To: Dr. Oman and Amy Swartz

From: Bio-Inspired Design - Team 16

Subject: Hardware Review II

Date: March 29, 2019

This memo is an informal memo to communicate the manufacturing done following Hardware Review I. This includes figures of the manufacturing processes and the system (up until this point). These figures will have labels of the subsystems. Additionally, the current Design of Experiments CAD model will be provided, along with the final design CAD model (final design still to be finalized). Any aspects missing, or to be done, will be documented, along with any supporting evidence. Finally, a schedule of who contributed to what aspect of the manufacturing process will be provided. As of right now the team is 85% (90%, if all vents were printed and in hand) done with the manufacturing of their DoE system and vents.

Photos of Systems

Photos of the current state of our manufacturing are provide below in this section (figures 1-6). These are photos of the bio-inspired vents and the DoE pressuring chamber to be used for testing. All 3D printing was done by 3D systems, from sponsorship, printed in “Engineering Clear” (has the material properties needed for the project, but exact details have yet to be given, and may not be able to be given).

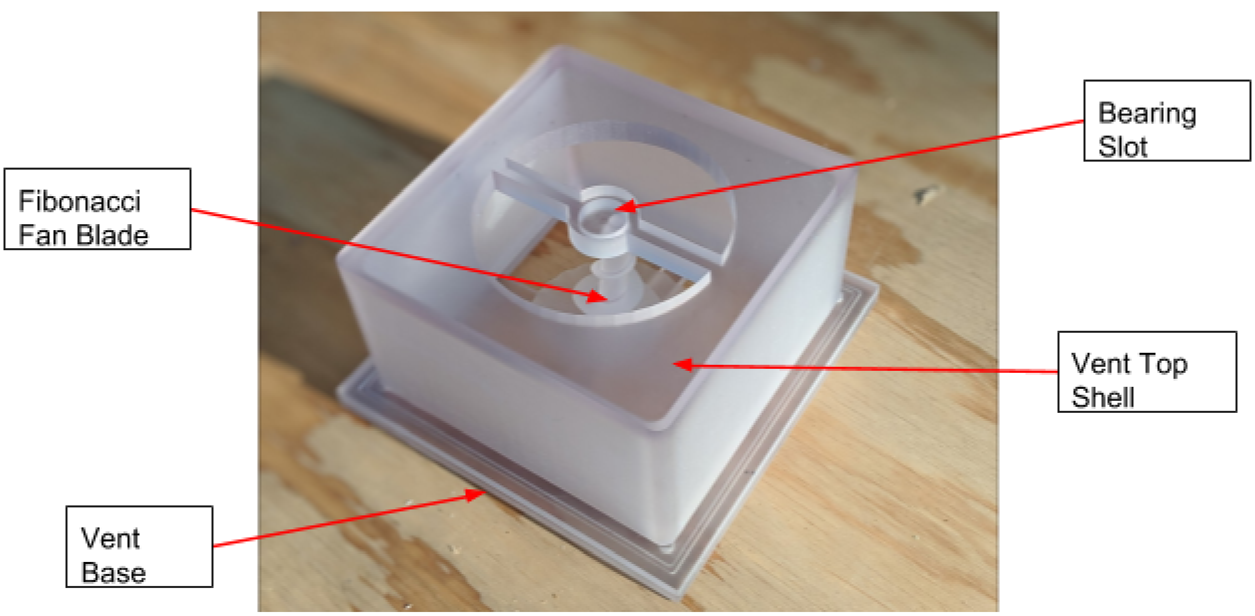

Figure 1: Fibonacci Vent 3D Printed Model

Figure 1 is a picture of the fibonacci vent design, it contains a bottom, top housing and the fibonacci blade. Additionally, it has spots for bearings to be placed (which are in the current model). This vent was designed by Taylor Mellon.

Figure 2: Termite Mound Vent 3D Printed Model

Figure 2 is a picture of the vent created based on how termite mounds vent. This design was created by Talon Mills.

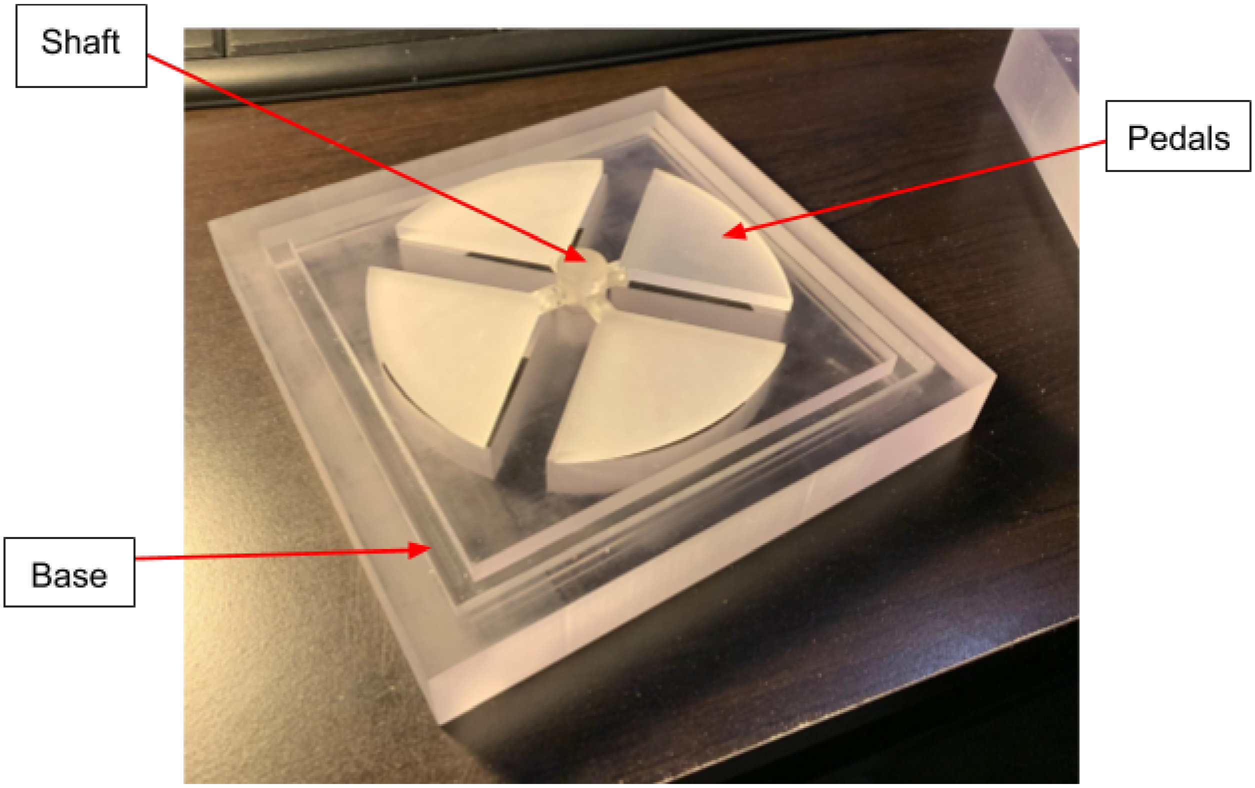

Figure 3: Flower Vent 3D Printed Model (Base)

Figure 3 is a picture of the flower vent design. This design incorporates flower “pedals” that move up and down based on the flow of air out of the pressure chamber. This design was created by Kyle Matsuoka.

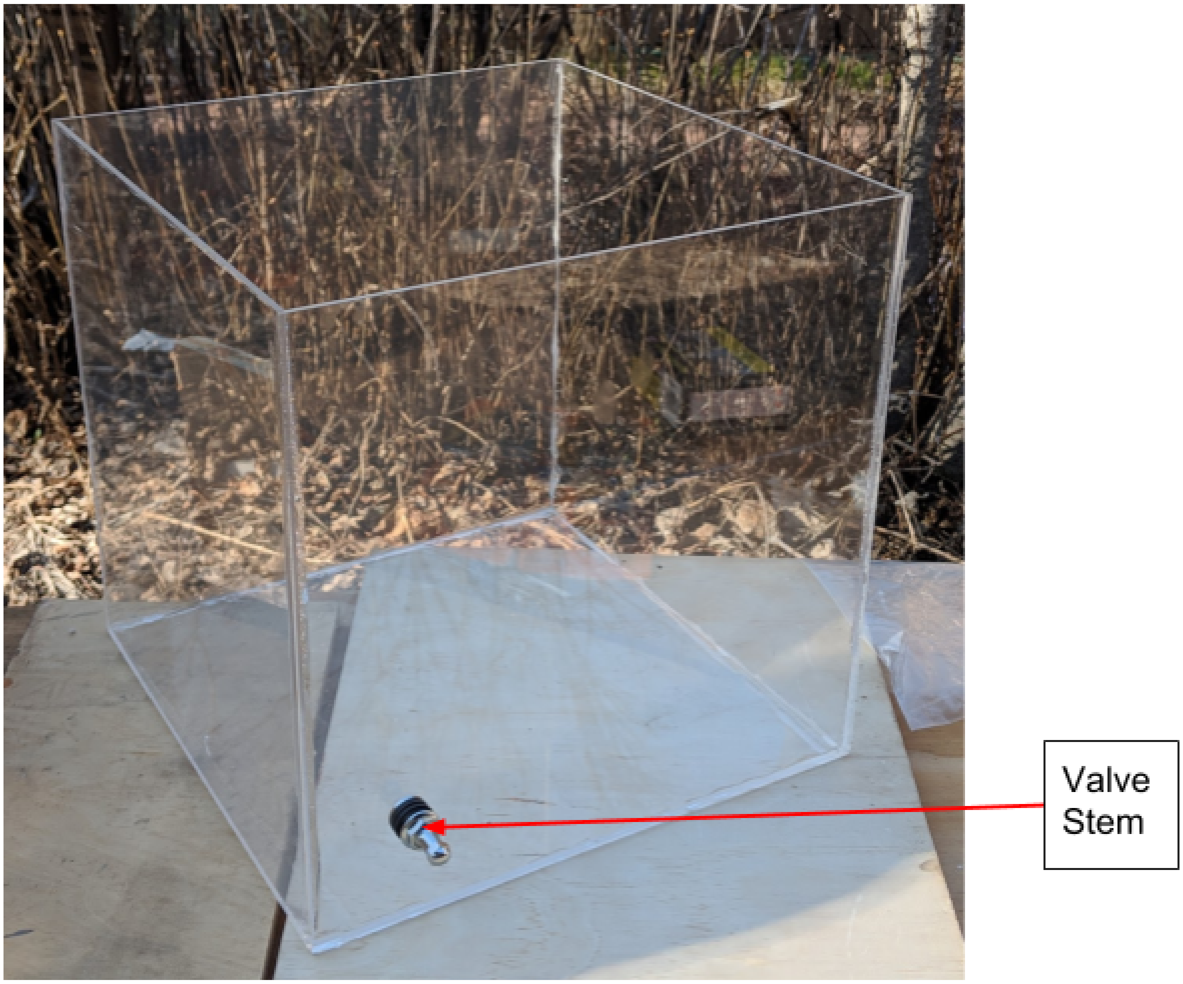

Figure 4: Pressure Chamber (Shown to Dr.Oman)

Figure 4 is the pressure chamber manufactured for the testing of the DoE. This figure is of the progress made when the team met with Dr. Oman for Hardware Review II. The top was not yet put on and the pressure release actuation, along with the vent sealing mechanism still needed to be completed.

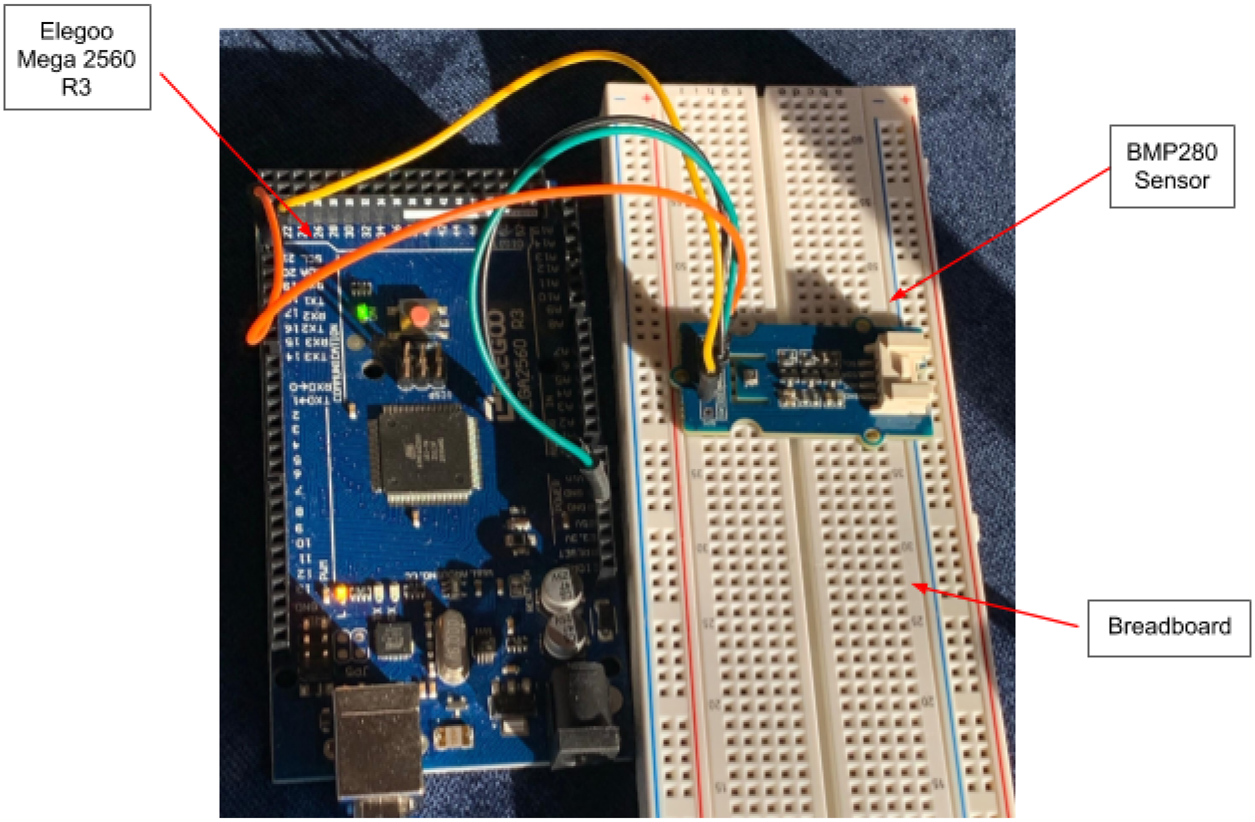

Figure 5: Arduino Setup

Figure 5 is the wiring setup using the Grove BMP280 Barometer attached to the Elegoo Mega 2560 R3 Arduino circuit board. There were complications with setting up the wires attaching the barometer to the Arduino circuit board. With the help of Dr. Trevas, the wiring of the barometer was able to be correctly set up and the code for Arduino works well gathering data of the temperature, pressure, and altitude every millisecond. The Arduino code can be seen in Appendix A. The team now needs to find a way to extract the data gathered from Arduino into MATLAB, creating a live graph of the barometer as data is being collected.

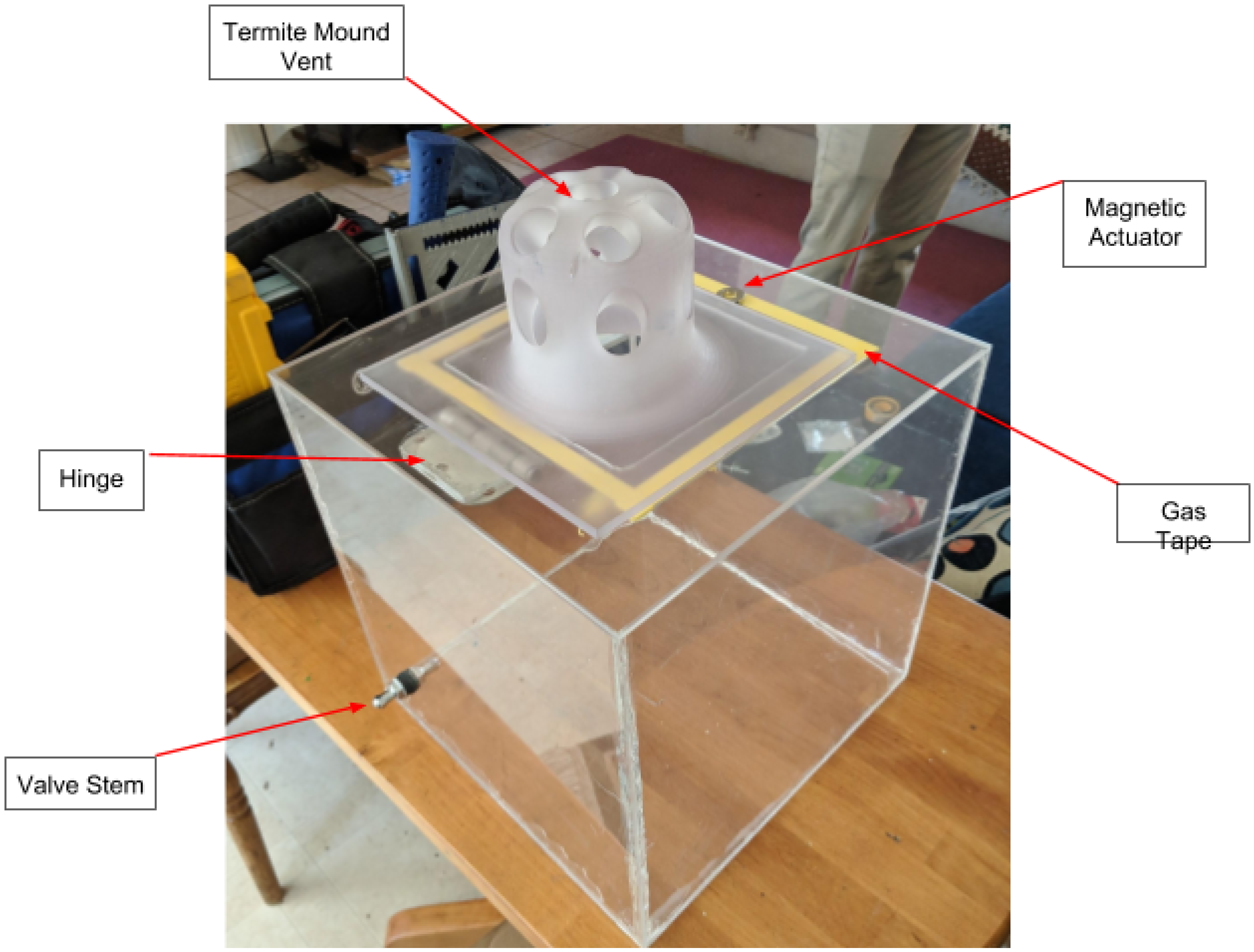

Figure 6: Pressure chamber fully assembled with termite vent in position to be tested.

Figure 6 is the pressure chamber with the top sheet attached (still to be epoxied) with the pressure releasing actuation system. The vent clamping mechanism is not seen in the picture due to the team not figuring out a way to deal with the varying vent sizes. However, the team determined the weight of the vents is substantial enough to seal itself. Gas tape will be used on the vents to help avoid any leakages.

The manufacturing of these designs were created based on SOLIDWORKS models created by the team.

CAD Models of DoE and Final Design (before bio-inspired aspect)

This section contains the SOLIDWORKS models created for the pressure chamber, including the hypothesized actuation pressure release method and vent attachment system.

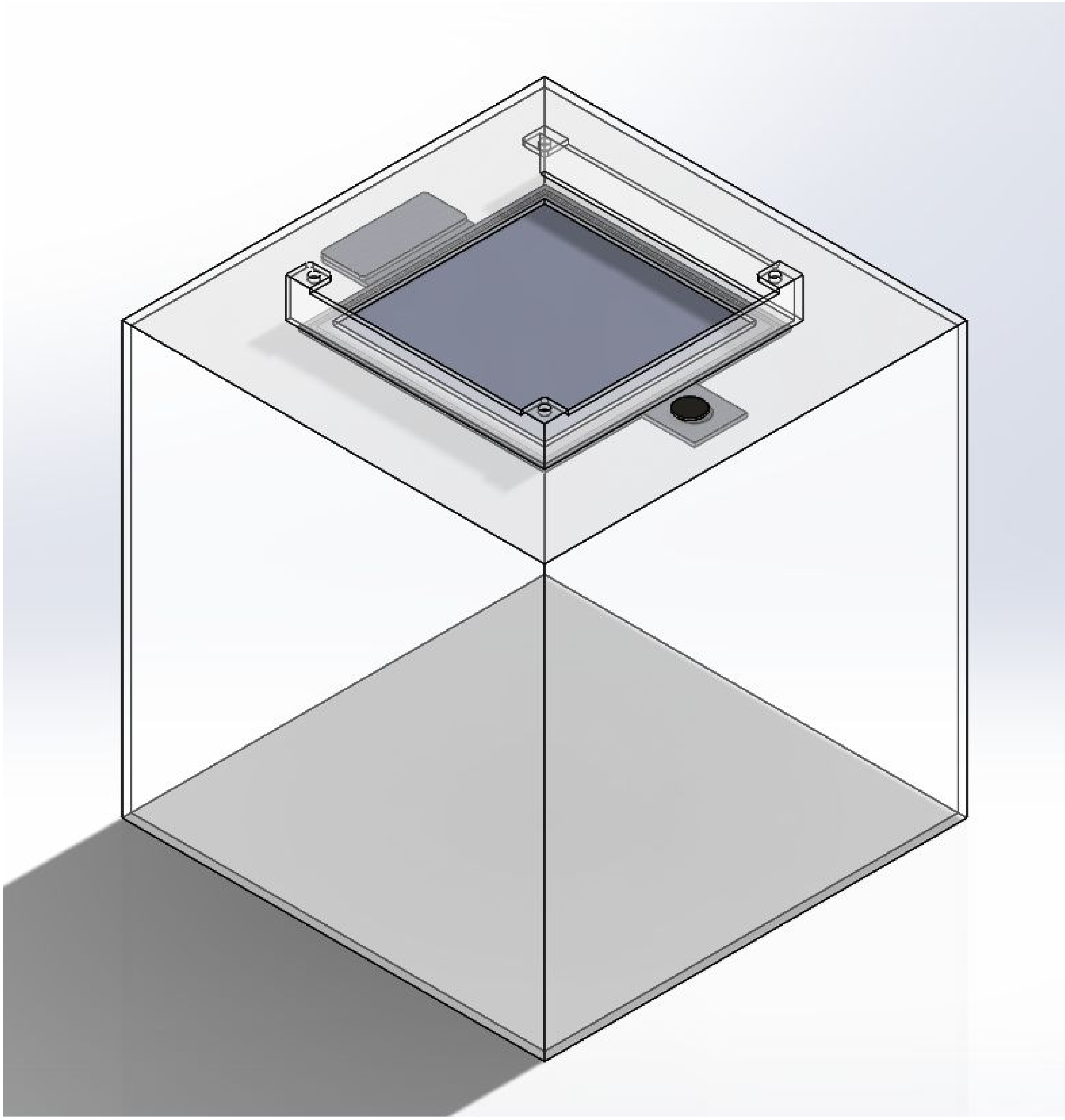

Figure 7: CAD assembly showing magnetic trap door actuation

Figure 7 is a SOLIDWORKS model of the chamber with the actuation system for the air to be released (using a magnite). With the proposed attachment mechanism for the vents.

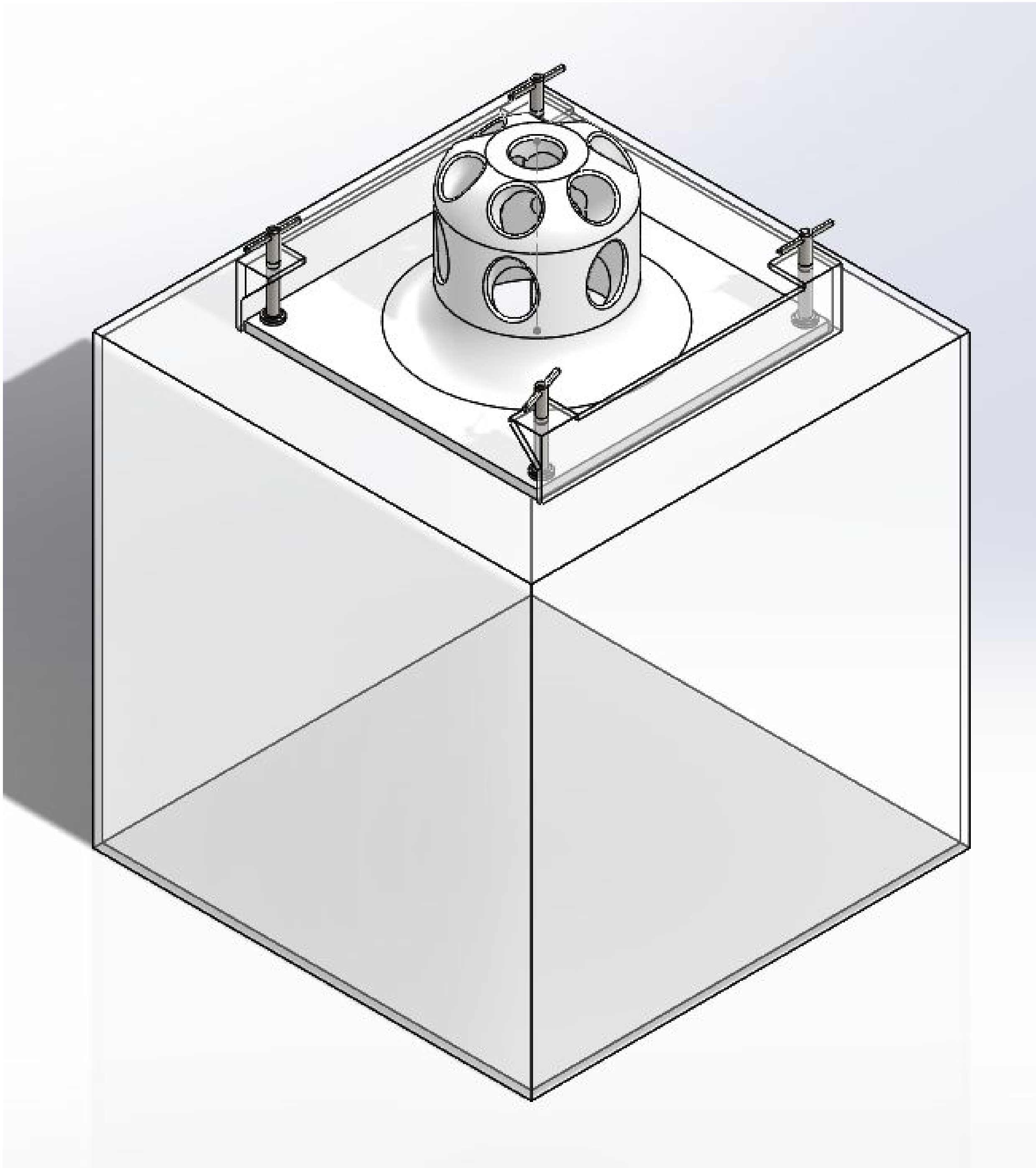

Figure 8: CAD assembly of pressure chamber with the first iteration locking mechanism

Figure 8 is a SOLIDWORKS model of how the team initially thought about locking the vents onto the pressure chamber. However, the team has decided to not use this method since the 3D printed vent's base varies in size and would interfere with this mechanism.

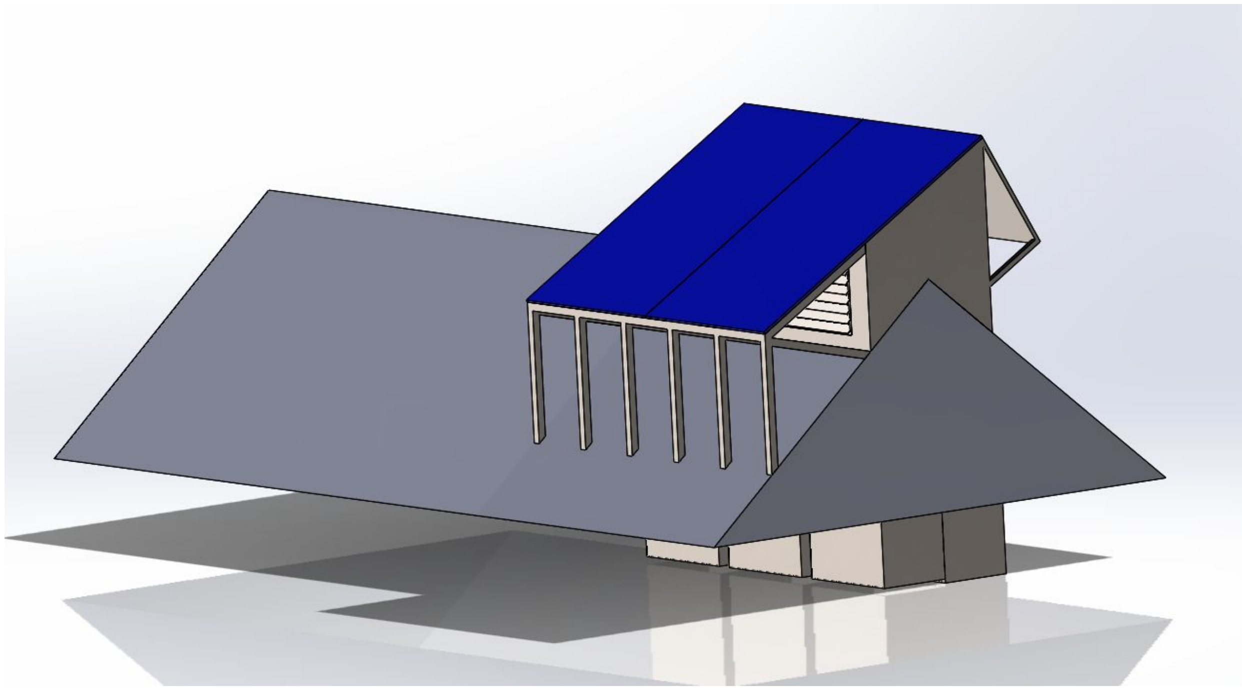

Figure 9: CAD assembly of SBS West solar ventilation system to replace current venting ridge

Figure 9 is a SOLiDWORKS model of the proposed final design from last semester. This design is almost complete. However, it still needs details to be added and for the bio-inspired venting aspect to be added. The bio-inspired aspect can not yet be added due to the testing of the different vents designs still needing to be tested in the DoE. Once the final design is complete the team will have a scaled model 3D printed by 3D systems.

Evidence and Future Manufacturing

This section contains evidence of parts that were not ordered and a list of parts that still needs to be designed and manufactured.

Evidence

- 3D Systems was able to print our vents (and another other printing we need) for free and the prints could have any material properties we needed. The email explaining this and providing evidence can be seen in Appendix B, figure 1.
- The Pinecone Vent was not able to be 3D printed since the design was too big for it to be 3D printed.
- The Pinecone Vent has been redesigned and is smaller, so that it could be 3D printed. Figure 11 shows the updated Pinecone design.

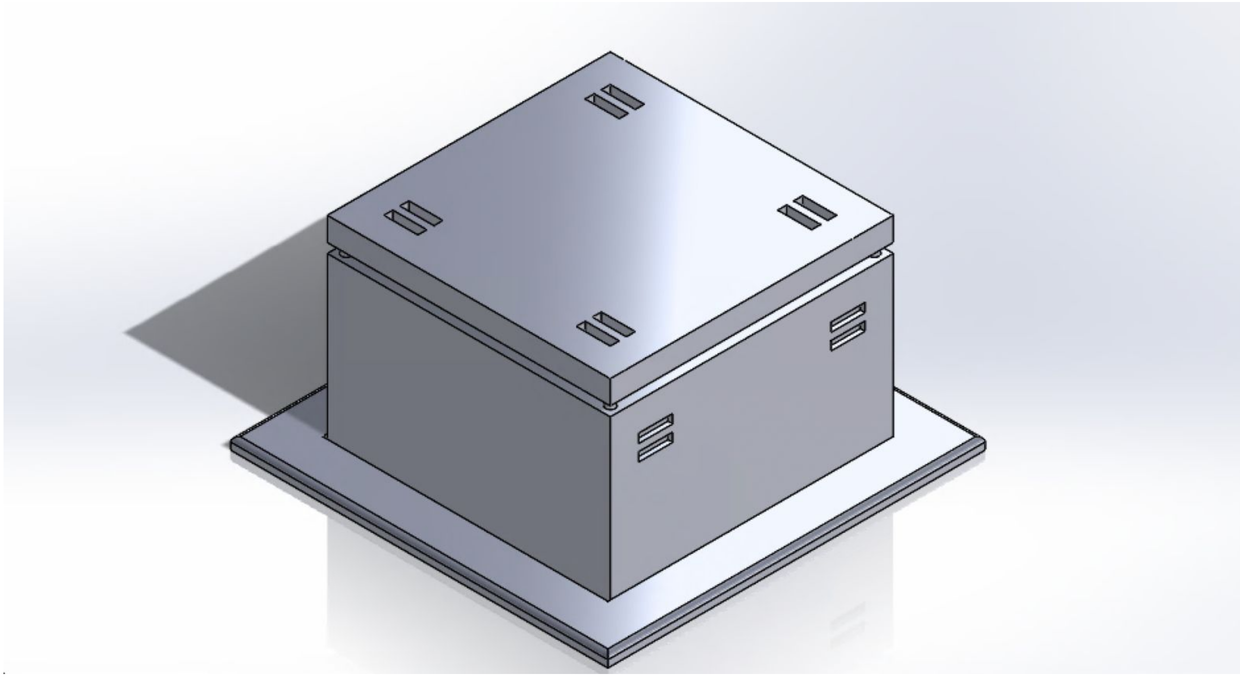

Figure 10: Redesigned Pinecone Vent

- Figure 10 shows a redesign of the pinecone vent. The design represent the pinecone when it gets humid and needs to vent itself, therefore, the mechanism used to do this design is based on natural ventilation. There are an open holes in the roof and two walls to vent the room when it gets to certain number of pressure. This design was created by Hani Alharbi.
- Emails proving the design could not be 3D printed can be seen in Appendix B, figure 2.

Future Manufacturing

- When testing the pressure chamber it was discovered that the seal around the actuation trap door is leaking and is still being designed and iterated upon to create an airtight seal.
- The Arduino section is not fully coded. The code is only is able to read temperature, pressure, and altitude every millisecond. The code still needs to implement extracting the data into MATLAB.

Responsibilities

This section contains a table of the different manufacturing tasks which need to be completed, who was responsible, who did the actual manufacturing and comments related to each task. This table can be seen in table 1 below.

Table 1: Task Responsibilities and Completion

Tasks	Originally Responsible for Task:	Task Completed by:	Additional Notes
Termite Vent	Talon	Talon	No editing needed after printing and is in working condition.
Pinecone Vent	Hani	Hani	First iteration could not be printed, CAD model redone and needs to be printed.
Fibonacci Vent	Taylor	Taylor	Fan blade chipped and is being reprinted, bearing mounts filed out after printing to fit bearings for fan blade into housing. In working condition.
Flower Vent	Kyle	Kyle	Flower petals and housing needed to be sanded after printing. In working condition.
Pressure Chamber	Team	Kyle, Taylor, and Hani	Talon out of town during build. Epoxy needed to be applied multiple times in order to make it airtight. A frame/jig was constructed to make sure the box was made correctly.
Arduino	Kyle and Taylor	Kyle and Taylor	Kyle and taylor struggled through the hardwiring and coding. Had to ask Dr.Trevas for help in order to get it working.
Actuation/ Pressure Release	Talon	Talon and Taylor	Design created and CAD models created by Talon. Taylor and Talon worked together in building it and troubleshooting issues that arose in the build.
Vent Sealing	Team	Team	Vent sealing was attempted by the team. Multiple issues arose during manufacturing leading the team to rethink the sealing all together. The team decided that the weight of the vents with gasket tape will be enough to seal the vents to the pressure chamber.

Conclusion

With approximately 90% of the system to conduct the DoE being manufactured, the team will do final touches to ensure the chamber and vents are functioning in the proper way. Once these final touches and manufacturing have been completed, the bio-inspired vents will be tested to see which design performs the best. Using the results found, the team’s final ventilation design for Social Behavioral Sciences West building will be innovated/revised with an implementation of a bio-inspired vent design (one which performs the best in the DoE).

APPENDIX A

Below is the Arduino code that is used to measure the temperature, pressure, and altitude:

```
/***************************************************************************
  This is a library for the BMP280 humidity, temperature & pressure sensor

  Designed specifically to work with the Adafruit BMEP280 Breakout
  ----> http://www.adafruit.com/products/2651

  These sensors use I2C or SPI to communicate, 2 or 4 pins are required
  to interface.

  Adafruit invests time and resources providing this open source code,
  please support Adafruit andopen-source hardware by purchasing products
  from Adafruit!

  Written by Limor Fried & Kevin Townsend for Adafruit Industries.
  BSD license, all text above must be included in any redistribution
 ***************************************************************************/

#include <Wire.h>
#include <SPI.h>
#include <Adafruit_Sensor.h>
#include <Adafruit_BMP280.h>

#define BMP_SCK 13
#define BMP_MISO 12
#define BMP_MOSI 11
#define BMP_CS 10

Adafruit_BMP280 bme; // I2C
//Adafruit_BMP280 bme(BMP_CS); // hardware SPI
//Adafruit_BMP280 bme(BMP_CS, BMP_MOSI, BMP_MISO,  BMP_SCK);

void setup() {
  Serial.begin(9600);
  Serial.println(F("BMP280 test"));

  if (!bme.begin()) {
    Serial.println("Could not find a valid BMP280 sensor, check wiring!");
    while (1);
  }
}
```

```
void loop() {
  Serial.print("Temperature = ");
  Serial.print(bme.readTemperature());
  Serial.println(" *C");

  Serial.print("Pressure = ");
  Serial.print(bme.readPressure());
  Serial.println(" Pa");

  Serial.print("Approx altitude = ");
  Serial.print(bme.readAltitude(1013.25)); // this should be adjusted to your local forcase
  Serial.println(" m");

  Serial.println();
  delay(1);
}
```

Frontier <tuffsfamily@frontier.com>
to me

Sun, Mar 10, 4:48 PM

Hi Taylor,
Absolutely I can get these printed for you.
What are the material properties you need? I'm assuming rigid but I don't know if there are thermal sensitivities (repeated hot/cold cycles), or if there is a durability expectations.
Our publicly available materials have these different properties, but if you are just looking for a general purpose usage, then there are a couple we can use. Do you have a colour preference? Clear, black, grey or white are your choices. All the materials can be painted if needed too.
Let me know how many you need printing.
If you have a couple of designs send them and we'll print them all.

The platform size for the machines here is 11.5"x 8.25"x5.7" so if you can bear that in mind we can print what you need. Cost is free - an acknowledgement in any published paper is all I would ask.

Best guess is they'll take 12 ish hours to print -so get them to when you can, and I'll make sure you get them over spring break. I told Rich I would take a day off work to come and visit you anyway - we could probably meet up somewhere half way .

Hope this helps

Moira

Sent from my iPhone

On Mar 10, 2019, at 2:42 PM, Taylor Mellon <trm268@nau.edu> wrote:

> Greetings,
>
> First of all, this is Taylor (Richard's friend). Secondly, my capstone team and myself are working on a project which is to redesign the ventilation of a building. We are wanting to test four bio-inspired vents we have generated in SOLIDWORKS. In order to test these vent designs we need to have them 3-D printed. Unfortunately, the large 3-D printers at NAU are down, so we are having to out source I was curious as to if it is possible for 3-D Systems to print these vents? They are vents which are roughly 7" X 7" X 5". If your company is able to print these vents, what are our options for printing and if possible the rough costs? Finally, if these vents are able to be printed, would I be able to pick them up during Spring Break if we were to get the files needed to you or the company by 13th of March?

Figure B.1: Email Providing proof of the 3D Printing

Hi Taylor,

I'm trying to get this part printed on our larger printer (all of the extents are larger than our Z height of 145mm) but I can't guarantee it will be done next week – I would suggest you make a backup plan for this part.

I'll keep you posted when I know for sure

Moira

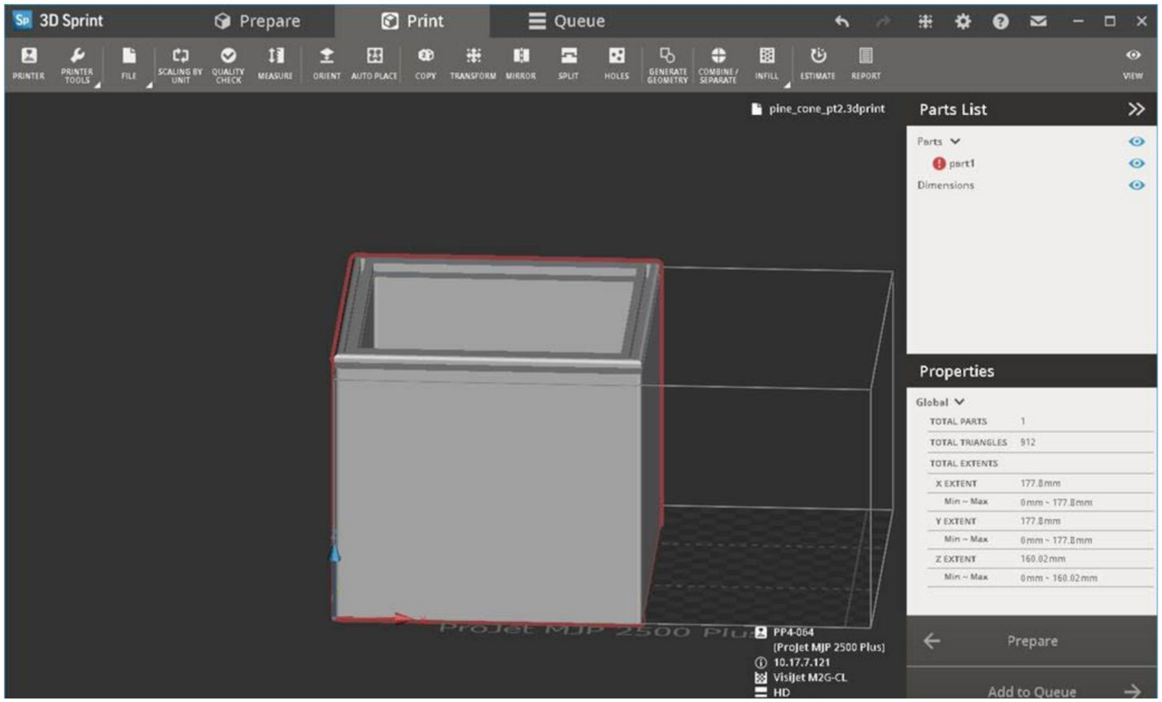

Figure B. 2: Email Proof for why Pincone Vent could not be printed.