

# Leo Gabriel

Mechatronics Engineering 2025 | University of Waterloo

Robotics · Rapid Prototyping · Machine Design · Automation · Innovation

## Rapid Cryogenic Protein Freezing and Substrate Deposition Robot

### CONSTRUCTION & IMPROVEMENTS

#### Plunge stage

The linear translation stage now accepts crystal loops in goniometer bases held in sample wands. Side-to-side motion during plunges is greatly reduced.

#### Gas exchange manifold

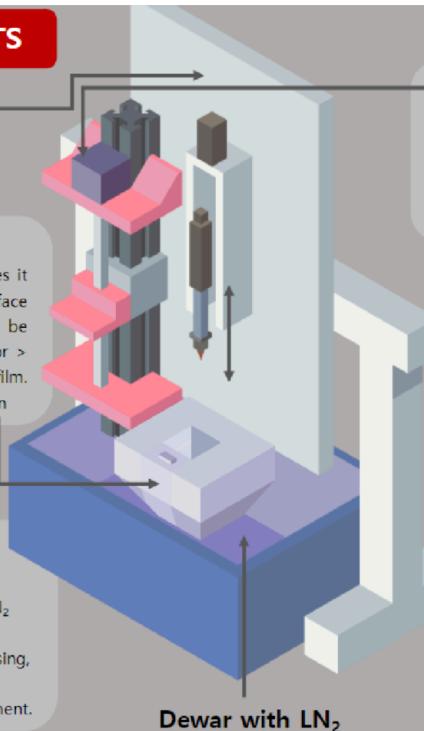
The manifold removes cold gas above the LN<sub>2</sub> surface, replaces it with ambient temperature N<sub>2</sub> gas, and isolates the LN<sub>2</sub> surface from ambient air. A new manifold allows substrate loops to be placed within 5 mm of the LN<sub>2</sub>-air interface and held there for > 10 s without appreciable cooling of the substrate-containing film. Samples can then be cooled within ~2.5 ms of reaction initiation.

#### Insulated Chamber

A stage holding a UniPuck has been added.

#### Control system

A computer running LabVIEW controls plunge motions, gas and vacuum flows, and records sensor data. Direct plunging into LN<sub>2</sub> achieves the shortest reaction time points. Long time points are obtained by translating the sample into the substrate loop, pausing, and then plunging. Different cooling rates can be achieved by plunging at different speeds, with or without cold gas management.



### SUBSTRATE DEPOSITION

#### Vertical motion stage

The substrate deposition apparatus (loop or drop dispenser) is mounted on a vertical motion stage driven by a stepper motor and lead screw. The stage is moved to a desired height via a Python visual interface, setting the time delay between reaction initiation and quenching.

#### Substrate deposition loop

Substrate solution film spans a thin 3D-printed loop, and liquid is transferred to crystals when they move through the loop. Plunge loops open and slip off the goniometer base as the base continues its downward travel. This simple approach to reaction initiation is economical in its use of substrate solution.



#### Drop-on-demand dispenser

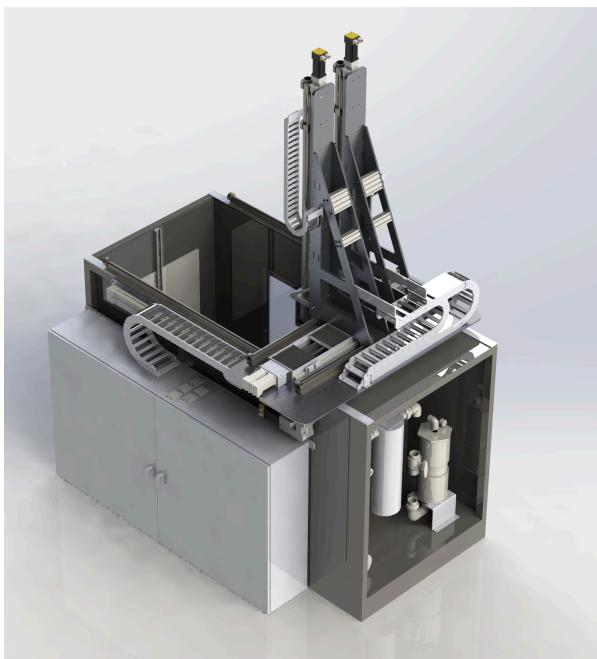
A piezo-driven drop dispenser fires one or a series of drops at the crystal support. The nozzle is close to the crystal support to obtain adequate aiming accuracy. This reaction initiation approach is more precise but requires precise timing to achieve the shortest time delays. Dispense head dead volumes are roughly 1 ml.



Image: Cornell University LASSP, Thorne Lab

- Worked on system to plunge 10-100μm protein crystals into LN<sub>2</sub> at 2m/s, while accurately depositing μL drops of substrate onto the crystal at a target T minus with 5ms accuracy
- Modeled structures and mechanisms in **SolidWorks**
- Increased encoder polling rates by implementing an **STM32** running custom C algorithms, increasing deposition timing accuracy to the 1-10μs range
- Developed a **Python** program for HMI, data processing, setting configuration, and robot control
- Prototyped various mechanisms and improvements for the system using **FDM/SLA 3D printing** as well as **machining**
- Analyzed results using X-ray crystallography at the Cornell High Energy Synchrotron Source beamline

## Ultrasonic Non-Destructive Testing (UT/NDT) Machine



- Tasked with retrofitting a decades-old long since decommissioned 9-axis UT machine
- Performed **design calculations** to ensure machine could reach desired accelerations, speeds, cycle times, and precision metrics
- Selected linear amplifiers as brushless servo drivers to reduce EMI to sensitive UT instruments
- **Communicated with manufacturers** to quote and compare different options for various components
- Identified areas that needed repair, replacement, and improvement
- Designed a waterproof machine, as water jets are used as the ultrasound transmission medium
- Conceptualized a new plumbing system to replace worn-out components
- Redesigned Z-axes and other machine components with a focus on increased **rigidity** for accuracy

## Film Processing Laser Cutter

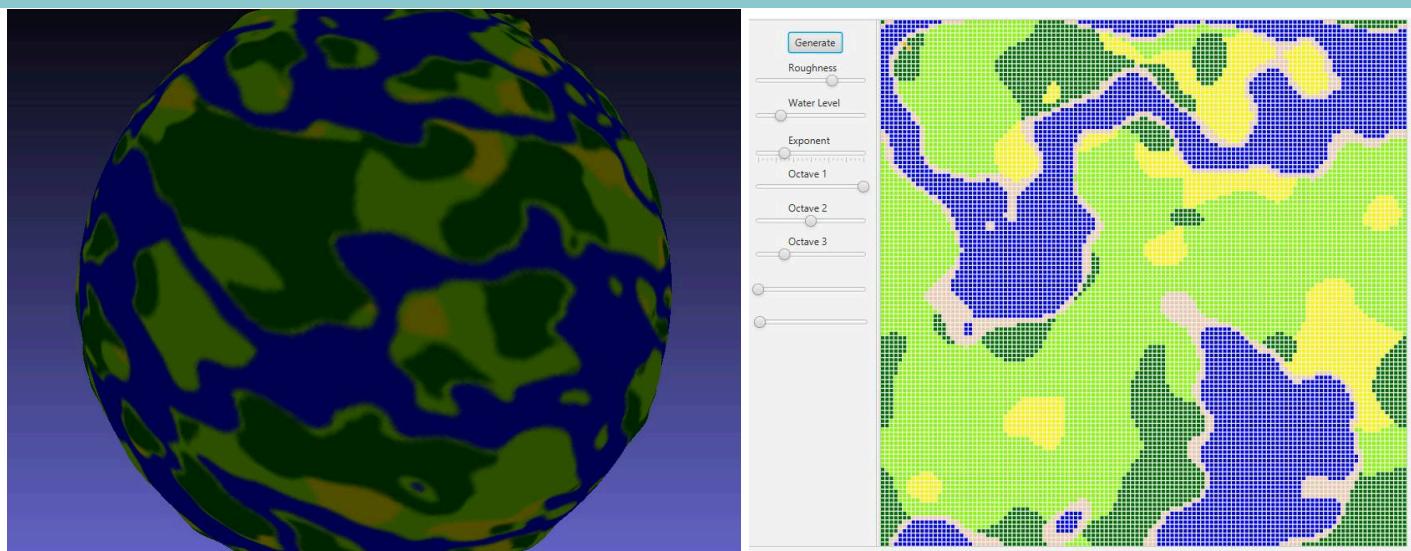
- Owned project to conceptualize, design, and build a film processing machine to automate laser cutting of custom parts on Questat's mass production line for their blood testing cartridge product
- Determined **process flow** for entire production line before diving into this first component of it
- Designed machine in **SolidWorks**, went through several design reviews and iterations before building
- Used **experimentation** as well as **analysis** to make decision on part selection and machine construction
- Developed a **C++/Python** real-time system with **TCP/IP** communication between multiple MCUs, the laser cutter, and an HMI
- Decoded packets between computer software and laser cutter to replicate communications in software
- Generated dimensional **drawings** of custom parts for external machinists, and hand-machined other parts in-house on lathe and mill
- Presented and **documented** the project for technical and non-technical staff use and development

## Barn Door Star Tracker



- A device to stabilize a camera and lens relative to the rotation of the earth for long-exposure astrophotography
- **Zero-budget** project using tools and materials on hand, mostly found from my garage
- Tuned car window motor and bent lead rod to perfectly counteract the effect of earth's  $\omega$
- Successfully took longer exposure photos with less star trailing

## Map Generator



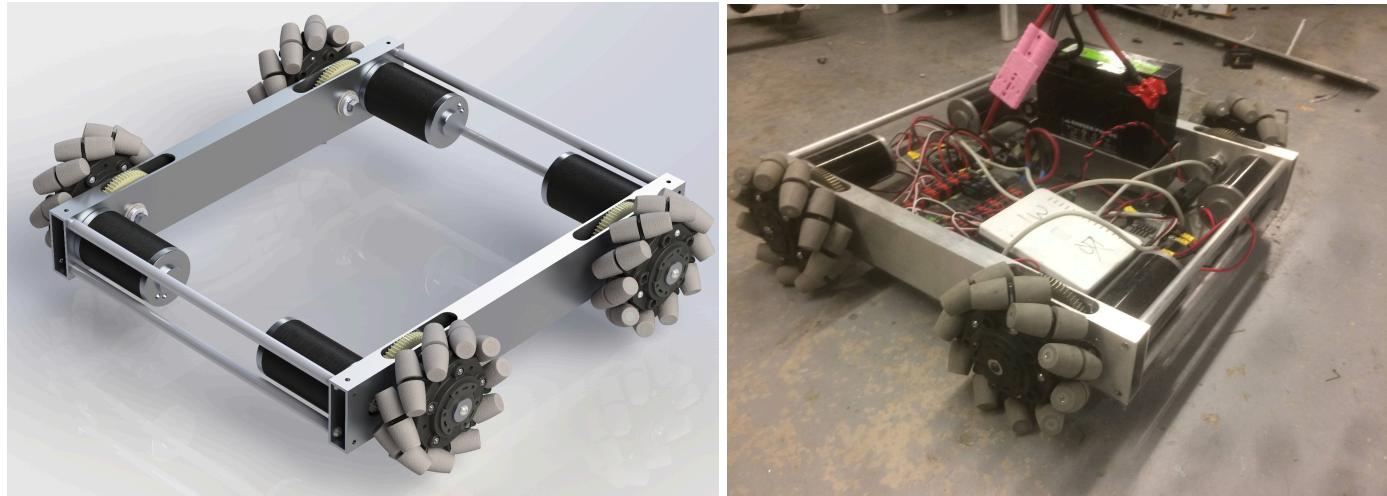
- Used **Java** and open-source libraries to build a procedural map generator
- Generated 3D cylindrical and 4D toroidal noise for 2D/3D maps and globes
- Maps displayed realistically generated and tuneable elevation and climate information
- Exported 3D maps as point clouds to make meshed models in MeshLabs, an open source mesh processing software

## Radar Pan/Tilt Manipulator for Testing Rig



- Tasked with creating a rig to reliably **automate** testing of new radar sensors for the eleven-x device seen
- Adapted a found design for a pan/tilt manipulator to better suit the application and to keep the sensor chip centered
- Rapidly designed, **3D Printed**, and built the device to get testing as soon as possible
- Designed control system around easily procurable and replaceable components (**Arduino**, NEMA 17s, TMC2209s)
- Coded interface to allow easy modification of test configuration and parameters by end-user for varied testing application

## Mecanum Drivetrain



- Designed, manufactured, assembled, wired, and coded individually as an 11th grade project
- Mecanum wheels allow omnidirectional movement with pivoting around different points

## ATmega Piano

- Stretched the limits of the **ATmega328P** MPU to emulate a piano, outputting MIDI and speaker audio
- Used onboard timers to approximate sine and complex waveforms beyond the capabilities of the onboard DAC
- Developed algorithm to generate chord waveforms on the fly due to memory limitations
- Optimized data structures to fit as much note data as possible within the chip's limited EEPROM

## Leo Gabriel

- Chronic **maker** (3D print, home improvement, automation, anything that crosses my mind)
- Likes cooking and baking (you get **free baked goods** on a **weekly** basis)
- Plays tennis, squash, and badminton (at varying skill levels)
- Plays **trumpet** in UW concert and Animusic bands (personal concert for an extra fee) (not really)
- Dabbles in nature **photography** (loves **hiking**)
- Board game enthusiast (Puerto Rico and Everdell are current favorites)