Development of a Zero Force Multi-Channel Pipette

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BACKGROUND

Trilobio aims to revolutionize synthetic biology, the subfield of biology engineering new biological systems. Their robot modules automate and improve synthetic biology data quality, reproducibility, and efficiency at affordable costs. Trilobio aims to speed up the experiments their robots can perform by designing a 96-channel pipette. However, using existing methods, of attaching pipette tips to the pipette, require over 500N of force, over 10x more force than their robot can deliver. The Trilobio clinic team is tasked with designing a 96-channel pipette that can create airtight seals and precisely aspirate volumes without loading the robotic arm with any considerable Z-axis force.

PROBLEM STATEMENT

The team must design and fabricate a multi-channel pipette attachment compatible with Trilobio’s existing autonomous robotic arm that reduces the force required to achieve a proper seal across all pipette tips. The design will facilitate automated, reproducible, faster, and lower-cost biological lab work.

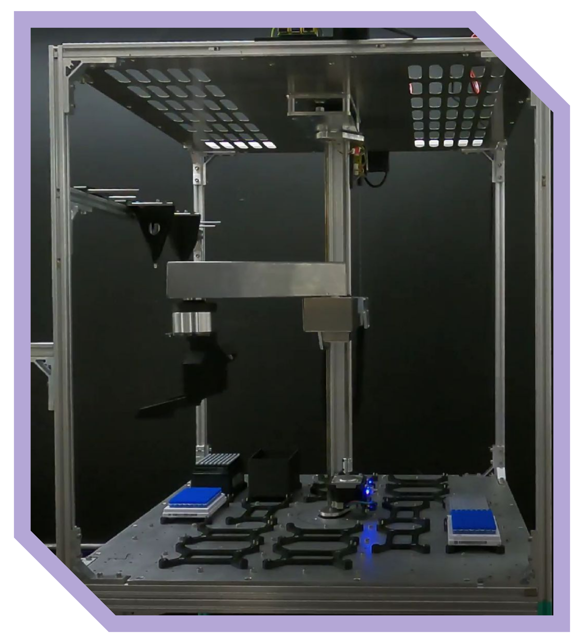

Figure 1: Existing Modular Trilobio Robot

ASPIRATION SUBSYSTEM

The team decided to use a **piston working method** that consists of a **pistons** with **o-rings** that slide through **machined bores**. These pistons are driven through the bores such that the walls radially compress the o-rings to create an airtight seal. All 8 pistons are attached to a plate such that they can be driven together. The pistons are driven using a NEMA 11 motor with a lead screw and controlled using an actuator board with a motor driver. The motor has a maximum driving force of 77N and the frictional force across all 8 pistons is 31N, giving a factor of safety of ~2.5.

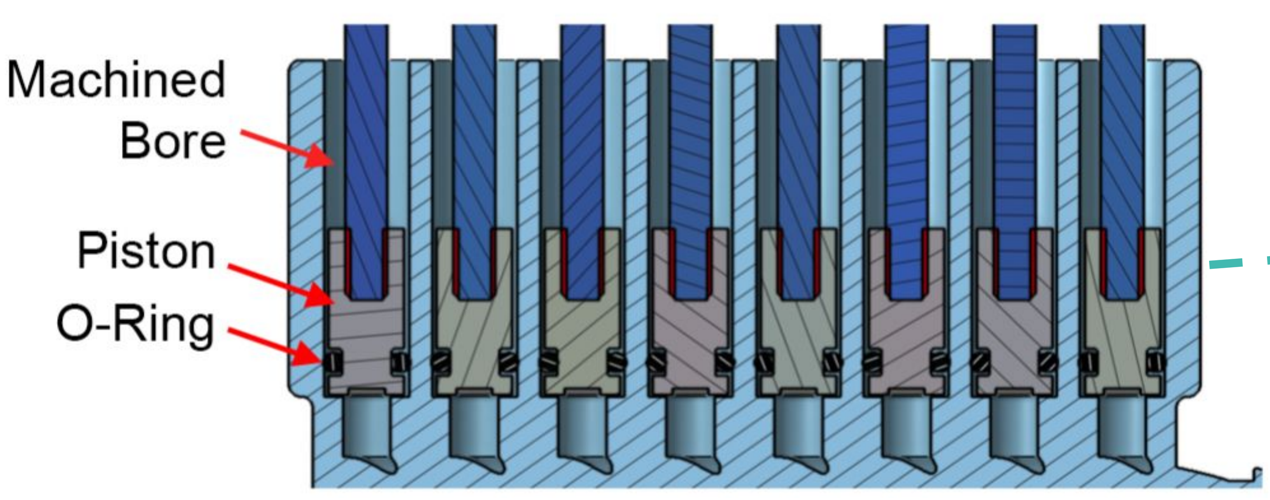

Figure 3: Cross Section of Base

DESIGN VALIDATION

Two types of tests were used to validate our designs and determine what could be improved (1) **wick testing** and (2) **cycle testing**

1) **Wick testing** validates seals across channels. The procedure involves aspirating a fluid into the pipette tips, and placing fluid-filled tips against an absorbent material. For an airtight seal, pressure will begin to drop above the fluid and eventually overcome capillary forces acting on the fluid. Therefore, a successful test is characterized by the fluid springing back to its original position in the channel, and an unsuccessful test is characterized by all of the fluid evacuating the channel.
2) **Cycle testing** ensures prototypes are durable under real loading conditions. This procedure for the hydraulic system involves repeated cycles of fully inflating and deflating the inflatable sleeves. Cycle testing for the aspiration system involves repeated cycles of aspirating and dispensing a fixed volume of fluid.

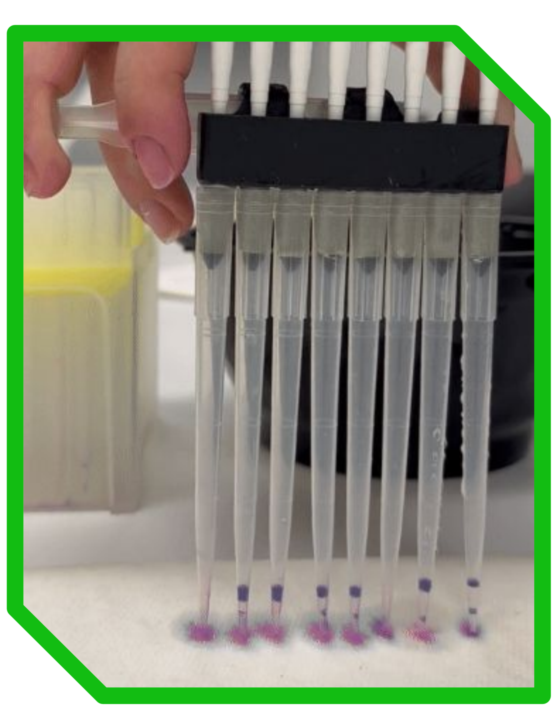

Figure 5: Wick Testing

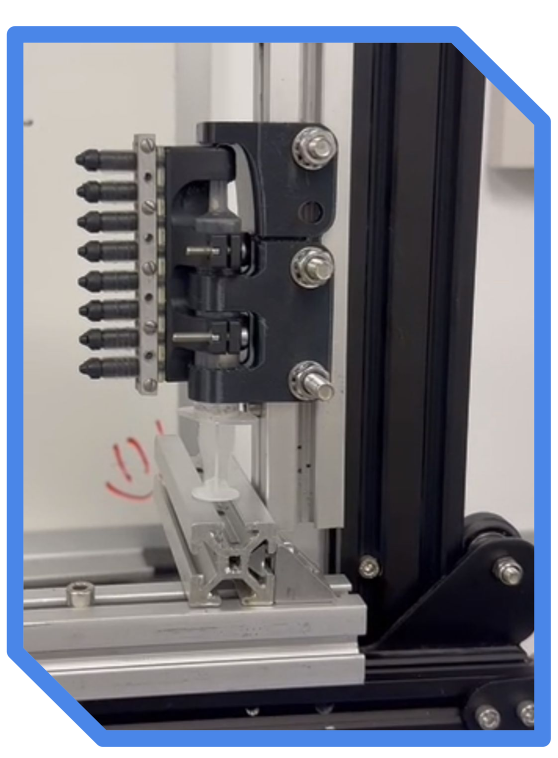

Figure 6: Cycle Testing

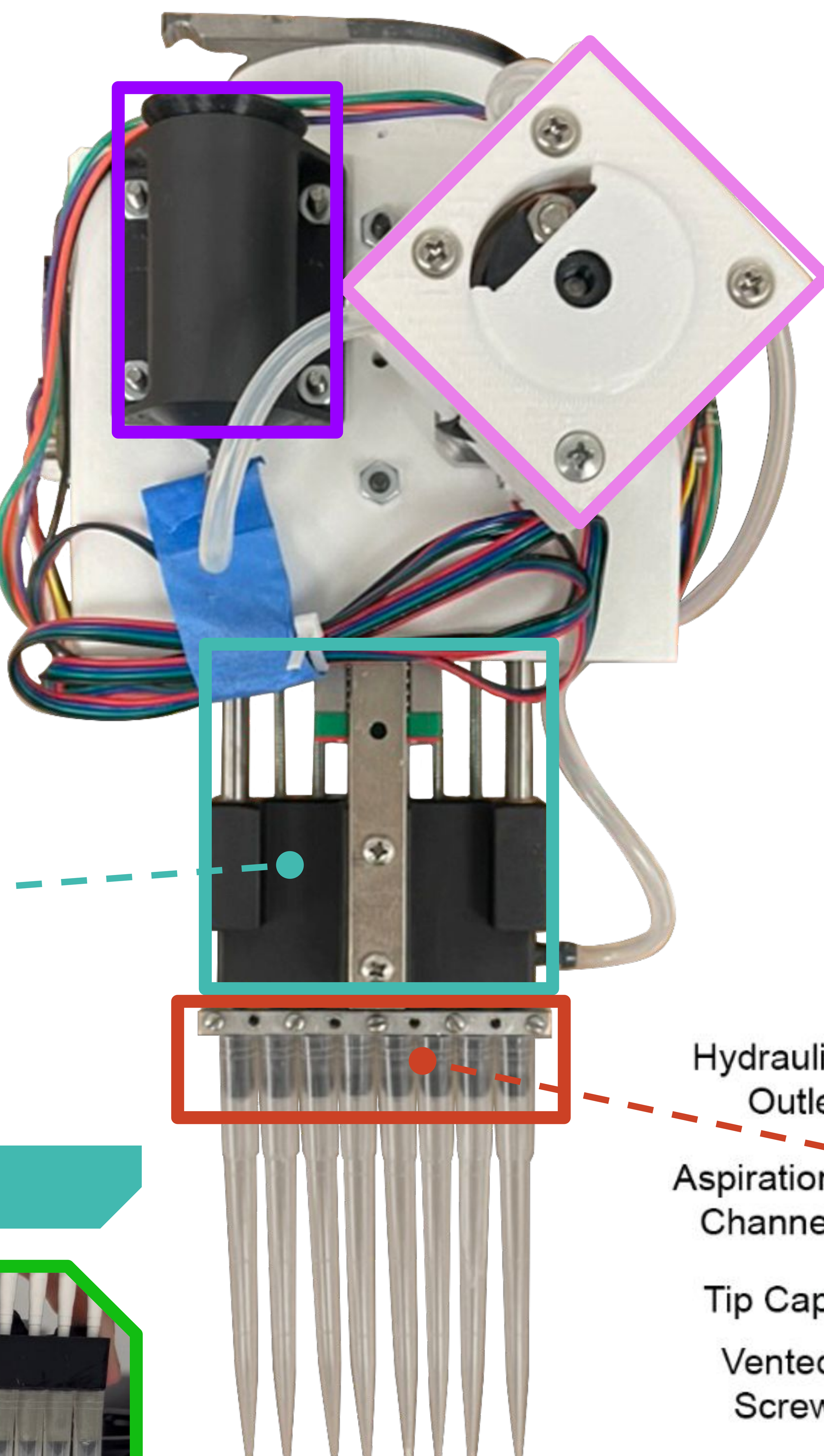

Figure 2: Final Prototype

TIP PICKUP SYSTEM

The hydraulic sleeve mechanism consists of (1) the **base**, and (2) the **inflatable sleeves**.

1) The base has one **reservoir** for inflation, where the inlet connects to a **pump [1]**, and 1 **outlet** per **barrel** allowing water to inflate the elastic sleeves and create airtight seals with pipette tips. The base is connected to the **aspiration channels** to allow for accurate and precise movement of fluids.
2) The inflatable sleeves are 3D printed as a singular piece of flexible material with 8 channels. They are pushed onto the base and seal to the base with machined clamps to seal the top portion and 3D-printed **tip caps**, secured with **vented screws**, to seal the bottom portion.

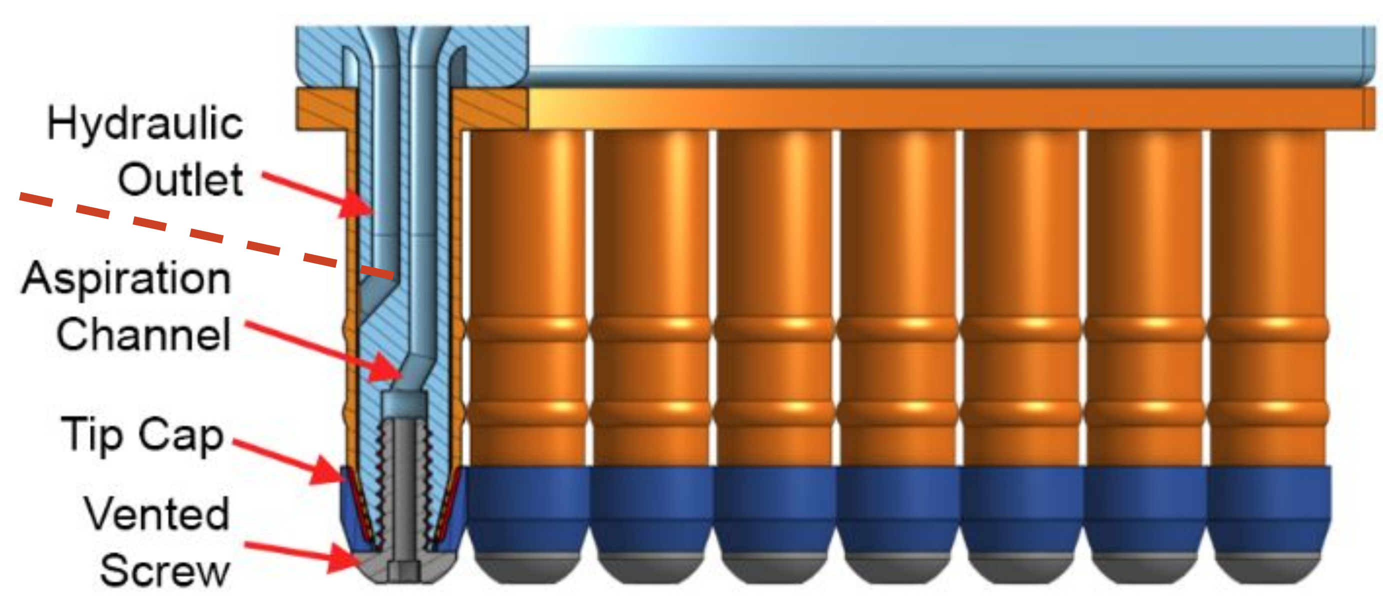

Figure 4: Cross Section of Barrels

ROBOT INTEGRATION

To integrate the pipette with the robot, the prototype must be able to attach to the tool changer and be able to communicate with the robot. To achieve this, the pipette was mounted in a **3D printed housing** which connects the pipette to Trilobio’s standard tool changing plate. The housing all holds and connects the stepper control boards required to actuate the aspiration and pump. The constraints for the tool include a max power consumption of 24V at 4A, and a max weight of 13.6kg. The team’s design safely meets all constraints as the the final tool is 1.34kg and has power requirements far under the maximum 96W allotment.

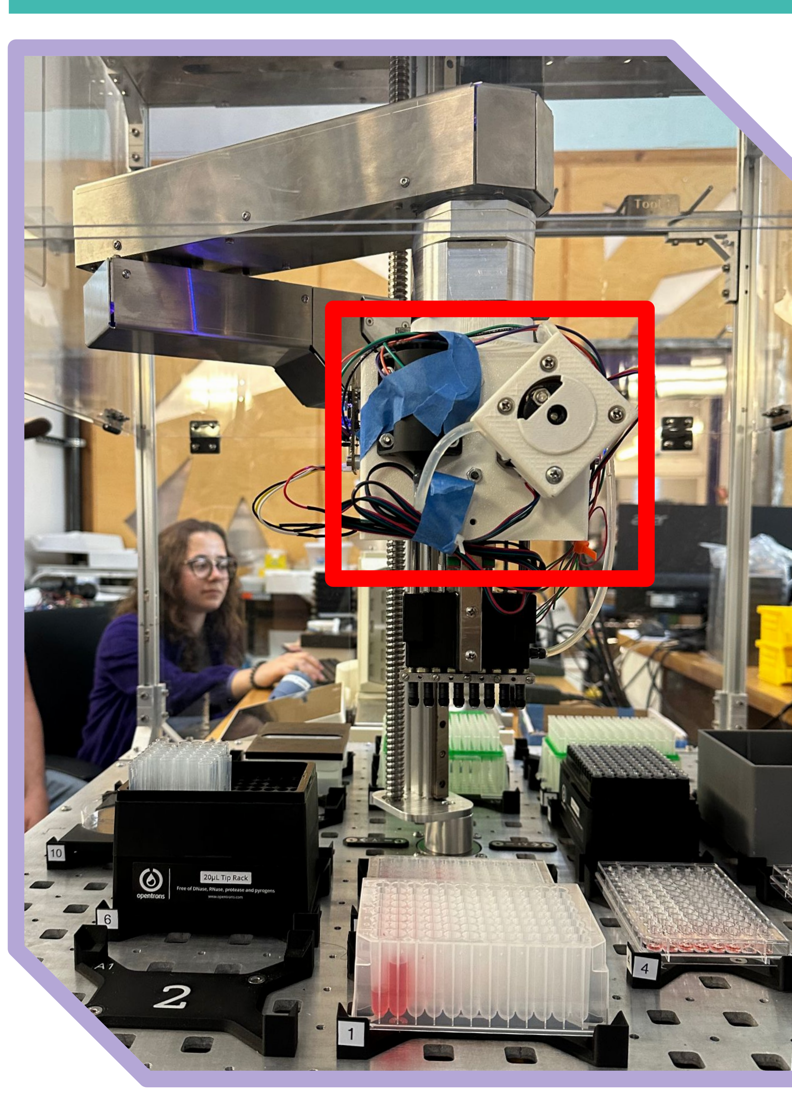

Figure 7: Final Prototype Interfaced with Trilobio’s Robot Arm

NEXT STEPS

To scale the existing design into a reliable 96-channel design, several critical design changes need to be made. First, the entire prototype should be machined or metal 3D printed and subsequently post machined to increase durability and precision. Next, 3 additional motors need to be added in order to have enough force to aspirate all 96 channels. Similarly, to get reliable hydraulic inflation, the team recommends switching the hydraulic pump from a peristaltic pump to a geared brushless pump. This pump will supply more pressure and be more reliable than the peristaltic alternative. Finally, the team suggests changing the 3D-printed flexible sleeve to a more flexible injection molded alternative. The injection molder part will be less fragile and easier to produce.

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REFERENCES

[1]GreatScottLab, “DIY Peristaltic Pump,” Instructables. https://www.instructables.com/DIY-Peristaltic-Pump/ (accessed Apr. 22, 2024).