# Portfolio

## Low-cost, Controllable Hypoxia Chamber for Exploring Stem Cell Behavior

Andrew Hartman, Jacob Knudson, Colin Marchus, Alexandra Morrison, Isabell Strawn

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# Problem Definition

## Value Proposition

A crucial component to conducting stem cell research is maintaining a hypoxic growing environment. Stem cells naturally grow in a low-oxygen environment and simulating this environment during experiments allows researchers to more efficiently cultivate stem cells and conduct research regarding the effect of low-oxygen environments on the cells' development. A hypoxic environment can be simulated by using cobalt chloride, but this has undesired side effects on the cells' health. A more realistic and effective solution is to cultivate the cells in a hypoxic chamber. However, current commercial hypoxia chambers are expensive. The objective of this project is to develop a functional, simple, and low-cost hypoxia chamber for stem cell research. The results of this project will include the hypoxia chamber design and physical product as well as a published paper detailing our design and construction process. This will allow other researchers to utilize our technology and ideas.

## Expected Deliverables

Upon this project's completion, the expected deliverables will be:

- A functional, low-cost chamber which has been modified for the purpose of conducting cell culture research under hypoxic conditions.
- A control system, contained in separate housing, which connects to the chamber to control the oxygen and carbon dioxide levels within the chamber.
- A graphical user interface which allows the user to set the appropriate conditions within the hypoxia chamber and monitor/record the data from the control system.
- A finished paper detailing the project's purpose, materials used, manufacturing steps and outcome of the project, which will be published in an open-access journal.

## Product Requirements

## Objective

The purpose of this project is to design and develop a low-cost, controllable hypoxia chamber for stem cell research. Stem cells naturally grow in a hypoxic environment and simulating this environment during experiments will allow researchers to more efficiently cultivate stem cells as well as to conduct research regarding the effect of low-oxygen environments on the cells' development. Current commercial hypoxia chamber systems are expensive, so the goal of this project is to develop a functional and simple hypoxia chamber with a low cost. The results of this project will include not only the hypoxia chamber design and physical product, but also a published paper detailing our design.

## Scope

The scope of this document is to outline the functional, mechanical, electrical, software, environmental, regulatory, and cost requirements, as well as outlining a schedule for the design and construction of the product. This document will outline the criteria that will be used in the design of the product to determine the qualities of a successful design.

## References

### *Cited Documents*

### *Acronyms*

EPO - Engineering Purchase Order

ER - Engineering Release

POC - Proof of Concept

## Functional Requirements

### *User Interface Requirements*

The interface must allow the user to control and monitor the levels of oxygen, and carbon? in the chamber, as well as allowing the user to turn the device off and on.

### *What It Should Do*

The hypoxia chamber must maintain an inner environment with oxygen levels between 1% and 21% (atmospheric). It must be able to withstand these conditions for a minimum of 21 days. The chamber must also be able to maintain $CO_2$ levels at 5%.

## Mechanical Requirements

### *Strength Requirements*

Be able to support at least 4 well multidishes and be reused for multiple experiments.

### *Spatial Requirements*

The inside of the chamber must at least fit 4 13cm x 9cm x 2.5cm well multidishes. The chamber must fit inside an incubator with inner dimensions of:

-Height = 19.5”

-Depth = 18.25”

-Width = 16”

The chamber has a hole in the back for tubing/wiring that is 1.5” diameter.

### *Weight/Mass Requirements*

The chamber should be light enough to be easily portable. Must not exceed 20lbs. The components outside the incubator do not have a weight requirement besides being portable.

### *Mounting/Interface Requirements*

The opening to the chamber must be able to have a tight seal when closed.

### *Appearance Requirements*

The final product should be transparent, so the well plates are visible through the chamber walls.

### *Durability Requirements*

The chamber components must be able to withstand either being autoclaved or cleaned with an alcohol/ethanol solution.

### *Reliability Requirements*

All components should function with 100% reliability for periods of at least 21 days.

## Electrical Requirements

### *Operational Voltage*

The operating voltage will remain at 5V during use.

### *Physical Requirements*

Any components that connect inside the hypoxia chamber and/or incubator must be able to be sanitized. Outside control components will be within an enclosed housing.

## Software Requirements

### *Functionality*

Monitor the oxygen level within the chamber. Monitor the $CO_2$ levels, temperature, and humidity. Control a gas valve to bleed nitrogen into the chamber lowering the oxygen level. If found to be needed, control $CO_2$ or humidity levels. Allow a setpoint to be maintained for a minimum of 21 days. Communicate the monitored data over a serial protocol such as UART/I2C?

### *User Interface*

Allow for control of oxygen level setpoints and maintain time from a screen or connected GUI. Provide a readout of current oxygen levels. Switch to indicate the door is opened and disable functionality to save nitrogen.

## Environmental Requirements

### *Temperature & Humidity*

The product is expected to have full operational capabilities in environments with ambient temperatures of -20 to 40 degrees Celsius. The typical incubator for stem cells in which the hypoxia chamber must operate maintains a temperature of 37 degrees Celsius. Therefore, the chamber should be fully operational at this temperature and slightly warmer temperatures (up to ~50 degrees Celsius) for a sufficient safety factor. The typical incubator must function at 85-95% humidity to ensure that the media in which cells are growing does not dry out. Therefore, any electrical components that are placed inside the incubator must be able to withstand this humidity and the required temperatures.

### *Environmental Sealing*

All electrical components shall be contained in a container so that they will be safe in the humid environment of the incubator.

## Regulatory Requirements

### *UL Requirements*

N/A

### *Shipping Requirements*

N/A

## Cost Requirements

### *Prototype Cost*

Cost to build a POC prototype shall not exceed $1000.

### *Production Requirements*

Usage of 3D printing/machine shop. Make production as simple as possible.

# Project Learning

## Creating the GUI

When beginning to develop the GUI, it was necessary to do some research to determine the best module to use for its construction. One option that was found is a program called guizero, a simple and easy to use program for making a GUI. This program, however, lacks a good option for creating live graphs. Another option that was found is a program called PySimpleGUI. Links to the resources used can be found below:

https://projects.raspberrypi.org/en/projects/getting-started-with-guis

https://lawsie.github.io/guizero/start/

https://lawsie.github.io/guizero/widgetoverview/

# Project Management

## Budget

| Capstone Project Budget Template - Fall/Spring | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project:** Hypoxia Chamber Design | | | | | | | | | | | | |
| **Last Updated** 1/25/2021 | | | | | | | | | | | | |
| | Year | | | | | | | | | Item | | |
| **Expense Items** | Sept | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Total | | |
| | | | | | | | | | | | | |
| **Equipment/Tools:** | | | | | | | | | | | | |
| | | | | | | | | | | $ - | | |
| | | | | | | | | | | | | |
| **Travel:** | | | | | | | | | | | | |
| None | | | | | | | | | | $ - | | |
| | | | | | | | | | | $ - | | |
| | | | | | | | | | | | | |
| **Supplies / Parts / Services:** | | | | | | | | | | $ - | | |
| Arduino Mega Equivalent | | | $ 16 | | | | | | | $ 16 | | |
| Raspberry Pi | | | | | | | $ 35 | | | $ 35 | | |
| SD Card | | | | | | | $ 8 | | | $ 8 | | |
| Oxygen Sensor | | | $ 99 | | | | | | | $ 99 | | |
| CO2 Sensor | | | $ 179 | | | | | | | $ 179 | | **Expenses** |
| Logic converter | | | $ 7 | $ 3 | | | | | | $ 10 | | |
| Input Solenoids x2 | | | $ 24 | | | | | | | $ 24 | | |
| Exhaust Solenoid | | | $ 12 | | | | | | | $ 12 | | |
| Breadboard & Wires | | | $ 9 | | | | | | | $ 9 | | |
| Replacement Solenoid | | | | | | | | $ 13 | | $ 13 | | |
| Carbon dioxide | | | | | | $ 56 | | | | $ 56 | | |
| Nitrogen | | | | | $ 35 | $ 35 | | | | $ 70 | | |
| Acrylic | | | $ 20 | | | | | | | $ 20 | | |
| Through wall Tubing connecter x2 | | | $ 15 | | | | | | | $ 15 | | |
| Transistors/Diodes/Resistors | | | $ 10 | | | | | | | $ 10 | | |
| Epoxy | | | $ 12 | | | | | | | $ 12 | | |
| Tubing | | | $ 10 | | | | | | | $ 10 | | |
| 3D -printing filament | | | $ 26 | | | | | | | $ 26 | | |
| Pre-made Container | | | $ 22 | | | $ 22 | | | | $ 44 | | |
| Power Supply | | | $ 13 | | | | | | | $ 13 | | |
| Ras Pi Power Supply | | | | | | | $ 8 | | | $ 8 | | |
| O-ring | | | $ 7 | | | | | | | $ 7 | | |
| Tubing Barbed Adapter Fittings | | | | | | $ 9 | | | | $ 9 | | |
| Tubing Y-Fittings | | | | | | $ 5 | | | | $ 5 | | |
| Through wall ethernet cable | | | | $ 5 | | | | | | $ 5 | | |
| Ethernet adapter | | | | $ 10 | | | | | | $ 10 | | |
| Ethernet connecter | | | | $ 3 | | | | | | $ 3 | | |
| Ethernet Cable (15 ft x2) | | | | | | | $ 12 | | | $ 12 | | |
| Micro HDMI to HDMI Cable | | | | | | | | $ 7 | | $ 7 | | |
| HDMI to VGA Adapter | | | | | | | | $ 10 | | $ 10 | | |
| Steel socket head screw 25 pack | | | | | | | | | $ 9 | $ 9 | | |
| Hex nuts 25 pack | | | | | | | | | $ 9 | $ 9 | | |
| Water Trays | | | | | | $ 10 | | | | $ 10 | | |
| PCB | | | | | | | $ 2 | | | $ 2 | $ 786 | **Subtotal** |
| **Shop Usage (est. Hrs):** | | | | | | | | | | Hours | | |
| 3d-printing | | | 15 | | | | | | | 15 | | |
| Soldering | | | | | | 5 | | | | 5 | | |
| Containment Manufacturing? | | | 20 | | | | | | | 20 | | |
| | | | | | | | | | | 0 | | |
| | | | | | | | | | | 0 | | |
| | | | | | | | | | | 0 | | |
| | | | | | | | | | | | | |
| | | | | | | | | | Graduate Student Support | $ 200 | including fringe | |
| | | | | | | | | | Shop Overhead | $ - | | |
| | | | | | | | | | University Overhead | $ - | 5% of all expenses | |
| | | | | | | | | | Totals | $ 986 | $ 1,000 | $ 14 |
| | | | | | | | | | | | Budget | Excess |

# Schedule

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Year | 2020 | | | | | | | | | | | | | | | | |
| | | Month | Sept | | | | Oct | | | | | Nov | | | | Dec | | | |
| Task Description | Duration | Assigned | 9/3 | 9/10 | 9/17 | 9/24 | 10/1 | 10/8 | 10/15 | 10/22 | 10/29 | 11/5 | 11/12 | 11/19 | 11/26 | 12/3 | 12/10 | 12/17 | 12/24 |
| Team Contract | 1 Day | All | | * | | | | | | | | | | | | | | | |
| 1st Instructor/Team Meeting | 1 Day | All | | * | | | | | | | | | | | | | | | |
| Client Interview | 1 Day | All | | * | | | | | | | | | | | | | | | |
| Product Requirements Document | 1 Week | All | | | * | | | | | | | | | | | | | | |
| Budget Draft | 1 Week | Isabell | | * | | | | | | | | | | | | | | | |
| Brainstorm | 1 Month | All | * | * | * | * | | | | | | | | | | | | | |
| Design a Prototype Chamber | 1.5 Weeks | Colin | | | | | * | * | | | | | | | | | | | |
| Design a prototype control system | 1.5 Weeks | Andrew | | | | | | * | * | * | | | | | | | | | |
| Manufacture rough prototype chamber | 1 week | Jacob | | | | | | * | * | | | | | | | | | | |
| Snapshot #1 | 1 day | All | | | | | | | * | | | | | | | | | | |
| Have 3D model completed | 1 day | All | | | | | | | * | | | | | | | | | | |
| Have control system model completed | 1 day | All | | | | | | | * | | | | | | | | | | |
| Create BOM for electronics and order | 1 week | Alex | | | | | | | | | | * | | | | | | | |
| Create BOM and manufacturing plan for chamber | 1 week | Colin | | | | | | | | | | | * | | | | | | |
| Design Validation Plan Document | 1 week | All | | | | | | | | * | | | | | | | | | |
| Value Proposition | 1 week | Isabell | | | | | | | | | * | | | | | | | | |
| Draft Wikipage | 1 week | Jacob | | | | | | | | | | * | | | | | | | |
| Submit Concept Design Review | 1 week | All | | | | | | | | | | | | * | | | | | |
| Fabricate functional prototype Chamber | 3 weeks | Colin, Jacob | | | | | | | | | | | | | | | | | |
| Fabricate prototype control system | 3 weeks | Andrew,Alex | | | | | | | | | | | | | | | | | |
| Test if chamber is airtight and reaches temp and humidity | 1 day | all | | | | | | | | | | | | | | | | | |
| Snapshot #2 | 1 day | all | | | | | | | | | | | | | | * | | | |
| Conduct Testing | 4 months | Isabell, Jacob | | | | | | | | | | | | | | | | | |
| Complete oxygen & CO2 sensor testing | 1 day | Isabell | | | | | | | | | | | | | | | * | * | * |
| Test how long the chamber holds an oxygen level | 2 weeks | Isabell | | | | | | | | | | | | | | | | | |
| Test response time of control system | 1 week | Andrew | | | | | | | | | | | | | | | | | |
| Create user interface | 3 weeks | Andrew | | | | | | | | | | | | | | | | | |
| Have testing complete - report results | 1 day | all | | | | | | | | | | | | | | | | | |
| Snapshot #3 | 1 day | all | | | | | | | | | | | | | | | | | |
| Fix issues found during snapshot | 2 weeks | All | | | | | | | | | | | | | | | | | |
| Write a paper | 1.5 month | Colin | | | | | | | | | | | | | | | | | |
| Prepare Booth Display | 2 weeks | Isabell | | | | | | | | | | | | | | | | | |
| Deliver chamber to client | 1 minute | All | | | | | | | | | | | | | | | | | |
| Expo Presentation | 1 day | all | | | | | | | | | | | | | | | | | |
| Final deliverables due | 1 day | all | | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Year | 2021 | | | | | | | | | | | | | | | | | | | | | |
| | | Month | Jan | | | | | Feb | | | | Mar | | | | Apr | | | | May | | | | |
| Task Description | Duration | Assigned | 12/31 | 1/7 | 1/14 | 1/21 | 1/28 | 2/4 | 2/11 | 2/18 | 2/25 | 3/4 | 3/11 | 3/18 | 3/25 | 4/1 | 4/8 | 4/15 | 4/22 | 4/29 | 5/6 | 5/13 | 5/20 | 5/27 |
| Team Contract | 1 Day | All | | | | | | | | | | | | | | | | | | | | | | |
| 1st Instructor/Team Meeting | 1 Day | All | | | | | | | | | | | | | | | | | | | | | | |
| Client Interview | 1 Day | All | | | | | | | | | | | | | | | | | | | | | | |
| Product Requirements Document | 1 Week | All | | | | | | | | | | | | | | | | | | | | | | |
| Budget Draft | 1 Week | Isabell | | | | | | | | | | | | | | | | | | | | | | |
| Brainstorm | 1 Month | All | | | | | | | | | | | | | | | | | | | | | | |
| Design a Prototype Chamber | 1.5 Weeks | Colin | | | | | | | | | | | | | | | | | | | | | | |
| Design a prototype control system | 1.5 Weeks | Andrew | | | | | | | | | | | | | | | | | | | | | | |
| Manufacture rough prototype chamber | 1 week | Jacob | | | | | | | | | | | | | | | | | | | | | | |
| Snapshot #1 | 1 day | All | | | | | | | | | | | | | | | | | | | | | | |
| Have 3D model completed | 1 day | All | | | | | | | | | | | | | | | | | | | | | | |
| Have control system model completed | 1 day | All | | | | | | | | | | | | | | | | | | | | | | |
| Create BOM for electronics and order | 1 week | Alex | | | | | | | | | | | | | | | | | | | | | | |
| Create BOM and manufacturing plan for chamber | 1 week | Colin | | | | | | | | | | | | | | | | | | | | | | |
| Design Validation Plan Document | 1 week | All | | | | | | | | | | | | | | | | | | | | | | |
| Value Proposition | 1 week | Isabell | | | | | | | | | | | | | | | | | | | | | | |
| Draft Wikipage | 1 week | Jacob | | | | | | | | | | | | | | | | | | | | | | |
| Submit Concept Design Review | 1 week | All | | | | | | | | | | | | | | | | | | | | | | |
| Fabricate functional prototype Chamber | 3 weeks | Colin, Jacob | | | | * | * | * | * | * | | | | | | | | | | | | | | |
| Fabricate prototype control system | 3 weeks | Andrew,Alex | | | | * | * | * | * | * | | | | | | | | | | | | | | |
| Test if chamber is airtight and reaches temp and humidity | 1 day | all | | | | | | | | * | | | | | | | | | | | | | | |
| Snapshot #2 | 1 day | all | | | | | | | | | | | | | | | | | | | | | | |
| Conduct Testing | 4 months | Isabell, Jacob | | | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | | | | |
| Complete oxygen & CO2 sensor testing | 1 day | Isabell | | | | | | | | | | | | | | | | | | | | | | |
| Test how long the chamber holds an oxygen level | 2 weeks | Isabell | | | | | | | | * | * | * | * | * | | | | | | | | | | |
| Test response time of control system | 1 week | Andrew | | | | | | | | * | * | * | | | | | | | | | | | | |
| Create user interface | 3 weeks | Andrew | | | | | | | | | * | * | * | * | * | * | * | * | | | | | | |
| Have testing complete - report results | 1 day | all | | | | | | | | | | | | | | | | | | * | * | | | |
| Snapshot #3 | 1 day | all | | | | | | | | | | * | | | | | | | | | | | | |
| Fix issues found during snapshot | 2 weeks | All | | | | | | | | | | | * | * | | | | | | | | | | |
| Write a paper | 1.5 month | Colin | | | | | | * | * | * | * | * | * | * | * | * | * | * | * | * | | | | |
| Prepare Booth Display | 2 weeks | Isabell | | | | | | | | | | | | | | | | | * | * | | | | |
| Deliver chamber to client | 1 minute | All | | | | | | | | | | | | | | | | | | * | | | | |
| Expo Presentation | 1 day | all | | | | | | | | | | | | | | | | | | | * | | | |
| Final deliverables due | 1 day | all | | | | | | | | | | | | | | | | | | | * | | | |

# Meeting Minutes

**09/08/2020**

- Team Recorder: Alex Morrison
- Team Name: HYPEngineers?
- Ian Glasgow: team mentor, will give machine shop training and assist with some design help.
- Instructor: Dr. Dev Shrestha
- Agenda creator: Colin
- Weekly meetings: Thursdays at 3:30pm with Dr. Shrestha, and Friday at 2:45pm. Will discuss whether to meet in person (and where) or on Zoom on a case by case basis, but will meet on Zoom until a room is found.
- Client: Dr. Nathan Schiele
- Finances and budgeting: Izzie
- Documentation: Jacob
- Main client contact: Colin
- Meeting coordinator: Andrew

- Discord: https://discord.gg/vRFz9k

**09/11/2020**

- Questions for Dr. Schiele
    - Why are we doing this?
    - What will the chamber be used for – what specific research are you hoping to accomplish with it?
    - Are we building just a controller or a chamber as well?
    - If it is the chamber as well, does it need to maintain the temp/humidity environment or will that be regulated by some other device.
    - What does the budget look like?
    - Do you have some of the materials or is this a project from scratch?
    - How would a device maintain Oxygen and CO2 levels?
    - Do you have an ideas for how you would like the human interface to function?
    - On device controls, link to a computer, etc.
    - Are controllers such as the ProOx C21 good examples of what we're trying to design?
    - How frequently should the sensor be polled/recorded for logging data?
    - Have you done research into what sensors or hardware to use for the project within budget?

- Final report would likely be just working on the open source paper, hopefully to be done by May
    - Used Open Science?? to submit
    - Have one team member understand the formatting necessary for the paper and take the lead on that

- Use a nitrogen-controlled device to remove the oxygen
- Don't need a separate device to control CO2, the incubators do that by pumping in the gas
- Building a new chamber that would control the hypoxia levels and must still maintain the CO2 levels and other environment of the incubator
- Budget – less than $1000
- Need to price out components
- Try to balance using parts that other labs would typically have versus manufacturing our own parts
- GUI setup – either real buttons or hooking up a computer to use software (using computers can cause issues with networks or be cost limiting)
- Would like a physical data interface such as rs232 or something else for data communication?

- Hypoxia can activate hiff 1 alpha factor – this may induce production of lysol oxidase (causes cross linking of collagen = stronger tendon)
- Currently: use cobalt chloride to mimic hypoxia response, but long term this can cause cell death, and is not realistically "natural"
- Hardware x opensource paper withing university computers

**09/16/2020**

- Quick review of which questions were asked/answered from Dr. Schiele last week
- Someone will need to take the CSWA exam to get a license for SolidWorks
  - Will take 3 hours, can get prep help from Ian
  - Need to see if we feel that it's necessary
- Project deadlines excel was created, for us to view both team and individual goals and when they must be completed
- Excel sheet for possible products was created for us to use as we determine which sensors/etc. to use for the project
  - Sensors need to be wiped down with alcohol or autoclaved in the incubator
  - Arduino might be the best controller system, multiple people have some experience with it
- Budget planning
- Product Requirement Document
  - Izzie – Objective, Environmental Requirements
  - Andrew – Software Requirements, Electrical Requirements
  - Alex – Electrical Requirements
  - Colin – Scope, Regulatory Requirements, Functional Requirements
  - Jacob – Mechanical Requirements, Cost Requirements

https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0148923

**09/17/2020**

- Went over deadlines Excel with Dr. Shrestha
- Went over Possible Projects Excel
    - May want to have a $CO_2$ sensor inside the chamber to monitor the levels inside to ensure they match the incubator levels
    - Should check on this with Dr. Schiele
- Went over Budgeting Excel
    - Confirmed that it makes sense to order parts early, so that we can test them out early on
    - Add ~$200 for graduate student fees
- Oxygen sensors --
    - Possibility of enclosing sensor somehow within the chamber so that it doesn't need to be cleaned with alcohol (as this would likely break the sensor)
    - Many sensors don't list their prices outright, need to actually ask for them
    - https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0148923
        - Article will help lots in regards to figuring out how to use the sensors with a control system such as an Arduino
- Chamber itself will likely have to be metal or acrylic to withstand conditions
    - https://onlinelibrary.wiley.com/doi/full/10.1002/mds3.10064
- Solidworks license
    - Someone must pass CSWA to get license, unsure if this is needed
    - OnShape is a free online resource for students that is similar, the only drawback is whatever we work on there will be in the public domain
- Tasks
    - Work on Product Requirements Document and Product Schedule

**09/18/2020**

- Went over Product Requirements Document
    - Unsure of what to do about References, since we don't seem to have standards
    - Functional Requirements should be a very general overview of what we want the finished product to do
- Questions for Dr. Schiele
    - Need a time to measure the incubator
    - Should also double-check desired weight
    - Unsure if monitoring Co2, humidity, and temperature are desired for the finished product or if they should just be part of the development
    - Should the chamber be airtight?
        - If so, we'll have to specifically control the Co2 and humidity levels

        - If not, we'll essentially have to turn the whole incubator into a hypoxic environment
- Everyone should try to find 1-2 papers concerning our project so that we have more research to pull from
- The Product Requirements Document should be finished by next meeting

**09/24/2020**

- Shown example of an old logbook
    - Cross out empty space on pages for legal reasons, to show that backfilling was prevented
- Explained Product Requirements document to Dr. Shrestha
    - For weight, attempt to hit all requirements while trying to keep it as light as possible
    - Shelves inside the incubator can't hold more than 22lbs.
- Debate on whether it should be airtight
    - Possibility of adding a way to exchange the air inside/outside the incubator/chamber to help adjust humidity/temperature
- Oxygen sensor might need to be covered by cloth or housed separately so that the chamber can be cleaned.
    - This will affect how quickly the sensor can read the oxygen levels, so we're sacrificing response time for sanitation
- A way to log data would be nice, but isn't first priority. Possibly a project for next semester, once we have a working prototype
- Balance time with saving money. Don't spend 2 days trying to save $20. Going over budget a bit is okay.
- Goal for Oct 13 (Snapshot 1):
    - Having a 3D model of our design
    - Dr. Shrestha recommends having some physical way to represent our project, either simply using a cardboard box to demonstrate the idea or 3D printing something
    - Make something that we can show fitting the well plates inside, and possibly have the components of the control system wired up just to show our idea
- Need to split up a bit – have someone work with Ian to design the chamber, Andrew & Alex can work on refining the control system a bit more
- Design doesn't have to be all glass/acrylic, bottom could be metal, or wooden blocks could be used as the "corners" with the glass panes slid into them to add stability
    - Need to make sure all materials are safe to use in a hypoxic environment

- Action Items
    - Andrew – Sensor and ways to house it that reduce contamination and allow cleaning
    - Jacob – rough sketch of the chamber
    - Colin – Start a possible design of the chamber in 3d modeling software, as well as looking into the materials that could be used for the chamber.

    - Isabell – Investigate materials and what are safe options for the chamber
    - Alex – Work on control system housing and the sensor wiring

**09/25/2020**

- For housing the oxygen sensor: it's possible to 3D print a housing for the sensor within the chamber, and then use a filter (such as the ones from the flasks). This way the filter and housing could be cleaned, but the sensor itself would be protected. Oxygen could still flow through to the sensor, and contaminants would not be able to affect the main chamber
- Ian's logbook
    - Make sure any printed items are laid flat
    - Make sure each page is filled completely
- Design ideas
    - Make two pieces and use an O-ring to get the seal
    - Trying to think of 1-step manufacturing ideas
    - Use 3D printed brackets, then slide in laser-cut acrylic
    - Need a release valve to get rid of the extra oxygen/nitrogen in the chamber without releasing directly into the incubator (pressure regulator valve -- $200)
    - Need a way to make chamber have humidity – leave a cup of sterile water
    - How to deal with gases -
        - Other projects have used a mixture of 1% oxygen, 5% $CO_2$, and 94% nitrogen, but this was premixed by another company (no idea how expensive it is)
            - This path could be detrimental because we'd need different mixtures for varying oxygen levels
- For snapshot
    - Get box dimensions, manufacture a quick test box
- For meetings, split up the time so that everyone has to talk about what they did each week, to make sure that everyone is pulling their own weight

**10/01/2020**

- Preliminary model that Colin made (simple box, no door, only enough room for the 4 well plates
- Izzie found that glass might be the cheapest option, but acrylic or polycarbonate are easier to work with
- There are other polycarbonate boxes for sale that are cheap (~$50) that we could buy and customize
- Need to look into whether 3D printing will be okay for corner pieces and sensor housing
- Thickness -- ~1/4 inch
- Ask Dr. Schiele
    - Optimal way to create hydration in chamber
    - Let him know we want to have the chamber be air-tight, which means we'll need to tap into his $CO_2$ system

- Is using filter caps acceptable for sanitation
  - Optimal way to diffuse gas into the chamber
  - How to get rid of old air that might be toxic (exhaust)
  - Ask about possible need for shelves or if he wants a 1x4 stack
  - How long can the cells be kept at room temperature as the chamber heats back up after gases are distributed
- Pumping in $CO_2$
  - Discussed the finding of a $109 sensor that could detect $CO_2$, humidity, and temperature
  - Pumping in both gases creates control system issues, so possibly premix the gases in another container and then pump them into the chamber
- Wanting to use solenoids to control gas flow (can be opened or closed at specified times to control flow)
- Pump gas in at the bottom and then out at the top
- Using both an Arduino for controlling the gas and a Raspberry Pi to work the user interface
  - Option to download files using a USB
  - PID type controls? Ask Dr. Sullivan?
- Think about how to safeguard for the chamber failing and releasing gases into the room
- Design ideas
  - Lower thickness of the chamber
  - Add corner pieces that will be 3D printed, while the faces of each box are acrylic sheets
    - Andrew's design
  - Door that hinges to either a side or the bottom that has an o-ring
  - Possibility of adding a shelf on the bottom that has holes in it so that a sponge could be put on the bottom for humidity
- Questions for Ian
  - What thickness should we use?
  - Are there materials on campus that we could use?
- Action Items
  - Send questions to Dr. Schiele
  - Check designs with Ian

**10/02/2020**

- Created Project Schedule
- Reviewed Colin's model for the chamber
- Will make rough prototype out of cardboard for Snapshot 1

**10/06/2020**

- Ian is worried that our current design idea would eventually fail because the adhesive might not withstand moving, and we'd lose our integrity

- However, it would be simple to just print it out and then test it, so we can do that for this snapshot
- Ideas to correct this
    - Could screw through the acrylic so that the adhesive is really just there for a seal instead of bearing the weight of actually holding the box together
    - Could extend the corner pieces to be fully along the sides instead of just the corners
- More of a jigsaw way of attaching the acrylic to the corner pieces
- Trying to get the design done by Thursday so that we can get the box made for snapshot
- Need to find a way to support top piece
    - Could also use jigsaw-ish method
- Going to go without a door for now
    - Want to create the piece for the door, but not seal it right away so that we can put things in for snapshot, and then we can seal it later for testing
    - Need to ask Ian if this is feasible
- Showed off sensor housing design
- Adjusted OneDrive files to match portfolio requirements
- Will add an input tubing so that we can test the sealing later

**10/08/2020**

- Convert all our files to pdfs to make it easier to turn in for our portfolio
- Went over Andrew's sensor housing idea
    - Could attach to the outside of the chamber or be inside the chamber
        - Either way we'll need holes in the chamber to let things go outside
    - Want to make housing able to split into 2 parts so that we can put the sensors inside
    - Has a screw cap that the filter cap will fit onto
    - Will make slots for the sensors to fit into to keep them steady
    - Want to keep the threads steady, the 3D printing might not hold
    - Might want to buy 2 sensors to make sure we know how long it takes to get an equilibrium
    - Could make it cylindrical
- Went over Colin and Jacob's new design for the chamber
    - Has jigsaw sides to add structural stability
    - Has the corner pieces
    - Door needs some work, thinking about having it hinge at the bottom and open top-down, and have an o-ring for the seal
    - Needs to be exported as a dxf file
    - Make sure Ian knows what unit system we're using for laser cutting (inches)
    - Can't manufacture as is right now because we'd have to redo lots of parts and wouldn't be able to close up the chamber
    - Need to take away the jigsaw on the front face so the door can seal in
    - If we're putting hinges on the outside bottom then we need to "stilt" it up higher so that there's room

- Project Schedule
  - Have more solid milestones for the schedule so that we have deliverables
- Snapshot
  - Have Colin let Dr. Schiele know that he can join us for snapshot
  - Have at least two people in our room going over the slides at all times
  - We can rotate and look at other projects as well
- Need to buy the acrylic and 3D printing filament to create the chamber
  - Might check Moscow Building Supply for acrylic
  - Need to check nominal/actual sizes
  - Might have access to wood for building
  -
- Will try to see if we can get the chamber created for snapshot

**10/12/2020**

- Snapshot Schedule
  - We'll all stay for about 15 minutes (3:30-3:45)
  - Jacob, Izzie, and Alex will take first half (3:45-4:15)
  - Andrew and Colin will take second half (4:15-4:45)

**10/15/2020**

- Review Snapshot
  - Have we checked into seeing if we can find a chamber that's already airtight that we can modify
  - Dr. Schiele -
    - Testing with a sensor in the incubator itself might
    - Measuring humidity is definitely on the back burner, not very important
    - We should expect the door to open about once a day, with most of those being very quick, then every three days they'll change out the medium that the cells are in
    - It could take more than a few minutes to reach equilibrium and be just fine because the cells sit in the chamber for days and days during the experiment
- Dev really thinks that we should buy an already airtight chamber so we don't have to spend time trying to make sure ours is airtight
  - Sealed container: https://www.walmart.com/ip/Snapware-Airtight-Plastic-17-Cup-Rectangle-Food-Storage-Container-4-Pack/17202462?wmlspartner=wlpa&selectedSellerId=466
- DFRobot C02 sensor
  - CO2 sensor: https://www.amazon.com/DFROBOT-Gravity-Analog-Sensor-Arduino/dp/B00R5CCH7U/ref=b2b_gw_d_simh_1/146-4611514-5640501?_encoding=UTF8&pd_rd_i=B00R5CCH7U&pd_rd_r=6e5dcfc4-7a42-45e8-a319-759c3df926d8&pd_rd_w=uhxyX&pd_rd_wg=yDrja&pf_rd_p=735a47f3-23e0-4241-

        8d86-8c87b91c9083&pf_rd_r=WWB3SEB5GZVW5Q0Y5HRM&psc=1&refRID=1TV0J9B9ZYYD8B69ST45

- We're not sure what the lifetime of our sensors is, so we should check and make sure we won't be needing to replace them every few months
    - The $110 one we found is great, but we don't necessarily need to be checking for humidity and temperature
- Chamber
    - Dr. Schiele wants the chamber to be bigger
    - The new idea for the door is to have a cut-out door that would latch onto the front face so that we don't have to redo the jigsaw
    - Might not be a great idea to have to hold the door, could possibly change up the design to still be a hinged door despite being inside the jigsaw portion?
- Goals for next snapshot
    - Functional prototype
        - Have a chamber built that can seal
        - Have the sensors hooked up
        - Have the control system set up enough to read measurements from the sensors and open/close the gas valves
- Short term tasks
    - Choose if we want to manufacture or buy a chamber
    - Figure out if sensors will be inside or outside the chamber
    - Figure out how precise the sensors need to be, will they allow us to hit our setpoints, communication method
    - What is the lifecycle of the sensors and how often do they need to be calibrated
    - How will we control the gas (solenoids etc)
    - How to deal with humidity
- Chamber options
    - Manufacture our own
    - Buying one
    - Sensor options – inside or outside
- Action Items by Tuesday
    - Colin and Jacob
        - Will scale up the chamber and add door design (possibly both the removable door and door with hinge)
        - Need to know prices for acrylic, door material, 3D printing, hinge, latch, etc
    - Izzie
        - Look into other boxes that could be purchased to use as our chamber instead (acrylic material, tupperware, almost anything)
    - Andrew and Alex
        - Researching sensors – will they hit our setpoints, what's their lifecycle, how we'll control the gases,
- Try to meet with Dr. Schiele to present our design in a week and a half-ish

**10/21/2020**

- Began work on the Design Validation document
- Izzie went over options for pre-made chambers
    - Tupperware ones seem to be already airtight and have lids that can seal well, but they might need some work to adjust the lid to work well
        - Could add stilts to lift it up so that unlatching the bottom side is easier
        - Using those latches could jostle the chamber too much
    - Fish tanks
        - Worry about airtight seal
        - Glass is difficult to adjust
    - Most of these chambers are $20-$40
- Andrew shared pros/cons of sensor placement
    - Sensors outside of incubator
        - Would mean needing to add a way to pump the gas through tubes to reach the sensors
        - Would decrease response time by quite a bit
    - Sensors inside of incubator
        - Probably fastest response time
        - Will need to design our own sensor housing
        - If something goes wrong with sensors they are difficult to get to without losing hypoxic environment
            - We could possibly design a plug for the hole left by the sensor housing to help with this
- Sensors
    - The oxygen and $CO_2$ sensors we already found seem to be our best options. They hit all our setpoints (sensing $O_2$ from 0-21%, sensing $CO_2$ at 5%). The high percentage of $CO_2$ is what contributes to the higher cost of the $CO_2$ sensor.
- Chamber Design
    - Jacob and Colin finished adding the door design
    - They priced out building our own chamber and it comes to about $100
- Solenoids
    - What pressure will they need to be rated to?
    - Will solenoids themselves need to be sterile, or how will we ensure that they gas they are controlling is sterile?
    - How will they be controlled exactly?
    - They seem to be about $80 per solenoid
- Action Items
    - Colin – write overview of pricing
    - All – fill out Solution Ideas Excel file with pricing and pros/cons of all our options

**10/23/2020**

- Went through pros/cons of buying a prebuilt chamber vs building our own
  - Dr. Dev thinks it would be worthwhile to continue to design our own chamber and prototype both in order to compare them in real life
  - Prebuilt – we'd need to drill holes for tubing and possibly add stilts so that the lid can be opened easily
  - Our design – has a shelf for humidity, is complete with door design now, it might not be airtight
    - Could maybe add 3D printed supports for the shelf instead of having it jigsaw into the walls of the design
- We decided to manufacture both designs so that we can test both
- Buy acrylic sheets that are less than 32x18 inches (not a big deal)
  - Buy from a Moscow glass shop (??)
- Control system pros/cons of sensors inside/outside
  - Might want to have a separate tank of premixed gases at the right percentages to act as a contingency plan if something goes wrong -- this is a project for later
  - Want to minimize holes into the chamber – could
- Ian is worried about pressure
  - Might have difficulties getting gas to go out the exhaust tube
  - We could have a control system that opens up the exhaust tube whenever we pump gas in
  - The CO2 sensor can measure pressure, so we could have the control system make sure it's maintaining a certain setpoint for the pressure of the chamber.
    - This solution would mean having the sensors be inside the chamber
- The sensors we picked out are good for this project
- Need to know what pressure the solenoids should be rated for
- Door materials
  - Might need a different way to manufacture the door instead of laser cutting so that it's still see-through
  - Ian will check to see if there's a material we could use (such as plastic) that will withstand manufacturing and still be see-through
- To purchase items: give Dr. Schiele a list of everything we want and he'll buy it for us
- Action Items
  - Working towards manufacturing
    - Chamber - **Colin and Jacob**
      - Figure out if we need to redo door design
      - Get holes for tubes figured out
      - Figure out how tubes are going to be attached
      - Build supports for the shelf
      - Pick out final materials for the chamber
    - Pick out tupperware chamber - **Izzie**
    - Sensors
      - We know the sensors and Arduino board we need, need to see if we need adaptor boards for this

  - Need to create full list of materials to give to Dr. Schiele to get them ordered
  - Create BOM – **Alex and Andrew**

**10/29/2020**

- Went through changes to design
  - Added 3D supports for the humidity shelf
  - Fixed the way the door will be manufactured
  - Just needs holes placed for the tubing/control system and it can be manufactured
  - Would ethanol mess with the epoxy? (chamber can't be autoclaved because of acrylic)
    - Nope!
- Izzie found a good plastic chamber on Amazon
  - $26 for a pack of 6
  - Can fit quite a few well plates
  - Will need supports built for it, holes drilled in, humidity cup placed inside
  - Needs to be bought sooner rather than later
- Electronics BOM
  - Sensors
  - Solenoids
  - Arduino & Raspberry Pi (?)
- Still need ways to deal with gas
  - Even 3psi will cause problems
- Ordering parts:
- Need to get holes figured out
  - Create three holes, all 15mm. One at the top and two at the bottom
- Action Items
  - For Friday: finish powerpoint for Dr. Schiele
  - By Tuesday: finish BOM for manufacturing chamber and electronics to send to Dr. Schiele so that materials can be ordered
  - Next week: prep for concept design review, begin manufacturing chambers and control system as it arrives, decide on sensor system

**10/30/2020**

- Reviewed powerpoint
  - Maybe in the future create a way to have an emergency pressure release valve
  - Will build door without latches initially to test for what amount of pressure will pop off the door, then add latches to final design once we know our control system will successfully control pressure
  - See if there are larger sizes of tupperware
  - Might want to check for 3/8 inch instead of using ½ inch thickness for door acrylic
  - Might want to redesign humidity

        - Larger pan on the very bottom that has larger surface area which would increase surface area, cover it with a shelf with holes
    - Sensors
        - Condensation issues?
        - For sensors outside we might need to have temperature controls to avoid condensation
        - Find check valves to ensure that tubing is one-way
    - Seems like gases should diffuse on their own and mix well within the chamber
        - How long will the gases take to de-stratify(??)
        - Gases will sit and be static in the chamber for a maximum of 3 days
- Chemical solvent and then epoxy it to seal chamber

**11/03/2020**

- Izzie showed a new tupperware container she found
    - $23, should be plenty big to fit many well plates and a humidity tray
    - Had reviews that it should be airtight
- Finalized first order of materials. Not everything is being ordered right away, so some materials (like the Raspberry Pi) are still listed in the Total BOM, but not this first order list.
- We'll wait to order until tomorrow 11/4 so we can get an answer from Ian about recommended 3D printer filament
- Action Items:
    - Colin will send order list to Dr. Schiele
    - Jacob will finalize Wiki-page with help from Izzie
    - We need to finalize where hole placements are going to go
    - Design Review will either

**11/06/2020**

- Decided to ask Dr. Schiele about setting our design review for Wednesday, Nov 18 at 2:30pm-ish
    - Could also do Tues/Thurs at 3:30pm, or Wed at 4:30
- For Design Review
    - Make sure we get the "big picture" conveyed (value proposition)
    - Fix up powerpoint to make it more professional
    - Go over different options that we're pursuing (different chambers), how we're moving forward, how we're following our budget, etc
- Wikipage
    - Good progress writing up
    - Will show how to edit the page next week over zoom (maybe Mon or Tues?)
    - Needs a group picture of the team and individual pictures sent in
- Chamber edits
    - Shelf for humidity spans the whole bottom of the chamber now

        - Cut it in half so that the shelf can be taken out so we can get to the trays underneath
    - Need to find/build water trays?
- Sensor placement
    - Leaning towards inside the chamber itself
    - Will need to redo sensor housing because they are different sizes now
    - Put them next to the exhaust so that they can get airflow
        - Could possibly make it so that the air has to go through the filter and sensor housing to be able to exhaust
        - The filter would probably not let the air go through very well, which would build up pressure in the chamber
        - Might want to look up different options instead of the filter cap
- Premade chamber
    - Needs same hole placements as our designed chamber
    - Is slightly tapered, so we'll need to design stilts for it
    - Possibly change the door so that it doesn't come all the way off
- Portfolio and logbooks are due Thurs
- Action Items
    - Andrew will create model for sensor housing by Tues so that we know where to put holes
    - Izzie will start updating slides for design review
    - Jacob will work on wikipage
    - Colin will keep editing chamber design
    - Alex will start drawing up schematics for the control system
    - We will all help with building the chamber and electronics system
    - We'll all work on the powerpoint together

**11/10/2020**

- Went over wikipage
    - To edit, create an account using your vandal email, then go to our page and edit
    - Low-cost, controllable hypoxia chamber
    - Use cheatsheet (on left panel) to find code examples
    - Need to finish up Design Ideas section (prebuilt chamber, designed chamber, control system) by Thursday
    - [https://www.tablesgenerator.com/mediawiki_tables](https://www.tablesgenerator.com/mediawiki_tables)
    - The above link can help with table generation
- Design Review powerpoint
    - Goes through overview of how the system will look, then into each chamber, then the control system
    - We can all take turns talking about the slides that go with what we've been working on more specifically
- Sensor housing

  - Had to be redesigned to hold both new sensors
  - Trying to mount it up high so that they can pull exhaust air through it
  - Andrew has a pretty good model so far, need to figure out how to keep the housing up
  - We could make the sensors attach to the bottom side so that it can be pulled out, and the rest of the housing would just be glued to the walls using epoxy
  - Has threads on the front for the filter cap, and a hole in the back to accommodate the through-wall fitting for the tubing for the exhaust
  - Wires could go out below the housing so that when the sensors get pulled down they don't rip out wires
- Humidity
  - Bottom shelf has been split in two to get it out easier
  - Want to add velcro to the top of the supports and the bottom of the shelves so that they can come in and out and be secured
- Circuit diagram
  - Made in Tinkercad, doesn't have all the right parts, but is a basic model of how things connect
  - Need to make a more official diagram that's more generic
- Action Items
  - Jacob – finish wikipage by W and then assemble portfolio for Th
  - Andrew – finish sensor housing and give placements for holes to Colin
  - Colin – continue contacting Moscow Glass & Awning, finish adjusting designs and look up how chemical welding etc works
  - Jacob & Colin will work with Ian on manufacturing when the parts come in, will let us know when that happens so we can all help
  - Izzie – finish up the powerpoint, maybe figure out how to accomplish sensor mounting and humidity within prebuilt chamber
  - Alex – finish up a more generic circuit diagram
  - Team – make sure everyone sends a picture to Jacob for the wikipage
  - Meet on Monday around 5:15 to go over the powerpoint and how we're going to present it

**11/13/2020**

- Acrylic
  - Cracked while using ethanol to clean it
  - Even after using epoxy on the cut edges it still cracked after using ethanol
  - Might need to use polycarbonate
    - $12 for 1/4inch thick on Amazon
- Design Review powerpoint
  - Want to screenshare different programs to show off what we're doing instead of just having pictures
  - Need to go into pretty good detail on everything so we can get good feedback

        - Budget, schedule, design validation, requirements, etc., along with our designs and any testing we've done
- Tupperware container
    - Pretty good size
    - Dimensions are similar to what they were stated to be
    - Hard plastic, might need to be careful so that we don't crack it during manufacturing
    - Is thicker than we thought it would be
    - Izzie is working on models for the tupperware
- Wire system
    - Use RJ45 cables to pull wires into chamber
    - Square connecter will get put into wall, then a cable will run into another one-sided connecter that is attached to the sensor housing, which has a pinout on the back so that we can connect to the sensors
    - The other side of the RJ45 cable will connect to another one-sided connector so we can connect to the adapter board/Arduino
    - Adapter boards that we bought are all broken, we'll probably need to get more, but we want to test the sensors more first
- We'll meet at 5:30pm on Monday to go over the powerpoint before we present on Tuesday

**11/16/2020**

- Adjusting design review powerpoint
    - Jacob will take slides 1-3
    - Izzie will take 4&5
    - Colin will take 6-9
        - Colin will share to begin and then show his models in fusion 360
    - Alex will take 10-13
    - Andrew will do 14&15
    - Izzie will do 16&17
    - Andrew will finish up with 18

**11/20/2020**

- Updates:
    - Acrylic isn't working because it cracks, so we might just focus on the tupperware chamber and not move forward with our design
    - Adapter boards had broken and so we couldn't run tests with $CO_2$, but the new ones are here now
- Need to think about whether or not we want to use Arduino and Raspberry Pi or just Raspberry Pi because it communicates on 3.3V, so we wouldn't need to use the adapter boards
- Sensor Housing
    - Could use magnets to attach the housing so it's more temporary

    - Could rearrange screws to only use one or two or keep them away from the corners so they're easier to get to
- Acrylic tests
    - Continue spraying with ethanol so that
- Manufacturing tupperware chamber
    - Stilts
        - Possibly 3D print two parts that thread together so that we can level out the chamber easier
    - Humidity tray/shelf
        - Can use stainless steel to create the humidity shelf
        - Will buy a tray to hold the water
        - Can use snaps to hold the shelf to the supports
        - Don't really need the supports attached to the chamber, we'll just
    - Sensor housing
        - Use fillet gauge to create the curved edges
    - Door adjustments
        - Make sure stilts allow clearance to open the bottom latch
    - Holes for tubing
        - Use backing or some method to reinforce the plastic so it doesn't crack during drilling
- PLA for the 3D filament might have problems with the ethanol treatment, we'll move forward with it for now
- For snapshot 2:
    - Have finalized design for the tupperware chamber
    - Show designs that didn't work (the acrylic)
    - Make sure we're getting measurements from both sensors and controlling the solenoids well
- Action Items
    - Colin – look into whether or not using acetone and epoxy will help the edges of the acrylic not crack, maybe look into what the company uses to treat the edges so that they don't crack
    - Jacob – collect extra acrylic from Ian so that he can also perform the testing (after break)
    - Andrew – will redesign the sensor housing to fit in the tupperware and work on Arduino code
    - Alex – will keep the electronics and run tests with the sensors and solenoids
    - Izzie – will work on getting more accurate dimensions of the tupperware

**11/30/2020**

- Izzie started working on making supports for the tupperware chamber
    - The design currently is blocks that can thread into each other so that the level of the chamber is adjustable

    - Might not be completely necessary since it's only slightly tapered
- Andrew adjusted his sensor housing a little more
    - Took off a back corner so that it fits the rounded corners of the tupperware chamber better
    - Because the walls of the chamber are tapered, the straight edges of the housing don't sit completely flush with the walls. However, epoxy can probably fill this hole
- Need to test and get readings from the CO2 sensor
    - Needs to be attached to the adaptor board, which works, but doesn't have legs
    - Need to email Dev to see if he has legs that can be soldered on to the adapter board
    - Unsure if we're allowed on campus, so finding equipment to test with may be more difficult
- Next step is to adjust the control system so that the Arduino gets readings from the O2 and CO2 sensors and then tells the solenoids to open/close accordingly, showing that we can take data, parse it, and then adjust our gas levels accordingly
- Collin has tried to dissolve acrylic into acetone and it takes a loooong time to do
- For tupperware chamber
    - Make sure we have the stilts and humidity tray/shelf dimensioned correctly and ready to be 3D printed
    - Make sure the sensor housing has everything figured out and is dimensioned correctly so it can be 3D printed
    - The sensor housing will help place the exhaust hole, the input hole should be lower and towards the front. Needs to be higher than the humidity tray and not in the way of the door snaps.
    - The wires will need a third hole to run inside the chamber, which means slightly redesigning the RJ45 system for getting the wires inside
- For snapshot:
    - Get control system working so we can get measurements from and control each thing separately
        - Possibly shoot for getting measurements from the sensors and adjusting the solenoids accordingly as mentioned above, but this might be too ambitious for this week. Will definitely be done by end of semester
    - Get full design for tupperware chamber finished (holes placed, stilts, humidity tray/shelf, sensor housing, and wiring system fully designed)
    - Get stilts 3D printed and humidity shelf built, with humidity tray ordered
- By end of semester:
    - Actually manufacture chamber by drilling holes and placing through-wall connecters
    - 3D print sensor housing and any other small pieces
    - Have a working (as much as possible) control system
    - That way next semester can be focused on testing and writing the paper
- Action Items
    - Izzie – modify 3D design for humidity control system and stilts
    - Andrew – will sort out new RJ45 wiring system and adjust the sensor housing model accordingly
    - Colin – finish testing acrylic to see if we can build our designed chamber or not

- Jacob – work on updating design review powerpoint to work for snapshot, shop around for a tray to use for humidity
- Alex – get legs soldered onto adapter board and test control system to get readings from CO2 sensor

**12/03/2020**

- Sensor testing
  - Both the CO2 sensor and the O2 sensor were placed in a box with candles lit so that the oxygen would be burned out of the air. The data did show that the CO2 went up while the O2 went down as the candle burned
- Premade chamber developments
  - Izzie made the stilts 2.5" tall to allow for the door to hinge well
- Sensor housing
  - Andrew updated the housing to fit the RJ45-pinout connecters.
  - We'll order the RJ45 wires and things soon so that we can get the proper measurements of them
- Humidity trays
  - Jacob found one that will work, but it's pickup in store only from Target, so we'll have to figure out how to get it
- Next week we can try to manufacture the stilts, the humidity shelf, and possibly drill holes into the chamber
- We have snapshot 2 tomorrow morning from 8:30-10:10am, where we present from 9:10-9:30am. We'll be showing the single "poster" slide and giving the presentation 2-3 times in the 20 minutes
- We'll meet next Tuesday at 3:30pm, hopefully with Dev to get approval for our plans

**12/08/2020**

- Reviewing snapshot: seems like it went well, everyone ends up having questions about the sensor housing. May want to look into diffusion eventually
- Prepping for manufacturing:
  - Stilts can be 3D printed
  - Supports for humidity shelf can be 3D printed
  - Humidity shelf itself can be made of scrap metal with holes put into it
    - Don't make holes with different diameters so that it's easier to manufacture
    - Need to be careful what material we use to that it works well with epoxy and won't cause problems with the cells
  - Humidity tray will be bought
  - Sensor housing will be 3D printed – next semester, needs more dimensioning
  - Holes can be drilled into the tupperware once we decide on the official placement
- Alex and Andrew can start parsing data and researching feedback systems to get the control system ready for testing next semester

- New total for switching to using polycarbonate instead of acrylic is about $100
    - Issues with this:
        - No sharp edges because of machining, have to choose tiny radiuses and make lots of passes to try to resemble sharp corners
        - We can talk more about this next semester
- We'll meet on Thursday at 3:30pm (need to discuss wikipage)
- Action Items for end of semester
    - Andrew wants to have a final sensor housing design
    - Files can be sent to Ian (make sure they're 1:1) to print out the 3D parts (make sure they're STL) during finals week
    - Also give Ian the tupperware so that he can drill holes and fit the humidity shelf metal into it
    - Work on parsing data so that we can save and plot it

**12/10/2020**

- Wikipage needs new pictures
    - Updates to sensor housing, tupperware chamber, control system experimentation
- Changing up where things are so it looks better for the portfolio
- Meet tomorrow with Dev at 2:30pm

**12/11/2020**

- Updated Dev on our manufacturing plan
- We should eventually design and make a pcb for the solenoid side of the circuit
- Need to email Dr. Schiele
    - Let him know Andrew received the ethernet quick connect fittings
    - Ask where the other ethernet connecter is so that Izzie can pick it up at some point
    - Also ask about the fittings to his gas canister to make sure that we can order some for ourselves for next semester

**01/14/2021**

- Reviewing what we finished up last semester:
    - The supports got 3D printed, Ian has them
    - Andrew has the ethernet connecters that we ordered right before break, he just needs to adjust his sensor housing model to ensure that all the dimensions are correct, and then we can 3D print it
    - The control system works as far as the Arduino getting readings from both sensors, we need to start making a feedback system for it
    - Colin has managed to get the acrylic welding method with acetone to a point that it seems like it would work if we wanted to go that route

- We’re going to focus on the prebuilt chamber for now and then decide later on if we want to continue with the custom chamber, which will likely require re-budgeting as we switch to polycarbonate
- Snapshot 3 is March 9. We should have the chamber fully built by then (at the latest) so that we have time for writing the paper and other testing afterwards
- Izzie has concerns that putting the lid for the box on sideways is not very easy. The clamps for the lid require some force to seal the lid shut, which is easier to do when the box is facing upright
    - She tested how the box would fit in the incubator, and thinks that changing the orientation of the box to be upright would work well inside the incubator, we would just need to adjust our placing of the sensor housing and the holes
        - Changing the orientation to be upright might mean adding magnets to the top of the lid or something similar so that the lid can be “set” somewhere without having to bring the lid all the way out of the incubator and introducing contaminants
            - The walls are stainless steel, so this might not work, but making sure the lid stays inside the incubator is something to consider
- We’re changing our meeting times to being Tuesday at 2:30pm
- Action Items:
    - We’ll meet next Tuesday to decide which orientation the box should be, which will determine how we manufacture everything
    - Andrew wants to finish out the sensor housing and make sure it’s dimensioned correctly and ready for manufacturing
    - Izzie will create a design for if we switch the design to upright so we have something to go off of for manufacturing
    - Ian can look for a sheet of metal that we can use for the humidity shelf. Stainless steel is ideal, aluminum is a no-go. Max dimension is about 12 inches
    - Jacob will check on the water tray links that he had found earlier
    - Colin can look into materials for the humidity shelf to make sure that no metals are going to affect the cells or rust or anything
    - Alex will make sure the Arduino system can read two serial ports at the same time, which hasn’t worked in testing earlier

**01/19/2021**

- We’re changing our meeting times to Monday at 9:30am and Thursday at 3:30pm
- Stainless steel would work the best as the humidity shelf, but aluminum would work too, as would plastic
    - We need to double check materials, but basically we just need to not have the metal rust
- To change to an upright design
    - The humidity tray and shelf will now cover the entire bottom of the chamber
    - We don’t need stilts anymore

- We need to make sure the humidity tray can be taken out without spilling
- The sensor housing and holes for gas input/output and wires will need to be moved

- Action Items
  - Andrew – finish sensor housing dimensions so it can be machined soon. If the top portion of it can be printed soon then we can figure out where the holes should go in the chamber. Also get the threading figured out for the cap
  - Colin – email Dr. Schiele to see when someone can go look at his tubing system so we can connect with the CO2
  - Jacob – find a tray that we can officially use
  - Ian – take the box and use aluminum to make the shelf
  - Alex – work on the code more to try to get the communication with the sensors working

**01/25/2021**

- Jacob found some water trays that we can use. They're made of pvc, 0.8" tall, and 6x6" width and length, so they're the right size and we know that pvc won't have any issues
- Andrew has been starting to make sure that we can fit our tubing with Dr. Schiele's. His tubing uses barbs to attach things, so Andrew is searching for a barb-to-quick-connect adapter so that we can attach Schiele's tubing to our tubing. The other option if we can't find that is to get an adapter that has a barb on one side and a thread on the other side, and then we'd need to get another thing to convert from the thread to the quick-connect fittings we have
- We'll also need to get Y-connecters so that the tubing from the N2 and from the CO2 canisters can combine together before going into the chamber
- Andrew also adjusted how the wiring connecters will fit into the sensor housing. He needs to meet with Ian to help get ideas for how to hold the O2 sensor in, to get the fillet dimensions that Ian took so he can adjust which side of the housing will be rounded, and to get help putting the threading onto the space for the filter cap
- Izzie has concerns about where we should fit the sensor housing within the chamber, because we can't drill too close to the edge, and we also don't want the drilling to cause a crack up to the top of the box
- We need to fill out the form for being in the Design Expo
  - We don't need a ramp or elevator, but we'll need electricity (1 plug)
  - We won't be able to bring the gas canisters and show the chamber fully working, but we'll try to show off the sensors and user interface a bit. Because of this we'll probably want to have a video of our chamber fully working for our technical presentation at Expo
  - Andrew will send the value statement we have to Dev for his approval, and then Izzie will write up the survey
- Izzie has also been adjusting the budget spreadsheet, it is up to date now
- Action Items
  - Andrew – meet with Ian to get lots of dimensioning work done for the sensor housing, and also meet with Alex to work on a plan for the code for the sensors

    - Jacob – do a quick calculation to compare the incubator's volume vs the surface area of its drip pan against our chamber's volume and the surface area of our proposed tray, so that we can have some validation that we'll reach the correct humidity readings
    - Izzie – submit Design Expo survey and work on adjusting where the sensor housing fits into the new chamber design
    - Colin – send email to Dr. Schiele so that we can meet with him this week to confirm our design changes, also ask if Jacob can go to the lab to get dimensions for his calculation, and respond to Ian with dimensions for the shelf. Also keep working on getting our final paper formatted correctly so we can start working on it
    - Alex – continue working on code to get sensors working, and meet with Andrew to make overall plan for feedback system

**01/28/2021**

- Jacob did the volume analysis and our chamber with the 6x6 water tray we are looking at purchasing, and our chamber has a ratio of about 0.23, while the incubator and its water tray has a ratio of about 0.18, so we'll have plenty of humidity
- Andrew has looked at trying to connect our tubing with Dr. Schiele's tubing, and there are still some issues with connecters (not able to find one that goes from barbs to push-to-connect).
- The chamber is going to be right-side up now, which changes the rotation of everything
    - Humidity tray: needs to be slightly smaller now so that it doesn't hit the sensor housing when it's pulled out
    - Humidity shelf: will be made of aluminum, with holes in it to let the water to create humidity
    - Sensor housing: will get turned on its side. Will connect to the chamber with screws.
    - Still has 3 holes, 1 for exhaust coming through sensor housing, 1 for gas input, and 1 for the wiring
- Dr. Schiele and Dev like the new design, so we will start manufacturing immediately
- Sensor housing should get printed before we drill holes into the chamber, so that we can get a feel for where they should go
- Action Items
    - Andrew will finish up some of the sensor housing design, and send it to Ian to start printing
    - Jacob will send the water trays and a few other parts to Dr. Schiele to get ordered (along with the nitrogen)
    - We want Ian to change the shelf to have handles on the long side, but then he can manufacture the shelf
    - Colin has started working on getting the formatting for the paper, we'll need to look into it more. He'll also do a quick Fusion 360 course so we can test that our airflow in the chamber will go the way we think it will
    - Izzie will start looking at the design validation spreadsheet to figure out what testing we can start doing now as we wait for the code to get finished up

    - Alex and Andrew will design a structure for the code and start working on it, to get a working feedback system

**02/01/2021**

- Andrew has worked on the sensor housing quite a bit with Ian.
    - The correct edge is now rounded, we'll know what the exact dimensions for the edge are a little bit better when Ian makes the aluminum shelf.
    - The hole for the filter cap is the right size, but it is difficult to create the exact threads for it in Fusion 360, it might need to be exported and done in Solidworks
    - We'll be using nuts/bolts to attach the housing to the chamber to the walls and to attach the sensor portion to the overall housing. This is due to the threaded inserts we had originally thought about using not being available
    - The O2 sensor has a slightly different way to hold it in now, there will be a sort of cap that will go over it and then be zip-tied into place
    - The way that the sensor housing will print, we'll need to print the filter cap tube separately. It's possible we could also use a small pvc pipe and cut the threads into it.
    - The oxygen sensor holder might need some fillets on the bottom part where the wires go
    - He'll meet up with Ian to work on dimensioning this week
- Izzie is worried about drilling into the plastic more with the new holes for the nuts to hold the housing to the chamber
- Andrew also tried to check if Schiele's tubes and fittings will work with our tubing, and it seems like it could work, especially if we use clamps or zip ties to really make sure our tubing is secure on the barb fittings
- Andrew and Alex worked on the code over the weekend, and developed a rudimentary feedback system that can take measurements, determine how far away they are from certain setpoints and then open the solenoids to let gas in for set amounts of time
- Izzie worked on getting a document ready detailing how we'll try to tackle our design validation
- We need to figure out when the nitrogen is going to get here so that we can begin our testing
- We either need access to Dr. Schiele's lab and his CO2 cylinders or we can buy a smaller cylinder so that we can do our testing on our own. The latter might be ideal so that then we don't have to do all our testing in Schiele's lab, and won't be in his way
- We can share the github that the code is stored in currently so that everyone has access to it
- Jacob wants to work on the wikipage, so we'll need to get pictures and things to him
- OXARC could be able to supply the smaller CO2 cylinder so that we can get it sooner, someone should call and see if we can connect with them
- Ian will hopefully manufacture the shelf some time this week, and we hope to have someone there to work with him on it

**02/04/2021**

- Andrew tested barb fittings for tubing by pushing the connection underneath water and then blowing through the tubes. No bubbles came out of the connection and air came out of the other side, so it seems to be airtight enough
    - We now need to order the Y-connecters to be able to connect the nitrogen and CO2 inputs to a single input tube for the chamber, and more of the barbs to be able to actually connect our tubing
- Colin will send an email to Dr. Schiele checking that the water tray and nitrogen that we sent a request for have actually been ordered, and requesting the new tubing connection parts
- We should call OXARC to see if they sell smaller canisters for CO2
- Colin will talk to Dr. Schiele about the CO2 canisters
- Code currently opens solenoids for a min of 10ms and a max of 100ms, depending on its readings. Testing can help adjust these numbers, but some calculation is also possible to try to solve the problem of what the limits should be. Using the volume of the box and the pressure of the gas coming in (we think it's about 3psi), we might be able to calculate how much gas we'll need to let in to reach our setpoints
- Colin did a class to see if we can simulate airflow within our chamber
- Izzie is asking Ian if we can spend time in the workshop with him drilling holes into the chamber
- Colin has been looking at the paper requirements more and has done some work on the bill of materials
- The code was explained in detail to everyone
- Action Items
    - Andrew will make more models of the threaded piece so that when he prints parts with Ian they can make them easily to test which threading will work best with the filter cap. He'll also make a flow chart diagram of the code for the wikipage
    - Colin will work on the fluid simulation some more, talk with Dr. Schiele tomorrow about purchasing CO2 tanks and whether or not he wants us to test in his lab, and work on the paper more
    - Izzie will start thinking about the calculation of how to find out how long the solenoids should be open, possibly using Colin's data from the simulation
    - Jacob will make more updates to the wikipage, adjusting it to meet Dev's suggestions
    - Alex will work on the bugs in the code on the CO2 side of things, and work on commenting/documenting the code better, and begin researching better ways to implement a feedback system
    - Jacob and Izzie will also try to meet with Ian next week to drill holes into the chamber

**02/08/2021**

- The tube fittings we ordered last Thursday are here, so we'll be all set to hook up to gases and start testing once we get holes drilled in the chamber
- Andrew will meet with Ian today to work on making sure the thread of the filter cap will work correctly

- Code is working with the $CO_2$ sensor, but it gives error messages about half of the time at the beginning. Will need to look into the documentation for the sensors to see if there is a different timing we should use for asking for measurements
- Izzie and Jacob will work with Ian to get holes drilled into the chamber tomorrow
- Izzie called OXARC and they have 2.5lb, 5lb, 10lb, and 50lb tanks. We can calculate how much gas we'll need to get. Izzie can call back about the prices for those different tanks. Dev can put out an order for the tank, or give Schiele a budget order to use for it. We'll need to also purchase fittings things to be able to use this new $CO_2$ canister
- Colin is still working on the fluids simulations
- We'll hopefully begin testing later this week once more gases get here
- The code works for measuring $O_2$ and $CO_2$, but it doesn't record any other variables. Making sure we grab humidity, temperature, and pressure would be good, along with actually logging the values
- Action Items
    - Izzie and Jacob and maybe Colin will work on drilling holes with Ian tomorrow, and will possibly work on the fluids problem to see how long the solenoids should be open
    - Andrew will meet with Ian today to work on getting things ready to 3D print
    - Colin will keep looking at the fluids simulations
    - Alex will work on adding variables to the code

**02/11/2021**

- Tupperware has 3 holes drilled into it, the hole for wire input is a little higher than what was originally planned, which may slightly affect the sensor housing design
- Andrew will make these adjustments and also fix how the nuts hold the sensor housing top to the bottom
- The code can now take measurements every second from both sensors to get $O_2$, $CO_2$, temperature, humidity, and pressure
    - There's an issue currently where the $O_2$ sensor gives bad readings for every other measurement if we increase the time between measurements at all
- We should test the filter cap to see how it affects the pressure and airflow, we can tape the cap over the exhaust hole to test this
- Colin completed the simulation, but he wasn't sure what the velocity of the gas entering the box would be
    - We can use Bernoulli's equation to calculate the velocity
- We're trying to find the volume flow rate so that we know how long to open the solenoids
- We're tentatively setting our Engineering Release Review for Tuesday Feb 23 at 3:30pm, need to double check this time with Dev and Ian, but we know it works for Dr. Schiele
- We will conduct a pressure test next Tuesday (2/16) at 3:30pm in Schiele's lab. There will be a general session during that time, so we'll need to kinda watch that while we work
- Action Items
    - Andrew will work on an adjusted sensor housing model and work on the timing for the sensor code

- Izzie will update the chamber model to have the holes in their correct placements now
- Jacob will update the wikipage with pictures of the drilled chamber and our team photo
- Colin will work on the Bernoulli equation calculations that we discussed so he can find the velocity to adjust his simulation
- Alex will help Andrew with adjusting the sensor code over the weekend

**02/22/2021**

- We went over the pressure test we did last Thursday where we pumped air into the chamber using a bike pump and measured the spike in pressure and how long it took to go back to equilibrium
- The actual air hole in the quick-connect fitting is much smaller than the outer diameter, so we need to update the simulation Colin is working on
- We need to talk to Dr. Schiele to see when we can get into the lab to hook up to his nitrogen and CO2 so that we can get measurements and begin adjusting the way the code works
- We might want to use some kind of sensor to tell when the door of the chamber is opened. We will eventually need to implement either that or just a button that the user can press to indicate that they are about to open the door
- We want Dr. Schiele to order his normal size and type of CO2 tank that he uses so that we can use it without having to tap into his lines. There's an option for him to simply lease the tank so that he can return it after we're done with it in a few months
- For the Engineering Release Review powerpoint:
    - We should focus on just the newer chamber that we have, instead of going back through all the old work we've done
    - We need to update the sensor housing pictures
    - We need to update the circuit pictures, should probably begin working on a pcb design

**02/25/2021**

- Andrew and Alex ran tests with the nitrogen yesterday morning
    - The tube fittings that we ordered didn't fit as well as we thought they would, they may need to be tested with soapy water to ensure that they don't leak
    - Variables were changed progressively throughout the test to see how the system responded to different ranges of time that the solenoids would be open
    - Eventually the system reached 5.1% O2, which was within 0.1% of the setpoint, so it stopped blowing in N2. The system then reached an equilibrium of 4.98% O2 for about 15 minutes
    - Throughout the experiment the O2 sensor would give lots of bad readings, so this problem needs to be remedied before we can move forward with the code
- Izzie, Colin, and Jacob worked on the equation for our fluids problem on Monday
    - They decided that they can calculate the velocity at which the gas enters the chamber, but felt like they were missing some constants when calculating how much gas we'll need to enter the chamber

    - They plan to contact a professor for help
- We are beginning to design a pcb, which will be needed at some point
    - We need to decide how to attach wires to the pcb, whether that's soldering them down or using pin headers, etc.
- We need to design our user interface
    - We could connect the Arduino to a Raspberry Pi to be able to store data, and then set up a web interface to display the gui and data
        - We'd have to fully code the web interface, but anyone who wanted to connect to the system could do so anywhere, you wouldn't need a laptop to be permanently connected
    - Labview could be used as the gui
    - An SD card shield could be used to store the data instead of a Raspberry Pi
    - We'll research user interfaces over the weekend to have a discussion with Dev on Monday
- We need to get in contact with Ian about manufacturing the shelf
- We need to ensure that Dr. Schiele gets a $CO_2$ canister ordered for us, along with a backup chamber
- Action Items
    - Colin will work on the fluid simulation and the paper
    - Izzie will work on writing up the fluids problem and reach out to Dr. Tau
    - Jacob will update the wikipage
    - Andrew will get the data from the nitrogen test uploaded into Excel and write up the procedures followed and analyze the data. He'll also look trying to finish up the sensor housing
    - Alex will work on getting a pcb design ready, and help Andrew with writing up/analyzing the nitrogen test data
    - Everyone will research user interface ideas

**03/01/2021**

- Andrew showed some graphs from the nitrogen experiment
- Dev wants us to create a PID system, possibly with only the P and I elements
- Izzie shared some of the setup for the fluids calculation. We know the diameter of the tubing, but not the diameter of the solenoids. We believe we can find the velocity of the gas flowing, and with the addition of the other missing parameters, find out how much gas should flow past the solenoid
- Dev had helpful information on attempting the calculation
    - $Q = k*\sqrt{2*q*\Delta P}$
    - [https://www.efunda.com/formulae/fluids/calc_orifice_flowmeter.cfm](https://www.efunda.com/formulae/fluids/calc_orifice_flowmeter.cfm)
- The tubing connecters that we got don't fit quite as well as we thought they would, we're going to do more testing with it, but we may want to order different ones eventually
- Andrew will meet with Ian sometime this week to discuss the sensor housing and try to get that finished up so it can be printed

- Alex created a pcb layout. We need to ensure that the current to the solenoids can be handled by the pcb, and that the adapter board won't overheat. We may want to look into using hookups like RJ45 that are easier for the user than the pin headers. We need to look into where the board should be printed, balancing price with speed of delivery.
- For the UI:
    - Labview is redundant because it would require a computer to always be connected to the Arduino or Raspberry Pi which defeats the purpose of the Raspberry Pi
    - We'll move forward with trying to use Raspberry Pi to log data and control the system
- Jacob has updated the wikipage and will work with Colin to get a first draft of our paper written

**03/04/2021**

- Izzie made a model for the humidity shelf in Fusion 360
    - Wants to make a water tray model
- Andrew wants to meet with Ian tomorrow to go over the sensor housing model and hopefully get it printed soon
    - He should check with Ian to see if making the shelf is anywhere on his radar
- Andrew added a PID library to a new code folder in the github repository
    - We need to find the Kp, Ki, and Kd constants for both $O_2$ and $CO_2$ in order for it to run properly
    - The library assumes that you're trying to work up to your setpoint, so we have to reverse the $O_2$ measurements for it to work
- It seems like the fluids calculation is more trouble than it's worth, we don't know enough of the values to be able to find what we want
- The pcb needs to be updated to include an ethernet connection for the sensors. The pin connectors for the Arduino need to stay since that's the best way to connect to the Arduino. The solenoids could possibly also have ethernet connectors, we need to decide
- We need to figure out where we want to put the solenoids, whether they should be close to the canisters (more wiring) or with the electronics (more tubing)
- We want to use a Raspberry Pi for the user interface, we need to decide if we want to use a small touch screen or a monitor/keyboard/mouse setup
- Action Items
    - Andrew will work with Ian on the sensor housing and test nitrogen tomorrow
    - Izzie wants to make a animation for snapshot and maybe look into creating the UI using Python
    - Colin will maybe get a design of a lid, maybe start designing the electronics housing for the Arduino, Raspberry Pi, and pcb
    - Jacob will make the design for the water tray and continue updating the portfolio and wikipage
    - Alex will do nitrogen testing tomorrow and continue updating the pcb design to have the ethernet connectors

**03/08/2021**

- Andrew and Alex ran nitrogen testing on Friday using the new PID controls. After adjusting some constants, the chamber hit 1% $O_2$, but then continued to decrease. This is due to the integral and derivative portions of the PID control. If these constants are tuned then we can fix this problem to not overshoot
  - Dev will send a lab detailing how to tune PID systems to aid us with this
- Izzie made a new animation for the chamber using Jacob's water tray model and Colin's lid model
- Alex will work on getting a picture of the pcb into the snapshot poster
- Based on conversation with Dr. Schiele, we'll be using the third incubator for testing. This means the solenoids should probably be inside the same housing as the Arduino, Raspberry Pi, and pcb. Because of this we'll use pin headers on the pcb to connect to the pcb
- Dr. Schiele also already has a monitor we can use with our UI, so we don't need to get our own
- Izzie has done a bit of research into making the UI, and found a module called guizero that we can use to help make this process easier
- For snapshot:
  - Jacob will discuss background, objective/value proposition, key requirements
  - Colin will discuss current progress and looking forward
  - Izzie will discuss our overall setup and current chamber design
  - Alex will discuss the control system
  - Andrew will discuss the design validation and sensor housing
- We present from 4:10pm-4:30pm. We'll need to attend other presentations and take notes in our logbook

**03/11/2021**

- Andrew has printed sensor housing
  - It needs to possibly be reprinted
    - The filter cap part might need to gradually become thicker
    - The zip tie part might need to be sturdier
    - The hole for the ethernet port is a little too large
    - One of the three ports to connect the top to the bottom is not accessible
  - We need to make sure it fits in the chamber so it fits over the ethernet port, and that the hex shape fits in it, etc
- The humidity tray got pushed back because the machine shop has been closed, so hopefully we'll have it by the Friday after spring break (March 26)
- Dev did send Andrew the PID lab document
  - Look at labs 9 and 10 (pages 50-60)
- We should look into seeing how long it takes for commercial systems to get down to hypoxic levels
- The week after spring break we should run another test with $CO_2$ and $N_2$
- The week after that we should run a 5-day test (we may have to leave a laptop

- We need to order a Raspberry Pi and SD card and power splitter, an ethernet cable, an HDMI (or other type) cable.
  - We've adjusted the BOM to reflect these new purchases
- Action Items
  - Andrew will get started on getting serial communication to work between the Arduino and Raspberry Pi
  - Alex will finish the pcb routing and get it ready to be ordered
  - Izzie, Jacob, and Colin will begin working on the GUI

**03/22/2021**

- We'll conduct $CO_2$ and $N_2$ testing at 1:30pm tomorrow in the lab
- We need to check on the parts we ordered before break
- Before Expo
  - Need to have humidity shelf manufactured
  - Run tests and ensure code is working
  - Mount sensor housing
  - Implement GUI
  - Get pcb manufactured
- Izzie will follow up with Ian to get shelf manufactured
  - Also ask when he'd be willing to drill holes to get the sensor housing mounted
- Andrew fixed up the sensor housing a bit, so he'd like to reprint that at some point after we do testing with the current one
- Andrew read through the PID lab Dev sent, and he will adjust the controller to be just a PI controller
- Andrew also started working on a python code to communicate with the Arduino for data logging
- Izzie did some research on the module we'll be using for the GUI
  - It has a set of boxes to type in and then set the setpoint, along with an area to display the current conditions
- Expo could possibly be in person
- Pcb is almost done
  - Some traces for carrying current might need to be made larger
  - Need to check price and manufacture lead time
  - Holes for standoffs need to be added
  - Vias need to be adjusted
  - Need to finish up labeling
- Housing for electronics needs to be started
  - Will need holes for tubing to go in+out for solenoids, sensor ethernet cable to exit, power to enter for Arduino and Raspberry Pi, and display cable to exit from Raspberry PI
  - Will need removable lid, using bolts might be best
- There will be a little meeting at 9am on Wednesday to discuss the GUI progress
- Action Items

- Izzie will work on the GUI and meet with others to discuss it, and check in with Ian for manufacturing
- Colin will get started on the overall electronics housing and work on the GUI
- Jacob will work on the GUI
- Andrew will run $CO_2$ and $N_2$ testing and continue working on finalizing the code
- Alex will work on finalizing the pcb and also run $CO_2$ and $N_2$ testing

**03/25/2021**

- We have a meeting set with Ian for Tuesday at 1:30pm to do more manufacturing
    - We're starting the 5-day test next week on Monday, so we can't drill holes into the chamber, but we might be able to create the shelf. Izzie will check with Ian to see if he can make the shelf without the chamber
- Andrew will work on the code more before our 5-day test next week
    - He wants to make sure the CSV file on the Raspberry Pi works for the test, which also means setting up teamviewer so we can connect to it
    - He should also add a way for the $O_2$ sensor to reset itself if it's giving bad readings
- The pcb is essentially done. It will cost about $17 and be a 4-day turnaround time. It needs resistor values added to the silkscreen and a label
- Izzie has worked on the functionality of the GUI a bit more. She's having an issue with a function that doesn't like when the window gets closed
- Colin has worked on the CSS version of the GUI to make it prettier
- Jacob has added places to document the other variables. The pressure should be converted to kilo-Pascals (likely in Python)
- The GUI needs the following additions:
    - There should be a start/stop button, and also a pause/continue button. The start button will start the gas flow and start saving data to the SD card, and the stop button will stop both of those. The pause button will only pause the gas input, but keep
    - There should be a place to add the pressure limit
    - There should also be a place to state the file name you want to save things to
- Next order for Dr. Schiele:
    - Ethernet connector
    - New solenoid
    - PCB
    - Display cable
    - Extra chamber
- We're switching the 5-day test to occur later in the week so that we can finish manufacturing the chamber
- Action Items
    - Izzie is going to work on the functionality of the GUI more (making the changes that we discussed today and possibly starting on the live graph)
    - Colin will continue to work on beautifying the GUI, get a model of the sensor housing, work on the paper

    - Alex will work on finishing up the pcb and sending in the order to Dr. Schiele
    - Andrew will work on getting the Raspberry Pi working in time for the test
    - Jacob will add labels on the GUI

**03/29/2021**

- Izzie worked on the GUI code more, attempting to implement some of the features that we talked about
    - We're still getting the error when closing the program because the variables continue between iterations in Spyder
    - There is a place to enter the pressure, we need to have the program start with a default pressure. We still need to adjust the pressure readings to kilo-Pascal
    - A place to enter the file name where the data will be stored has been added
    - The pause button has been added separately from the begin/end
- PCB is almost done
    - New pcb should be designed to allow for quick connection to Arduino
        - We could make the new pcb shield down into the original pcb and the Arduino more
- O2 sensor is consistently giving bad readings at random times
    - We might need to clear the buffer before reading each time
    - We may need to look into whether we can give the O2 sensor commands so that it doesn't mess up
- We still want to order the extra solenoid, spare chamber, and display cables
- Izzie and Jacob are meeting with Ian to manufacture the holes in the chamber and the humidity shelf tomorrow at 1:30pm
- We're going to try to begin the 5-day test on Wednesday in the morning (10am-ish)

**04/01/2021**

- Andrew will check in on the chamber later tonight using an HDMI cable. It seems like it's still working well
- Andrew will try to get the sensor housing reprinted with Ian soon
- Izzie added more to the GUI
    - There's a place to add a file path that does actually open up a browser for file explorer, and it grabs the file path added
    - She wants to adjust some of the labeling and layout
    - There aren't errors anymore!
    - Adjust labeling on the start/stop and pause/continue
- It might be a good idea to add functionality to see if gas is leaking, and stop the experiment, and say on the GUI that leakage is the reason for the stop
- We might change the pressure button to grab the first pressure value from the CO2 sensor to use as a limit. Then once the pressure reaches a certain percentage above the initial measurement, we can issue warnings and possibly stop the experiment

- We should ask Dev about when to start making a poster for Expo
- Andrew explained the sort of L-shape that we might have the electronic housing be
- Alex will attempt to change the pcb again to integrate the Arduino pins with the original design
- Jacob has tried to update the wikipage, and will keep working on the paper with Colin

**04/05/2021**

- Andrew was unable to check on the chamber experiment over the weekend, so we'll see how it's doing later today. We'll also be stopping the 5-day experiment today
- Izzie has been working on the GUI more, and added some functionality, but broke lots more (which is typical for working on code). She and Andrew and Jacob will meet tomorrow at 1:30pm to work on debugging the code
- Alex fixed the pcb again, now it will snap onto the Arduino. An order needs to be sent to Dr. Schiele that includes the pcb order, and the ethernet connector. Dev has pins that can be used for the other soldering joints
- We got our order of parts from Dr. Schiele, we should manufacture the spare chamber as well just in case. Someone needs to contact Ian to get a time set for that, as well as see when the shelf will be done
- Jacob and Colin have been working on adding pieces to the paper, we'll go over it as a team on Thursday, and then hopefully send that rough draft to Dr. Schiele
- Andrew will get the new printed sensor housing from Ian and clean it up for use in later experiments
- We need to contact Dr. Schiele for when we can get into the incubators for another test
    - It would be ideal to have the shelf built and the GUI working
- Action Items
    - Alex will send in the pcb order and then work on getting the paper ready for Thursday
    - Izzie will contact Ian about getting the shelf built and eventually manufacturing the spare chamber, and keep working on the GUI code
    - Andrew will stop the long term test, help out with debugging the GUI, and get the sensor housing finished up
    - Jacob and Colin are gonna keep working on the paper

**04/08/2021**

- Colin has worked on the electronic housing file
    - The SD card hole for the Raspberry Pi will need to be the largest hole so there's room for fingers to pull it out
    - The solenoids will be mounted to the top somehow, possibly with just a shelf to hold them
    - There will need to be three more holes for tubing to exit the housing
    - Most of the hole sizes can be found online
    - The Arduino and Raspberry Pi will need standoffs so they sit off the ground

- Ian made the aluminum shelf. It's very thick and not smoothed out, but it will work. If there's time we may give it back to him to polish
- Izzie finished the functionality of the GUI
- Reviewing paper
    - We should maybe see if we should put Dr. Schiele's email instead of our school emails, since eventually our emails will be gone
    - Open Source License???
    - Hardware in Context will eventually be one paragraph
    - How do we show parts that we used but didn't have to buy
- Results of 5-day test
    - We used up most of the nitrogen during the 5-day test so we need to be careful
    - The $CO_2$ fluctuated a lot during the test, while the $O_2$ stayed pretty steady
    - The code doesn't show when we input gas currently, so we need to fix that and retest it
- Action Items
    - Izzie will keep making the GUI look pretty
    - Jacob will try to polish up the hardware in context section of the paper
    - Andrew will work on getting the GUI integrated with the Arduino code
    - Colin will keep working on the paper and the electronic housing
    - Alex will also keep editing the paper

**04/12/2021**

- Jacob and Colin finished a rough draft of the paper
    - They should use Mendeley for a source repository so that they don't have to manually cite the sources
    - Still need to figure out the open source license
    - Create mock drawings for some of the future work ideas, such as the pcb within the sensor housing idea
- Andrew will try to get the sensor housing reprinted this week
- We hope the pcb will get here this week to start soldering
- Colin will try to get the electronic housing printed next week
- Jacob and Colin will meet with Dr. Schiele today to discuss the rough draft of the paper
    - They should ask about how to represent things in the paper that people would need, but we didn't buy, along with other questions about the paper
    - They should also ask if he knows when the pcb is gonna get here
    - They should also ask about when we might be able to do a 2-hour test inside the incubator. We'd like to perform that test as soon as possible
    - We'd like to do another 5-day test eventually, so we might need more nitrogen for that. We have the money for it, but we should get Dr. Schiele's opinion on whether we can buy another tank for it or not.
- Andrew got GUI working with Arduino
    - Start/stop/pause buttons work

    - File browser doesn't let us create new files. We should change it to let us select a folder, and then immediately create a new file using the current date and time
    - We should add another button setup that lets us pull data directly to a USB drive after an experiment is done
    - The 5-day test that we performed used Andrew's personal Raspberry Pi, so he'll make sure everything works on ours so that the next test will be on our own hardware
- Izzie will contact Ian to see if he can manufacture the new box and deburr the shelf at some point, but also make it clear that 3D-printing the new sensor housing and electronic housing are top priority
- Logbooks are due this week
- Dev wants us to make a short video describing our work
    - https://www.webpages.uidaho.edu/~devs/Teaching/BE478.html
- Dev will check with Matt Swenson to see if we need to print a physical poster for expo
- Action Items
    - Jacob will get feedback on the paper with Colin and then keep working on it
    - Colin will get feedback on the paper with Jacob and then work on the electronic housing with some assistance from Andrew
    - Andrew will continue working with Izzie to get the GUI and other code running properly, and get the sensor housing printed this week
    - Izzie will keep making adjustments to the GUI with Andrew and contact Ian to get more manufacturing done
    - Alex will start working on a poster and other side projects while waiting for the pcb to get here so that the soldering can start

**04/15/2021**

- The pcb is here, so Alex will begin soldering it tomorrow and have it done by Monday
- Ian will be reprinting the sensor housing tomorrow
    - He should also have the drilling in the new chamber done by then
- For Expo:
    - Our technical presentation will be online on either Thursday or Friday, sometime between 2-5pm
    - Our booth presentation will be in person in the Memorial Gym on Friday, sometime between 9am and 12pm
    - We don't know out time slots for either yet
    - We need to get the poster made so the copy center can print it
    - We need to submit our technical presentation powerpoint by April 25 (next Sunday)
- Colin has made progress on the electronic housing, it has some structural issues with the shelf for the solenoids
- Jacob and Colin have talked with Dr. Schiele about the paper a little bit
    - For items others will need but we didn't buy, we should find identical components to list in the paper's BOM

- We need to check with Dr. Schiele about setting up an incubator test early next week, and then setting up another longer test later that week. The longer test can be just a day or so, since we only need to test how much air we're passing through the solenoids
- If there's time after Expo we can try to run a test where we have an oxygen sensor in the sensor housing and another outside of it for design validation for the paper
- To finish:
  - Need to have pcb soldered
  - Need to get electronic housing designed and printed
  - Need to finish adjusting GUI and get it functioning on the Raspberry Pi 4
  - Need to create a poster and powerpoint for Expo
  - Need to finish the paper
  - Need to create a video for Dev
- GUI improvement
  - We want the browsing for a file to select a file directory, then have the code add on a file name that is the current date and time, then Andrew's code can take that file path and create a file to write to
- Action Items
  - Andrew will meet with Ian tomorrow to get the sensor housing reprinted and make sure our Raspberry Pi 4 is working for testing next week
  - Izzie will try to find a function that will find the file path and work on the export button
  - Jacob will go over the wikipage to make sure we know what should be finalized and will work on the paper with Colin
  - Colin will work on the paper with Jacob and work on the electronics housing
  - Alex will solder the pcb and start working on the poster

**04/19/2021**

- The pcb works! Alex got it soldered on Friday, and then tested it with Andrew on Sunday, and it works perfectly
- Andrew adjusted the Arduino code to display when the solenoids are actually letting gas through so that we can see how much gas we're using
- Andrew also found a python function that will let us make a file as soon as we find a file path
- Izzie adjusted the GUI to select a folder for the file path and then append a date/time name to the file
- Andrew will look into making the export button useful
- Andrew will email Dev to see if we can use the BE 3D printer since Ian is quarantined
- Colin has made more progress on the electronic housing
  - The solenoids need to be raised up so that they don't hit the transistors on the pcb
  - Standoffs need to be added to the Arduino and Raspberry Pi
  - All the holes for them will need to be raised when the standoffs are added
  - The holes for the solenoids need to be adjusted
  - The wall connected to the top that will help hold the solenoids needs to be adjusted so that it doesn't hit the fittings

- Jacob and Colin have worked more on the paper
  - They started a source file repository using OSF
  - We're unsure what kind of file type should be used to upload the design files
- We need to have our Expo poster submitted to the print shop and uploaded online by Sunday Apr 25
- We're doing incubator testing later today at 3pm
- Action Items
  - Andrew will see if we can use Dev's 3D printer and run today's testing
  - Izzie will update the official GUI code and work on the poster
  - Jacob will ask Dev about what file types to use for the repository, submit the rough draft of the paper to Dr. Schiele, and work on the poster
  - Colin will finish the electronic housing
  - Alex will run today's testing and then work on the poster/technical powerpoint

**04/22/2021**

- Andrew hasn't gotten the sensor housing printed yet, but he'll try to work with Ian to print it tomorrow
- Andrew also fixed up the GUI to work
- We're still waiting on feedback from Dr. Schiele about the paper
- We should make sure the Github and OneDrive are owned by Dr. Schiele or someone other than Andrew so that others have access to them after we graduate
- Colin worked on the electronic housing more, he's going to continue making edits and will try to get it printed on Monday
- We'll run our longer test tomorrow
- The Expo poster is almost done, we'll send it out tomorrow morning

**04/26/2021**

- Andrew submitted our Expo poster on Sunday to both the print shop and the online spot
- Colin has finished up the electronic housing
  - The standoffs have been added -- the Arduino standoffs could be shorter
  - There's not much space between the pcb transistors and the solenoids, so Colin will fix that
  - We gotta figure out what bolts to use to secure the Arduino and Raspberry Pi, and then make sure the proper nut fittings are also used, with 10 thou clearance
  - The holes for the tubing going into the solenoids should be vertically slotted just in case
  - The print should start later today at 3:30pm
- Andrew started printing the revised sensor housing on Friday, it's done now so he can pick it up today
- Andrew adjusted the GUI a fair bit
  - He added a 'Connect Arduino' button

  - He added placeholder text in all the value boxes
  - He added a Settings button that allows you to set the PID values and how often you read measurements
  - He's gonna work on creating a settings document that the Pi can pull from that saves the setpoints and PID constants, so that the GUI will have its default values come from there
- Expo presentation
  - Jacob will add slides about the paper and looking forward
  - Colin will add pictures of the electronic housing
  - Andrew will add pictures of the sensor housing and a GUI video
  - Alex will work on combining and cutting out slides to make it shorter
- We're going to meet at 9:30am on Wednesday to practice our technical presentation
- We'll also still meet at 3:30pm on Thursday to set up for Expo, and then we'll need to go in again early Friday morning to get it all working for the day
- We're still waiting for feedback from Dr. Schiele for the paper
- Jacob will try to get the wikipage updated so we can go through it on Wednesday
- We should talk to Dr. Schiele about getting the onedrive and GitHub files put in his name instead of Andrew's

**04/28/2021**

- We ran through the presentation. Each person knows what slides they have been assigned
- Andrew is going to update the GUI video
- We should update the pictures of the electronics housing and sensor housing to show their components inside
- We're meeting tomorrow at 3:30pm at the ambassador room to take these pictures and then move our stuff to the memorial gym to prep for Expo
- We gotta figure out how to get our poster – Andrew will call
- Next week:
  - We need to finish the paper. Schiele says to add lots of pictures, and then we need to finish up the future work and design validation sections
  - Andrew wants to reprint the sensor housing again, since this second reprint didn't go well
  - We should run another test for validation's sake, and teach Dr. Schiele how to use the system while we're setting up

**05/03/2021**

- Due by Friday:
  - Team member citizenship
  - Paper
  - Wikipage
  - Turn in poster and equipment
- Andrew and Colin want to do reprints

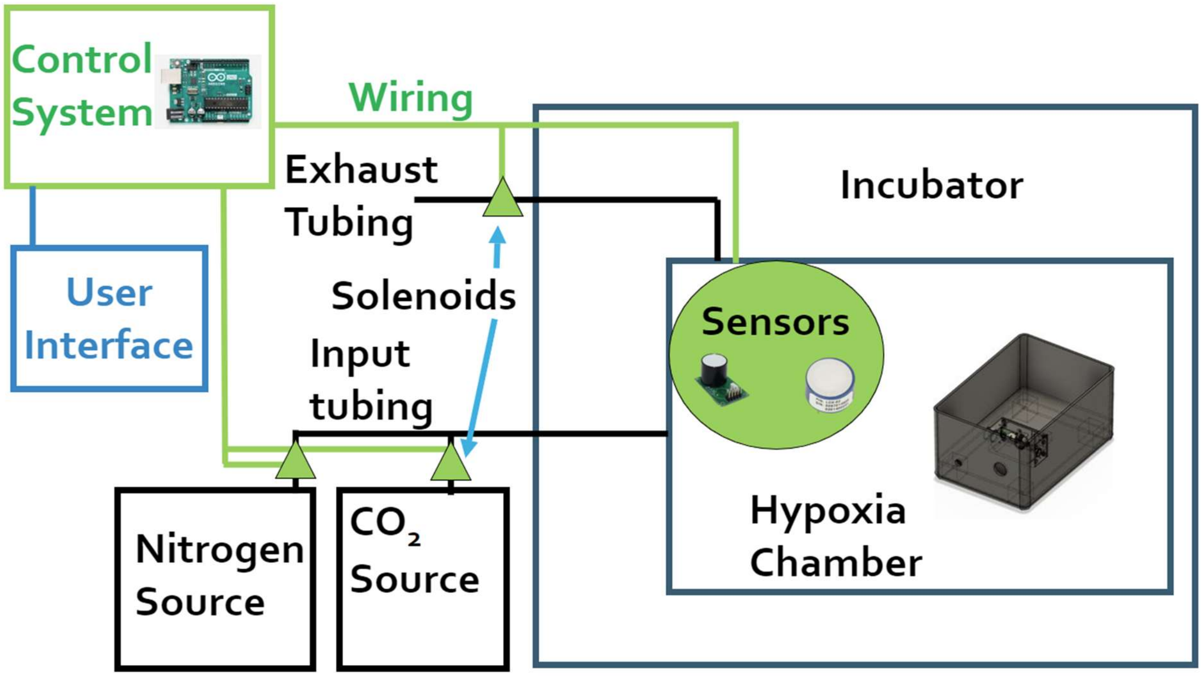
- Andrew needs to increase clearances for the O2 sensor and some of the nuts, and increase thickness for the filter cap area
- Paper needs the future work section to be written, the validation section to be fleshed out, and lots of pictures
- Portfolio needs final designs of housings and chamber put in, budget to be updated correctly and added in along with the newer meeting minutes, and any project learning/design validation stuff to be put in
- We'll set up a time with Dr. Schiele and Nick so that we can teach them how to use the equipment
- Wikipage needs some updates, i.e. pictures of final products and pictures of Alex and Izzie
- Action Items
    - Andrew wants to work on the sensor housing and get it reprinted, work on the GUI and run that, add design validation pictures to everything, and help Colin with the electronic housing
    - Izzie will work on editing the paper more and help update the portfolio
    - Jacob will finish up the wikipage, edit the paper, and update the portfolio
    - Colin will work on finishing up the electronic housing and getting it reprinted, and will also work on the paper
    - Alex will help edit the paper and portfolio as well

# Wiki Site

The link to the Wiki page for this project is: http://mindworks.shoutwiki.com/wiki/Low-Cost,_Controllable_Hypoxia_Chamber

# Design Solution

## System Diagram




## Component Selection & Sizing

### Materials

All materials which will be inside of the chamber must be safe for use in hypoxic conditions as well as be chemically resistant to ethanol for sterilization purposes. Because of those criteria, the following materials were chosen for each component: The chamber itself is a BPA-free food grade plastic container, the 3D printed material for sensor housing and shelf supports is PLA plastic, the shelf is made from aluminum, and the humidity tray is PVC plastic.

### Sensors

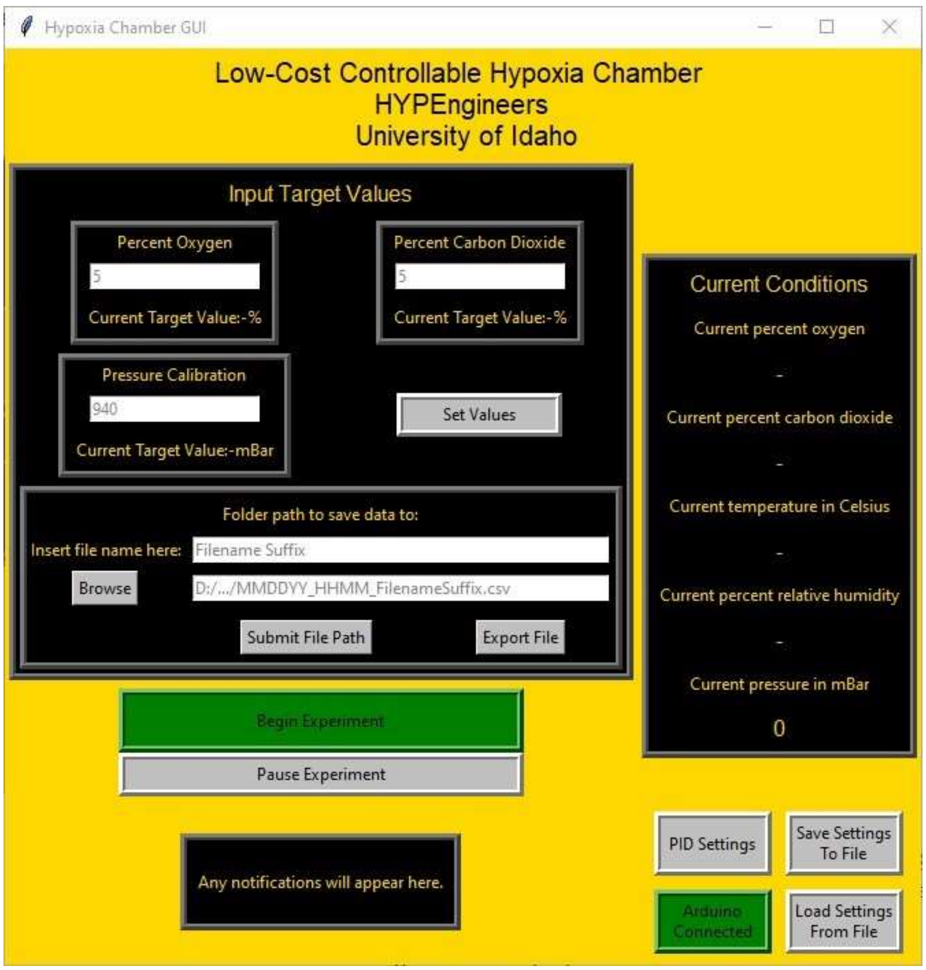
When choosing sensors for the control system, the sensors must be operational in the necessary O2 and CO2 ranges, have appropriate accuracy, and fit within the project budget. Keeping these criteria in mind, the sensors chosen are the ExplorIR®-M 20% CO2 sensor and the LuminOX LOX-O2 25% Oxygen sensor.

### Sizing

When determining the dimensions of the chamber, there were two criteria; the chamber must be small enough to fit in an incubator with inner dimensions (L x W x H) of 18.25” x 16” x 19.5” , and must be large enough to fit at least four well multidishes with dimensions of 5.12” x 3.54” x 0.98”, along with the sensor housing, shelf and humidity tray. Considering these criteria, the chamber has dimensions of 13.8” x 10” x 7.3”. This allows the chamber to be easily moved in and out of the chamber, while providing sufficient space for all items which need to go inside the chamber.

## User Interface

The user interface for this system was created using python and it runs on a raspberry pi that is connected to the mega microcontroller. There is a button on the interface where the user can click to connect to the microcontroller. The Through the UI, the user can set custom O2 and CO2 setpoints, and monitor the O2%, CO2%, temperature, humidity, and pressure within the chamber. There is also a place to select a CSV file to save experiment data to. Once the desired setpoint values have been entered, the experiment can be started by pressing the “Begin Experiment” button. If, at any point, the chamber needs to be opened during an experiment, there is a button to pause the system to avoid wasting gas. The experiment can easily be resumed using the button after the chamber is resealed. If the user finds they need to adjust the PI control for the system, there is a button which will open a window where the PI values can be adjusted. The settings for the PI control can be saved, so that the settings will stay at the adjusted values for future experiments.




## Key Features

Some key features of the product include:

- A chamber with a sealable lid for air tightness.
- A removable tray on the bottom of the chamber which covers a water tray that maintains appropriate humidity.
- O2 & CO2 sensors in a 3D printed housing which are mounted in the upper corner of the chamber.
- A control system in separate housing which connects to the sensors for monitoring purposes.
- Gas solenoid valves which control the input and output gasses of the chamber.
- A graphical user interface which allows the user to set and monitor appropriate O2 and CO2 levels in the chamber.

# Implementation & Manufacturing

## Bill of Materials

Below is a breakdown of all items used for the project so far and their associated costs. Note that this BOM will differ from the BOM in our published paper, as the one in the paper will only pertain to items other researchers would need to by to replicate our final product. This BOM includes the materials that were purchased throughout the duration of the project.

| Part reference | Component | Quantity | Unit cost | Total cost | Link | Material type |
|---|---|---|---|---|---|---|
| **Control System & GUI** | | | | | | |
| 10pcs logic level converter | 10pcs 4 Channels IIC I2C Logic Level Converter | 1 | $7.29 USD | $7.29 USD | Source | Metal, polymer |
| 10pcs transistors w/ diodes | TIP120 NPN BJT ST Darlington Transistor | 1 | $9.99 USD | $9.99 USD | Source | Silicon, germanium |
| Breadboard & jumper wires | DEYUE 3 Set Standard Jumper Wires Plus 3 Set of Solderless Prototype Breadboard | 1 | $8.59 USD | $8.59 USD | Source | Metal, rubber, plastic |
| $CO_2$ sensor | ExplorIR®-M 20% $CO_2$ Sensor | 1 | $179.00 USD | $179.00 USD | Source | Metal, polymer |

| | | | | | | |
|---|---|---|---|---|---|---|
| Ethernet cable 2 pack | Cat6 Ethernet Cable, 15 Feet (2 Pack) | 1 | $11.95 USD | $11.95 USD | Source | Metal |
| Ethernet connecter | Jack Modular Connector 8p8c (RJ45, Ethernet) 90° Angle (Right) Shielded | 1 | $2.71 USD | $2.71 USD | Source | PBT plastic |
| HDMI to VGA adapter | Benfei HDMI to VGA Adapter | 1 | $9.99 USD | $9.99 USD | Source | Metal, polymer |
| Hex Nut M1.6 25 Pack | Steel Hex Nut M1.6 x 0.35 mm Thread | 1 | $9.19 USD | $9.19 USD | Source | Stainless Steel |
| Logic level converter | BSS138 Logic-Level Translator Interface Evaluation Board | 1 | $2.95 USD | $2.95 USD | Source | Metal, polymer |
| Mega Microcontroller | ELEGOO MEGA 2560 R3 Board ATmega2560 | 1 | $15.86 USD | $15.86 USD | Source | Metal, polymer |
| Micro HDMI to HDMI cable | Micro HDMI to HDMI Adapter Cable, Wenter 6.5ft | 1 | $6.99 USD | $6.99 USD | Source | Metal, polymer |
| Oxygen Sensor | LuminOX LOX-02 25% Oxygen Sensor | 1 | $99.00 USD | $99.00 USD | Source | Metal, polymer |
| Panel mount ethernet cable | RJ-45 Ethernet Round Panel Mount Extension Cable - 30cm | 1 | $4.95 USD | $4.95 USD | Source | Metal, polymer |
| PCB | Printed circuit board | 1 | $2.00 USD | $2.00 USD | Source | Epoxy, metal, teflon |
| Power supply | DC 12V 3A switching power supply | 1 | $12.50 USD | $12.50 USD | Source | Semi-conductor, metal |

| | | | | | | |
|---|---|---|---|---|---|---|
| Raspberry pi 4 | Raspberry Pi 4 Model B - 2 GB RAM | 1 | $35.00 USD | $35.00 USD | Source | Metal, polymer |
| Raspberry pi power supply | Official Raspberry Pi Power Supply 5.1V 3A with USB C - 1.5 meter long | 1 | $7.95 USD | $7.95 USD | Source | Semi-conductor, metal |
| RJ45 terminal adapter connecter | 2pack RJ45 /8p8c Female Jack to 8 Pin Screw Terminal Connector | 1 | $9.59 USD | $9.59 USD | Source | Metal, polymer |
| SD card | Samsung (MB-ME32GA/AM) 32GB 95MB/s (U1) microSDHC EVO Select Memory Card with Full-Size Adapter | 1 | $7.99 USD | $7.99 USD | Source | PVC plastic, metal |
| SHCS M1.6 14mm 25 Pack | Steel Socket Head Screw M1.6 x 0.35 mm Thread, 14 mm Long | 1 | $8.97 USD | $8.97 USD | Source | Stainless Steel |
| Solenoids | Tailonz Pneumatic 1/4 inch NPT 12V | 3 | $11.99 USD | $35.97 USD | Source | Metal, plastic |
| Solenoid (replacement) | Tailonz Pneumatic 1/4 inch NPT 12V | 1 | $12.99 USD | $12.99 USD | Source | Metal, plastic |
| **Chamber, Gas & Tubing components** | | | | | | |
| Acrylic | SourceOne 1 Sheet - 1/2" Clear Acrylic Sheet Heavy Duty | 1 | $19.98 USD | $19.98 USD | Source | Acrlyic |
| 3D printer filament | 3D printer yellow PLA filament spool, 1.75mm diameter | 1 | $25.50 USD | $25.50 USD | Source | PLA |

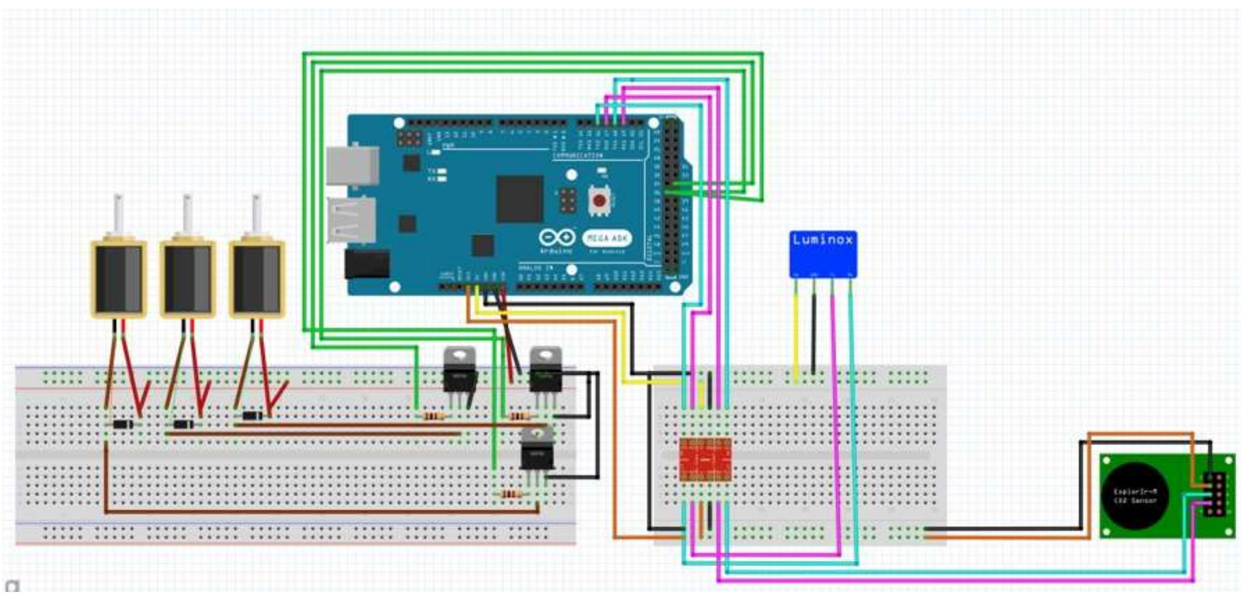
| | | | | | | |
|---|---|---|---|---|---|---|
| 5 pack heavy duty water tray | 5 Pack Green Plant Saucer Heavy Duty Sturdy Drip Trays | 1 | $9.99 USD | $9.99 USD | Source | PVC |
| Airtight container | Komax Biokips Extra Large Food Storage Container | 1 | $21.99 USD | $21.99 USD | Source | Plastic |
| Barbed tube fitting | Plastic Barbed Tube Fitting for Air and Water<br><br>Tight-Seal, Connector, for 5/32" Tube ID | 1 | $8.67 USD | $8.67 USD | Source | Nylon Plastic |
| CO2 Tank | Compressed CO2 tank | 1 | $55.84 USD | $55.84 USD | Source | Carbon Dioxide |
| Epoxy | Gorilla 2 Part Epoxy, 5 Minute Set, .85 Ounce Syringe, Clear | 1 | $12.15 USD | $12.15 USD | Source | Epoxy |
| Nitrogen tank | Compressed nitrogen tank | 2 | $34.28 USD | $68.56 USD | Source | Nitrogen |
| O-ring cord stock | Viton® Fluoroelasto mer O-Ring Cord Stock Chemical-Resistant, 1/8 Fractional Width | 1 | $7.29 USD | $7.29 USD | Source | Viton® Fluoroe las- tomer Rubber |
| Push to connect wye connecter | Push-to-Connect Tube Fitting for Air<br><br>Wye Connector, for 6 mm Tube OD | 1 | $5.30 USD | $5.30 USD | Source | Nylon Plastic |
| Rubber tubing | Firm Polyurethane Rubber Tubing for Air and Water<br><br>4 mm ID, 6 mm OD | 1 | $10.00 USD | $10.00 USD | Source | Polyurethane rubber |
| Spare Chamber | Komax Biokips Extra Large Food Storage Container | 1 | $21.99 USD | $21.99 USD | Source | Plastic |

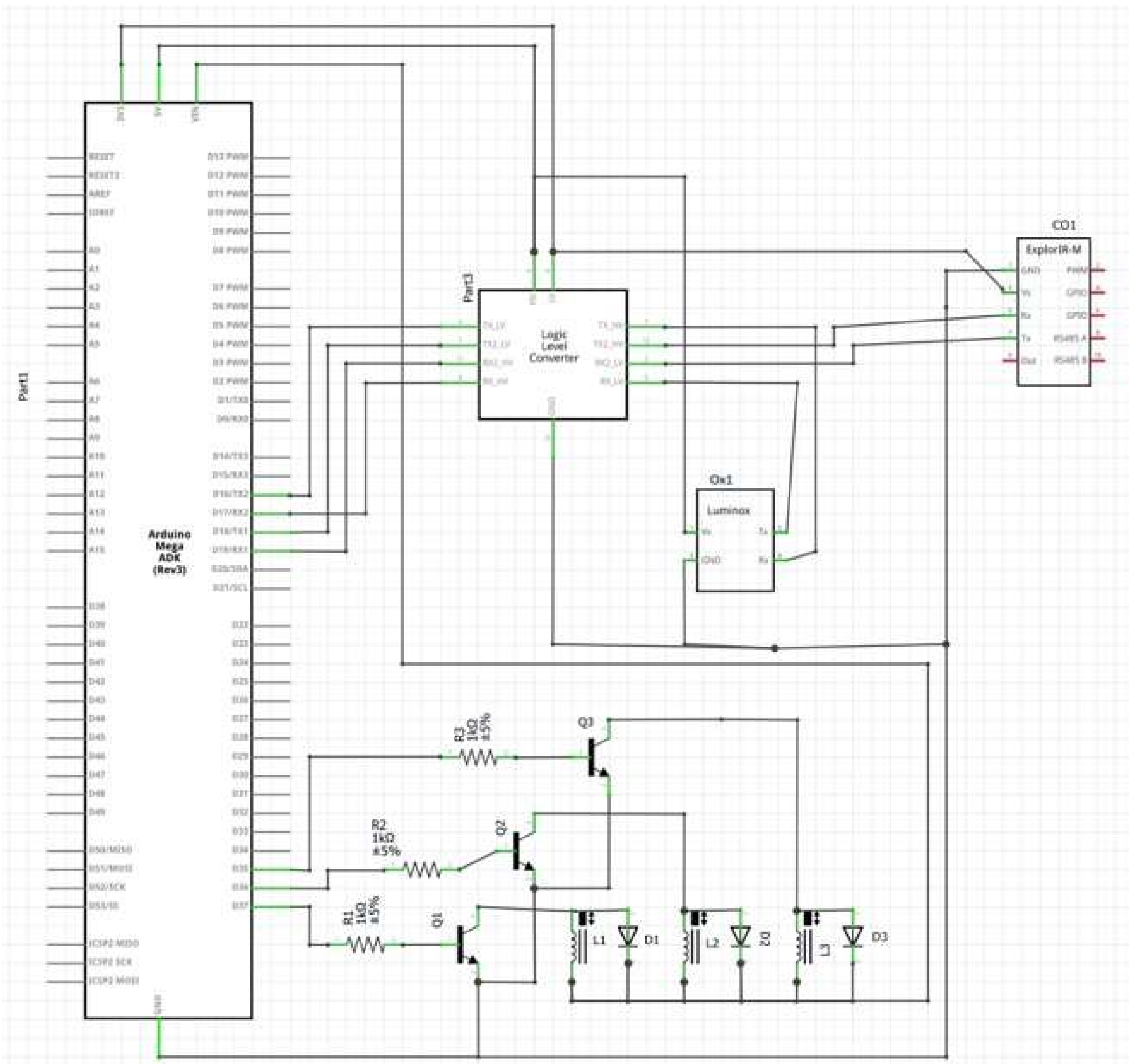
| | | | | | | |
|---|---|---|---|---|---|---|
| Thru wall gas adapter | Thru-Wall Adapter, for 6 mm Tube OD x 1/4 BSPT Female | 2 | $7.65 USD | $15.30 USD | Source | Metal, nylon plastic, polyurethane rubber |
| **Total Price of Components: $783.98** | | | | | | |

## Diagrams and Models

### Control System

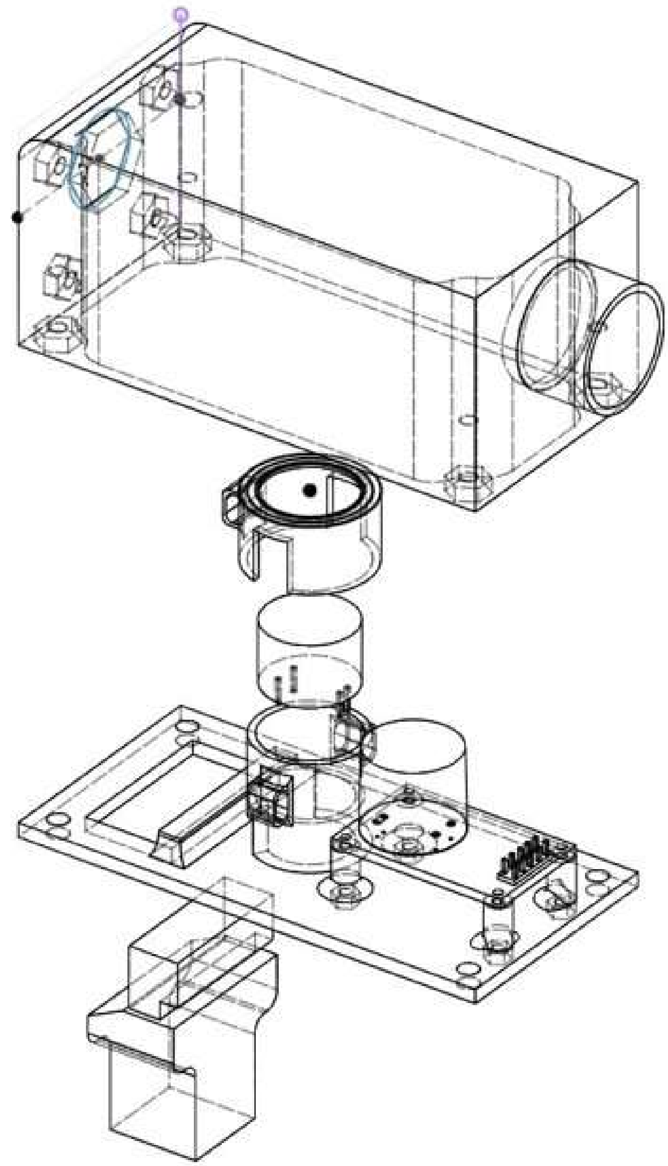
The control system consists of an O2 sensor, a CO2 sensor, and three gas solenoids, two of which input O2 and CO2 into the system and the other exhausts gas out of the chamber. The sensors will be mounted inside the chamber to monitor the conditions, which are sent to the microcontroller via serial communication. The solenoids are then opened, if needed, for the appropriate amount of time necessary to reach and maintain the desired chamber conditions. The system relies on a PI controller to avoid overshoot while reaching the O2 and CO2 setpoints.





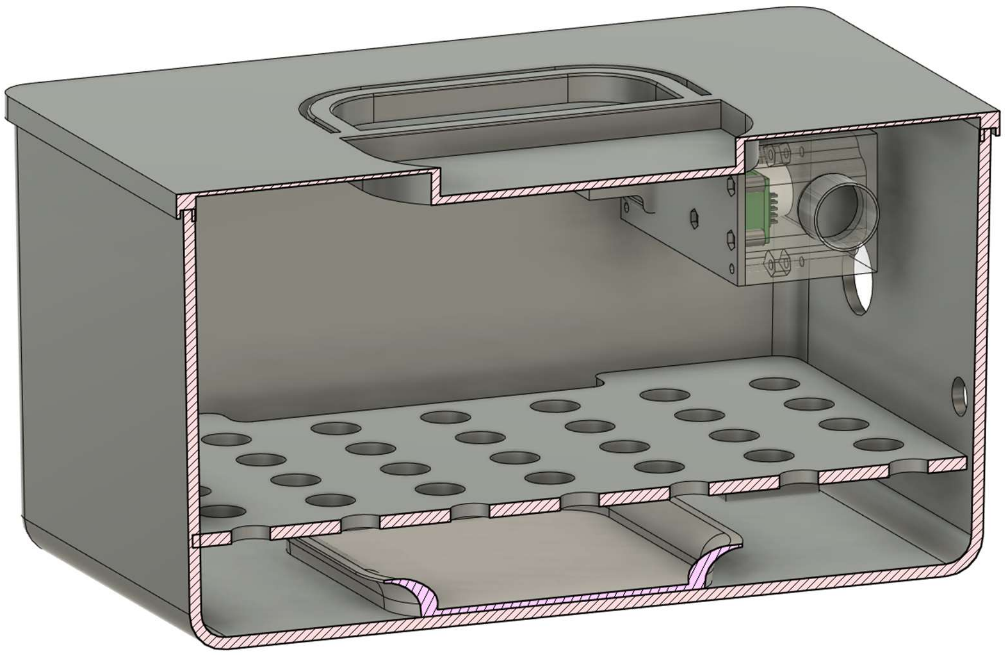

## Sensor Housing

In order to maintain a sterile environment inside the chamber, a housing was created for the sensors to be contained in. This way, the housing exterior can be sterilized with a solution without any damage to the sensors. A filter cap is also placed over the opening to the sensor housing. The housing will be mounted in the upper corner of the chamber and connected to the chamber exhaust port, so that the exhausted air will flow through the filter cap and then over the sensors before exiting the chamber.



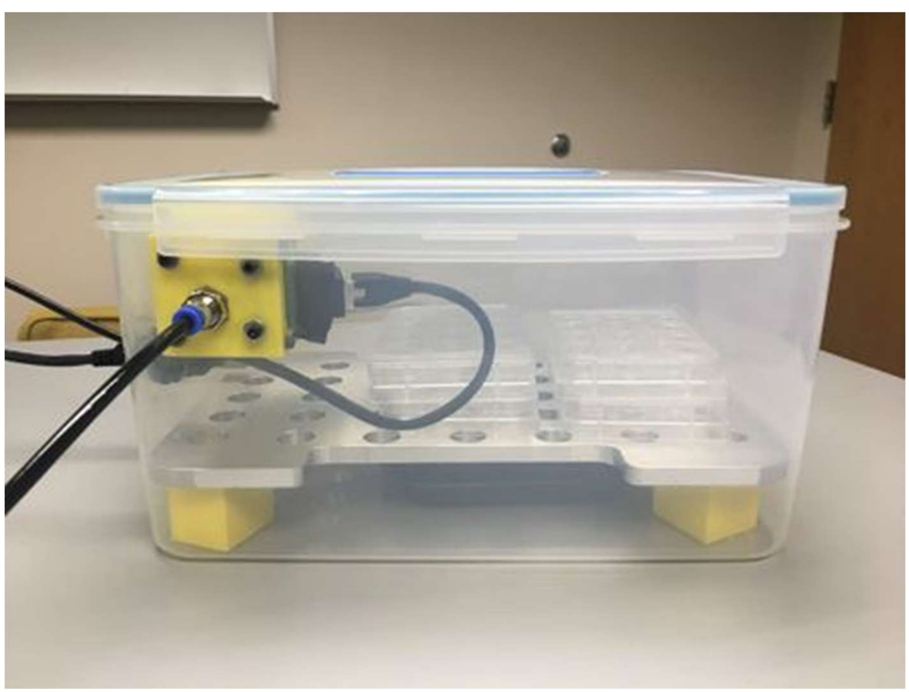
## Chamber Model Section

This is a section of the final design for the chamber. For the chamber, a premade, airtight container was purchased and modified to fit our purposes. There is a water tray sitting in the bottom of the chamber to maintain the appropriate humidity inside the chamber. There are four supports in the corners of the chamber which hold up the shelf that covers the water tray. The cell plates would be placed on top of the shelf. As previously mentioned, the sensor housing mounted in the upper corner of the chamber.



## Final Product

The final product of this project is a functional, low-cost and simple to manufacture hypoxia chamber. It is capable of maintaining variable O2 levels of 1% to 21% and a CO2 level of 5% for extended periods of time. The chamber fits within a standard sized incubator and operates within the incubator environment. The O2%, CO2%, temperature, humidity and pressure conditions within the chamber can be monitored from a simple user interface. The UI is also where the O2 and CO2 setpoints can be customized, and the user can set a CSV file to save experiment data to.



# Design Validation

## Experiment Design

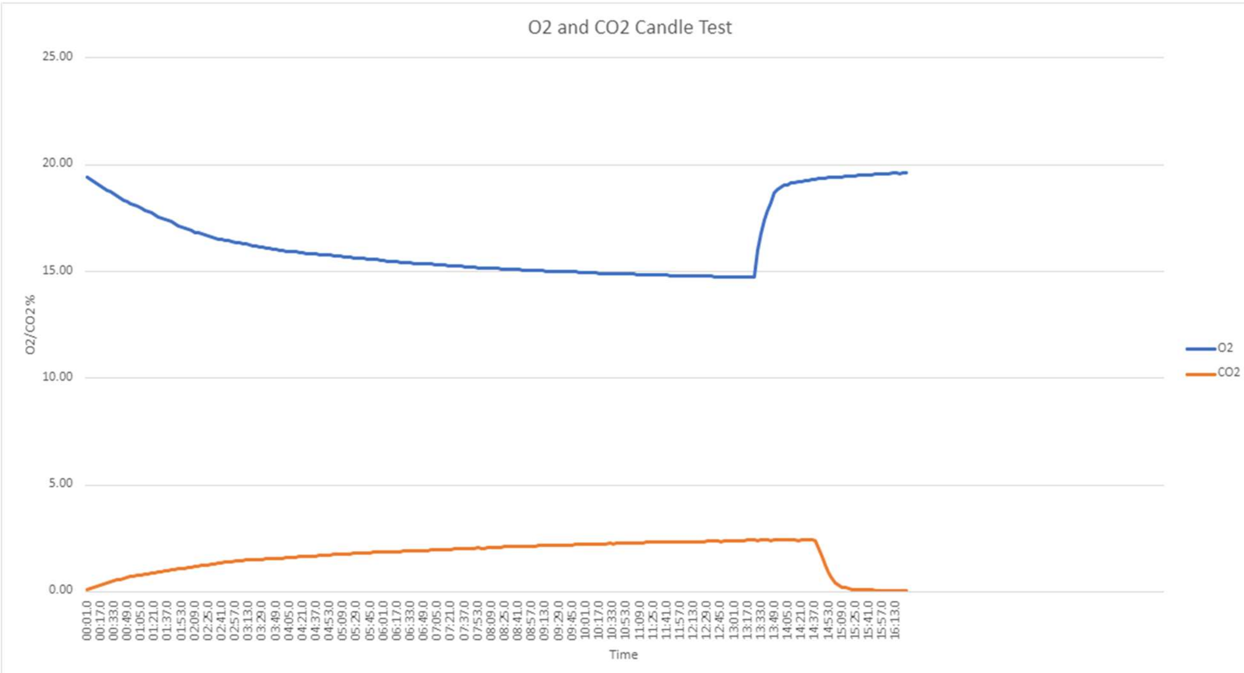
**Design Validation Plan & Results (DVP&R)**

| Requirement | Test | Test Subject | Target Date |
| --- | --- | --- | --- |
| Chamber should maintain a hypoxic environment environment for a period of at least 21 days | Run control system to pump the correct % of gas in to create hypoxic environment | Fully functional prototype | 1/30/21 |
| Chamber should be airtight | Slightly pressurize chamber and use soapy water to check for bubbles on all edges | Chamber prototype | 12/3/20 |
| Maximum weight shall not exceed 20 lbs | Virtually weigh it within CAD software. Weigh the full system on the scale in GJ 126 | Virtual Testing and Chamber Prototype | 12/3/20 |
| Maintain 5% CO2 levels | Use the CO2 sensor for daily measurements for 5 days | Fully functional prototype | 12/17/20 |
| Maintain 1 to 21% O2 levels | Use the O2 sensor to test various O2 levels for a period of 5 days each | Fully functional prototype | 12/17/20 |
| Reach proper setpoint Hypoxic and CO2 levels within 15 minutes | Create a setpoint on the GUI and check if it reaches that level within 15 minutes. Then open the door and test again. | Fully functional prototype | 1/14/21 |
| The chamber should be structurally stable | Apply various forces to chamber and observe any sctructural changes | Chamber prototype | 12/3/20 |
| Product must be durable to potential autoclaving or sterilization procedures | Review the properties of all of the components used | Virtual Prototype | 12/3/20 |
| The inside of the chamber must at least fit 4 13cm x 9cm x 2.5cm well | Model the plates and attempt to place plates inside the chamber | Virtual Prototype | 12/3/20 |
| Sensors are able to read accurate data to the arduino | Connect the O2 and CO2 sensors to the arduino and try and get sensors values. | Control System prototype | 11/26/20 |
| Arduino communicates sensor data to the raspberry pi interface | Connect the arduino and raspberry Pi together over serial communication | Control System prototype | 12/3/20 |
| Arduino control over solenoid gas valve | Purchase a solenoid valve and connect to the arduino to ensure control works | Control System prototype | 11/26/20 |
| Disable functionality whenever the door is opened. | Create a switch on the gui to alert when the door is open and disable input of gas | Control System prototype | 1/30/21 |

## Data Collection & Analysis

### O2 & CO2 Sensor Test

In order to ensure the O2 and CO2 sensor were accurately reading, a test was performed using a candle. The sensors were placed into a box and a candle was lit then placed in the box, after which the box was closed. As time went on, the sensors showed that the O2 in the box was declining while the CO2 in the box was rising. This test confirmed that the sensors were properly working.

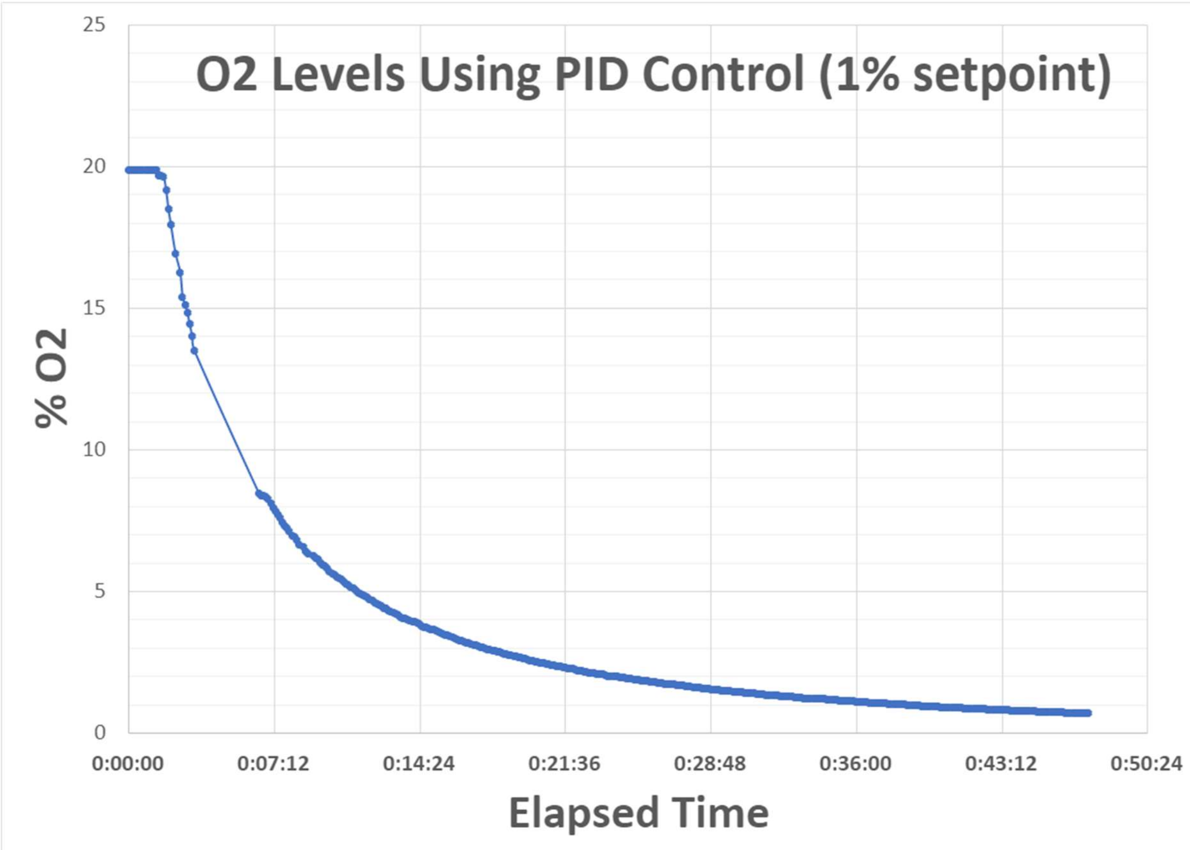



## N2 Test

The purpose of this test was to see if the control system could reach the appropriate O2 levels and how long it takes for that to happen. This test was performed using just N2, as there was no CO2 tank to use simultaneously. As the test was performed, edits were made to the control system code to change how long the solenoids were open and letting gas flow in and out to determine the most appropriate time. Results showed that the control system did reach a 5% O2 setpoint, however it took 1hr40mins to do so which is longer than what would be ideal.

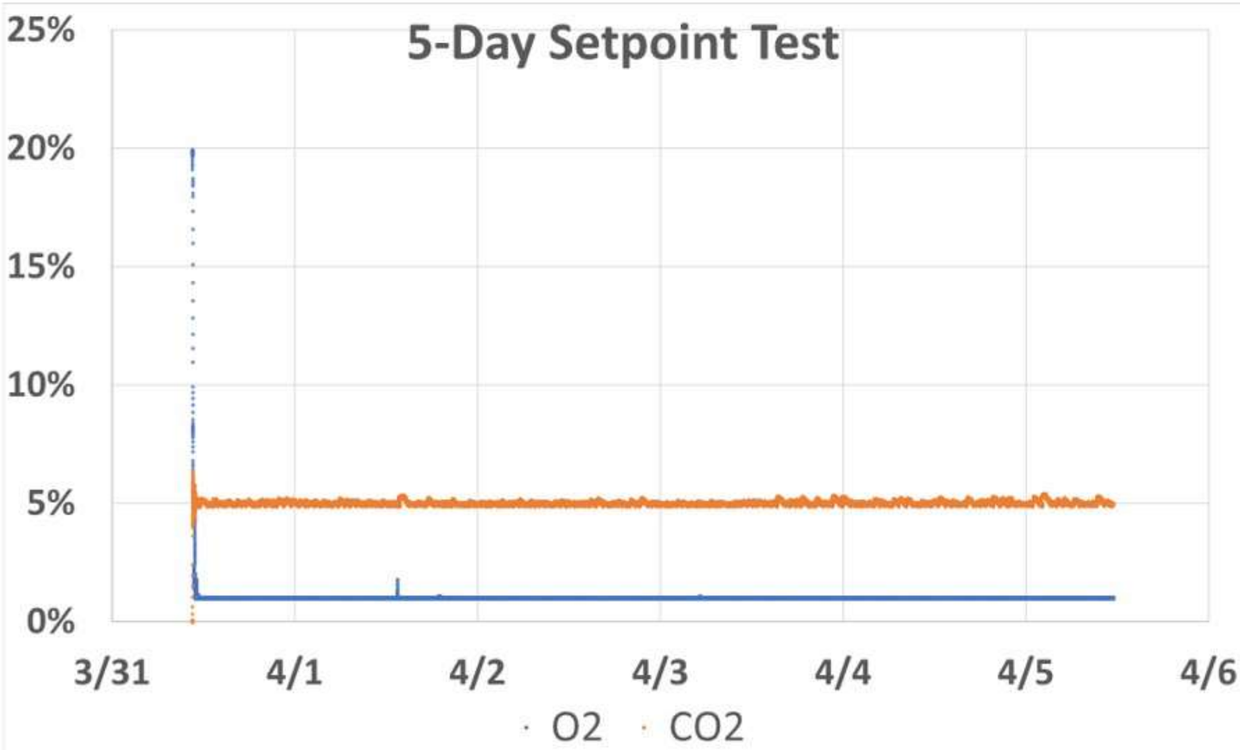

## PID N2 Test

This test was to determine whether a PID control system would work better for reaching and maintaining the appropriate O2 setpoint. This test was performed using just N2 like the previous test. The results showed that the PID control system reached the 1% O2 in a relatively short amount of time, about 36 minutes. However, the system overshot the setpoint and ended up bringing the O2 level down to 0.7%. Some tweaking of the PID control system will be necessary to ensure it does not overshoot the setpoint in the future.



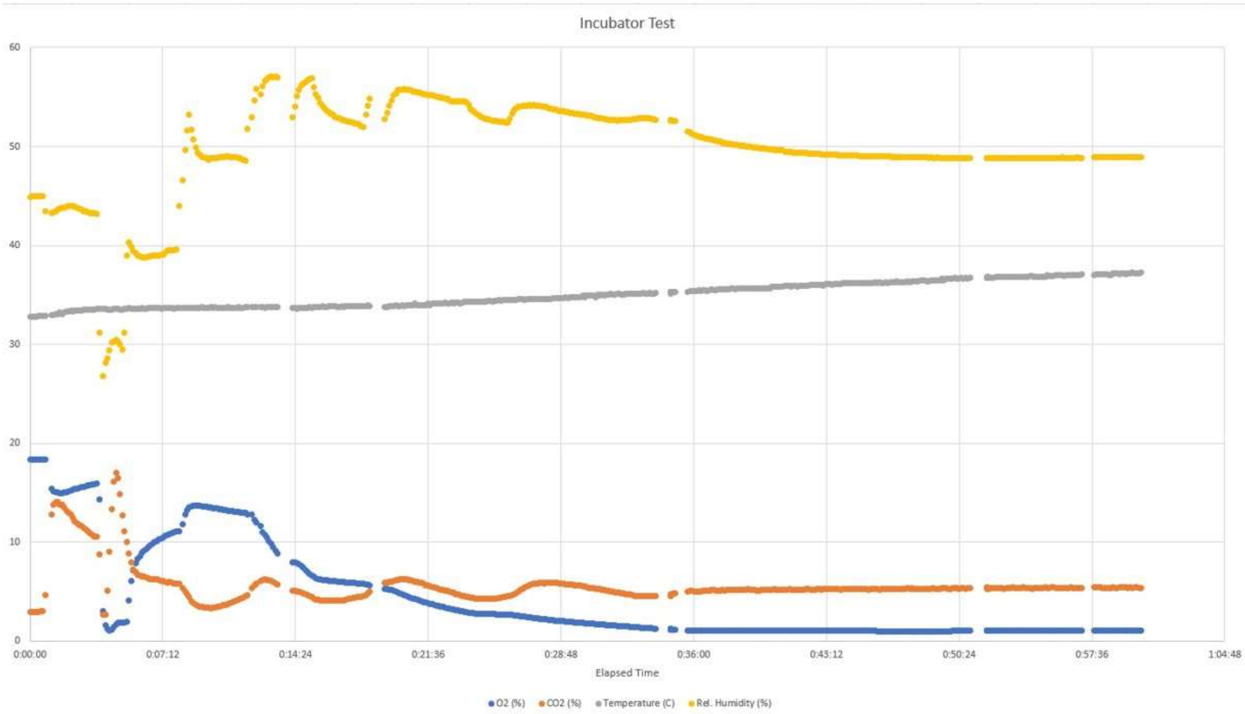

## 5-Day Test

This test was conducted to determine whether our system could maintain its setpoints for an extended period of time. One of the requirements of the system was to hold its environment for at minimum of 21 days, but as there wasn't time to conduct a 21-day test, this 5-day test would be the proof of concept test for this requirement. As shown, the system does reach its 5% $CO_2$ and 1% $O_2$ setpoints within about 30 minutes, like normal, and it holds these setpoints within minimum variation for the entirety of the 5 days. However, the exhaust solenoid was open for the duration of the test, meaning gas was leaking out of the chamber during these 5 days. This resulted in much more $N_2$ and $CO_2$ being used than expected.



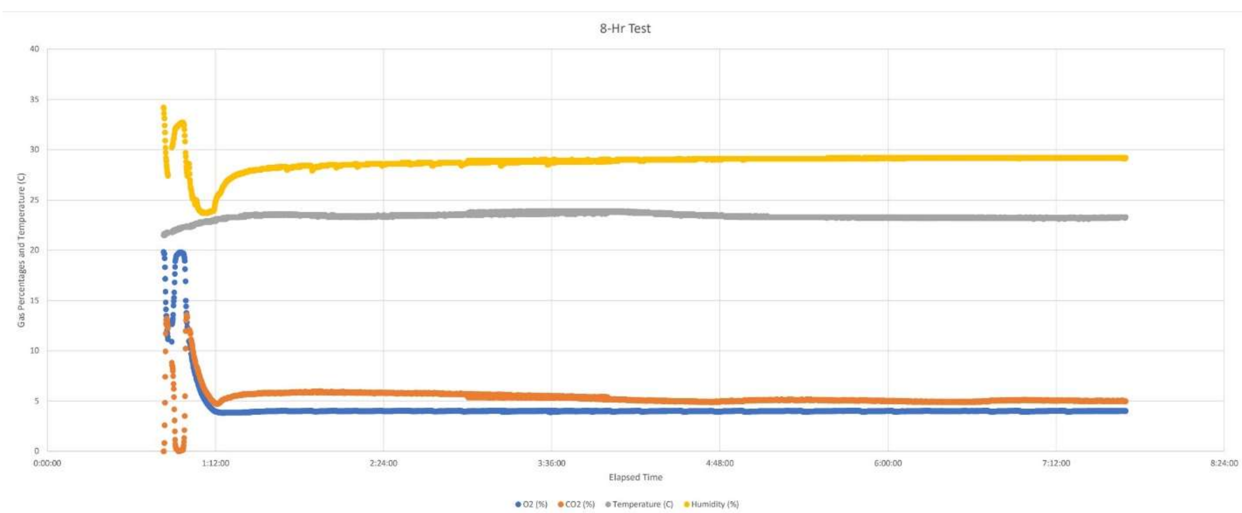

## Incubator Test

After lots of testing attempting to reach the correct CO2 and O2 setpoints, it was finally time to test for the final two parameters, humidity and temperature. This test also tested to ensure that placing the chamber inside the incubator wouldn't have any negative repercussions. The input and exhaust tubes were initially switched by accident, but this mistake was quickly noticed and remedied. This accounts for the strange spikes in O2 and CO2 at the beginning of the test, but once the tubing was fixed the setpoints were hit within the normal 30 minute mark. The temperature of the chamber steadily rose throughout the test, eventually ending at the desired 37°C. The humidity varied throughout the test, but although it was nowhere near the desired 95%, it was beginning to rise again at the end of the test. This indicates that the chamber should be placed inside the incubator for an hour or more before beginning a test to allow the large aluminum shelf to warm up. This change would have allowed the chamber to reach the correct humidity levels.




## 8 Hour Test

This test was conducted to once again ensure that the system can maintain its environment for an extended period of time. This test also had the purpose of seeing whether too much gas was used, since the solenoids had now all been tightened/replaced. As the results show, the 5% CO2 and 4% O2 setpoints were met within the normal 30 minute mark, and were held throughout the test.



## References


| Resources | What is it? |
| --- | --- |
| https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0148923 | A Lab Assembled Microcontroller-Based Sensor Module for Continuous Oxygen Measurement in Portable Hypoxia Chambers |
| https://onlinelibrary.wiley.com/doi/full/10.1002/mds3.10064 | Portable, low-cost hypoxia chamber for simulating hypoxic environments: Development, characterization and applications |
| https://www.future-science.com/doi/full/10.2144/000114341 | An effective, low-cost method for achieving and maintaining hypoxia during cell culture studies |
| https://www.onshape.com/ | Online CAD software |
| https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3902232/ | A novel experimental hypoxia chamber for cell culture |
| https://bmedesign.engr.wisc.edu/projects/s12/hypoxia_chamber | A team from University Wisconson-Madison created a hypoxia chamber back in 2012/13. It took three semesters (three teams) to finish the project |
| http://beweb.ucsd.edu/courses/senior-design/projects/2011/project_9/designsolution.html | Oxygen & Carbon Dioxide Controlled Incubator for Cell Culture Studies |
| https://bc-robotics.com/tutorials/controlling-a-solenoid-valve-with-arduino/ | Hooking up solenoids to an Arduino board |