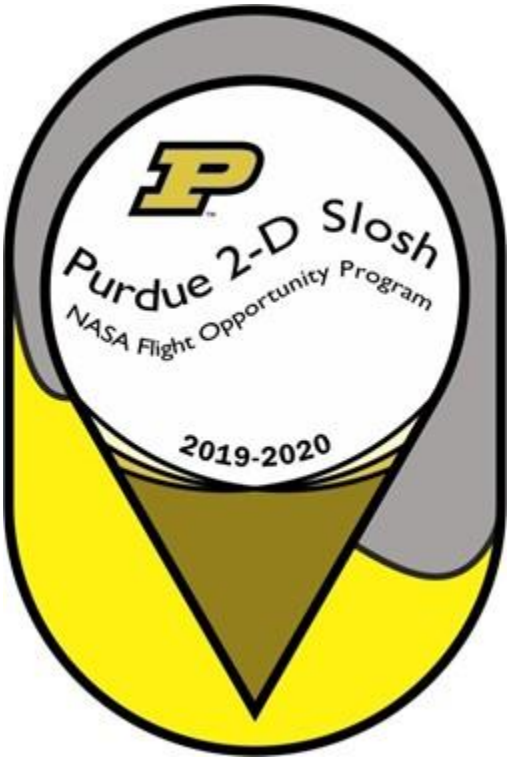
AAE 418 2D Slosh Final Report
Fall 2021



Rishabh Midha, Kathleen Johnson, Jacob Perry, Kole Pempek, Keertana Yendru, Monish Lokhande

Introduction

The main aim of the zero-gravity 2-D slosh experiment is to simulate the two-dimensional sloshing motion of liquid in zero-gravity conditions using translation plates andelectric motors. This motion will be recorded on a camera, with the liquid being propylene glycoland the sloshing motion occurring in four vessels with non-zero contact angles. Electric motors will be used to provide the power for the sloshing motion with a crankshaft used to convert the motion of the electric motor to translational form. The general layout will consist of the liquid vessel assembly with multiple containment units, and a camera facing a mirror that points to a liquid vessel assembly. A set of two cameras, mirrors, and vessels will be on each sliding plate, and there will be two levels, with one sliding plate each. This experiment will be used to help improve the knowledge level of liquid sloshing motion in zero gravity, and the whole assembly can be seen in the Catia in figures 1 and 2 below. Our team's goals during the fall term were to update the required parts on the CAD after realizing issues during assembly, machine updated parts needed for construction, complete the assembly of the entire structure and test the sliding capabilities. We also aimed to finish, iterate and test the code for the experiment and initialize the Blue Origin Integrated Payload Controller in order to simulate the experiment.

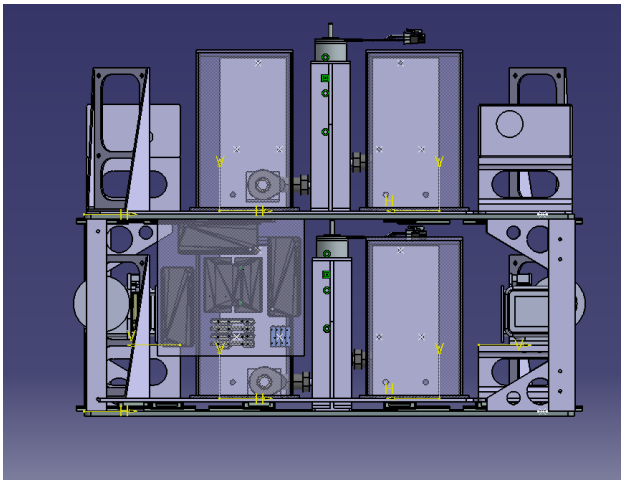


Figure 1: 2D Slosh System Front View

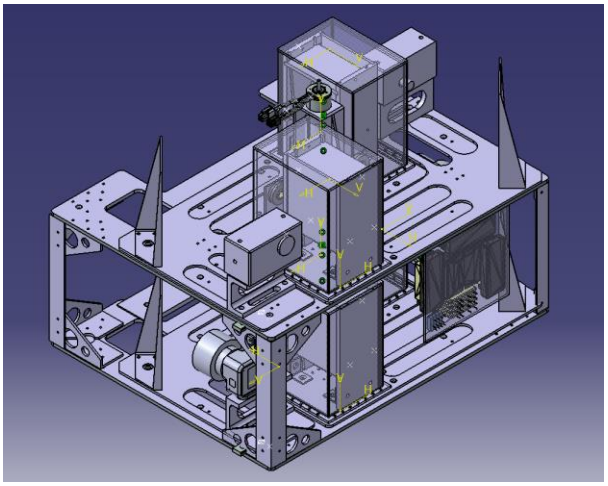


Figure 2: 2D Slosh System Isometric View

Summary of Previous Work

In Summer 2021 the team completed finished up multiple CAD files as well and began to construct the overall experiment. The physical parts that were made by the Summer 2021 team include the camera mounts for the GoPro and Blue Origin cameras, the sacrificial plate, base plate updates, new sliding plates, and rod mounts. In terms of CAD modeling, the previous team mostly worked more on updating the files created by the Spring team, and focused more on the manufacturing and assembly. The previous team also created the vessel that we are using for the liquids and are shaped like ice cream cones. They were able to complete the CAD, manufacturing, and assembly for these four vessels.

All CAD models done by Summer 2021 can be found in:W:\Suborbital\2Dslosh\CAD - NEW\Summer 2021

Comments on Previous and Current Work

During the assembly, the Summer team discovered some errors in their calculations, which now require updated parts and CAD models. The new vessel given to us affects the hole placement on both the sliding and base plates. The new vessel also requires us to create a new 3D printed gluing jig for assembly of the vessel. The secondary containment also needed updated holes as they were not aligned with the sliding plate any more. One of the base plates were still usable but required some new holes, and the other had to be edited and remanufactured. Entirely new sliding plates needed to be manufactured out of ⅛ in aluminum sheets. New screws, nuts, and aluminum stock were ordered for the manufacturing and assembly. Also, new holes and parts have been labeled directly on them with sharpie for ease of identification.

All CAD models done by Summer 2021 can be found in:
W:\Suborbital\2Dslosh\CAD - NEW\Summer 2021
Access to the online fusion library for this project can be gotten from: ibyely@purdue.edu
(All fusion files are downloaded and in the fusion folder as well)

WARNING: Due to the nature of BIDC only accepting Fusion 360 CAM's we have modeled some parts in Fusion 360. To convert between Fusion 360 and CatiaV5 save as a Step file and open in the other program. Refer to BIDC resources on their website for information on converting, Fusion 360, and manufacturing procedures.

Completed Work

Sacrificial Plate

This part will help produce the sliding plate, the base plate, or future parts that need to be made on the CNC machine. We took the files and plate that the summer team designed and manufactured to add 4 new holes to the plate, to be used for mounting the sliding plates, and machined the 4 holes using the CNC machine.

This part will be mounted with:

- Slider Plate
- Base Plate

Assembly location:

- Assemble with the sliding plate, the base plate, or future parts on VF-4 vice.
- 5/16th holes along sides

File location:

Fusion

- \Suborbital\2Dslosh\CAD - NEW\Summer 2021\Fusion\parts\Block (sacrificial plate)

For an updated version with holes for slider plates:

- \Suborbital\2Dslosh\CAD - NEW\Summer 2021\Fusion\parts\Block (sacrificial plate)(Sliding).f3z

Fusion CAD File:

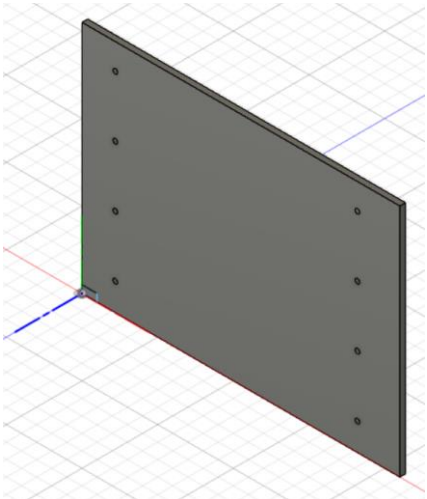


Figure 3: Sacrificial Plate (No Sliding Plate Holes), Fusion CAD File

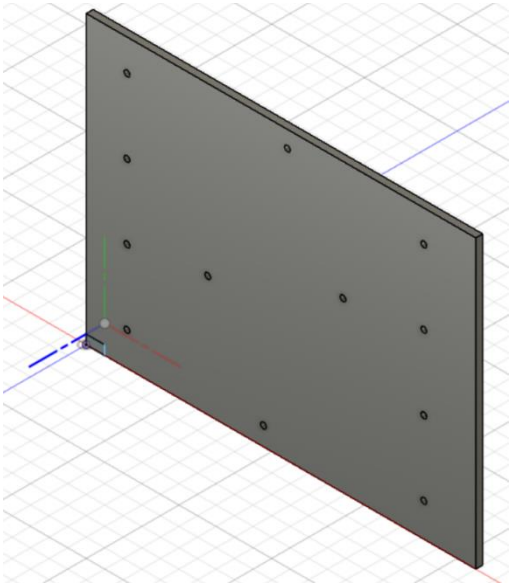


Figure 4: Sacrificial Plate (w/ Sliding Plate Holes)

Manufacturing:

- Produced by BIDC VF-4 CNC Machine

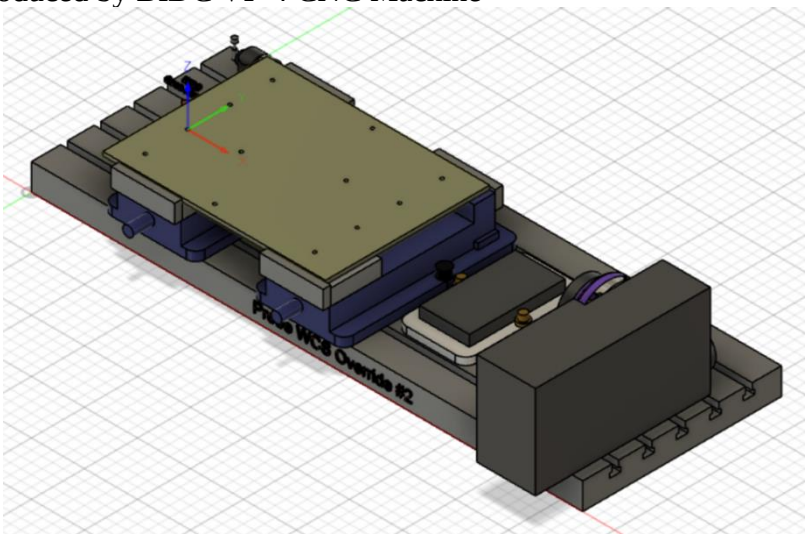


Figure 5: Sacrificial Plate Mounted on VF-4 Vice, Fusion Manufacturing

Actual Parts:

- Number made: 1

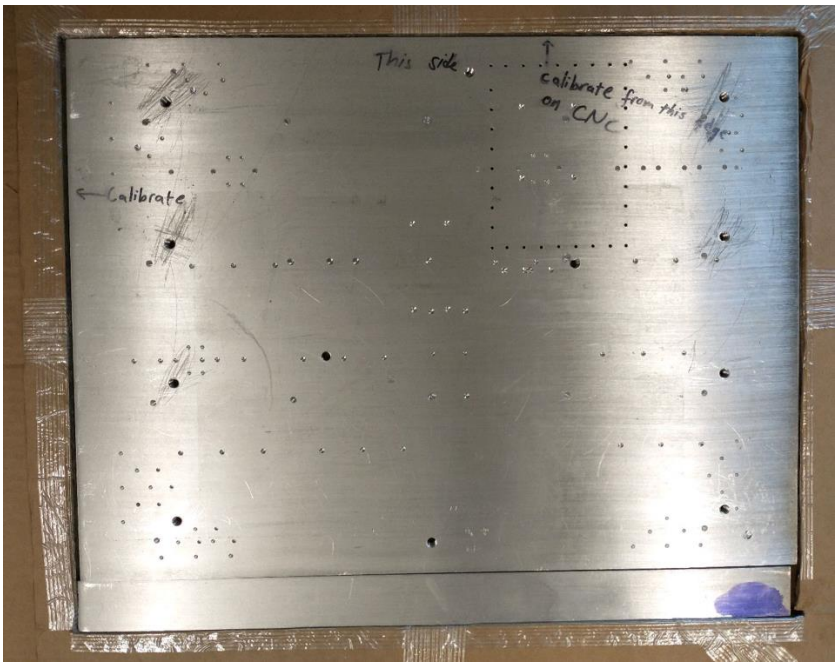


Figure 6: Sacrificial Plate with Mounting Holes

Notes: Be mindful that there are two sides to the sacrificial plate and the holes are not placed evenly from edge to edge but the holes are spaced evenly apart from each other to fit the baseplate and slider plate.

Base Plate

This part will help to mount the sliding plates. Previous teams created the CAD file and made it with few mounting holes. During this Fall, our team copied the Base plate design to have both a bottom base plate (that attaches to the payload box) and a top base plate (which attaches to the assembly to mount the 2nd level of the experiment).

Top Base plate

To the top base plate our team added 6 new slider holes (as the slider position on the sliding plates had changed) as well as 4 weight reduction cut outs to the Catia Part file and are looking to have them drilled in the airport shop in the next semester.

Bottom Base plate

Our team added 23 new holes and 4 weight reduction cut outs to the Catia Part file. We also changed the dimension of the holes that were to originally be used as sacrificial plate mounting holes, as they were too big to then use to attach to the payload box. We then changed the y positions of some of the slider holes as we noticed that they did not line up with their positions in the sliding plate. We bought the stock online and had the plate manufactured by McKinney with the weight reduction cut outs and some of the larger holes (see Catia drawing section), then had the rest of the holes drilled by the airport shop (see Catia drawing section).

To Do:

- The Top Base plate needs to have the additional 6 slider holes manufactured after the hole placement of the ones on the Bottom Base plate can be tested and found to adequately interface with the Sliding Plate. These changes are reflected in the current part file as well as the drawing (however the drawing is not fully dimensioned), but they should be reviewed before being sent to manufacturing.
- The Top Base plate needs the weight reduction cutouts manufactured. These changes are reflected in the current part file as well as the drawing (however the drawing is not fully dimensioned), but they should be reviewed before being sent to manufacturing.
- There are 8 holes in the Catia files for the plates that we didn't add but aren't in the manufactured plates we have from previous semesters. They aren't mentioned, and our thoughts are that they could be for wiring or lighting. They have been added to the newly manufactured plate, but are not drilled in the old plate we are modifying for use. They may need to be drilled, but should be reviewed before being sent for manufacturing.
- The crank shaft holes are in the old versions of the manufactured parts, however they were not in any of the Catia files, so they will need to be manufactured in the newly manufactured bottom base plate. The holes are present in the Catia part file and drawing, however they have not been dimensioned in the drawing and are highlighted red.

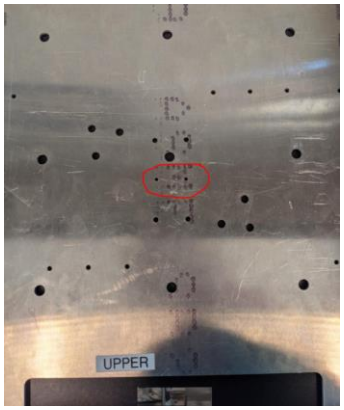


Figure 7: Holes Base Plate

- Currently in the Catia parts and drawings files, the holes for the spacers are .116, theoretically using a 4-40 screw. HOWEVER, in all of our documentation, as well as the current screws and manufactured parts in the cage, the spacers use 8-32 screws. We manufactured the new bottom base plate for 8-32 screws, but the size of the holes in the part and drawing files need to be updated for the size of an 8-32.

Notes:

- Some of the holes are a tight fit and may need to be worked through the holes intially
- Moving into the project the summer team recommended to us to manufacture using the BIDC. While we used the BIDC to add the holes to our sacrificial plate, we wasted a lot of time jumping through hoops to try and get our baseplate and sliding plates manufactured using them, and at the end of the semester was advised by Professor Collicot to use the airport machine shop instead. We found this experience to be much more pleasant, with the Scott/Chris/Jerry being much more helpful to us during the process and less overall time needed to manufacture.
- After getting baseplate and sliding plate machined at the shop, we were given some advice from Chris about how to give them drawings for parts that have a lot of features. He said to only include the measurements for what we were getting machined (besides dimensioning the overall part) and that features can be split into multiple drawings (ie all of the 4-40 holes in one drawing, all of the 8-32 in another).
- We changed the y positions of the slider holes in the Bottom Base plate as it was getting re-manufactured, however the y positions in the Top Base Plate remain the same, with a slight difference in location.
- The Catia part file for the base plate is extremely convoluted, having been created over multiple semesters. This makes it very difficult to work with at times and when editing things, caution should be taken as many of the current features are linked to each other, so editing or deleting something can cause a chain reaction.
- There are 8 holes in the Catia files for the plates that we didn’t add but aren’t in the manufactured plates we have from previous semesters. They aren’t mentioned, and our thoughts are that they could be for wiring or lighting.

This part will be mounted with:

- L Channel Support
- L Channel Support w/ Gusset X 3
- Motor Mount
- Slider X 6
- Payload Box (Only for Bottom Base Plate)
- Payload Box Spacer (Only for Bottom Base Plate)
- Crank shaft Mount

Assembly location:

- Payload Box with Bottom Base Plate
- Channel Supports with Top Base Plate

File location:

Top Base Plate

- aae418sh\Suborbital\2Dslosh\CAD - NEW\Fall2021\Catia**Drawings(catia)**\Base Plate top
- aae418sh\Suborbital\2Dslosh\CAD - NEW\Fall2021\Catia**Parts(catia)**\Top Base Plate

Bottom Base Plate

- aae418sh\Suborbital\2Dslosh\CAD - NEW\Fall2021\Catia**Drawings(catia)**\Base Plate 9.23.21
- aae418sh\Suborbital\2Dslosh\CAD - NEW\Fall2021\Catia**Parts(catia)**\Bottom base plate
- aae418sh\Suborbital\2Dslosh\CAD - NEW\Fall2021\STEP_files\Bottom Base plate

McKinney Manufacturing Base Plate

- aae418sh\Suborbital\2Dslosh\CAD - NEW\Fall2021\Catia**Drawings(catia)**\Base Plate McKinney
- aae418sh\Suborbital\2Dslosh\CAD - NEW\Fall2021\Catia**Parts(catia)**\Base Plate McKKinney 2
- aae418sh\Suborbital\2Dslosh\CAD - NEW\Fall2021\STEP_files\Base plate McKinney

Manufacturing:

- Produced by McKinney Corporation with holes added by Airport Shop
- A CAM was made for use on the BIDC VF-4 CNC Mill, but we abandoned it in favor of the airport shop

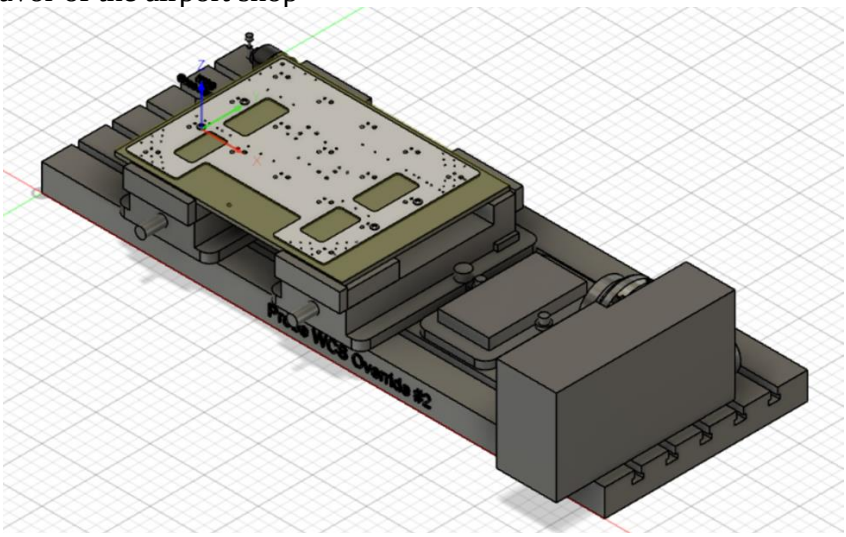


Figure 8: Base Plate Unused CAM

Actual parts:

Bottom Base Plate

- Number made: 1

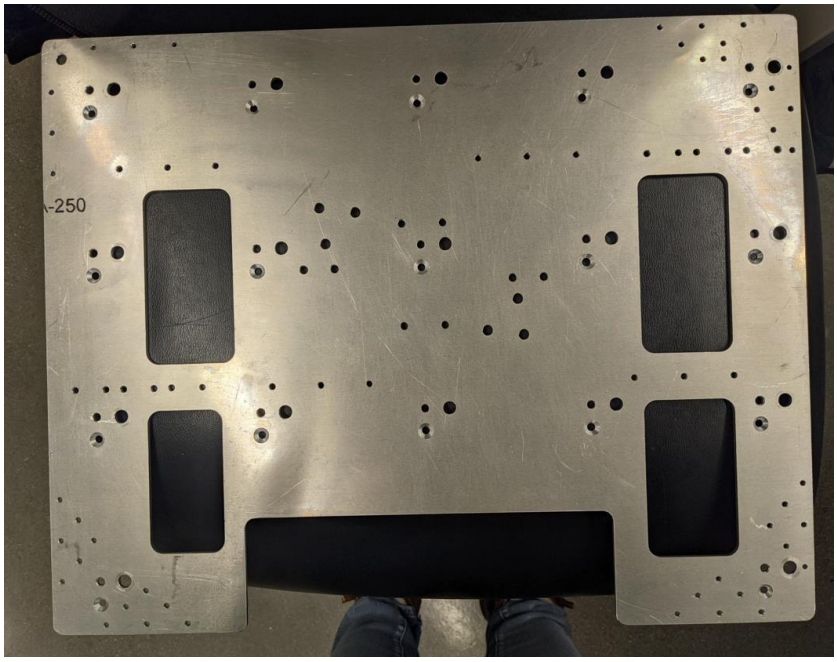


Figure 9: Bottom Base Plate after McKinney and Airport Shop manufacturing

Top Base Plate

- Number edited: 1

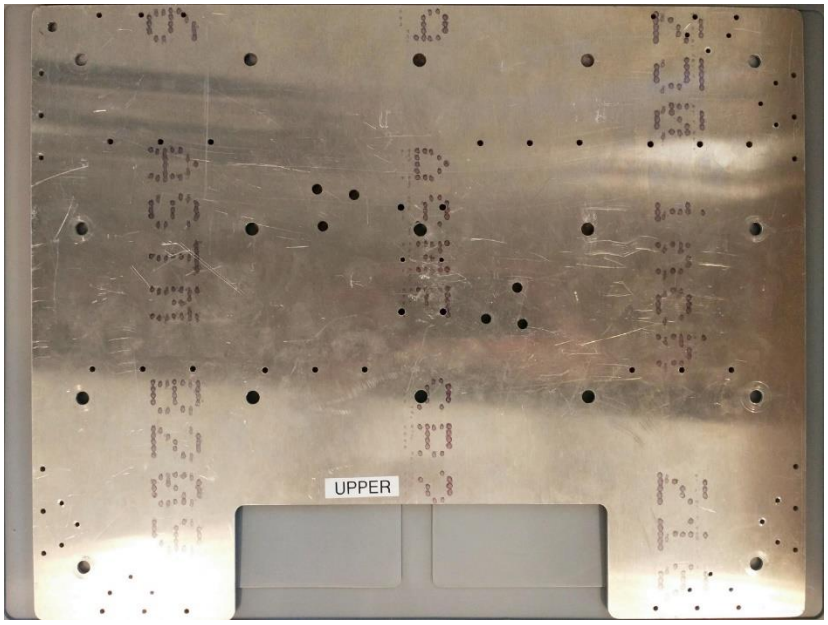


Figure 10: Top Base Plate, current state

Catia drawings:

McKinney Bottom Base Plate

Holes added/changed:

- Weight reduction cutouts x4
- Sacrificial Plate Mounting Holes x17
- Changed Original Sacrificial Plate Mounting Holes to Payload Box attachment holes x17

Holes manufactured (McKinney Corp):

- Plate
- Weight reduction cutouts x4
- Sacrificial Plate Mounting Holes x17
- Payload Box Attachment Holes x17
- Large corner support hole x1
- Holes of unknown use not in old versions of the files but we did not add them this semester x6

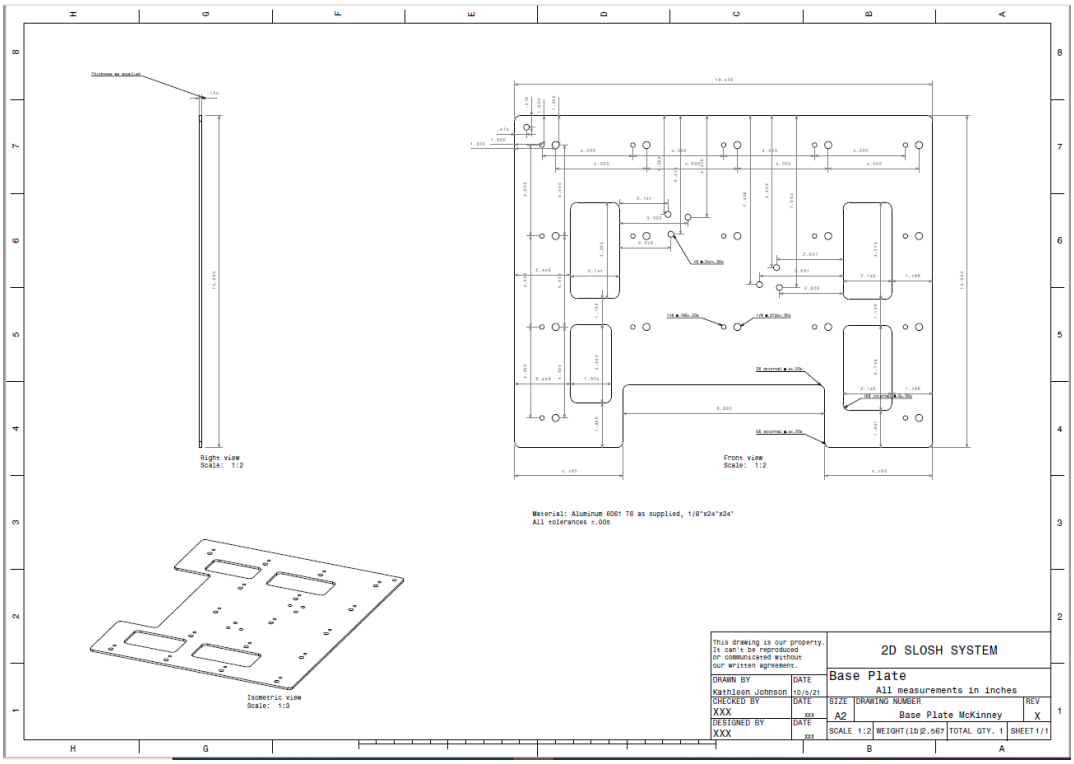


Figure 11: McKinney Bottom Base Plate, Catia Drawing

Bottom Base Plate

Holes added/changed:

- Added Slider Holes x6
- Changed y position of Slider Holes x12

Holes manufactured (airport shop):

- Motor Mount holes x4
- Small corner support holes x42
- Payload Spacer holes x17
- Slider Mount holes x24
- Holes of unknown use not in old versions of the files but we did not add them this semester x2

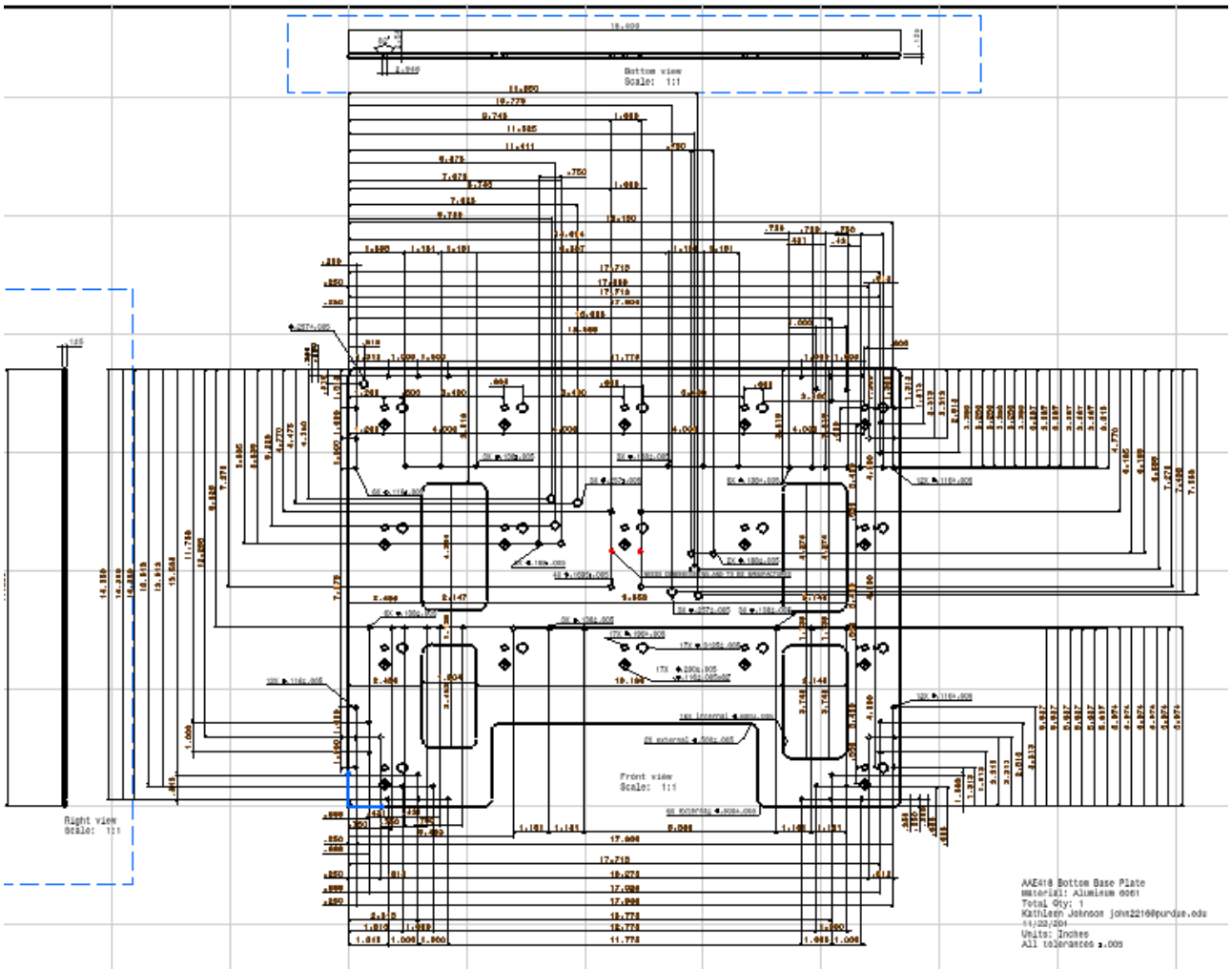


Figure 12: Bottom Base Plate, Catia Drawing

Top Base Plate:

Holes added:

- Slider holes x6
- Weight reduction cutouts x4
- Holes of unknown use not in old versions of the files but we did not add them this semester but they're not in the current model of this baseplate that needs to have holes added x8

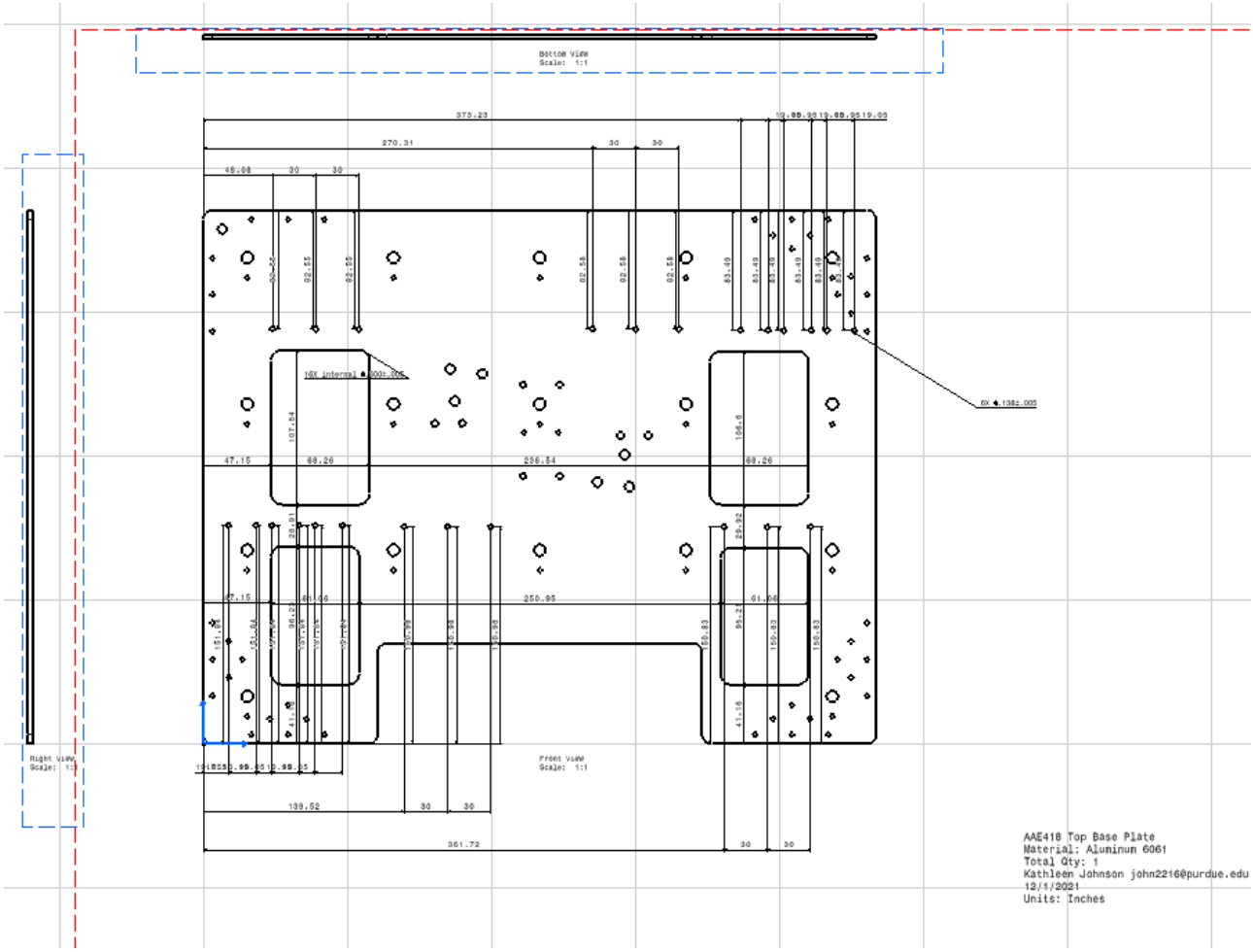


Figure 13: Top Base Plate, Catia Drawing

Sliding Plate

The Sliding Plate will hold most test equipment including cameras, mirrors, and liquid containers. It has been regenerated due to the new design of the liquid container size/location, weight control, and unnecessary edge features from the previous design. This oscillates because it screws into a slider that uses metric screws only. The metric screws that go to the sliding plate areM3 and the screws that go to the base plate are M3.5, however the M3.5 screws that were ordered have a head that restrict movement, so we will be moving forward using only M3 screws.

This semester the team changed the x position of the slider holes located near the camera mount, to ensure that there wouldn't be interference with it. Along with that, we changed the y position of the camera mount holes. This should ensure that the slider screw heads fit well in the cutout of the camera mount. Since the design for the vessel changed, new inner and outer containment holes had to be added. These changes can all be seen in the Catia drawing section. Because of these changes, 4 new sliding plates were manufactured. We bought the stock online and had the plates manufactured at McKinney including the weight reduction cutouts, sacrificial plate holes, and camera mount holes. These were then brought to the airport shop where we had all other holes added.

To Do:

- The corner of the plate (shown below) should be trimmed as it interferes with the corner supports. The old sliding plate currently used in the assembly has this done the previous team hand sanded this, which is why it does not show up in the parts files. Our suggestion would be to lay that over the plates and trace the line in sharpie to be cut. However this method is not at all precise and should be verified before moving forward with manufacturing. This could also be good to include in the Catia files.

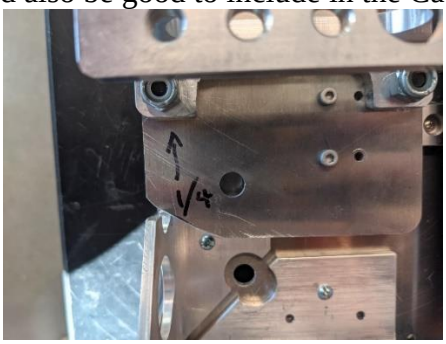


Figure 14: Sliding Plate Sanding

- The edge of the plate at the mirror mount (shown below) should also be reduced, as is currently done on the old sliding plate used in the assembly (the previous team hand sanded this, which is why it does not show up in the parts files). Once again, our suggestion would be to lay that over the plates and trace the line in sharpie to be cut. However, this method is not at all precise and should be verified before moving forward with manufacturing. This could also be good to include in the Catia files.

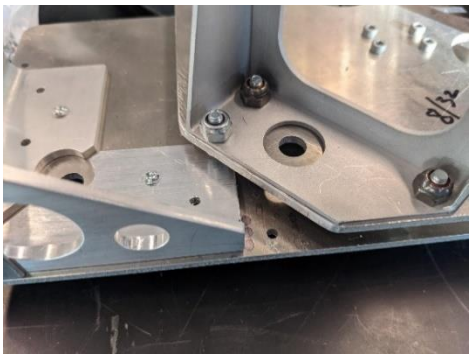


Figure 15: Sliding Plate Sanding

Notes:

- Moving into the project the summer team recommended to us to manufacture using the BIDC. While we used the BIDC to add the holes to our sacrificial plate, we wasted a lot of time jumping through hoops to try and get our baseplate and sliding plates manufactured using them, and at the end of the semester was advised by Professor Collicott to use the airport machine shop instead. We found this experience to be much more pleasant, with the Scott/Chris/Jerry being much more helpful to us during the process and less overall time needed to manufacture.

  <u>This part will be mounted with:</u>
  - Slider
  - Camera Mount (GoPro)
  - Camera Mount (BlueOrigin)
  - Connecting Rod Mount
  - Welco Pump Mount
  - Mirror Support

  <u>Assembly location:</u>
  - On base plate with sliders

  <u>File location:</u>
  - aae418sh\Suborbital\2Dslosh\CAD - NEW\Fall2021\Catia**Drawings(catia)**\Sliding Plate
  - aae418sh\Suborbital\2Dslosh\CAD - NEW\Fall 2021\Catia**Parts(catia)**\Sliding Plate Updated holes
  - aae418sh\Suborbital\2Dslosh\CAD - NEW\Fall2021\STEP_files\Sliding Plate Updated holes

  McKinney Manufacturing Slider Plate
  - aae418sh\Suborbital\2Dslosh\CAD - NEW\Fall2021\Catia**Drawings(catia)**\Sliding Plate McKinney

- aae418sh\Suborbital\2Dslosh\CAD - NEW\Fall 2021\Catia**Parts(catia)**\Sliding Plate McKinney
- aae418sh\Suborbital\2Dslosh\CAD - NEW\Fall2021\STEP_files\Sliding Plate McKinney

Manufacturing:

- Produced by McKinney Corporation with holes added by Airport Shop
- A CAM was made for use on the BIDC VF-4 CNC Mill, but we abandoned it in favor of the airport shop

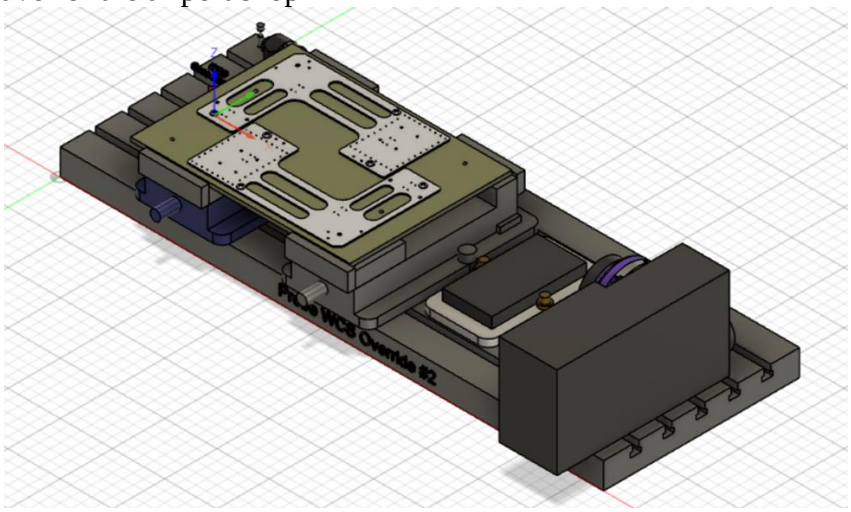


Figure 16: Sliding Plate Unused CAM

Actual parts:

- Number made: 4

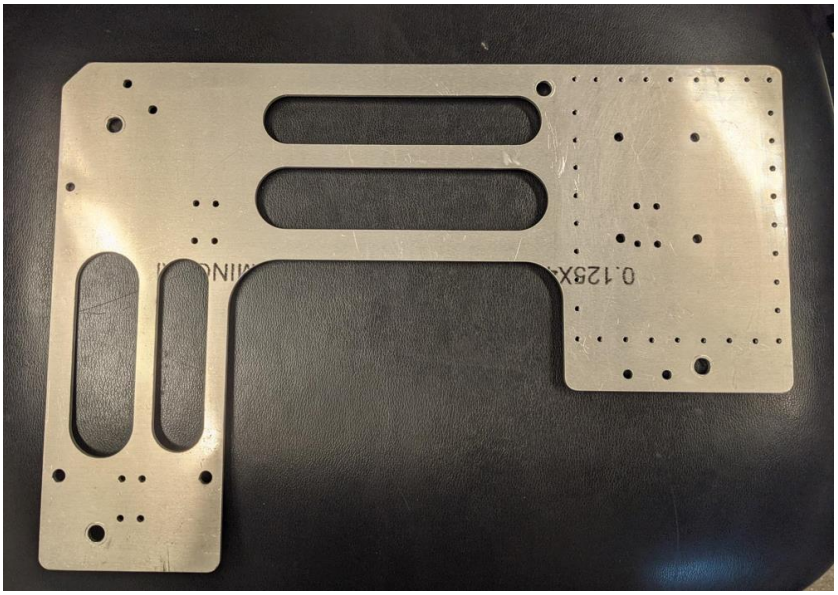


Figure 17: Sliding Plate after McKinney and Airport shop manufacturing

Catia drawing:

McKinney Sliding Plate

Holes added/changed

- Location of Camera Mount holes x2

Holes manufactured (McKinney)

- Location holes for mounting on sacrificial plate x4
- Weight Reduction cutouts x4
- Camera Mount holes x2

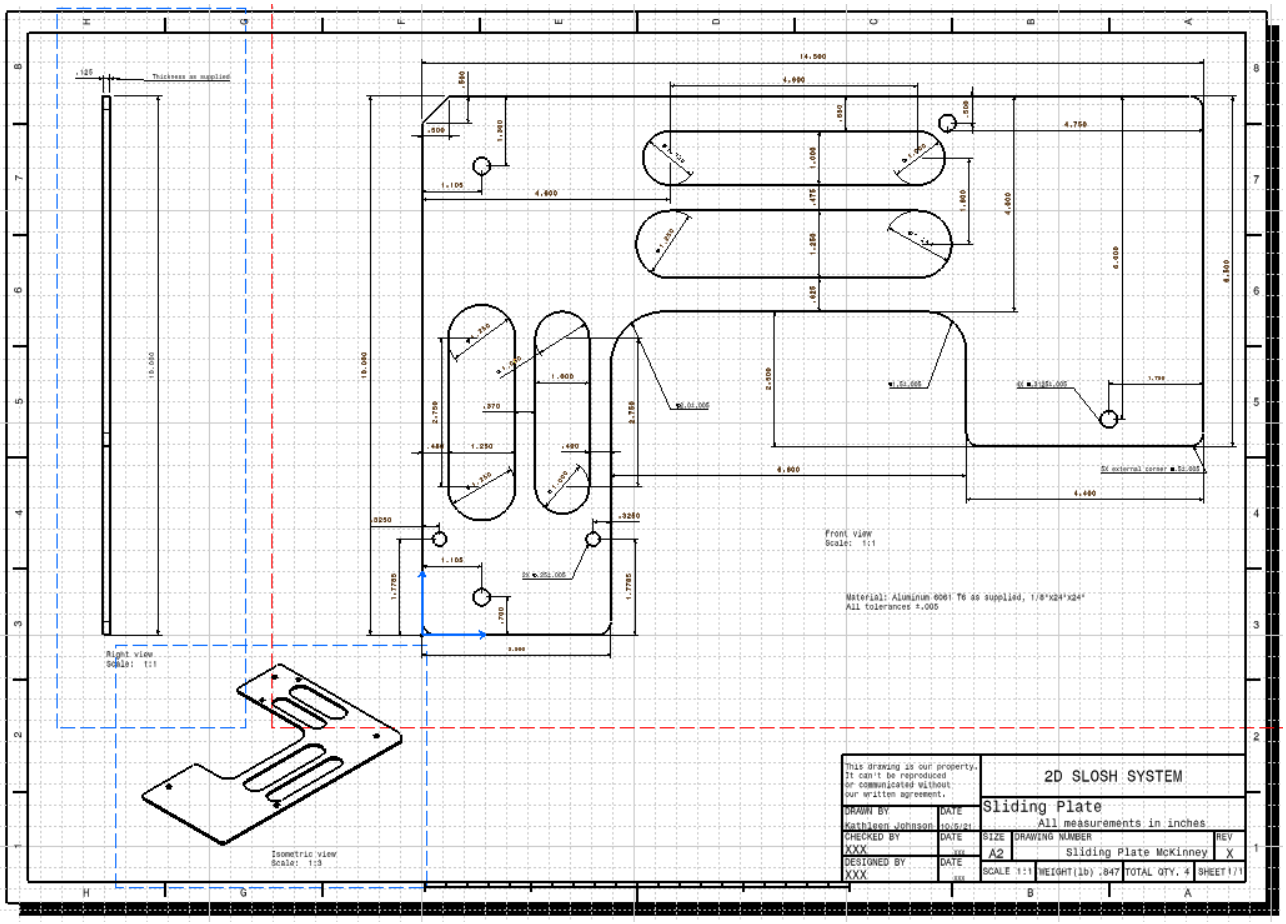


Figure 18: McKinney Sliding Plate, Catia Drawing

Sliding Plate

Holes added/changed

- Slider holes x4 (bottom-most grouping on drawing shown below)

Holes manufactured (airport shop)

- Slider holes x12
- Mirror mount holes x3
- Connecting Rod Mount holes x2
- Inner containment holes x4
- Outer containment holes x34

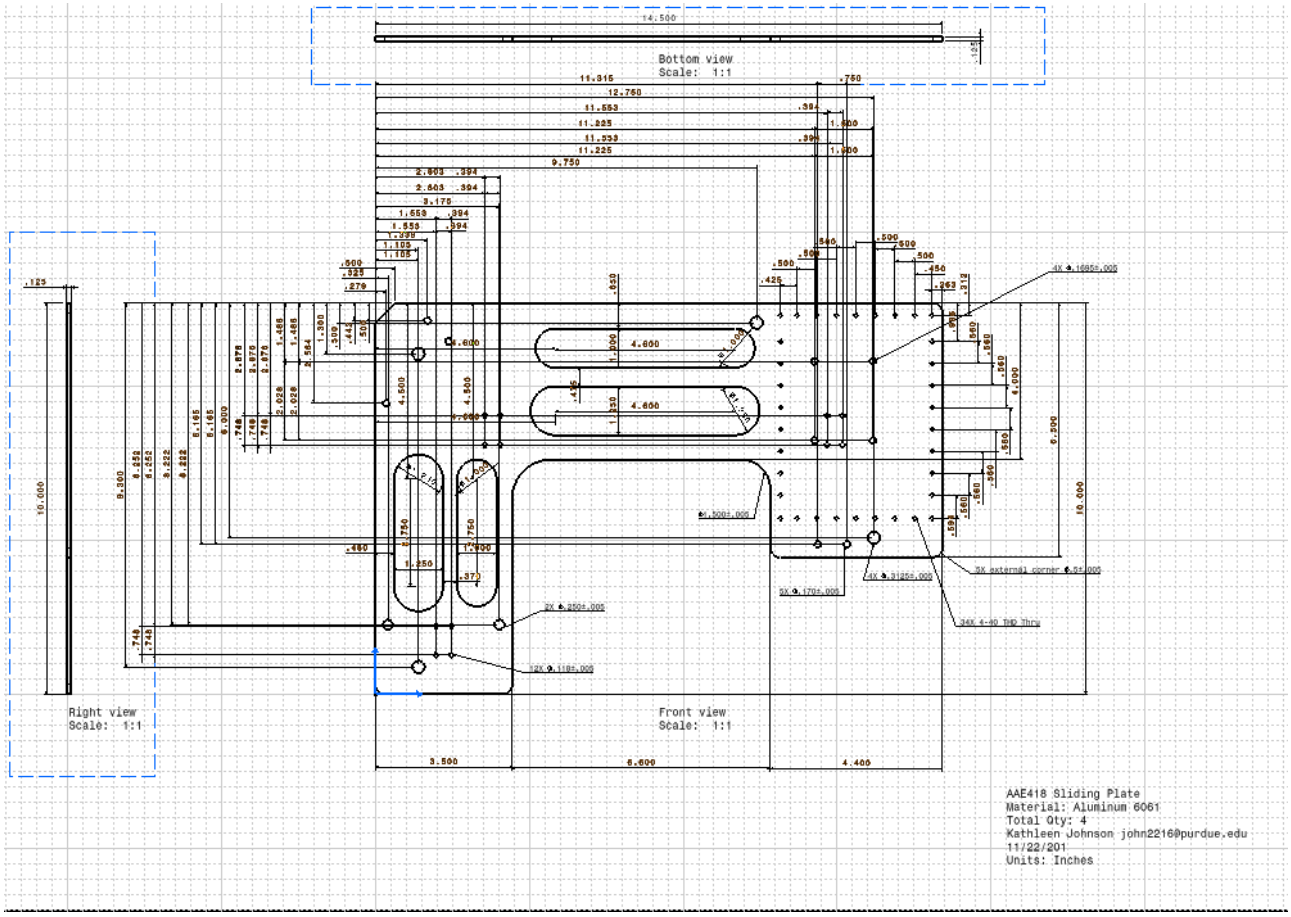


Figure 19: Sliding Plate, Catia Drawing

New Fluid Vessel

This is an updated part of the vessel containing the liquid used in our project. The previous vessel had an error with the contact angle and had to be redesigned. During the fall, we worked to create new CAD models and drawings for the part. The drawings have been sent off to the aero lab, once they are manufactured the vessels can be glued together.

The vessel is broken up into multiple individual parts which are four left and right plates, four top and bottom Teflon plates, four back plates and eight side walls. The Aero-Lab will manufacture enough materials and plates for 4 vessel containments.

<u>This part will be mounted with:</u>

- The sliding plates
- L-Bracket

<u>Assembly location:</u>

- Sliding plates

<u>File location:</u>

Catia

- aae418sh\Suborbital\2Dslosh\CAD - NEW\Fall 2021\Catia**Products(catia)**\New Vessel Assembly

<u>Manufacturing:</u>

- Produced by: Purdue Aerospace Science Lab

<u>Catia Drawings:</u>

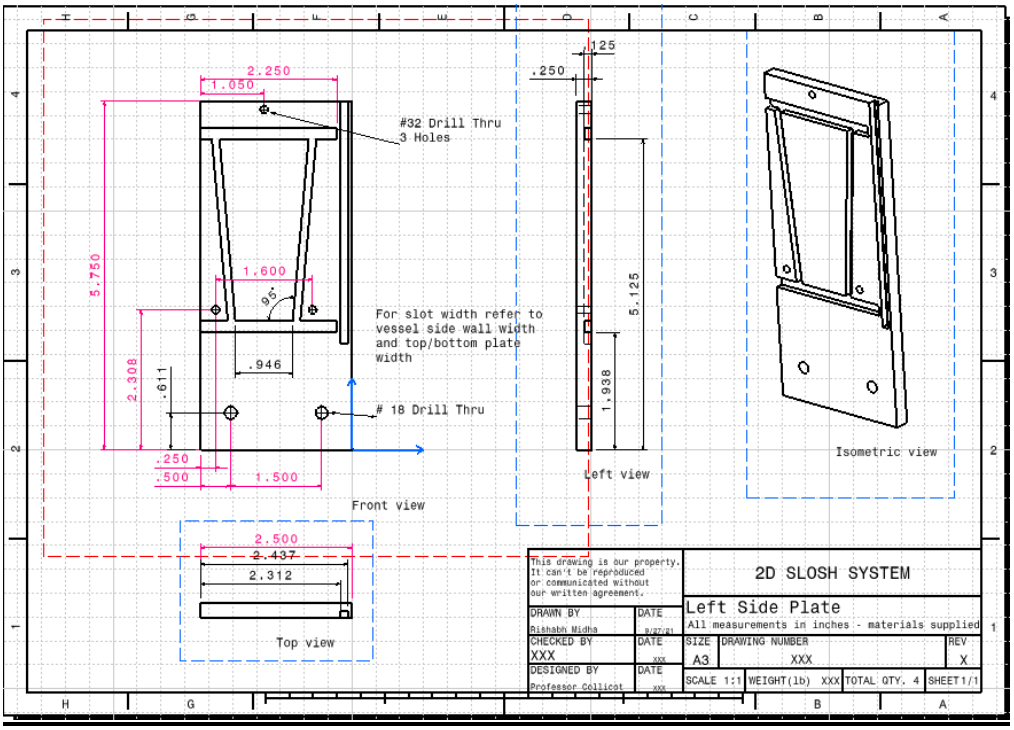


Figure 20: New Vessel Left Plate, Catia Drawing

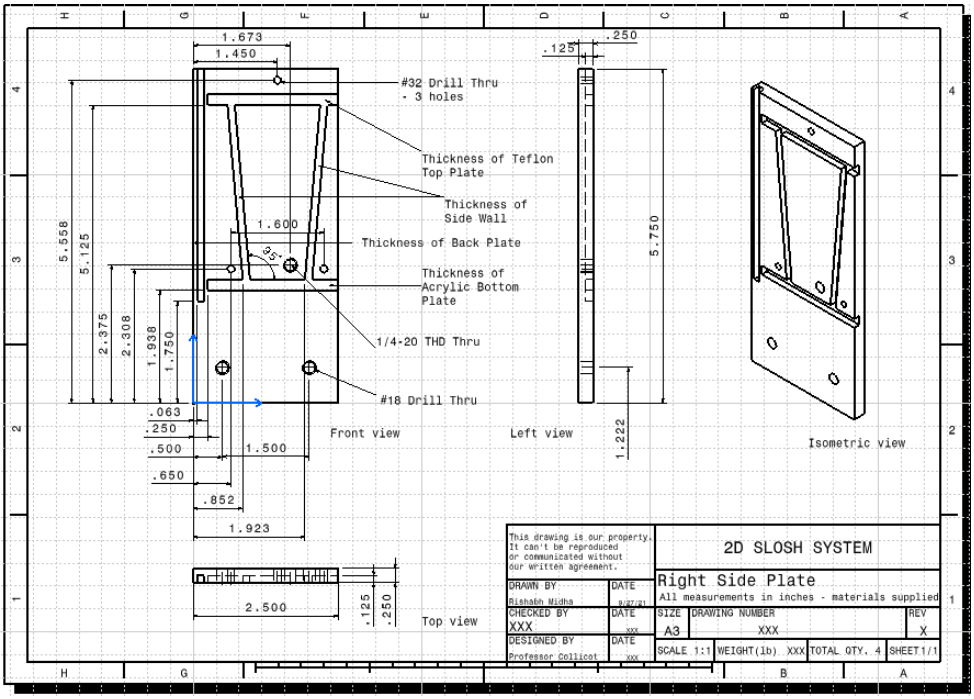


Figure 21: New Vessel Right Plate, Catia Drawing

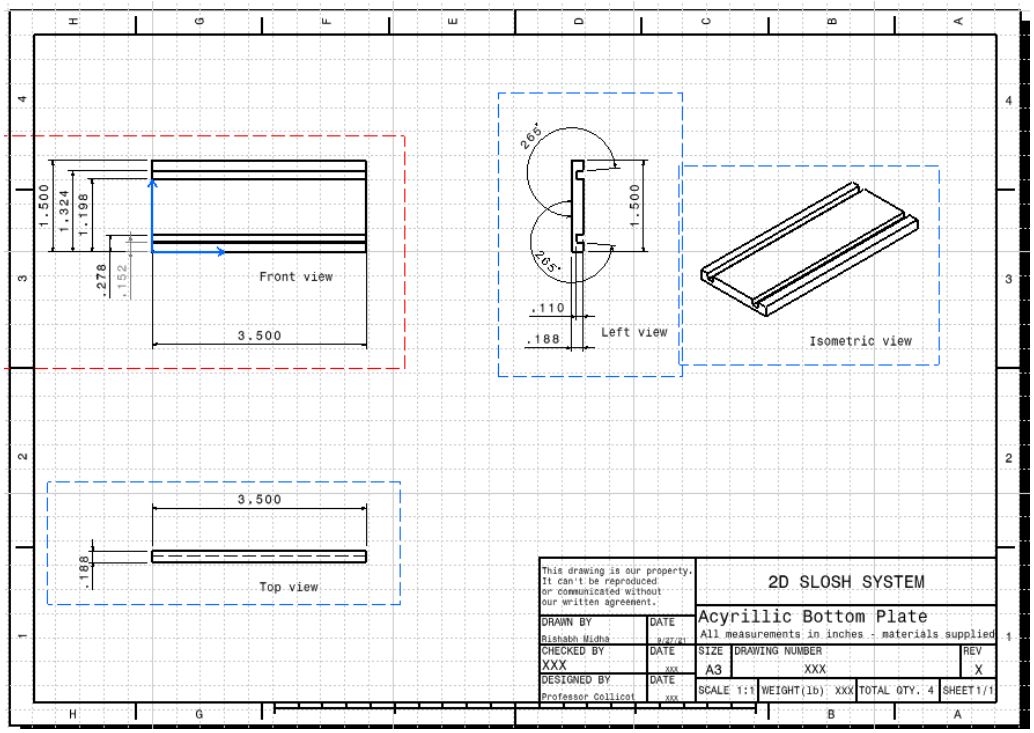


Figure 23: Acrylic Bottom Plate, Catia Drawing

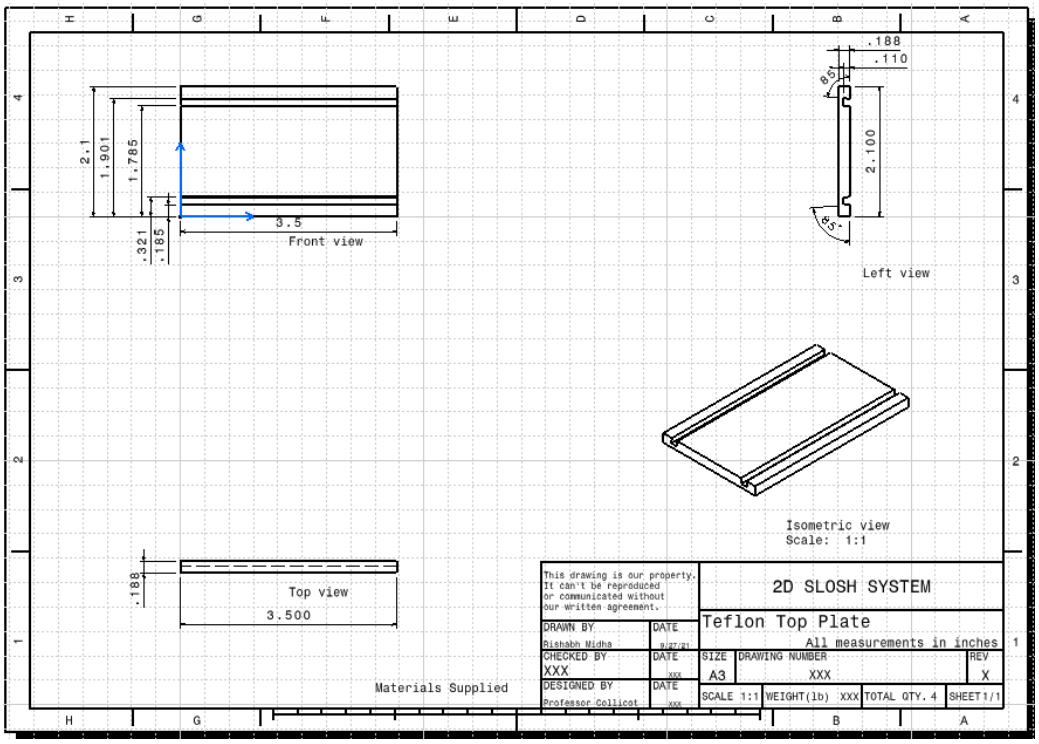


Figure 22: Teflon Top Plate, Catia Drawing

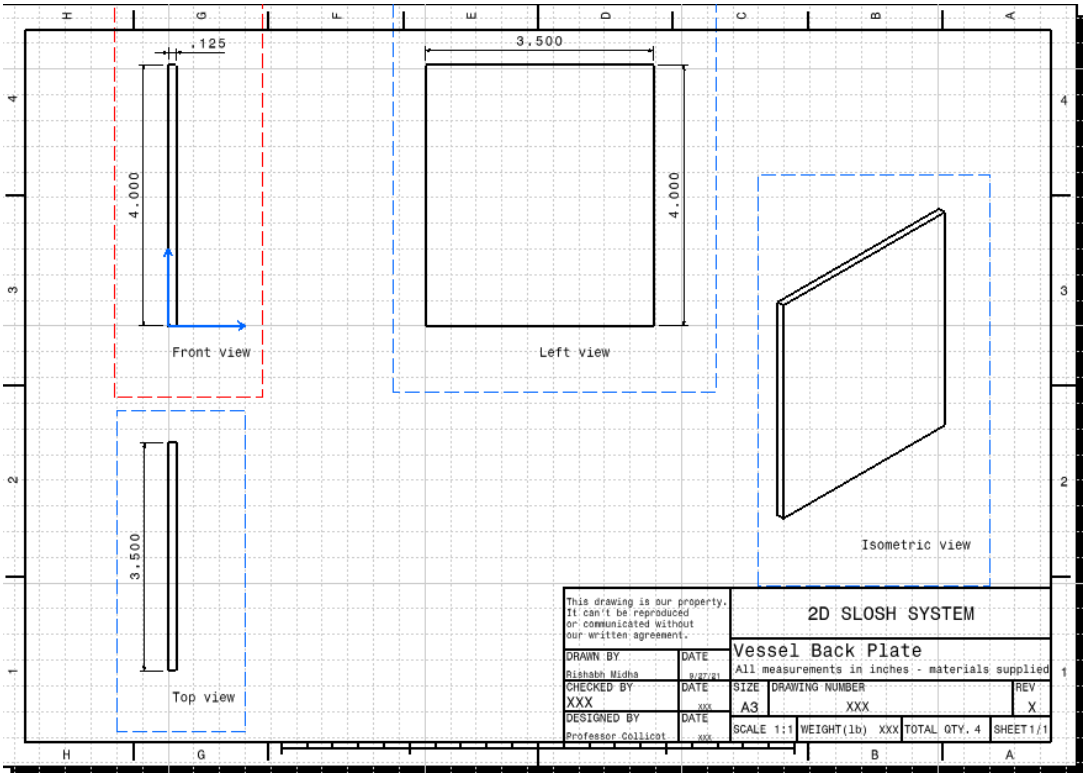


Figure 24: Back Plate, Catia Drawing

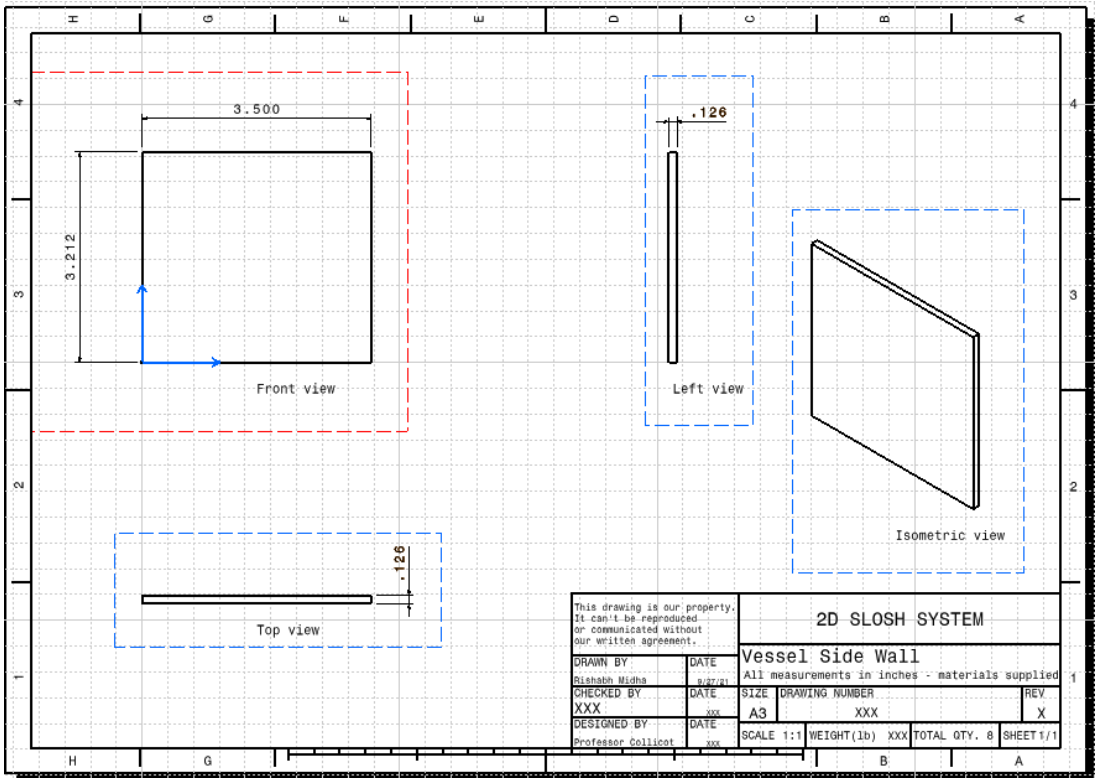


Figure 25: Side Wall, Catia Drawing

Secondary Containment

This part was created to allow for a secondary barrier between the vessel holding the water, and the rest of the build. In the event of a leak in the main vessel, the hope is that the secondary containment is able to hold the water inside and away from important parts such as the motors or onboard computers.

Flanges have been received and cut to be attached to the bottom of the secondary containment. Gluing has begun on one of the vessels. The flanges have to be sanded to create a perfect rectangle around the secondary containment and then glued on.

This part will be mounted with:

- The slider plates
- New Vessel

Assembly location:

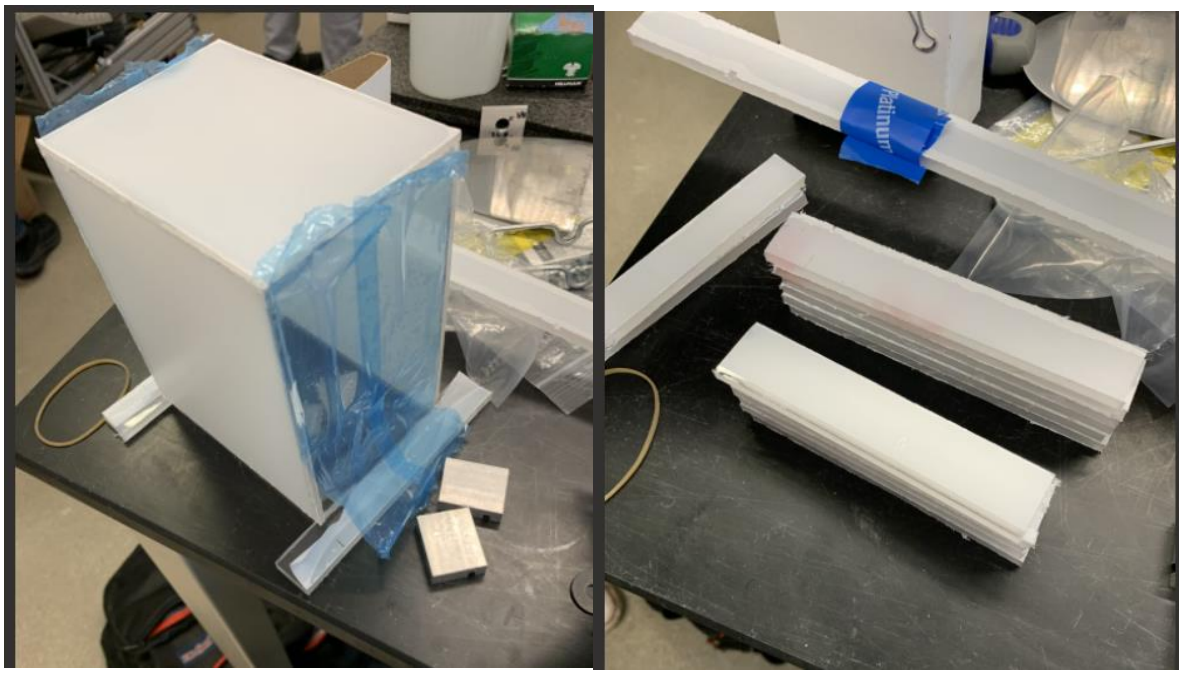
- Slider plates

File location:

Catia - \\roger.ecn.purdue.edu\aae418sh\Suborbital\2Dslosh\CAD - NEW\Fall 2021\Catia\Products(catia)\Secondary Containment

Actual parts:

- Number made: 4
- Produced by: Purdue Aerospace Science Lab, glued in class



Figures 26 and 27: The above images are the secondary containment and flanges yet to be glued on

Connecting Rod Mount

When we were working on getting the shoulder screws to connect the mount to the crankshaft, there was an issue with the torques and forces on the mount. We redesigned the mounts to better be able to handle this torque and have had it sent off to the Aero-Lab for manufacturing.

This part will be mounted with:

- The slider plates
- Connecting Rod

Assembly location:

- Slider plates (all 4)

File location:

- FOR **SHORTER** MOUNT: \aae418sh\Suborbital\2Dslosh\CAD - NEW\Fall 2021\Catia\Drawings(catia)\Short Rod Mount - NEW
- FOR **TALLER** MOUNT: \aae418sh\Suborbital\2Dslosh\CAD - NEW\Fall 2021\Catia\Drawings(catia)\Tall Rod Mount - NEW

Manufacturing:

- Produced by: Purdue Aerospace Science Lab

Actual parts:

- Number made: 4 – 2 tall 2 short

Catia Drawing:

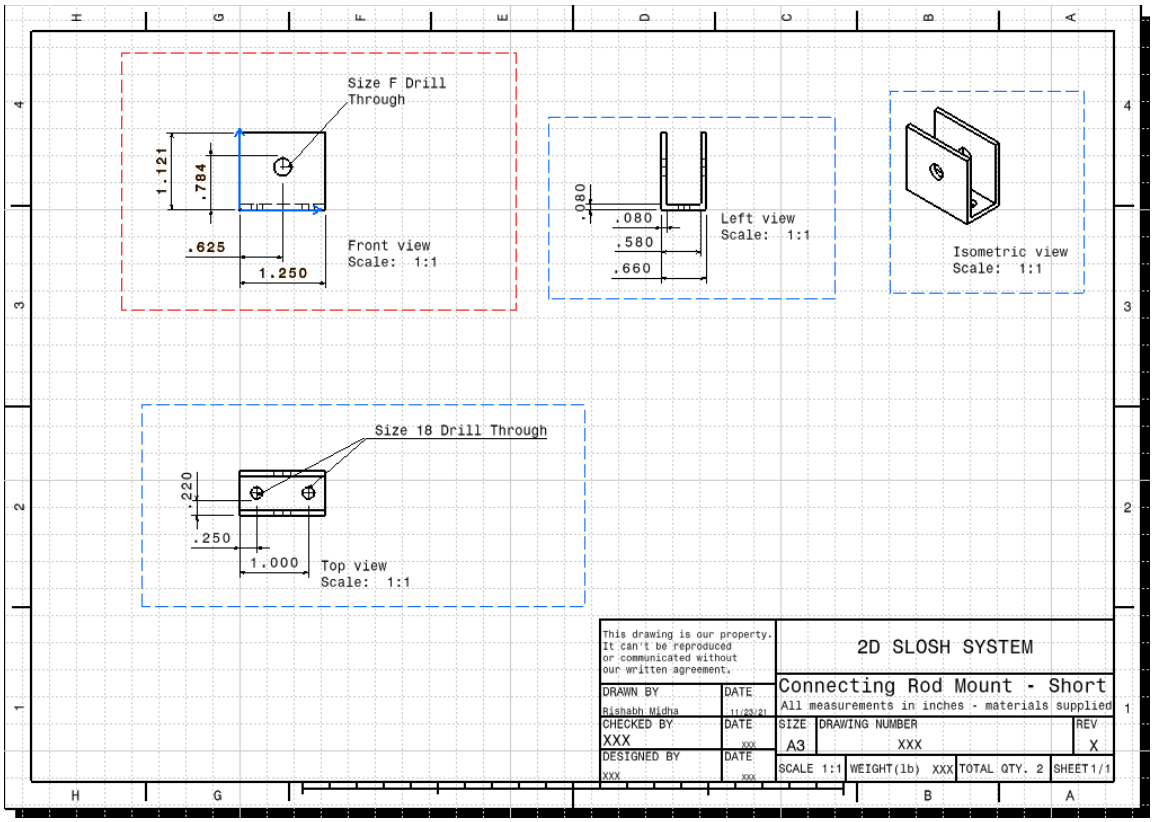


Figure 28: Connecting Rod Mount Short, Catia Drawing

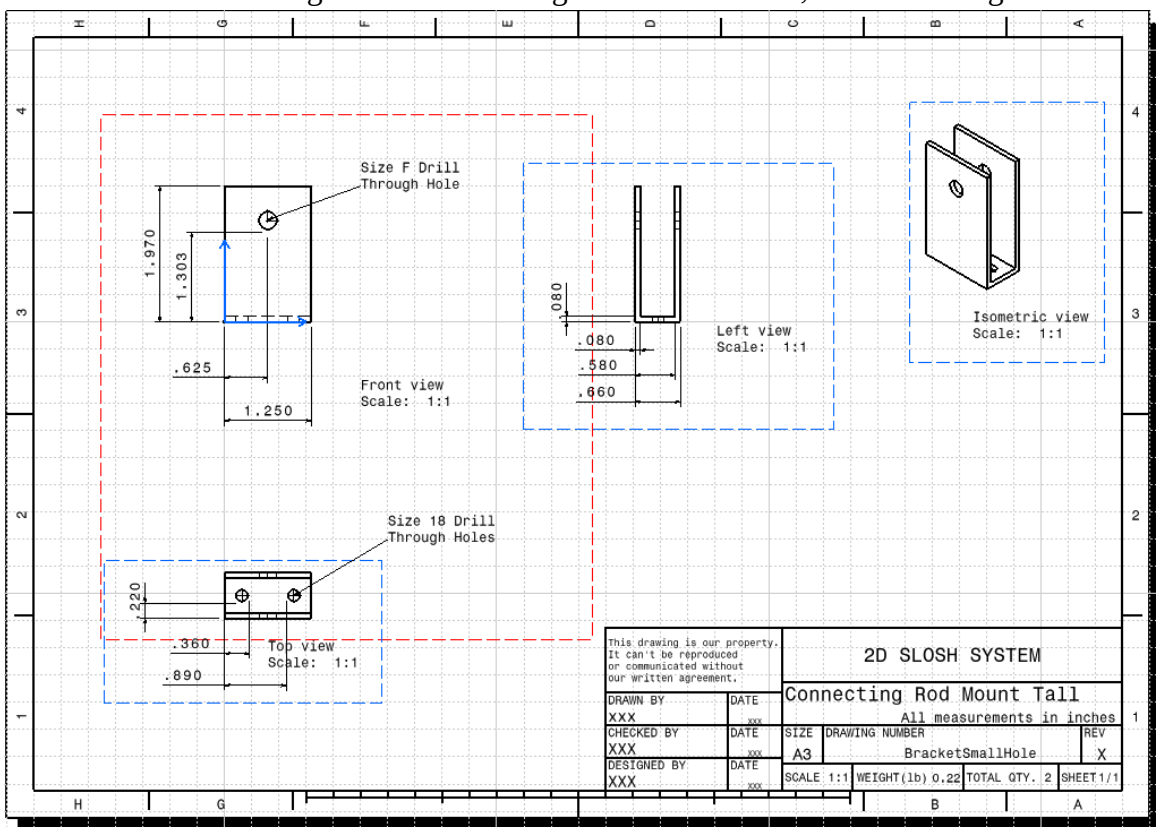


Figure 29: Connecting Rod Mount Tall, Catia Drawing

Crankshaft Spacer

The following is a sleeve/spacer that attaches onto the crankshaft in order to normalize the size of the crankshaft connection. This part has yet to be manufactured and will need to be 3D printed or ordered somewhere online if it can be found.

This part will be mounted with:

Crankshaft

Assembly location:

On base plate with crankshaft

File location:

- For Crank Shaft Spacer: aae418sh\Suborbital\2Dslosh\CAD - NEW\Fall 2021\Catia\Parts(catia)\Crankshaft_Plastic_Piece

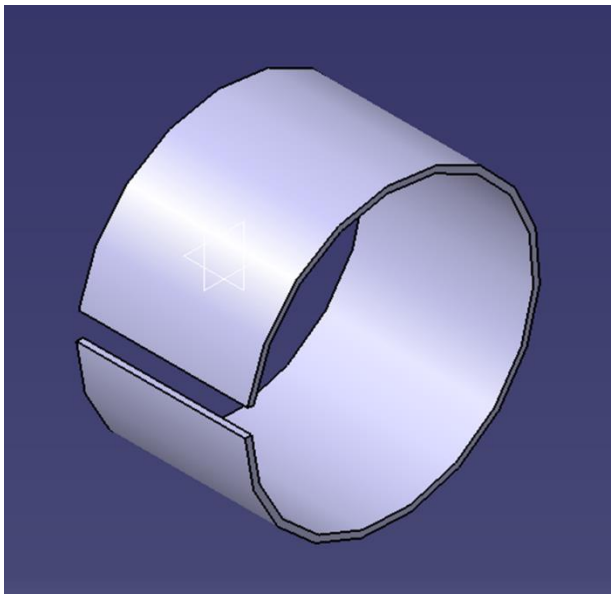


Figure 30: Crankshaft Sleeve/Spacer

Electronics

The following electrical systems are attached to the payload and controlled by the Integrated Payload Controller. As the decision of not pumping the fluid was finalized, pumps were no longer needed. The electrical systems on the payload are as follows:

1. Brushless DC motor with Planetary gears:

   Two motors were used to achieve the motion of the oscillating plates. The motors move in opposite orientation (clockwise and anticlockwise) to reduce net torque of the apparatus. They are powered and controlled by the Motor controller and therefore do not need any input.
   The specifications sheet can be found in:
   Z:\Suborbital\2Dslosh\Fall 2021\Electronics\Motor

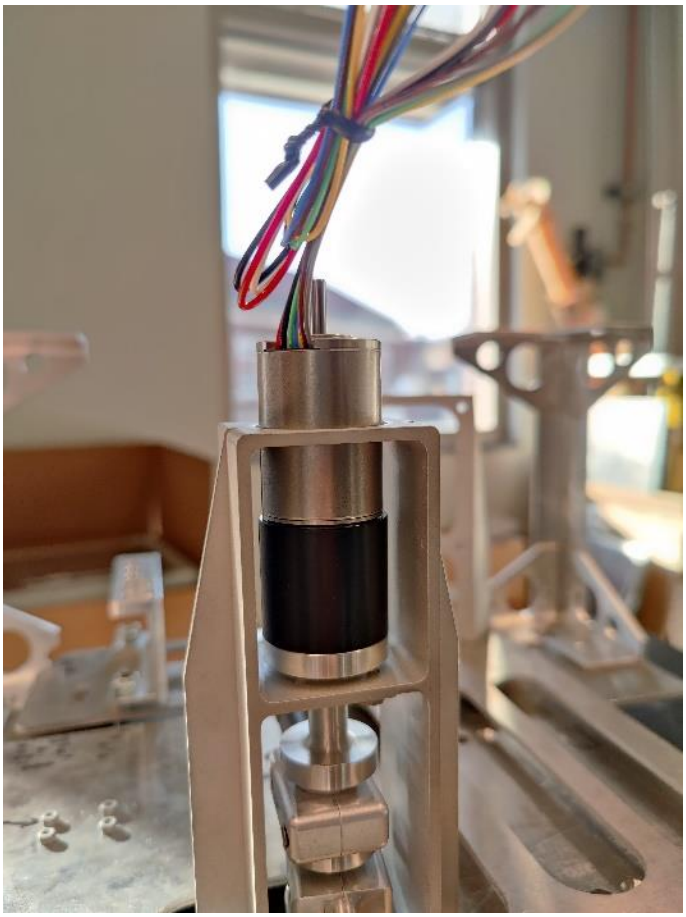


Figure 31: DC Motor

2. Motor Controller:

The motors are controlled using a standard motor controller.
The datasheet for the same can be found in:
Z:\Suborbital\2Dslosh\Fall 2021\Electronics\Motor Controller
The following inputs are needed and used for the Motor controller (per Motor):

Table 1: Motor Controller Inputs

Name	Signal	Voltage Limit	Purpose
Power	Analog		Provide power to controller and motor
Enable	Digital	0 – 5 V	To Enable power supply to motor
Speed control	Analog	0 – 5 V	To vary the speed of the motor
Direction	Digital	0 – 5 V	To set the direction (clockwise/anticlockwise)

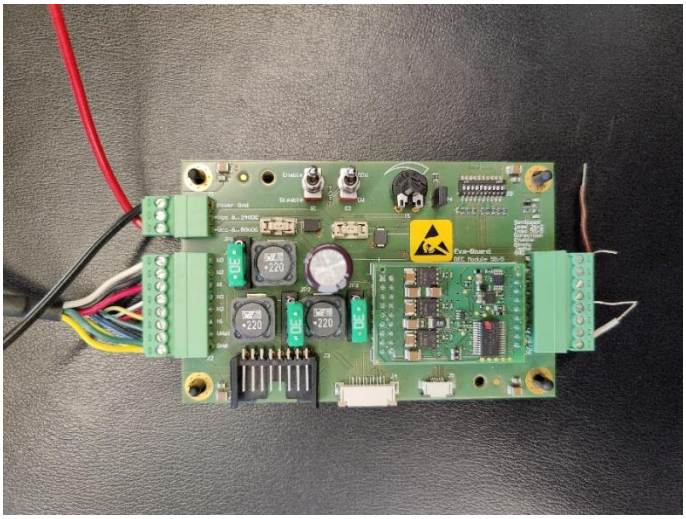


Figure 32: Motor Controller

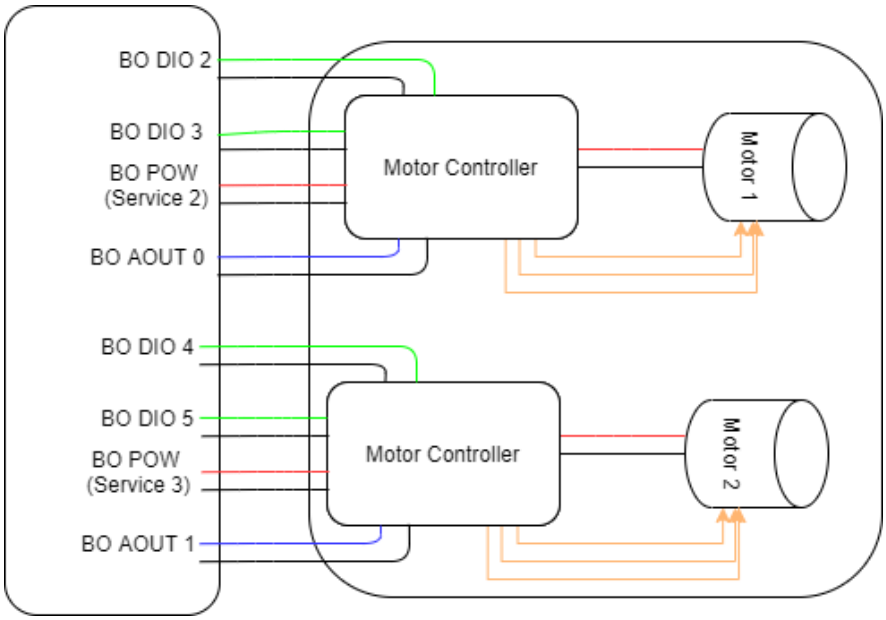


Figure 33: Schematic of the Motor, Motor Controller Setup

3. Digits (Camera Control):

The Go Pro Cameras are turned on by the Camera Control. It uses Power input and a Digital input impulse of 100 milliseconds for turning on the camera. Once the impulse is sent to the digits, the digit arm moves and turns on both the cameras.

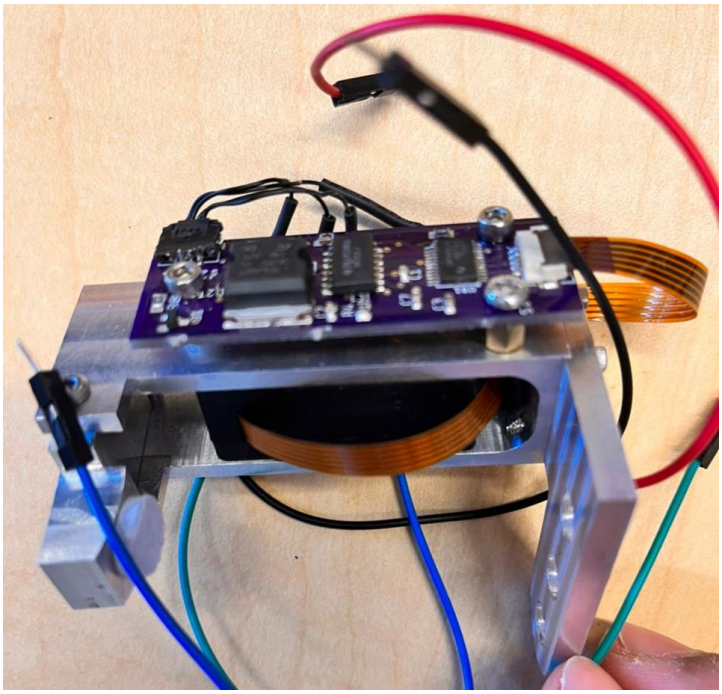


Figure 34: Camera Control (Digits)

4. LED:

LEDS are turned on using a power channel to view the experiment. They are controlled by simply providing power for the time by the IPC.

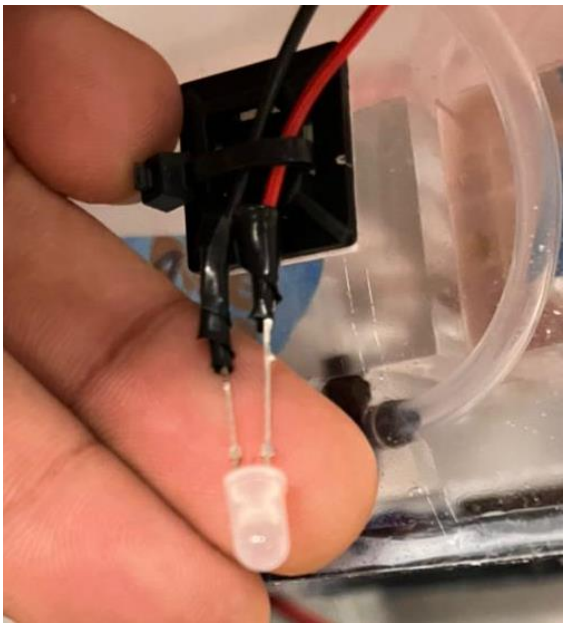


Figure 35: LED

5. Cameras:

There are two cameras that are used to record the behavior of the fluids:

a. Go Pro:
The cameras are battery operated and don't need any power supply and turn on by "The Digits".

Figure 34: Camera Go Pro

b. Blue Origin:
Cameras are operated by the Blue Origin controller itself and have no need to provide any input.

Figure 35: Camera Blue Origin

Integrated Payload Controller
Introduction

The Integrated Payload Controller (IPC) is the primary connection interface between the payload and the New Shepard Crew Capsule. It is a compact data acquisition and computing unit mounted on the side wall of a payload locker and provides power, command and control, communication, data, and camera interfaces to each active payload (Blue Origin, 2021). The electrical specifications of the IPC are specified below:

Electrical Service	Qty	Specifications	IPC Internal Connector
Power Channels	4	27 V (± 7 V) DC @ 2 A max	C1
Ethernet	1	IEEE 802.3ab Gigabit Ethernet for TCP/UDP[1]	
RS-232	1	Full Duplex, 115200 baud rate max (configurable)	C2
Digital I/O	16	5 V TTL Bidirectional	
PWM Output	4	5 V TTL swing, 10 kHz max frequency16 bit duty cycle resolution	
RTD Interface	8	Compatible with 3-wire PT100 Resistance Temperature Devices (RTD)	C3
Analog Outputs	4	Single Ended, + 10 V output range12 bit resolution	
Analog Inputs	4	Differential Input, ± 10 V input range16 bit resolution, 100 samples/sec	
Chassis Return Path	1	N/A	N/A

Table 2: Electrical Specifications

Coding the XML file

In order to communicate with the IPC, a Blue Origin payload kit was installed on the computer being used to test the experiment. With the help of this guide, an XML file was created and updated to align with the experiment objectives. The process of coding this file began with identifying the objectives of the experiment and using these to edit the file accordingly. The aim was to code the file in such a manner that:

- The LED lights would turn on after Liftoff
- Both the Blue Origin camera and the Go Pro camera would turn on after Separation
- The motors would move the sliding plates back and forth with increasing speeds after even intervals of time
- The rotation of motion on the lower level is clockwise and that on the upper level is counterclockwise

Once the objectives were identified, the XML file was coded accordingly. After rigorous testing and multiple iterations, the XML file was coded using the following channels:

Table 3: Channel specifications for actions

Device	Channel name	Channel number	Start Event	End Event
LED	Power	0	Liftoff	Mission End
Camera 1	DIO	0	Separation	Mission End
Camera 2	DIO	1	Separation	Mission End
Motor 1	POWER	1	Coast Start	Coast End
	DIO	2	Coast Start	Coast End
	DIO	3	Coast Start	Coast End
	AOUT	1	Coast Start	Coast End
Motor 2	POWER	2	Coast Start	Coast End
	DIO	4	Coast Start	Coast End
	DIO	5	Coast Start	Coast End
	AOUT	2	Coast Start	Coast End

Testing and Simulating the Experiment

The next step was testing the code that was developed. In order to do this, the IPC was initialized with the help of the instructions given in the Blue Origin IPC QuickStart Guide. A standard Trajectory was used to simulate the experiment. During the simulation, the motor was powered on by the IPC at coast start and turned off at coast end. The following procedure was followed to connect the experiment to the IPC and simulate it:

1. Using the payload kit, the Blue Origin Hardware Setup page was opened. The instructions for IPC configuration were followed.
2. Next, the IPC was connected to the Blue Origin computer using the cap and wire provided.
3. The motor controllers were connected to the IPC using C1 and the cameras were connected to the IPC using C4. The appropriate wires were used for each connection. The details for these wire connections are given in the following table:

Table 4: Pin specifications for channels

Action	Cap number	Pin number(s)
LED power	1	K,M,J
Digits	1	N,P,L
Camera 1 power	2	1
Camera 2 power	2	2
Motor 1 power	1	T,U
Motor 2 power	1	R,S
Motor 1 enable	2	3
Motor 1 direction	2	4
Motor 2 enable	2	5
Motor 2 direction	2	6
Motor 1 control	3	12
Motor 2 control	3	13

The log files of the simulations can be found in the following folder:
Z:\Suborbital\2Dslosh\Fall 2021\2dslosh\Fall 2021\IPC\Logs

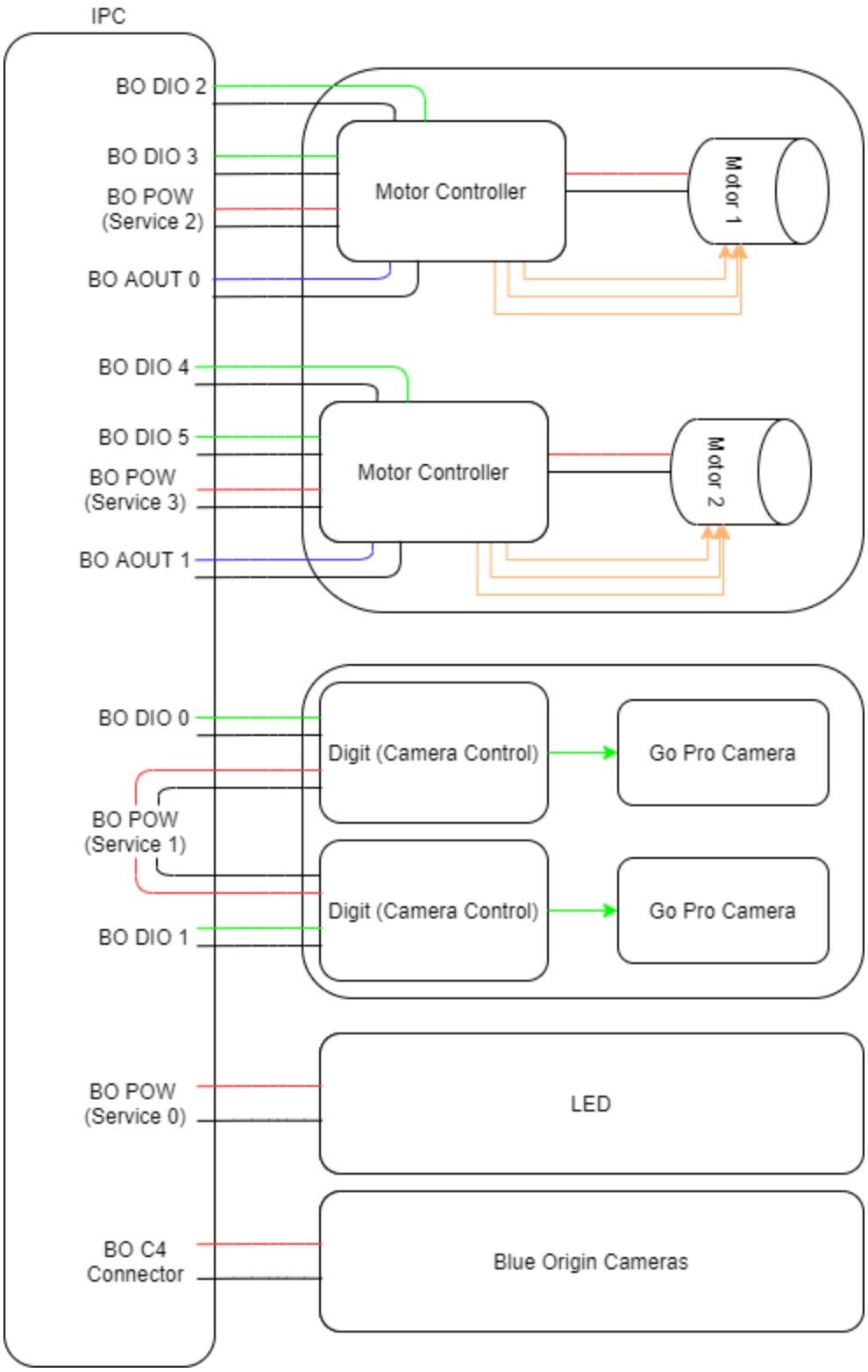


Figure 36: IPC Controller Connection Diagram

Additional Information for Assembly

We made this table so that it could be easier to figure out which screws and nuts go where and if they are ordered or not. Items that are labeled as unknown are labeled as such due to not having the part yet to measure. Some purchase request forms were also added for clarity.

Table 1: Screws & nuts list for base plate and slider plate assembly
Red – Ordered and not arrived or need to be ordered
Yellow – double check on quantity
Green – all clear, parts are ordered, arrived, and correct quanitity

Screw size	Type	Number	Location	Need to Order ?	Order Number	Nut Type	Need to Order?	Order Number
4-40 x ½”	Round Head, Phillips	36	Support Struts, Base Plate x2,	No maybe	N/A	Nylon Step	Ordered	McMaster - 90631A005
M3 x 6mm	Flat, Phillips	36	Translation Plate	Ordered	McMaster -92010A116	Screw Glue might be needed	No	N/A
8-32 x 1/2	Round Head, Phillips	8	Motor Mount	No	N/A	Nylon Step	No	N/A
¼” x long enough(saw needed)	Hex Head	2	Corner Small Strut	No	N/A	Nylon Step	No	N/A
8 -32 x 1/2	Flat, Phillips	17	Base Plate to Spacers	Ordered	McMaster - 91771A194	N/A	No	N/A
10-32 x 1”	Round Head, Phillips	17	Base Plate to Blue Origin Box	Ordered	McMaster -91772A833	N/A	No	N/A

¼” x ~ ½”	Any use drawer	4	Sliding plate to Blue	No	N/A	N/A	No	N/A

			origin camera mount					
¼” x Unknown	Any use drawer	4	Mount to Blue Origin camera	No	N/A	N/A	No	N/A
¼” x ~ ½”	Any use drawer	4	Sliding plate to GoPro camera mount	No	N/A	Nylon Step	No	N/A
¼” x unknown	Unknown	6	Mount to GoPro camera	No	N/A	Unknown	No	N/A
8-32 x ~ ½”	Round Head, Phillips	12	Mirror Mount	No	N/A	Nylon Step	No	N/A
4-40 x ¼”	Round Head, Phillips	8	Sliding Plate to pump mount(pump no loger in se)	No	N/A	Nylon Step	No	N/A
4-40 x ¼”	Round Head, Phillips	4	Pump Mount to welco pump (pump no longer in use)	No	McMaster-91772A106	Nylon Step	Maybe	N/A
M3 x 6mm	Socket Head	8	Motor Mount to motor	Ordered	McMaster-91274A102	N/A	No	N/A
8-32 x ½”	Any	8	Base Plate to motor mount	Maybe		Nylon Step	No	N/A

¼ in shoulder screw length TBD	Shoulder screw	4	Crank shaft to sliding plate	yes		Nylon Step	No	N/A
	ips		mounts					
4-40 x 5/16	Philips head	128	Secondary containment	Ordered				

Purchases made in Fall 2021

ARMS Business Office Purchase Request Form

Please submit to:

Department (please circle): AAE ENE MSE EPICS MEP WIEP Other:_____

Date: 9/30/2021

Individual needing reimbursed/Vendor needing paid

Vendor:	Metals Depot
Contact:	Corporate Headquarters Metals Depot International
Address:	4200 Revilo Road
City:	Winchester
State:	KY ZIP: 40391
Phone:	1-859-745-2650
Email:	mdsales@metalsdepot.com

Personal/Specific Benefit to the Project: (Be as detailed as possible)

AAE418: 2D SLOSH aluminium plate for manufacturing Base Plates

Please Order Pay Invoice Reimbursement CC Receipt

Person who submitted Purchase Request

Name:	Steven Collicott
Building:	ARMS
Room:	3106-2
Phone:	42339
Email:	collicott@purdue.edu
Professor	Collicott
Need By Date:	ASAP

Order	WBSE	GL Account	% or $	Begin Date	Expiration	Account Balance	Date
	F.90025007.						

CATALOG #	ITEM NAME & DESCRIPTION	QUANTITY	UNIT COST	TOTAL COST
S318T6	1/8" X 24" X 24" 6061 - T6 aluminium plate, cut-to-order 24x24 inches	1	$ 84.36	$ 84.36
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
	Shipping/Handling/Fees/Tip			$ -
REQUISITION TOTAL				$ 84.36

Dept. Head/ Advisor/PI: Signature Date

Comptroller: Signature Date

Order Placed By: Signature Date

YELLOW CELLS Mandatory For All Orders, Do Not Alter Formulas

Business Office Use Only:

CC - Trans ID#

Reimbursement / Check payment - Ref. Doc#

Credit Card # (last four only):

Reconciled:

Received:

Table 3: Purchase Request Form for Base and Sliding Plate Stock

ARMS Business Office Purchase Request Form

Please submit to:

Individual needing reimbursed/Vendor needing paid

Vendor:	McKinney Corporation
Contact:	Todd Morris
Address:	4710 Fastline Drive
City:	Lafayette
State:	Indiana ZIP: 47905
Phone:	765-448-4800
Email:	tmorris@mckinneycorp.com

Department (please circle): AAE ENE MSE EPICS MEP MIEP Other:_____

Date: 10/29/2021

Purpose/Specific Benefit to the Project: (Be as detailed as possible)

AAE418:
2D SLOSH, Manufacturing of 1 base plate and 4 sliding plates from our stock material

Please Order Pay Invoice Reimbursement CC Receipt

Person who submitted Purchase Request

Name:	Steven Collicott
Building:	ARMS
Room:	3106-2
Phone:	42339
Email:	collicott@purdue.edu
Professor	Collicott
Need By Date:	ASAP

Order	WBSE	GL Account	% or $	Begin Date	Expiration	Account Balance	Date

CATALOG #	ITEM NAME & DESCRIPTION	QUANTITY	UNIT COST	TOTAL COST
	Water jet cutting, see quote SQ-40205, attached	1	$ 262.50	$ 262.50
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
	Shipping/Handling/Fees/Tip			$ -
REQUISITION TOTAL				$ 262.50

Dept. Head/ Advisor/PI: Signature Date

Comptroller: Signature Date

Order Placed By: Signature Date

YELLOW CELLS Mandatory For All Orders, Do Not Alter Formulas

Business Office Use Only:
CC - Trans ID#
Reimbursement / Check payment - Ref. Doc#

Credit Card # (last four only):
Reconciled:
Received:

Is there a discount? Yes____ No____ [Fill out the Form 4101 if educational discount, track internally.]
Has an equipment screening been completed? Yes____ No____ [Required for >$25,000 on Sponsored Funds, Desired for all other awards]
Was the Request for Waiver of Competitive Bidding document been completed? Yes____ No____ [Required for all single source acquisitions >$10,000].
Is there proper documentation from the PI approving the purchase (signature, email, other_____)?

Table 4: Purchase Request Form for McKinney Manufacturing

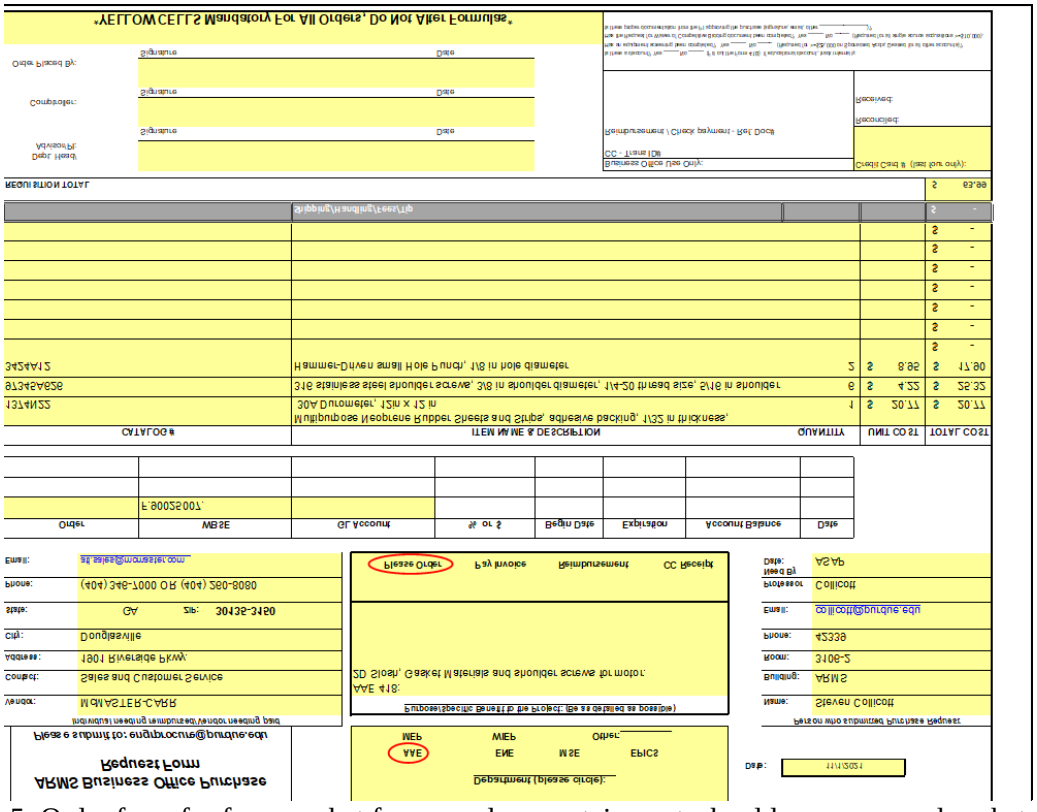


Table 5: Order form for foam gasket for secondary containment, shoulder screws, and gasket cutter

ARMS Business Office Purchase Request Form

Please submit to: engrprocure@purdue.edu

Department (please circle): AAE ENE MSE EPICS MEP WIEP Other:_____

Date: 10/27/2021

Individual needing reimbursed/Vendor needing paid

Vendor:	McMASTER-CARR
Contact:	Sales and Customer Service
Address:	1901 Riverside Pkwy.
City:	Douglasville
State:	GA ZIP: 30135-3150
Phone:	(404) 346-7000 OR (404) 260-8080
Email:	atl.sales@mcmaster.com

Purpose/Specific Benefit to the Project: (Be as detailed as possible)

AAE 418:
2D SLOSH, Screws

Please Order | Pay Invoice | Reimbursement | CC Receipt

Person who submitted Purchase Request

Name:	Steven Collicott
Building:	ARMS
Room:	3106-2
Phone:	42339
Email:	collicott@purdue.edu
Professor Need By Date:	Collicott ASAP

Order	WBSE	GL Account	% or $	Begin Date	Expiration	Account Balance	Date

CATALOG #	ITEM NAME & DESCRIPTION	QUANTITY	UNIT COST	TOTAL COST
97710A115	18-8 Stainless Steel Narrow Cheese Head Slotted Screws, M3 x 0.5 mm Thread, 10 mm Long, 4.(	5	$ 5.04	$ 25.20
91253A194	Black-Oxide Alloy Steel Hex Drive Flat Head Screw, 8-32 Thread Size, 1/2" Long	1	$ 15.75	$ 15.75
92196A107	18-8 Stainless Steel Socket Head Screw, 4-40 Thread Size, 5/16" Long	2	$ 4.08	$ 8.16
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
	Shipping/Handling/Fees/Tip			$ -
REQUISITION TOTAL				$ 49.11

Dept. Head/ Advisor/PI: Signature Date

Comptroller: Signature Date

Order Placed By: Signature Date

Business Office Use Only:
CC - Trans ID#
Reimbursement / Check payment - Ref. Doc#

Credit Card # (last four only):
Reconciled:
Received:

Is there a discount? Yes ____ No ____ (Fill out the Form 41B) If educational discount, track internally
Has an equipment screening been completed? Yes ____ No ____ (Required for >$25,000 on Sponsored Accts. Desired for all other accounts)
Has the Request for Waiver of Competitive Bidding document been completed? Yes ____ No ____ (Required for all single source acquisitions >$10,000)
Is there proper documentation from the PI approving the purchase (signature, email, other _____)?

YELLOW CELLS Mandatory For All Orders, Do Not Alter Formulas

Table 6: screws for secondary containment attachment, as well as some updated screw needs

ARMS Business Office Purchase Request Form

Please submit to: engrprocure@purdue.edu

Department (please circle): AAE ENE MSE EPICS MEP WIEP Other:_____

Date:

Individual needing reimbursed/Vendor needing paid

Vendor:	
Contact:	
Address:	
City:	
State:	WA ZIP:
Phone:	
Email:	

Purpose/Specific Benefit to the Project: (Be as detailed as possible)

Please Order | Pay Invoice | Reimbursement | CC Receipt

Person who submitted Purchase Request

Name:	Steven Collicott
Building:	ARMS
Room:	3106-2
Phone:	42339
Email:	collicott@purdue.edu
Professor Need By Date:	Collicott ASAP

Order	WBSE	GL Account	% or $	Begin Date	Expiration	Account Balance	Date
	F.90025007.						

CATALOG #	ITEM NAME & DESCRIPTION	QUANTITY	UNIT COST	TOTAL COST
18-8 Stainless Steel Narrow Cheese Head Slotted Screw	M3 - 0.5 Thread screws, 10mmfor motor connection and sliders https://www.mcmaster.com/screw	5	$ 5.04	$ 25.20
Alloy Steel Hex Drive Flat Head Screws - Black Oxide	1/2 in 8/32 countersuck holes for Vessel Brackets https://www.mcmaster.com/screws/thread-size-	1	$ 15.75	$ 15.75
18-8 Stainless Steel Socket Head Screws - stainless stee	5/16 in 4-40 screws for the secondary containment vessel https://www.mcmaster.com/screws/thre	2	$ 4.08	$ 8.16
	coupling nuts for containment vessel			$ -
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
	Shipping/Handling/Fees/Tip			$ -
REQUISITION TOTAL				$ 49.11

Dept. Head/ Advisor/PI: Signature Date

Comptroller: Signature Date

Order Placed By: Signature Date

Business Office Use Only:
CC - Trans ID#
Reimbursement / Check payment - Ref. Doc#

Credit Card # (last four only):
Reconciled:
Received:

Is there a discount? Yes ____ No ____ (Fill out the Form 41B) If educational discount, track internally
Has an equipment screening been completed? Yes ____ No ____ (Required for >$25,000 on Sponsored Accts. Desired for all other accounts)
Has the Request for Waiver of Competitive Bidding document been completed? Yes ____ No ____ (Required for all single source acquisitions >$10,000)
Is there proper documentation from the PI approving the purchase (signature, email, other _____)?

YELLOW CELLS Mandatory For All Orders, Do Not Alter Formulas

Table 7: screws for motor connection, vessel brackets, and secondary vessel

What to do next

1. The new vessel has been sent for manufacturing and are being completed off at the lab. The crankshaft sleeve needs to be manufactured. Once the manufacturing is complete, assembly should begin.
2. The new base plate, sliding plate, and mounts have come back from manufacturing but require some small edits. If brought to the airport shop during the first week, they should be done by week 3. Check the to-to list in the base plate and sliding plate sections. Once they are manufactured assembly should be done. Check the to-to list in the base plate and sliding plate sections.
3. The connectors of the IPC (C2 and C3) are requested and need to be wired up. The IPC control code is ready and needs to be tested with the full assembly once.
4. Look into the final construction of 2D SLOSH!

Assembly Guide

1. The Bottom Base Plate is bolted to the spacers, sliders, motor mounts and the columns. The base place is attached to the Blue Origin Payload box first as we lose the access to certain holes after attaching the oscillating plate.
2. Assemble oscillator plates away from base plate, ensure vessel, mounts, mirrors, and everything is complete before attaching to base plate. Add in cameras, mirrors, crankshaft, and other more technical parts to the assembly in the box. Attach the oscillator plates to the Bottom Base plate AFTER step 1.
3. Assemble the top upper base plate and attach the oscillator plates to it. Assemble the top assembly to the columns.
4. Ensure all parts are in, build is secure in box, then close off lid and ensure security of the Blue Origin safety box.
5. Send project off to Blue and await the launch!