MWI Labs NRL Loss Arch Redesign

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Client Description

Client: Mr. Jeff Peebles of Material Wave Interactions Laboratories (MWI)

- Began as a subsidiary of ASU's engineering program
- Analyze radio frequency absorbing (RF) materials using electromagnetic radiation
- Rents devices to third party military contractors

History of Navy Research Lab (NRL) Arch

- Proposed by Thomas Edison and was first developed on July 2, 1923
- Primary Function: repeatable, non-destructive testing of microwave absorbent materials over a wide frequency range

Fig. 1: NRL Arch located at the National Synchotron Light Source [1]

Importance of NRL Arch Technology

- Testing material with a high capacity for reflecting EM radiation necessary for military applications
  - Allows for the construction of airplanes, foils, and other military supplies that are invisible or resistant to radar
  - Protects vital resources and personnel
  - Non - destructive testing equipment

Project Description

- Original device uses gaussian beams (a type of EM radiation) to bounce waves off of material and observe the response
- Mainly used to test for military applications
- Primary concern of client is the reduction of harmonic vibration in the NRL Arch arms
- Current system requires intensive human interaction to set up and test

Fig. 2: Original Design [2]

Video of Previous Model's Vibrations

Customer and Engineering Requirements

Customer Requests	Engineering Interpretation
Eliminate or reduce harmonic vibrations in the arms of the NRL Arch redesign	Observable response should reduce amplitude to a steady rate close to zero within two to three minutes of disturbance
A new control system needed to be implemented to replace the guide wires and hand crank--GUI should require as little human intervention as possible	A motor control system with associated GUI was needed to provide the arms with motion
Increase the portability of the device	Device is to come in no more than 4 pieces, and customer should be able to assemble it within 4 to 6 hours
Device must meet CE (Certified European) safety standards	NRL Arch arms must be able to withstand three times the expected load supplied by the antennae

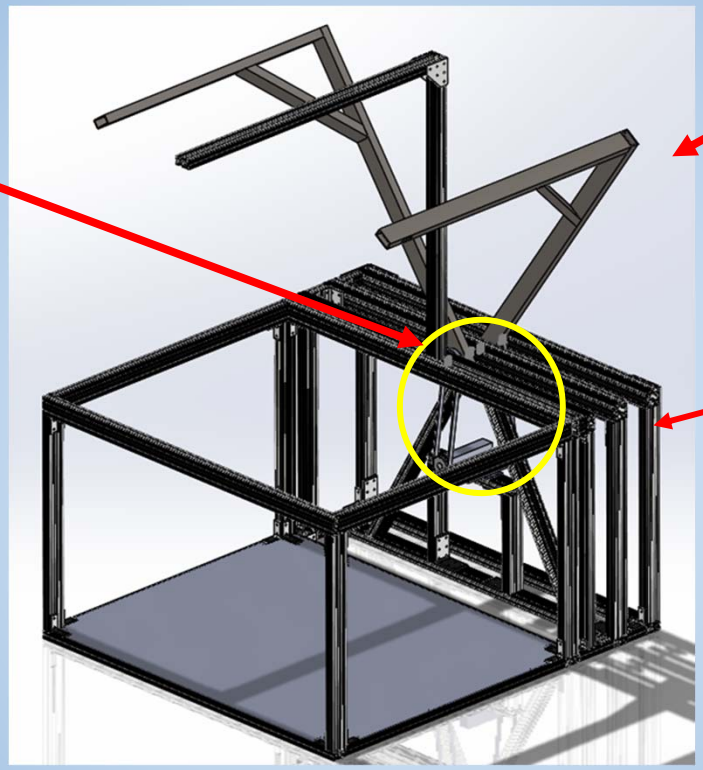
Generation Three Prototype

Based on the customer and engineering requirements, a prototype was developed

The prototype included the following changes:

- Arm material was changed to 1010 HR Steel
- The arm geometry was changed
- A motor driven system was devised
- Frame integrity was improved

Arms each driven separately by a motor operated electronically to reduce user interference.



Arms reinforced with trusses for stability.
Not pictured: Antennae.

Extended rear for increased stability, permits independent operation of arms.

Fig. 3: Detailed Layout of Final Prototype Design

Testing

The following methods were used to test the effectiveness of the device's redesigns

- Frequency Analysis
- Deflection Analysis via FEA
- Testing of motor control systems

Frequency Analysis

- Arduino-Based Data Collection
  - Data obtained using an MPU-6050 Accelerometer
  - Measure the amount of time until vibration stops
- This data is then compared to the theoretical data based on the changes in arm material

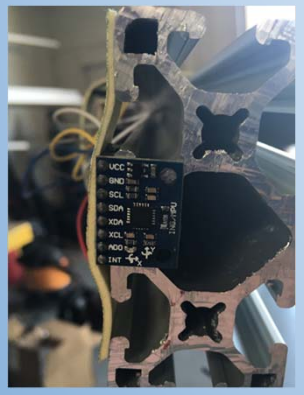


Figure 4: MPU-6050 Accelerometer

Figure 5: Genuino Uno Board, Attached For Testing

Frequency Analysis Results

- Behavior of vibrations, seen right in Fig. 6
- Vibrations return to constant amplitude after one second

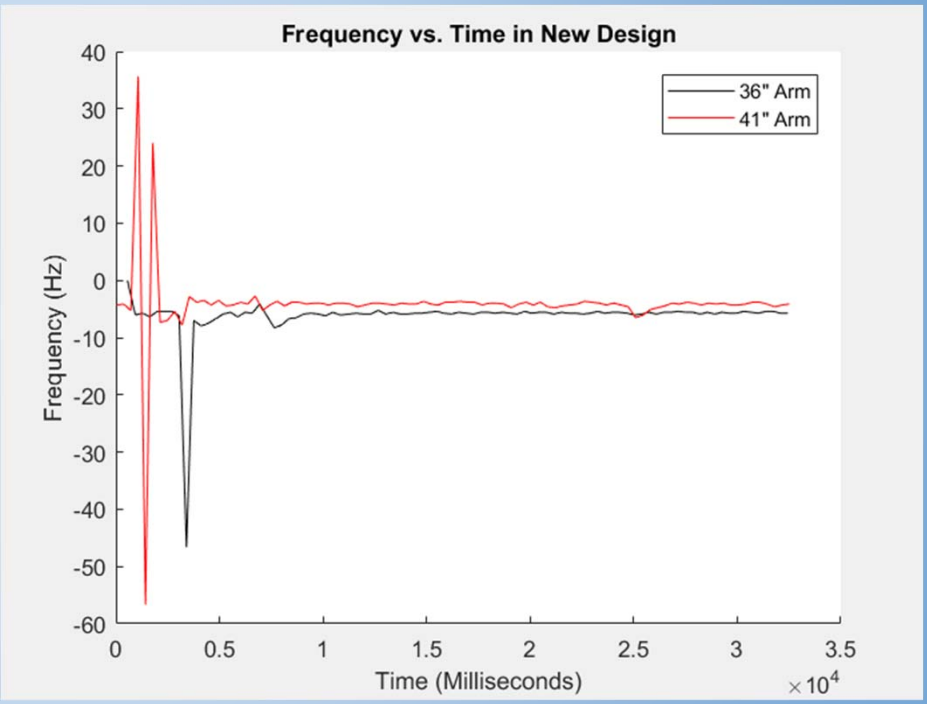


Fig. 6: Plot of Frequency vs. Time

Deflection Analysis

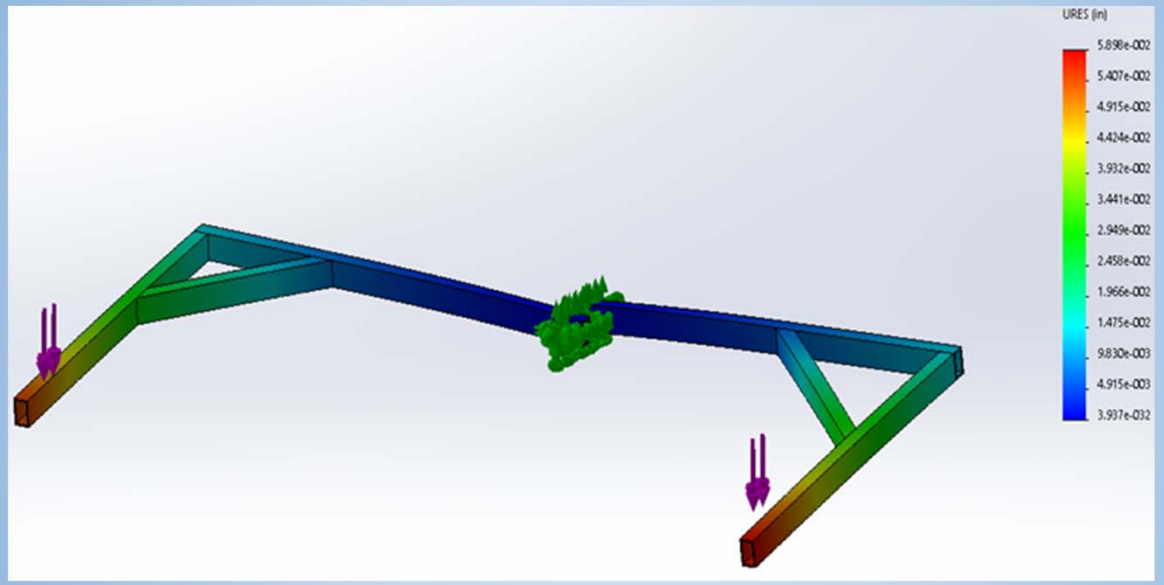


Fig. 7: Deflection FEA

Maximum Al deflection: 0.37”
Maximum Steel deflection: 0.059”

Portability Condition

- High-weight capable caster wheels
- Integration of arms and table

Figure 8: Rear-end Integrated Assembly

Motor Controlled Systems

- 19V Power Source
- NEMA 23 Motor
  - 5.6A Max Current
  - With Stepper Current, 1.2V
  - Arduino Controlled
  - Torque: 286 oz. inch or 1.49 ft. lb.
  - 29.8 lb ft. with 20:1 Gearbox
- T6600 Microstep Driver
  - Applies 3.0A

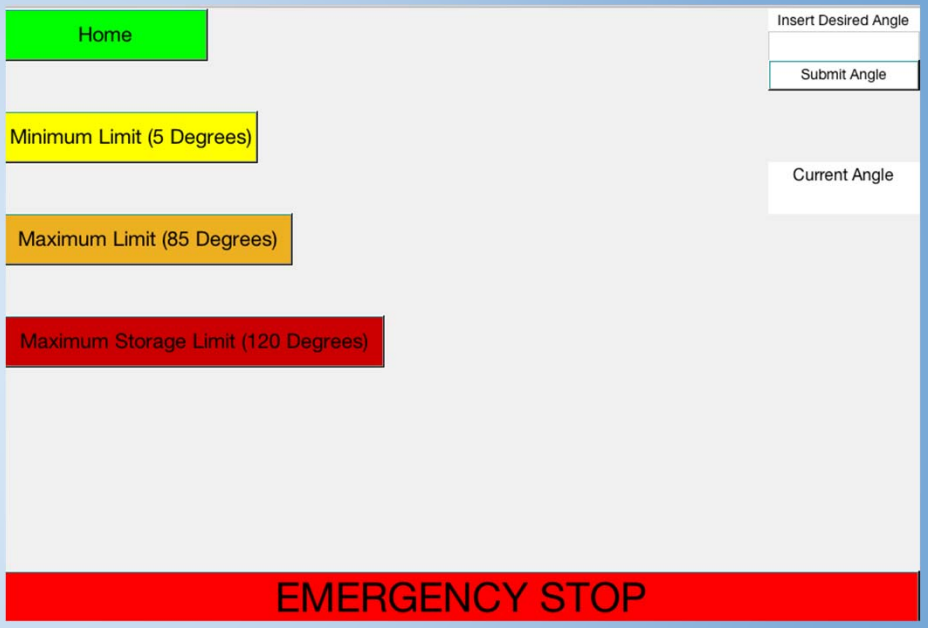
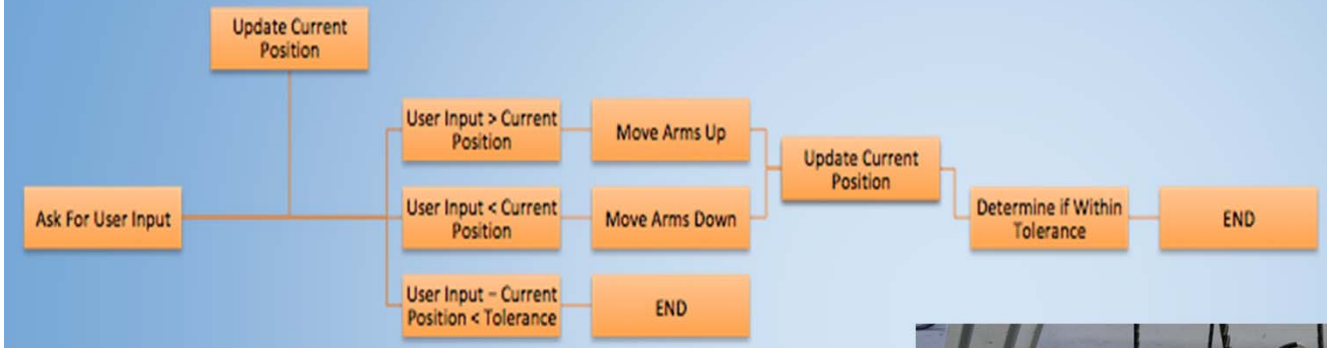


Fig. 9: Graphical User Interface (GUI)

Motor Control



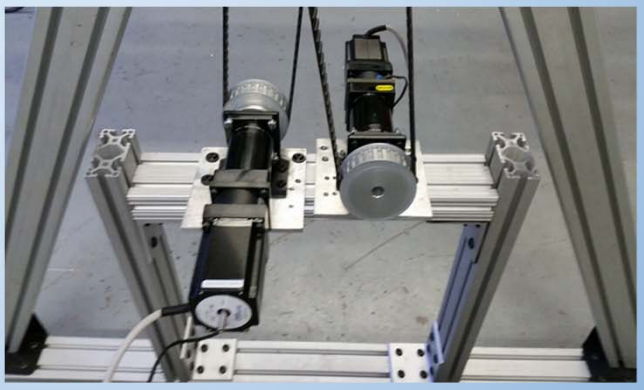


Fig. 10: Belt-Driven Motor System

Motor Control Hardware

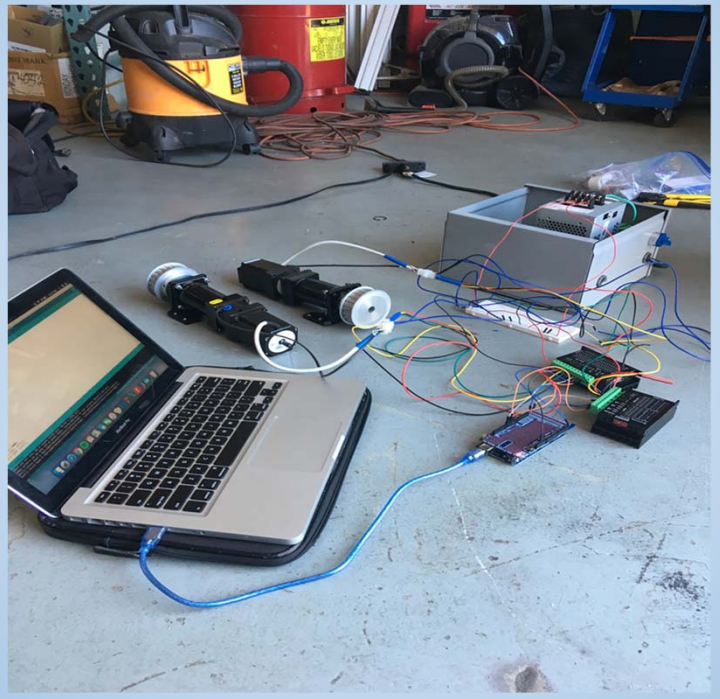


Fig. 11: Arduino Communication Setup

Final Design Details

Selected Material and Geometry:

- Arm material selected is 1010 HR Steel due to its availability.
- Trusses/cantilevered beams composed of 15 series 8020 Aluminum due to weight restrictions
  - Customer Request

Final Design is a Gen III Design

- Ultimately reduces risk for client and user in future production
  - Multiple generations for Prototyping (Gen I, III, V, etc.)
  - Capstone NRL Arch is a Generation III Prototype

Knowledge and Skills Gained

- Learned the importance of NRL Arch technology
- Insight into prototyping process in industry
  - Iterative generations
  - Risk-management
- Learned new skill
  - Programming
  - Finite element analysis software (SolidWorks)
- Teamwork and Communication Skills

Conclusion

Metric for Goals Accomplished

- Primary goal: Reduction in Harmonic Vibrations
  - Success
- Secondary Goal: Motor-Driven Arms
  - Did Not Succeed
- Secondary Goal: Device Meeting CE Standards
  - Success
- Tertiary Goal: Increased mobility
  - Success

Reasons for successes and lack of success...

Conclusions

Capstone NRL Arch is Gen III prototype for the first mobile NRL Arch design

Suggestions for future iterations:

- Lighter and cheaper material for the arms
- Decrease steel arm length to avoid interference
- Recommended 90 degree gearbox to save space
- Recommended risk assessment to be performed

Acknowledgments

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References

[1] Tms.org. (2018). The Naval Research Laboratory: 75 Years of Materials Innovation. [online] Available at: http://www.tms.org/pubs/journals/jom/9807/rath-9807.html [Accessed 25 Apr. 2018]

[2]

Questions?