Automated Assembly of a Satellite Wiring Harness

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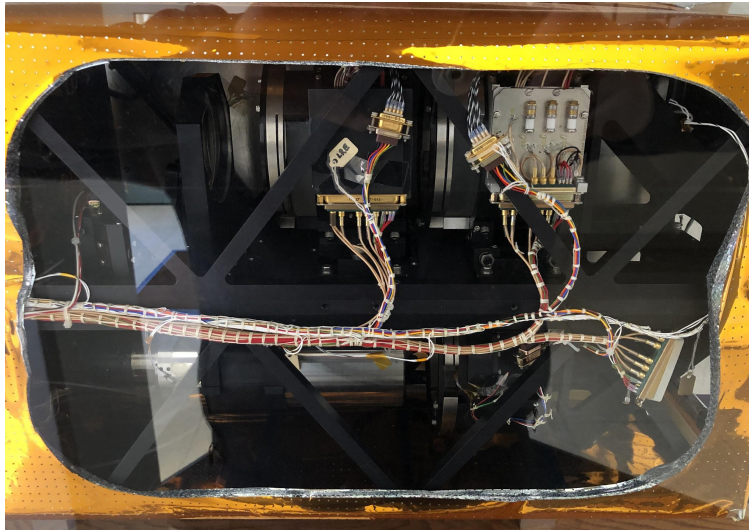
MULTIDISCIPLINARY DESIGN PROGRAM

NORTHROP GRUMMAN

What Is a Wire Harness?

Wire harnesses:

- Are bundled assemblies of cables and connectors
- Transmit signals and power between components
- May consist of thousands of wires



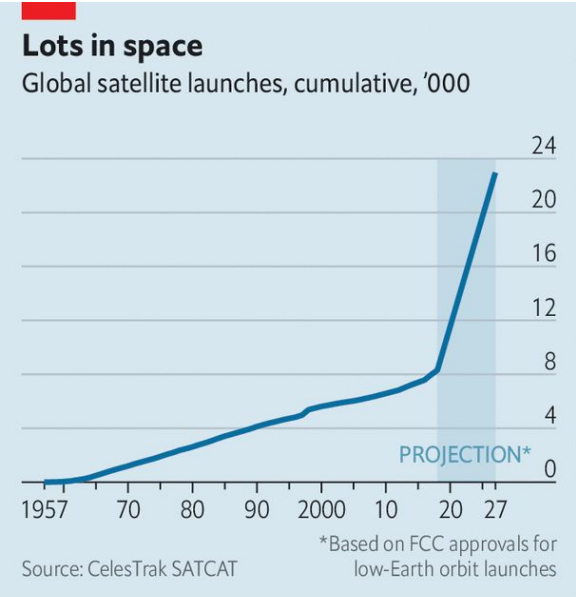
Background and Motivation

Space industry has undergone recent resurgence

- Increased demand for commercial satellites
- Sponsor experienced trouble meeting demand

Wire harness assembly contributed to delay

- Harness assembly is difficult to automate
- Complex harnesses lead to human error



Reproduced from *"Satellites may connect the entire world to the internet"* (The Economist, 2018)

Project Goal:

Develop a machine that outputs a completely assembled wire harness when supplied with a 3D input harness, with minimal human interaction.

Project Objectives

Preliminary project objectives included:

- Wire routing, cutting, and stripping
- Wire splicing, termination, labeling, and lacing

Due to the present challenges:

- Most stretch goals were shelved
- Success redefined to producing sample harness

Approach

Approach/Personal Contribution

As a member of the hardware subteam:

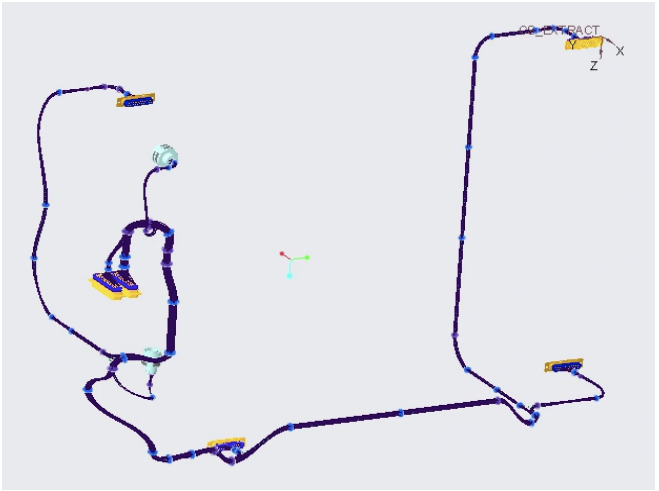
- Contributed to concept generation
- Developed wire routing strategy
- Designed machine structure
- Tested embedded systems

I was able to continue my work over the summer.

Approach/Task Breakdown

Multiple challenging aspects to this project:

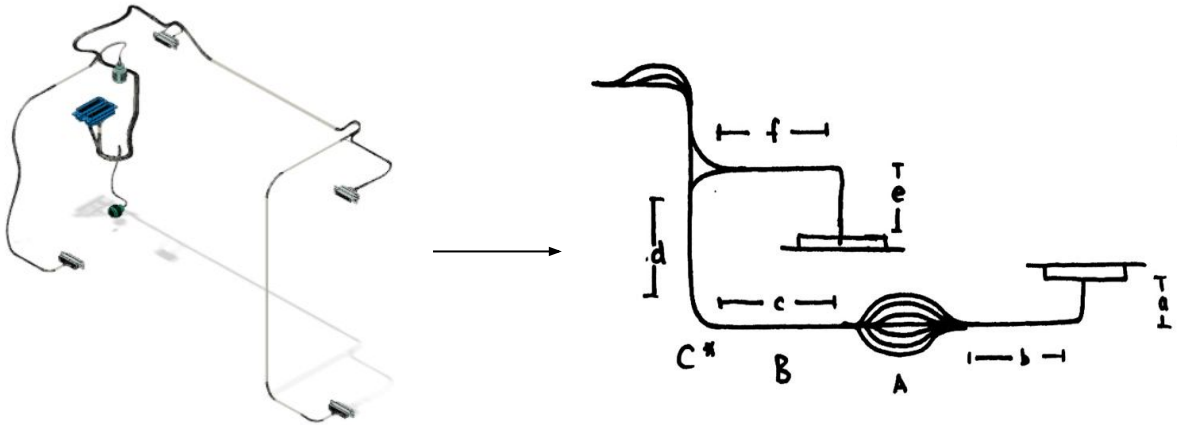
- Develop structure and mechanisms
- Develop embedded systems and controls
- Be able to read input file
- Test and validate machine capabilities
- Ensure final product meets NASA standards



Approach/Concept Generation

Concept: create a 3D-printer for wires

- Influenced by existing 3D printer/CNC designs
- Machine will “extrude” wire onto workspace
- Harness laid out in 2D, fold into 3D afterwards

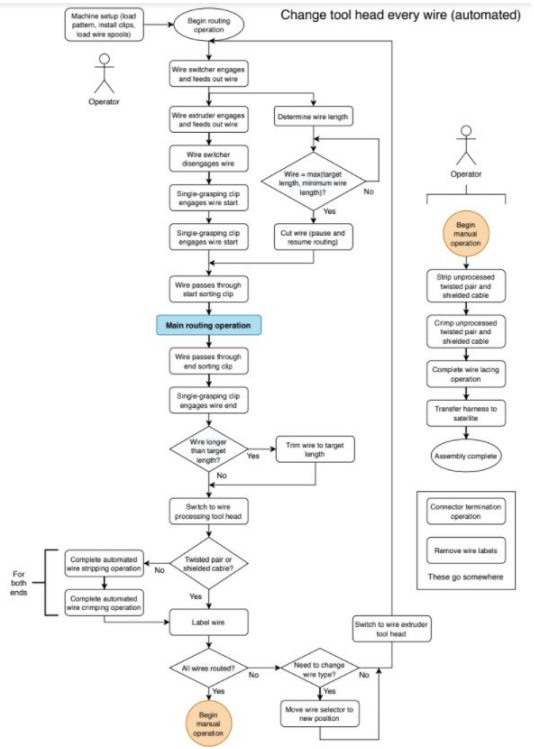


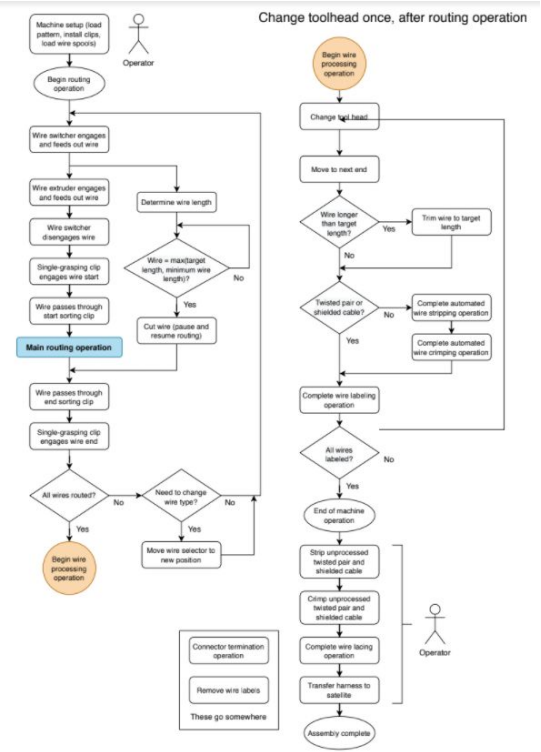
(Prusa Research s.a., 2017)

Approach/Wire Path Through Machine

Multiple potential order of operations to process wire

- Final design features only one tool head
- Wire is processed in one continuous path
- Allowances made to have operator do difficult tasks





Approach/Literature Review

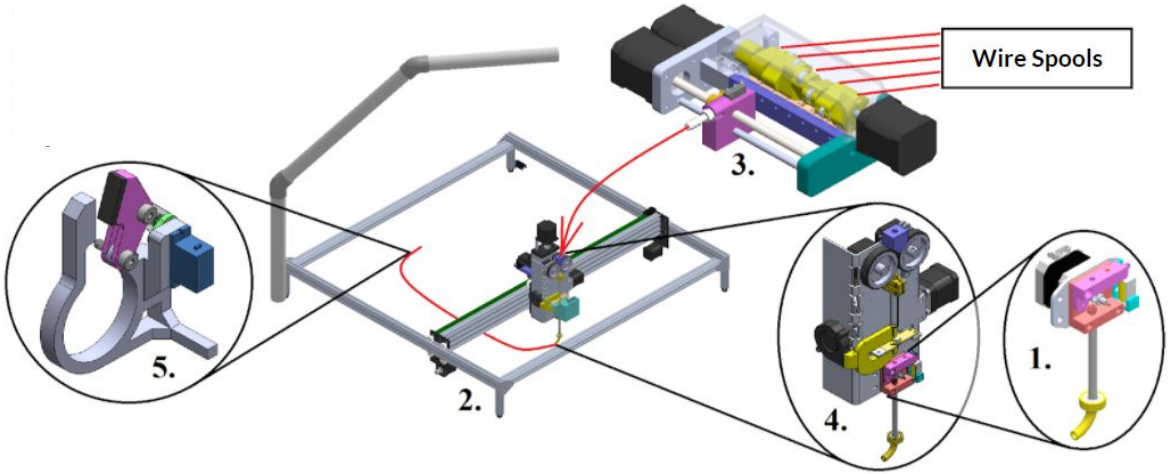
Researched previous automation efforts.

- Many individual subsystems have been automated
  - Wire cutting and stripping
  - Wire crimping and labeling
  - Translation motion in XYZ
- Challenge: integrate everything into continuous action

Approach/Mechanical Design

Machine was split up into subsystems:

1. Wire extruder
2. 3D translation stage
3. Wire switcher/selector
4. Cut/strip unit
5. Passive and active anchor clips



Subsystems developed entirely in CAD

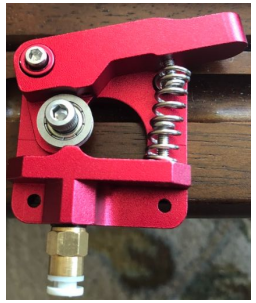
Wire Extruder Design

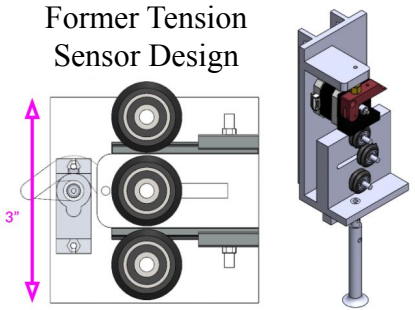
Repurposed existing filament extruder

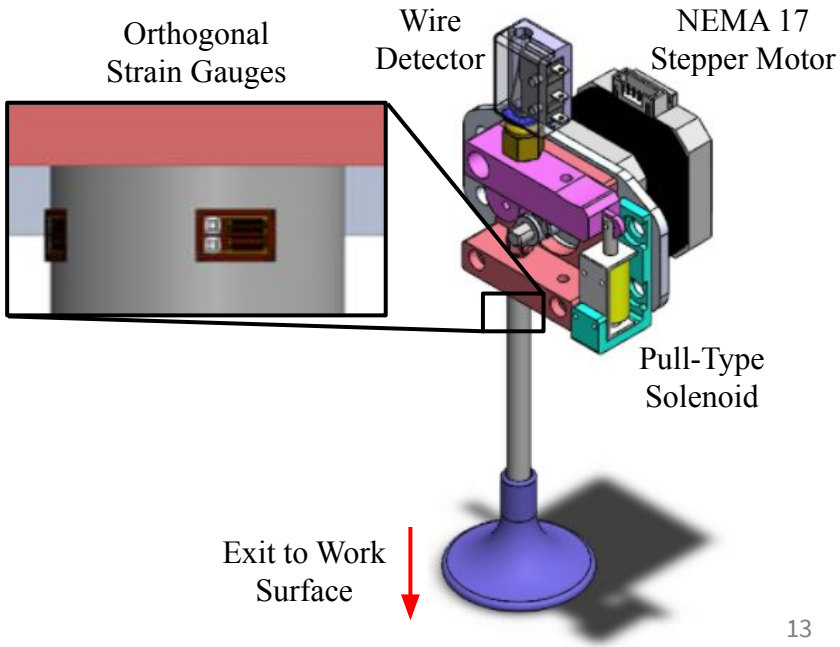
- Functionality is extremely similar

Tension sensor

- Initial design included mechanical tension sensor
  - Bulky, large increase to wire unsupported path length
- New implementation uses strain gauges



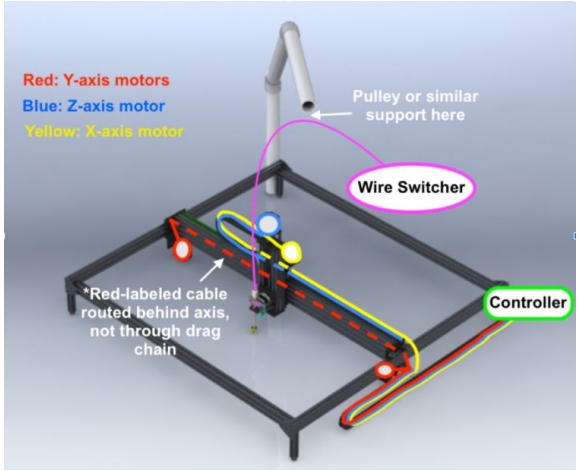


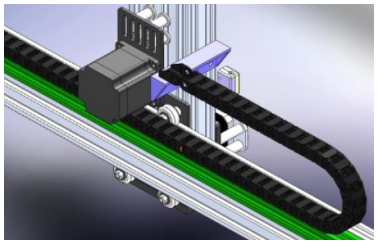


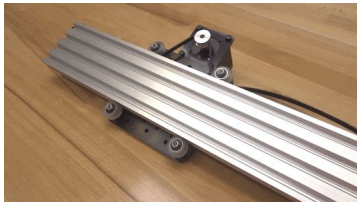
Translation Stage

Design based on existing CNC machines

- Large horizontal range of motion
  - Need to accommodate unfolded harness
  - 1 m x 1 m footprint
- Small vertical range of motion
  - 2D routing strategy, infrequent vertical mvt.







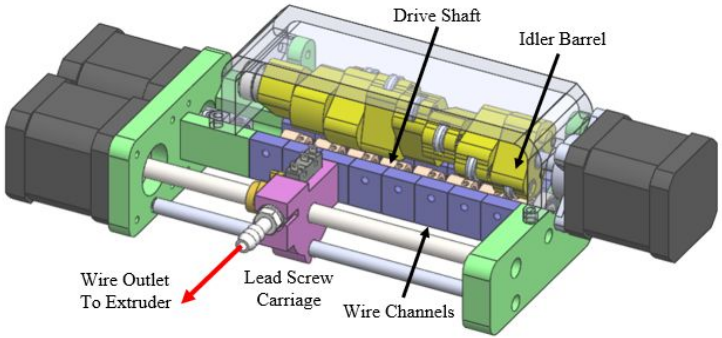
Design features

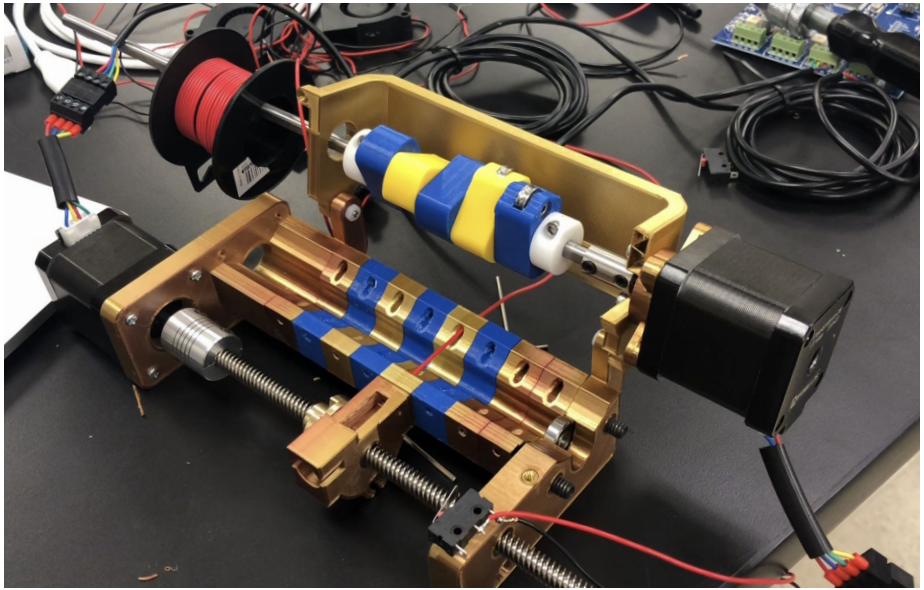
- Need quick motion in XY-axes -> belt and pinion
- Need precise motion in Z-axis -> leadscrew
- Motor selection based on force, precision requirements

Wire Switcher

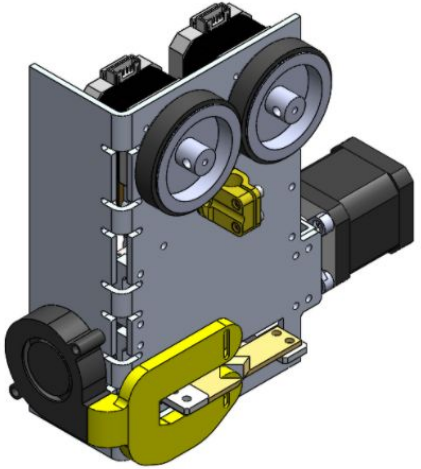
Design influenced by existing 3D printer filament switcher

- Enables automatic feeding
- Automatic wire switch/select
- Single output stream





Cut/Strip Unit

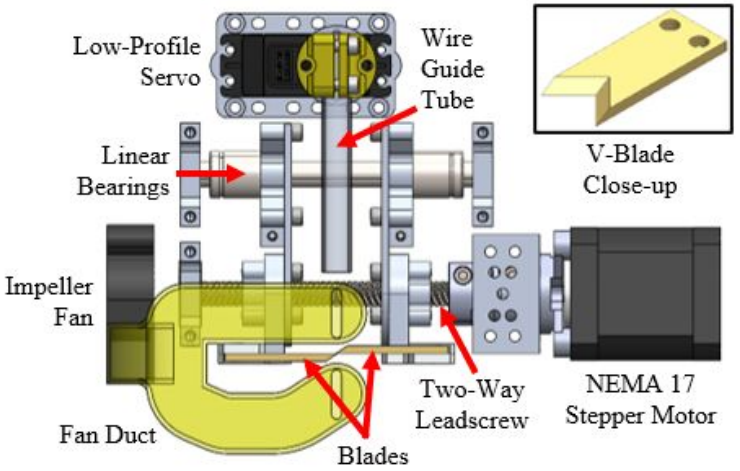


Design influenced by existing self-contained units

- Multiple wires follow a single path
- Cutting and stripping operation happens in line

Benefits of this system

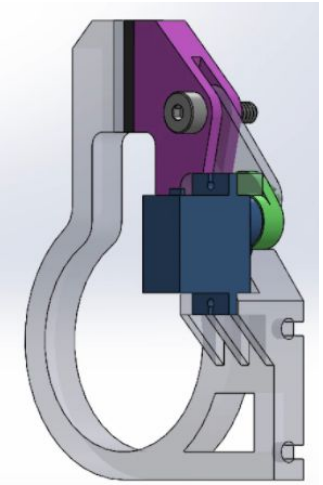
- In-line action satisfies requirements
- Very compact, small footprint
- Able to fit on machine end effector



Clips

Active clip

- Designed to secure single wire during routing
- Servo actuated, controlled by Raspberry Pi



Passive clips

- Three types of passive clips
- Designed to guide the wire path during routing

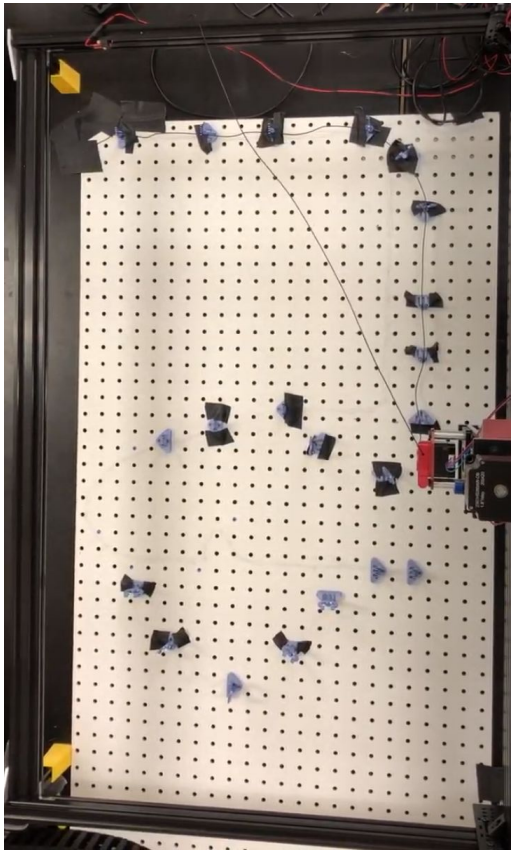
Results and Discussion

Results/Overall

Machine was effective in routing demo harness

- Simplified version of original harness
- Intended to demonstrate motion capabilities

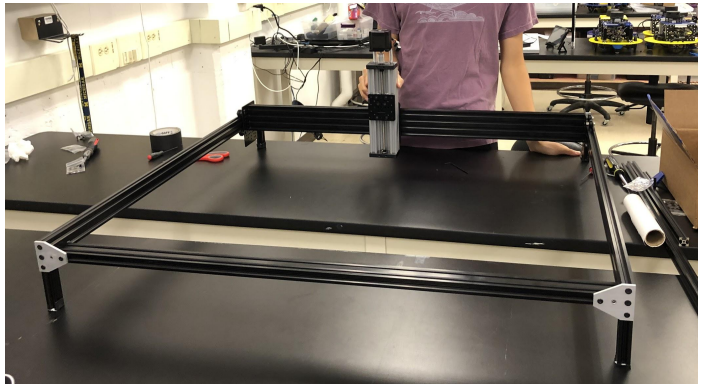
More testing required for full harness...

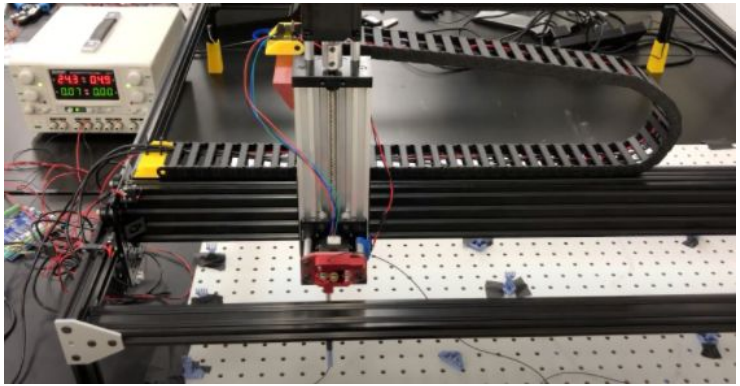


Discussion

Prototype is incomplete, but shows potential

- Missing subsystems have not been tested
- Existing subsystems have not been tested thoroughly
- However, the main concept of routing has been demonstrated





Conclusions and Future Suggestions

Remaining work will be continued through MDP next year.

Suggestions:

- Continue developing clips and active clips
- Refine routing algorithm
- Implement remaining unfinished systems

Q&A