LANL Human Robotic Arm Attachment

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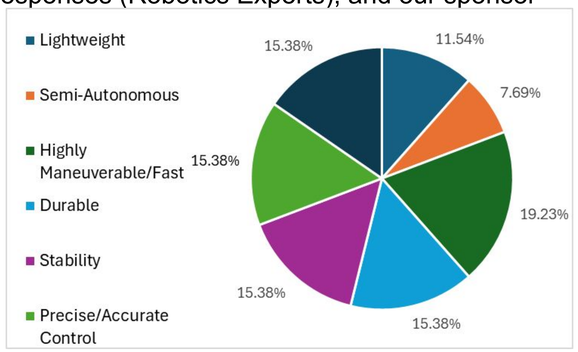
Problem Statement & Project Motivation

There is a need for a technology that has **5 degrees-of-freedom** and can move through its full range of motion in **four degrees-of-freedom of at least 1 Hz.**

- The **Hanford Site in Washington** stores **56+ million gallons of radioactive waste** in **deteriorating underground tanks.** [1]
- Many tanks **exceed their lifespan capacity** and pose **serious environmental and safety risks**
- Key challenge: Solidified waste is hard to remove due to **small access ports (~1 ft diameter)** and **extreme radiation levels** [2]
- **Existing robotic solutions** lack the **mobility, speed, and/or reliability** to operate in **confined, hazardous conditions**
- Our goal: Design a **5 degrees-of-freedom** robotic arm to be eventually mounted on **a quadruped robot** for **effective remote cleaning** of nuclear waste tanks

Customer Needs & Design Requirements

Identified Customer Needs - Derived from interviews with Engineers at Savannah River National Laboratory, supplemental survey responses (Robotics Experts), and our sponsor



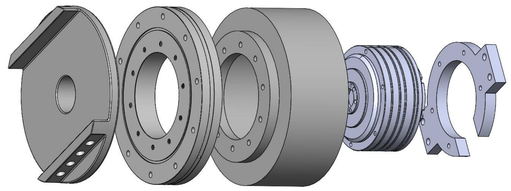
Only Survey Responses are shown in pie chart*

Design Requirements

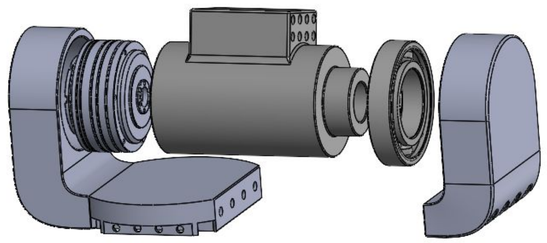
- Total system weight: ≤ 14 kg (~30 lbs)
- Minimum Joint Torque (to hold itself up):
  - J1 & J2 > 10 Nm, J3 & J4 > 2 Nm
- Reach: ≥ 0.67 meters
- Motion Frequency: ≥ 1 Hz (J1-J4)

System Design Overview

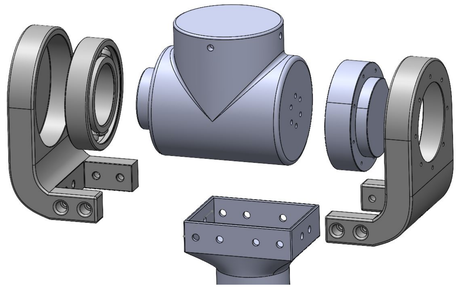
Joint 1 SolidWorks Assembly:



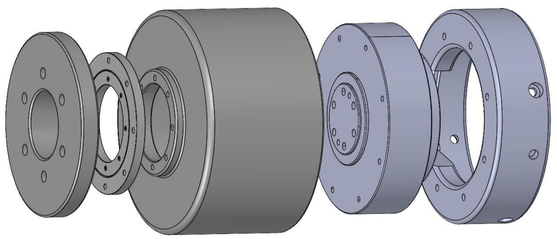
Joint 2 SolidWorks Assembly:



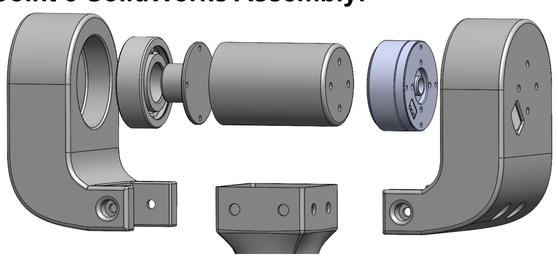
Joint 3 SolidWorks Assembly:



Joint 4 SolidWorks Assembly:



Joint 5 SolidWorks Assembly:



Design Decisions & Trade Offs

Component Selection

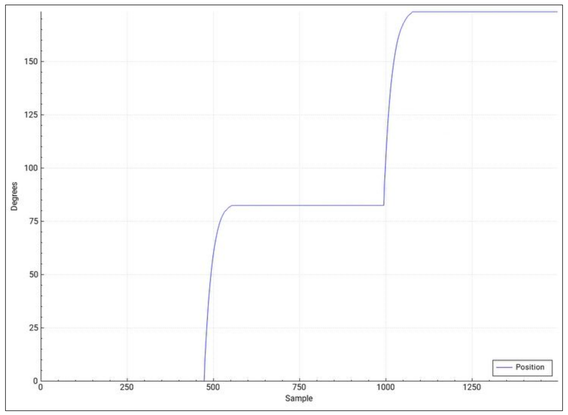
- Linkages: 3D printed PLA
- Motors: CubeMars Brushless DC & Gimbal
- Controls: R-link & Upper Computer Software (USB to serial port communication)
- Power Supply: B&K Precision 9115B (80V-60A)
- M6 - M2.5 Various Length Fasteners

Trade Offs:

- Selected **Modular Design** Instead of Integrated
- Prioritized **Speed** Instead of Accuracy

Testing & Validation

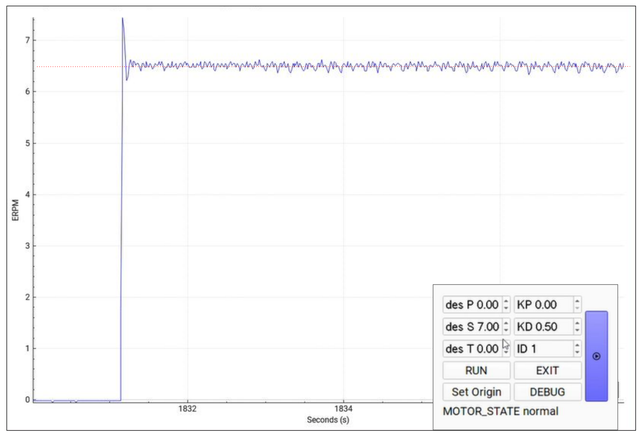
The testing process for the robotic arm focused on **motor performance** under **position, speed, and torque control**, with testing performed both individually and integrated within the system.
J1 - J4 motors exceeded the **target motion frequency of 1 Hz** and demonstrated **accurate responsiveness to positional commands (0°-180°)**. **Full-extension load testing** on joints J2 and J3 confirmed the arm could **sustain torque demands to hold itself up without structural failure**, validating the motor selection and mechanical integrity of the design.



J1 motor positional response during integrated testing. Verification confirms accurate Position control for (0° - 180°).*

Joint	Calculated Torque (N-m)	Actual Torque (N-m)
J2	21.3	20
J3	3.7	2

Fully integrated torque testing at maximum extension, comparing the calculated values against the operational torque values to validate that the arm can successfully support itself at full reach. *



J1 motor speed response during integrated testing. Verification confirms motion frequency at 1 Hz (6.26 rad/s). *

Metric	Required Values	Verified Values	Units
Weight of the Arm	<14	11.88	kg
Minimum Torque Output	2-10	2-20	Nm
Reach of Robotic Arm	>0.67	0.9	m
System Mass Distribution	0.209	0.132	kg/cm
Frequency of Motion	1	1	Hz

Budget, Limitations, Impact & Future Work

Cost Accounting and Cost Model

- Total Spent on Capstone Budget: **$4,330**
- Total Project Cost Model: **$8,370**

Our sponsor contributed significantly by providing critical components, including J3 and J4 motors (approx. $700 each) and a power supply (approx. $2,550). The team also incurred an unexpected customs fee of around $500 during motor importation.

Future Work & Lasting Impact

- Implement Arduino-to-CAN communication for streamlined multi-motor control and reduced wiring complexity
- Integrate wiring to enable full range of motion
- Develop gimbal-based control for the J5 motor
- The project intends to support ongoing research and spot robot integration

References

[1] Department of Energy. "Hanford Site Overview." U.S. Department of Energy, 2021, https://ecology.wa.gov/waste-toxics/nuclear-waste/hanford-cleanup/hanford-overview.
[2] D. Herman et al., "Evaluation of Technology for Dry Retrieval of Tank Waste," OSTI OAI (U.S. Department of Energy Office of Scientific and Technical Information), Feb. 2024, doi: https://doi.org/10.2172/2319155.

Acknowledgements

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