HASP Student Payload Application for 2018

Payload Title: Miura II		
Institution: University of Colorado at Boulder		
Payload Class (Enter SMALL, or LARGE): LARGE		Submit Date: 12/15/17

Project Abstract: The Miura II payload shall explore possible applications of reusable, expandable soft-shell structures in a near space environment. The deployable structure will attempt to recreate thermal and barometric conditions similar to the International Space Station in order to test the application of the structure to human spaceflight. The goal of Miura II is to build upon the Miura origami folding technique explored by Miura I in the HASP 2017 flight. Miura II will be a technological demonstration for large-scaled expandable soft-shell structures. HASP allows Miura II to test the viability of a thermally-insulated, pressurized, reusable soft-shell structure in a harsh near-space environment where temperature, pressure, and other environmental factors are more accurately represented than during testing on the ground. The Miura II team will be comprised of undergraduate engineering students from the University of Colorado Boulder. The management and team breakdown will include a project manager, systems engineers, team lead engineers, and a faculty mentor from the Colorado Space Grant Consortium.

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Miura II

Colorado Space Grant Consortium

HASP 2018 Proposal

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December 15, 2017

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1 Mission

The Miura II payload shall explore possible applications of reusable, expandable soft-shell structures in a near space environment. The deployable structure will attempt to recreate thermal and barometric conditions similar to the International Space Station in order to test the application of the structure to human spaceflight. The goal of Miura II is to build upon the Miura origami folding technique explored by Miura I in the HASP 2017 flight. Miura II will be a technological demonstration for large-scaled expandable soft-shell structures. HASP allows Miura II to test the viability of a thermally-insulated, pressurized, reusable soft-shell structure in a harsh near-space environment where temperature, pressure, and other environmental factors are more accurately represented than during testing on the ground. The Miura II team will be comprised of undergraduate engineering students from the University of Colorado Boulder. The management and team breakdown will include a project manager, systems engineers, team lead engineers, and a faculty mentor from the Colorado Space Grant Consortium.

1.1 Mission Statement

Miura II shall repeatedly expand, sustain, and contract a thermally-insulated, pressurized, soft-shell structure on the High Altitude Student Platform while recording and monitoring the deployment process in order to evaluate the viability of a reusable, collapsible, soft-shell structure in a near-space environment.

1.2 Mission Objectives

1. Repeatedly expand, sustain, and contract a foldable soft-shell structure in a near-space environment.

2. Pressurize and thermally-insulate the foldable soft-shell structure in a near-space environment.

3. Qualitatively monitor and record the expansion-contraction cycle of the soft-shell structure.

4. Capture high-quality visual data to analyze the soft-shell structures pressurized expansion process, the retention of the extended state, and the contraction back to the original folded state.

1.3 Mission Premise

1.3.1 Deployable Structures

Currently, most habitable space modules utilize a solid, hard-shell design. Although these designs have proven to be durable and resistant to the conditions of space, they are hard to manipulate and expensive to launch. As world governments and industries seek to expand our reach further into the Solar System, a new, more flexible design is required. A soft-shell structure will be the more economical habitat deployment method that provides the solutions to the problems associated with a hard-shell design.

NASAs Advanced Exploration Systems, along with Bigelow Aerospace, has provided an initial solution to this problem via the Bigelow Expandable Activities Module (BEAM), which is currently deployed on the International Space Station. Most significantly, BEAM was recently deployed on its eighth SpaceX Commercial Resupply Service mission on April 8th, 2016, where it was filled with air to prepare the habitat for a two-year test period during which astronauts on board will conduct several tests to ensure the capability and practicality of a soft-shell space habitat.[1]

Deployable soft-shell structures hold many significant advantages to their solid counterparts when considering the economic feasibility. Expandable structures are lower-mass and lower-volume, which will potentially reduce the number of launches and overall mission costs for deep-space travel in the future. The structure will occupy a minimum volume during launch, but will expand to provide a comfortable living space for its occupants. In addition, the shell will provide adequate protection from debris, radiation, and other harsh environmental factors in space. One of the biggest advantages the soft-shell mechanism will have over a hard-shell habitat is its collapsible nature. After expansion, the design can be de-pressurized and collapsed down to its original compressed state and transported to a different location or stowed for future use. Project Miura II will study and improve the design of a folding soft-shell structure that can be retracted and reused. This technology could prove to be essential in the future of human space transportation.

1.3.2 Folding Mechanisms

The Bigelow BEAM Module has a fully-expanded to initially-compressed volume ratio of 400%. For this mission, we want to preserve the advantages of a soft-shell design while improving on the expansion ratio. The folding technique chosen for this mission is the Miura-Ori tessellation pattern, for which this mission is named. The Miura folding technique involves a pattern of triangles and parallelograms that allow the transformation of a two-dimensional object to a three-dimensional object along a single axis of expansion. The technique was developed by Koryo Miura and Masamori Sakamaki from Tokyo Universitys Institute of Space and Aeronautic Sciences.[2] The design pattern, called a Miura-Ori map, utilizes alternating mountain and valley folds, which makes it more resistant to tears and inversions, and insures it will collapse into the same structure every time.

1.3.3 Need for HASP Platform

Although this structure can be tested on the ground, a high-altitude balloon platform such as HASP would provide the optimal environment for this experiment. Though certain environmental factors can be simulated in a laboratory, not all environmental factors can be simulated accurately at once. HASP will allow Miura II to remain at float altitude for an extended period of time in order to repeatedly test the pressurization and expansion mechanism and determine its viability in a harsh space environment.

1.4 Principle of Operations

Miura II shall have all of its systems verified prior to Integration and Launch with the HASP platform. All systems will be powered on prior to launch to set a baseline of atmospheric conditions. The soft-shell structure will begin its cycles once Miura II reaches a float altitude of roughly 36 kilometers. During an expansion-contraction cycle, the pressurization system shall expand the soft-shell structure, sustain the fully-expanded state, then contract the structure to its original folded state in a span of 100 minutes. Prior to release, the soft-shell structure will finish its cycles and remain in a closed position for descent and recovery. The Principle of Operations is shown in Figure 1.

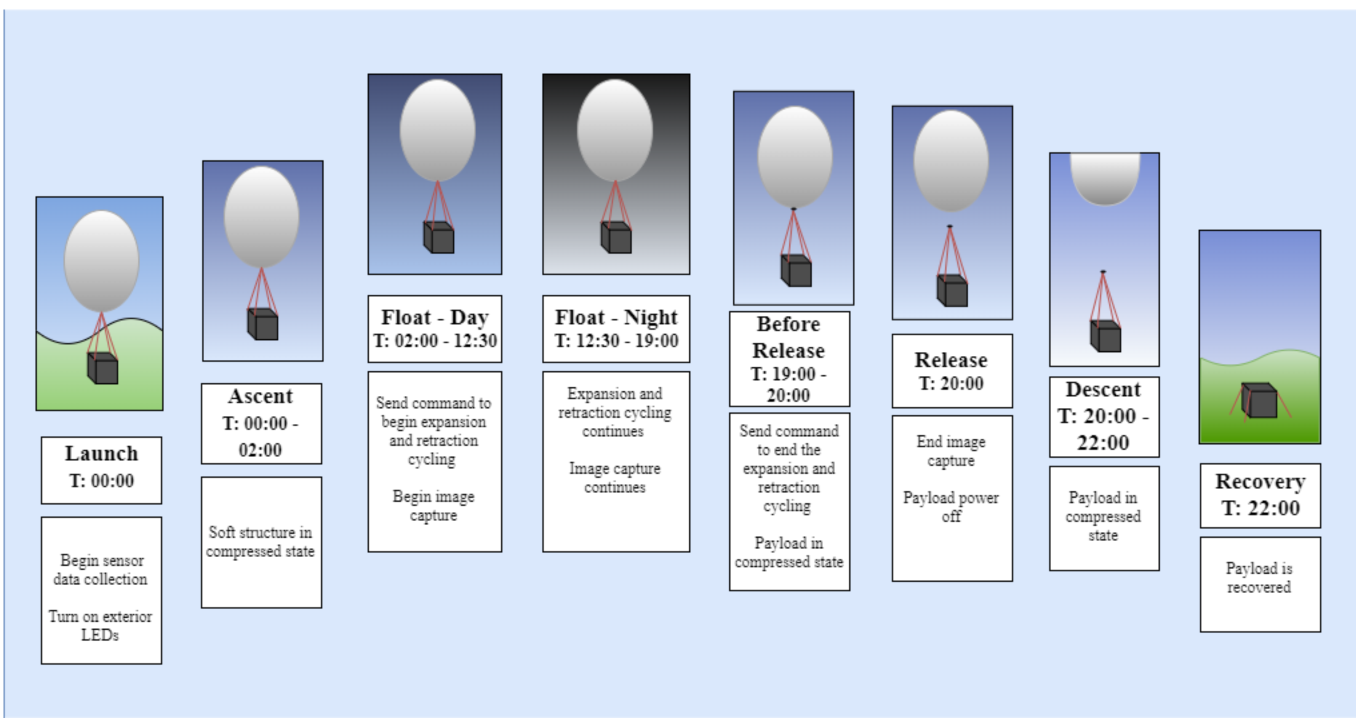


Figure 1: Principle of Operations Diagram

1.5 Concept of Operations

The soft-shell structure will begin its 100-minute cycle approximately two hours after the launch via a manual uplink command, or via an automatic backup five hours into the mission. In the first five minutes of a cycle, the soft-shell structure will pressurize to 1.0 atm. Then, the structure will retain its pressurization and extension to at least five times the minimum volume for 60 minutes. An escape valve will release the pressure and contract the structure over a five minute window. Then, the structure will remain in its compressed state for 30 minutes. Throughout the entire cycle, two cameras shall record visual data from opposite sides of the payload for accurate post-flight analysis. The USB cameras shall also take pictures of the soft structure every second at a lower image quality for post-flight analysis and troubleshooting, if necessary. All environmental data (pressure, temperature, and humidity) will be recorded every second. The Concept of Operations diagram is shown in Figure 2.

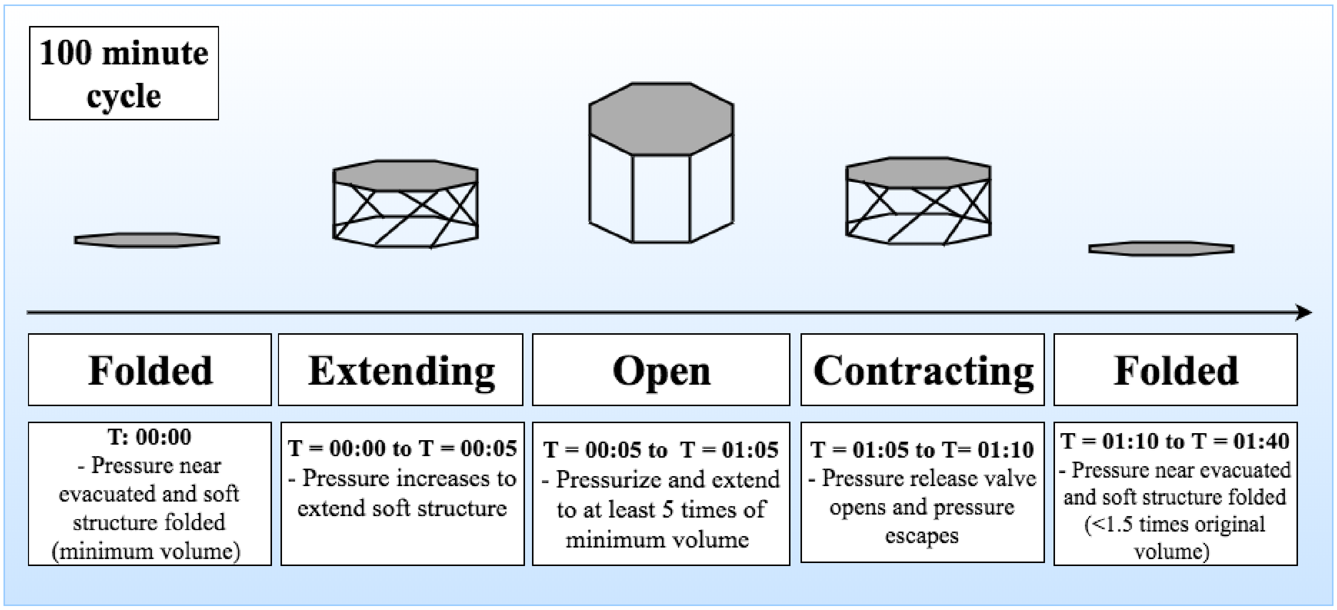


Figure 2: Concept of Operations Diagram

1.6 Mission Success Criteria

In order to achieve mission success, Miura II must complete successful expansion-contraction cycles defined by the following criteria:

1. Extend the soft-shell structure to at least five times of its initial compressed volume at least twice during flight.
2. Sustain the soft-shell structure at at least five times of its initial compressed volume at least twice during flight.
3. Contract the soft-shell structure from five times or higher to 1.5 times or lower of its initial compressed volume at least once during flight.
4. Sustain a pressure between 0.9 atm to 1.1 atm at least once during flight.
5. Sustain a temperature between 15 °C to 25 °C at least once during flight.

2 Mission Requirements

Type	Description
Mission Statement	Project Miura II shall controllably expand, sustain, and contract a foldable, soft-shell, thermally insulated structure multiple times with a pressurization system on the High Altitude Student Platform while recording and monitoring the process to evaluate the viability of deploying a reusable, collapsible structure in a near space environment.
Primary Objective	Repeatedly expand, sustain, and contract a foldable soft-shell structure in a near space environment.
Primary Objective	Pressurize and thermally-insulate the foldable soft-shell structure in a near-space environment.
Primary Objective	Qualitatively monitor and record the expansion-contraction cycle of the soft-shell structure.
Primary Objective	Capture high-quality visual data to analyze the soft-shell structures pressurized expansion process, the retention of the extended state, and the contraction back to the original folded state.

Level 0	Requirements	Rationale	Derived
0.1	A foldable soft-shell structure shall expand, sustain, and contract multiple times.	Mission Statement	0
0.2	The payload shall visually document the position of the soft-shell structure.	Data for downlink and post-flight analysis.	0
0.3	The pressure within the soft shell structure shall remain within $1.0 \pm 0.1^\circ$ atm while fully expanded.	Mission Statement	0
0.4	The soft shell structure shall be thermally insulated.	Mission Statement	0
0.5	The payload shall quantitatively document the environmental conditions to which the soft-shell structure is exposed.	Data for downlink and post-flight analysis	0
0.6	The payload shall comply with all requirements set forth by the HASP Call for Payloads 2018.	Must be met for flight in September	0
0.7	Pertinent risks associated with pressurization shall be mitigated.	Safety	0

Level 1	Requirements	Rationale	Derived
0.1.1	The soft-shell structure shall fully extend without hindrance each cycle.	Make sure no mechanical errors hinder the extension of the structure	0.1
0.1.2	The soft-shell structure shall complete each cycle every 100 minutes.	Make sure no mechanical errors hinder the extension of the structure.	0.1
0.1.3	The soft shell structure shall return to its original compact state after each cycle.	Make sure no mechanical errors hinder the extension of the structure.	0.1
0.2.1	The payload shall collect unhindered visual data.	Visually analyze the folding structure.	0.2
0.2.2	The payload shall measure the height of the soft shell structure throughout each expansion-contraction cycle.	Monitor the position of the soft shell structure during flight.	0.2
0.4.1	The internal temperature of the system shall remain within a temperature range of 20 $\pm 5°$C once fully pressurized.	Analyze the thermal insulation of the soft shell structure.	0.4
0.5.1	The payload shall sample environmental data once every second.	To analyze the environmental factors of flight for downlink and post-flight analysis.	0.5
0.6.1	The payload shall not exceed the physical constraints of a large payload space.	HASP 2018 Requirements	0.6
0.6.2	The payload shall be built to withstand the entire duration of a High Altitude Student Payload flight.	HASP 2018 Requirements	0.6
0.6.3	The payload shall interface with HASP power and telemetry connectors.	HASP 2018 Requirements	0.6
0.7.1	The soft-shelled structure shall be designed to avoid over-pressurization.	Prevent burst of pressure vessel	0.7
0.7.2	The payload shall be capable of containing fragments in the case of a pressure failure.	Maintain safety in case of reservoir burst	0.7

3 Design

3.1 Functional Block Diagram

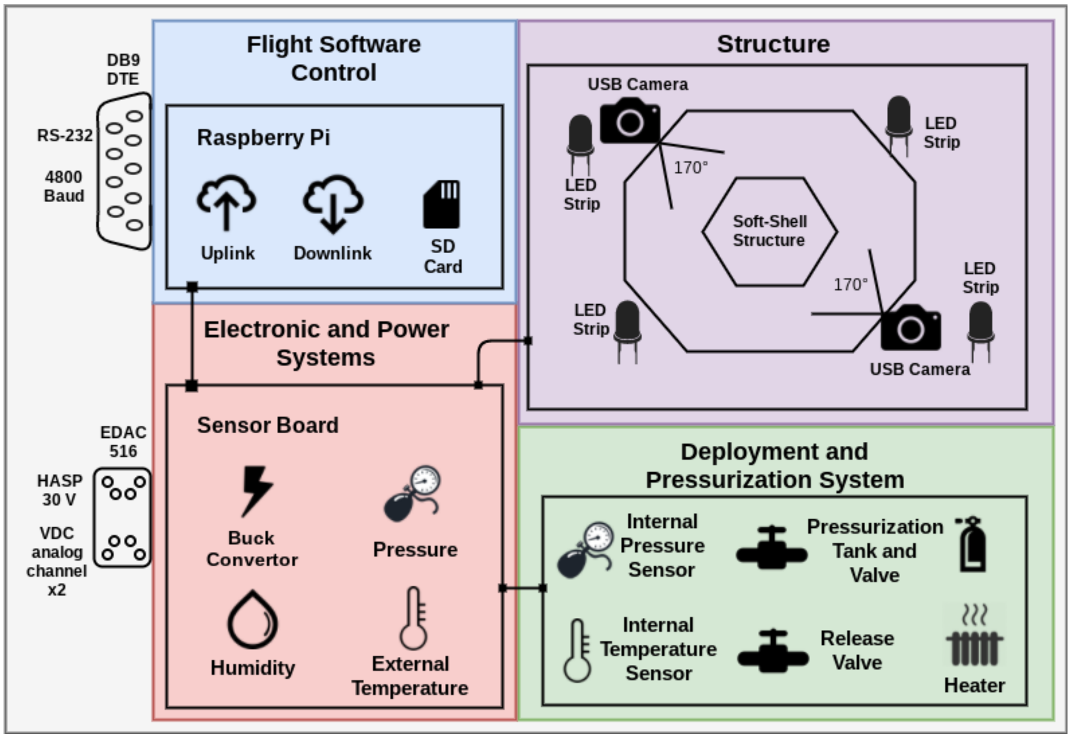


Figure 3: Functional Block Diagram

3.2 Payload and Payload Monitoring

3.2.1 Environmental Data

Table 1: Environmental Data collection and use

Data To Be Collected	How it will be collected	What it will be used for
Video of the soft-shell structure	ELP 8 Megapixel Webcam Camera Sony IMX179 *Saved to SD card*	Visually analyze the functionality of the soft- shell structure for the duration of flight.
Pressure inside the soft-shell structure	MS5803-14BA SparkFun Pressure Sensor Breakout *Downlinked, saved to SD card*	Quantitatively track the pressure inside the structure during inflation and retraction.
Temperature inside the soft-shell structure	MAX31820 One-Wire Ambient Temperature Sensor *Downlinked, saved to SD card*	Quantitatively monitor the temperature inside the pressurized structure for the duration for flight.

3.2.2 Science Data

Table 2: Science Data collection and use

Data To Be Collected	How it will be collected	What it will be used for
HD video of the soft-shell structure	ELP 8 Megapixel HD Webcam Camera Sony IMX179 Saved to SD card	Visually analyze the functionality of the soft- shell structure for the duration of flight.
Pressure inside the soft-shell structure	MS5803-14BA SparkFun Pressure Sensor Breakout Downlinked, saved to SD card	Quantitatively track the pressure inside the structure during inflation and retraction.
Temperature inside the soft-shell structure	MAX31820 One-Wire Ambient Temperature Sensor Downlinked, saved to SD card	Quantitatively monitor the temperature inside the pressurized structure for the duration for flight.

3.2.3 Camera Choices and Location

Miura II uses two 8 mega-pixel USB cameras to document the expansion and contraction of the structure. The cameras will be positioned in opposing corners of the camera boom structure to provide adequate coverage of the expanding soft- shell structure. The color images taken during flight will be of HD quality. After flight each image will be referenced with images taken during ground testing for reference to determine the extent of the expansion during flight.

3.2.4 Kevlar Expandable

The Miura folding technique will be applied to a rectangular sheet of 0.254 mm thick Kevlar, with an area of roughly 932 square centimeters. The sheet of Kevlar will also be secured to three layers of Mylar for thermal regulation, two layers of polyethylene film for pressurization, and natural gum rubber strips for the internal pressure vessel. The natural gum rubber strips will be used as a method for compressing the expandable structure without the use of mechanical or vacuum techniques to mitigate the number of failure points.

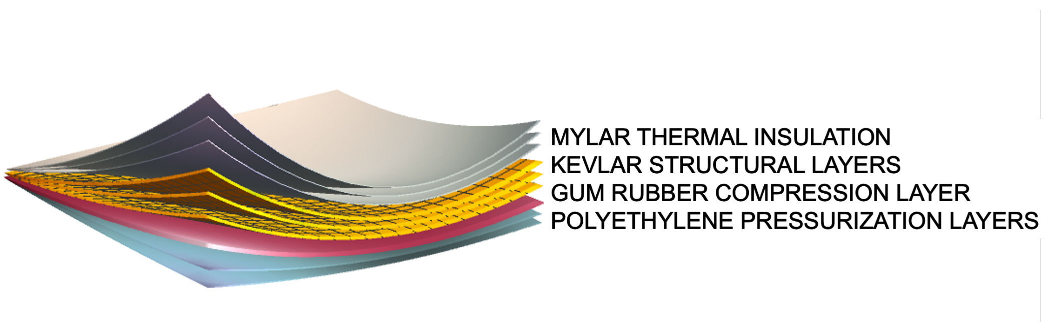


Figure 4: Layers of Miura Module

The sheet will fold to form the sides of a hexagonal prism. When compressed, the sides will fold into a near two dimensional hexagon contained within the bases. This piece of Kevlar will be custom fabricated to ensure it folds and expands in the necessary places. This is accomplished by varying the weave pattern of the Kevlar. Along the flat faces, the Kevlar will be woven at 90 degree angles for a higher rigidity. Along the edges, the weave will be at a more acute angle to increase flexibility. The direction of the weave will ensure that all faces and creases fold in the proper direction. This will ensure the structure folds into the same orientation each time, so as to not damage the expandable structure.

Figure 5: Kevlar Shell fully Expanded

Due to the tessellation pattern, the structure is most stable at its two extremes, when fully expanded and fully collapsed. The top face of the prism undergoes a 90 degree clockwise rotation to expand fully, and a 90 degree counterclockwise rotation to retract. While the bottom face of the structure will remain fixed, the top face will be allowed to rotate freely. The geometry of the Miura folds means only an applied force in the positive z-axis is required to expand the structure. As long as the top face can rotate freely, the structure will fully expand.

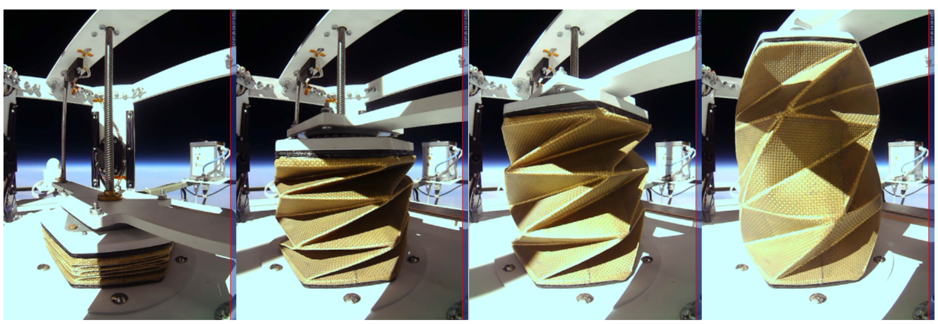


Figure 6: Kevlar Shell in stages of expansion

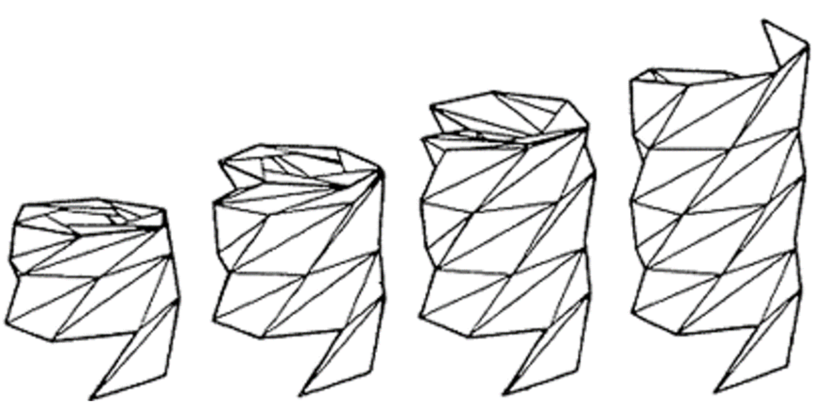


Figure 7: Kresling fold design

3.2.5 Pressure System

The Miura II experiment includes three main structures: the central Kevlar expandable structure, the pressurization system, and the support structure. The central expandable structure is made of several layers, including three Kevlar weave layers, three Mylar thermal layers, two layers of polyethylene film, and a stretchy later, made of natural gum rubber strips, with the top and bottom made of ABS plastic. The structure will expand from 70 cubic centimeters to 400 cubic centimeters.

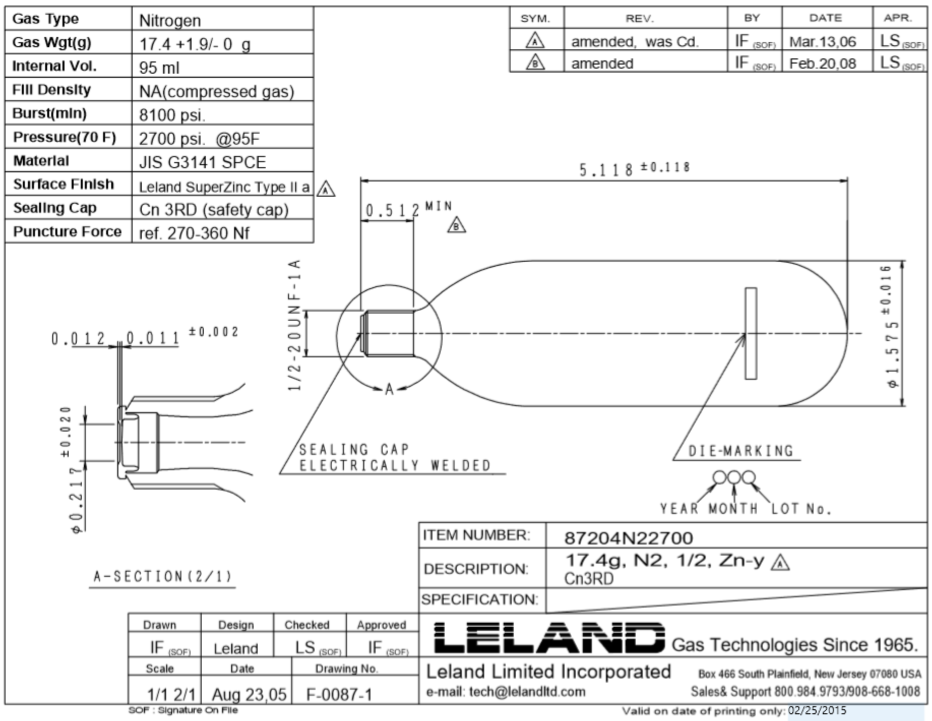


Figure 8: Nitrogen Canister Specifications

The pressurization system includes a compressed nitrogen tank, a solenoid, and pneumatic tubing. The nitrogen cartridge, shown in figure 8, will be purchased from Leland Gas Technologies. The safety information detailing how the canister is expected to function under flight conditions is shown in Section 8, Special Requests. The solenoid controls the flow of air into the expandable structure. The nitrogen will be pumped into the structure until the pressure difference is 1.0 atm. After the difference is achieved, the solenoid will stop pumping the nitrogen until the next cycle.

The depressurization system includes pneumatic tubing and a secondary solenoid to regulate the flow of nitrogen out of the Kevlar structure. The rubber strips will stretch when the structure is pressurized. The elastic material will aid in collapsing the structure during depressurization.

3.2.6 Thermal Regulation System

The outermost layer of Miura II will be three sheets of Mylar insulation blanket to maintain the internal temperature and protect the internal components of the payload from the extreme temperatures of near-space. This will be used to mimic a space habitat that would need to maintain a reasonable temperature for people to live within it. This thermal layer will cover all other layers and shall act as a passive thermal regulation system. The pressurized chamber will also contain a 10 kOhm resistive heater attached to the baseplate of the pressure vessel to maintain an internal temperature of 15 degrees Celsius to mimic livable temperatures for humans. This will be active throughout the pressurization and depressurization phases of flight.

3.3 Structures

3.3.1 Hard Structures

Figure 9: Base Plate

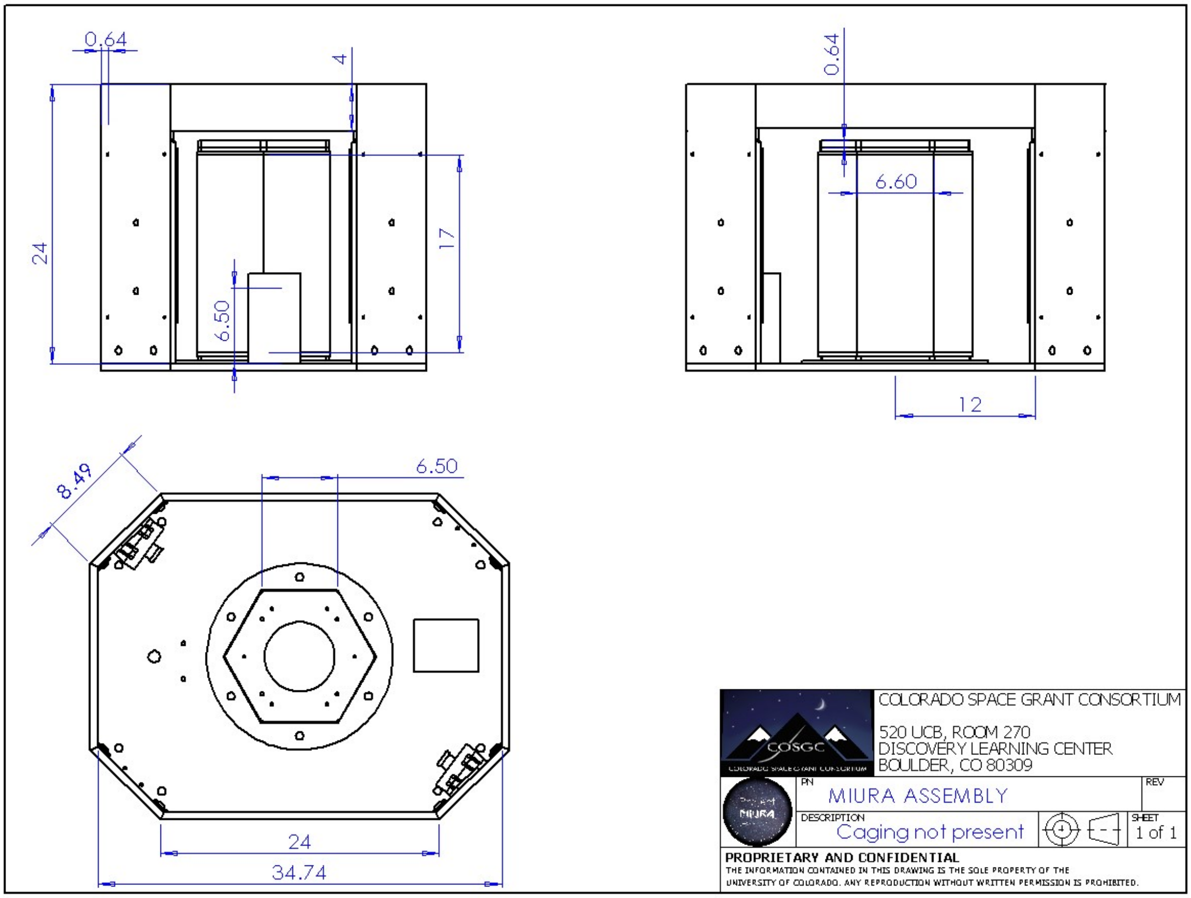


Figure 10: Dimensioned Pressurization Assembly without Aluminum Cage

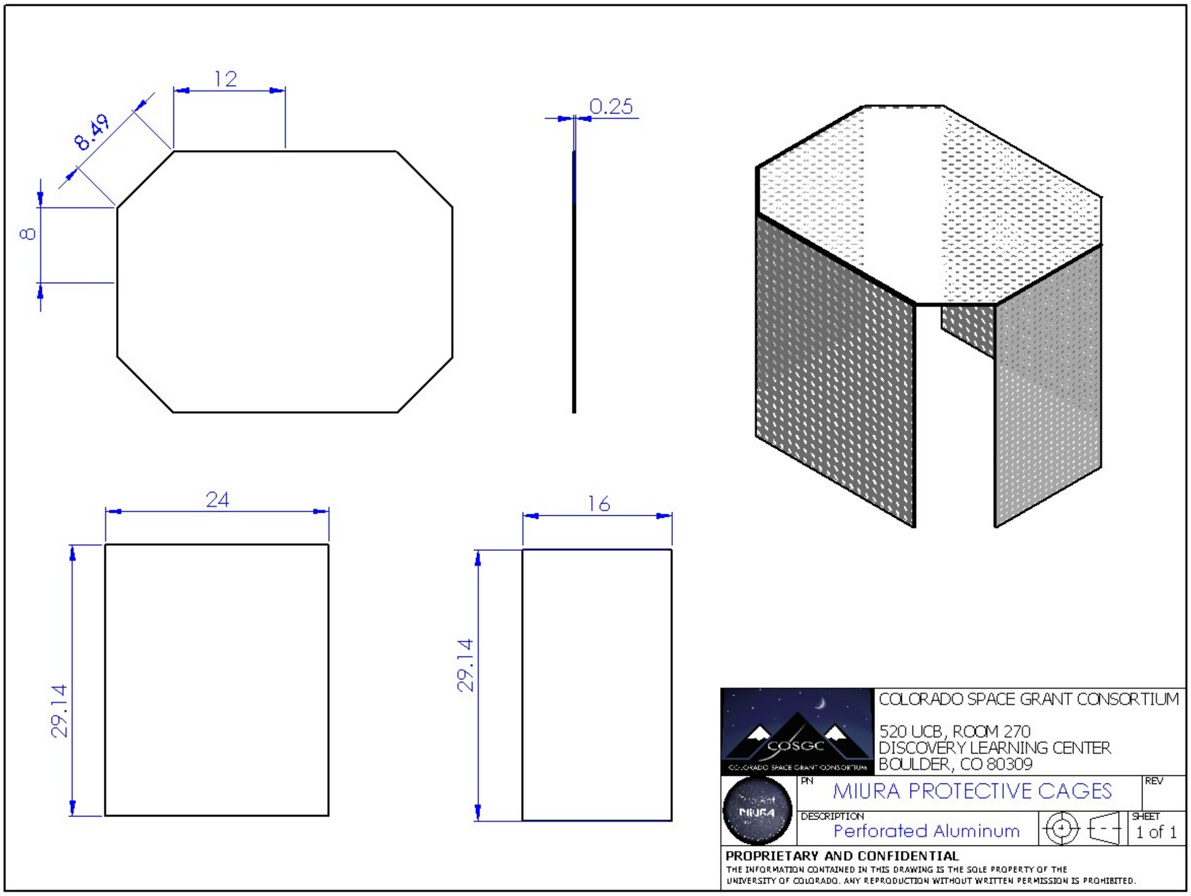


Figure 11: Dimensioned Pressurization Assembly without Aluminum Cage

The base housing consists of eight side plates, one baseplate, and one top plate. The Miura II team will manufacture seven of these custom plates, while using the mounting plate supplied by HASP. The manufactured plates will be made of 6061-T6 aluminum, and will serve as a thermal dissipation system for any EPS system components. The base housing will contain the main EPS power board, the Raspberry Pi, and the motor system. In addition, it will act as a ground for any EPS components. A thin layer of polyethylene terephthalate will cover the outside of the box to protect any internal components.

The camera mount consists of a 3D printed ABS base with a standard camera connector. Due to the necessity of multiple camera viewing angles, an arch-like structure will encompass the entirety of the payload. The ABS mount will be connected directly to this structure.

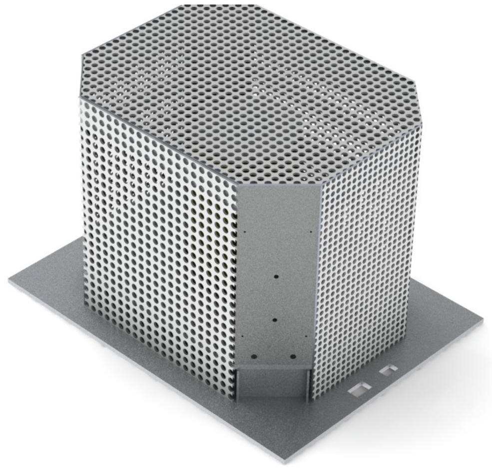


Figure 12: Base housing with aluminum cage

Miura II will be flying a pressure vessel, so there will be extra precautions taken to ensure the safety of other payloads on the HASP platform and the platform itself. The outside of the main base housing will be a perforated aluminum cage that encases the entire payload, and the gas canisters will be contained in a solid aluminum case. Testing shall be done to verify that the cage will contain any unplanned rapid depressurization that might happen during flight.

3.3.2 Structural Integration

The Miura payload will be integrated with the HASP structure using the provided baseplate and four bolts. The bottom plate of the payload contains four holes, allowing a bolt to pass through the base of the structure, and four additional holes drilled into the guide plate provided. The structure will be measured against the provided guide plate to ensure proper structure and hole alignment as well as DB9 and EDAC placement.

3.3.3 Power System Thermal Regulation

Thermal systems will be implemented to ensure no mission failures due to low or high component temperatures. The electrical housing compartment will be insulated by two millimeter thick polyethylene terephthalate on the top and sides. This insulation serves to help maintain adequate operational temperatures for the electrical components. All electronic components will be directly connected with the 6061-T6 aluminum wall structure to allow for proper heat dissipation. The primary heat sink for all EPS components will be the aluminum payload walls.

The amount of current drawn by the motor drivers and buck converters puts this system at the greatest risk of exceeding optimal operation temperatures. Of these two, the buck converters are the most susceptible to overheating. In order to combat this, the Buck converters will be mounted directly to the walls of the aluminum structure. All other components will be mounted to the aluminum walls via a thermal gap filler.

The two USB cameras will be exposed directly to harsh temperatures at maximum altitude. Multi-Layer Insulation (MLI) blankets will be used in conjunction with any additional casing provided by the manufacturer, such as the provided GoPro skeleton case, to minimize temperature exposure. These precautions will ensure that all components remain within operating temperatures for the full duration of flight.

3.4 Flight Software

The Flight Software (FSW) system aboard Miura II is responsible for communications with the HASP platform, running the mission, and collecting data during flight. The FSW system utilizes one Raspberry Pi 3, which has several loops running at the same time, separated for simplicity into distinct Python control threads. These threads allow for parallel processes, providing multitasking capability as well ease of organization and increased efficiency.

Table 3: All of the tasks of the Flight Software subsystem can be organized into 5 general categories. To ensure that the code body will be organized and extensible, each of these categories will be given a separate concurrently running thread.

Camera Control (CAMC)	**Pressure and Temperature Control (PTC)**	**Sensor (SENS)**	**Uplink (UPLK)**	**Downlink (DWNL)**
• Take pictures of the structure every 10 seconds. • Save images to SD card.	• Pressurize soft-shell structure • Heat soft-shell structure • Depressurize soft-shell structure • Pass Internal and External Pressure to Downlink Thread • Detect Full Pressurization • Detect Full Depressurization	• Temperature Sensors (x8) • Humidity Sensor (x1) • Save data to SD card. • Pass data to Downlink Thread	• Monitor Serial Bus. • Parse Commands. • Pass Commands to Thread.	• Writes messages to log files. • Writes data to downlink bus.

3.4.1 Camera Control Thread (CAMC)

The Camera Control Thread takes color images with a predetermined resolution through the USB Cameras every second and stores the images in an SD card.

3.4.2 Pressure and Temperature Control Thread (PTC)

The Pressurization and Temperature Control Thread is responsible for the deployment, heating, and contraction of the soft-shell structure. Once the payload is ready for flight and has been powered on, the thread will monitor the internal and external pressure readings. When the pressurization command is received, or 4 hours have passed since launch, one solenoid valve will be opened, allowing the gas to flow in and pressurize the soft-shell structure. When the internal pressure reaches a difference of 1 ± 0.1 atm, compared to the outside sensor, the solenoid valve allowing the gas to flow in will be closed. During pressurization, if the pressure inside the soft-shell structure does not increase for 10 seconds, or if while inflating the pressure fails to increase for at least 10 seconds, then an error message will be sent to the Downlink Thread. If this error is produced, the cycle will stop and the depressurization cycle will be run. Once the structure has reached its collapsed state, another cycle will be run. If the error occurs three times, the structure will depressurize and remain in that state for the rest of the flight. Upon successful pressurization, the heater will heat the inside of the structure to 15 degrees Celsius. The structure will remain in this pressurized and heated state until the depressurization command is received. Upon receiving the depressurization command, the second solenoid valve will open, allowing the gas to escape from the soft-shell structure until the internal pressure equalizes with the external pressure within a certain experimentally determined tolerance. The escape valve will remain in the open position while the natural gum rubber strips compress the soft-shell structure to its folded state. At this point, the escape valve will close, returning the structure to its initial state. While the mission is operating, it will be monitored through the pressure sensors. Both pressure values will be passed to the Downlink Thread and sent to the ground every second.

3.4.3 Sensor Thread (SENS)

The Sensor Thread manages the reading and recording of all sensors on the payload. It includes eight temperature sensors and a humidity sensor. As a secondary objective, every sensor will assist with data and failure analysis. The primary objectives of each sensor are listed below, as well as each system's unique information that will be sent to the Downlink Thread.

Temperature Sensor Seven temperature sensors will be placed on key components of the payload and outside to record ambient temperature. Two temperature sensors will be placed next to the solenoid valves while two other temperature sensors will be placed on the USB cameras. The Raspberry Pi has its own temperature sensor. Two more sensors will be placed on the baseplate, one will be on the buck converter, and another will be placed inside the expandable structure. A reading of each of these temperature sensors will be taken once every 10 seconds before being passed to the Downlink Thread to be recorded and sent to the ground. This data will be monitored to prevent overheating of mission critical components.

Humidity Sensor One humidity sensor, located inside the base, will assist with data analysis and troubleshooting. This allows the team to determine whether humidity was the cause of an error. It takes a reading every second and passes this reading to the Downlink Thread to be recorded and sent to the ground.

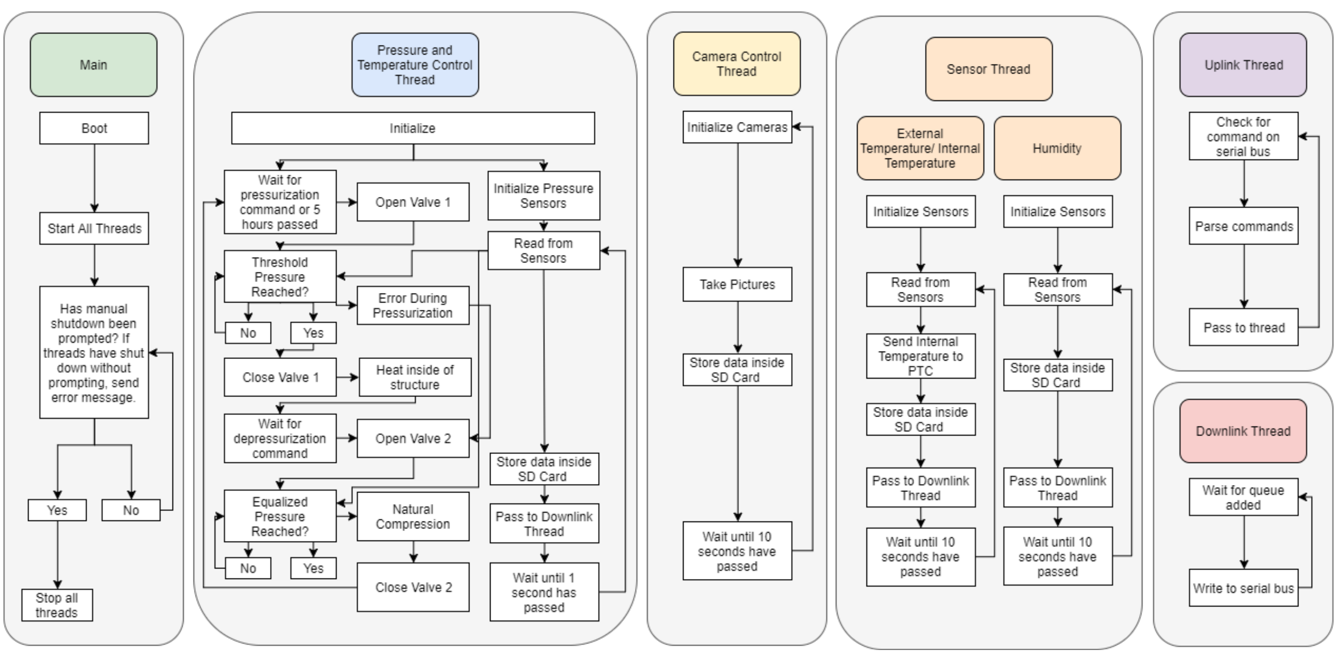
3.4.4 Downlink Thread (DNLK)

The Downlink thread manages all information that needs to be sent to the ground over the serial bus, as well as all messages to be logged. Whenever a different thread has another piece of information to be logged or downlinked, it adds it to a queue which the Downlink thread regularly reads off. Each thread has its own separate log kept by the Downlink thread for ease of analysis and debugging.

3.4.5 Uplink Thread (UPLK)

The Uplink thread acts as the counterpart to the Downlink thread; all messages sent up from the ground pass through the Uplink for handling. The thread constantly monitors the serial bus, and appends the command to its target threads command queue for handling in the thread.

3.4.6 Code Functional Block Diagram



3.4.7 Uplink Commands

The following uplink commands will provide the team with basic troubleshooting capabilities, as well as allow the team to manually downlink data as needed.

Table 4: All uplink commands with 2 byte hex and description

Payload Command	Two Byte Command	Description
Ping Pi	0xAA 0x01	Pings payload to test communication
Pressurize	0xBA 0x00	Pressurize main structure
Depressurize	0xBA 0x01	Depressurize main structure
Query Pressurize	0xBA 0x02	Returns ON if currently pressurizing. Else return OFF.
Query Depressurize	0xBA 0x03	Returns ON if currently depressurizing. Else return OFF.
Safe Mode OFF	0xBB 0x00	Does nothing if safe mode not previously activated. If safe mode previously activated, essentially resets payload to initial state.
Safe Mode ON	0xBB 0x01	Halts motor and sets all relevant flags to false.
Query Safe Mode	0xBB 0x02	Returns ON if safemode is set. Else return OFF.
Reboot Pi	0xDA 0x01	Reboots Pi

3.4.8 Preliminary Data Packet

As previously mentioned, Miura II will downlink data packets every 1 - 10 seconds, depending on which sensor the data is coming from. Each data packet will have the following general format:

`Institution Name, Project Name, Sensor Name and Number of Sensors Working, Hash Value, Time, Sensor Values`

Consider the following example:

`CU M2 HU1 <adler32 checksum> <POSIX timestamp> <sensor data>`

Read from left to right, this data packet identifies the packet as coming from the University of Colorado as part of Project Miura II, and containing one successful read from the humidity sensor. The checksum allows the team to verify that the data hasnt been corrupted. Finally, <sensor data> in this example is the current humidity as measured by the humidity sensor on Miura II.

3.4.9 Anticipated Downlink Rate

The anticipated average downlink rate of Miura II is 1000 bits per second, based on the average downlink rate of Miura I. Every ten seconds, data from the seven temperature sensors, two pressure sensors, and one humidity sensor shall be downlinked.

3.4.10 Discrete Commands and Analog Downlink

Miura II will not use discrete commands nor analog downlinks. These capabilities are not necessary for the successful execution of this mission.

3.5 Electrical Power System

Muira II shall receive 30VDC from the HASP platform, which will require the use of two buck converters to convert the provided 30VDC to 5VDC and 12VDC. The 5VDC will be used to power the USB Cameras and will have a power protection system that will not require an external monitoring system. The 12VDC will be used to power the two solenoid valves.

The Power budget for Miura II is in Table 5 and includes each component's voltage, current, and power of each major device. The total maximum power will be 10.05 W, accounting for all budgeted components operating at maximum power. The HASP platform provides 2.5A at 30VDC for a maximum of 75 W, exceeding what Miura II will require.

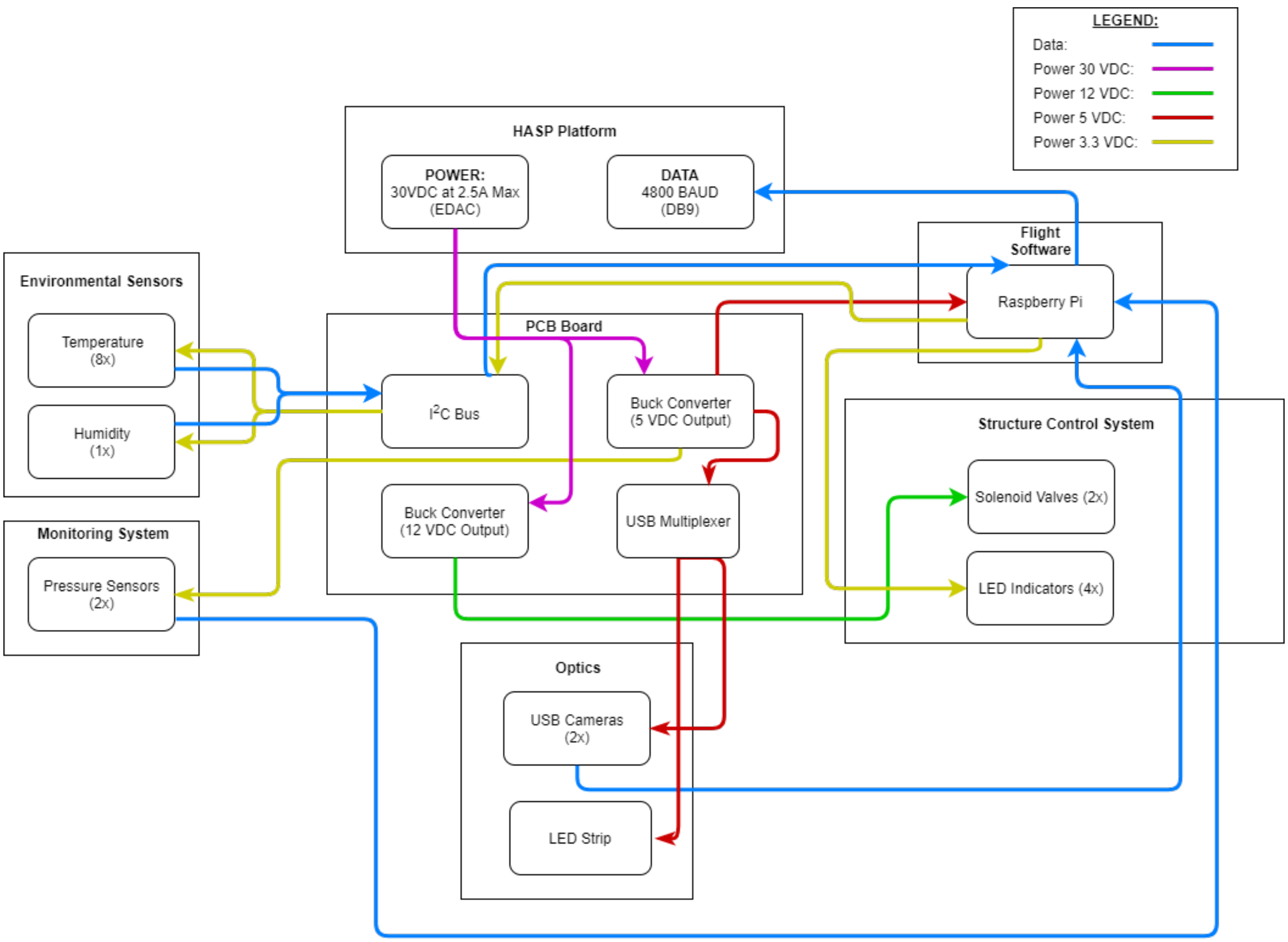


Figure 13: Electrical Power Systems

The Raspberry Pi will power the Environmental sensors and monitor their outputs. The Raspberry Pi will communicate through the I2C protocol, storing the data on the SD Card. The LED strip will be located at the top of the structure facing Miura II and will be powered through the 5VDC buck converter.

Each buck converter provides 5VDC, but each subsystem will receive its necessary voltage through voltage regulators. The USB cameras will be powered by the USB Multiplexer, and each camera will store its data in the SD card as well. Thermal dissipation of all components with high thermal energy generation will use the 6061-T6 aluminum baseplate of the payload as a heat-sink as to maintain stable operating temperatures of the EPS system. Based on the Miura I tests, no heater is necessary. However, cold tests shall still be conducted in order to ensure that all components function while under those conditions. If there is an issue, heaters will be strategically placed to heat the components and overcome the problem. The electrical components are accounted for in Table 6 and it includes their part numbers and quantity.

Table 5: All electrical components on the payload.
*Environmental Sensors consists of 8 temperature sensors, 2 pressure sensors, 1 humidity sensor

Components	**Voltage (VDC)**	**Current (A)**	**Power (W)**	**Tolerance (±W)**
Environmental Sensors*	3.30	0.025	0.0825	0.03
USB Camera	5.00	0.15	0.75	0.01
LED Strip	5.00	0.08	0.72	0.25
STC Solenoid Valves	12.0	0.25	3.00	0.05
Raspberry Pi	5.00	1.10	5.50	1.01
Total			10.05	±1.53

Table 6: Tally of electrical components and part numbers.

Part Number	**Component**	**Count**
B00XL7JSXE	Buck Converters	2
MAX4999	USB Multiplexer	1
MS563702BA03-50	Pressure Sensors	2
HIH6130	Humidity Sensor	1
MAX31820	Temperature Sensors	8
ELP-USB800W0Z6-L21	USB Cameras	2
2P025-1/8	STC Solenoid Valves	2
516-090-000-401	EDAC Connector	1
Raspberry Pi 3	Raspberry Pi	1
RS-232	DB9 Connector	1

Figure 14 shows the EDAC and DB9 connectors that will be used for flight. The EDAC will connect directly to the buck converter on the PCB, because the necessary voltage for all devices is 5VDC and under (not 30VDC). From the buck converter, the chosen wires from figure 17 will split out to connect to the rest of the devices. The pins that will be used from the EDAC are A, B, C, and D for 30V of power (connected to the buck converter), and W, T, U, and X for power ground. The DB9 pins that shall be used are pins 2 (received data), 3 (transmitted data), and 5 (signal ground).

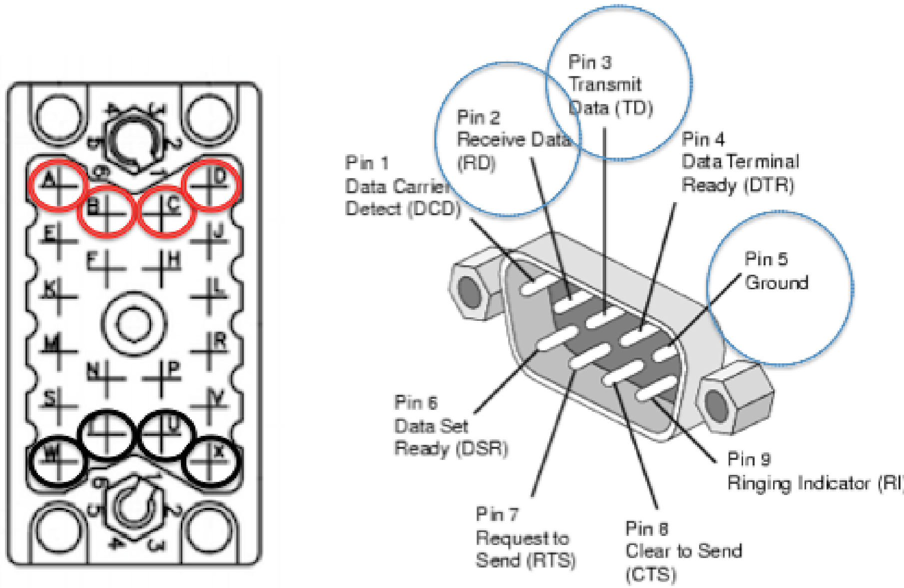


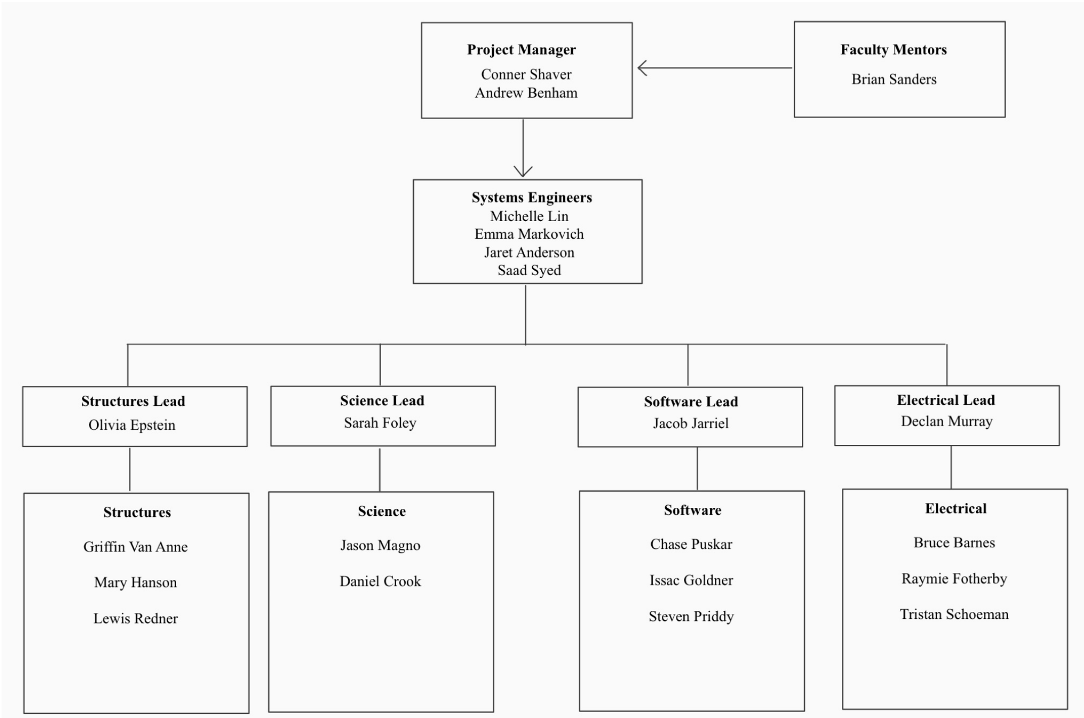
Figure 14: EDAC and DB9 Layout

3.6 Power Budget Uncertainties

The listed power, wattage, and amps are likely to fluctuate once the building process begins. Since the environmental sensors (humidity, acceleration, temperature, and pressure sensors) generate a small output, they will not account for very much fluctuation. The total wattage of the environmental sensors are expected to be significantly less than 1 watt, (0.1 Watts), and the total amps were also approximately 20mA. The tolerance section for the system shows that the wattage can range from 8.52 W to 11.58 W (tolerance of 1.53 W). These tolerances should not be a problem but the team will keep track of them during production. The future budget could change subtly due to additions or removals of components however will not surpass the limit 30VDC and 2.5A.

4 Management

4.1 Team Roles and Organization



Project Manager

The Project Manager (PM) will be responsible for obtaining project funding and maintaining the financial affairs of the team. The PM will keep track of high-level schedules, including the deadlines set forth by HASP and self-imposed deadlines. He or she will also hold weekly full team meetings lasting about an hour (described in detail later). The PM shall also hold weekly executive meetings with the teams Space Grant mentors.

The PM will be responsible for all communications with HASP, including creating monthly status reports and attending the monthly teleconference.

Systems Engineers

The systems engineers will be responsible for creating and verifying requirements, and coordinating interfaces between subteams. They will also manage system-level budgets and the Concept of Operations. Systems engineers will look for potential risks or requirement conflicts, as well as challenge the teams ideas.

Team Leads

Each of the team leads will be responsible for their own subteam, including setting high-level goals and deadlines. The team leads will work with the PM and the systems engineers to create semester expectations, then break those down into smaller tasks for their team members. Regular team working hours are expected, which will be scheduled and run by the team leader.

After each weekly full team meeting, each team lead must submit a status report discussing priorities for the week to be completed by the next meeting. These tasks shall be concrete and verifiable.

Team leads will be expected to look out for system-level risks, and raise concerns to the PM and systems engineers. While not required, team leads are encouraged to prepare a list of questions for full team discussion at weekly meetings.

All Team Members

All team members will be held accountable for their own decisions. Team members must keep documentation for parts, procedures, contacts, and key decisions. Anything not recorded in writing does not exist.

Mentors

The teams Space Grant mentors will attend weekly executive meetings with the PM to check on action items and upcoming deadlines. The mentors shall also attend all design reviews.

4.2 Meeting Formats

Weekly Full Team Meeting

During each weekly full team meeting, the PM will update the team with upcoming deadlines and the high-level schedule for the next few months. The team leads will then go over subteam updates, including successes and accomplishments, current work, help needed, system-wide decisions, and the status of action items reported last week. The meeting shall end with priorities for each subteam to focus on over the next week.

Subteam Working Hours

Subteam working hours will be 2-3 hours per week during the semester, and all team members are expected to attend. Team leads will run these meetings and focus the team on meeting semester goals.

Weekly Executive Meeting

Weekly executive meetings with the PM and Space Grant mentors will be led by the PM, who shall send the agenda the night before the meeting with appropriate links and attachments. The PM will get advice and discuss upcoming deadlines and action items. The mentors will challenge the PM to justify decisions.

4.3 Schedule Tracking

All major deadlines, team meetings, and working hours shall be stored in an online calendar and shared with the full team.

Table 7: Schedule

Milestone	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Submit Proposal	X												
Officially Form Team		X											
Submit Proposal Revisions			X										
Submit UROP Grant Request			X										
CoDR			X										
Finalize Design				X									
PDR				X									
Preliminary PSIP Due					X								
Finish Machining Plan					X								
CDR					X								
Finish Machining					X								
Finish PCB Board					X								
Fabricate Pressure system						X							
Create Expandable Structure						X							
Assemble Hard Structure						X							
Integrate all Systems							X						
PSIP Due							X						
Systems Testing							X	X					
FLOP Due								X					
Integration in Palestine									X				
Flight										X			
Data Analysis										X	X	X	
Final Science Report Due													X

4.4 Action Item Tracking

All team leads shall submit weekly action items the evening after the full team meeting. These action items should be concrete with distinct success criteria, and should be completed before the next full team meeting.

The Project Manager shall keep a spreadsheet of all submitted action items, and mark them as completed or not at each full team meeting.

5 Mass

5.1 Mass Budget

The current mass limit for any HASP large payload is 20 kilograms. In its current form, the Miura II payload has a projected mass of 15 kilograms. This is comprised of a 1.5 kilogram Kevlar expandable structure with thermal and pressure layers included, an 8 kg payload structure (including 3 kilograms of aluminum caging), 1.5 kilograms of pressure tubing, a 1 kilogram solenoid system, a 1 kilogram electronics system, and 2 kilograms of pressure vessels.

5.2 Mass Uncertainties

Table 7 shows the mass budget and uncertainty in each component on Miura II. As Miura II is still in the preliminary planning stage, these numbers are overestimates and will be calculated more accurately when a refined design has been reached.

Table 8: Mass budget

Component	**Mass (kg)**	**Uncertainty (kg)**	**Quantity**	**Combined Mass (kg)**	**Combined Uncertainty (kg)**
Baseplate	1.60	± 0.20	1	1.60	± 0.20
Wall Structure	0.80	± 0.10	1	0.80	± 0.10
Top Plate	1.40	± 0.20	1	1.40	± 0.20
Camera Mounting Surface	0.40	± 0.05	2	0.80	± 0.10
Long Band	0.20	± 0.01	2	0.40	± 0.02
Short Band	0.10	± 0.01	2	0.20	± 0.01
Insulation	0.09	± 0.02	2	0.17	± 0.03
Camera Mounts	0.25	± 0.06	1	0.25	± 0.06
Misc. Structures Hardware	0.06	± 0.01	-	0.60	± 0.01
Integration Plates	0.10	± 0.20	1	1.00	± 0.20
Payload Top Plate	0.05	± 0.01	1	0.05	± 0.01
Payload Shield	0.30	± 0.05	1	0.30	± 0.05
Payload	0.02	± 0.01	1	0.02	± 0.01
Aluminum Caging Small	0.65	± 0.10	2	1.30	± 0.20
Aluminum Caging Large	0.85	± 0.10	2	1.70	± 0.20
Pressure Tubing	1.50	± 0.10	1	1.50	± 0.10
Pressure Vessels	1.00	± 0.10	2	2.00	± 0.20
Solenoid Valves	0.40	± 0.10	2	0.80	± 0.20
EPS Components	0.10	± 0.05	1	0.10	± 0.05
Total	-	-	-	**14.99**	**± 1.95**

6 Testing

In all testing pressurization of the payload will occur. In order to assure that Miura II can successfully pressurize an independent pressure test will occur prior to all other testing to ensure that Miura II will be able to pressurize under all simulated environments.

6.1 Soft-Shell Testing

6.1.1 Pressure Test

To ensure the soft-shell structure will successfully expand in conjunction with the pressurization system, pressure tests will be conducted first to ensure that pressurization will not hinder the mechanism in any other tests. In addition, the pressurization test is vital to familiarize the team with the pressurization system to avoid mechanical errors during flight. The soft-shell system and deployment mechanism will be connected to the pressurization system. In order for the pressurization test to be considered successful, Miura II must complete successive extension-contraction cycles defined by the following criteria:

1. Expansion of the soft-shell structure to at least 5 times of its minimum volume and at least a 1.0 ± 0.1 atm difference (2.0 atm for testing in atmospheric pressure)
2. Sustention of the soft-shell structure at 5 times or higher of its minimum volume and a 1.0± 0.1 atm difference
3. Full contraction of the soft-shell structure to 1.5 times or lower of its minimum volume and a pressure difference of 0.1 atm or lower
4. Completion of the expansion-contraction cycle without tearing of the soft-shell structure
5. Completion of the expansion-contraction cycle without cracking, warping, or otherwise altering of the material
6. Any change in rigidity of the material due to pressurization shall not hinder the expansion, sustention, and contraction of the soft-shell structure
7. The mechanical system shall not experience additional mechanical resistance due to the pressurization system

6.1.2 Cold Test

To mimic the low atmospheric temperatures to which the soft structure will be subjected during its flight, a cold test will be conducted. The average temperature at 37 km is around -30 °C and the coldest temperature for the entire flight could reach down to -60 °C at the tropopause. The soft structure and deployment mechanism will be sealed in a large cooler with 2 kg of dry ice. The system will be left in the cooler for 5 hours and allowed to complete 10 cycles of extension and retraction. Dry ice is capable of reaching a surface temperature of -80 °C so this temperature will be more than sufficient for the test. In addition, the Cold Test will test for the capabilities of the thermal insulation of the payload. In order for the test to be deemed successful, Miura II must complete successive extension-contraction cycles defined by the following criteria:

1. Expansion of the soft-shell structure to at least 5 times of its minimum volume and at least a 1.0 ± 0.1 atm difference (2.0 atm for testing in atmospheric pressure)
2. Sustention of the soft-shell structure at 5 times or higher of its minimum volume and a 1.0± 0.1 atm difference
3. Full contraction of the soft-shell structure to 1.5 times or lower of its minimum volume and a pressure difference of 0.1 atm or lower
4. Completion of the expansion-contraction cycle without tearing of the soft-shell structure
5. Completion of the expansion-contraction cycle without cracking, warping, or otherwise altering of the material
6. Any change in rigidity of the material due to low temperature shall not hinder the expansion, sustention, and contraction of the soft-shell structure
7. The mechanical system shall not experience additional mechanical resistance due to the low temperatures

6.1.3 Condensation Test

To ensure the soft-shell structure will successfully expand in the case that condensation causes ice to form on the material during flight, a condensation test will be performed. The soft structure and deployment mechanism will be sprayed with water from a squirt bottle, and again be placed inside a large cooler with 2 kg of dry ice and for 5 hours to complete 10 cycles of extension and retraction. In order for the test to be deemed successful, Miura II must complete successive extension-contraction cycles defined by the following criteria:

1. Expansion of the soft-shell structure to at least 5 times of its minimum volume and at least a 1.0 ± 0.1 atm difference (2.0 atm for testing in atmospheric pressure)
2. Sustention of the soft-shell structure at 5 times or higher of its minimum volume and a 1.0± 0.1 atm difference
3. Full contraction of the soft-shell structure to 1.5 times or lower of its minimum volume and a pressure difference of 0.1 atm or lower
4. Completion of the expansion-contraction cycle without tearing of the soft-shell structure
5. Completion of the expansion-contraction cycle without cracking, warping, or otherwise altering of the material
6. Any change in rigidity of the material due to the freezing of condensation shall not hinder the expansion, sustention, and contraction of the soft-shell structure
7. The mechanical system shall not experience additional mechanical resistance due to the freezing of condensation

6.1.4 Bell Jar Vacuum Chamber Test

To ensure the soft-shell structure will operate properly in a zero pressure environment, the system will be subjected to a pressure test in the Space Grant Bell Jar Vacuum chamber. The purpose of this test is to ensure the structural integrity of the system and proper behavior of the material under pressurization in a vacuum. The soft-shell structure and deployment mechanism will be subjected to zero pressure for 5 hours and allowed 10 cycles of extension and retraction. In order for the test to be deemed successful, Miura II must complete successive extension-contraction cycles defined by the following criteria:

1. Expansion of the soft-shell structure to at least 5 times of its minimum volume and at least a 1.0 ± 0.1 atm difference (2.0 atm for testing in atmospheric pressure)
2. Sustention of the soft-shell structure at 5 times or higher of its minimum volume and a 1.0± 0.1 atm difference
3. Full contraction of the soft-shell structure to 1.5 times or lower of its minimum volume and a pressure difference of 0.1 atm or lower
4. Completion of the expansion-contraction cycle without tearing of the soft-shell structure
5. Completion of the expansion-contraction cycle without cracking, warping, or otherwise altering of the material
6. The mechanical system shall not hinder the expansion, sustention, and contraction of the soft-shell structure when operating in a vacuum
7. The geometry of the folding design shall not be deformed, or altered in any way during or after operating in a vacuum

6.2 Systems Testing

6.2.1 Day in the Life Test

To ensure the payload's subsystems all function independently as well as function as a whole system, the payload will be tested extensively for 24 hours to simulate the longest duration of a flight on the High Altitude Student Platform. The continuous running of the payload will test the consistency and reliability of the system and each of its subsystems. The test will also demonstrate the compatibility of each of the subsystems with each other. In order for the test to be deemed successful, Miura II must fulfill each of the following criteria during the test:

1. Expansion of the soft-shell structure to at least 5 times of its minimum volume and at least a 1.0 ± 0.1 atm difference (2.0 atm for testing in atmospheric pressure)
2. Sustention of the soft-shell structure at 5 times or higher of its minimum volume and a 1.0± 0.1 atm difference
3. Full contraction of the soft-shell structure to 1.5 times or lower of its minimum volume and a pressure difference of 0.1 atm or lower.
4. Completion of the expansion-contraction cycle without inversion of the folds
5. Completion of the expansion-contraction cycle without tearing of the soft-shell structure
6. Completion of the expansion-contraction cycle without cracking, warping, or otherwise altering the material
7. The mechanical system shall not hinder the expansion, sustention, and contraction of the soft-shell structure
8. All components receive the correct voltage and remain powered for the entire duration of the test
9. Camera batteries shall last the entire duration of the test
10. SD cards in cameras shall be able to store the video for the entire duration of the flight
11. The cameras shall capture each extension, sustention, and contraction of the soft-shell structure
12. All sensors store accurate data to the SD cards
13. The code shall execute as designed
14. The payload downlinks data accurately through the downlink thread
15. Commands are sent and executed properly through the uplink thread

7 Integration and Launch Procedures

7.1 Integration

For integration with the HASP platform, team leads, systems engineers, and the project manager shall ensure proper the integration procedure is followed. A comprehensive checklist shall be used to confirm a successful integration of the Miura II payload. The systems engineers shall test all communication processes and equipment throughout integration to assure proper function. The following is the integration plan Miura II will follow at the Columbia Scientific Balloon Facility in Palestine, TX. In order to make sure that the pressure canister remains in tack and arrives at the facility safely the canister will be shipped via a ground shipping company with all of the proper paperwork and safety precautions.

1. Arrive with payload assembled but pressurization system disconnected
2. Ship the pressurization system to Integration and Testing location via ground shipping
3. Confirm that all components are intact after transportation
4. Test payload to ensure proper functionality
   (a) Connect pressure reservoir
   (b) Power on and let run through start-up

   (c) Confirm that the pressurization cycle is functional
   (d) Confirm that downlink is functional
   (e) Check SD cards for successful video capture

5. Deliver payload to HASP directors
   (a) Weigh payload to confirm it is under weight restrictions
   (b) Attach payload to test stand and power on
   (c) Ensure payload is powered on and is downlinking data
   (d) Deliver payload to be integrated to the platform
   (e) Ensure payload powers on and downlinks data from the platform

6. Run thermal vacuum tests
   (a) Begin pressurization cycles
   (b) Confirm that all downlinked data is seen in data logs
   (c) Analyze test data to verify payload is functioning as expected
   (d) Uplink relevant commands to payload to verify all systems are working as intended
   (e) Confirm that all downlinked data is seen in data logs

7.2 Launch Procedures

Miura II will send at least four team members to New Mexico with the payload. All members who wish to be present for launch will go. Referring to the experiences of the Miura I team and the HELIOS teams, the Miura II team has concluded that it is not necessary to stay in New Mexico for the entire duration of flight, as a monitoring system from Colorado has proved adequate, but members who wish to remain present may stay. To prevent accidents during shipping from derailing the mission, the Miura II team will send representatives to ensure that the structure arrives without any damage and to complete the integration.

The following table is an approximation of the launch procedure of the Miura II team constructed from information in the CFP as well as the Miura I and Helios V proposals. The leftmost column is an estimate for when the task would be carried out. The rows associated with each time slot are flight events and system directives. The Project Manager will be responsible for ensuring that all of the flight procedures will be properly followed and completed. The team leads of each subsystem shall be responsible for ensuring that their respective subsystems successfully undergo integration onto the HASP. During the flight the software lead will be responsible for controlling all discrete commands to the Miura II payload on the HASP.

Time	Task	Instructions	Indication of Completion
Upon Arrival	Ensure all parts of structure have arrived without damage.	Inspect for damage or irregularities in the hard and soft-shell structures.	Visual inspection confirming all components are in place and without cracks, dents, tears, or other damage.
Upon Arrival	Ensure that proper connections are made between all components.	Check for leaks in pressure seals and ensure all moving components are connected to the microprocessor.	Visual confirmation that wires are secure and proper connections are in place.
Upon Arrival	Ensure all cameras are ready for flight.	Confirm that cameras are securely attached to structure and connected to proper power supply.	Micro SD cards confirmed to gather data from cameras and have been securely inserted back into cameras.
Upon Arrival	Uplink and sensor check.	Power on structure, run uplink commands, confirm accurate sensor functionality.	Acknowledgement given by mock ground control.
Upon Arrival	System check	Send command to pressurize soft-shell structure.	Visual confirmation of pressurization, soft-shell must stay pressurized with no leaks.
Following Integration	Ensure successful integration.	Structurally and electrically attach payload to platform, confirm power on and downlinking.	Physical check of payload security and visual confirmation of powering on when instructed.
T = 0 hours	Launch payload is powered on.	Ensure data downlink is active.	Confirm data being received by ground control.
T = 1 hours	Verify command uplink.	Send ping to payload.	Ensure acknowledgement is in downlinked data.
T = 2 hours	Begin observation.	Verify tracking and data downlink is behaving correctly. If not, send commands or toggle power on the payload to compensate.	Ensure that data is being received.
T = 2 hours	Expansion cycles start.	Uplink command to begin cycles.	Cycle data verified to be in downlink.
T = 4 hours	Backup cycles start.	Hard-coded cycle start starts expansion cycle if uplink fails.	Cycle data verified to be in downlink.

Table 9: Approximate Launch Procedure

8 Special Request

Since Miura II hinges on the use of a hazard, a pressure vessel, the team is prepared to take rigorous safety precautions to counteract pertinent risks associated with pressurization. Pressurization is an essential mechanic for carrying out the mission. The payload must start in a space-efficient collapsed state, expand to a fully extended state, and collapse back to the original state using a pressurized gas, so without this hazard the method of deployment of the soft-shelled structure would be lost. Additionally, without this method of deployment the interior of the structure would not remain at a habitable pressure while expanded which is another critical objective of the mission.

With HASPs permission to include this hazard on the payload, the team shall take the following precautions to ensure that the payload does not become a danger:

1. A safety valve or similar mechanism will be installed in the soft-shelled structure and pressurization mechanisms to prevent over-pressurization in the N_2 canister or soft-shelled structure.

2. A mesh cage or similar structure will be installed around the soft-shelled structure to catch any shrapnel in the case of a rupture.

3. A sturdy aluminum structure will surround the N_2 canister to catch shrapnel.

4. All pressurization components will be securely attached to the structure to ensure that components are not ejected from the payload in case of a rupture.

In order to assure that the N_2 canister that Miura II will employ can withstand the temperatures and pressures at 36 kilometers a datasheet, [4], has been provided that details information on the strength of the canisters. The third reference is also to a website that sells the canisters that Miura II will use to pressurize the payload. Overall the canisters that Miura II will use can withstand 7,680 psi before bursting while containing an internal pressure of only 3,000 psi[3][4]. These numbers are at sea level, 14.7 psi, which means that at an altitude of 36 kilometers with an atmospheric pressure of 509.14 Pa [5], or 0.07384 psi, there will exist a pressure gradient of an extra 15 psi in the tank which will not be present on the ground. This added pressure of 15 psi is not nearly enough to make the canister rupture. The temperature difference the canisters are rated to is a maximum temperature of $120°F$. Since the temperature at float is roughly $-5°F$ the operating temperature for the canisters are not in question either [4]. The information provided in the References section coupled with an aluminum mesh surrounding the payload and solid aluminum housing around the canisters are adequate protection to prevent damage in a depressurization event.

9 Conclusion

To aid the development and research of expandable structures, the Miura II project will test a pressurized folding system to allow for a small module to be deployed and contracted repeatedly. In order to prove the habitability of the collapsible structure, Miura II will use a controlled pressurization system to extend and contract a thermally insulated, soft-shell structure in the harsh environment of near-space. Miura II will monitor the soft-shell structure to provide data to characterize its expansion and contraction as well as the internal conditions pertaining to habitability. A successful demonstration of the ability to refold a structure after deployment will contribute to advances in compact, reusable, habitable space modules. As it contains a hazard, Miura II will put a strong emphasis on safety. If selected to be part of HASP, Miura II will occupy a large payload spot and will meet all the requirements set by "HASP Call for Payloads 2018."

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