Southern New Hampshire University | College of Engineering, Technology, and Aeronautics

EG 310 Spring 2024 Final Presentation
Project: Altimeter Chamber
Team: Vacuum Vibes
Members: J. Swarbrick, J. Lear, D. Kimball

Final Presentation Agenda

- Project Description / Concept of Operations Summary (CONOPS)
- System Requirements and Verification
  - Functional
  - Performance
  - Physical
  - Safety
  - Enviromental
- Conceptual and Detailed Design
- Fabrication and Integration
- Comprehensive Performance Test
- Final Budget
- Conclusion and Lessons Learned

Project Description / Concept of Operations Summary (CONOPS)

- Stakeholders: Range from hobbyists to the manufacturing companies that manufacture altimeter components/assemblies. Others include but are not limited to climbing companies and aviation mechanics.
- Users: Closely related to the stakeholders, ranging from individuals to large corporations that are interested in experimentation and/or testing of altimeters or other pressure-related equipment or processes.
- System Description: Consists of a control unit and a vacuum chamber. The control unit needs a user-provided computer to run Arduino and LabVIEW programs. The control unit, consisting of two programs, will read environmental conditions and chamber pressure as well as control chamber pressure using a vacuum pump and pressure relief valves. The vacuum chamber will be cylindrical in shape, able to hold a standard altimeter and be able to maintain position on a workbench.
- Operational Environment: Includes both climate-regulated and non-climate-regulated facilities. Climate-regulated facilities refer to manufacturing plants where test/maintenance operations occur. Non-regulated facilities may include a hobbyist's garage or an airplane hangar work bench subject to varying conditions.
- Support Environment: Varies due to the amount of use. The more it's used, the more frequently calibration would need to occur. The calibration tools required for supporting this system include a known accurate altimeter, a list of associated elevations derived from barometric pressures, and data collection capability.
- Operating Modes: Consists of a single, user supplied input, to adjust chamber pressure for cross-referencing altimeter readings.
- Use: The vacuum chamber can be used daily or infrequently. One cycle of the system will replicate environments for testing altimeters in less than five minutes.
- Risks: Concern both user and stakeholders. The user may be injured due to negative pressures involved in operating the system. An example of a risk to stakeholders is where equipment failures due to negative pressure may lead to damage to nearby objects.
- Impact Considerations: System will provide an affordable option to the market and allowing users with less experience to perform the same tasks as more experienced personnel.

System Requirements and Verification

Functional Requirements

Req. ID or Se ction	Req. Title	Statement Subject	Req. Value	Performance	Margin	Notes/Basis
3.1.1	Autonomous	Simulation elevation from 0-5000m automatically	N/A	Complies	N/A	Met, Tested up to 7 km
3.1.2	Pressure	System shall incorporate an electric pressure sensor	N/A	Complies	N/A	Met, Inspection
3.1.3	Display	System shall display chamber pressure in [kPa]	N/A	Complies	N/A	Met, Demonstration
3.1.4	User Commands	System shall respond via user interface in LabVIEW	N/A	Complies	N/A	Met, Demonstration
3.1.5	Temperature Changes	System shall account for variations in pressure due to temperature change	N/A	Complies	N/A	Met, Demonstration and Analysis

System Requirements and Verification

Performance Requirements

Req. ID or S ection	Req. Title	Statement Subject	Req Value	Performance	Margin	Notes/Basis
3.2.1	Test Cycles	Test cycles should take no longer than [5 minutes]	T ≤ 5 min	25 seconds	1200%	Met, Test
3.2.2	Accuracy	System shall have altitude accuracy of 3%	H ± 3%	TBD	N/A	(Not tested, school's manometer broken, gauge used to verify has lower accuracy than ± 3 %)
3.2.3	Vacuum Pump	System shall utilize electric vacuum pump to achieve altitude simulation	N/A	Complies	N/A	Met, Inspection
3.2.4	Current Draw	System shall draw no more than 10 amps under operation	I ≤ 10 A	3.3A	-603%	Met, Analysis

System Requirements and Verification

Resource and Physical Requirements

Req. ID or S ection	Req. Title	Statement Subject	Req. Value	Performance	Margin	Notes/Basis
3.3.1	Transporation and Storage	System shall be packaged into one unit for transportation	N/A	Complies	N/A	Met, Demonstration
3.3.2	Altimeter	System accommodate a standard 3.5-inch pattern altimeter	N/A	Complies	N/A	Not Met
3.3.3	Weight	System shall weigh less than 15 lb	W ≤ 15 lb	TBD	N/A	Sub-10 Lb- Met

System Requirements and Verification

Safety Requirements

Req. ID or Section	Req. Title	Statement Subject	Req. Value	Performance	Margin	Notes/Basis
3.4.1	Under-Pressure	System shall warn users of under pressure	N/A	Complies	N/A	De-scope
3.4.2	Over-Pressure	System shall warn users of over pressure conditions	N/A	Complies	N/A	De-scope
3.4.3	Relief valve	System shall incorporate an emergency relief vent	N/A	Complies	N/A	De-scope
3.4.4	Operation	Main chamber shall operate without needing operation within 5 ft	N/A	Complies	N/A	Met, Demonstration
3.4.5	Hazardous materials	System shall not have exposed hazardous materials	N/A	Complies	N/A	Met, Demonstration

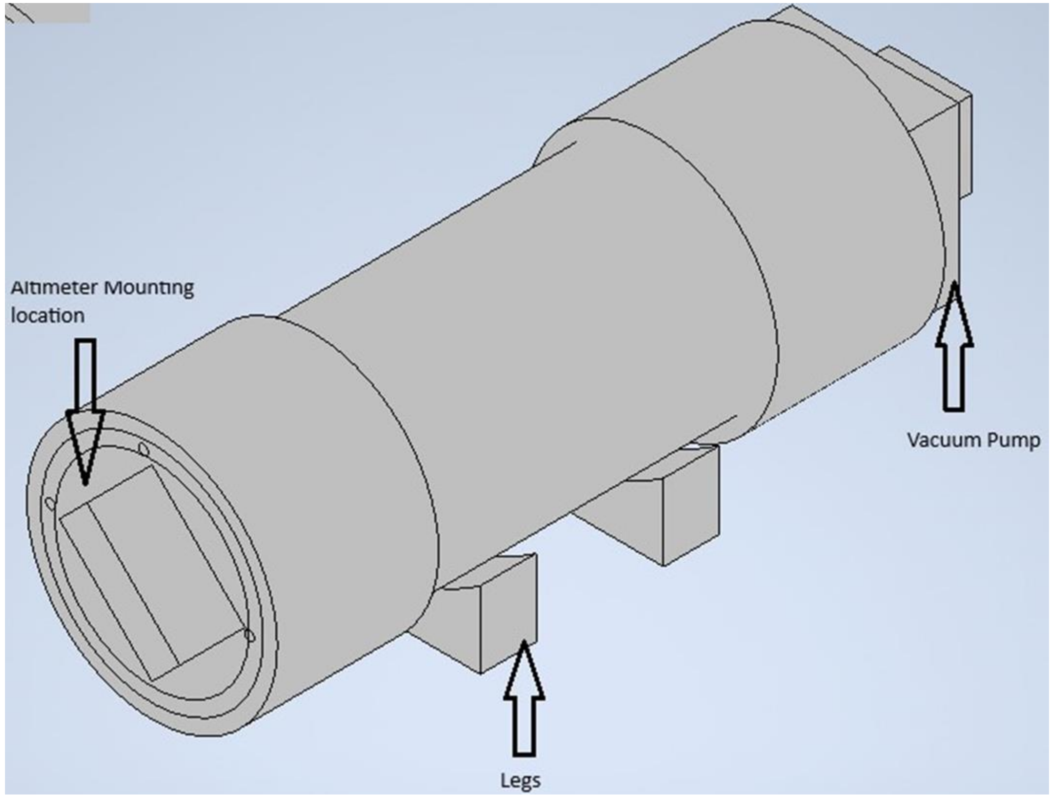
System Requirements and Verification

Enviromental Requirements

Req. ID or Se ction	Req. Title	Statement Subject	Req. Value	Performance	Margin	Notes/Basis
3.5.1	Ambient tem perature	System shall operate at ambient temperature ranging from –10°F to 110°F	–10°F ≤ T ≤ 110°F	TBD	TBD	(Not tested, environmental condition simulator not available)
3.5.2	Stable	System shall rest in a stable manner on a work bench	N/A	Complies	N/A	Met, test
3.5.3	Dry	System shall only operate in dry environments of ≤ 60% humidity	H ≤ 60%	TBD	TBD	(Not tested, environmental condition simulator not available)

Conceptual Design

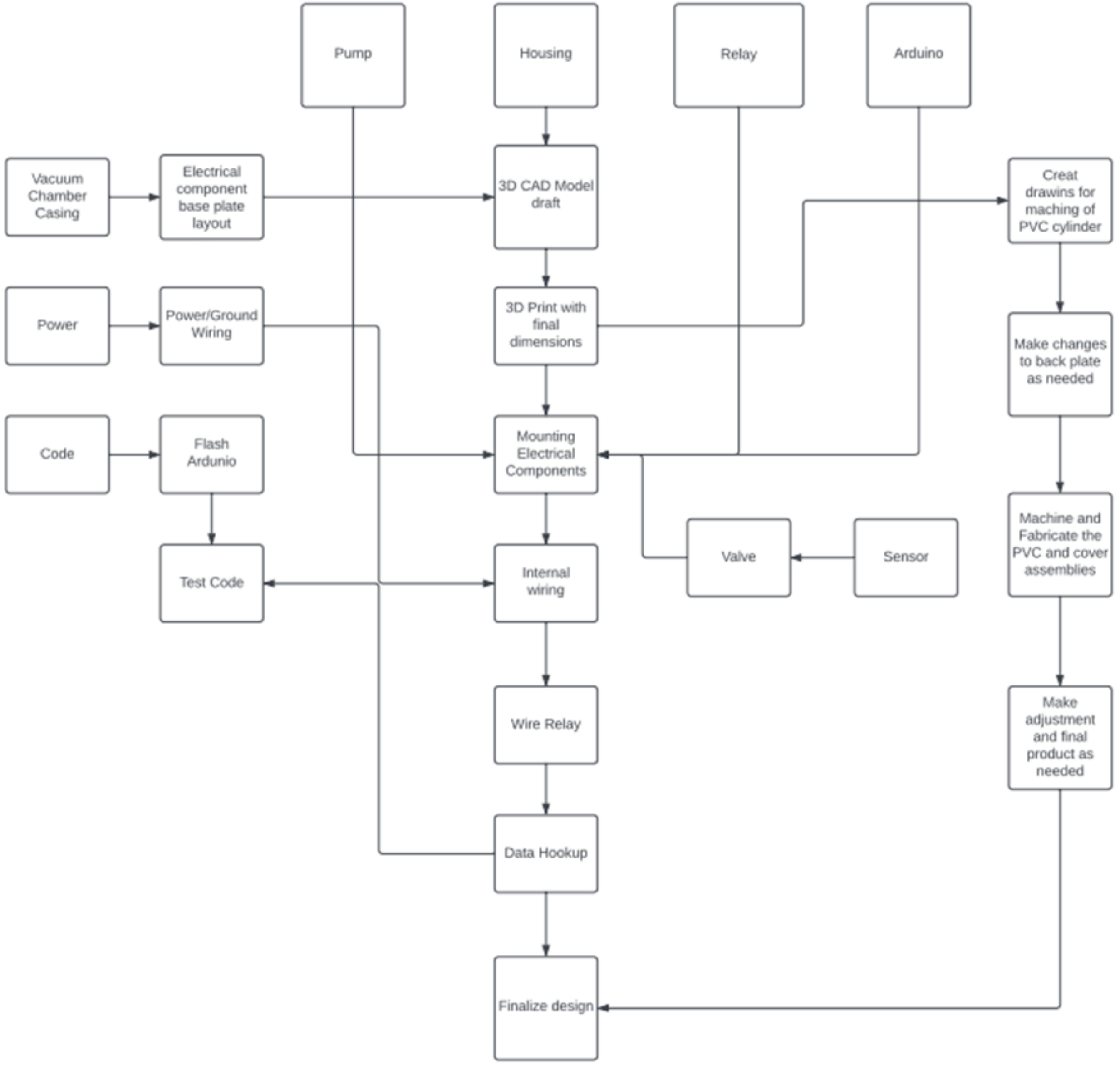
- Composition:
  - Main tube with one fixed and one removable cap
  - Electrically operated vacuum pump
  - Electrically operated release valve
  - Vacuum Sensor
  - Arduino control board
  - LabVIEW User Interface



Southern New Hampshire University

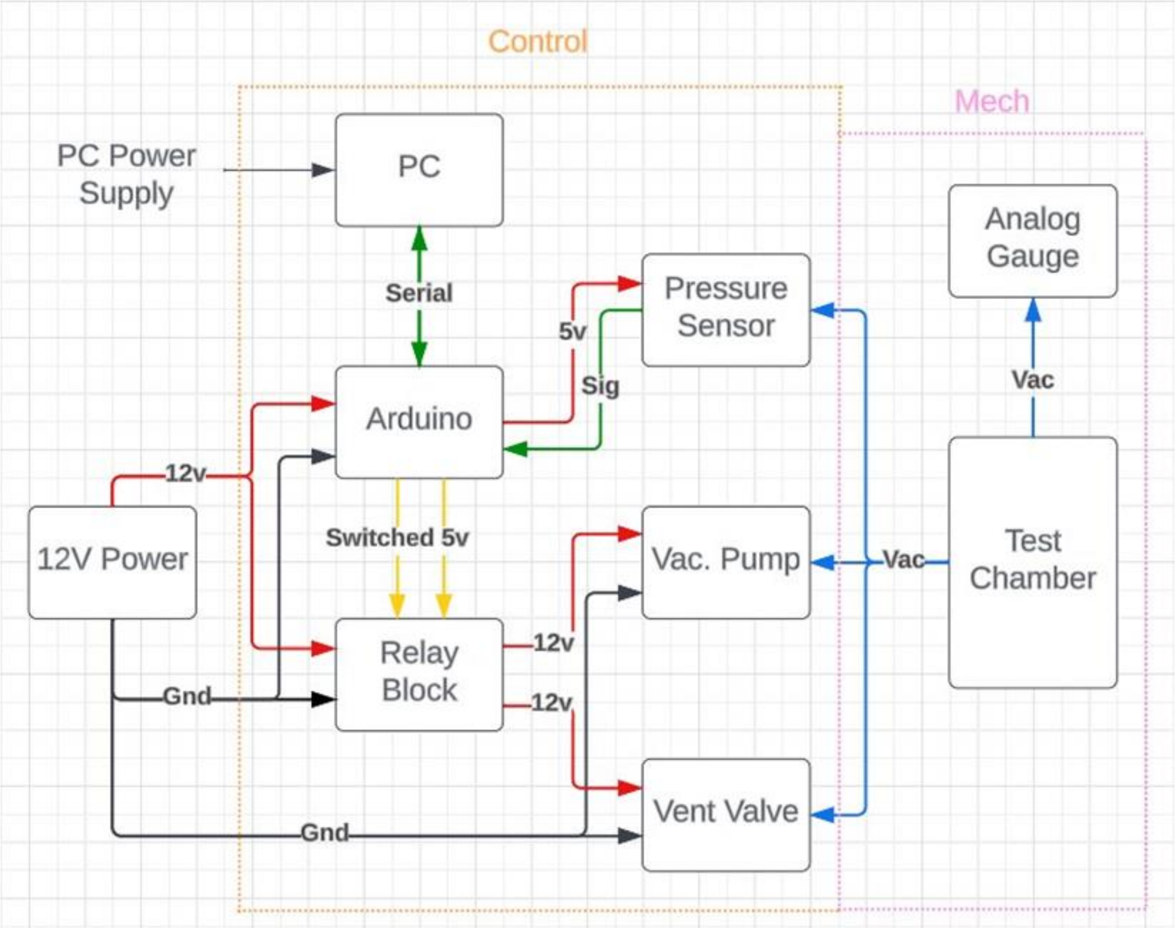
Detailed Design-Full System

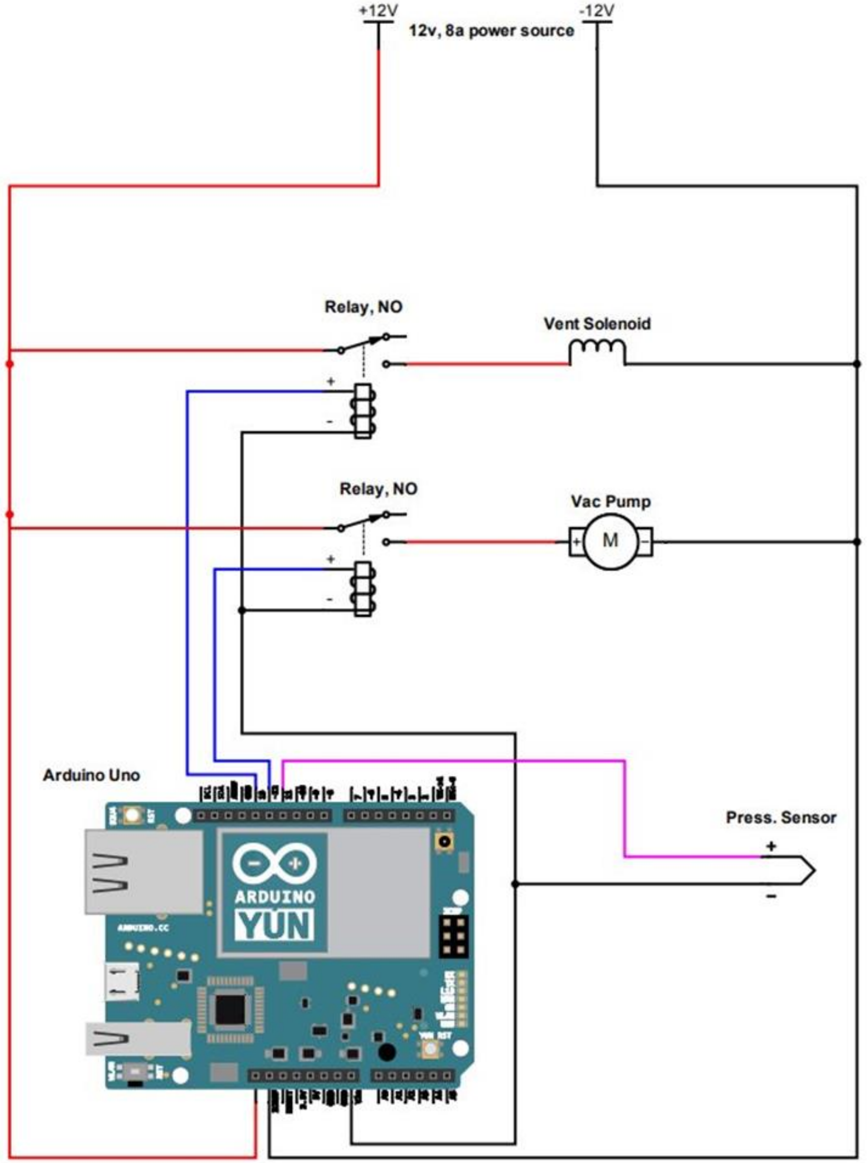
Detailed Design- Process



Southern New Hampshire University

Detailed Design
Electrical Subsystem

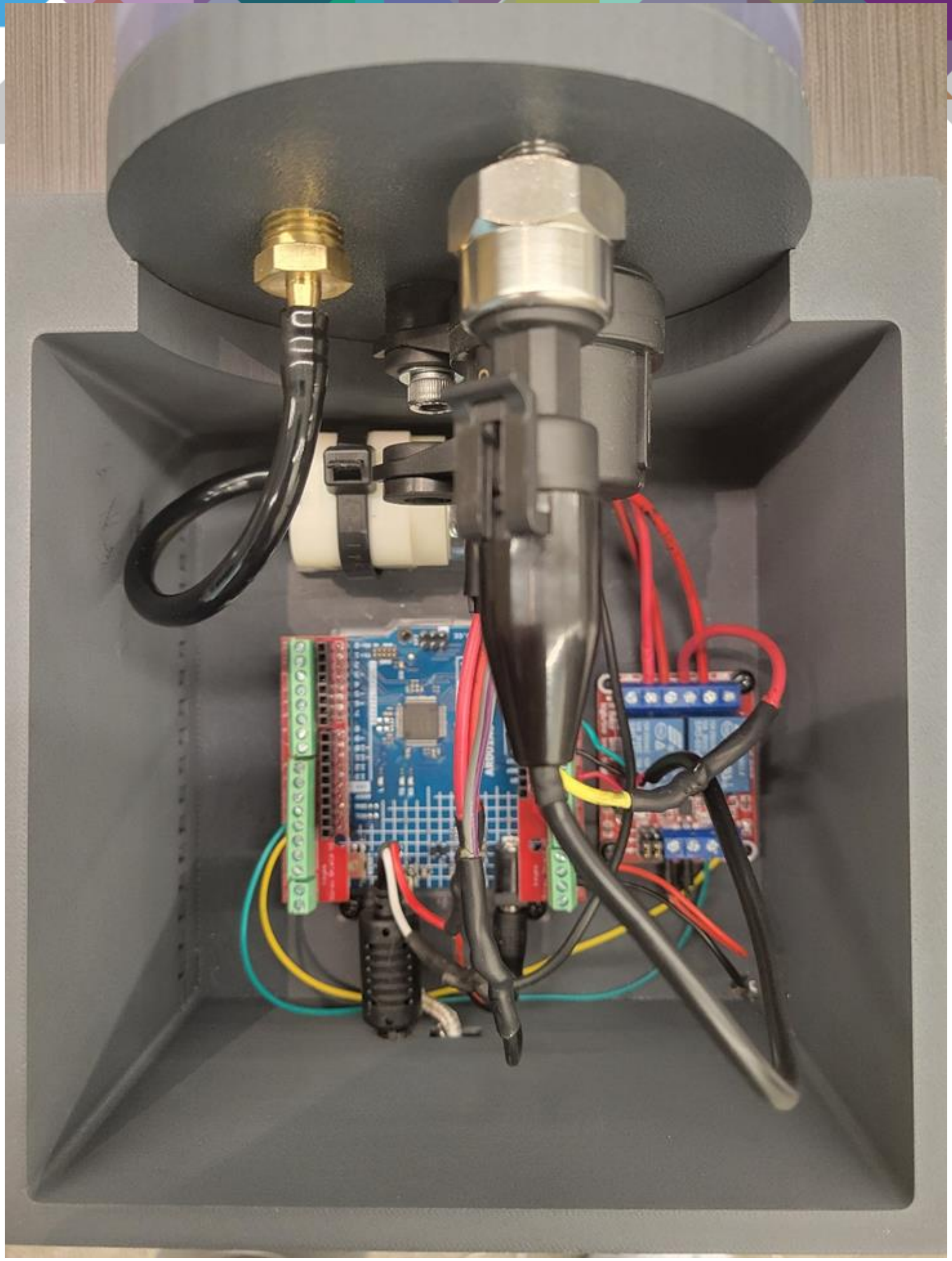




Southern New Hampshire University

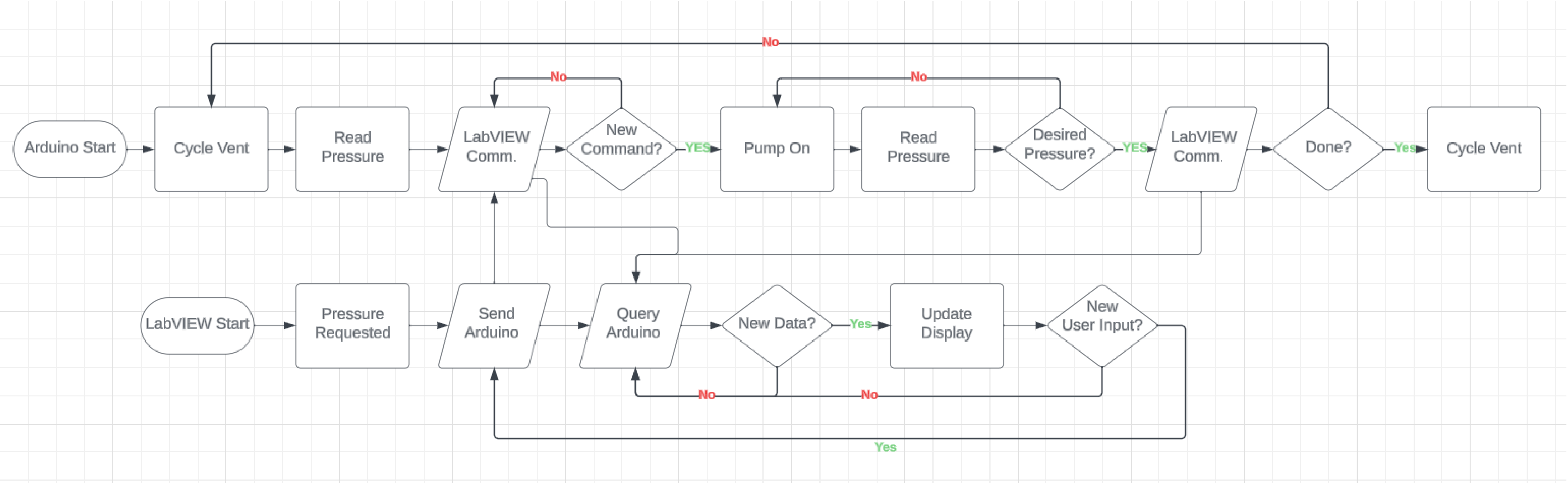
Detailed Design

Electrical Subsystem



Detailed Design

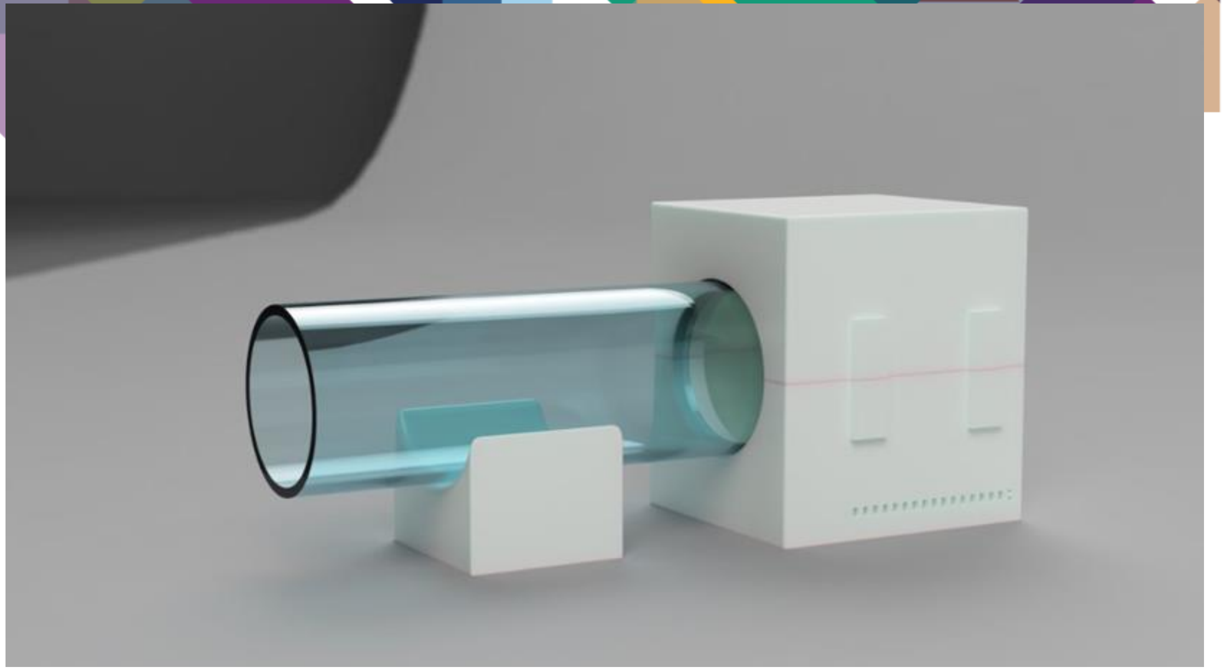
Software Subsystem



Southern New Hampshire University

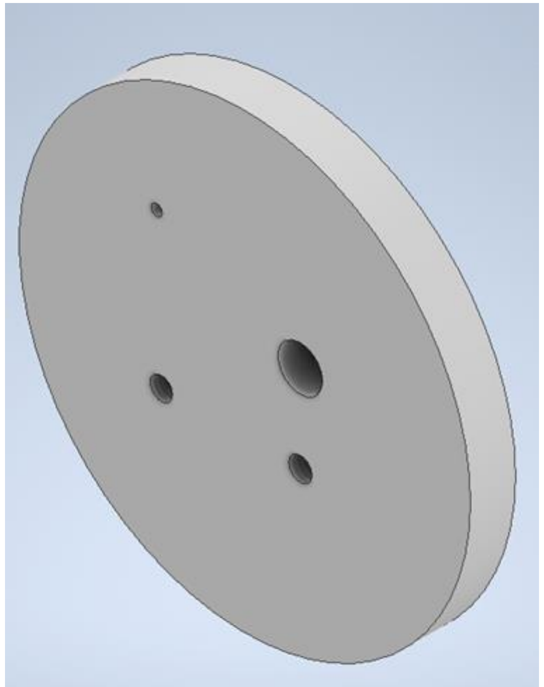
Detailed Design

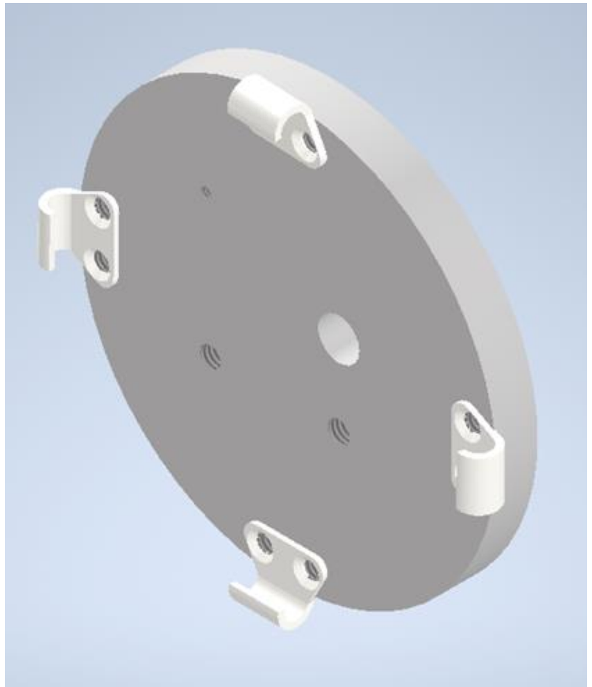
Mechanical Subsystem



This Subsystem includes:

1. PVC pipe machining
2. Closure caps and latching clamps.
3. Electrical components box
4. Analog pressure gauge.
5. PVC pipe stand.

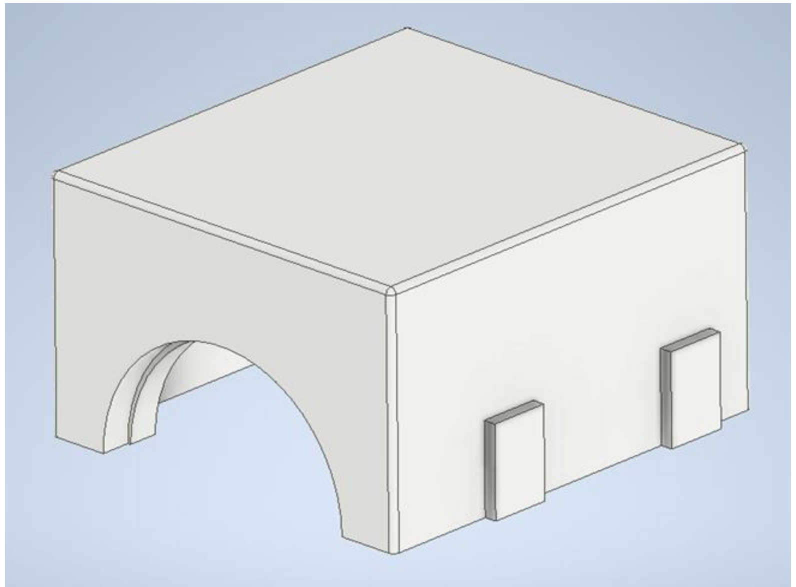


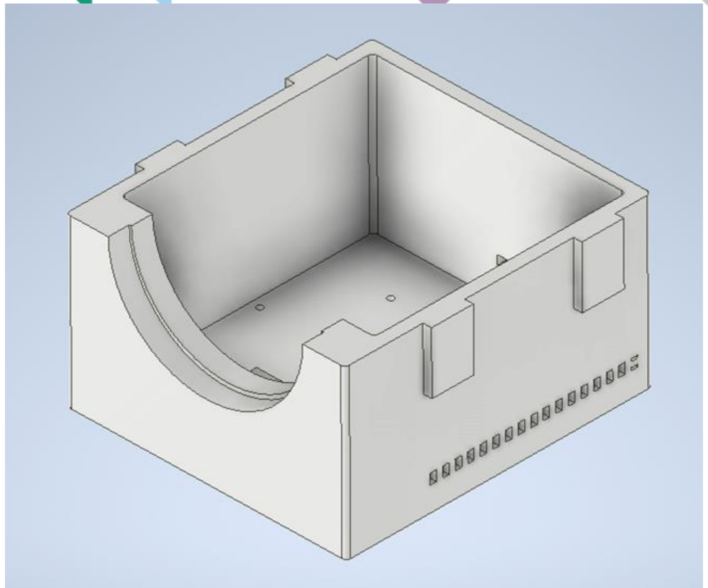


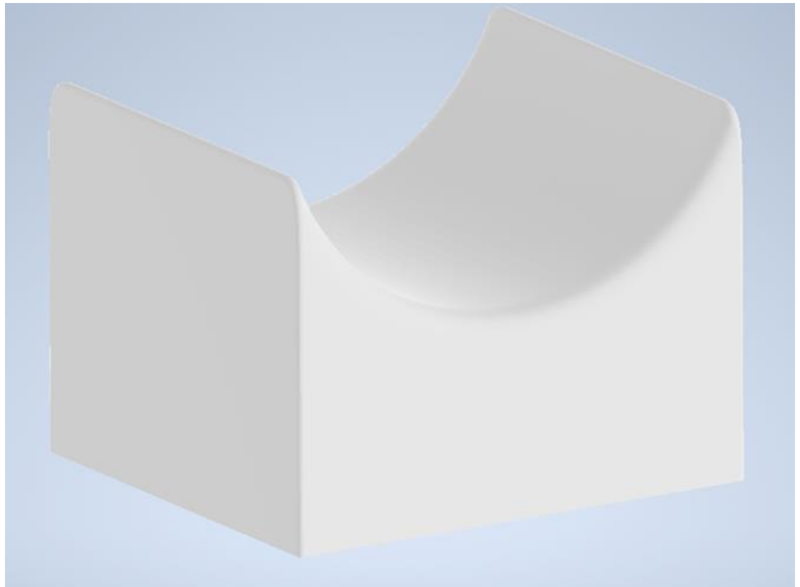
Southern New Hampshire University

Detailed Design

Mechanical Subsystem







Southern New Hampshire University

Fabrication and Integration

This consisted of the four main processes:

1. 3D printing
    - Five components were printed using ABS plastic as shown in the mechanical subsystem The caps were 100% infill because they were structural parts, and the back plate was tapped with a 1/8"-18 NPT hole and ¼"-18 NPT hole.
2. Machining
    - PVC pipe had a flat mill for easy drill of the ¼"-18 NPT hole and for ease of the clamp installation.
3. Electrical subsystem assembly
    - Consisted of mounting the electrical components to the housing as shown in the electrical subsystem. Screw-down connectors and soldering was used for this.
4. Subsystem integration
    - Once the above components were completed, we needed to assembly them all together. The O-ring we originally had did not seal properly so for a quick temporary fix we had to caulk the insides of the caps to get a proper demonstration.

Comprehensive Performance Test

Our key performance and operation requirements were verified during testing. Below shows the goal of each test:

1. System ability to simulate altitudes from 0-5000m.
    - The system accurately simulates up to 7000m
2. System ability to display chamber pressure during testing.
    - Displays both on the analog gauge and on the Arduino serial port monitor.
3. System ability to respond to user commands; System ability to automatically calculate correct simulator pressure.
    - Will pressure to input pressure and automatically simulates the pressure.
4. System ability to complete test cycle in <5 mins; System accuracy +/- 3%.
    - Pressure reached in approx. 25 seconds and venting takes less than 2 seconds, leaving over 4.5 mins for verification.
    - System accuracy not analyzed; Department's manometer requires service, no other instrumentation with appropriate capabilities available.

Final Budget

QTY	Description	Status	Part No.	Use	Cost	$Total
1	HYUDYO DC Vacuum Pump (12V ,1.8A)	Received	B0B6VKDJK4	Pressure Regulation		$9.54
1	Check Valves - 5mm (10 Pack)	Received	Marhynchus8gn7yedswz-13	Anti-Pressure Backflow		$9.06
1	Canister Purge valve	Received	RB-D547	Vent pressure after cycle		$13.99
1	5V relay module	Received	WJ-00010	Electronically Switch Components on/off		$5.90
1	Arduino Uno R4	Received	ABX00080	Control System		$22.00
1	Power Supply - (12V, 8A)	Received	PW12-8A	Power System		$17.99
1	Screw Shield Prototype shield	Received	GR-US-168	Secure Wiring		$9.99
2	PVC Clear Rounds	Received	Not used in Production	End Caps	$16.00	$32.00
1	4 Inch Diameter Clear PVC	Received	PVC SCH40/SCH80	Chamber Body		$38.00
1	Adhesive	Received	4200130	End Cap Sealing		$10.18
1	Toggle clamps with 1-inch screws (6 pack)	Received	4001-6PK	Removable end caps		$6.99
1	Vacuum Gauge (1/4" NPT)	Received	GDD001	Reference Gauge		$12.96
1	3/8" barb x 1/4" NPT Barb Fitting	Received	3/8" Barb x 1/4" NPT Male Pipe	Manometer Adapter		$5.99
1	4" ID O-Ring (5 Pack)	Received	Not used in Production	End Cap Sealing		$12.64
1	5mm barb x 1/4" NPT Barb Fitting	Received	B0C3V3F21S	Adapter for Vac Pump		$7.99
					Total:	$215.22

Conclusion

Overall, we produced a prototype that could accept user inputs and simulate altitude pressure conditions. As always with every design process we all had challenges. The problems encountered during the design process:

1. Communication instability between Arduino Uno R4 and LabVIEW.
2. Sealing the surface between the chamber housing and the front plate.
3. When the vacuum pump is turned off, the system slowly bleeds up through the pump.
4. Losing a teammate in the middle of the initial design phase of the project.

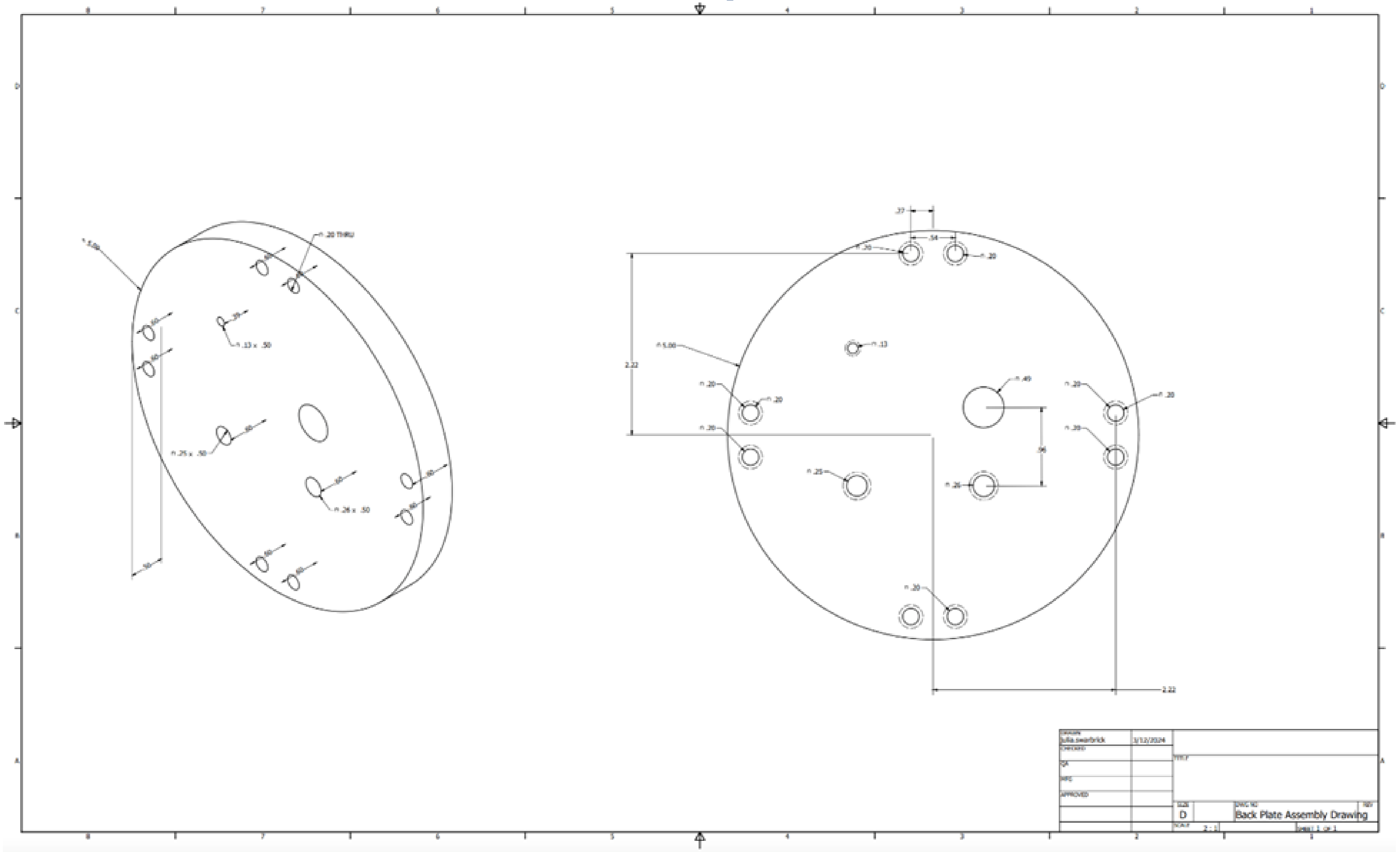
Lessons Learned

1. Management skills: As a team we decided to switch the team manager role so we could all experience the position. This allowed for all group members to explore if they wanted to be a program manager in the industry after graduating.
2. We all learned more about altimeters, applying hoop stress to a real application, and altitude and pressure changes within a confined environment and overall.
3. Engaged more this semester with Inventor, the 3D print lab and the machine shop.
    - We worked with Mr. Vincent on drawings and what the machine shops expects from us as students when creating views on the product and outcome we desire.
4. As a team, we learned better communication and how to adapt to each members strengths and weaknesses, as well as the importance of keeping information decentralized.
5. We learned the importance of fully verifying component compatibility, and of testing all sub-assembly aspects regardless of perceived simplicity.

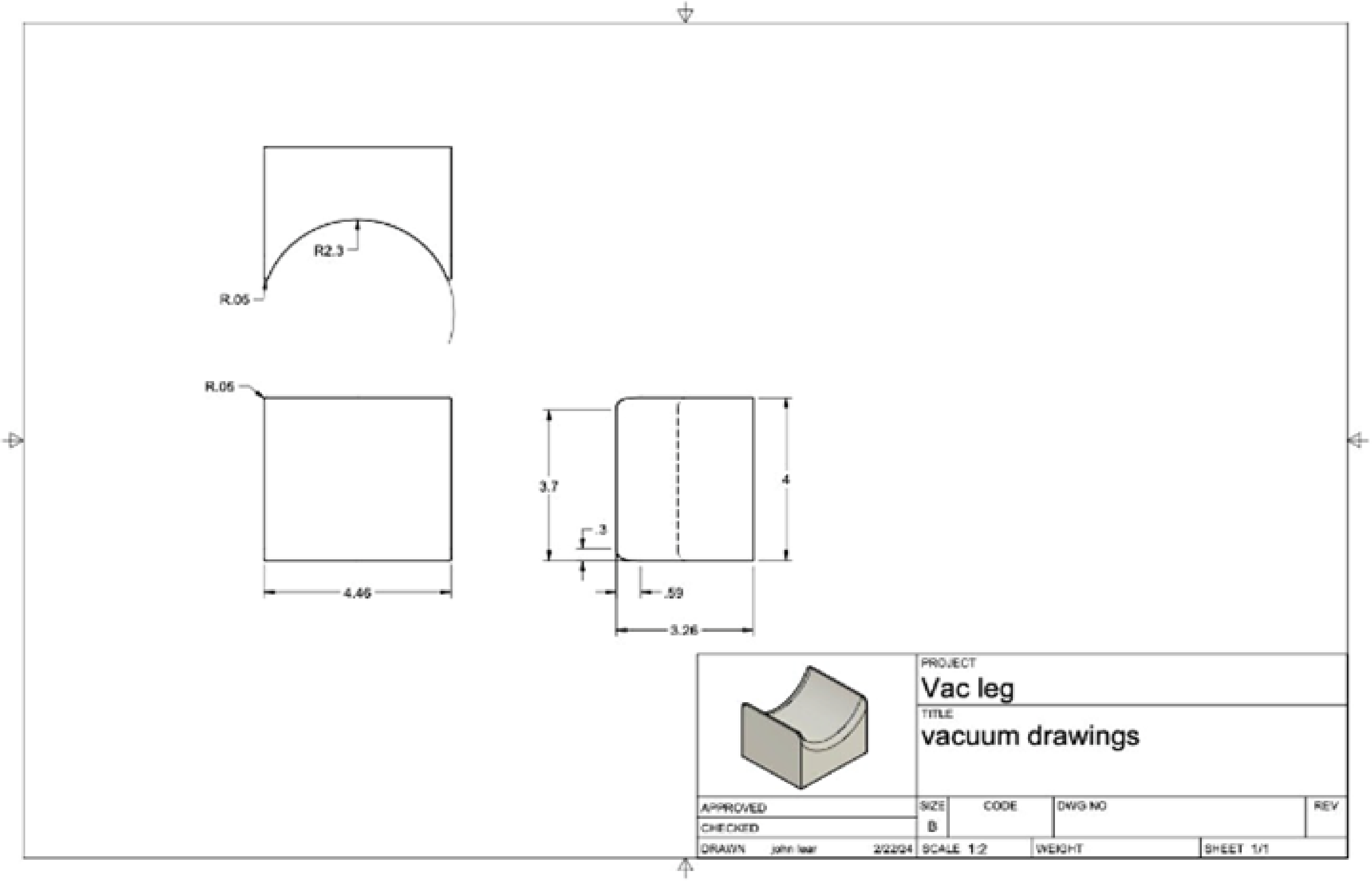
Questions?

Backup Slides

Drawings
Caps

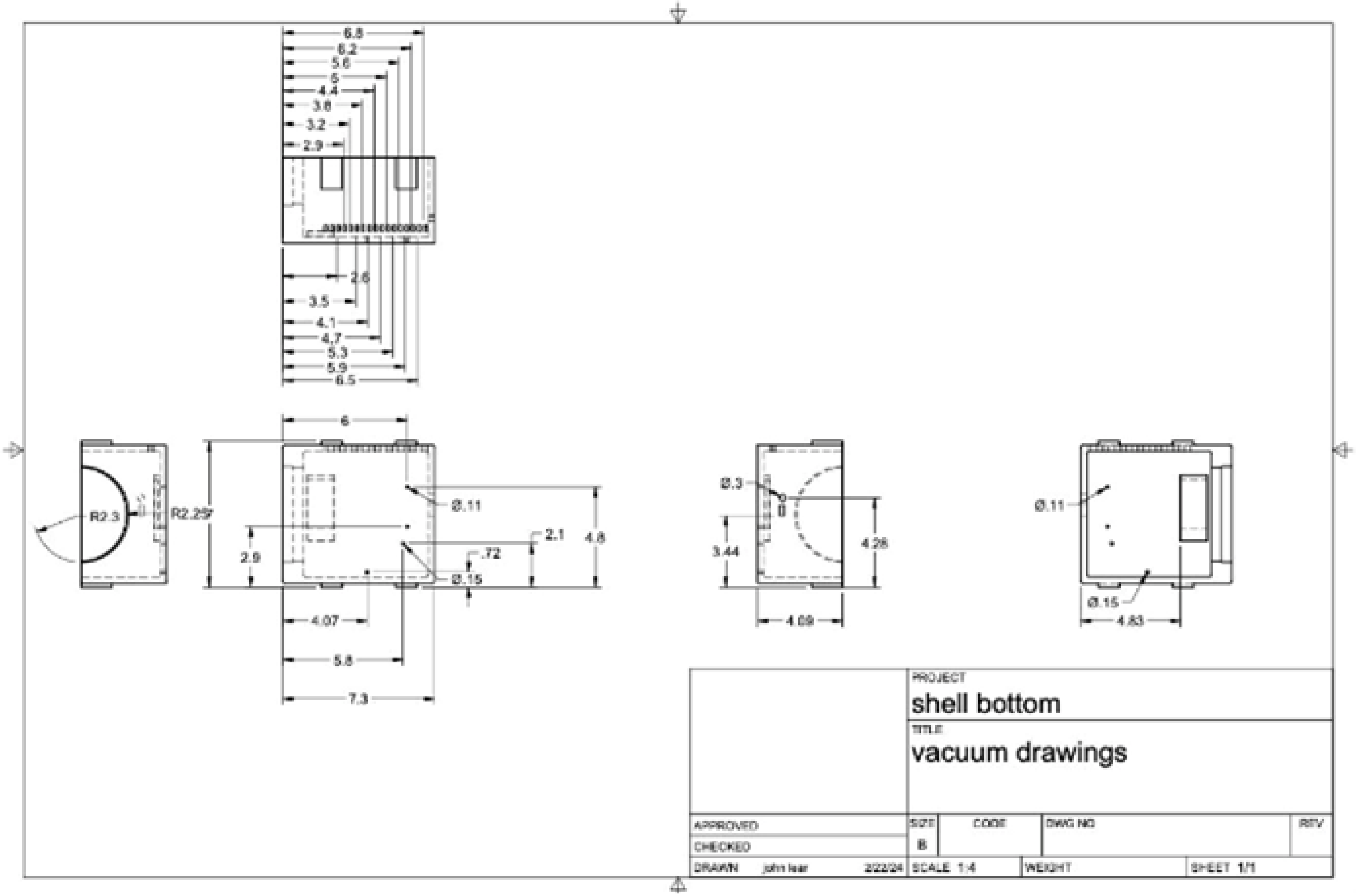


PVC Stand



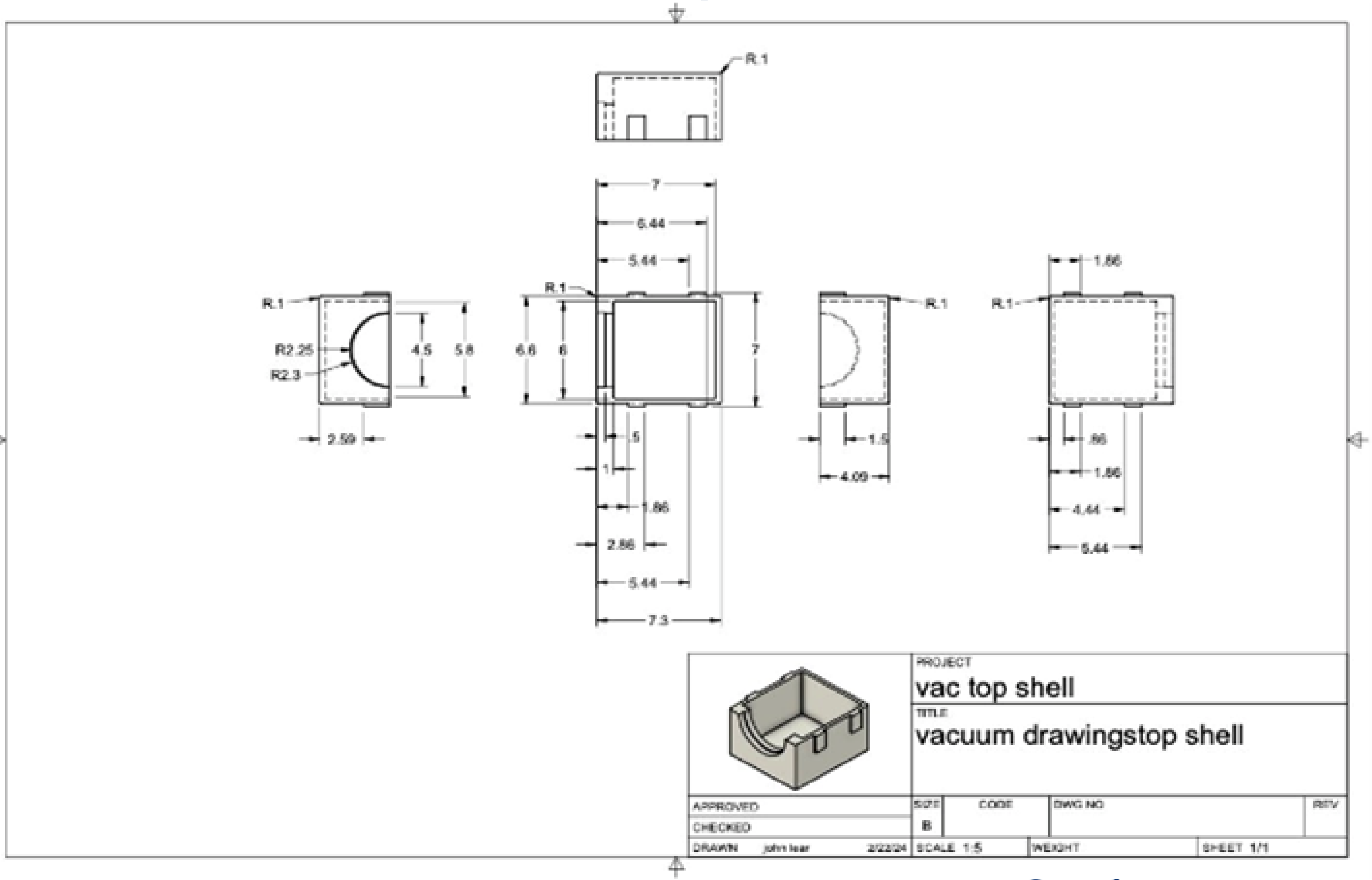
R2.3
R.05
R.05
4.46
3.7
.3
4
.59
3.26
PROJECT
Vac leg
TITLE
vacuum drawings
APPROVED
CHECKED
DRAWN john lear 2/22/24
SIZE B
CODE
DWG NO
REV
SCALE 1:2
WEIGHT
SHEET 1/1

Electrical Components Box Bottom



Southern New Hampshire University

Electrical Components Box Top



Southern New Hampshire University

Arduino Operation Code

```
/*                    Jr. Design Vacuum Chamber Arduino Code:
  Enter desired altitude. Arduino will convert to desired pressure, and operate pump and vent valve
      as requested to achieve and maintain requested altitude specific pressure.The system will then
      pause for 10 seconds before resetting and awaiting new desired altitude input.

  Arduino only functionality: Revision by D. Kimball 4/15 for Team Vacuum Vibes


*/        //Variables/Pins:
  #define pumpCmd 12
#define ventCmd 13
  #define pressVal A0
  String dsdAltStr;
  float dsdAlt = 0;
  int i = 0;
  float dsdPress = 0;
  float pressRaw = 0;
  float pressAct = 0;
  float initPress = 0;
  float tDsd = 0;
  float tAct = 295;
  float g = 9.81;
  float m = 0.02896;
  float r = 8.31432;
  float exponent = 0;
  float a = 0.3579;        //press sensor to kPa correction, y=ax+b
  float b = -39.075;       //press sensor to kPa correction, y=ax+b
```

Arduino Operation Code

```
int firstSensor = 0;      // first analog sensor
int secondSensor = 0;     // second analog sensor
int thirdSensor = 0;      // digital sensor
int inByte = 0;           // incoming serial byte
      //Subroutine to check chamber pressure and convert analog val to kPa
void ActPress(){
  pressRaw = analogRead(pressVal);                //read pressure sensor
  pressAct = a * pressRaw + b;                    //convert sensor reading to kPa
  //pressAct = 101;                               //FOR TESTING ONLY!!! COMMENT OUT!!!
}
      //Subroutine to calculate pressure necessary for altitude simulation
void DsdPress(){
  tDsd = tAct - (6.5 * dsdAlt) / 1000;            //calculate temp at desired altitude
  exponent = (-g* m * dsdAlt) / (r * tDsd);      //calculate exponential component of press calc
  dsdPress = pressAct * exp(exponent);            //calculate pressure at desired altitude
  //dsdPress = 55;                                //FOR TESTING ONLY!!! COMMENT OUT!!!
}
      //subroutine to look for serial input
void establishContact() {
  while (Serial.available() <= 0) {
    Serial.println("Please enter desired altitude in Meters...");
    delay(300);
  }
}


void setup() {
  // start serial port at 9600 bps:
  Serial.begin(9600);
  while (!Serial) {
    ;  // wait for serial port to connect. Needed for native USB port only
```

Arduino Operation Code

```
  }
  pinMode(pressVal, INPUT);
  pinMode(pumpCmd, OUTPUT);
  pinMode(ventCmd, OUTPUT);
}


void loop() {
  establishContact();                                   //Check for attempted contact
            //Altitude Requested
  if (Serial.available() > 0) {
    dsdAltStr = Serial.readString();                    //read input string
    dsdAlt = dsdAltStr.toFloat();                       //convert string to float
    //dsdAlt = 50;                                      //FOR TESTING ONLY!!! COMMENT OUT!!!
    ActPress();                                         //call subroutine to determine pressure at current altitude
    DsdPress();                                         //call subroutine to determine desired pressure
    Serial.print("Sea Level Pressure: ");               //display current and desired pressures
    Serial.print("\t");
    Serial.println(pressAct);
    Serial.print("Desired Pressure: ");
    Serial.print("\t");
    Serial.println(dsdPress);
    delay(1000);                                        //1 sec delay
            //run if pressure above desired - pump on
    while(pressAct > 1.005 * dsdPress){
      digitalWrite(ventCmd, HIGH);                      //close vent valve
      digitalWrite(pumpCmd, HIGH);                      //turn on pump
      ActPress();                                       //call subroutine to determine current pressure in chamber
      Serial.println(pressAct);                         //display current pressure
      Serial.print("Pump On Vent Closed");              //display system condition
    }
```

Arduino Operation Code

```
               //run if pressure below desired - vent open
    while(pressAct < 0.995 * dsdPress ){
      digitalWrite(ventCmd, LOW);                     //open vent valve
      digitalWrite(pumpCmd, LOW);                     //turn off pump
      ActPress();                                     //call subroutine to determine current pressure in
chamber
      Serial.print("Pump Off Vent Open");             //display system condition
    }
               //run when pressure within desired range - conditions met
    while(1.005* dsdPress < pressAct < 0.995 * dsdPress){
      digitalWrite(ventCmd, HIGH);                    //close vent valve
      digitalWrite(pumpCmd, LOW);                     //turn off pump
      ActPress();                                     //call subroutine to determine current pressure in
chamber
                                                      //Display current pressure and system condition
      Serial.print("Pressure for Desired Altitude Met. Chamber pressure:");
      Serial.print("\t");
      Serial.println(pressAct);
      delay(10000);                                   //10 sec delay
      digitalWrite(ventCmd, LOW);                     //open vent valve
      delay(3000);                                    //1 sec delay
      dsdPress = 0;                                   //reset desired pressure variable
      Serial.flush();                                 //clear serial to restart
    }
  }
}
```

Performance Calculations

Gauge Reading:	Conv. To kPa:	Raw Reading:
993.4	99.34	389
5	82.41	337.75
10	65.48	290
15	48.55	245
20	31.62	199