1.4 Project Proposal Submission to B&G	3	C
Milestone 2 - Bill of Materials		
2.1 Bill of Material Research	3	C
2.2 Bill of Material Submission to B&G	1	C
Milestone 3 - Order Parts		
3.1 Contact Supplier Representatives	2	C
3.2 Submit Proof of Ordering Test Parts to B&G	4	C
Milestone 4 - Prototyping		
4.1 Abstract - Draft	3	C
4.2 Video Pitch Presentation	3	C
4.3 Automated Cell - Design & 3D Modeling	5	C
4.4 End Effector - Design & Assembly	5	C
4.5 Feeder Bowl - Design & Assembly	5	C
Milestone 5 - Final Proposal/Report		
5.1 Poster Session Presentation	3	C
5.2 Prototype Interim Report	2	C
5.3 Abstract - Final	3	C
5.4 Prototype Revisions + Testing	4	C
5.5 Report - Final	5	I-P
5.6 Final Presentation	2	I-P
5.7 Final Deliverable Submission to B&G	3	I-C



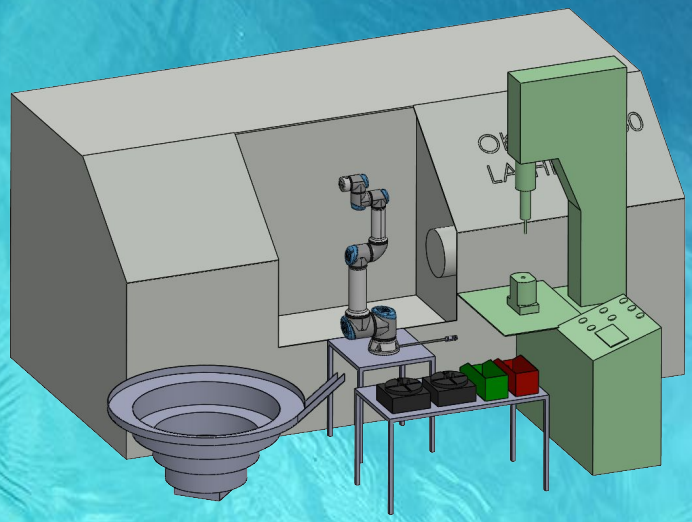
Team Member Responsibility

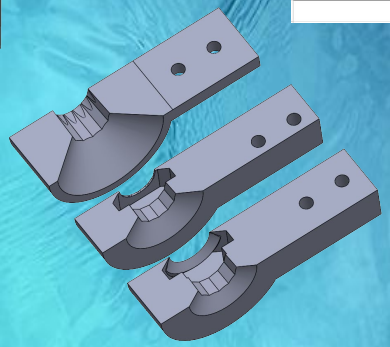


Final BOM

Bill of Materials (BOM)		
Company	**Item**	**Cost**
Universal Robot	UR-20 Collaborative Robot	$59,000.00
On-robot	Robotic Gripper	$4,963.00
Hoosier Feeder	Vibratory Feeder/Tumbler	$9,995.00
McMaster Carr	24V/DC Solenoid 1/8" NPT	$111.96
McMaster Carr	1/8" OD Air Tubing - 50ft	$14.50
McMaster Carr	1/8" Muffler	$2.33
McMaster Carr	1/8" NPT Air Fitting	$5.26
McMaster Carr	Arduino Mega 2560	$51.86
Overture Filament	PLA - easy space grey filament	$19.99
McMaster Carr	Low Carbon - A36 Steel (3" x 3" x 2")	$49.57
McMaster Carr	M5-0.8mm Steel Screws - 50 pack	$17.65
McMaster Carr	M5-0.8mm Steel Nuts - 100 pack	$4.05
McMaster Carr	Air Cylinder with 3" stroke - 15LB @100psi	$43.46
McMaster Carr	Proximity Sensor - 6mm Sensing Distance	$128.30
	Total Cost	$74,406.93

SUMMARY





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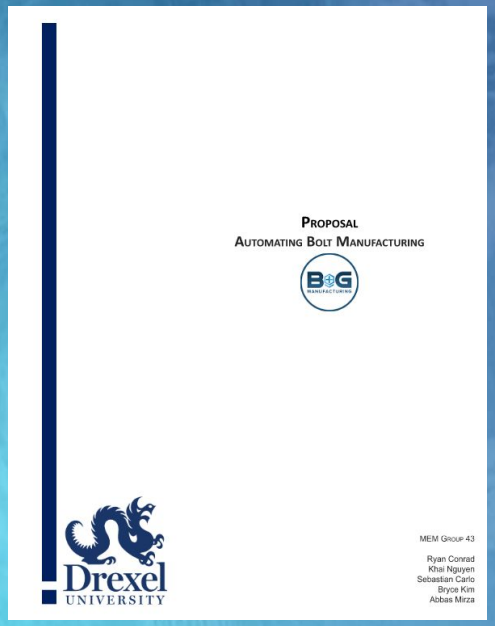

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F. Sherwani, M. M. Asad and B. S. K. K. Ibrahim, "Collaborative Robots and Industrial Revolution 4.0 (IR 4.0)," 2020 International Conference on Emerging Trends in Smart Technologies (ICETST), Karachi, Pakistan, 2020, pp. 1-5

M. Pearce, B. Mutlu, J. Shah and R. Radwin, "Optimizing Makespan and Ergonomics in Integrating Collaborative Robots Into Manufacturing Processes," in *IEEE Transactions on Automation Science and Engineering*, vol. 15, no. 4, pp. 1772-1784, Oct. 2018, doi: 10.1109/TASE.2018.2789820.

Wolfsteiner, P, & Pfeiffer, F. "Dynamics of a Vibratory Feeder." *Proceedings of the ASME 1997 Design Engineering Technical Conferences*. *Volume 1C: 16th Biennial Conference on Mechanical Vibration and Noise*. Sacramento, California, USA. September 14–17, 1997. V01CT15A011. ASME