Green Ellipsis

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Green Ellipsis Background

- Start-Up based out of St. Augustine, FL
- “Green Ellipsis Dreams of and Designs for a Sustainable Humanity”
- Engineering/3D Printing Services
- Apart of an open-source pultrusion community that focuses on upcycling 2-liter PET bottles into usable 3D printer filament

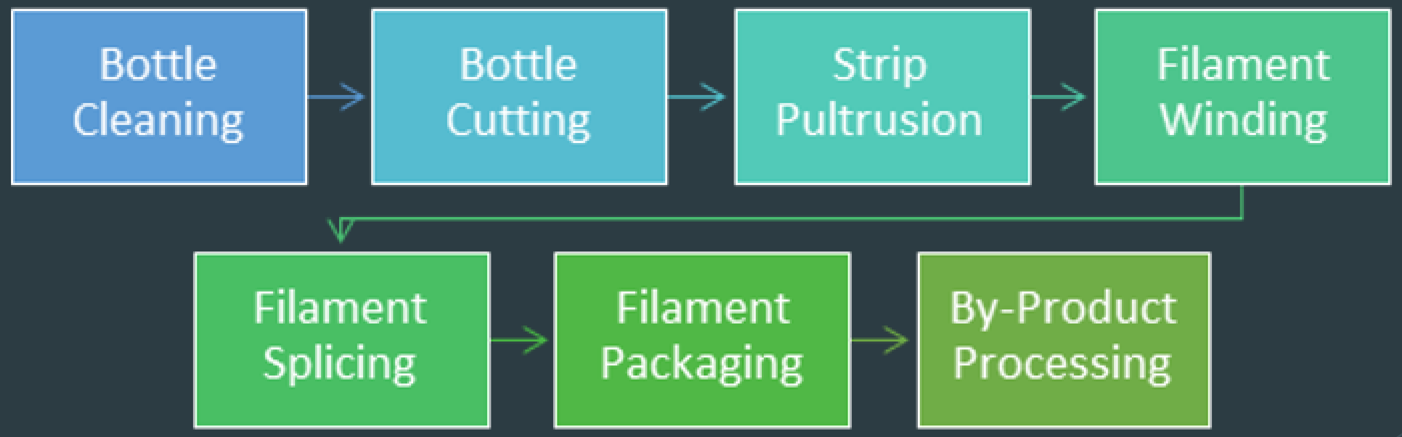
Key Terms

- Polyethylene Terephthalate (PET) – Commonly used plastic
- Upcycling – the process of repurposing single-use items into higher quality items
- Pultrusion – a process of manufacturing via pulling

Problem Statement

- Single-use PET bottles cause an abundance of pollution across the world
- Green Ellipsis aims to reduce the pollution by upcycling these bottles into 3D printer filament
- This process is called the Reclamation Process
- Our job is to automate one or more of the steps in this process for ease of use and to save time

Reclamation Process



Original Bottom Cutter

Process Step Selection

- Chose bottle cutting step
- This step cuts a strip of a set width along the bottle
- As well as cutting the angled cut required to integrate with the current system

Requirements

- Reduce user touches by 50% for the bottle cutting process
- Must accept clean 2-liter PET bottles
- Must cut an 8mm (±0.5mm) wide strip along the bottle
- Must cut the start angle at 1.4° (±1°)
- Must integrate with current pultruder machine

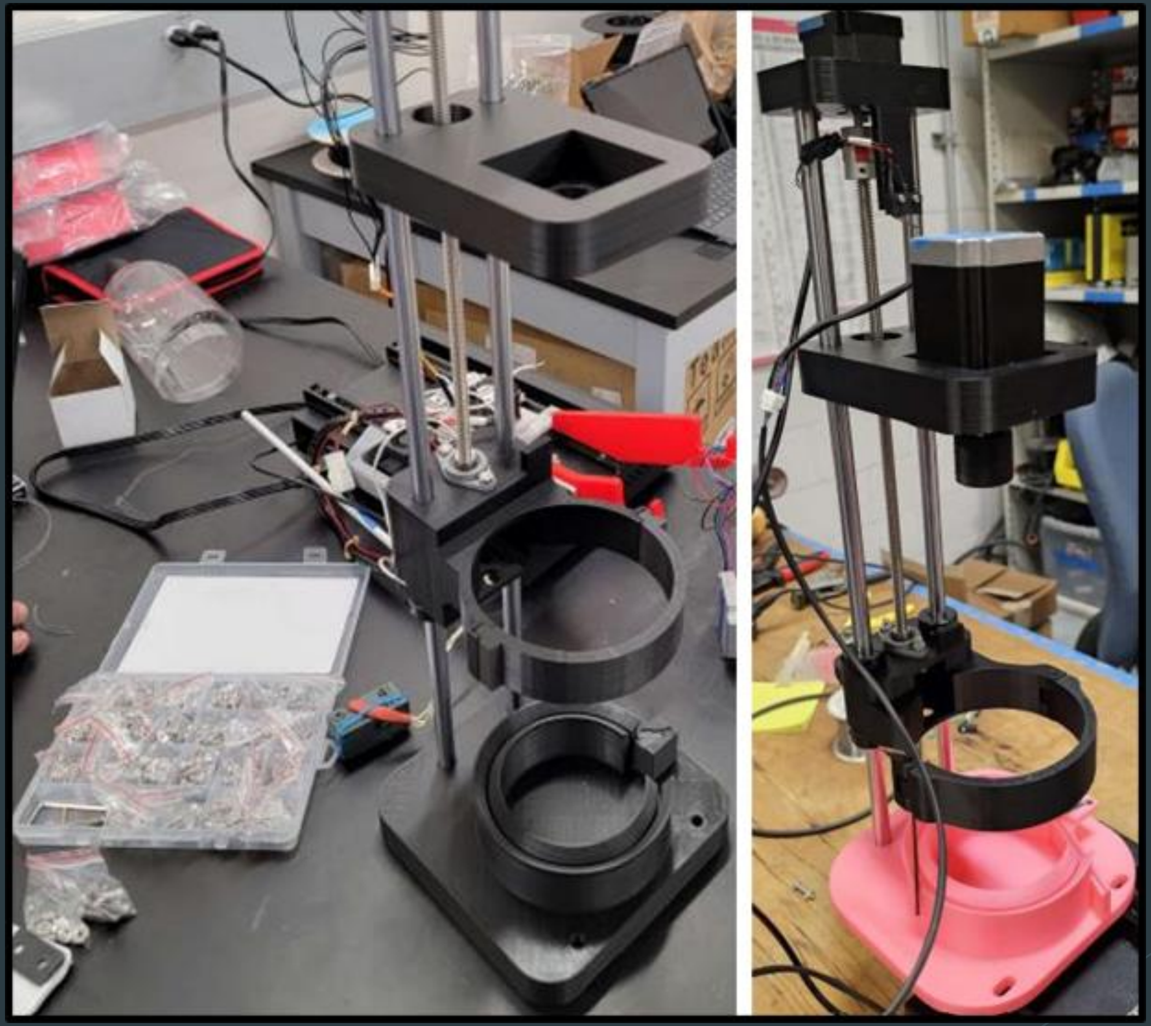
Constraints

- Needs to all fit in a 75cm x 240cm x 80cm volume area
- Must run off US standard 120 VAC 60 Hz power
- Cutting blades must be guarded in areas where the user interacts
- Utilize 2-liter round PET bottles (Pepsi Co.)
- $1,000 budget

Manufacturing & Assembly

Base and Collar Assembly Prints

Manufacturing & Assembly



Initial Printed Assembly

Mechanical Design & Changes

- Bottom Base
- Bottle Alignment
- Bottle Attachment Cap
- Device Stabilizer

Bottom Base

Design

- Slots for mounting to Recreator
- Feeds strip to pultruder

Changes

- Reduced bottom thickness – uses less material
- Additional support for blade
- Added strip channel for better feeding

Bottom Base
Initial v Final

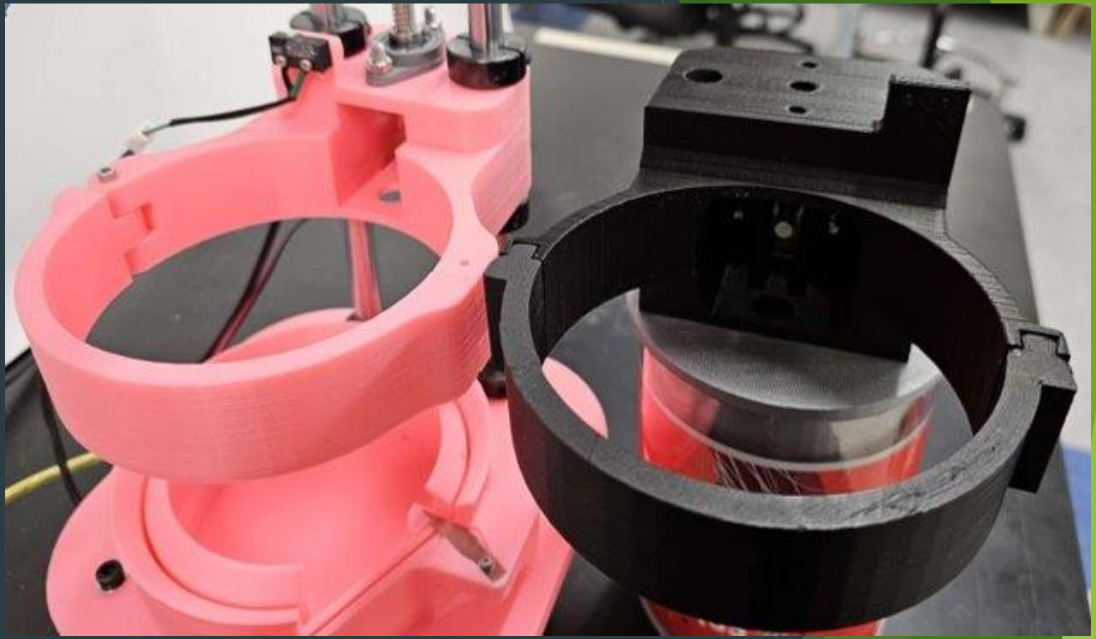
Bottle Alignment

Design

- Keeps bottle aligned during cutting process
- Stays stationary
- Fitted with removable collar for easy bottle replacement

Changes

- Changed dovetail design to a hinge
- Increased rigidity and mitigates wear



Bottle Alignment Collar

Dovetail

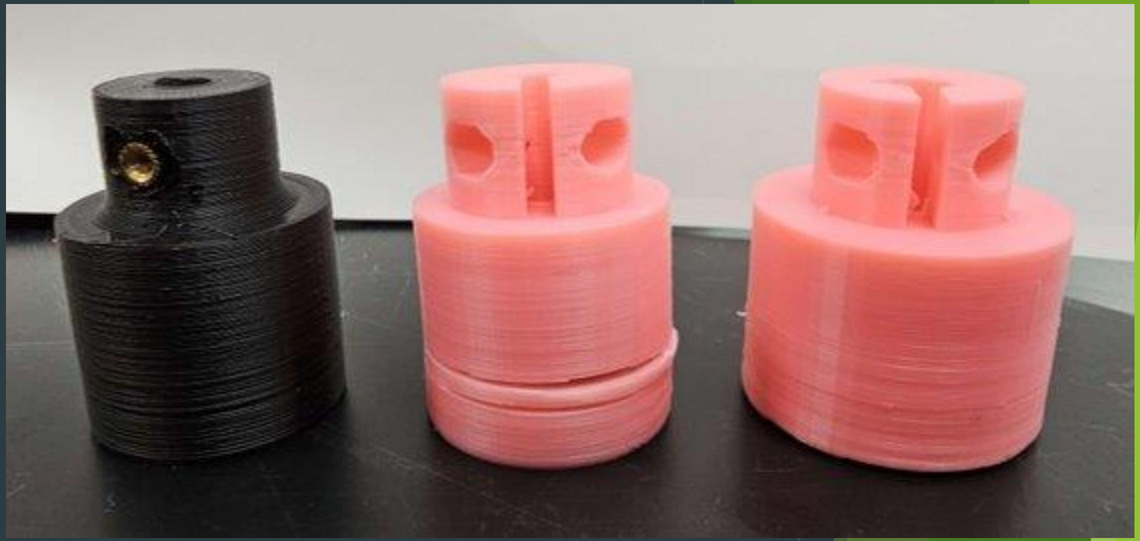
Bottle Attachment Cap

Design

- Interfaces bottle with bottle spinning Nema 17 motor
- Issues with melted inserts not setting
    - Tested different infills and wall layers
- Structural issues with direction of print
    - Tested different infills and wall layers

Changes

- Changed to clamping design to fit keyed shaft of Nema 17
- Increased thickness for extra rigidity
- Deepened socket to reduce the bottle from pulling the layers apart



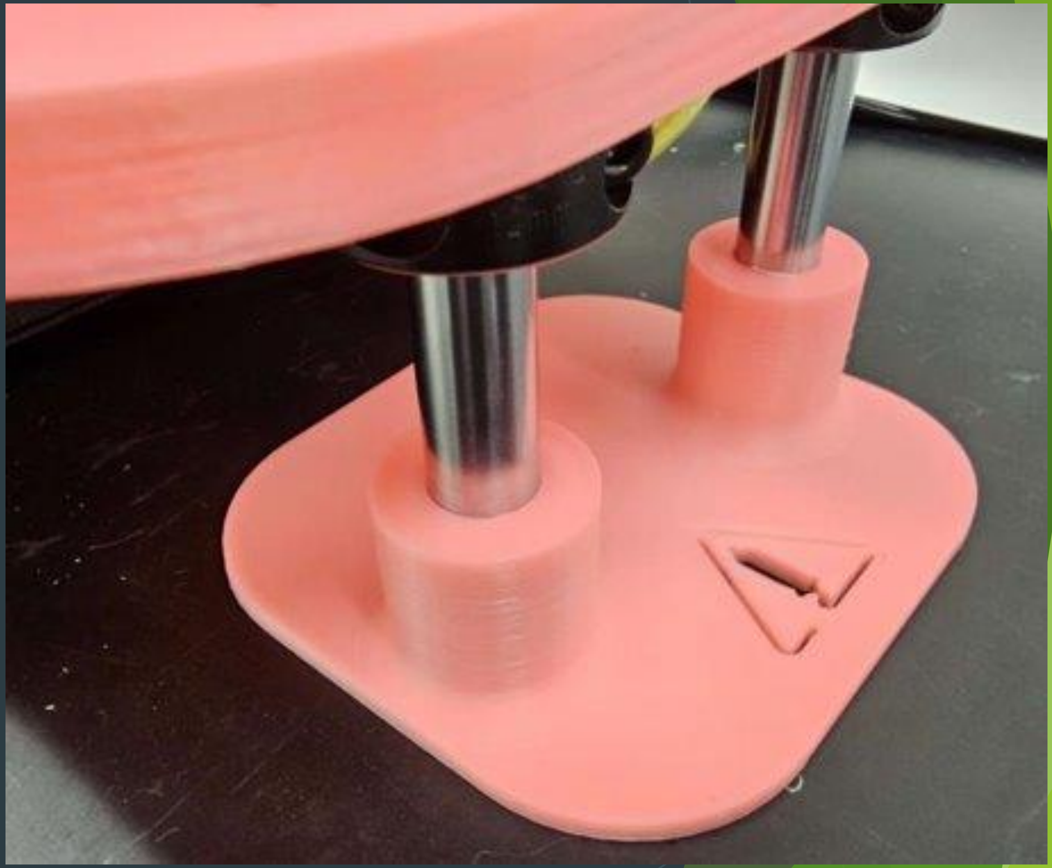
Bottle Attachment Cap Iterations 1

Bottle Attachment Cap Iterations 2

Stabilizer Block

Design Change

- Stabilized the device during operation
- Device was prone to lean causing issues during cutting and linear movement



Stabilizer Block

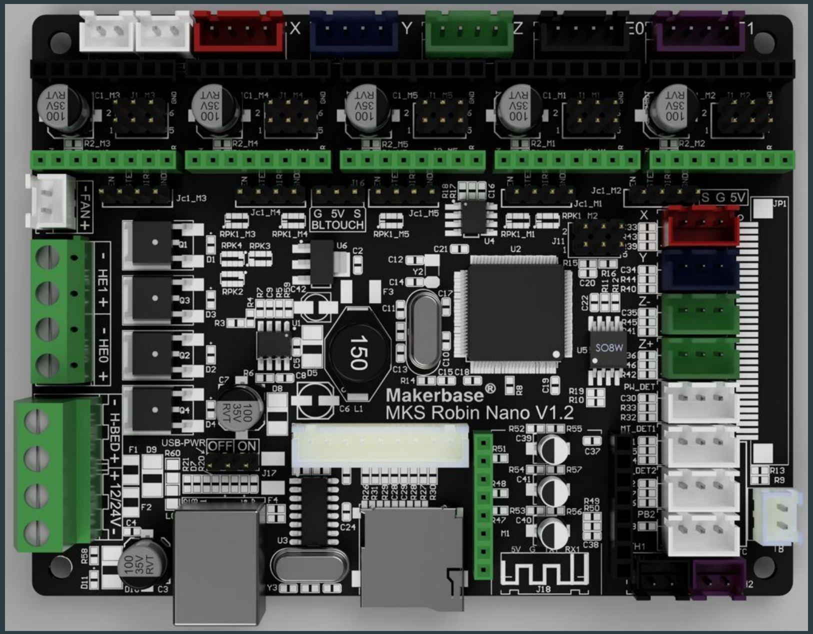
Electrical Design & Changes

- Motherboard & Outputs
- Key Components
- Firmware
- Software Design

Motherboard

Design

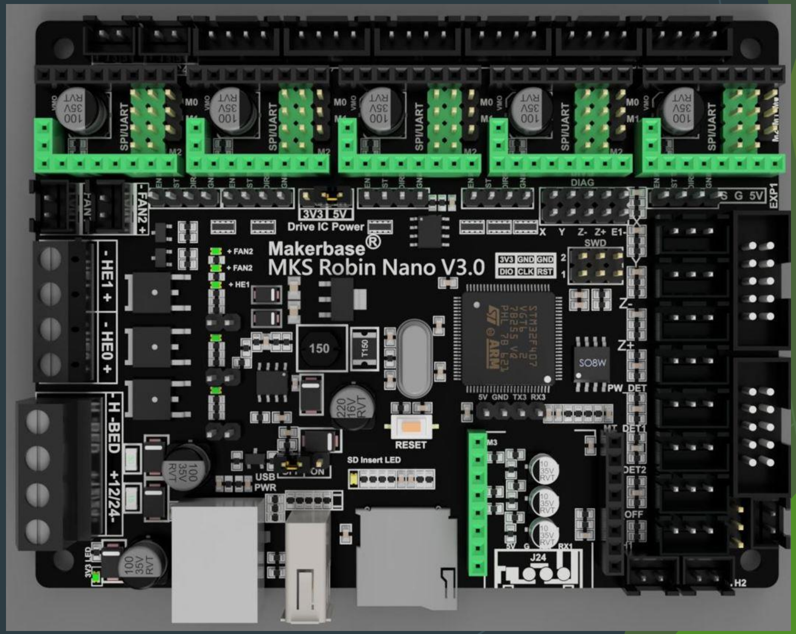
- Robin Nano v1.2
- A4988 Stepper Drivers



Robin Nano v1.2

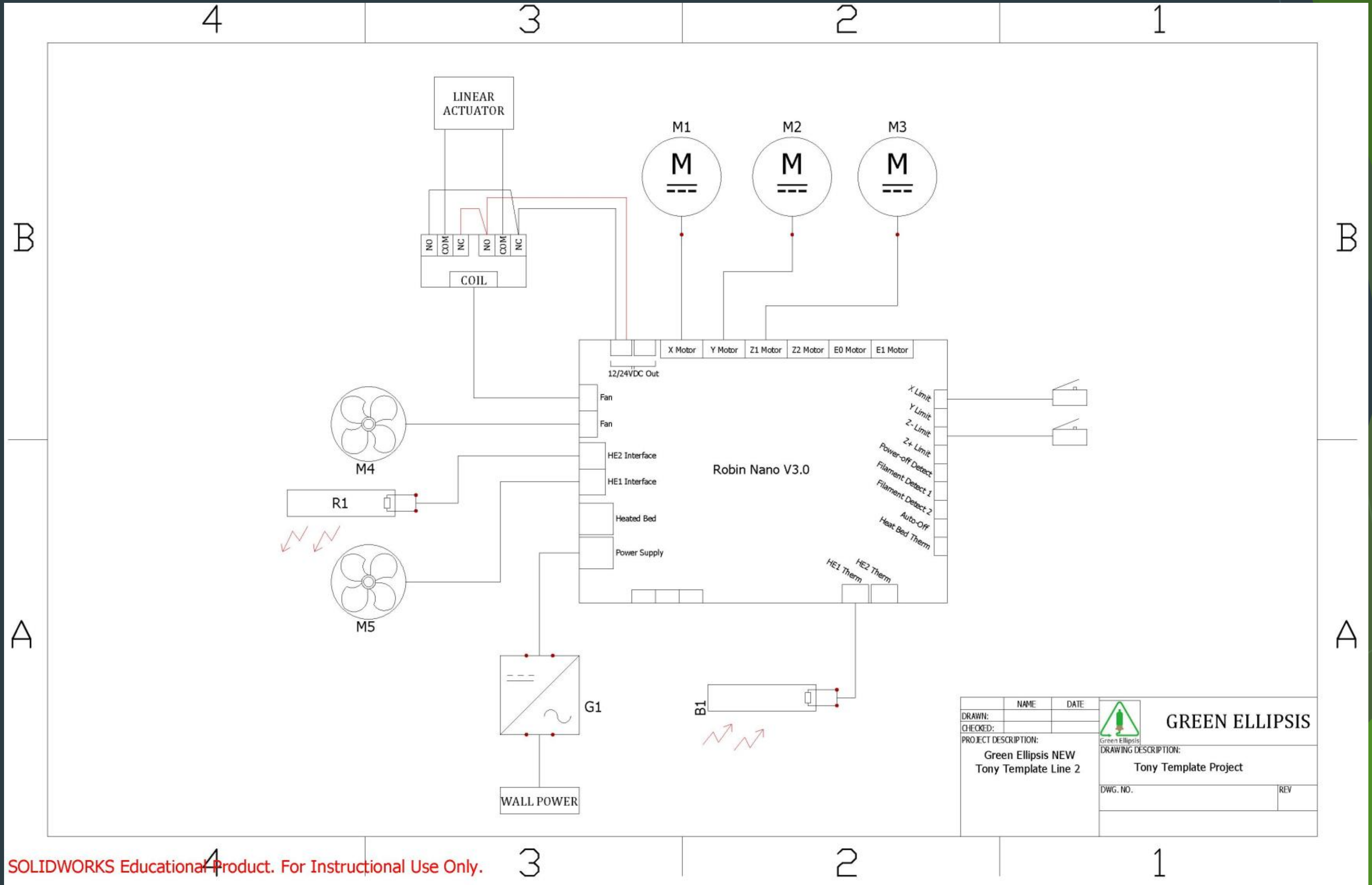
Changes

- Robin Nano v3.0
- TMC2209 Stepper Drivers



Robin Nano v3.0

Motherboard Outputs



System Line Diagram

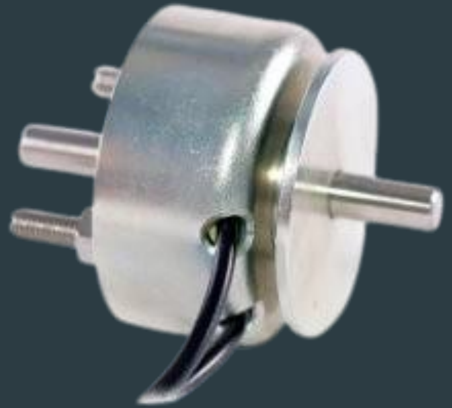
Key Components & Changes: Linear Blade Actuation

Original Design

- Meant to push the blade through the bottle and retract
- Solenoid
- Didn't retract
- Too fast (unsafe)

Change

- Spec'd a linear actuator that actuates forward and backward based on polarity
- Moves slower (safer)



Solenoid

Linear Actuator

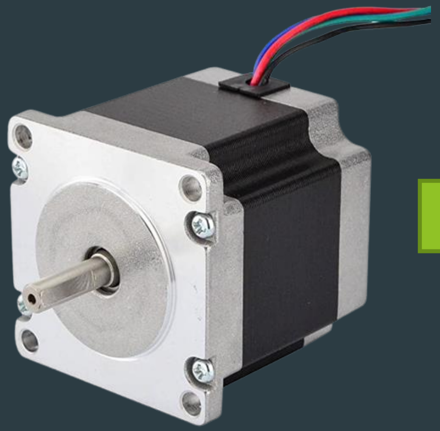
Key Components & Changes: Bottle Rotation Motor

Original Design

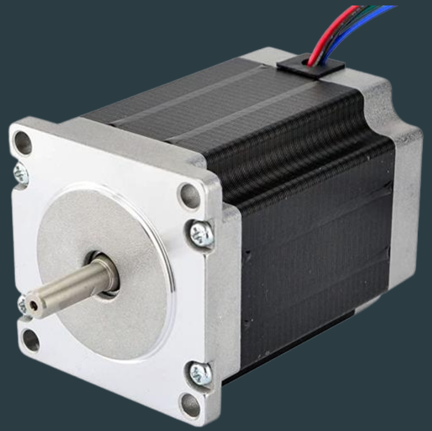
- Rotates the bottle to cut the bottom and strip
- Nema 23 for bottle rotation axis
- 1.26 Nm of holding torque (needed 0.89 Nm) at 2.8 A

Change

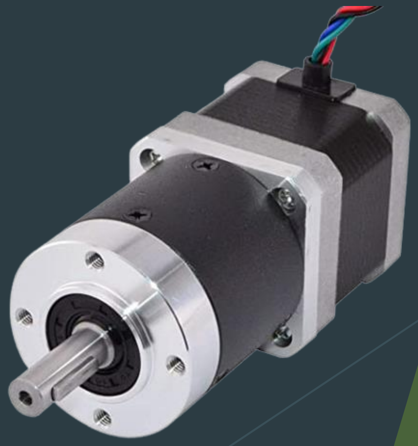
- Nema 17 w/ 20:1 gear box for bottle rotation axis
- 10 Nm of holding torque at 1.64 A



Nema 23 #1



Nema 23 #2

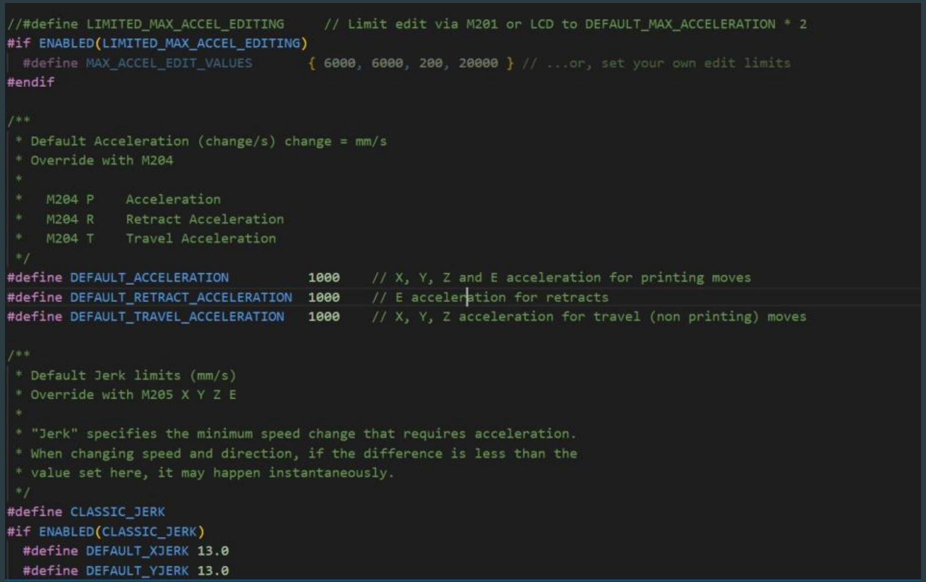


Nema 17

Firmware

- Updated and "Configured" Marlin firmware
- Added custom buttons for proper limit switch functionality
- Configured the following parameters:
  - Axis
  - Speed
  - Motors
  - Pinouts

Firmware Version



```
//#define LIMITED_MAX_ACCEL_EDITING     // Limit edit via M201 or LCD to DEFAULT_MAX_ACCELERATION * 2
#if ENABLED(LIMITED_MAX_ACCEL_EDITING)
  #define MAX_ACCEL_EDIT_VALUES       { 6000, 6000, 200, 20000 } // ...or, set your own edit limits
#endif

/**
 * Default Acceleration (change/s) change = mm/s
 * Override with M204
 *
 *   M204 P    Acceleration
 *   M204 R    Retract Acceleration
 *   M204 T    Travel Acceleration
 */
#define DEFAULT_ACCELERATION          1000    // X, Y, Z and E acceleration for printing moves
#define DEFAULT_RETRACT_ACCELERATION  1000    // E acceleration for retracts
#define DEFAULT_TRAVEL_ACCELERATION   1000    // X, Y, Z acceleration for travel (non printing) moves

/**
 * Default Jerk limits (mm/s)
 * Override with M205 X Y Z E
 *
 * "Jerk" specifies the minimum speed change that requires acceleration.
 * When changing speed and direction, if the difference is less than the
 * value set here, it may happen instantaneously.
 */
#define CLASSIC_JERK
#if ENABLED(CLASSIC_JERK)
  #define DEFAULT_XJERK 13.0
  #define DEFAULT_YJERK 13.0
```

Firmware

Software Design

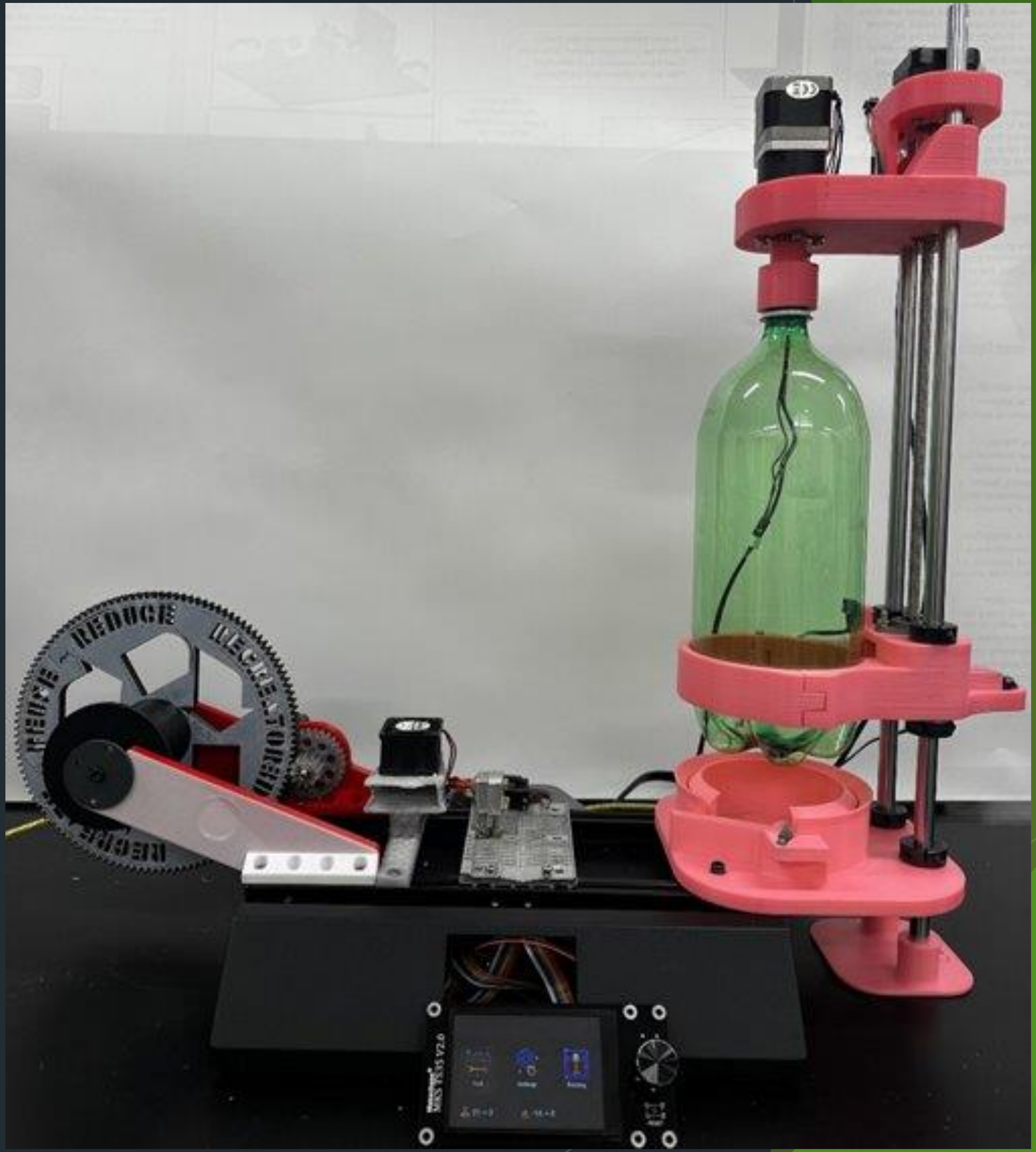
1. Start
2. Actuate Linear Actuator (punctures bottle)
3. Spin Bottle (cuts bottom off)
4. Stop Spin
5. Retract Linear Actuator
6. Wait 10 Seconds for Bottom Removal
7. Lower Bottle to Strip Blade
8. Simultaneously Lower and Spin Bottle for a set Length (cuts strip and strip angle)
9. Spin Bottle to Detach Strip
10. Home at Top of Device
11. Done!

```
G91 ; RELATIVE MODE


M106 P0 S255 ; Activates Fan (Actuator)

G4 S1.5 ; Delay for 1.5 Seconds

G1 F1000 Y-15 ; One Rotation of Bottle
M400 ; Wait till commands complete

G4 S1.5 ; Delay for 1.5 Seconds

M106 P0 S0 ; Deactivates Fan (Actuator)

M300 S300 P1000 V1 ; Alert User Through Beep
G4 S10


G1 F3000 Z750 ; Move Down 75mm
M400 ; Wait till commands complete


G1 F1250 Z768 Y-96 ; Cuts Strip G1 Z1600 Y-200
M400 ; Wait till commands complete
G1 F1000 Y-15 ; Rotates Bottle
G1 F3000 Z-2000 ; Move back to top
M400 ; Wait till commands complete
M300 S300 P1000 V0.5 ; Alert User Through Beep
```

GCODE

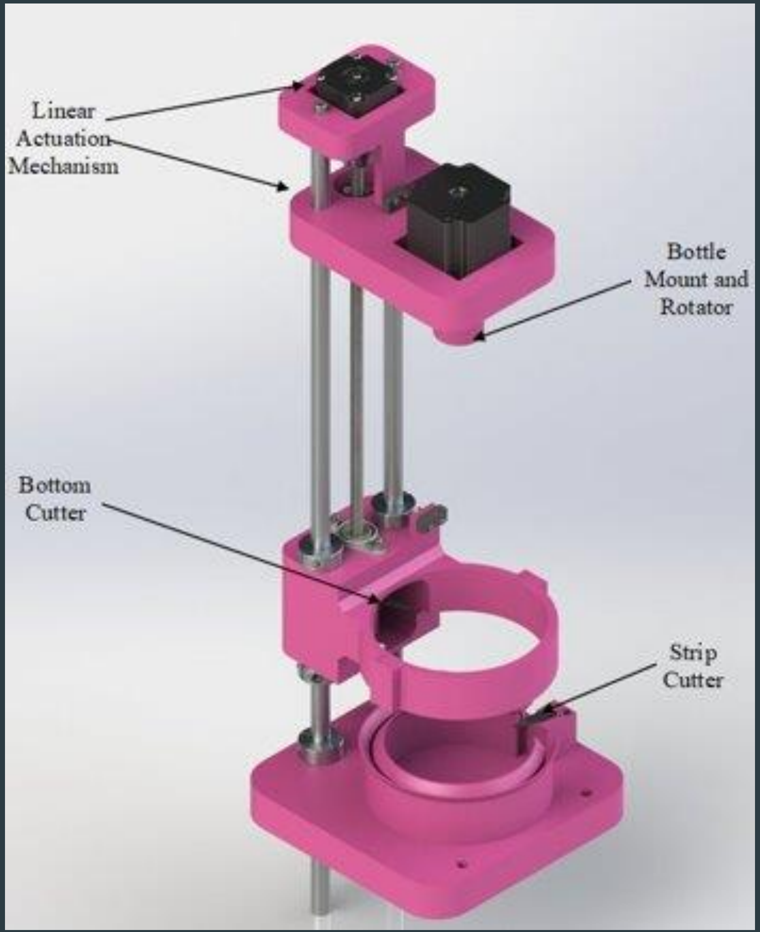
Implementation

- Electrical systems are run from the pultruder
- Bottle cutter mounts to the pultruder
- Future integration
  - Simultaneously cut strip while producing PET filament

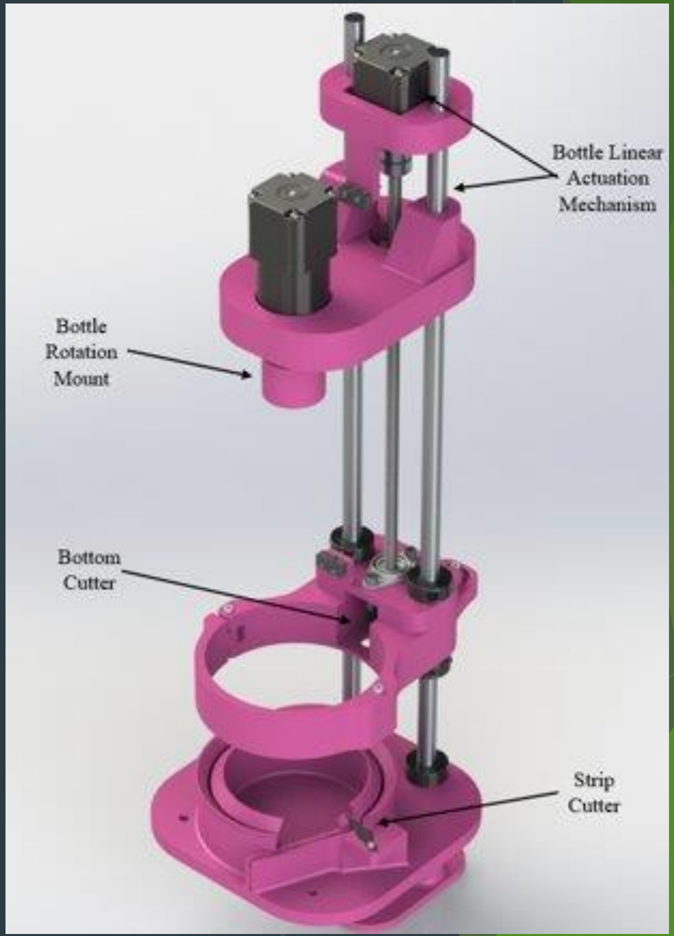


Complete Device

Initial v. Final Design CAD



Initial Design



Final Design

Final Design & Device Operation

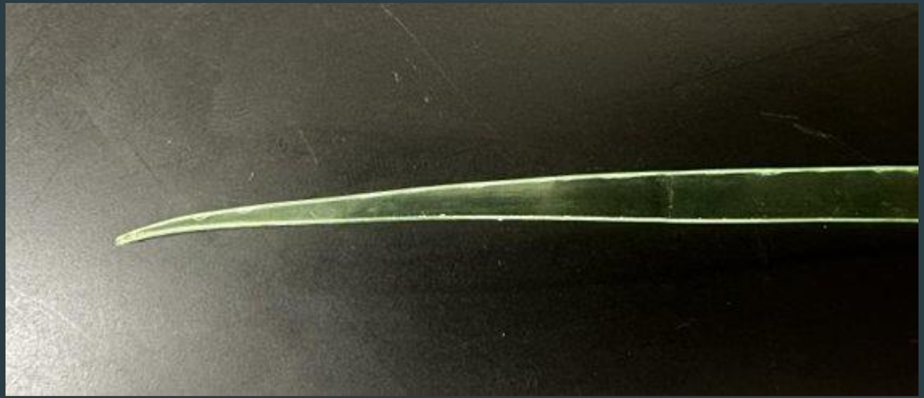
1. Device Power On
2. Home Device
3. Platform Raises to Default Position
4. Attach Bottle to Cap
5. Start “Print”
6. Linear Actuator Actuates
7. Bottle Rotates, Cutting Off Bottom
8. 10 Second Delay
9. User Removes Bottom
10. Platform Lowers to Strip Cutting Blade
11. Bottle Rotates Simultaneous to Bottle Lowering, Starting and Cutting Strip
12. Strip is Cut Clean
13. Platform is Homed

Final Device

Performance Testing

- Measured 23 strips in total
- Measured 30 points along each strip with calipers
- Measured strip angle using MATLAB Image Processing Toolbox
  - Measured pixels to determine angle

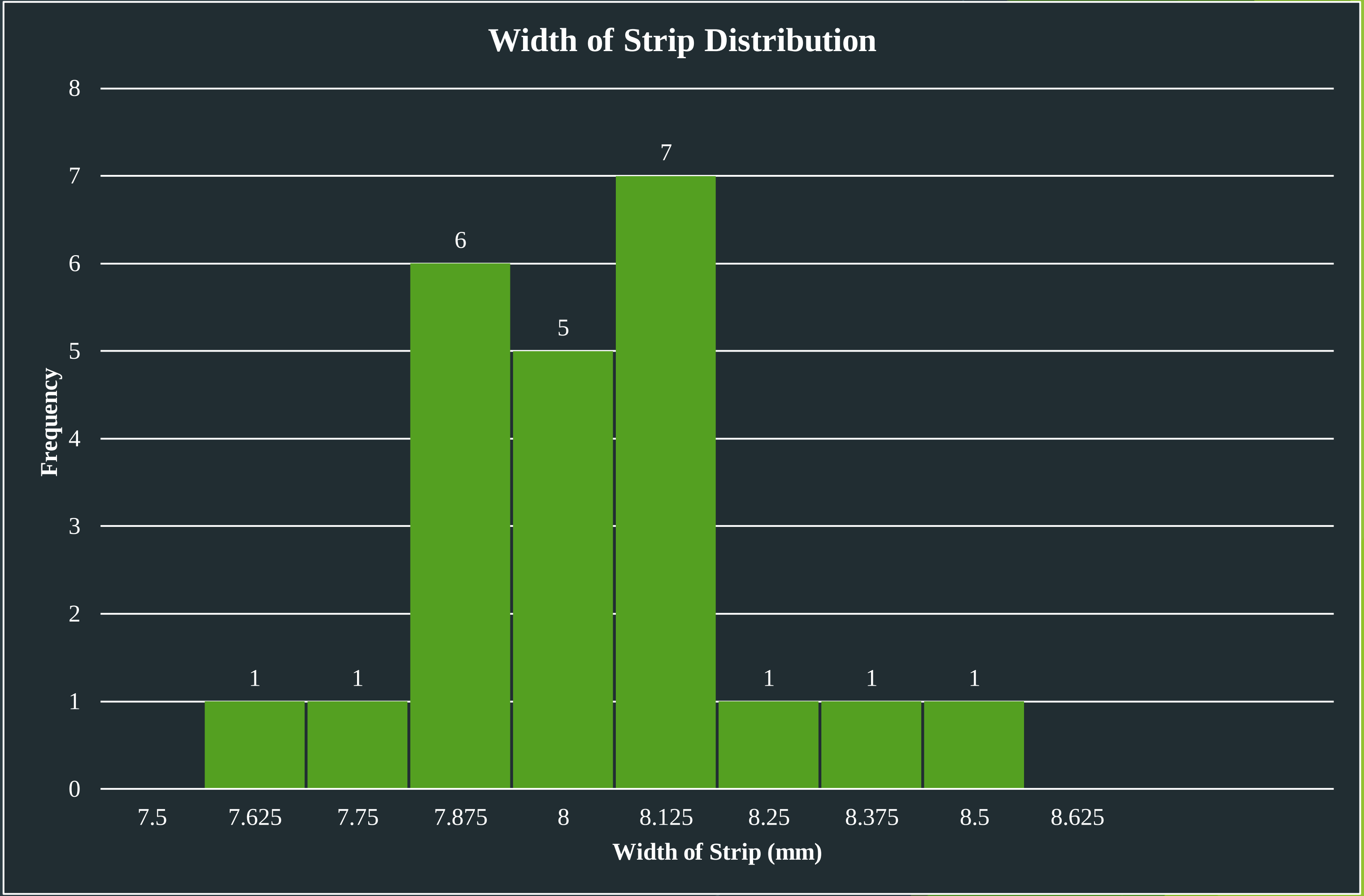
Strip Width



Angled Cut

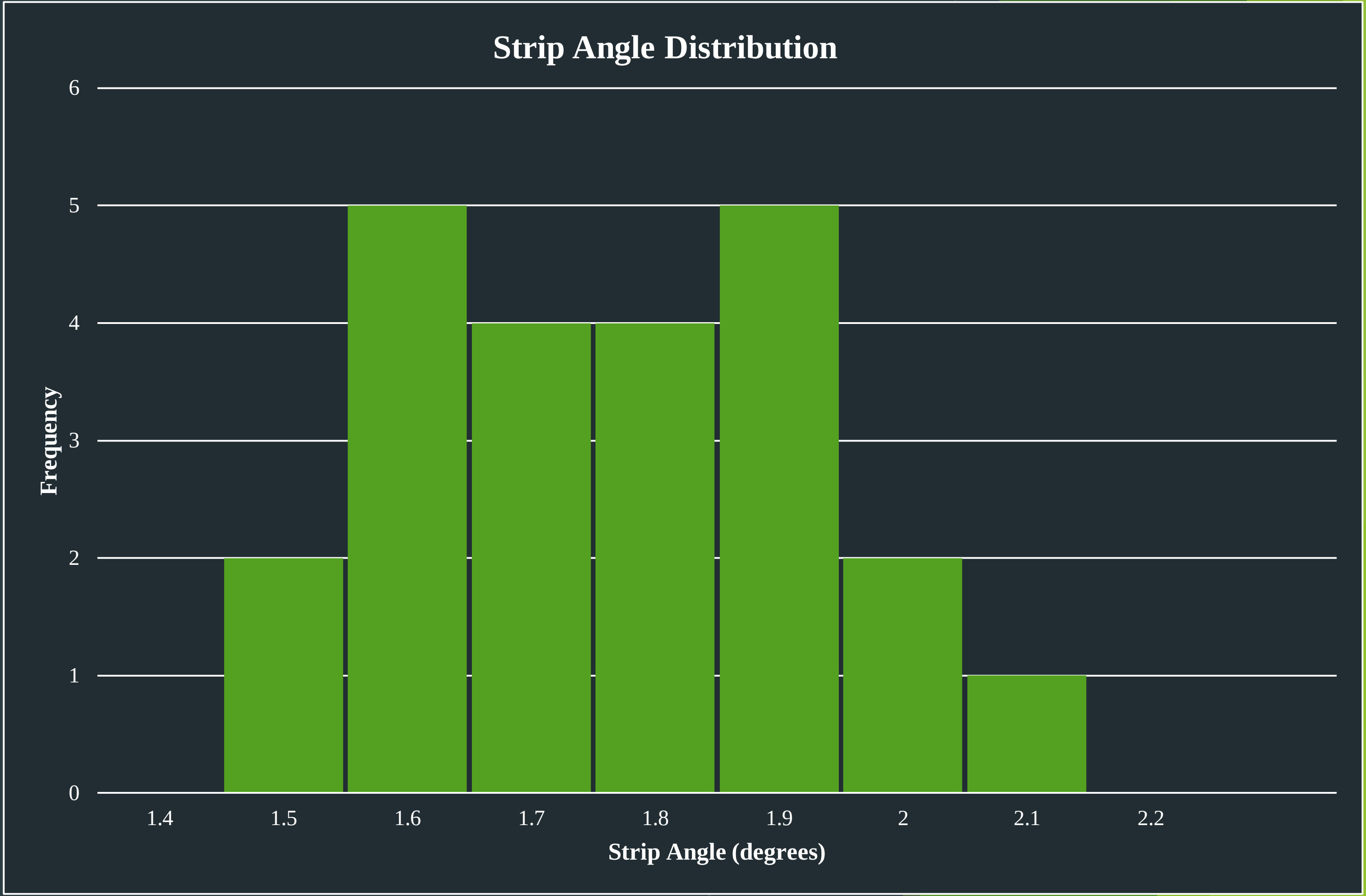
Strip Width Results

Mean	7.98 mm
Standard Deviation	0.20 mm
Tolerance Confidence	98.83%

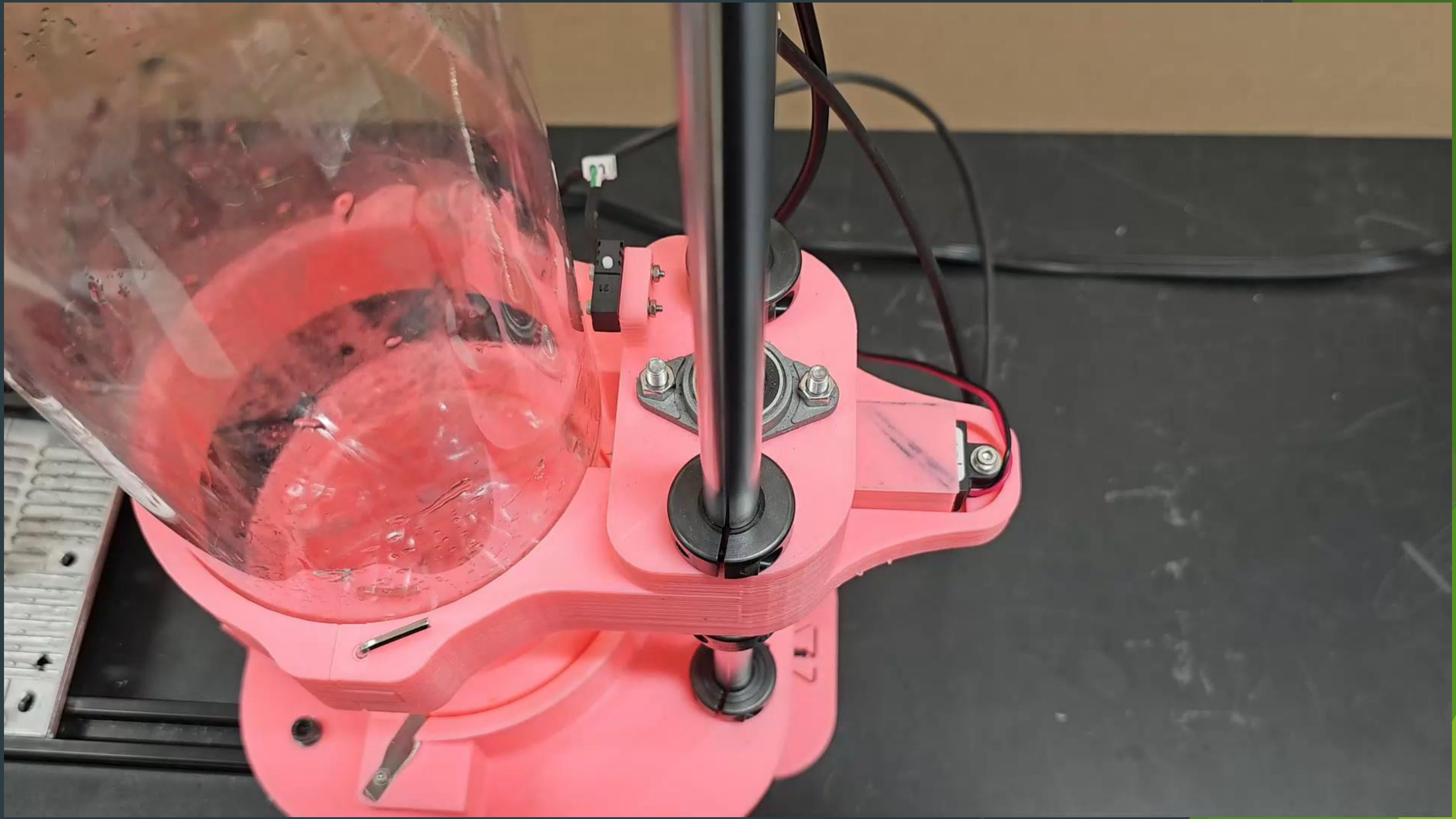


Strip Angle Results

Mean	1.72 degrees
Standard Deviation	0.17 degrees
Tolerance Confidence	99.99%



Device Operation



Recommendations

- Integrate by running the strip cutting process simultaneously with pultrusion
- Better way to account for 3D print shrinkage
- Cleaning the strip as its being pulled?

Questions?