Self Leveling Platform

ME 193: Printable Robotics
Maria Constable & Bence Gyuris

Problem

- Drones often face challenges landing on uneven or rugged terrain, increasing the risk of damage, which can cost between $200 to $600 [1].
- UAV accident data shows that 25-30% of failures stem from difficult landings [2], a significant issue for drones used in supply transport.

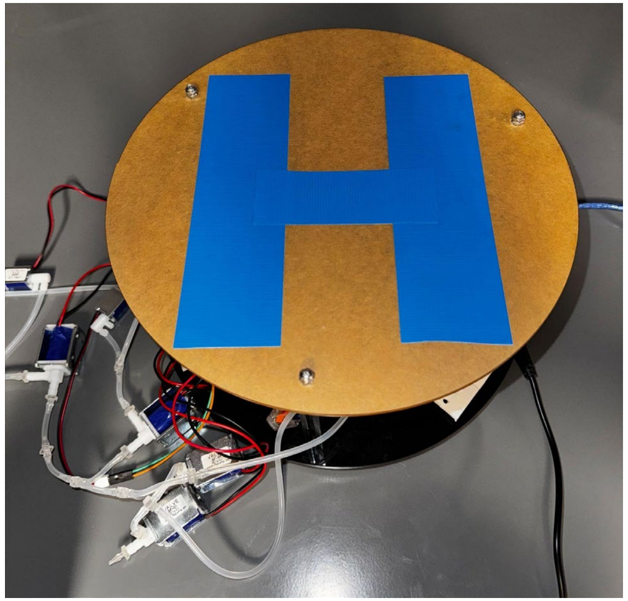
[1] “How Much Does it Cost to Repair a Drone?”, Elizabeth Ciobanu, 2021

[2] “Unmanned aerial vehicles (UAVs): practical aspects, applications, open challenges, security issues, and future trends”, Syed Agha Hassnain Mohsan et al., 2023

Approach

- We are developing a self-leveling landing pad.
- Using 3D printed linear actuators controlled by a microcontroller and an IMU, we will precisely adjust the platform’s tilt.

Results



- The table was fabricated using the laser cutter in Bray and the electronics housing was 3d printed in Nolop.
- We have wired our IMU sensor, Mosfet, Pump, and all our valves.

Impact

- By reducing the risk of damage and repair costs, the pad enhances drone safety and efficiency across diverse terrains, making them more viable for use in **search and rescue**, **agriculture**, and **military** operations.
- Drones can reduce emergency response times by up to 50% [3], but success depends on their ability to land on rough surfaces; our project ensures stable landings, maximizing drone efficiency and deployment in critical situations.

[3] “California city’s drone first responder program could cut 911 response times”, Sally French, 2024

Initial Research

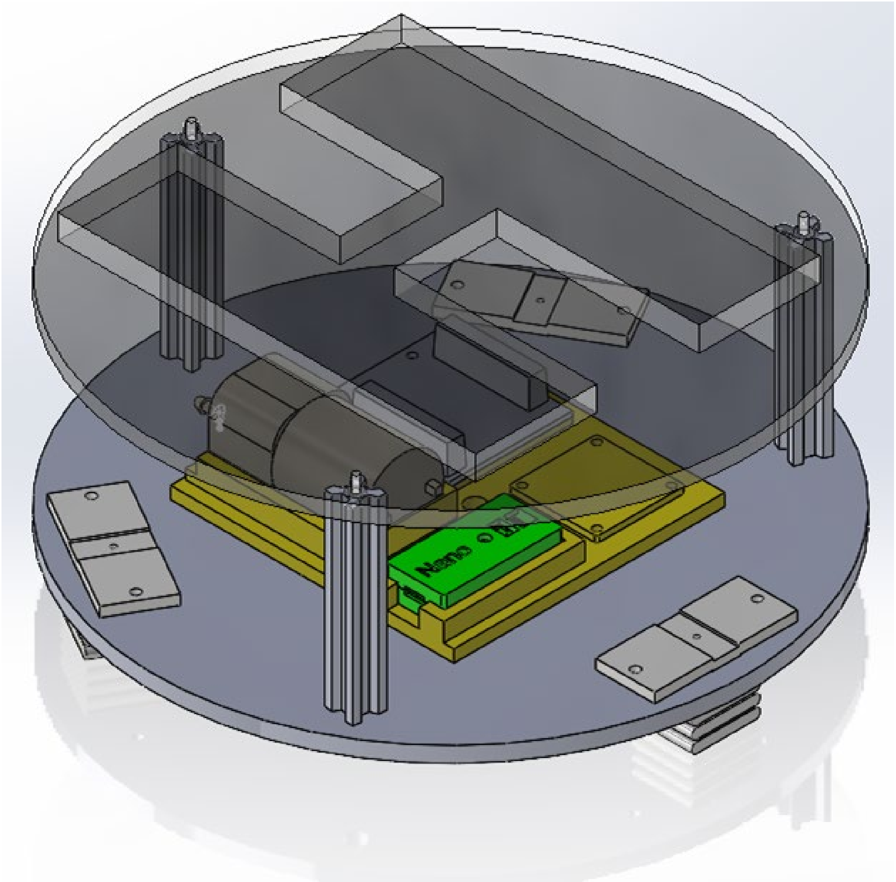
- In paper 1, we found a soft actuator design based on pneumatic networks that can extend and contract for leveling surfaces. This helped us design the type of linear actuator needed for the landing pad [1]. Additionally, the study discusses control strategies for actuators that are compatible with microcontroller-based systems, which align with our use of an Arduino for actuator control.

- In 2, we read about a system that incorporates an IMU sensor to monitor and adjust for angular changes in real-time, which further inspired our design to use an IMU sensor for precise orientation feedback. This ensures that our platform can actively sense and correct tilt [2].

- Source 3 provided us with a method for integrating microcontrollers with sensors to enable responsive actuation. The research focuses on how an IMU-based feedback loop can iteratively correct movements to achieve stability [3].

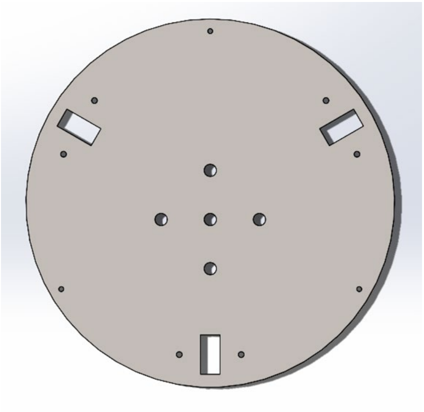
[1] "Soft Robotics: A Review of Recent Developments of Pneumatic Soft Actuators." *Actuators*, 9(1), 3. Srinivas Kumar, Minchul Shin et al., 2020.
[2] "Design and Optimization of an Active Leveling System Actuator for Lunar Lander Application." *Actuators*, 11(9), 263.,Sergio Salvatore, Nicola Amati et al., 2022.
[3] "IMU-based Iterative Control for Hip Extension Assistance with a Soft Exosuit." *ICRA*. Ye Ding et al., 2016.

1. Prototype Fabrication
2. Electronics & Components
3. Control Algorithm

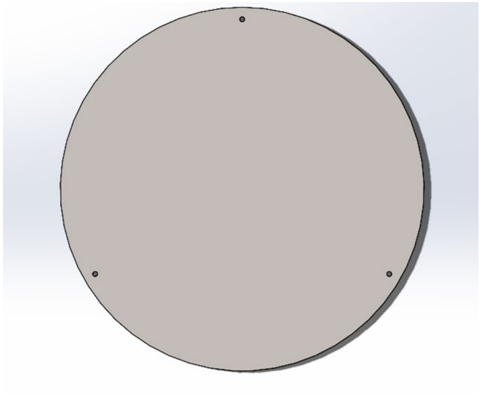


Fabrication: Laser-Cut Components and Motor Hub Iteration

Laser cut platforms

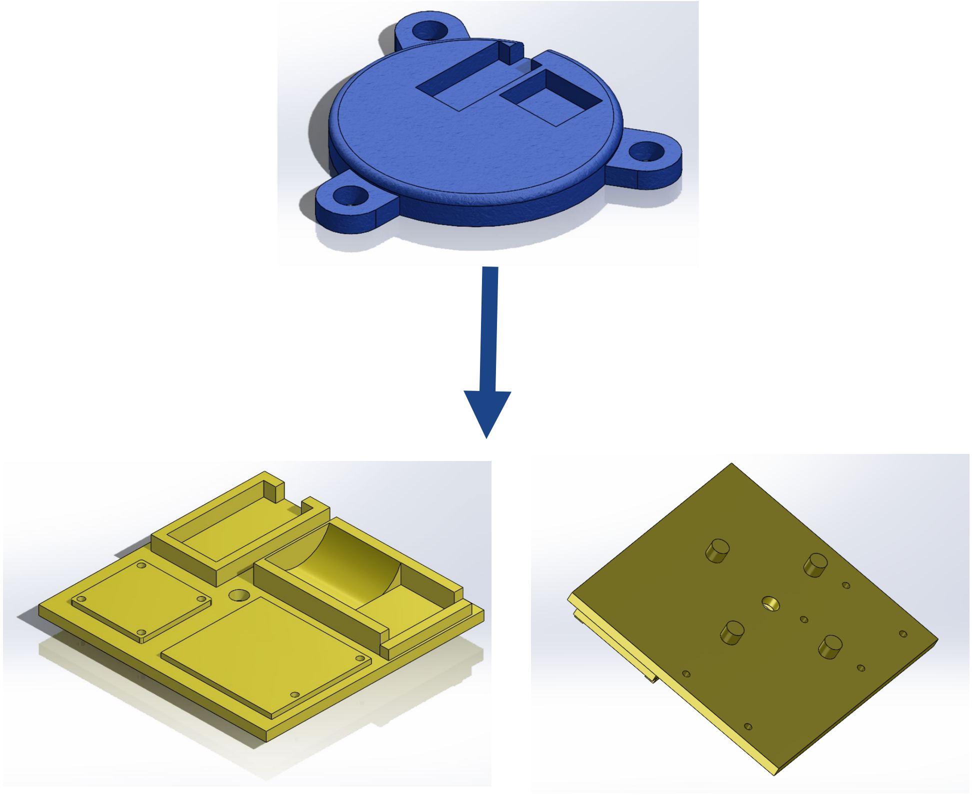


Bottom Platform



Landing Platform

PLA 3D prints

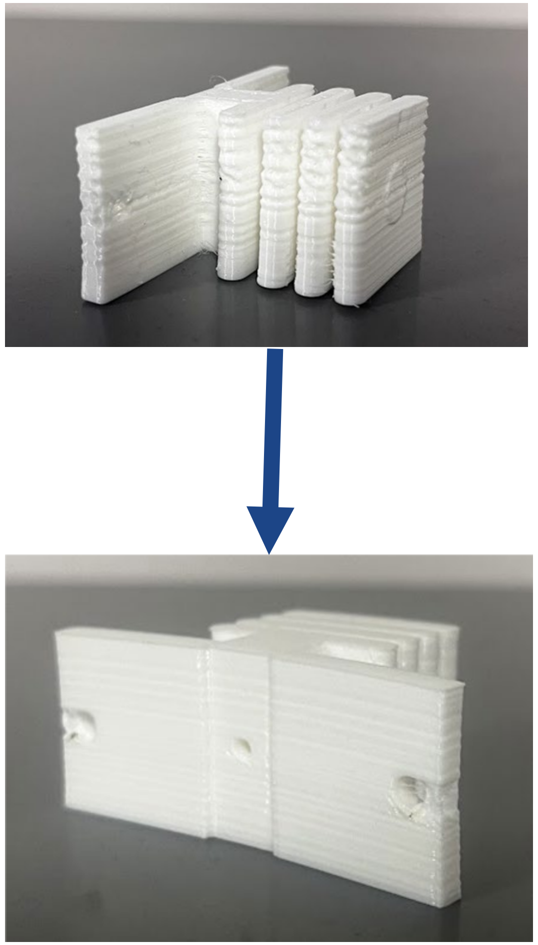


An Unexpected Journey:
3D Printing a Soft Linear Actuator

Main Issues
- Clogging
- Buckling
- Ringing
- Low Surface Adhesion

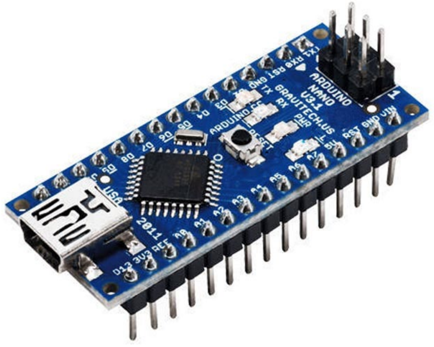
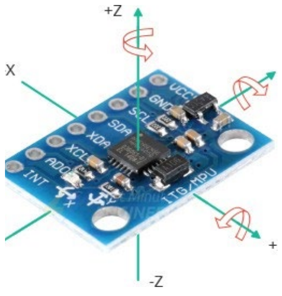
Resolutions tried
- Purging Filament
- Removing Buckled Filament
- First Layer Calibration
- Changing Print Parameters

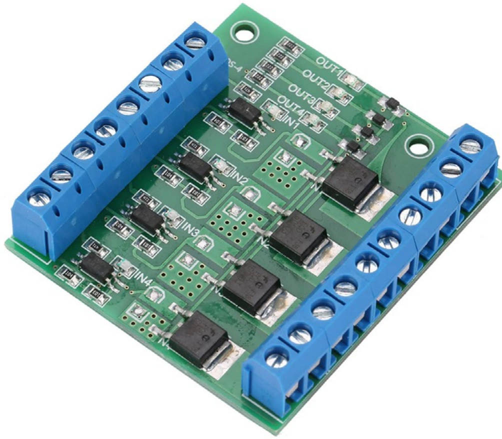
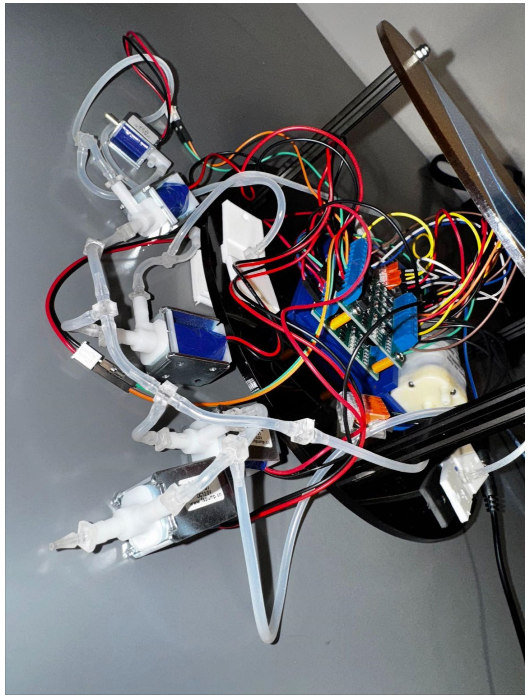
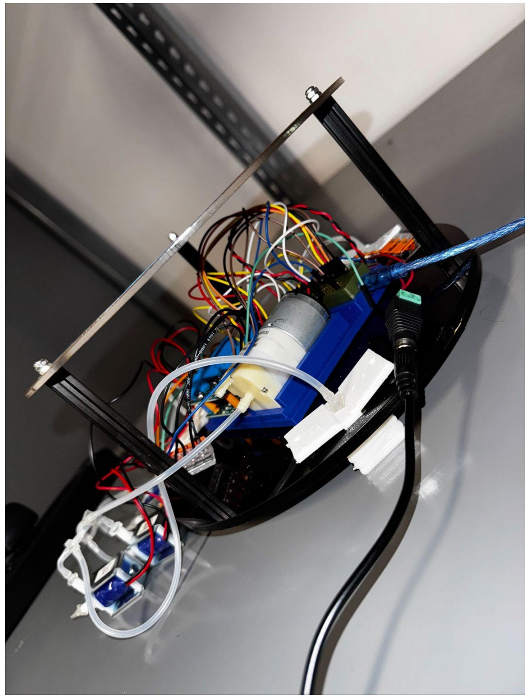
- Printing on Group 8's Printer



Electronics & Main Components

- IMU Sensor- MPU6050
- ESP32 WRoom
- Mosfet Board
- Arduino Nano
- Solenoid Valves
- Pump

Control Algorithm

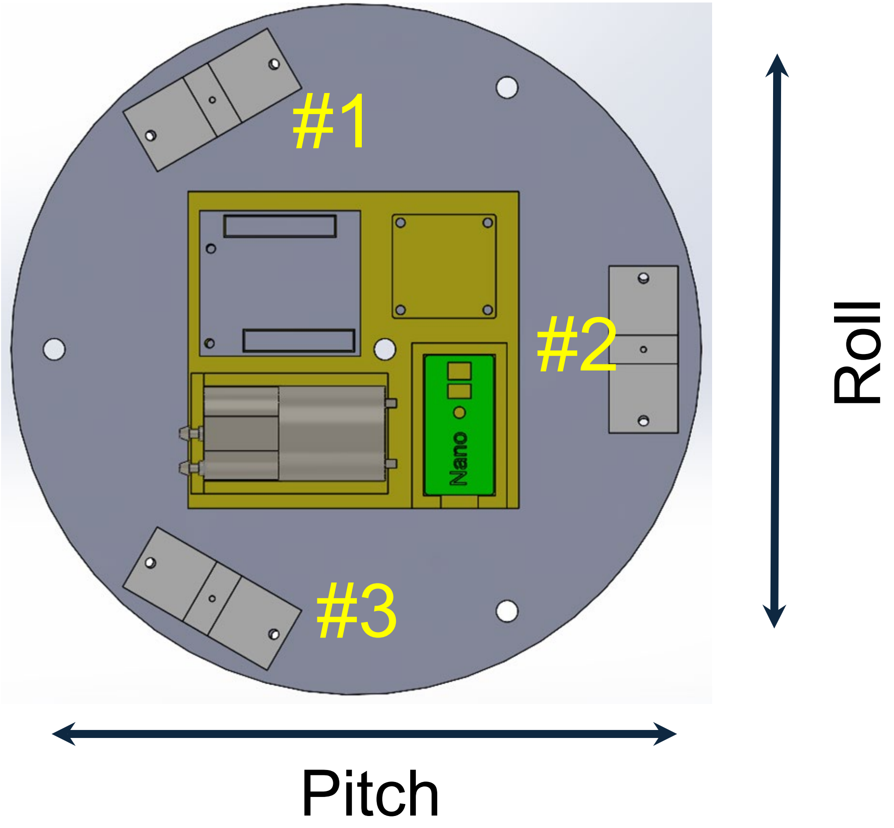
Key control logic

```
// Map pitch and roll errors to actuator adjustments
float leg1Adjustment = -rollError;
float leg2Adjustment = -pitchGain * pitchError;
float leg3Adjustment = rollError;
```

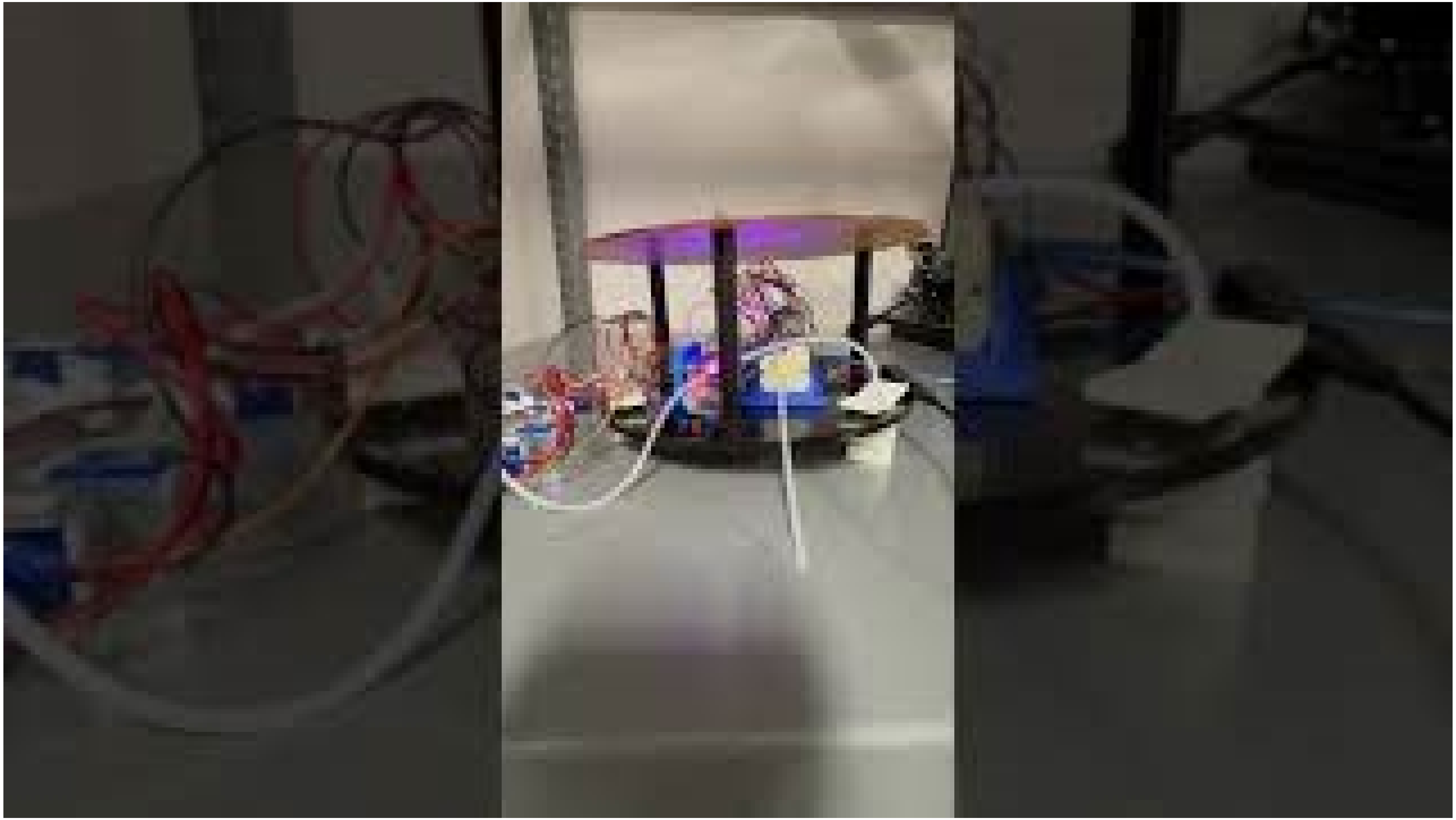
```
Function controlActuator(pumpPin, atmPin, adjustment):
    If adjustment is significantly positive:
        Open pump to inflate actuator
        Close after a short burst

    Else if adjustment is significantly negative:
        Open atmosphere vent to deflate actuator
        Close after a short burst

    Else:
        Keep both pump and vent closed
```



Live Demo



Future Prospects

- Controlled Pressure
- Stronger Motor - for more precise control
- Cleaner Wiring
- Larger Platform

Reflection: Our three biggest takeaways

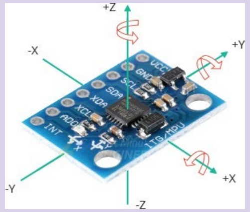
- When working with pneumatics, the airtightness of connections will drastically affect the responsiveness of the system.

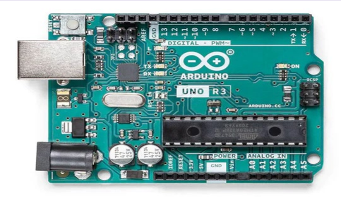
- We developed a good understanding for troubleshooting steps when it comes to printer issues.

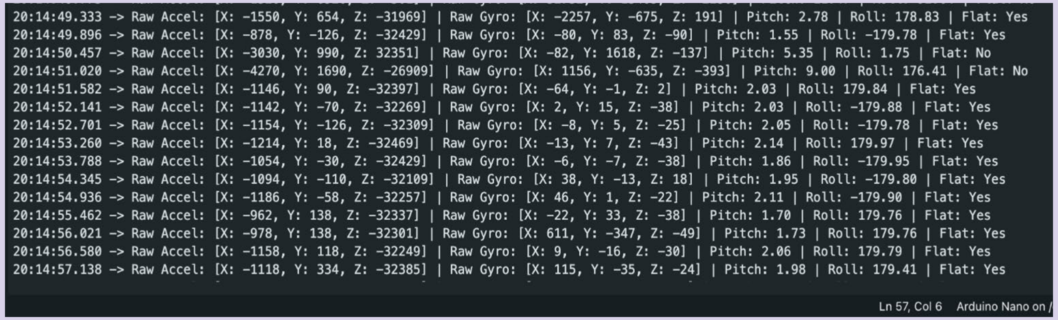
- Integrating sensors into mechanical systems requires a lot tuning to ensure reliable feedback and smooth operation of the actuators.

Questions?

Current work



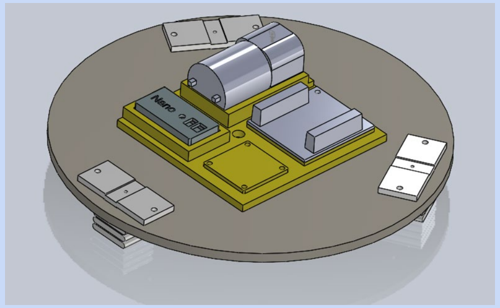


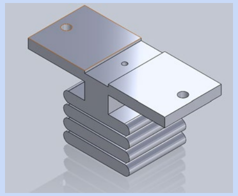


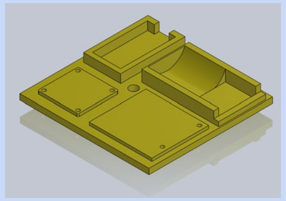
```
20:14:49.333 -> Raw Accel: [X: -1550, Y: 654, Z: -31969] | Raw Gyro: [X: -2257, Y: -675, Z: 191] | Pitch: 2.78 | Roll: 178.83 | Flat: Yes
20:14:49.896 -> Raw Accel: [X: -878, Y: -126, Z: -32429] | Raw Gyro: [X: -80, Y: 83, Z: -90] | Pitch: 1.55 | Roll: -179.78 | Flat: Yes
20:14:50.457 -> Raw Accel: [X: -3030, Y: 990, Z: 32351] | Raw Gyro: [X: -82, Y: 1618, Z: -137] | Pitch: 5.35 | Roll: 1.75 | Flat: No
20:14:51.020 -> Raw Accel: [X: -4270, Y: 1690, Z: -26909] | Raw Gyro: [X: 1156, Y: -635, Z: -393] | Pitch: 9.00 | Roll: 176.41 | Flat: No
20:14:51.582 -> Raw Accel: [X: -1146, Y: 90, Z: -32397] | Raw Gyro: [X: -64, Y: -1, Z: 2] | Pitch: 2.03 | Roll: 179.84 | Flat: Yes
20:14:52.141 -> Raw Accel: [X: -1142, Y: -70, Z: -32269] | Raw Gyro: [X: 2, Y: 15, Z: -38] | Pitch: 2.03 | Roll: -179.88 | Flat: Yes
20:14:52.701 -> Raw Accel: [X: -1154, Y: -126, Z: -32309] | Raw Gyro: [X: -8, Y: 5, Z: -25] | Pitch: 2.05 | Roll: -179.78 | Flat: Yes
20:14:53.260 -> Raw Accel: [X: -1214, Y: 18, Z: -32469] | Raw Gyro: [X: -13, Y: 7, Z: -43] | Pitch: 2.14 | Roll: 179.97 | Flat: Yes
20:14:53.788 -> Raw Accel: [X: -1054, Y: -30, Z: -32429] | Raw Gyro: [X: -6, Y: -7, Z: -38] | Pitch: 1.86 | Roll: -179.95 | Flat: Yes
20:14:54.345 -> Raw Accel: [X: -1094, Y: -110, Z: -32109] | Raw Gyro: [X: 38, Y: -13, Z: 18] | Pitch: 1.95 | Roll: -179.80 | Flat: Yes
20:14:54.936 -> Raw Accel: [X: -1186, Y: -58, Z: -32257] | Raw Gyro: [X: 46, Y: 1, Z: -22] | Pitch: 2.11 | Roll: -179.90 | Flat: Yes
20:14:55.462 -> Raw Accel: [X: -962, Y: 138, Z: -32337] | Raw Gyro: [X: -22, Y: 33, Z: -38] | Pitch: 1.70 | Roll: 179.76 | Flat: Yes
20:14:56.021 -> Raw Accel: [X: -978, Y: 138, Z: -32301] | Raw Gyro: [X: 611, Y: -347, Z: -49] | Pitch: 1.73 | Roll: 179.76 | Flat: Yes
20:14:56.580 -> Raw Accel: [X: -1158, Y: 118, Z: -32249] | Raw Gyro: [X: 9, Y: -16, Z: -30] | Pitch: 2.06 | Roll: 179.79 | Flat: Yes
20:14:57.138 -> Raw Accel: [X: -1118, Y: 334, Z: -32385] | Raw Gyro: [X: 115, Y: -35, Z: -24] | Pitch: 1.98 | Roll: 179.41 | Flat: Yes
```

Ln 57, Col 6 Arduino Nano on /

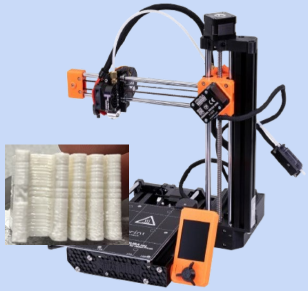
Finalized Design:

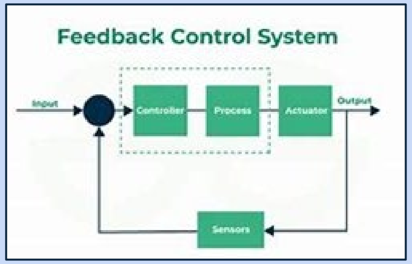






Next steps:





- **In 4**, we found a soft actuator design based on pneumatic networks that can extend and contract for leveling surfaces. This helped us design the type of linear actuator needed for the landing pad [4]. Additionally, the study discusses control strategies for actuators that are compatible with microcontroller-based systems, which align with our use of an Arduino for actuator control.
- **In 5,** we read about a system that incorporates an IMU sensor to monitor and adjust for angular changes in real-time, which further inspired our design to use an IMU sensor for precise orientation feedback. This ensures that our platform can actively sense and correct tilt [5].
- **Source 6** provides a method for integrating microcontrollers with sensors to enable responsive actuation. The research focuses on how an IMU-based feedback loop can iteratively correct movements to achieve stability [6].

Action Plan Timeline

- Week 1: Print linear actuator, Components list ✅
- Week 2: Continue printing, design components, Test circuitry ✅
- Week 3: Fabrication and assembly, begin control loop algorithm ✅
- **Week 4: Complete algorithm & conduct initial testing.**
- Week 5: Troubleshoot and finalize design for demonstration.

[4] "Soft Robotics: A Review of Recent Developments of Pneumatic Soft Actuators." *Actuators*, 9(1), 3. Srinivas Kumar, Minchul Shin et al., 2020.
[5] "Design and Optimization of an Active Leveling System Actuator for Lunar Lander Application." *Actuators*, 11(9), 263.,Sergio Salvatore, Nicola Amati et al., 2022.
[6] "IMU-based Iterative Control for Hip Extension Assistance with a Soft Exosuit." *ICRA*. Ye Ding et al., 2016.