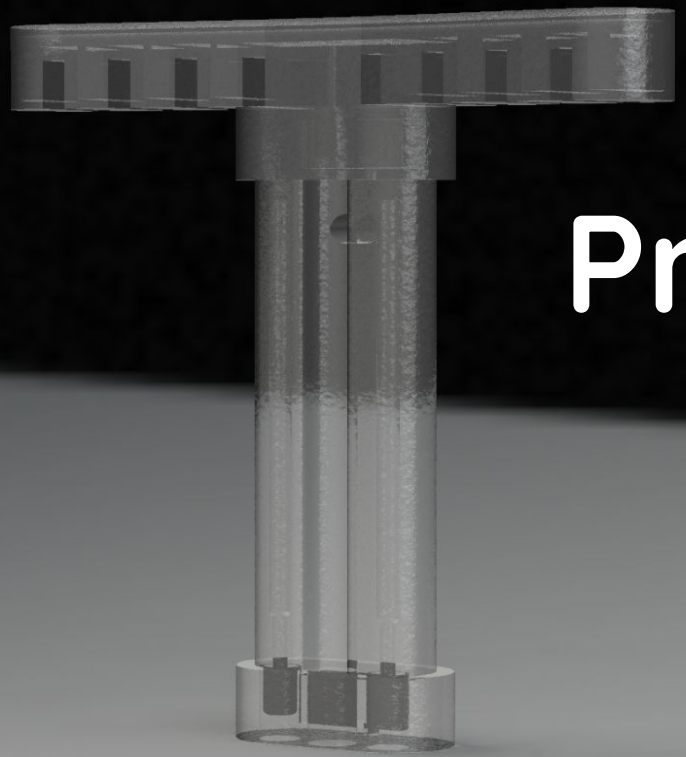
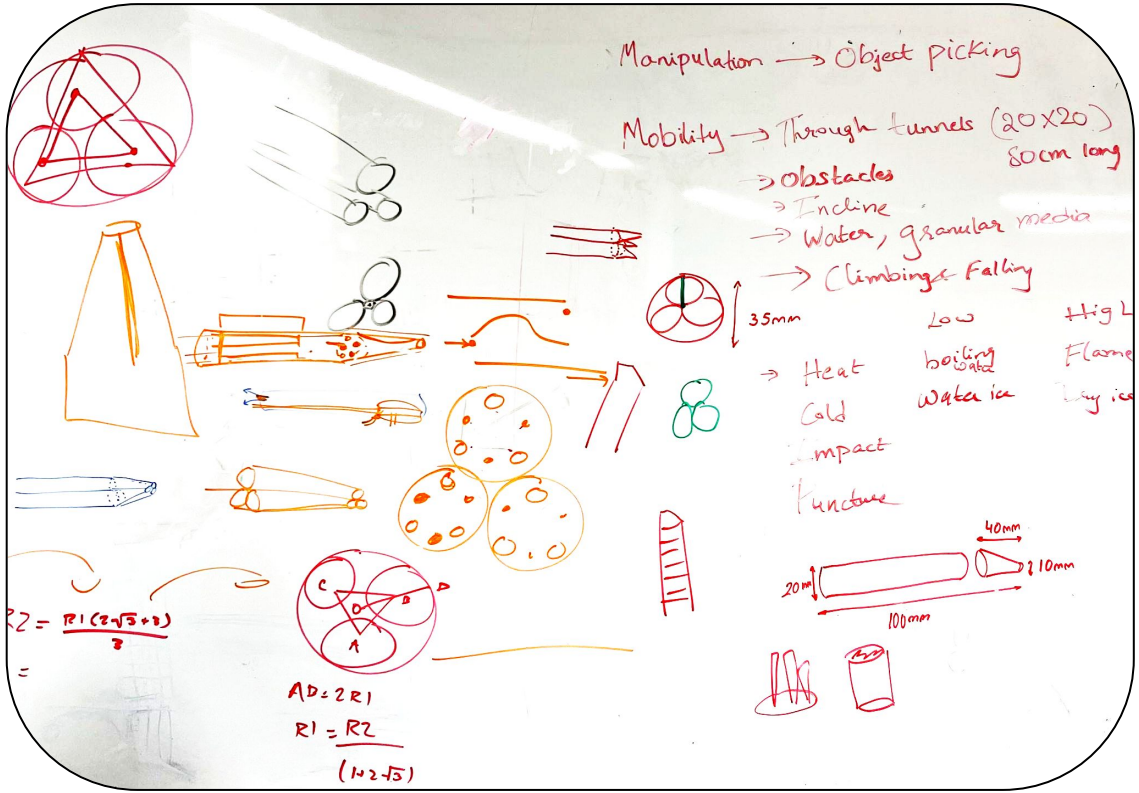


PneuSlinky

By Tristan Bourgade, Paolo Limcaoco, Amin Montazeri, Advaith Somula, Armaan Vasowalla

Ideation Phase

It all started here:



Bio-inspiration:

Bloodworms

Identified Strengths, Intellectual Merit & Broader Impact

We identify the following strengths with our design:

1. Multiaxial Bending

Combination of vertical & horizontal offsets
↳infinite degrees of freedom

Two distinct channels for locomotion allow body to contort to environment

2. Fluidic Actuation

High adjustability of actuation beyond what is achievable by a conventional hard robot

Low operating pressure allows robot to be handled safely even during actuator failure

3. Integrated Anchors

Control over stiffness allows for unique exploitation of the system's soft capabilities

Ballooning was exploited to achieve bio-inspired inching motion

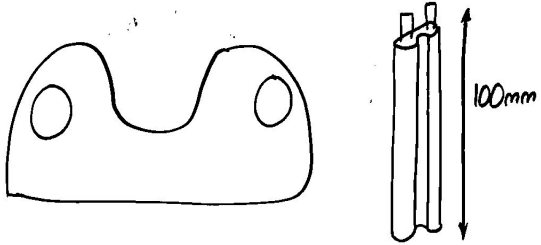
4. Soft Gripping with Stiffening

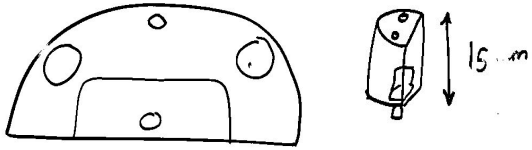
Pneunet design with jamming → sensitive grasping while remaining strong

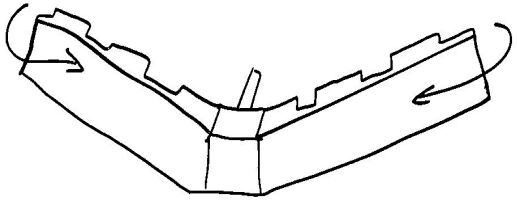
Stiffness of grip can be regulated by quantity of applied negative pressure

5. Silicone Exterior

Ensuring all exposed external surfaces of the body are silicone allows for handling with little-to-no safety concerns while remaining extremely durable

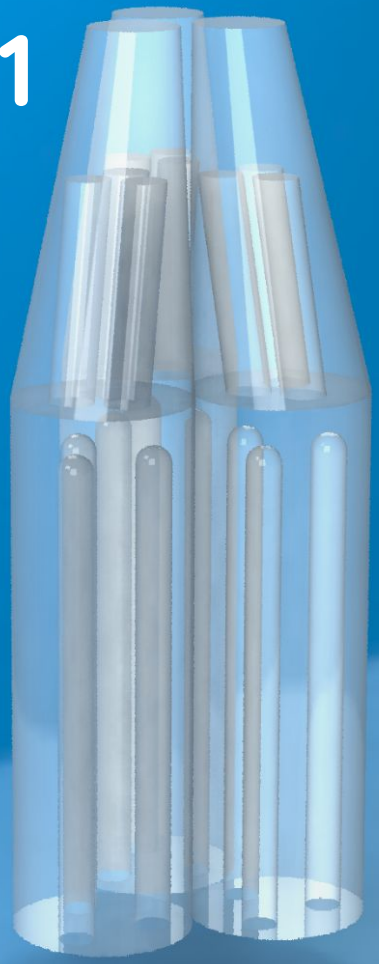






Industrial Applications (tight spaces), Aquatics?

PROTOTYPE #1

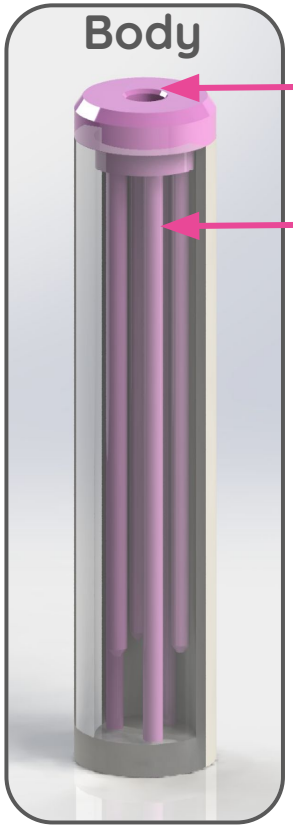


Prototype #1 (Robot Design)

When designing our first robot, we thought of the following:

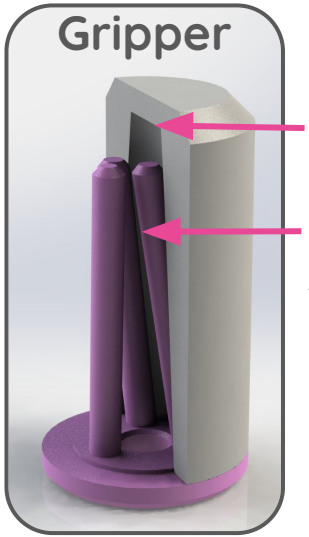
- The initial design consists of a three body system with locomotion through inchworm type movements
  - Three bodies makes it axisymmetric
  - Bodies have three chambers to allow for steering
- Gripper open with positive pressure, close with zero pressure.
  - Resting state at zero pressure is closed
  - Positive pressure opens the gripper
  - Grasping force comes from material properties and initial state

Prototype #1 (Robot Design + Molds)



Hole for excess silicone purging

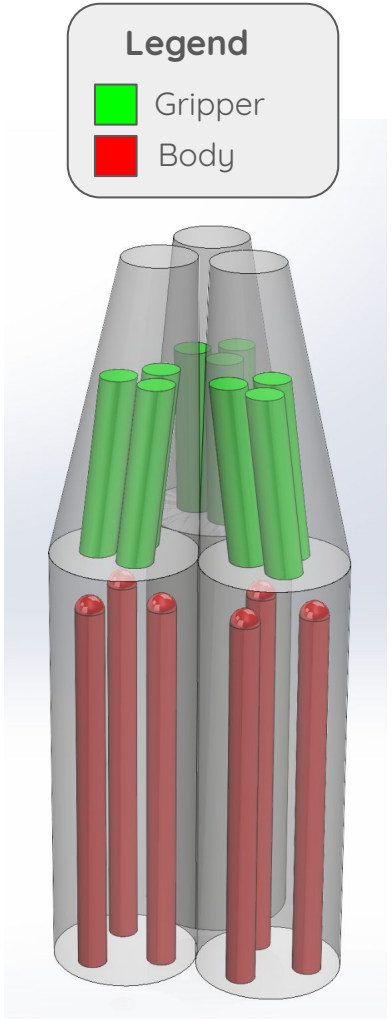
Cylinders to create air cavities + tube channels

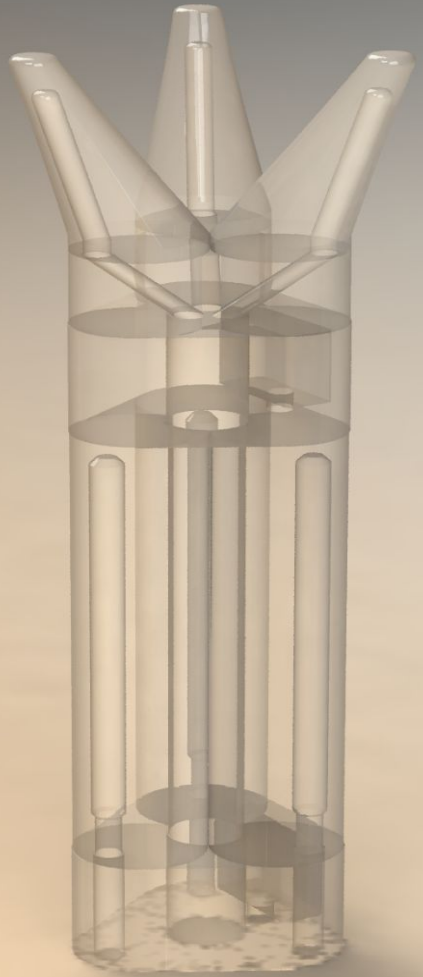


Split-cylinder design

Angled cylinders for converging air channels

Initial Mockup





PROTOTYPE #2

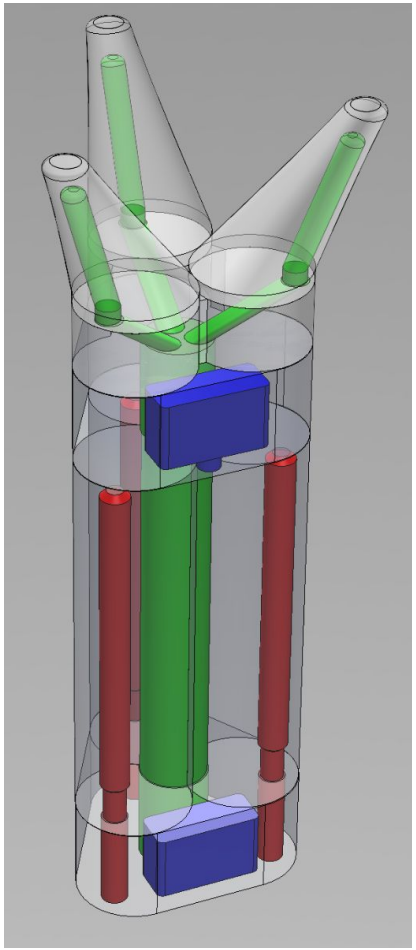
Prototype #2 (Robot Design)

Legend

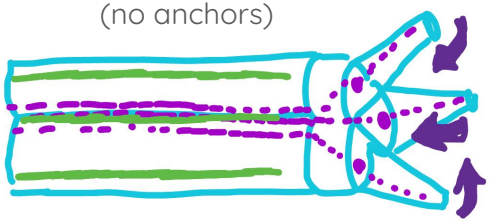
- Gripper
- Body
- Anchors

Updates to Design

- Grippers angled outward for non-passive grasping
- Grippers elongated by ~10mm
- Opening created in center for tube pass throughs (no more strain limitation)
- Body and Gripper air channels reduced to 3 (from 9), kept axisymmetric
- Body and Gripper air channel diameter slightly increased
- Anchors introduced → requires two new tubes
- Connector/Interface redesigned

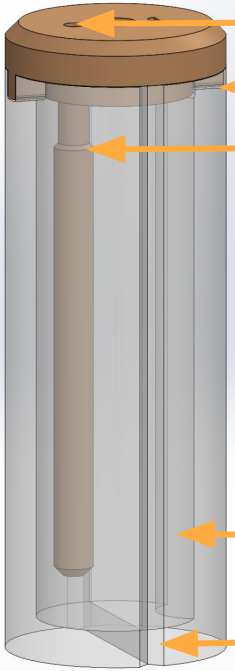


V1.5 Initial Sketch
(no anchors)



Prototype #2 (Mold Improvements)

Body



Indicators

Locking Pins

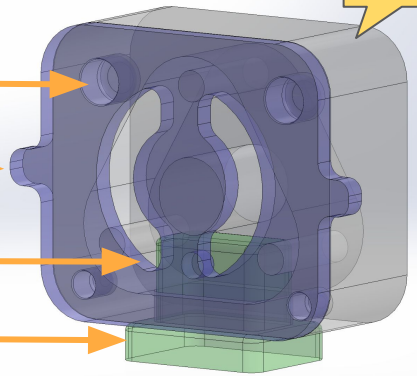
Tube draft angle (easy removal)

Added bump for easy actuator extraction

Added lip for easy mold splitting

Anchor

NEW



Locking pins

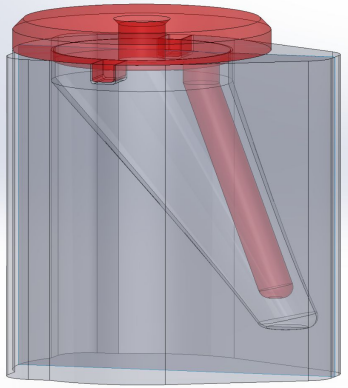
Handles (easy removal)

Tube pass through

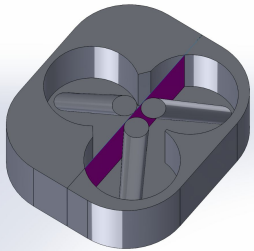
Lower mold creates air cavity

Gripper

(Same idea as last time, but new design)



Connector



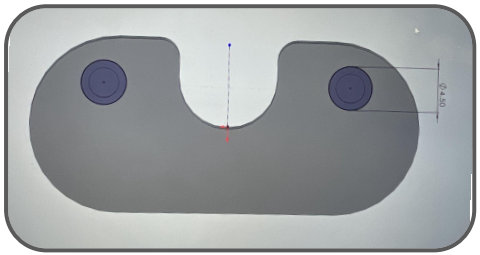
Prototype #2 Demo Video

PROTOTYPE #3

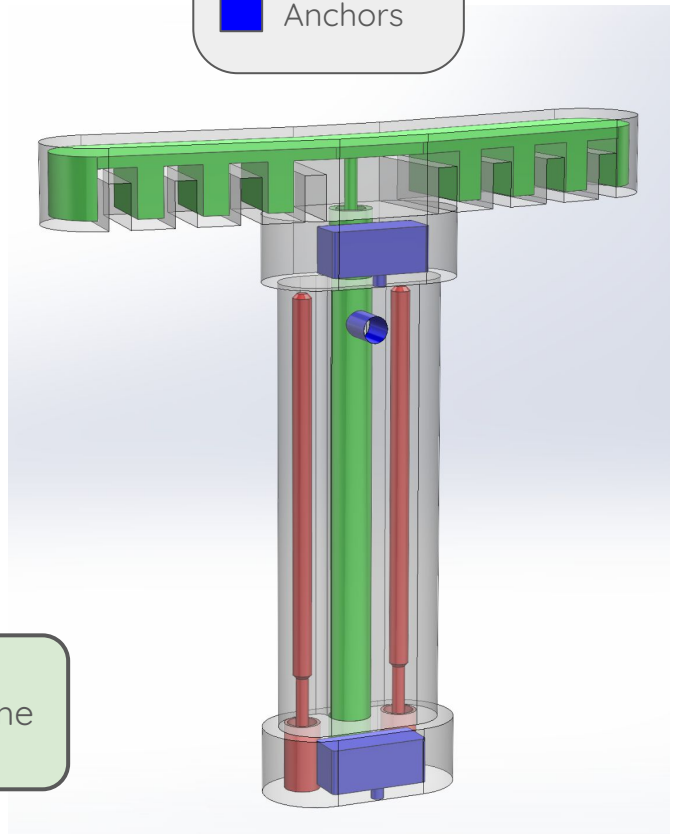
Prototype #3 (Robot Design)

Updates to Design

- Pneunet-inspired gripper
- Axisymmetric design removed
- Anchors larger than body (offset)
- Anchor air cavity width doubled
- Anchor “membrane” textured and fabricated via molds
- Body components fused into one piece
- Body and Gripper air channels reduced to 2 (from 3) and rotated 30 degrees due north (horizontal actuation)
- Body elongated from 50mm to 100mm
- Gripper arms elongated from 20mm to 50mm
- Added opening in body to route tube for front anchor
- Added lips to each component for zip ties
- Added 7 degree offset on gripper to prevent dragging



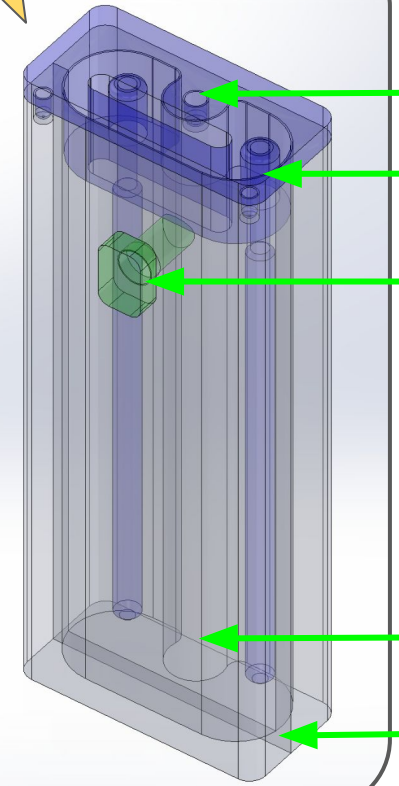
Although these updates were needed, they significantly complicate the mold design process...



Prototype #3 (Molds)

NEW

Body



Locking pins

Concentric cylinders for zip tie “lip”

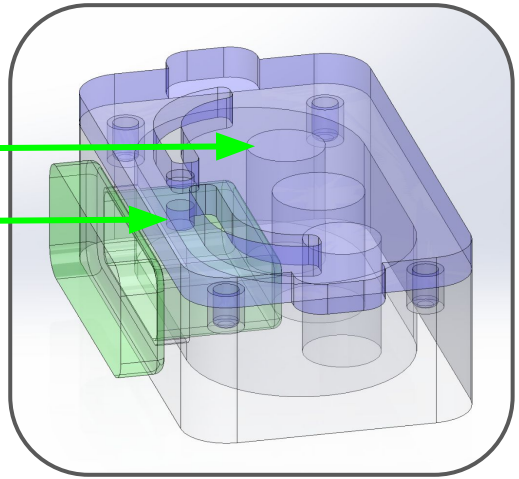
Opening for front anchor tubing

Groove for tube pass throughs

Split design (mold release)

Larger pass throughs to house zip ties

Anchor tube pass though

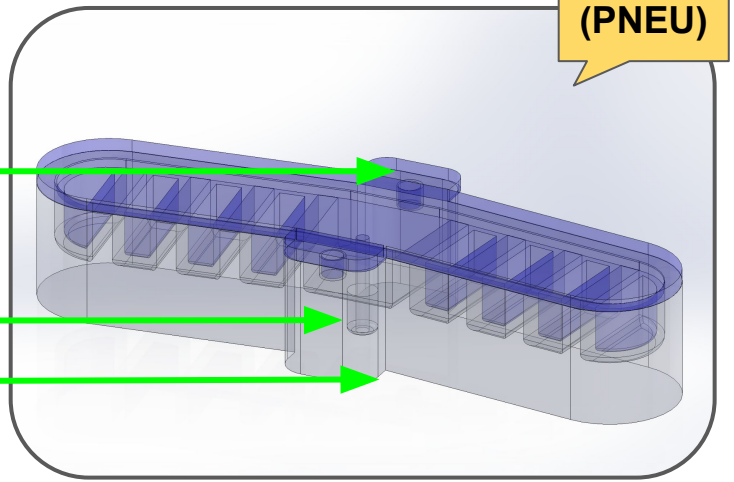


(PNEU)

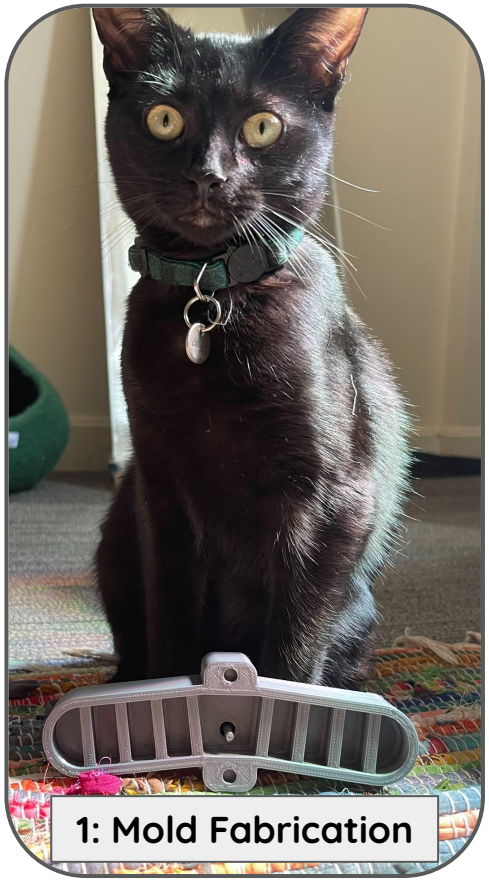
Handles with integrated locking pins

Zip tie “lip”

Slight angled offset



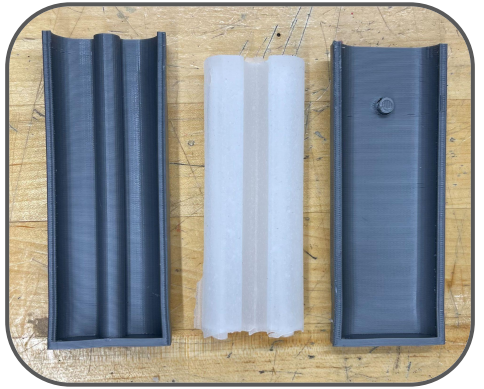
Prototype #3 (Fabrication)



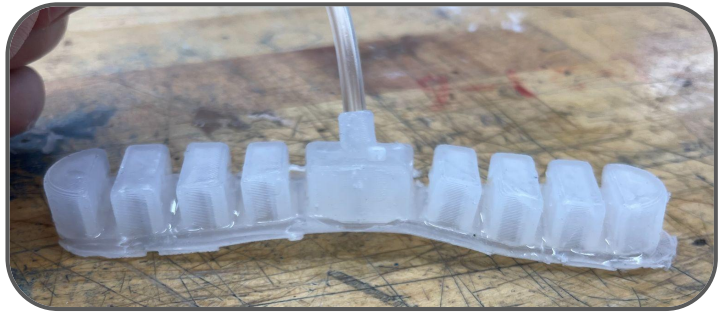
(1.5): Mold Assembly

2: Pouring/Curing

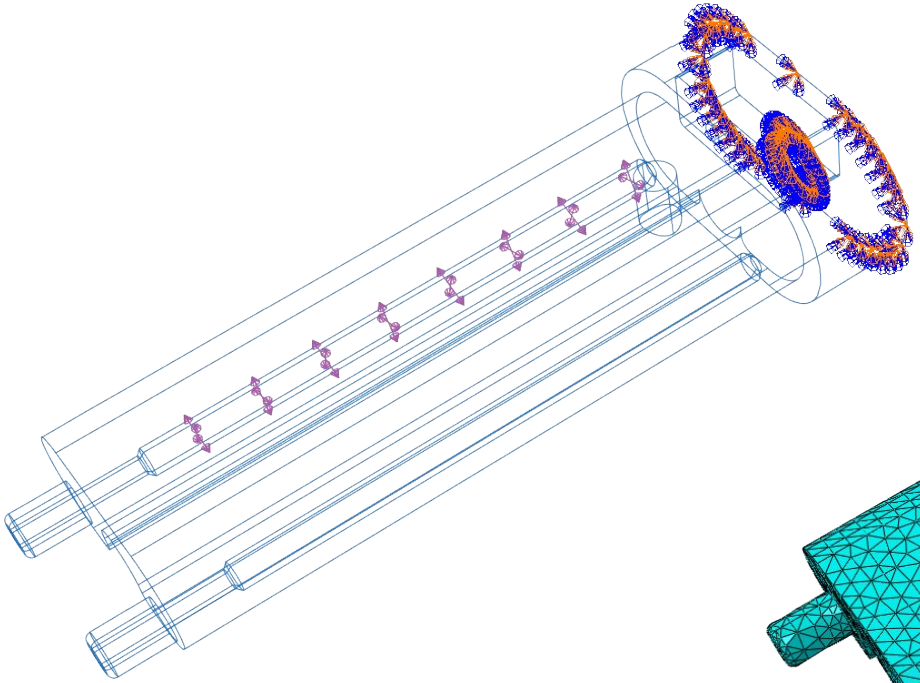
3: Removal

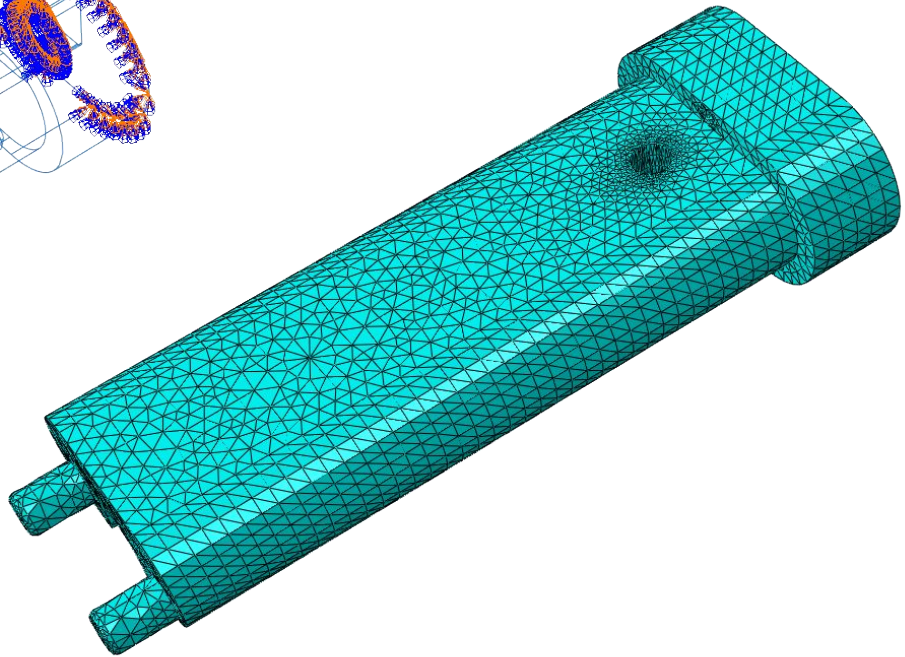


4: Assembly

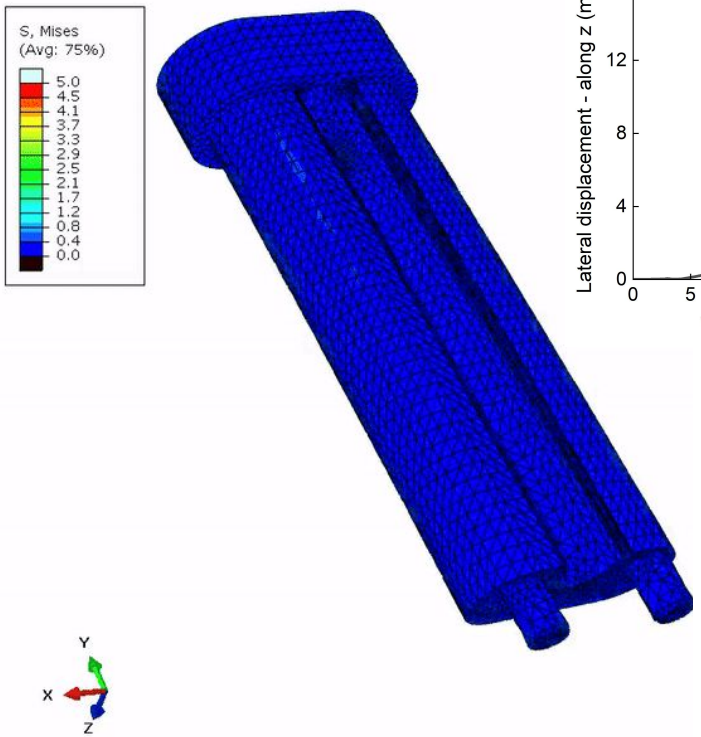


Finite Element Modeling: Mesh & Boundary Conditions

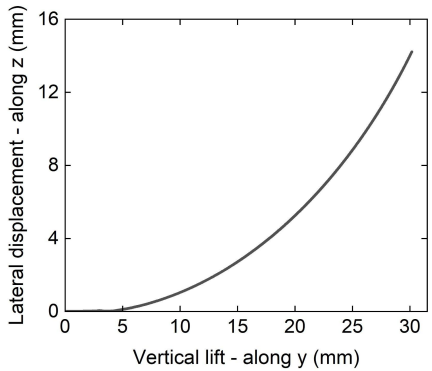




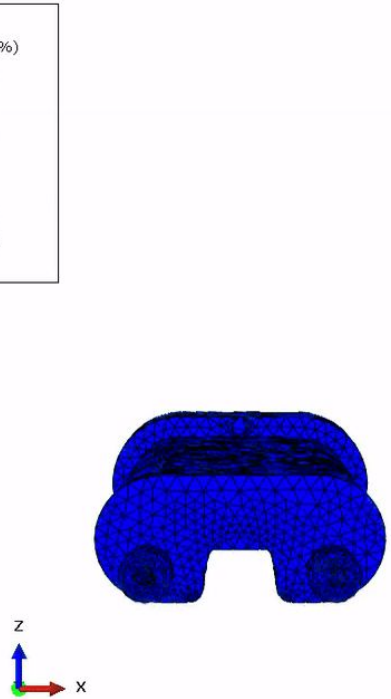
Body Motion Simulation via FEA in Abaqus: Bending



Isometric View

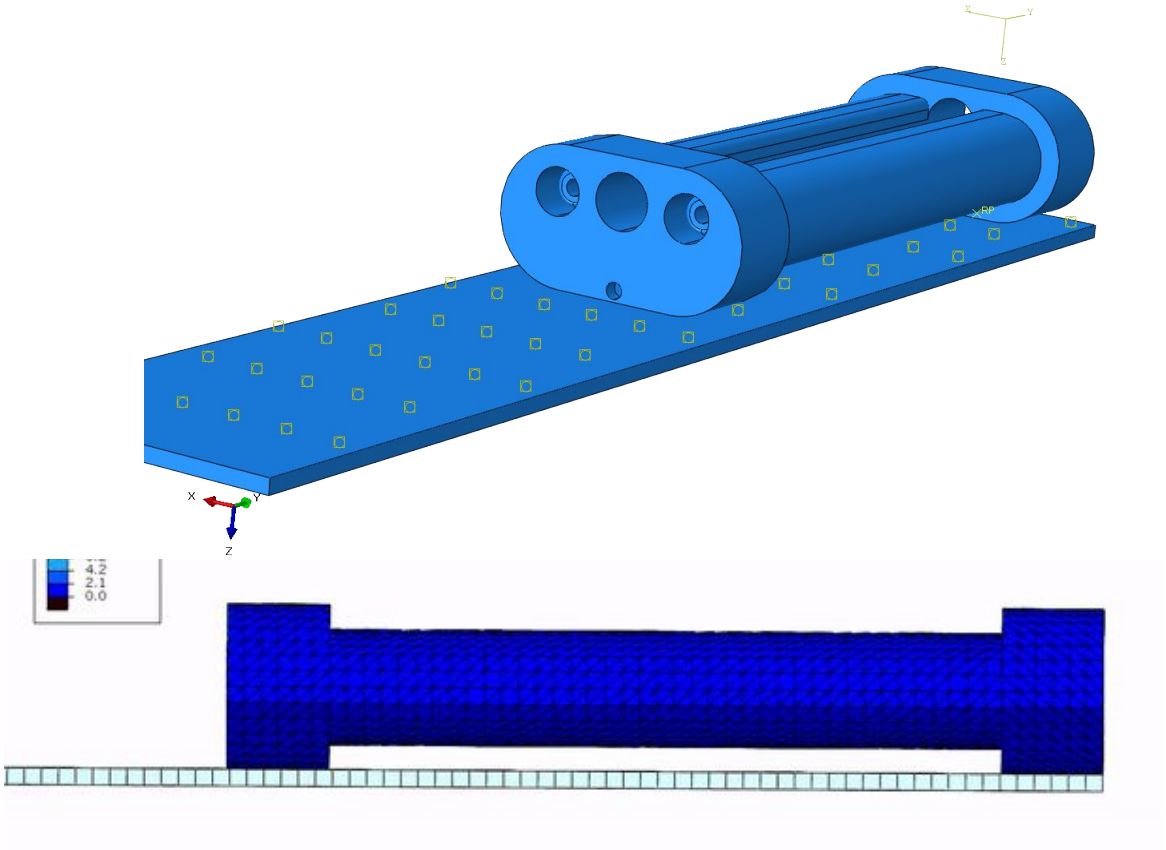


Side View



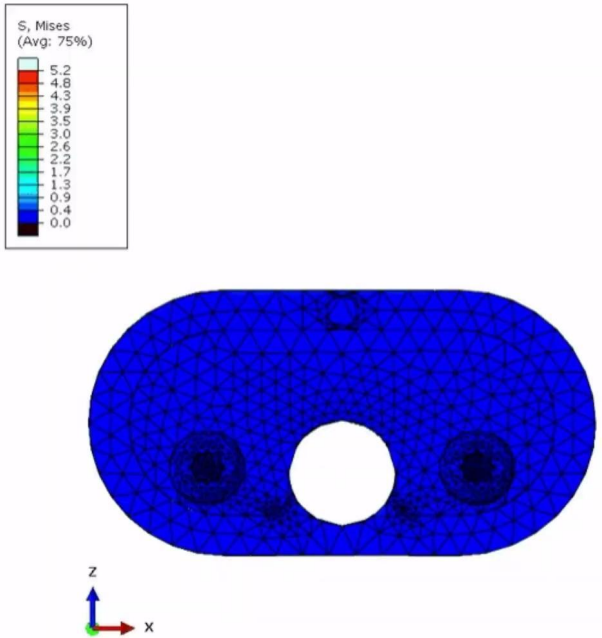
Front View

Body Motion Simulation : Boundary Conditions & Mesh

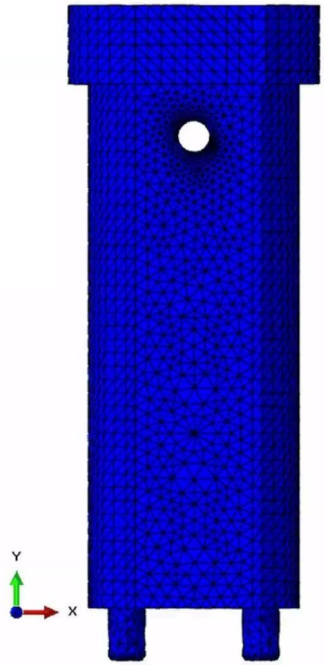


Side View

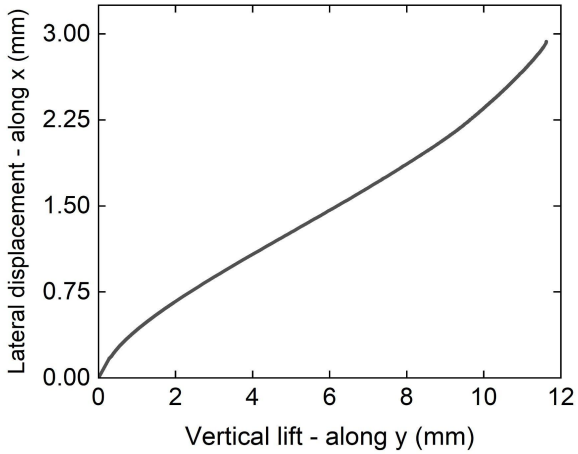
Body Motion Simulation via FEA in Abaqus: Steering



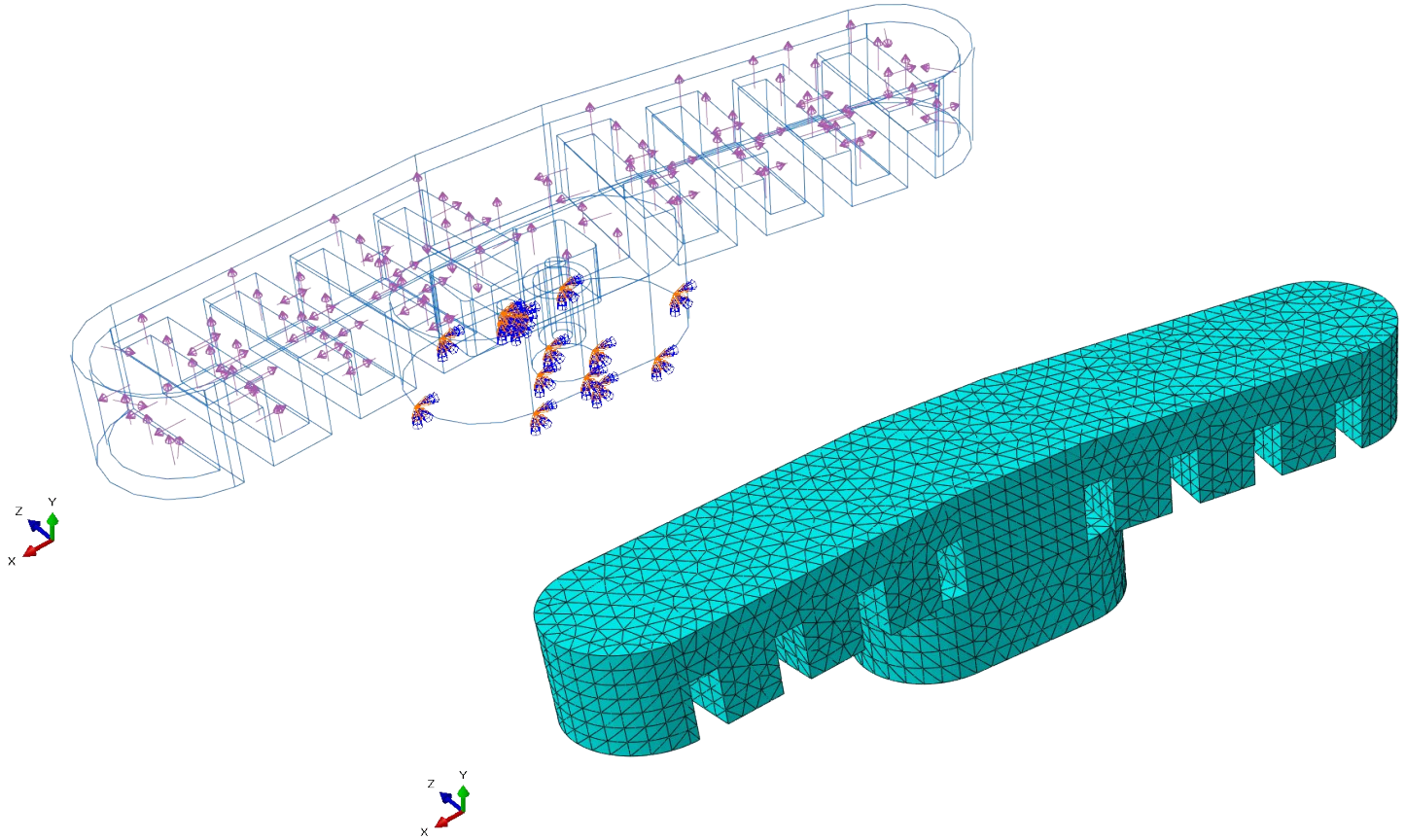
Top View



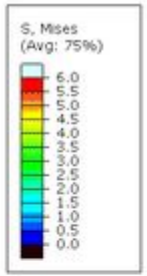
Front View

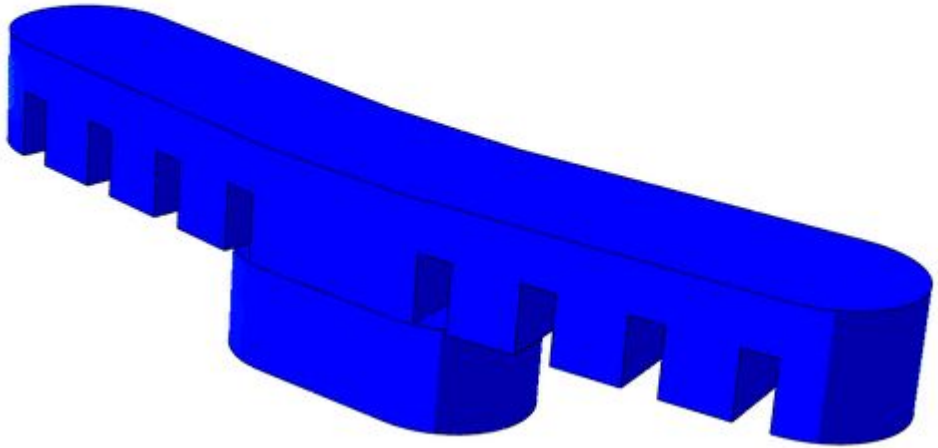


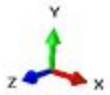
Gripper Motion Simulation: Mesh & Boundary Conditions



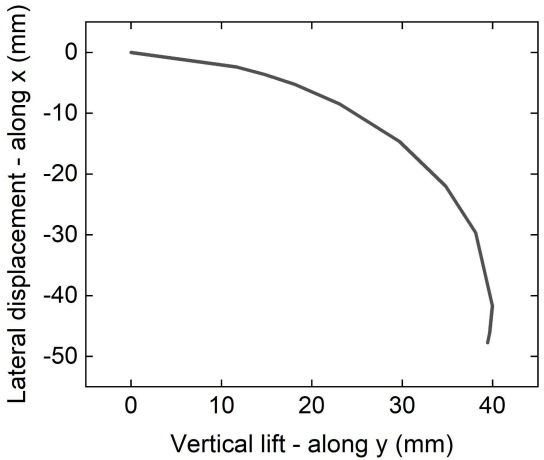
Gripper Motion Simulation Results







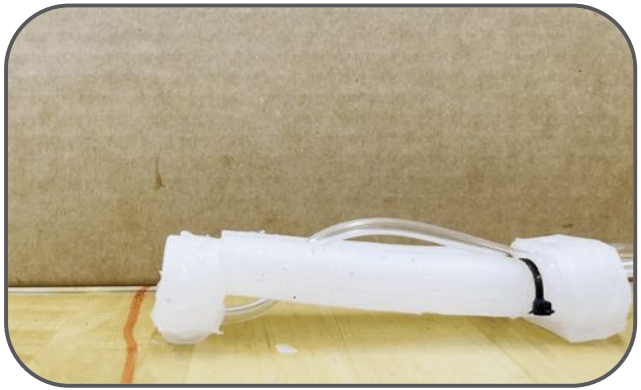
Isometric View

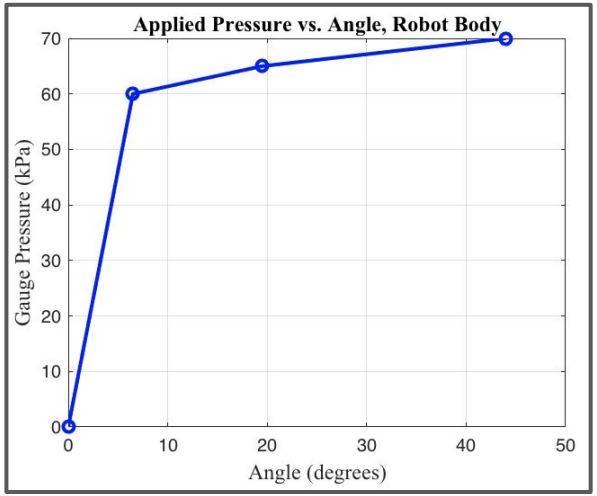


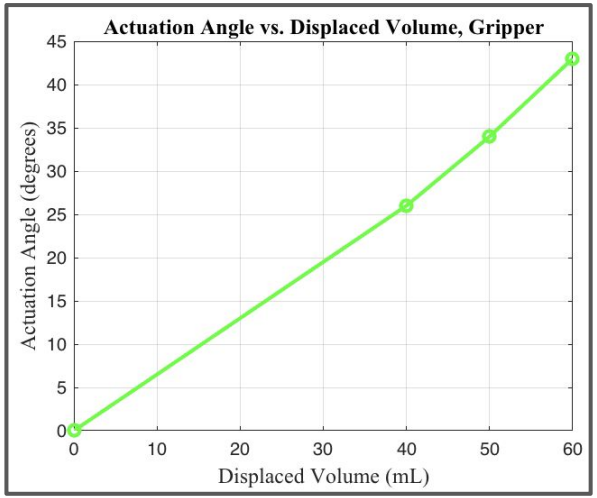
Granular Jamming Reinforcement

- Abaqus FEA simulations of Pneu-Net gripper identified concentrated stress regions required for actuation.
- These regions are susceptible to fail when grasping large/heavy objects.
- Reinforcing these regions can greatly increase the capability of grasper.

Final Testing & Characterization







Results & Discussion or Areas of Improvement

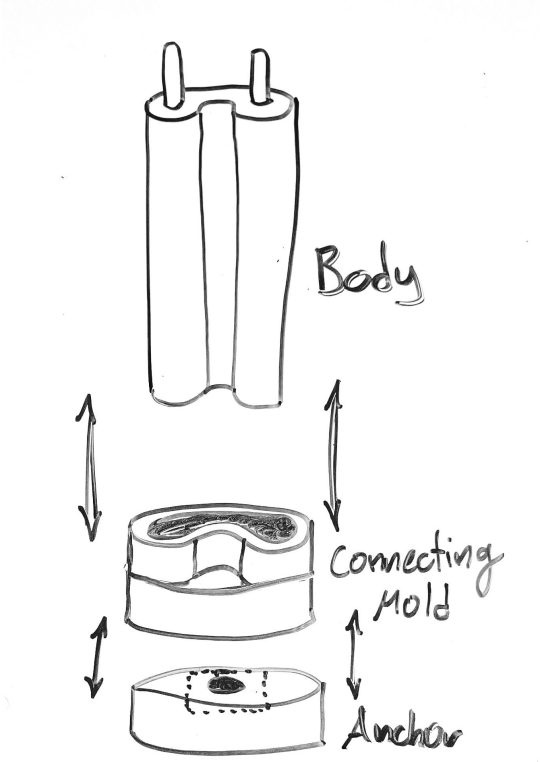
Here are changes to our process that we would implement for the 5th prototype:

TOP 5:

1. Large molds to help assemble parts after fabrication
2. Added incline to gripper → reduce drag
3. Integration of stiffening into original design (backbone)
4. Double-balloon (or more) anchor design
5. Integration of larger pumps for automated locomotion

minor changes

6. ABS or resin molds (less warping in oven)
7. Use of vacuum when casting molds (reduce bubbles)
8. Controller design for electronics for manual control
9. Soft sensing inside gripper? → software challenge



Credit & Distribution of Labor

Tristan Bourgade

Robot Ideation (all prototypes)

Illustrations

Robot CAD Designer

Mold CAD Designer

Mold Fabricator

Robot Fabricator

Characterization Processor

Presentation Design

Final Report Writer

System Characterization

Paolo Limcaoco

Robot Ideation (all prototypes)

Competition Electronics

System Characterization

Jamming-Based System Designer

Presentation Design

Final Report Writer

Amin Montazeri

Robot Ideation (all prototypes)

System Modeling (FEM)

Mold Fabricator

Robot Fabricator

Characterization Processor

Presentation Design

Final Report Writer

System Characterization

Advaith Somula

Robot Ideation (all prototypes)

Robot Fabricator

Characterization Processor

Presentation Design

Final Report Writer

Final Report Formatter (LaTeX)

System Characterization

Armaan Vasowalla

Robot Ideation (all prototypes)

Competition Control

Competition Electronics

Presentation Design

Final Report Writer

Works Cited

Images:

- https://www.google.com/url?sa=i&url=https%3A%2F%2Fen.wikipedia.org%2Fwiki%2FSandworm_%2528Dune%2529&psig=AOvVaw2aqA7qxi79Q892XH_9VBlK&ust=1714319445880000&source=images&cd=vfe&opi=89978449&ved=0CBQQjhxqFwoTCKDZk9_f4oUDFQAAAAAdAAAAABAE
- https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.advancedsciencenews.com%2Fhow-bloodworms-build-their-copper-teeth%2F&psig=AOvVaw0N8V_1WCnyqnImLLUDWSsk&ust=1714319271086000&source=images&cd=vfe&opi=89978449&ved=0CBQQjhxqFwoTCKi6tZbf4oUDFQAAAAAdAAAAABAJ
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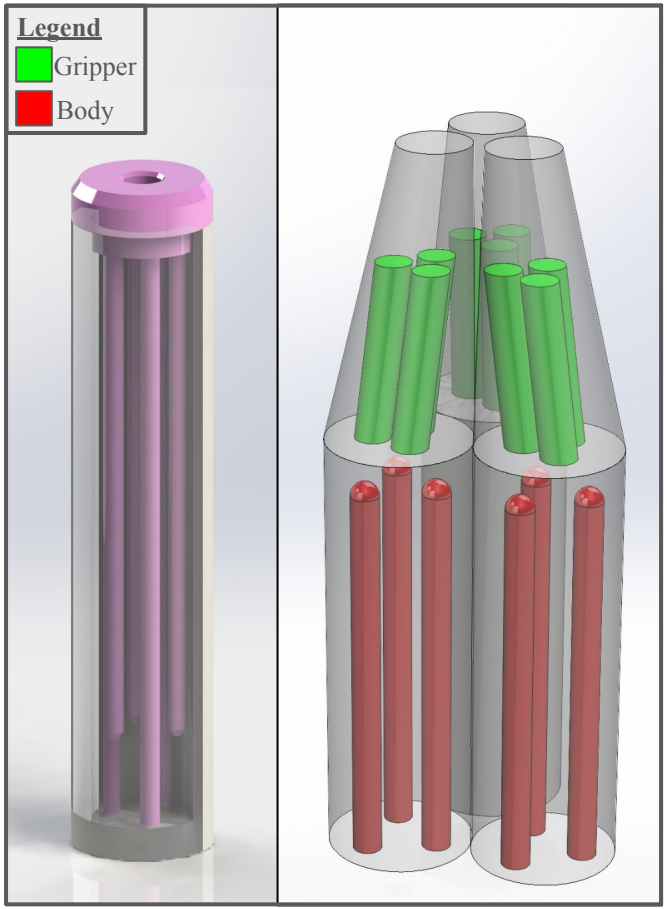
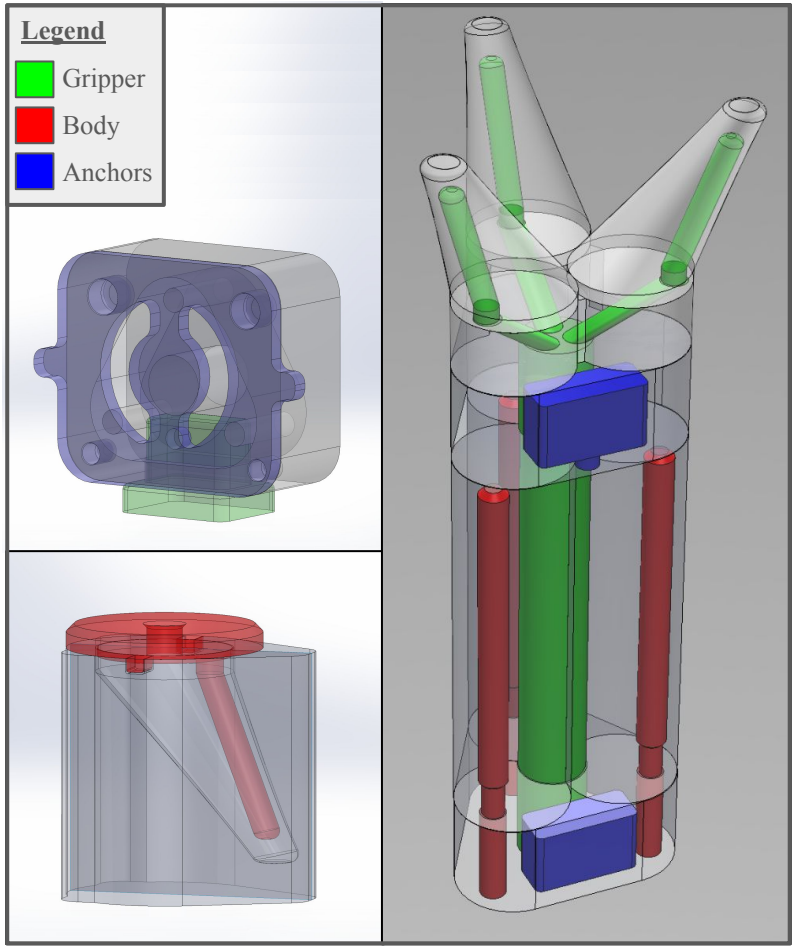
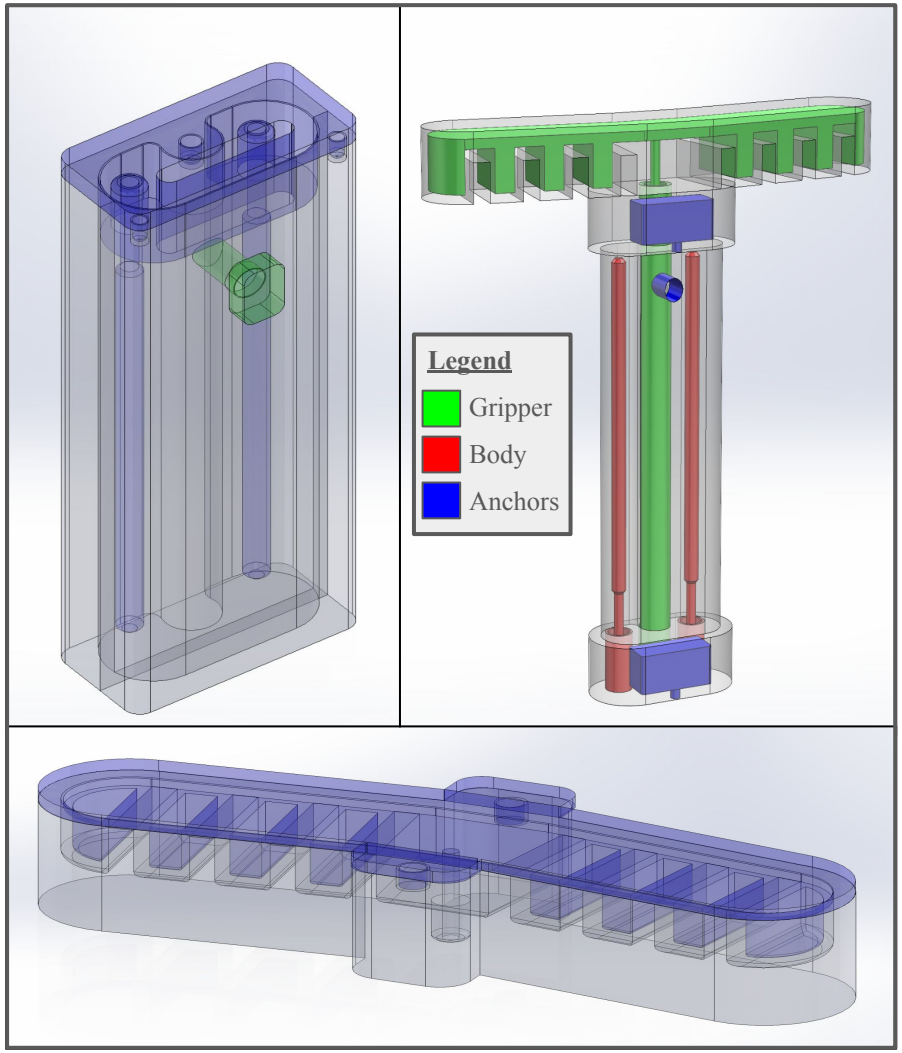
REMAINING SLIDES ARE FOR MAKING FIGURES FOR REPORT → **DO NOT TOUCH**

(but feel free to do the same)


Legend
Gripper
Body


Legend
Gripper
Body
Anchors


Legend
Gripper
Body
Anchors

R.I.P.
PneuSlinky
2024-2024