Dominique Gooden (Co-Team Leader)
Ana Toscano (BPAG)
Steph Vigmond (Communicator)
Sophia Speece (BWIG)
Mahathi Karthikeyan(Co-Team Leader)

Advisor: Professor Paul Campagnola

Client: Dr. David Dean

DEPARTMENT OF
Biomedical Engineering
UNIVERSITY OF WISCONSIN–MADISON

Microvascular Channel Bioprinter Shutoff Valve

Overview

- Problem Statement
- Background & Impact
- Competing Designs
- PDS & Client Requirements
- Overview of Designs
- Design Matrix

Current Project Status

Problem Statement

To create an automatic, programmable valve to seamlessly shut off or switch between KSM outputs, and therefore multiple hydrogel resolutions.

- Semester Goals:
  - Integrate with Dean Lab setup (**Voron** 3D printer)
  - Improve **IRE design**
  - Investigate **Clamp design**

Voron 3D Printer

- 3D Bioprinting setup in Dean Lab
  - Augment Voron for 3D bioprinting hydrogel extrusion
- Linear Actuator Integration
  - Design a basic mounting fixture for IRE–linear actuator attachment
  - Synchronize IRE rotation with actuator displacement
  - Develop an attachment for both designs that support future integration with the Voron system.
  - Use Raspberry Pi as the central controller

Figure 1: *Voron 0.2 R1 (v0.2) CoreXY desktop 3D printer [1].*

Electrical Components

Figure 2: *Raspberry Pi mount for Voron [3]*

- Voron works with Raspberry PI for controlling the printer
    - The main software used is Klipper which is controlled by Raspberry PI handling complicated software [2]
    - Raspberry PI can send motion commands to the Voron controlling speed and time for printing through MCU [2]
- Other motors can also be controlled in the Voron

Electronics Testing

- Test for basic Raspberry Pi connectivity
- Test if the component can control the speed of the printer
- Test internal motors on the motor which control movement of the printer (clockwise/Counterclockwise)
- Movement of IRE and rotation

Integrated Rotary Element (IRE)

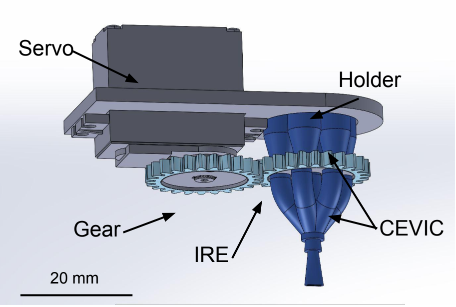

Figure 3: *Schematic of IRE setup*

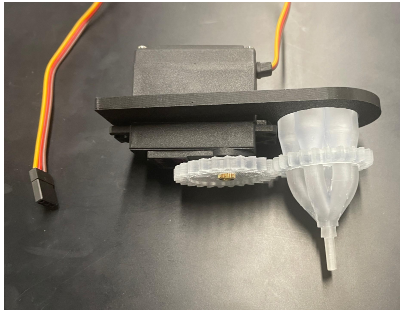

Figure 4: *IRE setup*

- CEVIC device split into two halves with IRE in between
  - Halves held together with pressure fit pin
- Allows output from one channel at a time to pass through
  - Diameter of IRE hole matches CEVIC channels
- Facilitates rapid switching between KSM outputs
  - Attach to Servo motor via Gear
  - Powered by Arduino

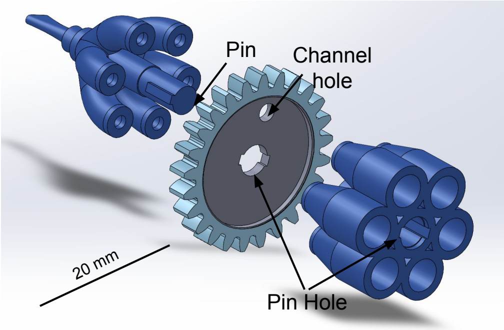

Figure 5: *IRE placement in CEVIC*

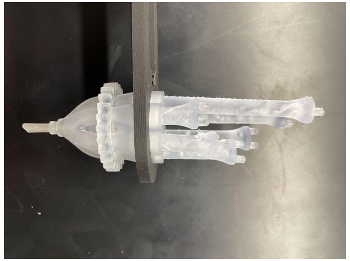

Figure 6: *Various KSM sizes within CEVIC*

IRE Improvements

- Improved locking mechanism
  - Ensure two CEVIC halves stay in contact with IRE surface
- Higher Torque motor
  - Ensure rotation is possible even with contact between IRE and CEVIC halves
- Alternative IRE material
  - Improved leak prevention
- Voron Integration

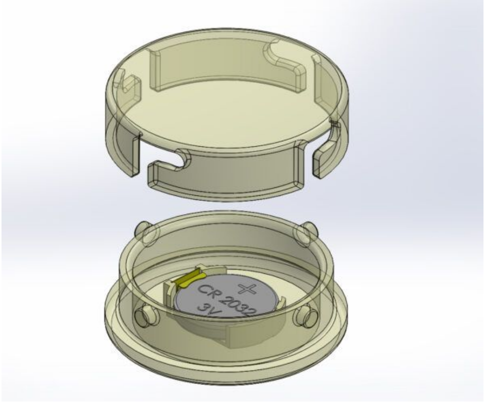

Figure 7: *Twist-locking mechanism [4]*

Figure 8: *High Torque Servo Motor [5]*

Material Improvements - Design Matrix

- **Flexible 80A Resin**
  - Durable, E = 8.9 MPa [6]
  - Compressible but not stretchable, maintain rigidity but allow for a seal [6]
  - Not explicitly biocompatible
    - BioMed Flex 80A Resin exists but would require outsourcing [7]
- **Medical Grade Liquid Silicone Rubber** (LSR)
  - Fulfills USP Class VI and ISO 10993 requirements [8]
  - However, low abrasion resistance

Category	Flexible 80A Resin IRE 		Medical Grade Liquid Silicone Rubber (LSR) IRE 		Medical Grade LSR Insert 	
Leak Prevention (30)	4/5	24	3/5	18	3/5	18
Biocompatibility (25)	2/5	10	5/5	25	5/5	25
Durability (20)	4/5	16	3/5	12	2/5	8
Integratability (15)	5/5	15	3/5	9	4/5	12
Accessibility (5)	5/5	5	2/5	2	2/5	2
Cost (5)	4/5	4	2/5	2	3/5	3
Total (100)	**74**		**68**		**68**	

Table 1: *Material Improvement Design Matrix*

Voron Integration

- Augment current Servo-CEV holder to be more similar to Dean Lab CEVIC extruder mount
- Include features:
  - Rest for CEVIC
  - Screw holes to attach to Voron/Linear Actuator
  - Spot for Servo motor

Figure 9: *Current CEVIC to printing setup attachment, front and back*

Figure 10: *Attachment backside*

IRE Testing

- **Functionality Testing**
  - Updated material choices
    - Check for any wear spots
    - Ensure IRE turns smoothly
    - Minimize leaking/backflow
  - Locking mechanism for pin to keep it in place

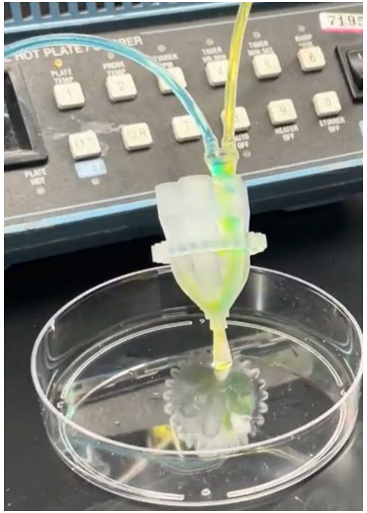

Figure 11: *Fall 2025 Functionality Testing*

Figure 12: *Fall 2025 Durability testing results*

- **Durability Testing**
  - Similar protocol to last semester, update based on properties of new material(s) chosen

Cell Testing

Figure 13: *Syringe Pump with 2 syringes and tubing attached*

- **Cell Viability Testing**
  - Push cells through syringe pump, tubing, and KSM/CEVIC to ensure forces are not too strong
  - Check cell viability after each “stage”
    - Control - cells in gel
    - Syringe pump
    - Tubing
    - KSMs and CEVIC
    - In gel sheets - looking into staining for cell viability
- **Cytotoxicity Testing**
  - Making sure the materials used are not toxic to cells

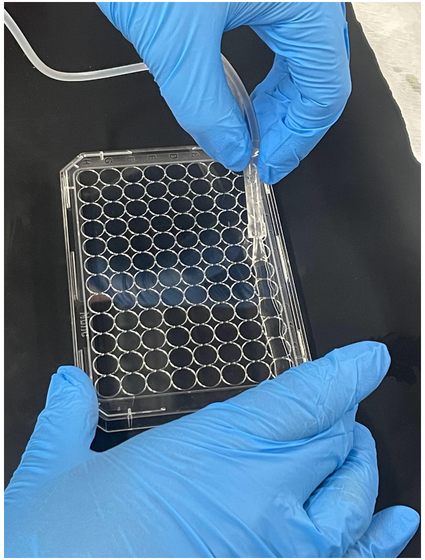

Figure 14: *Hydrogel sheet printed from KSM*

Clamp Design Overview

- **Fall 2025 Semester:**
  - Automated tube clamping using a gear attached to a servo motor (+/- 180 degree rotation)
  - Built a customized tube holder to test various tube clamping mechanisms

- **Results:**
  - Insufficient torque to adequately clamp tubing
  - Potential tube degradation concerns
  - Potential fluid backflow without adequate clamping mechanisms

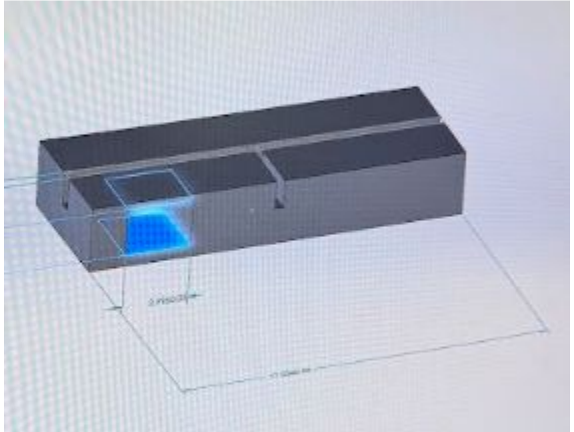

Figure 15: *Fall 2025 Clamp design*

Clamp Design Expansions - Spring 2026

a. Incorporate **sensors** to detect changes in fluid flow or fluid pressure
   - Float switches or capacitive sensors

b. Engineer clamping mechanisms to ensure **unidirectional flow** is paused and maintained

c. Afterwards, develop electric actuation tools to trigger **high speed clamping mechanism** [9]

d. Ensure the clamping mechanisms are **automatable** and **work in unison** with input and output flows

Clamp Design Idea 1

- A solenoid actuator has a uniaxial **push/pull mechanism** that can clamp tubing [10]

- Solenoid actuator is attached **directly on top** of a horizontal disc, that is placed <u>above</u> the CEVIC and KSMs

- The actuator and disk can **rotate 360 degrees in the +/- x direction** to clamp the appropriate tubing

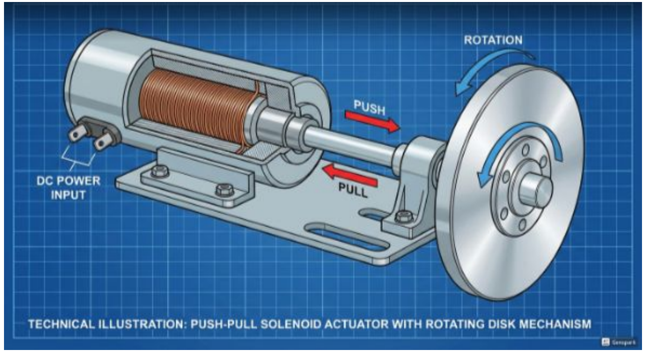

Figure 16: *Solenoid actuator with circular stopper for clamping*

Clamp Design Testing Objectives

- Functional Performance
  - Clamping Force: 5-10 N [11].
  - Achieve >99.5% flow occlusion for soft bioinks at 0.5 bar without damaging tubing [12].
  - Measure leakage rate (<0.05 mL/min target) [13].
  - Confirm response time (<500 ms)
- Tubing Preservation
  - Visual inspection for damage (cracks, tears, abrasion)
  - Verify maintained occlusion performance after cycling
- Integration Testing
  - Sequential switching between 3-6 KSMs
  - Operating Voltage: 12V DC (RasPi compatible)

Semester Timeline

Task Title	Task Owner	Phase	02/06-02/19	02/20-03/05	03/06-03/19	03/20-04/16	04/17-04/24
Brainstorm and finalize additional Clamp mechanism design ideas in design matrix		Phase 0 - R&D					
Clamp CAD drawings		PHASE 1 - Prototype					
SOLIDWORKS part modeling		PHASE 1 - Prototype					
IRE material change implementation		PHASE 1 - Prototype					
Add locking mechanism to IRE pin		PHASE 1 - Prototype					
Design testing plans Clamp		PHASE 2 - Testing					
Cell viability testing - syringe pump		PHASE 2 - Testing					
Attach design to Voron printer		PHASE 2 - Testing					
Test automated sheet printing (Voron)		PHASE 2 - Testing					
Print final product	Everyone	PHASE 3 - Final Design					
Write final report	Everyone	PHASE 3 - Final Design					
Prepare poster	Everyone	PHASE 3 - Final Design					

Table 2: *Spring 2026 Semester Timeline*

Acknowledgements

Professor Paul Campagnola - Advisor

Professor David Dean - Client

Mr. Joshua Alexander - Client

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Questions?