The Beast
3D Printing System

MAY14-06

ANDREW SPEER | CHENG SONG | KYLE LICHTENBERG | ROSS FRIEDMAN | JAKE MEYER

ADVISOR/CLIENT: DR. TOM DANIELS

About Us

Andrew Speer (EE)

- Controls Lead
- Focus on semiconductor fabrication and an interest in LEDs

Cheng Song (EE)

- Distribution Lead
- Focus on semiconductors

Jake Meyer (EE)

- Team Lead
- Focus on embedded systems and an interest in networking

Kyle Lichtenberg (EE)

- Extrusion Lead
- Emphasis on analog circuits with an interest in audio equipment

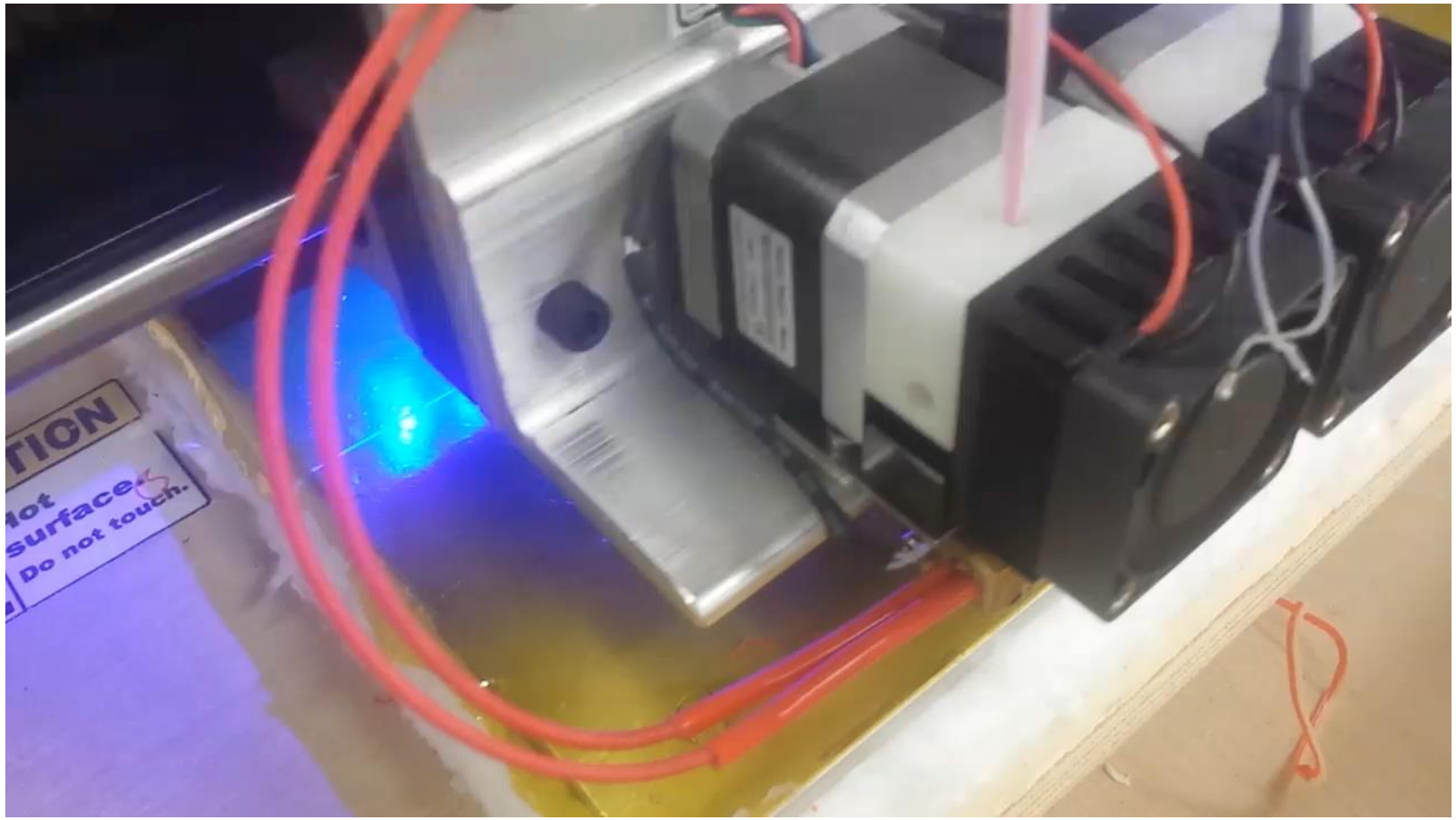
Ross Friedman (EE)

- Circuitry Lead
- Interest in power electronics and transistor layout

Advisor/Client: Dr. Tom Daniels

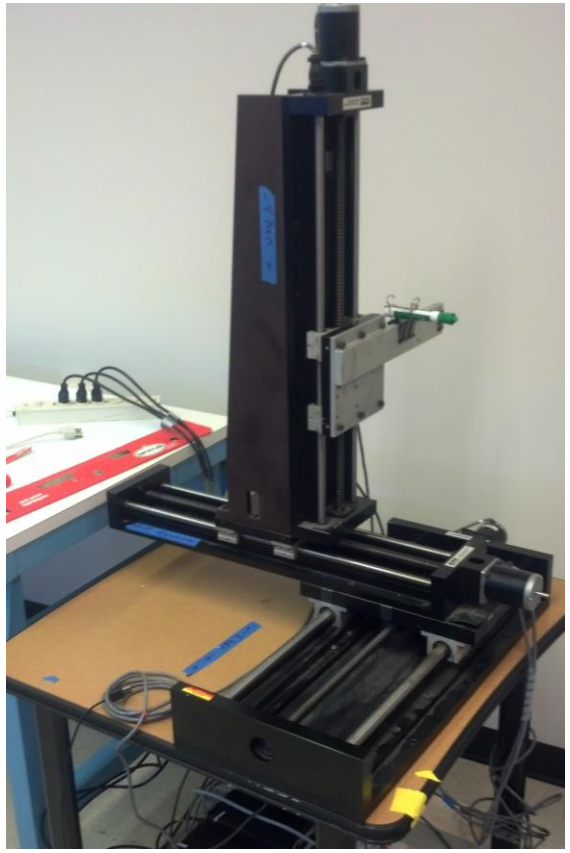
Department: Computer Engineering

How an Extrusion based 3d Printer Works

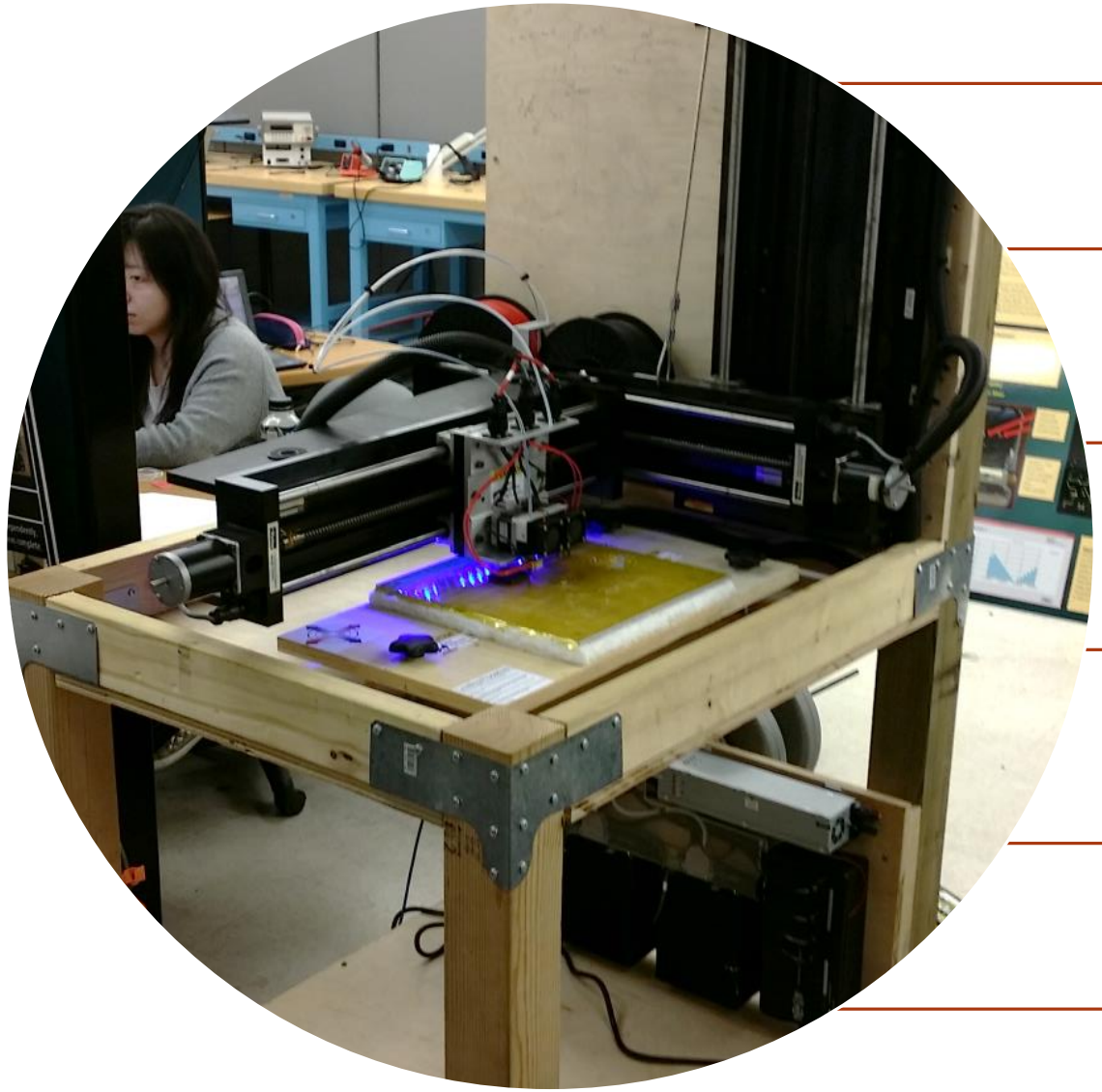


Project Scope

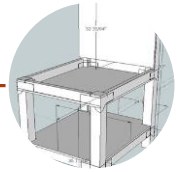
- Repurpose an unused 3-axis positioning system into a fully functional extrusion based 3D printer.
- Design must be modular with expansion in mind (conversion to a CNC mill or laser engraving system)



Deliverables Overview

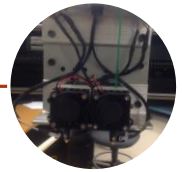


Safety Systems

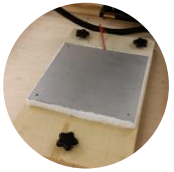


Bench

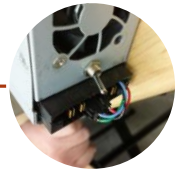
RAMPS Controller



Extruder



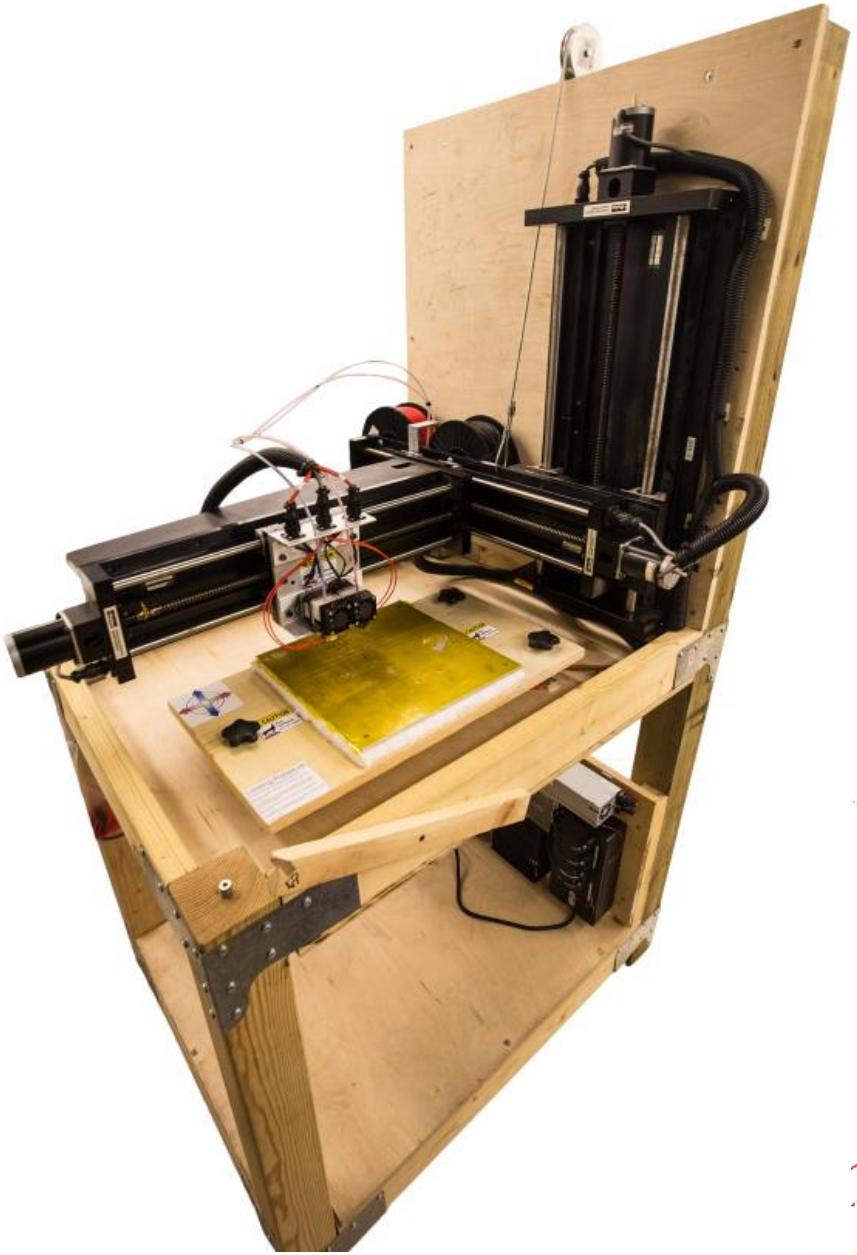
Heated Bed

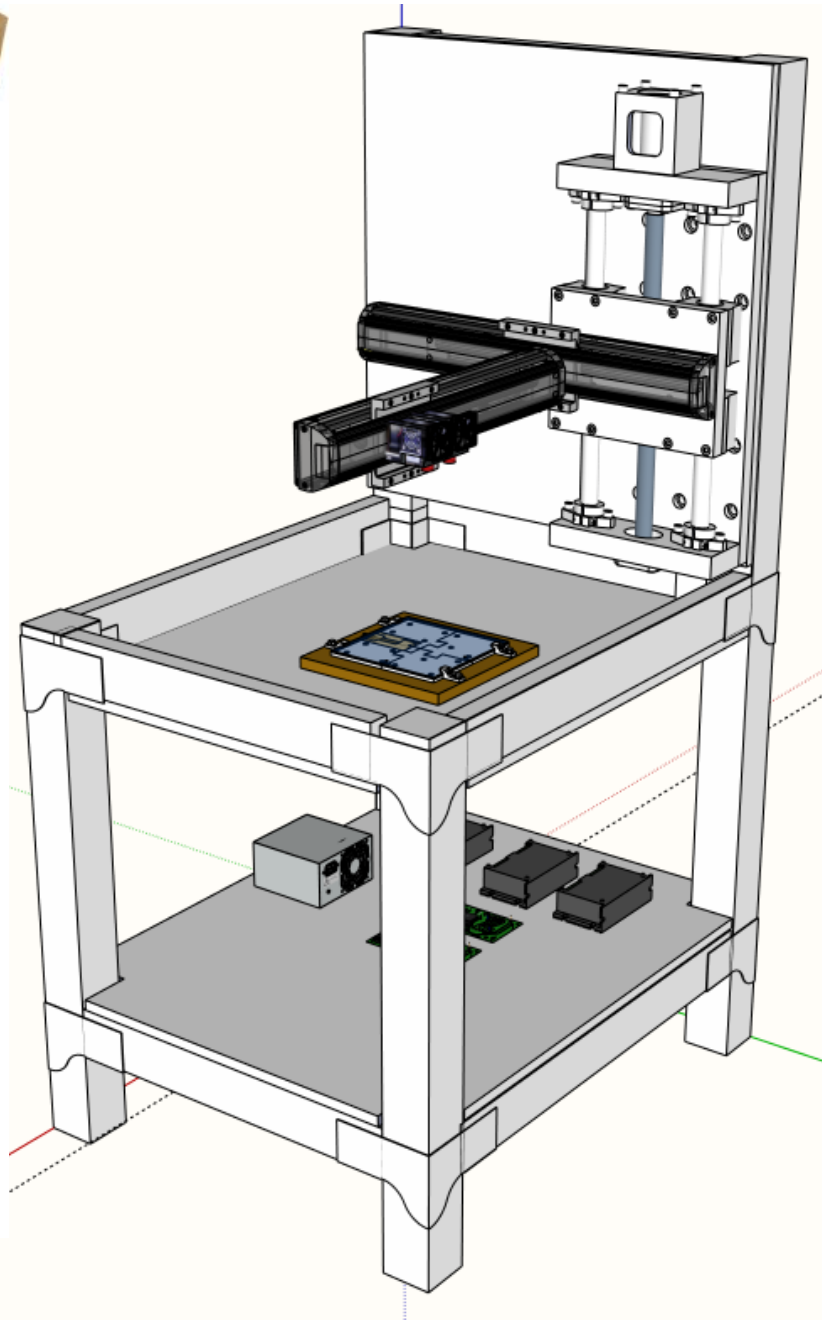


Power Supply & Wiring

Bench Design

- Designed in Google SketchUp
- Needed stable mounting of 3 axis system
- Mounted on its side for a usable orientation for 3D printing
- Must have room for all control electronics and heated bed
- Used wood with metal brackets for good cost/strength ratio

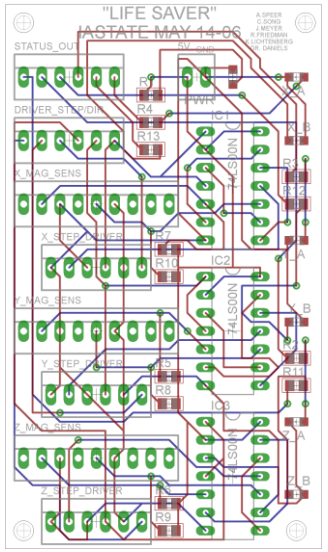


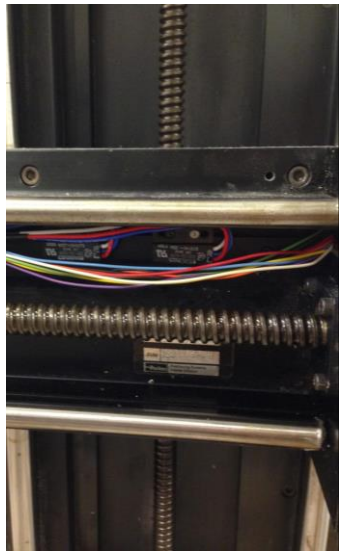


RF

Safety Systems

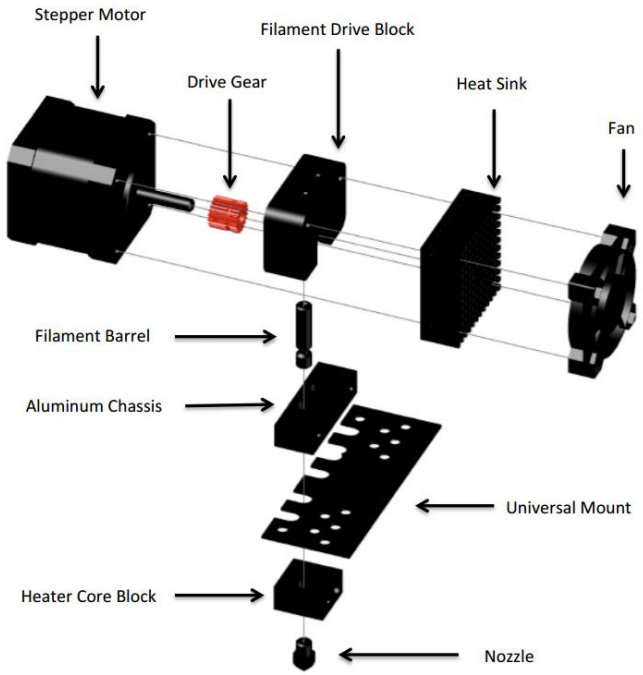
- Safety circuit
  - Designed in house using Eagle
  - Tripped by magnetic limits
  - Uses NAND gates primarily
- Counterweight
  - 50 lbs
  - Ensures x and y axis do not fall
  - Effective at this point
- Power loss
  - UPS has capability of powering equipment for a short duration
  - Future software implementation

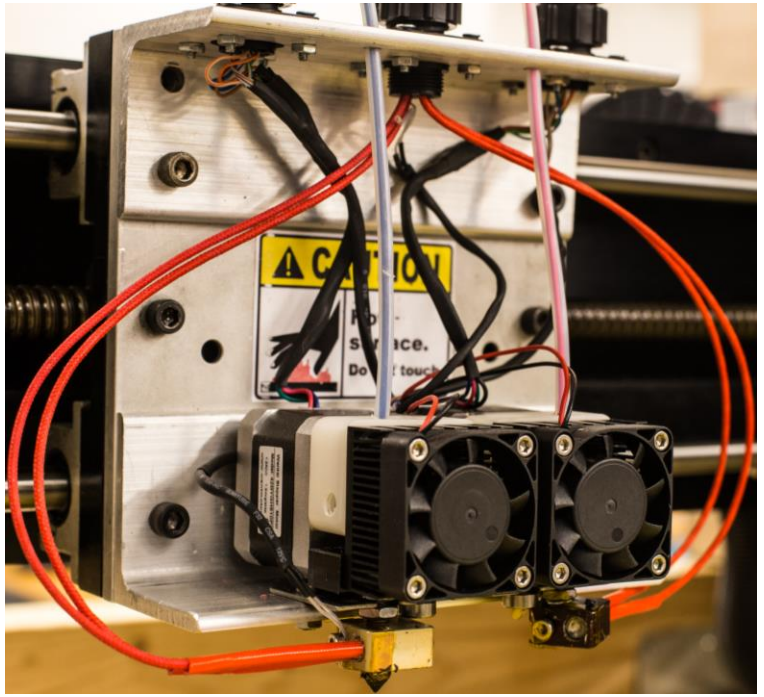


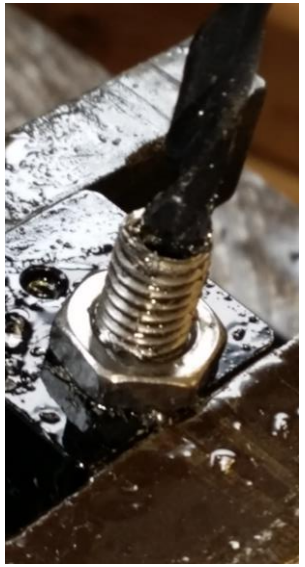


Extruder

- Melts plastic material and forces extrusion through heated nozzle
- Applies molten plastic to printing surface
- QU-BD MBE Extruder v9
- Assembled in house
- Had to be modified (filament barrel jamming and filament drive gear issues)
- Dual extruders allow for more printing capabilities

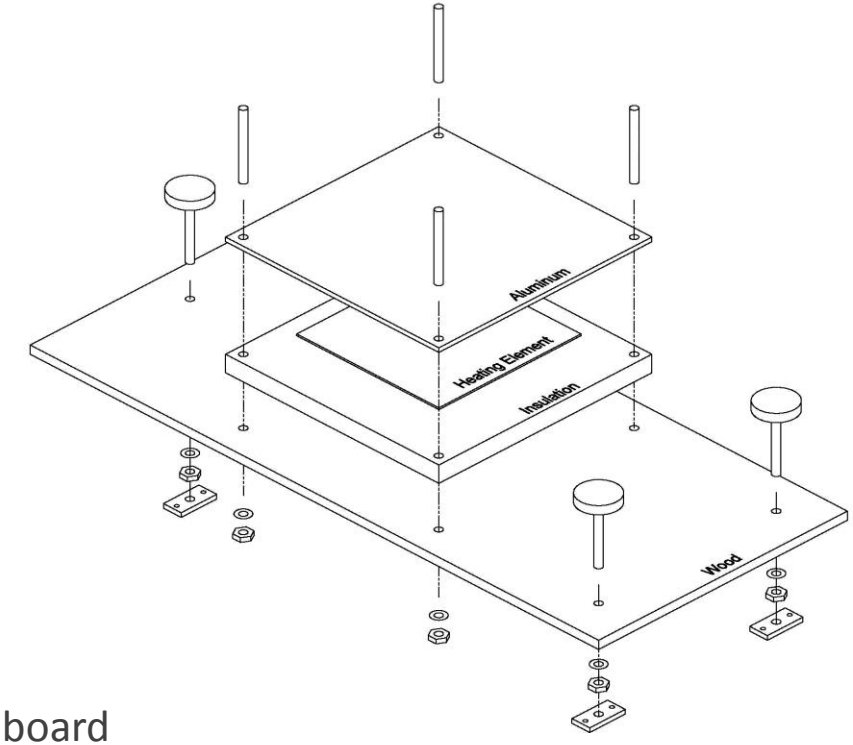


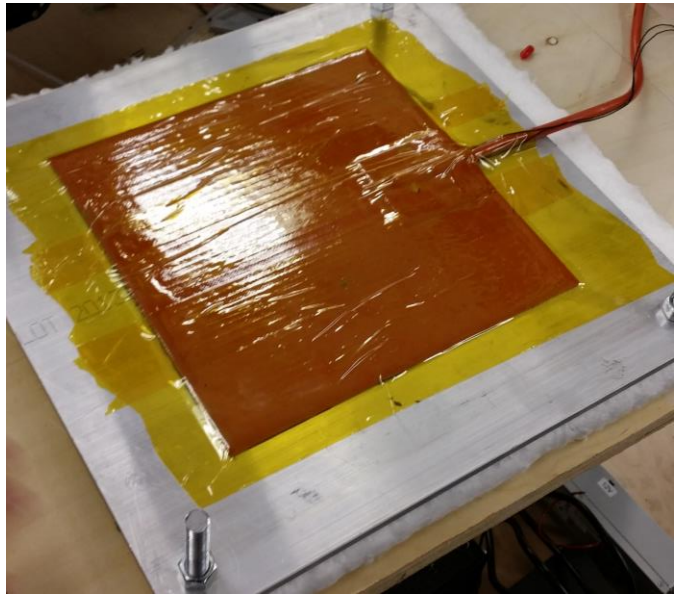


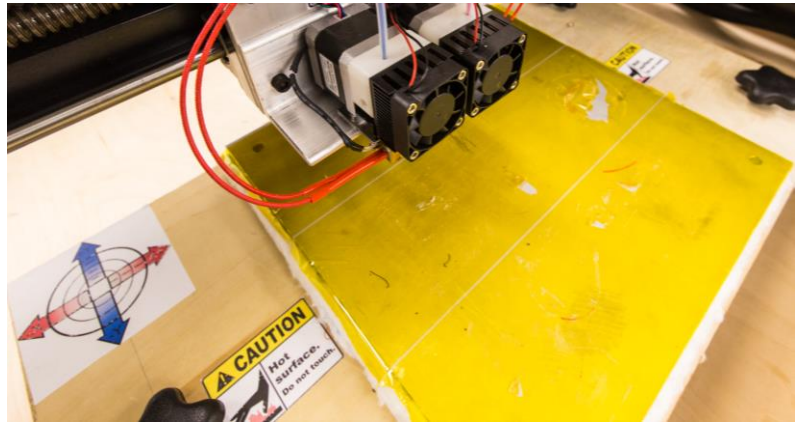


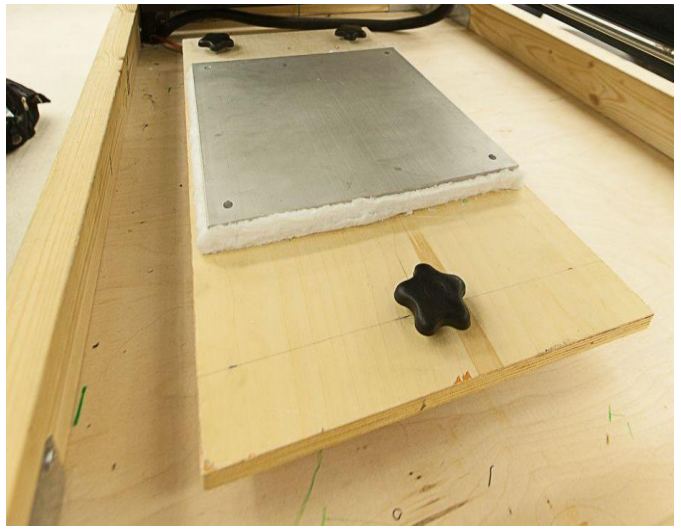
Heated Print Bed

- Prevents warping of printed plastic
- Target surface temperature ~70 C
- Silicon heater temperature ~100 C
- Our design
  - Silicone heating element
  - Aluminum surface with Kapton tape
  - Insulation between aluminum and leveling board
  - Adjustable leveling screws
- Even heat distribution
- Allows for more printing capabilities
- Not used for all 3D printers









Power Distribution & Cable Management

Power Distribution

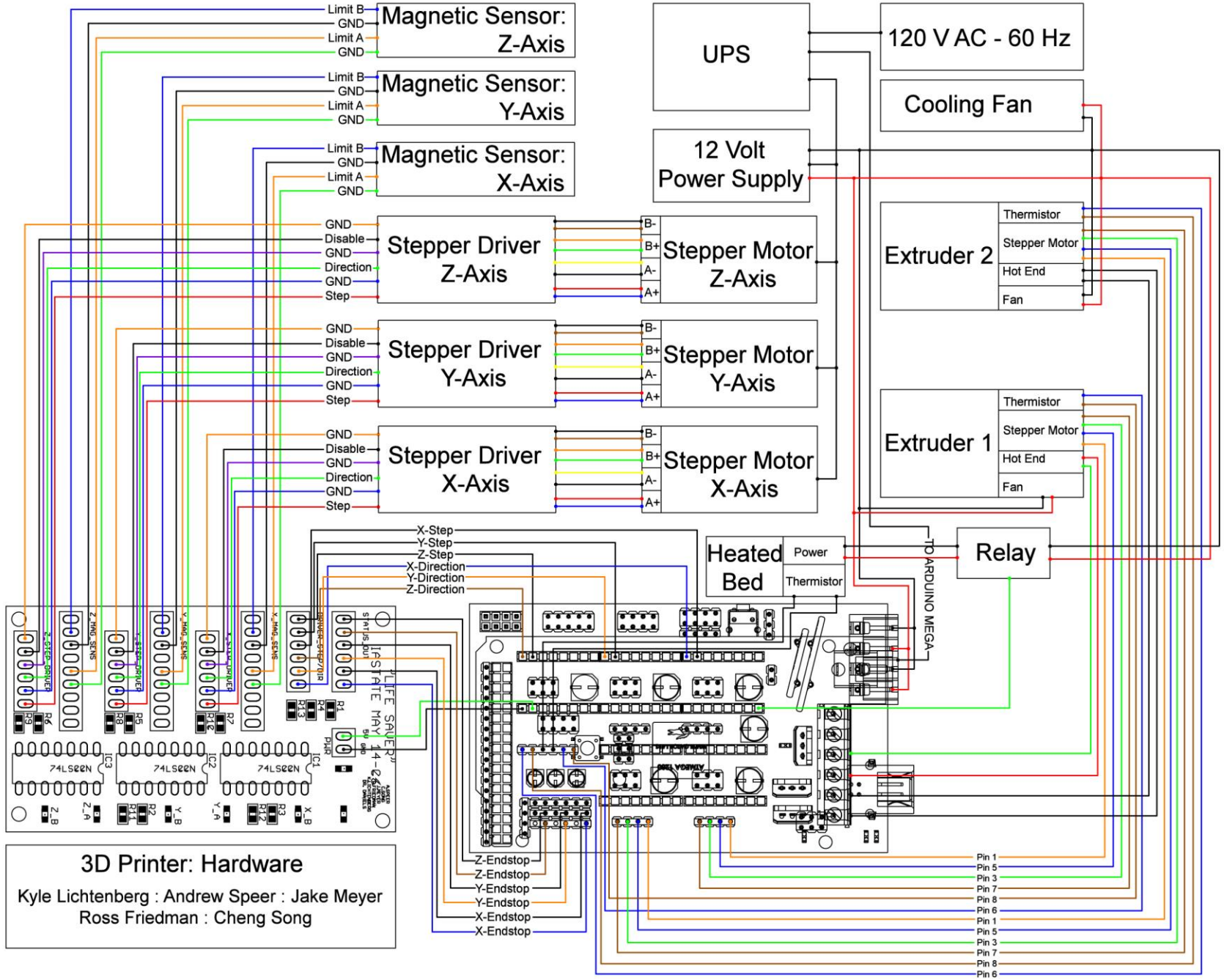
- High draw (20-30 A)
- 12 V power supply (47 A)
  - Modified server supply
  - Soldered jumpers
- UPS (Uninterruptable Power Supply)
  - Backup battery
  - Safety implementation (software)

Cable Management

- Intuitive layout
- Heating elements wired with higher gage wire
- All cables lying above the upper platform housed in sheathing
  - Nylon
  - Plastic
- Electrical hardware housed under protective plexiglass cover
- Duel 12V fans for relay cooling

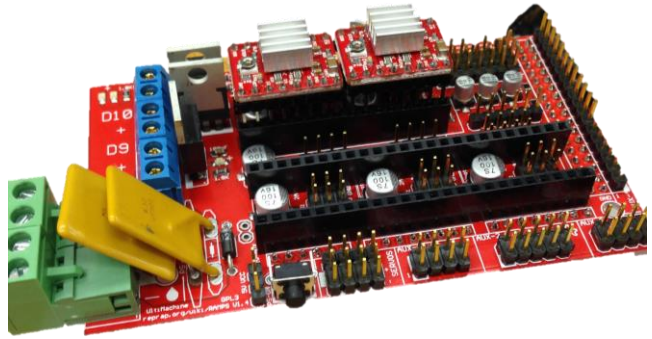
Wiring Diagram

- System understanding
  - Labeled devices and wires
  - Includes all hardware aspects
- Working with multiple teams
  - Hardware
  - Software
- Device reference
  - Modifications and/or upkeep
  - Future repurposing



RAMPS Controller & Firmware

- A RAMPS 1.4 Arduino shield provides stepper drivers for the extruders and relays for heating
- This was attractive due to cost restraints
- Open source firmware runs on the Arduino and interprets GCODE
- We are using customized configuration of the Repetier firmware
- Difficulty interfacing with our stepper drivers



Timeline

September 2013
- Bench design
- Printing research

October 2013
- Bench construction
- Printing research

November 2013
- Rough draft of entire system devised

January 2014
- Majority of parts ordered
- Safety system designed

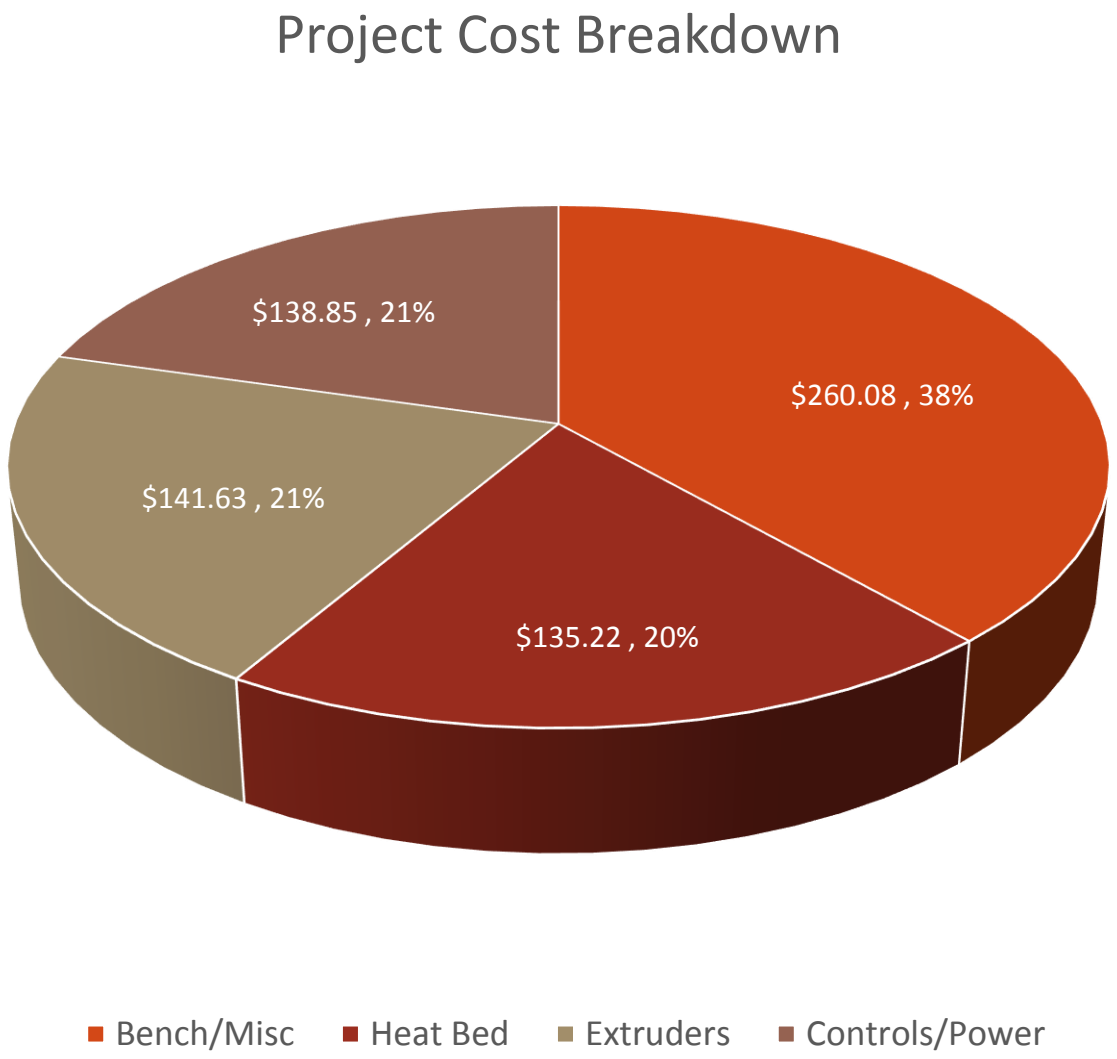
February 2014
- Safety system constructed
- Extruders constructed and modified
- Power distribution system constructed
- Testing

March 2014
- Cable management implemented
- Heated bed system designed
- Heated bed system constructed
- Testing

April 2014
- 3D printing system completed
- Vigorous testing of all components

Cost & Other Documentation

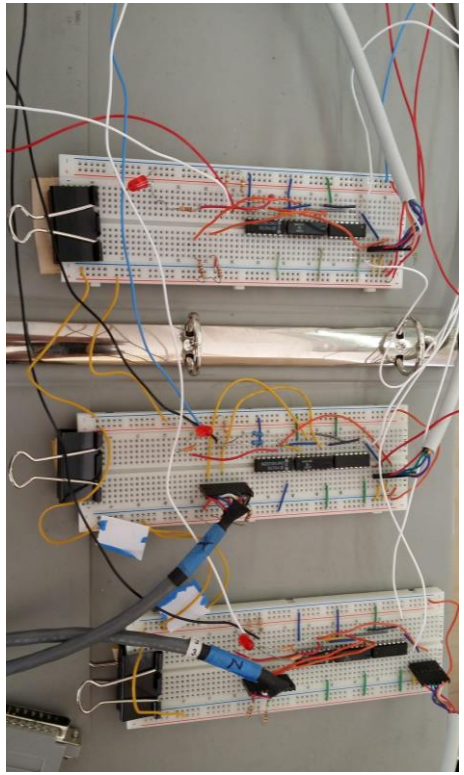
- **Cost**
  - Contained two teams
  - All purchases recorded
  - Broken into four main divisions
- **Other documentation**
  - Available for download on website
    - Design document
    - Project plan
    - Final document
    - Software downloads
    - Photos / Videos
    - Contact information



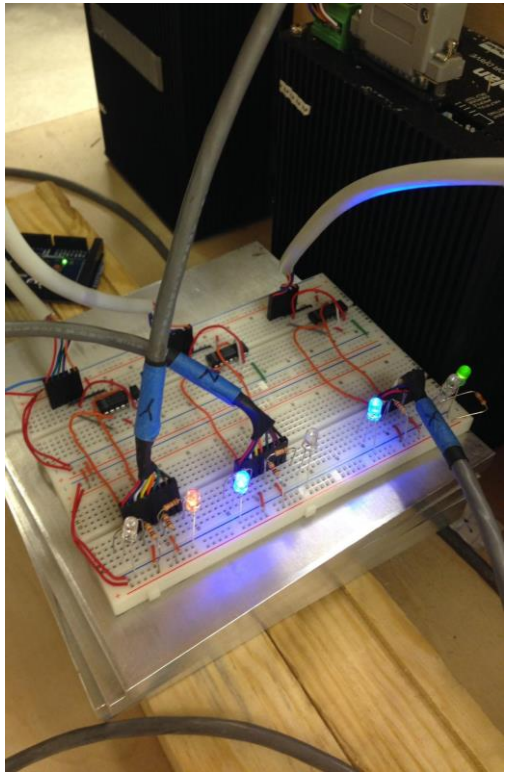
KL

Technical Challenges - Safety circuit PCB

- Design compact circuit to prevent driving axis past physical limits
- Circuit logic should allow stepper to be driven away from limit when at edge
- Illuminate LED to indicate when limit is reached
- Provide output to endstop connections on Arduino
- PCB designed using Eagle Software and later fabricated



Original safety circuit



New design prototype

Final circuit on PCB

Technical Challenges – Flex Couplers

- Instant change in direction
- Extreme vibrations with different fill characteristics
- Original couplers not designed for acceleration required for 3D printing
- Set screw couplers showed slippage with most prints

Original coupler

Set screw coupler

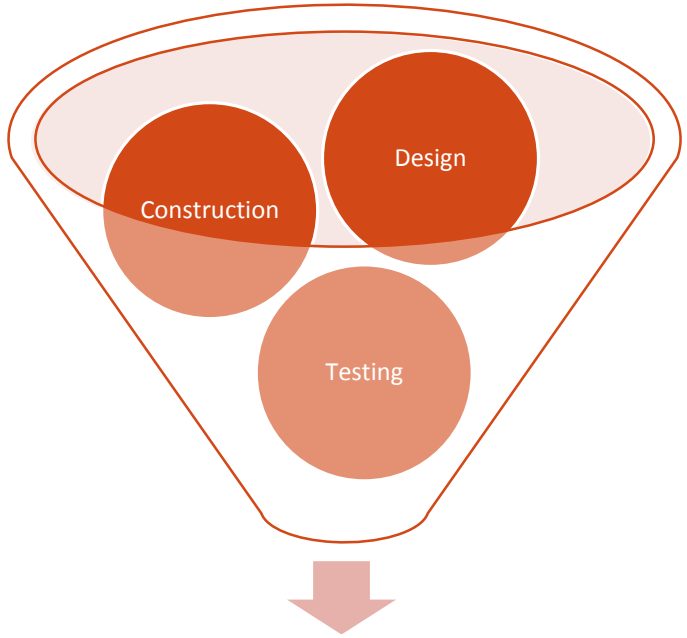
Current coupler

Print with slippage

Print without slippage

Testing Procedure

- Power systems
  - Proper distribution
  - Bench testing
- Movement systems
  - Stability
  - Acceleration settings
  - Drifting
- Alignment test
  - Predetermined pattern
  - Test prints
- Extrusion
  - Heat
  - Stepper motor feed rate
- Temperature sensors
  - Proper value
  - Accuracy



Results