Test Equipment Data Package: Effectiveness of thrombolytics in a microgravity environment

UBC Rocket Payloads Team

Team Members	Team Lead	Primary Institution
Moeid Elahi Maya Taylor Andy Kim Tristan Brown Amjad Yaghi Nathan Tourvieille	Kassandra Hawes kassandramhawes@gmail.com	University of British Columbia 2329 West Mall Vancouver, BC V6T 1Z4

Date of Submission: July 17, 2023

Table of Contents

1 Update

In order to focus on having fully working test units to display, we completed two test units, leaving the last one as an optional completion if time warrants. We now have test units 1 and 2 manufactured and tested, securely mounted, and being successfully controlled by our electronics. The electronics and Arduino are mounted inside a container to protect from spills and the 12V adaptor has been used to run the test units. Camera mounts have been printed and tested to verify positioning and lighting while the Pelican case is closed.

To finish the current setup, the final cameras that will be used have to be retrieved, as the UBC Rocket team uses them for other purposes, pass throughs for all wires into the electronics container need to be finalized, and methods to better organize and secure wires out of view of the cameras need to be explored. Pictures of the current setup can be seen later in the report and a video of our first ever test run can be seen here.

One minor error can be seen where a limit switch is not detected, it ended up having some glue blocking it that was remedied and now it works perfectly. The test was still successful however, as the code is designed to continue after a while if a limit switch is not triggered. There are also some important takeaways that we will focus on in the coming week to perfect the experiment:

1. All mounts must be tightened fully and double checked by at least one other person to ensure tightness. If properly tightened, the mounts will prevent the linear actuator from over actuating in the event that a limit switch fails.
2. Exact placement of linear actuators and syringes needs to be refined and marked in a way such that assembly is repeatable. This ensures syringes are actuated the same amount every time.

We will prioritize finishing up the items mentioned in the second paragraph, and refining our testing protocol as listed. This should leave us with two complete and reliable test units. After this, a third test unit will be manufactured as time permits.

2 Flight Manifest

Primary Mission Specialists	
Moeid Elahi	Canadian
Tristan Brown	Canadian
Backup Mission Specialist	
Kassandra Hawes	Canadian

3 Experiment Background

This experiment is being used to verify and explore the apparatus required to facilitate the study of blood clot formation and breakdown in microgravity. Vascular studies on the ISS have shown unusual movement of blood in the internal jugular vein of previously healthy astronauts, and other precursors for thrombosis.[1] As we spend more time in space, and microgravity, this raises concerns about how blood clots form in microgravity, and the best way to treat them. Our experiment will provide information on the difference in structure of blood clots that form in microgravity, and will also explore the effectiveness of traditional thrombolytics to break them down.

The experiment requires the careful measurement, control, and mixing of several reagents; and thus a complex apparatus. The current design utilizes syringes, valves, and linear actuators to remotely carry out the experiment. This design, with dummy reagents, will be flown in microgravity and tested to ensure it works as intended and does not face any complications during flight.

4 Experiment Description

Our experimental apparatus is being tested to ensure it has the capabilities to carry out the requirements of a full experiment, or could be easily adjusted and expanded to a usable design. This means we want to test as wide a range of viable possibilities as we can, and that the effectiveness of mixing and administered volume must be observed.

Our experiment is designed to house three test units in the pelican case. Test unit 1 uses two linear actuators to simultaneously push and pull syringes while facilitating the mixing process.This may be needed to minimize added pressure on the clot in the future experiment. This test will also include a higher viscosity dummy reagent to represent the clot. Test unit 2 verifies the effectiveness of mixing three reagents at staggered times, with different coloured dummy reagents being used to observe mixing. Test unit 3 will be identical to test unit 2, but will be oriented vertically while test unit 2 is oriented horizontally. Schematics of each test unit can be seen in the figures below.

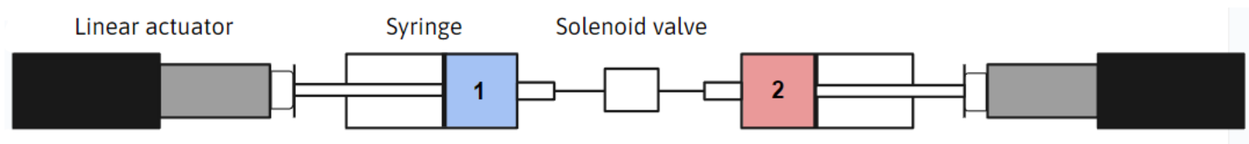


Figure 1: Conceptual diagram of test unit 1, push and pull

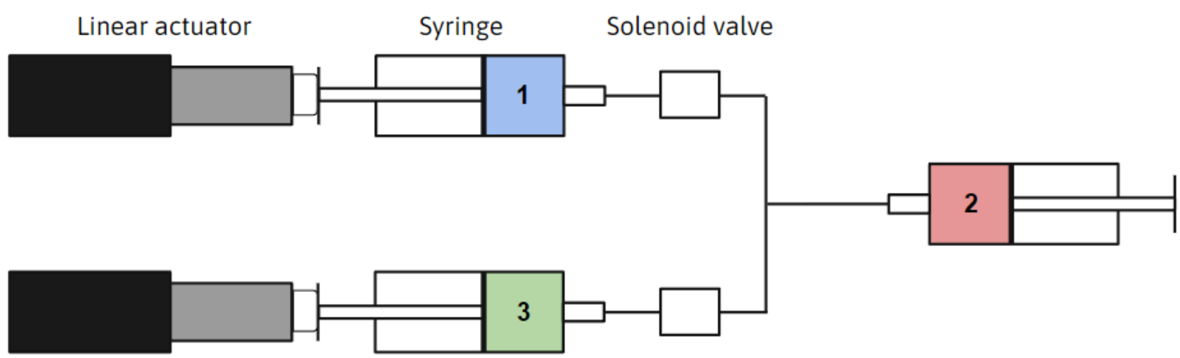


Figure 2: Conceptual diagram for test units 2 and 3, horizontal mixing and vertical mixing

As of present, two test units have been fully assembled and tested. Each test unit will have its own camera to observe the mixing process. The experiment is controlled via an Arduino that is connected to a laptop GUI. Limit switches on each experiment are used to monitor their position. The Arduino and primary circuitry is housed in a plastic container to avoid damage from leaks. A picture of the fully assembled pelican case, with area for tes unit 3 marked out, can be seen in Figure 3 below. Note the camera used is a stand in while we wait to get the proper cameras from others on UBC Rocket.

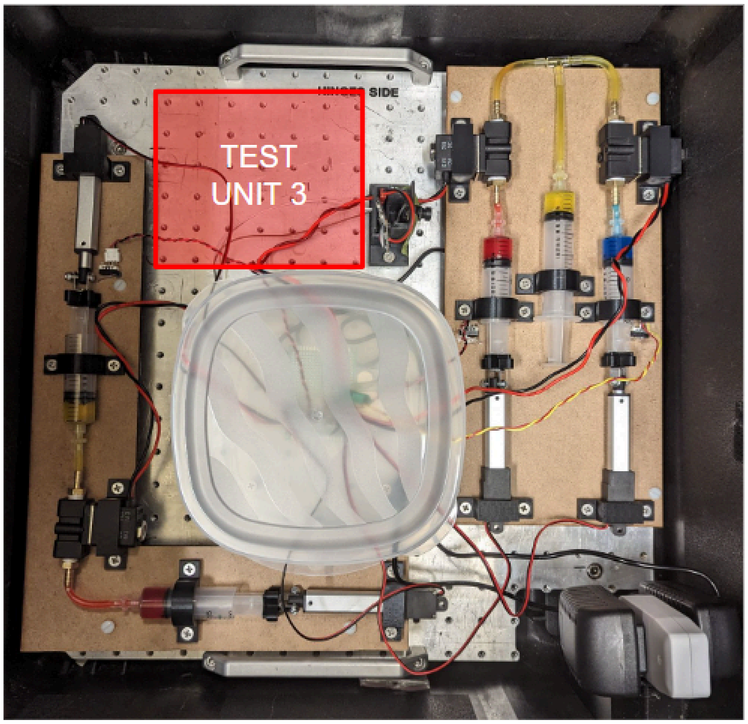


Figure 3: Fully assembled experiment in the Pelican case. Includes Test units 1 and 2.

The view of test unit 2 from its camera can be seen in Figure 4 below. Mounts have been manufactured and placement, including lighting, has been tested.

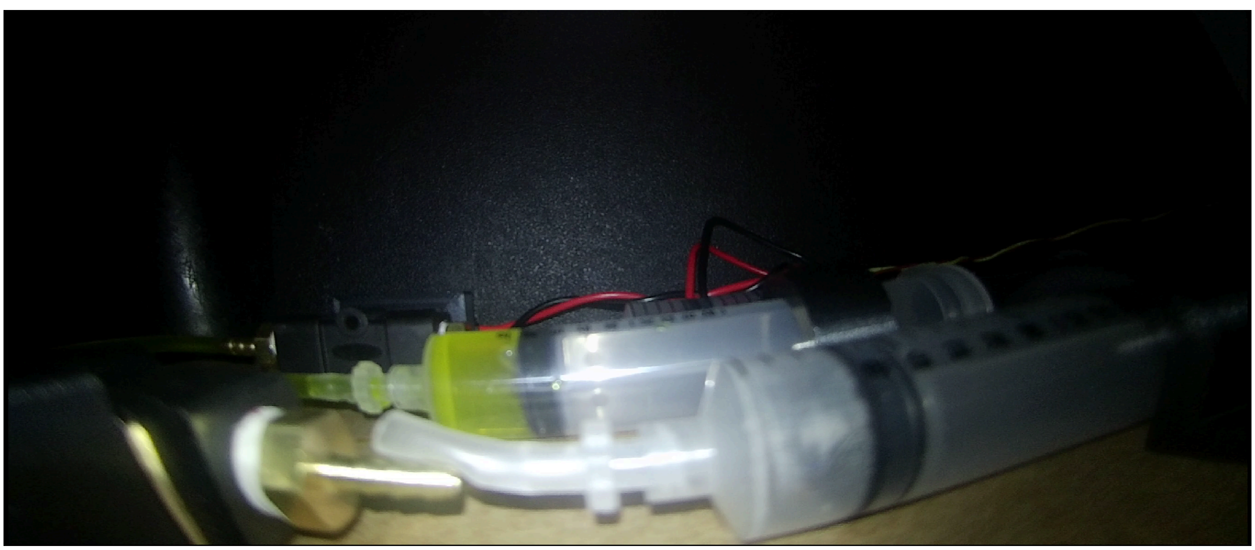


Figure 4: Camera view of test unit 2. The middle mixing syringe is full view, which is ideal. Some fish eye effect is noted, but shouldn't affect the use of the footage.

A screenshot of the current GUI is shown below. The prime button must be pressed before the experiment button to start a test unit. This minimizes the risk of accidentally pressing a button and starting an experiment. Green lights appear below each experiment button to represent which limit switches have been activated, shown in the second picture.

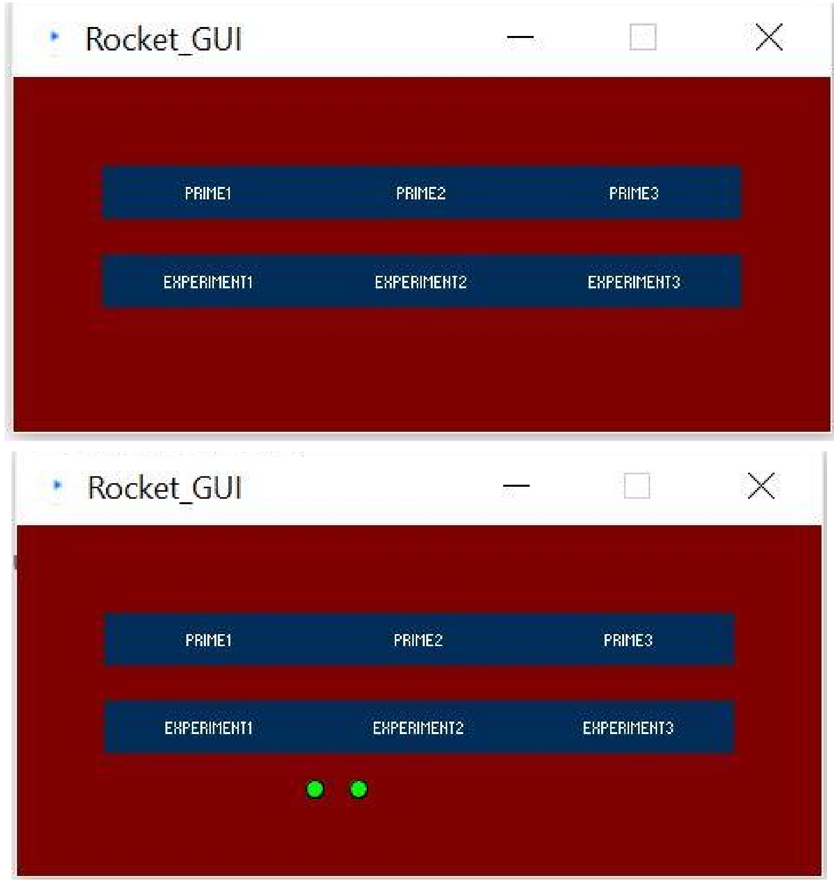


Figure 5: GUI screenshots, with and without activated limit switches.

5 Equipment Description

a Experiment Weight

All component weights have been measured using a scale and have not been estimated, except for phone weights. Test unit 3's weight has been predicted using the weight of expected components from other test units. The complete mass budget can be seen in Appendix A.

b Experiment Assembly

Upon arrival at the flight campaign, the Pelican case will have all test units and electronics assembled and mounted. Before flight, each test unit must be partially disassembled in order to load reagents, and then reassembled. Items that will be affected are primarily the syringes and mounts, and any tubing. Electrical connections between test units and the Arduino/circuit may have to be reattached as well. After this, the status of the test units, accelerometer, SD card, and cameras will be verified. Depending on the results, those items may require reassembly as well.

During the flight, no further assembly or alterations to the experiment should be needed.

No components pose special hazards or handling. Electrical connections and power sources should be given regular caution to ensure shorting does not occur.

6 Structural Verification

The essential items of each test unit and their mounting structures all survived two Rocket launches and recoveries as a payload. This likely speaks to their structural integrity.

For further verification, a 1kg weight, which is approximately double the weight of an entire test unit, was applied in different parts of the experiment, including the mounting boards and individual mounts. Areas of loading are marked in Figure 6 below. No signs of cracking, malformation, or failure were found during the loading.

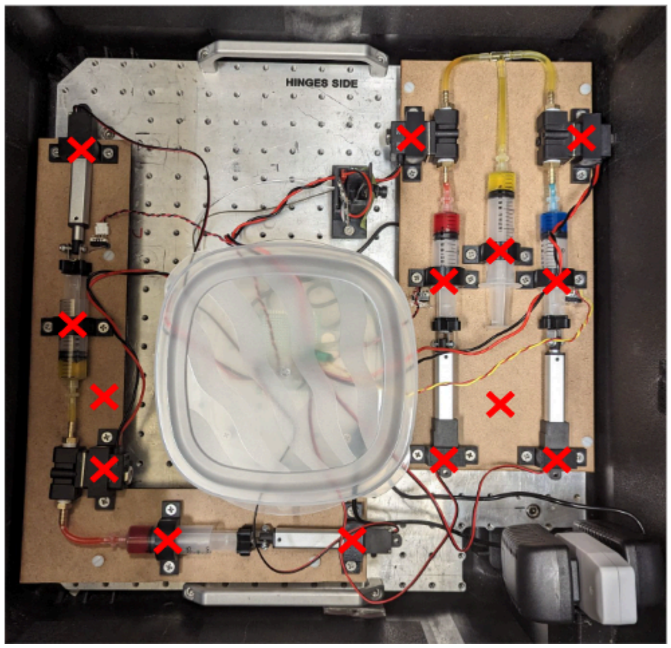


Figure 6: Areas of loading on the experiment for structural verification

7 Electrical Analysis/Verification

a Schematic

A complete electrical schematic is provided in Appendix B, with labeled wires. A table follows listing the wire gauge, and nominal and peak current values. Changes from the schematic provided in CDR include the removal of LS2 as it was redundant, the consolidation of MOSFETs as the ones sourced had high current limits, the inclusion of 10kOhm resistors to ensure gate voltages are not left floating, and the inclusion of flyback diodes on the solenoid valves.

Current limiting is as follows, the laptop is using its own rated charger which should limit as necessary, and the Arduino is plugged into the computer. This means the computer will provide the required current to the Arduino, although it has its own internal 500mA fuse. The cameras use a 5V adaptor which can supply up to 3A and the valves and actuators use 12V which can supply up to 2A. These items do not have current protection, but it is unlikely the adaptors will be able to provide enough current to damage them. This does mean care must be taken to ensure electrical connections are made correctly.

There are no larger metal surfaces that require grounding in the experiment.

b Load Table

Table 1: Load Table

Component	Status	Voltage [V]	Qty	Experiment Operational Mode				Notes
				Idle		Science		
				Average [W]	Duty Cycle	Average [W]	Duty Cycle	
12V Adapter								
Linear Actuators	M2	12V	6	0	100%	2.4	10%	Only 1 valve and 2 actuators running at a time
Solenoid Valves	M2	12V	5	0	100%	2.4	10%	
Power Used [W]				**0**	**-**	**7.2**	**-**	
Power Available or Allocated [W]				**24**	**-**	**24**	**-**	24W max from 12V adapter
Margin [%]				**-**	**-**	**30%**	**-**	
5V Adaptor								
Cameras	M1	5V	3	2.25	100%	2.25	100%	Runcam splitHD
Power Used [W]				**6.75**	**-**	**6.75**	-	
Power Available or Allocated [W]				**15**	**-**	**15**	-	15W max from 5V adaptor
Margin [%]				**45%**		**45%**		
Laptop								
Laptop	M1	110VAC	1	60	100%	60	100%	Can run on outlet or battery power
Arduino UNO	M1	5V	1	0.3	100%	0.5	100%	
Power Used [W]				**60.3**	**-**	**60.5**	**-**	

c Stored Energy

There are no components with large amounts of stored energy. The solenoid valves do have an inductive effect, which is why flyback diodes have been introduced to avoid damage to the MOSFETs.

d Emergency Shutdown Procedures

The sequence of events that follow from unplanned or emergency shutdown are fully explained in the following section, Loss of Electrical Power.

8 Loss of Electrical Power

In the event of electrical power loss, the following series of events will occur. Power is lost to the computer charger, 5V adaptor, and 12V adaptor. The computer will switch to battery power, so the Arduino will remain powered. In the event of an emergency, the cable connecting the Arduino to the computer can be unplugged, and the Arduino will also shut down. Without unplugging the Arduino though, the loss of the 12V and 5V will cause a loss of power to all cameras, actuators, and valves. The valves are normally closed and the actuators will turn off. Camera and SD data is still safely stored in the event of power loss. This is a very safe configuration, and the Arduino will no longer be able to control any of the powered items. As a contingency, the Arduino can still be unplugged.

If electrical power is restored, the Arduino program will not pick up where it left off and will wait for an experiment to be started again, so if shutdown happens in the middle of execution, it may not be able to resume it. Test unit execution does happen very quickly however, and even if partially executed, will still garner results. Also, camera and SD card storage will resume upon power restoration.

9 Crew Assistance Required

Ground crew will assist in assembly of the experiment and gathering of data post-flight, as laid out in the Procedures section. Ground crew assistance is not required during flight.

10 Hazard Analysis

There are no significant hazards to health associated with the experiment. The main minor hazard identified in previous reports is associated with handling of electronics. There are no hazards to personnel in the Falcon 20 or the aircraft.

There are no hazards as of present that would require termination of flight or stopping the current set of parabolas. Of the hazards identified that relate to successful science, the ones still relevant are displayed in the following table. With appropriate experiment assembly, they are all of low likelihood.

Table 2: Present hazards to successful science

Hazard	Controls
SD card or camera microSD card storage is full.	It is important for cards to be cleared pre-flight. The cards have been sourced such that they can carry several hours worth of data.
Cameras are not turned on.	All teammates will be informed on what the cameras' on state looks like, and will be verified prior to flight, and during if level flight occurs.
Wiring comes loose.	All wiring connected to the main circuit board uses JST connectors. Screw in terminals on the power adapters must be double checked. Power adaptors may need additional securing to ensure they do not come loose.
Limit switch is not activated.	The code is designed to override the limit switch activation if it doesn't occur in 5 seconds. This allows the experiment to continue. Overactuating is unlikely to cause harm to the experiment if mounts are properly secured.
Mounts are not properly secured.	All bolts will be double checked by two team members to ensure they are secured.
Incorrect hookup of electronics.	All JST connectors are directional which prevents incorrect directional hookup. Wiring and connectors will be labeled and all team members informed on the correct hookup locations. Power connections will be carefully labeled to ensure the correct one is used.
Camera light batteries die.	Brand new lights will replace the old ones for the flights.

11 Tool Requirements

No special tools are required to assemble, run, or test the experiment. Typical electrical equipment, such as a multimeter, soldering iron, wire cutters, etc are useful. Metric size wrenches as well as Phillips and slotted screwdrivers are used for assembly.

12 Hazardous Materials and MSDSs

No chemicals or hazardous materials are to be used in the experiment. Primary structures are made of hardboard, PLA, and steel. Lead is present in the electrical solder. Dummy reagents are accomplished using store bought food colouring and corn syrup. An MSDS can be supplied for any materials if requested.

13 Procedures

Pre and post flight procedures remain unchanged since CDR. The flight test matrix does not contain level flight. If level flight occurs, it will be used to verify the status of test units and ensure no leaks have occurred.

a Pre-flight

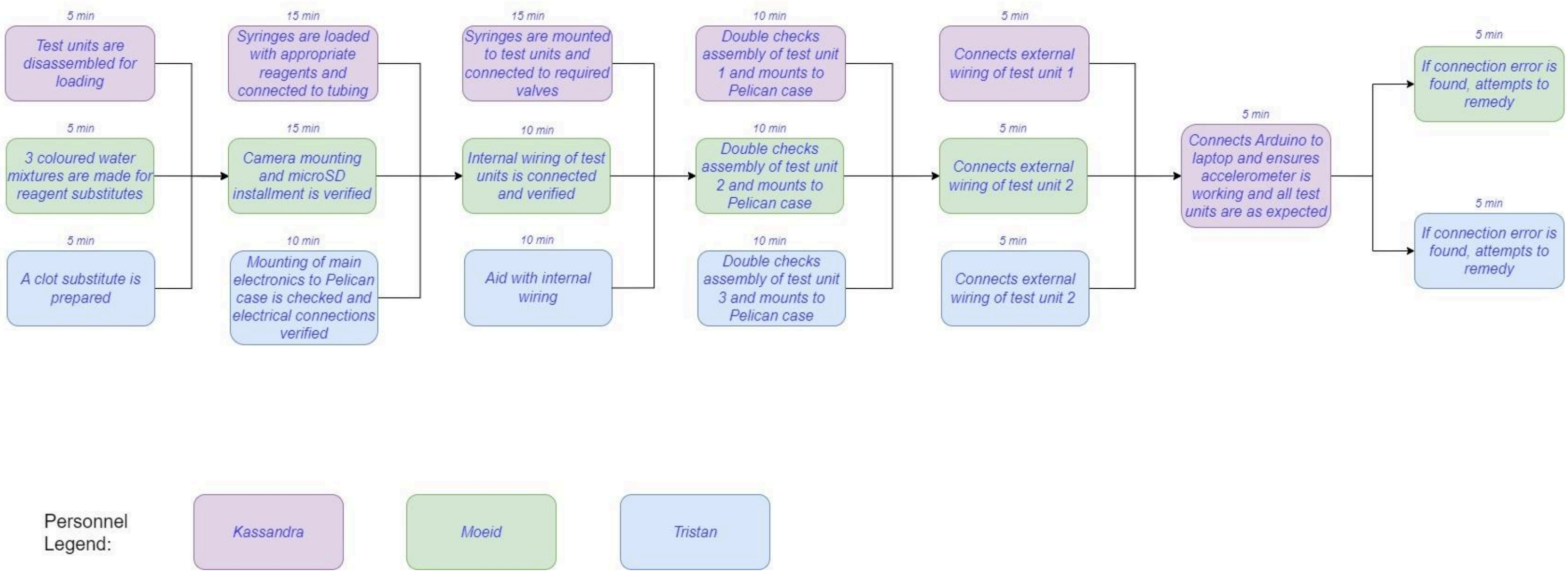


Figure 7: Pre-flight procedures

b Flight Test Matrix, see Appendix C

c Post-flight

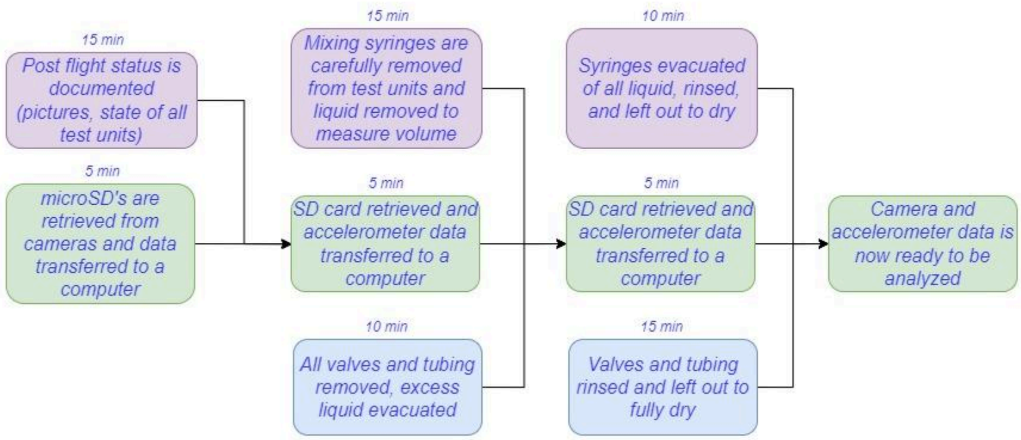


Figure 8: Post-flight procedures

d Emergency procedures

Off nominal behavior can be detected by the limit switch status on the GUI, or through inspection during level flight. Required action may vary greatly depending on the status of the test units, and it is unlikely that most issues can be remedied as the test unit cannot be restarted. If wires have come loose, they can be fixed. If spills are detected, they may need to be minimized.

There is very low likelihood that an emergency occurs with the experiment. In the event of another emergency on board, the Arduino and Pelican case can be unplugged to stop and control the experiment.

14 References

[1] S. M. Auñón-Chancellor et al, "Venous Thrombosis during Spaceflight," The New England Journal of Medicine, vol. 382, (1), pp. 89, 2020.

Appendix A

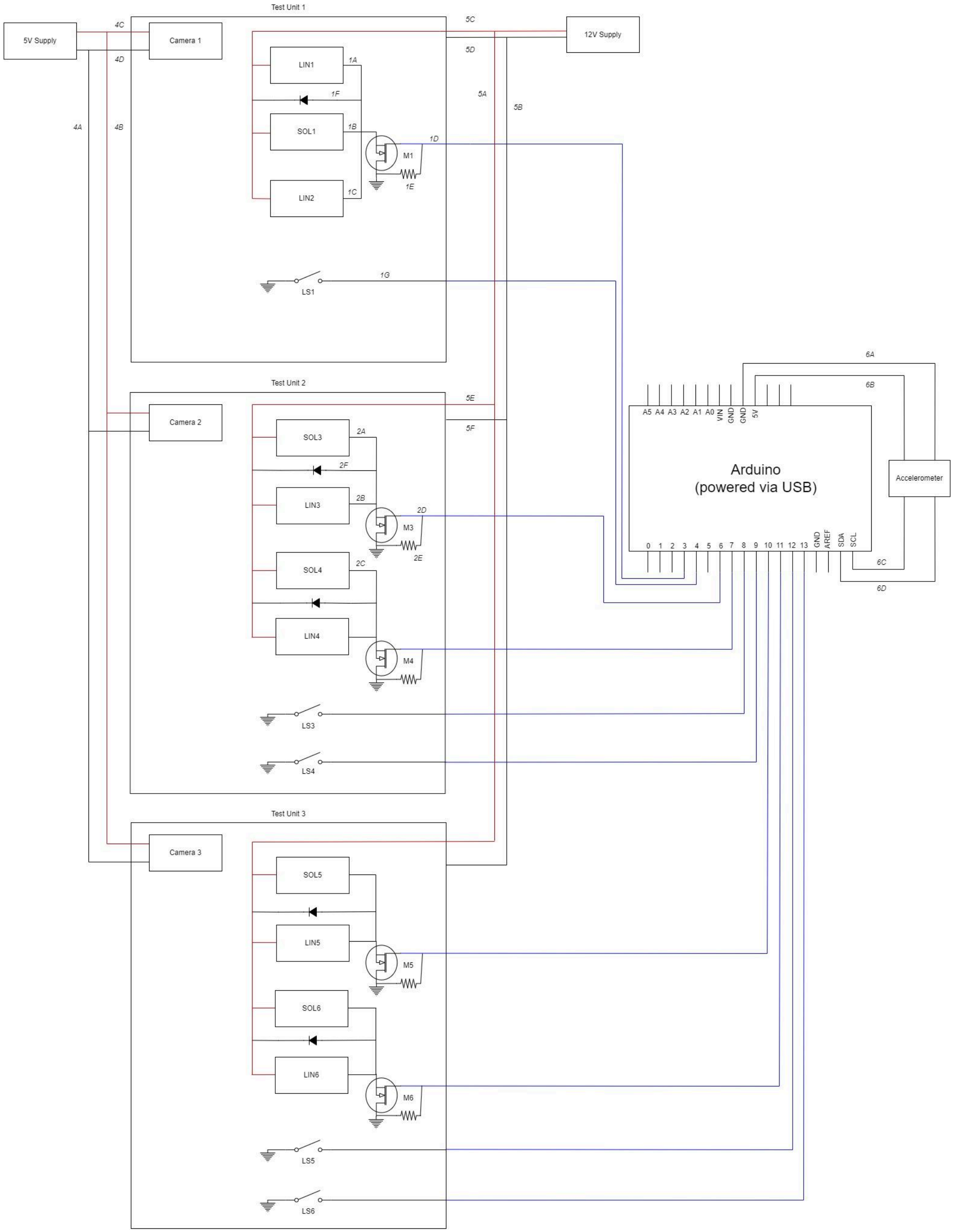
Table 3: Mass Budget

Component	Weight (g)	Number of Items	Total Weight (g)
Test Unit 1			
Tubing	1	1	1
Syringe + adaptor	13	2	26
Syringe mount + fasteners	10	2	20
Linear actuator	46	2	92
Linear actuator mount + fasteners	10	2	20
Solenoid valve	126	1	126
Solenoid valve mount + fasteners	11	1	11
Board + standoffs + fasteners	145	1	145
Limit switch	1	1	1
		Subtotal	442
Test Unit 2			
Tubing	5	1	5
Syringe + adaptor	13	2	26
Syringe	12	1	12
Syringe mount + fasteners	10	3	30
Linear actuator	46	2	92
Linear actuator mount + fasteners	10	2	20
Solenoid valve	126	2	252
Solenoid valve mount + fasteners	11	2	22
Board + standoffs + fasteners	209	1	209
Limit switch	1	2	2
		Subtotal	670
Test Unit 3 (expected)			
Tubing	5	1	5
Syringe + adaptor	13	2	26
Syringe	12	1	12
Syringe mount + fasteners	10	3	30
Linear actuator	46	2	92

Linear actuator mount + fasteners	10	2	20
Solenoid valve	126	2	252
Solenoid valve mount + fasteners	11	2	22
Board + fasteners	400	1	400
Limit switch	1	2	2
		Subtotal	861
Electrical and Cameras			
Camera + board	10	3	30
Camera mount + light	49	3	147
Arduino + circuit board	85	1	85
Mounts + container	65	1	65
12V adaptor	96	1	96
5V adaptor	87	1	87
Wall adaptor	48	1	48
Laptop + charger	1646	1	1646
		Subtotal	2204
Personal Items			
Tristan’s phone	245	1	245
Moeid’s phone	245	1	245
		Subtotal	490
		Total (kg, excluding Pelican case)	4.667
		Total (kg, including Pelican case)	?

I didn’t have a scale with me capable of measuring the weight with the Pelican case, can be obtained if important.

Appendix B



Test Unit 1
5V Supply
4C
4D
Camera 1
5C
5D
12V Supply
LIN1
1A
1F
5A
5B
4A
4B
SOL1
1B
1D
M1
1E
LIN2
1C
1G
LS1
6A
6B
Test Unit 2
5E
5F
Camera 2
A5 A4 A3 A2 A1 A0 VIN GND GND 5V
SOL3
2A
2F
Arduino
(powered via USB)
Accelerometer
LIN3
2B
2D
M3
2E
SOL4
2C
0 1 2 3 4 5 6 7 8 9 10 11 12 13 GND AREF SDA SCL
6C
6D
LIN4
M4
LS3
LS4
Test Unit 3
Camera 3
SOL5
LIN5
M5
SOL6
LIN6
M6
LS5
LS6

Table 4: Wire Gauges and Currents

Wire Label	Gauge (AWG)	Peak Current (mA)	Nominal Current (mA)
Test Unit 1			
1A	12	200	0
1B	8	200	0
1C	12	200	0
1D	12	0	0
1E	N/A	0.5	0
1F	N/A	200	0
1G	14	0.25	0
Test Unit 2			
2A	8	200	0
2B	12	200	0
2C	12	0	0
2D	N/A	0.5	0
2E	N/A	200	0
5V supply			
4A	12	1350	1.35
4B	12	1350	1.35
4C	12	450	0.45
4D	12	450	0.45
12V Supply			
5A	12	400	0
5B	12	400	0
5C	12	600	0
5D	12	600	0
5E	12	400	0
5F	12	400	0
Accelerometer			
6A	12	-	-
6B	12	-	-
6C	12	-	-
6D	12	-	-

Appendix C

If no procedure is written, the default action will be monitoring the GUI for unexpected changes.

Table 5: Flight Test Matrix

<table>
<tr><th colspan="2">Stage</th><th>Location</th><th>Length (mm:ss)</th><th>Procedure</th></tr>
<tr><td colspan="2">Boarding (Pelican case is already secured within Falcon 20)</td><td>Campaign site Tarmac</td><td>5:00</td><td rowspan="4">Power should be on, and connection made between laptop and Arduino.
The GUI program (UBCRocket_GUI.pde) is opened and run.
This launches the GUI and no further programs need to be used.</td></tr>
<tr><td colspan="2">Taxi</td><td>Airport</td><td>5:00</td></tr>
<tr><td colspan="2">Takeoff</td><td>Airport</td><td>5:00</td></tr>
<tr><td colspan="2">Transit to Research Airspace</td><td>Airport</td><td>15:00</td></tr>
<tr><td rowspan="3">Data Parabola 1</td><td>2g</td><td rowspan="3">Research Airspace</td><td>0:20</td><td></td></tr>
<tr><td>μg</td><td>0:20</td><td>Prime1 button is pressed on the GUI to confirm we want to start test unit 1.
Experiment1 button is pressed on the GUI to start test unit 1.
GUI is monitored to see if limit switch is activated as expected.</td></tr>
<tr><td>2g</td><td>0:20</td><td></td></tr>
<tr><td rowspan="3">Data Parabola 2</td><td>2g</td><td rowspan="3">Research Airspace</td><td>0:20</td><td></td></tr>
<tr><td>μg</td><td>0:20</td><td>Prime2 button is pressed on the GUI to confirm we want to start test unit 2.
Experiment2 button is pressed on the GUI to start test unit 2.
GUI is monitored to see if the first limit switch is activated, and then the second limit switch.</td></tr>
<tr><td>2g</td><td>0:20</td><td></td></tr>
<tr><td rowspan="3">Data Parabola 3</td><td>2g</td><td rowspan="3">Research Airspace</td><td>0:20</td><td></td></tr>
<tr><td>μg</td><td>0:20</td><td>Prime3 button is pressed on the GUI to confirm we want to start test unit 3.
Experiment3 button is pressed on the GUI to start test unit 3.
GUI is monitored to see if the first limit switch is activated, and then the second limit switch.</td></tr>
<tr><td>2g</td><td>0:20</td><td></td></tr>
</table>

Transit to YOW		15:00	
Landing	Ottawa Int'l Airport (YOW)	5:00	
Taxi	Ottawa Int'l Airport (YOW)	5:00	
Disembark (Pelican case stays mounted in Falcon 20)	Ottawa Int'l Airport (YOW)	5:00	