HASP Student Payload Application for 2011

Payload Title: SMITH (Sampling Microbes In The High atmosphere)		
Payload Class: (check one) ☐ Small ☑ Large	Institution: Louisiana State University A&M	Submit Date: 12/17/2010

The goal of the SMITH payload is to sample for biological particles in the stratosphere. These samples will enable us to determine the concentration of cells and the viable fraction. The SMITH payload will also characterize the environmental conditions microbes will be facing in the stratosphere. Here we propose to develop and test an atmospheric sampling payload that may provide basis for future studies for sampling in the atmospheres of other planets. The data obtained from each environmental sensor, along with the sampling result, will allow the team to draw convincing hypotheses on life on Mars. The SMITH team is led by Noelle Bryan, under the guidance of Dr. B. Christner, P.I, and Dr. T.G. Guzik, Faculty Advisor. The team members include A. Bordelon, R. Singh, C. Toguem, and J. Zhou. To interface with HASP, there will be 3 components mounted below a standard large HASP payload interface plate with a total of 10 bolts. Temperature, pressure, humidity, ultraviolet radiation and ozone will be measured during the flight. The components require 14 watts with the maximum current drawn by a single component to be 0.3 amps. HASP requires a RS-232 serial connection to downlink data and uplink commands.

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1.0 MISSION DESCRIPTION

1.1 Mission Goal

The overall mission goal of SMITH is to sample for biological matter in order to investigate whether or not microorganisms are present in the stratosphere and to return those samples uncontaminated to the lab for further enumeration and to determine the viable fraction.

1.2 Science Questions

- Is biological matter present in the stratosphere?
- If biological matter is present in the stratosphere, what is the biological concentration of the sampled volume?
- Is any of the biological matter viable?
- If so, what percentage of the biological matter found is viable?
- What are the extreme environmental conditions which viable organisms would encounter in the stratosphere?

1.3 Science Objectives

- Obtain a detectable sample of biological matter from a target region in the stratosphere
- Determine the amount and characteristics of contamination that the system will incur from the time that the system leaves the clean room to the time that it returns to the lab for analysis
- Determine the concentration of biological matter collected from the stratosphere
- Determine the viability of the biological matter collected from the stratosphere
- Determine the diversity of the biological matter collected from the stratosphere
- Determine the environmental conditions in the stratosphere

1.4 Science Background and Requirements

1.4.1 Science Background

In recent years, microorganisms have been shown to survive and thrive in environments previously thought uninhabitable. Bacteria have been widely documented in the troposphere and cloud droplets contain adequate organic carbon and nutrients to support growth (e.g., Sattler et al. 2001). Initial attempts at biological sampling of the stratosphere used high altitude balloons and meteorological rockets, and bacteria and fungi at altitudes as high as 20 km were first reported over 80 years ago (Rogers et al. 1936). Although the existing body of work on life in the upper atmosphere is impressive and pioneering, it is also very limited and technically primitive. The SMITH project will be the first attempt to systematically determine the quantity of cells in the stratosphere.

Sampling in the stratosphere will provide information on organisms' ability to survive extreme environments. Environmental conditions (pressure, temperature, and radiation levels) at an altitude of ~100,000 ft. are similar to the conditions on the surface of Mars (Table 1). Finding viable organisms in the stratosphere will provide insight to the possibility of life beyond Earth. Here we propose to develop and test an atmospheric sampling payload that may provide basis for future studies for sampling in the atmosphere of Mars.

Table 1: Cellular Stresses ***If background radiation levels are sufficiently high and ice entrapped population is ancient.***

	Atacama Soil	*Glacial Ice*	*Stratosphere*	*Mars*
Desiccation	Yes	Yes	Yes	Yes
Freezing	No	Yes	Yes	Yes
UV radiation	No	Yes	Yes	Yes
Ionizing Radiation	No	Maybe*	Yes	Yes

During the past year, low cost sounding balloon payloads (HABITAT) tested sampling at altitudes of 10,000 to 30,000 ft. where concentrations of cells per volume have been previously documented. The purpose of HABITAT was to compare the numbers of organisms collected with the existing data. The payloads used silicon grease coated sampling rods to collect microorganisms during the flight. These rods and the impaction method are commonly used to collect airborne particles for microscopic analysis (e.g. pollen counts). Since we anticipate that the concentrations of cells will be very low at high altitudes, minimizing contamination was critical (Figure 1).

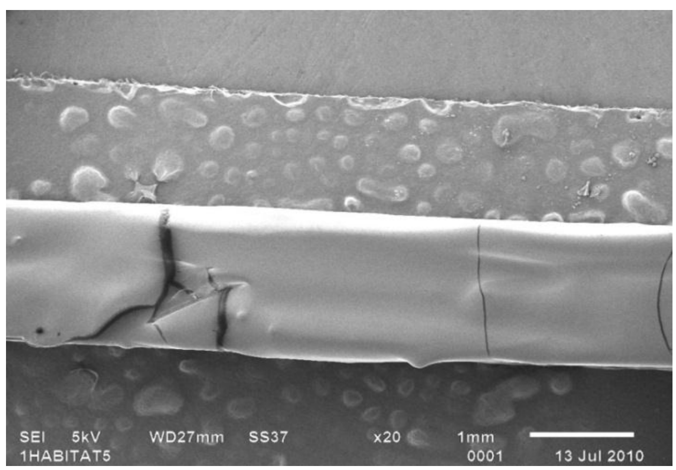

Figure 1: Lab Rod after Cleaning

Using a combination of ultraviolet irradiation, ethanol, sodium hypochlorite, and ethylene oxide, the background level of microbial contamination associated with balloon payload preparation was consistently under 100 cells/ rod, or 1.57 x 10^6 DNA-containing cells/m^2 (i.e. 50 ± 30 cells per sample rod). The payload was then stored in a sterile bag for housing until flight. During ascent (1000 ft/min) at the target altitude of 10,000 ft, the HABITAT doors opened, allowing the collection of organisms through a specific column of air. The doors closed at ~30,000 ft. to end sampling. The rods were returned to the lab and analysis began within 24 hours. Each experiment or assay was completed in triplicate. The rods were analyzed for direct enumeration, counting viable fractions, metabolic activity, culturing, and scanning electron microscopy. These methods allowed us to calculate a number of cells for a given volume sampled.

The HABITAT missions have taught us many important lessons. Payload protocols have been developed for decontamination, handling and transportation, launch, recovery and analysis. SMITH will prove to be the next-generation of instruments for biological sampling of the troposphere and stratosphere. A key capability of our technological approach is the ability to sample large volumes (~60,000 L). With the increased volume sampling capabilities which HASP affords, SMITH will return samples to the lab and establish a concentration of cells per volume sampled.

1.4.2 Science Requirements

The SMITH payload will sample at a target altitude of approximately 120,000 ft in the stratosphere to collect biological particles. The altitude of the payload shall be known during flight, and status of the payload operation will be relayed to the ground station.

Background contamination is a critical factor in determining if the experimental sample is truly from the stratosphere. In order to determine a detectable signal, the payload shall sample one order of magnitude above lab control measurements (~100 cells/rod). To reduce background levels of contamination, treatments of 20 minutes of germicidal UVC at 20 mW/cm^2, 20% sodium hypochlorite, and 70% ethanol solution and ethylene oxide sterilization will be applied to all samples. The chambers of the SMITH payload will remain sealed until the target altitude is reached to prevent further contamination during flight.

Several methods will be employed during post flight analysis to determine the concentration of cells in the stratosphere. Nucleic acid stains and epiflourescence microscopy will be used for direct enumeration of cells and to determine the viable fraction of cells. Metabolic assays will measure the amount of cellular respiration. In order to establish a level of background contamination, these tests will also be performed on the flight control and lab control. As stated previously, three rods from each chamber (sample, flight control, and lab) will be used for each test.

These three identical sets of rods will be monitored simultaneously. The lab control will remain sealed after sterilization until processing. The flight control will be attached to the payload but will remain closed and not actively sample the atmosphere. The flight control and the lab control will be identical to the sample bay. The sample bay will remain closed until at target altitude and then open to actively sample in the stratosphere. After collection, the flight control and sample bays will be sealed in sterile pouches. All rods will begin processing within 24 hours of recovery.

1.5 Technical Background and Requirements

The following technical requirements reflect the previously defined science objectives. Certain parameters must be defined and measured to achieve statistical data that satisfies the science objectives. In order to collect a sufficient number of cells, based on background contamination, the payload is required to sample a minimum of 1000 cells per rod per flight. The capture system shall be at least 10% efficient and the volume sampled will be known for the flight. The volume flow must be uniformly distributed throughout the sampling chamber to ensure all parts of the sampling system are evenly exposed. The payload shall survive all cleaning, atmospheric, and landing conditions. At least 20 rods are needed per chamber for multiple lab tests post flight.

To characterize the environment of any biological matter collected, several background parameters must be measured. These parameters include: temperature, pressure, humidity, ultraviolet radiation A, B, C, and ozone. These parameters in the stratosphere are similar to the conditions on the surface of Mars. During the flight, the payload will encounter temperatures ranging from -70 °C to 30 °C. The pressure encountered during the flight will range from 0 mbar to 1000 mbar, with the pressure at float being ~3 mb. We expect the water concentration at altitude to be extremely low due to low pressure. Measuring ultraviolet radiation will provide insight to the viability of any microorganisms in the stratosphere.

- Measure temperature in the range of -70 °C to 30°C, to a resolution of 1°C and at a rate of once per minute
- Measure pressure in the range of 0 to 1000 mbar, to a resolution of 5 mbar and at a rate of once per minute
- Measure relative humidity in the range of 0 to 100% to a resolution of 5% and at a rate of once per minute
- Measure UVA fluence in the range of 0 to 40 W/m^2, to a resolution of $1W/m^2$ and at a rate of once per minute.
- Measure UVB fluence in the range of 0 to 10 W/m^2 to a resolution of $1W/m^2$ and at a rate of once per minute.
- Measure UVC fluence the range of 0 to 5 W/m^2 to a resolution of $1W/m^2$ and at a rate of once per minute.
- Measure Ozone from 0 to 10 ppm to a resolution of 0.01 ppm and at a rate of once per minute.

Southern University will be responsible for fabrication and testing of the environmental subsystem. All measurements must follow the technical requirements set for the SMITH project. Integration of the sensor subsystem will occur under the collaboration of both the SMITH and SU teams. The SU team will work under the guidance of Dr. Larry Henry, Department of Physics. As both teams are located in Baton Rouge, LA, collaboration will occur on a frequent basis.

2.0 PAYLOAD DESIGN AND OPERATION

2.1 Principle of Operation

The main purpose of this payload is to take biological samples at a range of altitudes in the mid stratosphere. Since HASP will float at 120,000 ft, this will be the targeted altitude for this flight. The payload will consist of a sample chamber and a flight control chamber. The flight control chamber measures the background contamination throughout the flight without actively sampling. The sample chamber actively samples at the target altitude. Both chambers will be physically identical, but the flight control chamber will remained sealed. In the event the sample chamber fails to operate during flight it will be possible to use the flight control chamber to actively sample as the sample chamber. Since we would lose our flight control, this will be done only as a last resort.

Before flight, both chambers will be sterilized and sealed. They will remain in this state until HASP reaches float. At this point two commands will be sent to the payload to enable the sample chamber heaters. This will ensure the motors are in operational temperature range before use. Once at float, a command will be sent to begin sampling. This command opens the sample bay and begins the sampling procedure. Confirmation of a successful opening will be relayed to the ground station, at which point a command will be sent to disable the door heater. The reel heater will remain enabled to maintain the motor's temperature. Data on all sensors, including door and sampling status, will be relayed to the ground station throughout the flight.

Shortly before cut down, the door heater will be enabled to ensure it is in operational range before use. A command to stop sampling will then be uplinked to the payload. This will fully reel in the sampler and close the door, sealing the bay again. Once confirmation of a successful closing is received, a command will be uplinked to disable all heaters. The payload will then remain in this state until recovered. If for some reason the sample bay fails, commands can be relayed to the flight control bay that follow the same procedure as stated above.

The sampling device requires a minimum of 1000 L of atmosphere to pass across each rod during the entire flight. Since SMITH will be at float during active sampling, a volume needs to be passed across the sampling device. Two systems were analyzed to produce flow: pump and yo-yo. A trade off study was done between the two to determine which was best for our needs. The yo-yo system uses a rod chamber suspended below the payload. The rod chamber is lowered and reeled back up repeatedly throughout the flight to provide the necessary flow. The volume sampled is calculated by the horizontal cross-sectional area multiplied by the vertical distance traveled in a single up or down cycle.. In contrast, the pump is contained within the chamber and produces flow over the rods. The flow of this system is determined by the pump's flow rate.

A requirement states that the sample set shall contain a minimum of twenty rods. We will use thirty rods to account for additional analysis purposes. Since each rod can only sample in one direction, and the rod chamber will travel in two directions while sampling, sixty rods total will be used per rod chamber. Of these sixty rods, thirty will be sampling on the way up and the other thirty will sample on the way down.

A requirement was set that the sampling chamber must be at least 10% efficient. Each chamber will contain 60 sampling rods. Therefore $\frac{1000cells}{rod} * \frac{60rods}{10\%} = 600\text{k cells}$ are required to pass through the chamber.

With the assumption that there are $10^4 \frac{cells}{m^3}$, we will need to sample a volume of $60\ m^3$. With a chamber size of $4\ x\ 4\ in$, the area is $16\ in^2$ or $0.0103\ m^2$. The required travel distance is $\frac{60\ m^3}{0.01032256\ m^2} = 5812.5\ m$. Since only one directional sampling will occur per rod, the distance traveled doubles, for a total of $11625\ m$.

For a minimum 12 hour flight, $\frac{11625m}{720\ min} = 16.14 \frac{m}{min} = 0.269 \frac{m}{sec}$ vertical travel speed must be achieved in order to create a sufficient amount of flow. Assuming a 1 in diameter reel, the circumference of the reel will be $2* \pi * 0.5 = 3.14 \frac{in}{rotations} = 0.08 \frac{m}{rotation}$. Therefore, the reel shall spin at a minimum of $\frac{\left(0.269\frac{m}{sec}\right)}{0.08\frac{m}{rotation}} = 3.36\ rps = 201.8\ rpm$.

Alternatively, a pump can be used and would not require suspending SMITH below the platform. The pump will be contained inside the payload. For the same amount of volume to be sampled in 12 hours, a diaphragm pump can be used that provides flow of $\frac{30{,}000\ liters}{720\ min} = 41.67 \frac{liters}{min}$. There are several diaphragm pumps available on the market that can achieve this goal. One reviewed pump is a Thomas 6000 linear series pump. It provides $42.5\ liters/min$ of airflow. It requires 3A at 12 V_{DC}, consuming 36 W of power. The weight of this pump is 3.3 lb. Both the power and weight criteria are within the HASP specifications.

Table 2: Yo-yo vs. Diaphragm Pump

Categories	**Yo-yo**	**Diaphragm Pump**
Sample Volume	90K liters	47K liters
Command Lines	2	1
Minimum Doors	1	2
Sampling Direction	2	1
Weight	< 1 lb	3.3 lb
Price	\$ 11.95 + reel	\$ 275.00
Power Requirement	8 W	36 W

Table 2 compares various parameters between the yo-yo and diaphragm pump. Though both can achieve the required volume sampled, the yo-yo system consumes less power and weighs less. Although it is more complex, we can achieve a greater sampling volume with the yo-yo system. Due to these reasons, the yo-yo mechanism is the current design plan.

By selecting the yo-yo, we require access below the HASP mounting plate. A small payload has access below the platform. Due to the size and weight of two chambers, we require a large payload to meet the SMITH requirements. The standard large payload mounting plate does not allow access below the interface plate. Because of these restrictions we have an additional requirement of a large payload mounted in a position with access below the interface plate. This must be in such a way that there is a clear view below with no obstructions from any of HASP's components. Figure 2 describes how the device is proposed to be mounted on the CSBF mini-SIP frame.

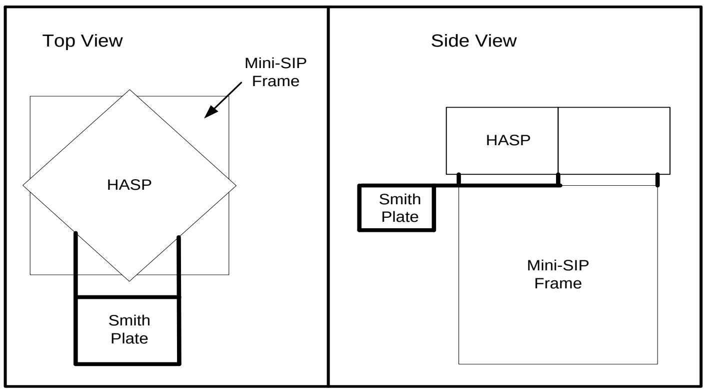

Figure 2: Mounting to CSBF mini-SIP Frame

2.2 System Design

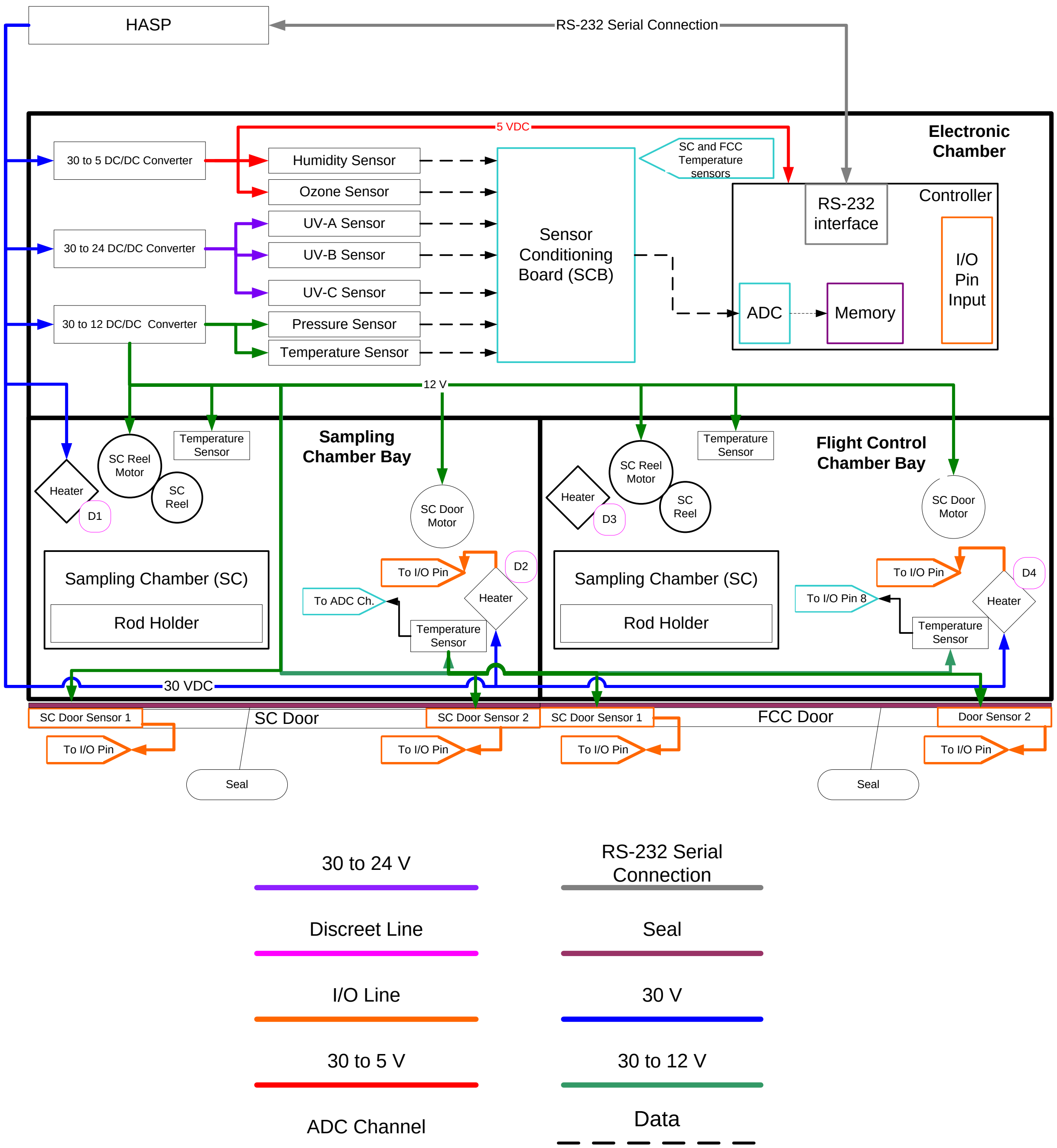

Figure 3: Subsystem Design

Figure 3 shows the system schematic of the payload. There are three main sections of the payload: electronic chamber, sample chamber bay, and flight control chamber bay. The electronic chamber consists of stepping down of the 30 V_{DC} to 5, 12, and 24 V_{DC}. It also consists of the environmental sensors, their conditioning, conversion from analog to digital, and storing of the values in the memory storage device. The memory storage device, along with ADC, and I/O lines are located on the controller. The controller will have serial interface with HASP, which allows two-way communication between the controller and HASP. The two bays house chambers with the rods. The chamber in the sample chamber bay will be reeled in and out to actively sample. There are temperature sensors to monitor all 4 motor temperatures. In case the temperature of the motors fall below the operating range, the heaters will turn on to warm them. The heaters are controlled through the I/0 pins and discreet lines for back up. The door sensors provide the door status throughout the flight.

3.0 SUBSYSTEMS

3.1 Mechanical

The SMITH payload must satisfy several requirements set forth by HASP. These include restricting the payload to a mass of 20 kg (44 lbs), a 30 x 38 cm (11.8 x 15 in) footprint with a height of 30 cm (11.8 in), and must withstand the landing impact.

There are three major mechanical subsystems that compose SMITH: the flight control bay, the sample bay, and the electronics chamber. These are shown in Figure 4. The bays must be independently removable, therefore all three of the major mechanical component will attach to the interface plate separately. Once attached to the interface plate, the payload will have an 11 x 14 in footprint and be 8 in tall.

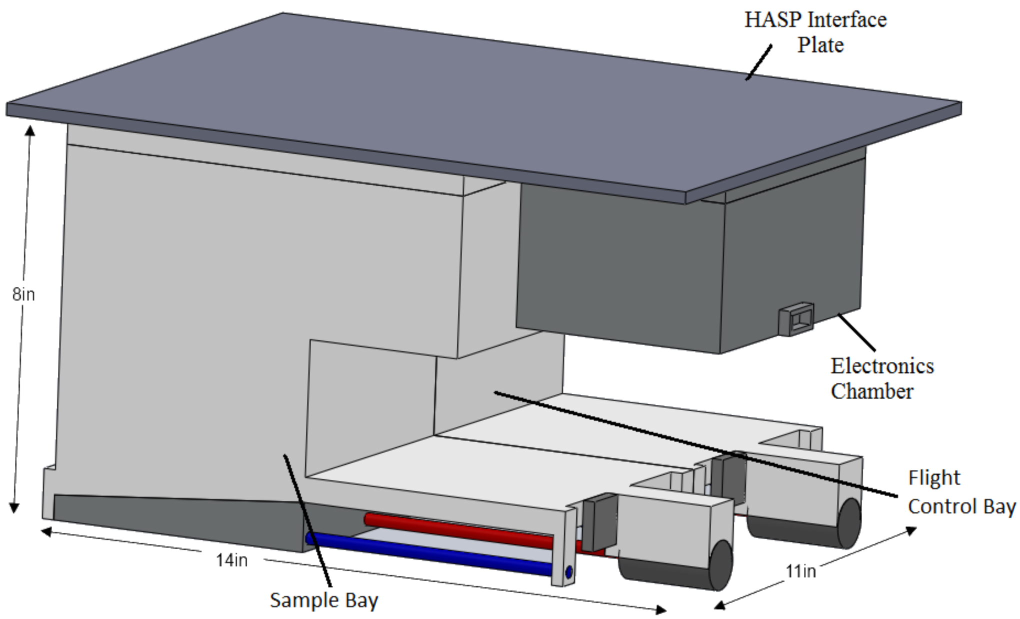

Figure 4: Full Mechanical System

To meet SMITH's science objective of sampling a specified volume of atmosphere, we developed a biological sampling chamber that will contain sampling rods sealed from the outside environment. These rods are unsealed during flight and suspended from two lines fed into a reel. These lines allow the rod chamber to descend a certain distance before being reeled back in. This is repeated over the course of the flight to reach the target sampling volume.

Both the sample bay and the flight control bay are physically identical in every way. The functional difference is the flight control bay will remained sealed from the time it leaves the lab to the time it returns. The bays must be independently removable and remain sealed. Each chamber fits within a 5.5 x 14 x 8 in cube and will be made from PVC. They are each mounted below the interface plate by three brackets. As seen in Figure 5, a door on the bottom of each bay will slide on two guide rails. The door is opened and closed by a screw that is turned by a motor. The motor will have a temperature sensor and heater attached for temperature control purposes.

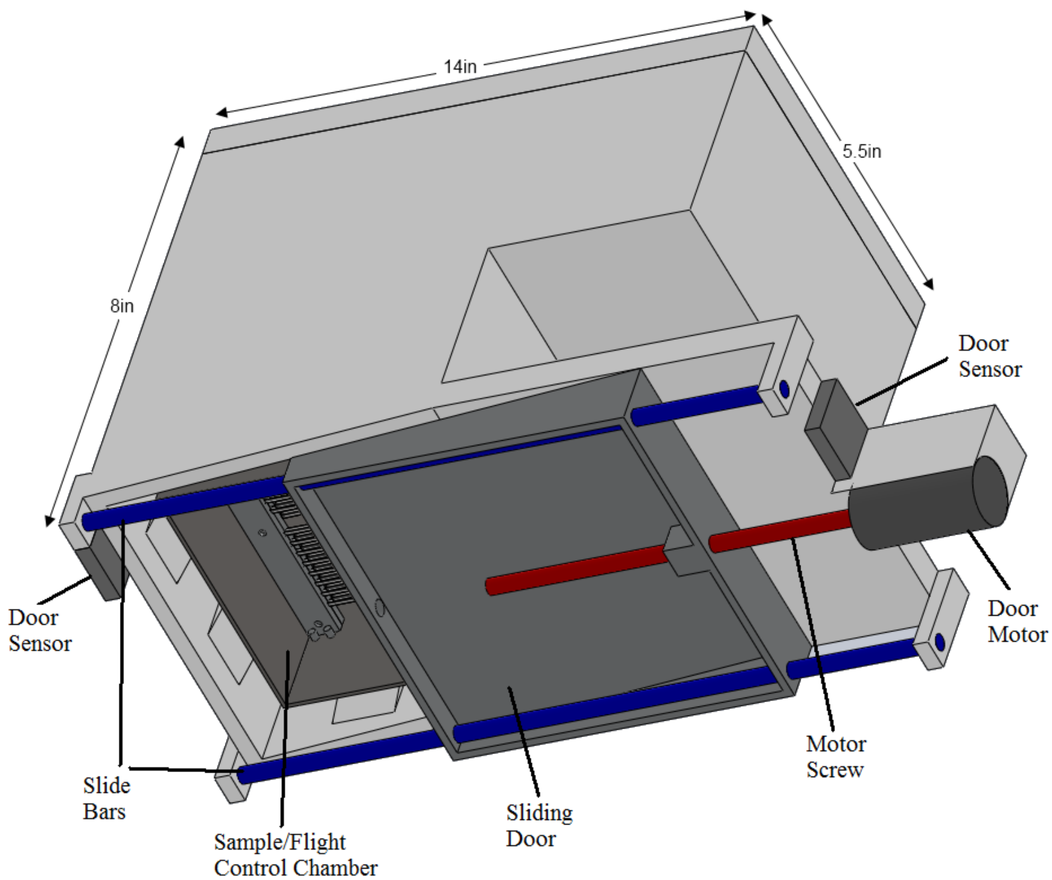

Figure 5: Single Bay Bottom View

The Montana dust collection group has used this corkscrew method before to produce a linear motion. As in our design, they used a motor and screw to slide a component on two guide rails. The Montana group moved a bar that was linked to two hinged doors, rather than directly sliding a single door. We will consult Dr. Berk Knighton on how they accomplished their design, as well as any possible issues that may arise.

The face of the door has a 5 degree slope that matches the face of the bay. The slope is designed to prevent drag across the seal and to allow the two faces to touch when completely closed. Each door will have a limit switch to be triggered when the door is completely open or closed. The top of each chamber will be removable for assembly and maintenance purposes, but will be sealed by screws before flight.

Contained within each bay is a smaller aluminum chamber that holds 60 sampling rods (Figure 6). Each chamber has an inner dimension of 4 x 4 in with a height of 3 in and constructed of 1/16 in aluminum. The rods are held in place by four 4 x 0.5 in aluminum brackets that hold 15 rods each. It is opened at the top and bottom to allow airflow and is suspended on either side by a line. As seen in Figure 7, these two lines will connect to the top of the chamber. The lines are then directed through several eyelets before being brought together and wound on a single reel. For safety purposes, any single line can suspend the payload in case the other fails.

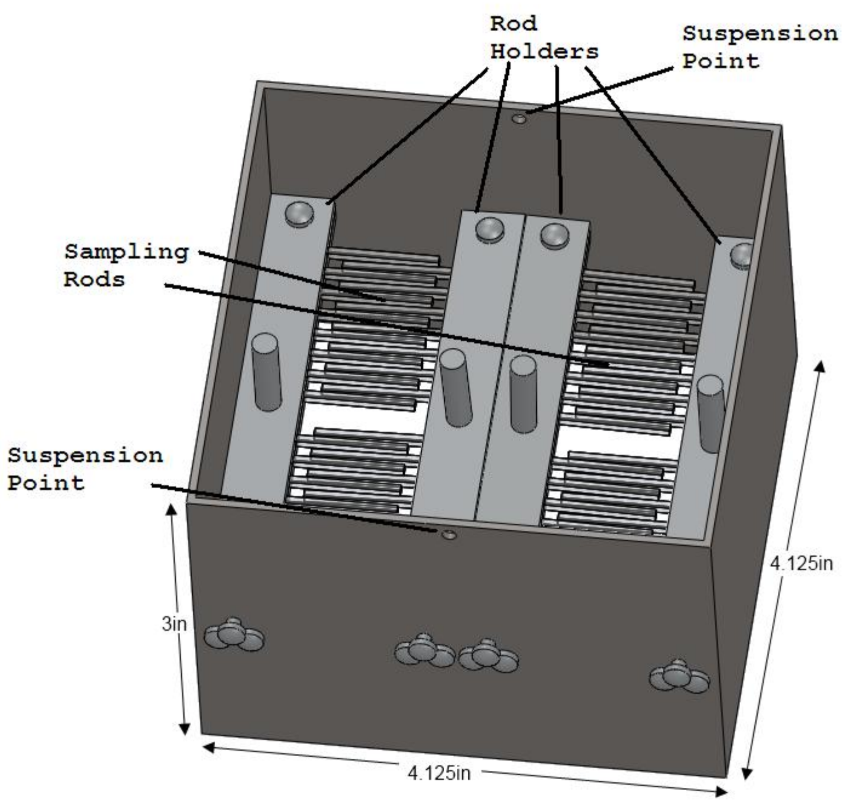

Figure 6: Sample/Flight Control Chamber

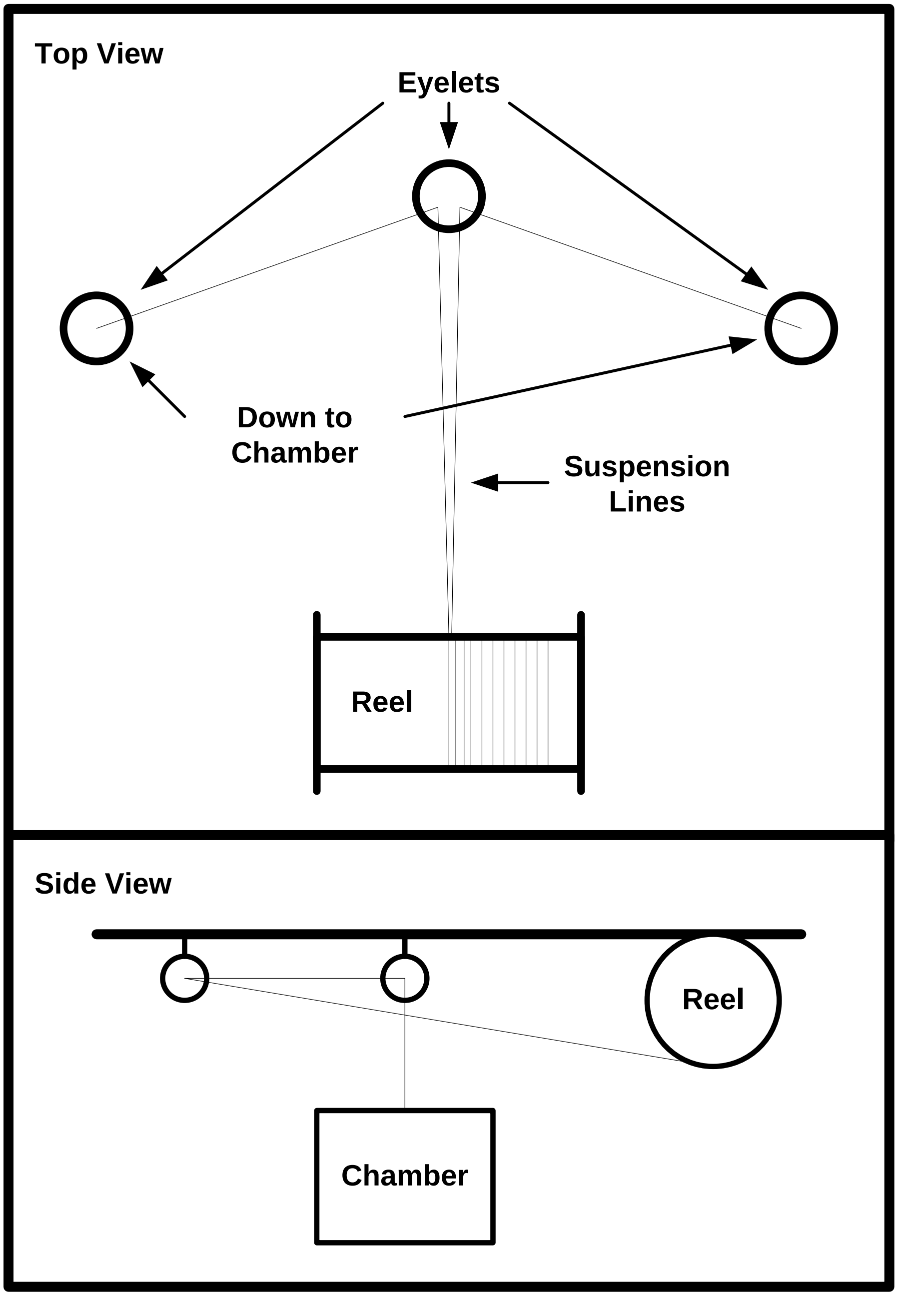

Figure 7: Reel Configuration

This reel will be an open face reel, similar to the one in the Figure 8. The crank will be removed and interfaced directly to a motor and a rotation sensor. The rotation sensor will allow the payload to know the location of the smaller chamber during sampling and will be used for control purposes. Extensive testing will be done to ensure the rotation sensor will not fail. If the rotation sensor is not sufficient to determine when the rod chamber is completely stored an alternate method such as a trigger will be used. To ensure the rod chamber remains attached, it will be completely secured so that when fully unwound, the line will not slip off.

The reel, motor, and rotation sensors will be housed at the top of the chamber as shown in Figure 8. The motor will also have a temperature sensor and heater attached for thermal control purposes.

Also shown in Figure 9, the guide slopes hold the rod chamber in place to prevent horizontal movement when not sampling. The slopes direct the chamber into place when docking. When fully docked the door is closed. This allows the rod chamber to rest on top and removes tension from the line.

Figure 8: Reel

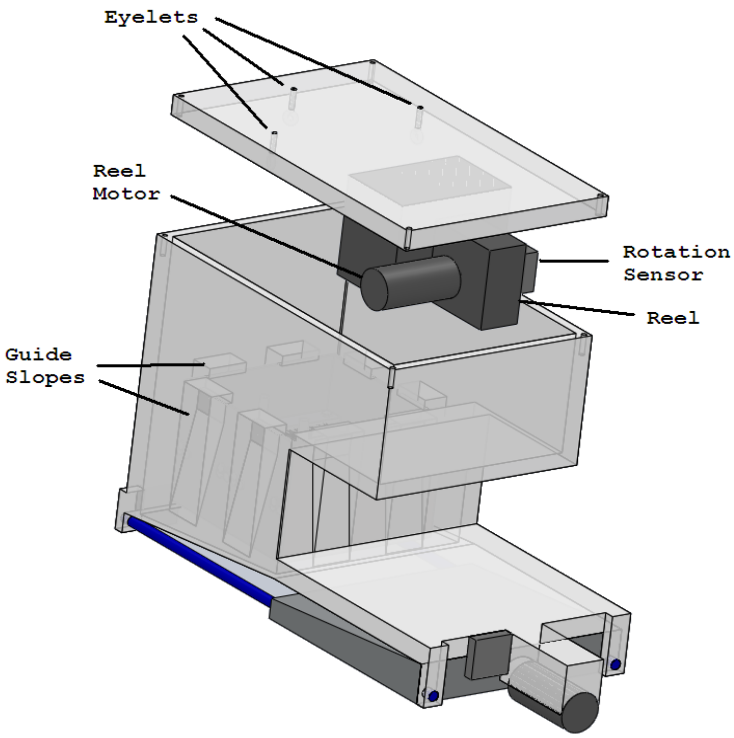

Figure 9: Sample/Flight Control Bay

The reel must spin at 200 rpm or greater to achieve the minimum sample volume. Since most fishing reels have a 5.2:1 gear ratio, this requires the motor to spin at 40 rpm or greater. With a suspended weight of 1 lb, the torque must be greater than 2.6 lb-in. There are a number of motors that meet these specifications and are within our power requirement. The motors, as well as the reel, will be cold and vacuum tested to ensure their performance.

The electronics will be housed in a 6 x 5 in electronics chamber, approximately 4 in tall, shown in Figure 10. The environmental sensor system will be housed in this box along with the control electronics. Depending on the electronic system's exact size and configuration, the box dimensions may be modified, up to a maximum of 10 x 5 x 6.5 in.

This housing will be an aluminum exterior for strength and lined with insulation. The insulation will keep the electronics warm throughout the flight by relying the electronics' heat output. If necessary, additional heaters will be used to maintain the temperature inside the box. To secure the lid, four screws will be used.

Each of SMITH's three major components will be attached to the HASP interface plate separately. Although they will be placed next to each other, the only connections between the components will be power and data lines. Each component will be bolted below the interface plate by means of a mounting bracket. The control and sample chamber will each have three brackets, and the electronics housing will have four brackets. Their configurations as well as the mounting bracket are shown in Figure 11. The brackets are connected to their respective payload components by two bolts and then to the interface platform by one bolt. The bracket will make the entire payload foot print 14.5 x 11 in. Sheer and stress tests will ensure the mounting bolts and brackets can support the payload and withstand any forces placed on them.

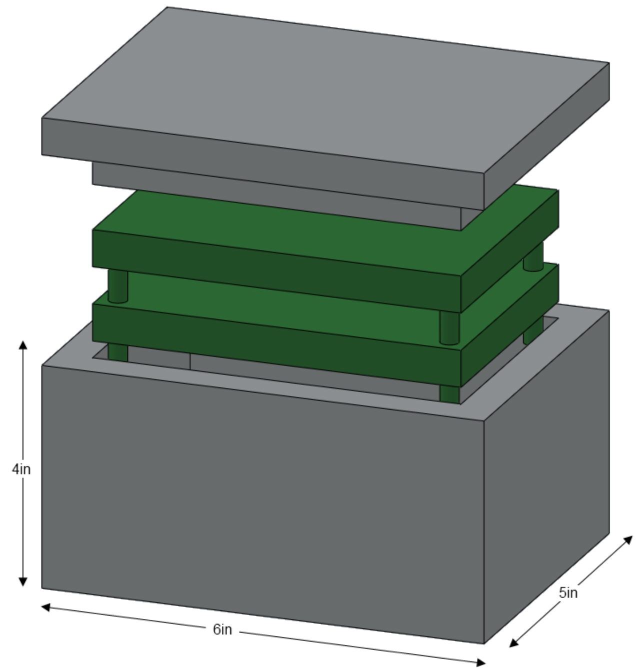

Figure 10: Electrical Housing

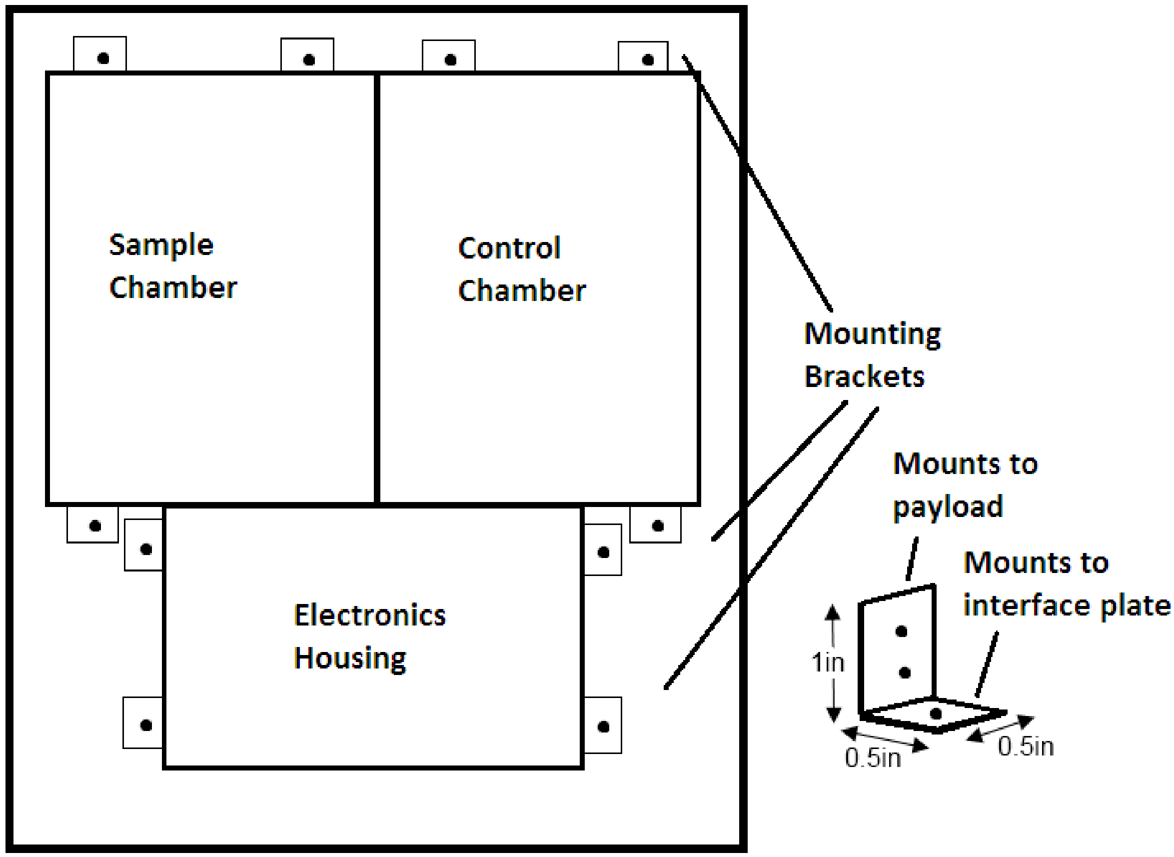

Figure 11: Payload Mounting

Table 3 lists several key components and their estimated weights. All the components estimate to be 20 lbs. which is below the allocated 44 lbs.

Table 3: Weight Budget

Item	Weight (lbs.)
Rod chamber (x2)	2
Motors (x4)	1
Housing bays (x2)	14
Line reel (x2)	1
Electronics (sensors & circuitry)	1
Electronics Housing	1
Total	20

3.2 Sampling Device

The SMITH payload utilizes plastic rods commonly used for pollen counts. The sampling rods follow the sterilization protocol before being inserted into the payload. The rods are 0.063 x 0.063 x 1.26 in. It is required to have at least 20 rods in each chamber. The requirement is exceeded by having a total of 60 rods per chamber, 30 of which are oriented to sample on the way up and 30 of which are oriented to sample on the way down.

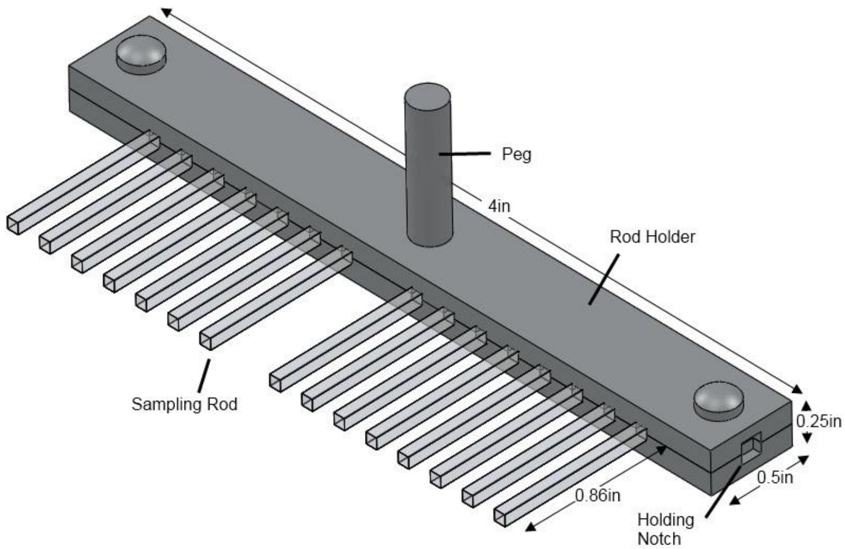

Figure 12: Rod Holder

The contraption to hold the rods is seen in Figure 12. Each rod holder holds 15 rods and there are a total of four rod holders per chamber. The rod holders are 1.5 in deep inside the sampling chamber. There are three screws on each side to secure each rod holder in place. To avoid any physical contact while handling with the rods, there are pegs on each rod holder for easy handling.

3.3 Door System

As mentioned in the mechanical section the door on each chamber is made of aluminum and is used to create a seal over the chamber when not sampling. This seal is important to prevent any contamination that may occur to the sampling system. To create an air tight seal some type of an O-ring will be used between the door and the chamber. It will be permanently secured to the chamber face and the door will slide shut against it. Since the door slides horizontally over the chamber by means of a screw, the face of both the chamber and door is slanted at a 5 degree angle. This is to allow contact only when fully closed and to prevent the sliding of the door from damaging the O-ring. Each door will have a sensor on each side to detect when it is fully opened or closed. These sensors will have either a high or low output and will be used to confirm the status of the doors throughout the flight.

3.4 Power

A twenty pin EDAC 516 connecter, shown in Figure 13, will be used to interface with HASP power supply. Pins A-D on EDAC will be used for +30 V_{DC} and W, T, U, and X will used to ground the power supply, as seen in Table 4.

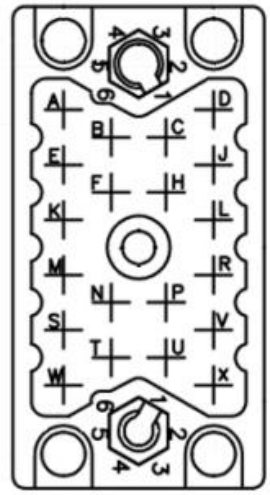

Figure 13: EDAC Connector

Function	EDAC Pins	Wire Color
+30 V_{DC}	A,B,C,D	White with red stripe
Power Ground	W,T,U,X	White with black stripe

Table 4: EDAC Pin Layout for Power

All four pins, A-D, will be used in parallel to provide appropriate power supply of 2.5 Amps at 30 V_{DC} to the payload. SMITH requires three DC/DC converters to step down voltages from 30 V_{DC} to 5, 12, and 24 V_{DC}. Besides the motors and heaters, all the other components will be powered throughout the flight. The power usage of each component is determined as following: $V * I * duty\ cycle$. The duty cycle is the amount of time, of the maximum 30 hour flight, the component will be powered. For the power consumption calculations of the DC/DC converters, efficiency of each DC/DC is also necessary to be known. Therefore, the total power consumed becomes $P_{in} * \ efficiency$. The efficiency of each converter is listed in Table 5.

Table 5: Converter Efficiency

Type of DC/DC Converter	Efficiency (%)
30 V-24 V	88.3
30 V-12 V	82
30 V-5 V	73

The total power required during the flight is 13.96 W. The power consumed by individual components can be seen in Table 6.

Table 6: Power Budget

Component	**Voltage (V_{DC})**	**Current (mA)**	**Duty Cycle (%)**	**Power (mW)**
30-24 V DC/DC Converter	30	90	100	2450
30-12 V DC/DC Converter	30	106	100	1540
30-5 V DC/DC Converter	30	105	100	716
Reel Heater	30	333	6.667	66.67
Door Heater	30	333	50	5000
Reel Motor	12	50	6.667	40
Door Motor	12	50	50	300
Temperature Sensor 1	12	1	100	12
Temperature Sensor 2	12	1	100	12
Temperature Sensor 3	12	1	100	12
Temperature Sensor 4	12	1	100	12
Pressure Sensor	12	1.5	100	18
UV-A Sensor	24	30	100	720
UV-B Sensor	24	30	100	720
UV-C Sensor	24	30	100	720
Humidity Sensor	5	0.5	100	2.5
Ozone Sensor	5	220	100	1100
Door Sensor 1	5	1	100	5
Door Sensor 2	5	1	100	5
Door Sensor 3	5	1	100	5
Door Sensor 4	5	1	100	5
Controller	5	100	100	500
Total				13961.17

Figure 14 shows the power schematic with input voltages to the components from the DC/DC converters. The power to the DC/DC converters is provided by the HASP power supply through the EDAC connecter.

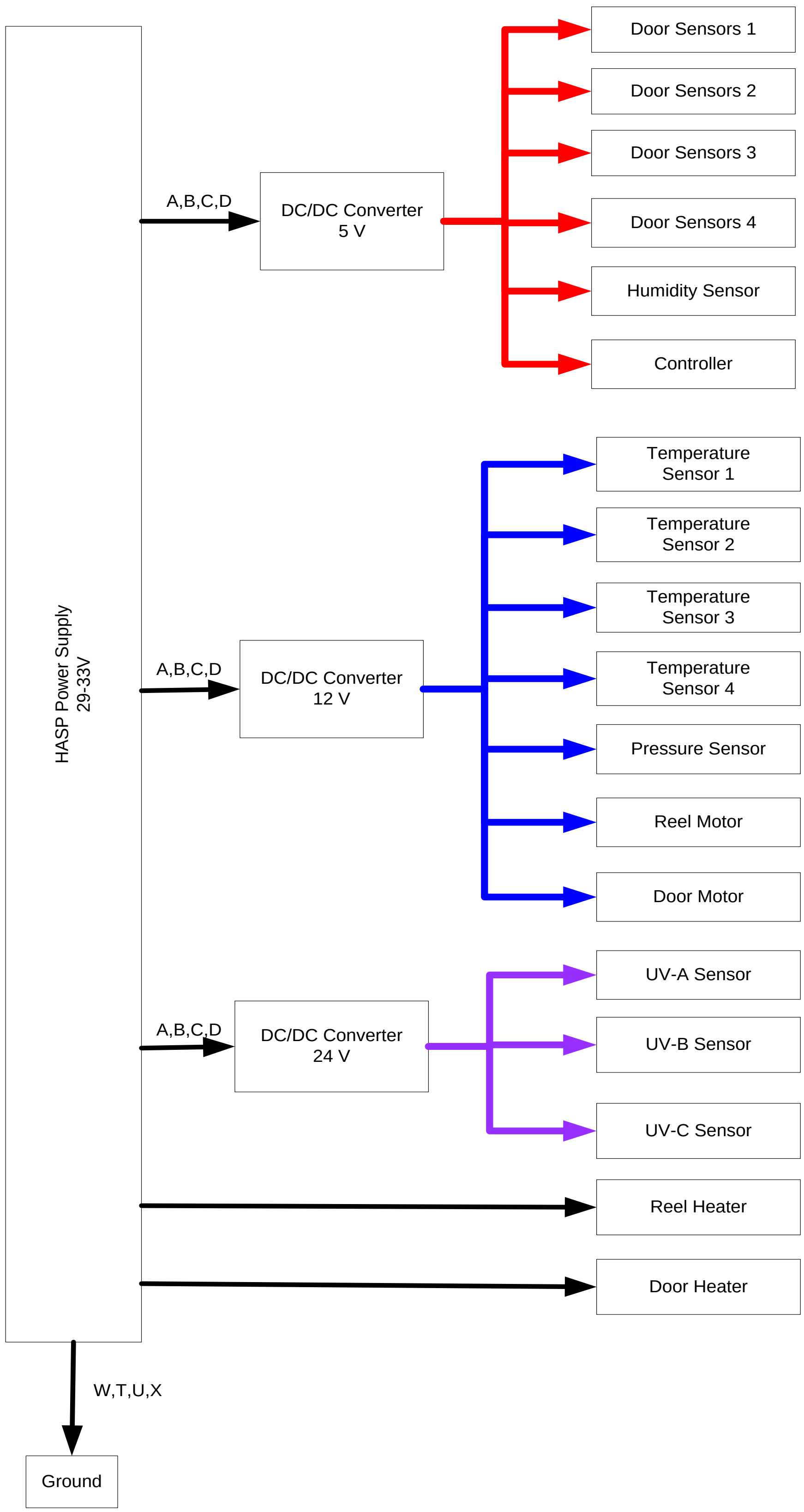

Figure 14: Power Schematic

3.5 Sensors

SMITH will investigate the presence of microorganisms in the stratosphere. Results have shown that it is reasonable to compare the atmospheric conditions in the stratosphere to the conditions on Mars. SMITH will record environmental measurements throughout the flight. The different parameters measured are temperature, pressure, humidity, ozone and ultraviolet radiations (A, B and C). Also, two sensors per door will verify the door status. Finally, each reel will have a rotational sensor to detect the motion of the sampling chamber. The data obtained from each environmental sensor, along with the sampling result, will allow the team to draw convincing hypotheses about life on Mars.

3.5.1 Door Sensors

To verify the position of the door before, during, and after sampling, limit switches will be used at each door extremity as illustrated in the Figure 15.

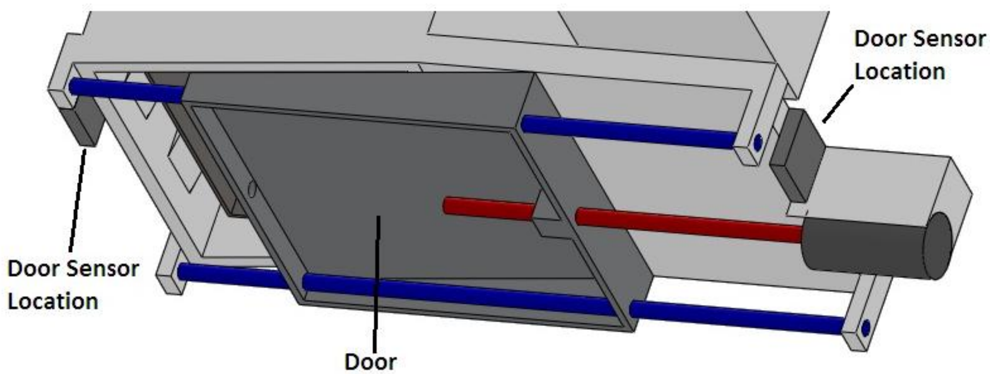

Figure 15: Door Sensor Location

As the door slides in one direction and reaches the extremity, the sensor detects contact with the door. The limit switch will disconnect and relay a logic low signal to controller. Therefore, a logic low signal from the door sensor at the right of Figure 15 will correspond to door open while a logic low signal from the left sensor means door close. Each door sensor would then require an individual I/O pin on controller chip. If a sensor is not triggered, its circuit is connected; this corresponds to a logic high signal.

3.5.2 Temperature Sensors

Besides measuring the temperature of the electronics and outside environment, sensors will also measure the temperature of the doors and reels' motors to ensure that they remain within their operating temperature range at all times during the flight. One reason behind the need of temperature sensors for this experiment is to activate the heater as soon as a motor reaches a temperature of -20°C.

3.5.3 Pressure Sensor

The pressure sensor for this experiment shall therefore be able to measure pressure over 0-1000 mbar. Most pressure sensors that meet SMITH's size and weight requirements have a temperature range of -40 °C to 100 °C. Housing the pressure sensor in the electronic chamber will ensure operational temperature. An ADC channel will be required to convert the pressure measurements to digital before saving them to the memory. Depending on its voltage range, the signal may require conditioning to match the ADC voltage range for linearity purposes.

3.5.4 Humidity Sensor

SMITH will measure relative humidity during the flight. It is likely that low temperatures will affect the operation of the humidity sensor. Different methods of insulation will be tested.

3.5.5 Ultraviolet Sensors

Another parameter to be measured is three types of ultraviolet radiation (UV), A, B and C. The same sensor model will measure three different types of ultraviolet radiation. The three ultraviolet sensors shall support light ranging from 0 to 40 W/m^2. They will be located outside of the payload. Since the temperature at night falls below -70 °C, insulation may be required for the sensors. The voltage signal from each sensor will be conditioned if necessary and then connected to an ADC channel. Measuring the full spectrum of UV radiation will require three ADC channels.

3.5.6 Ozone Sensor

Ozone inhibits bacterial activity and damages double-stranded DNA. Ozone also blocks UV radiations. Based on expected values, the ideal ozone sensor for our application should have a minimum range of 0 to 15 ppm. It will be located outside of the payload where the temperatures exceed the average range of ozone sensors, -30°C to 90°C. The payload's ozone sensor will need insulation. It will use an ADC channel for signal conversion.

3.5.7 Sensor Conclusion

SMITH will include a total of thirteen sensors, six motion/contact sensors and seven parameters sensors. Calibration and testing will be performed on each sensor. It is critical that all sensors operate properly throughout the whole flight hence the importance of developing efficient methods of protection against extreme conditions for some sensors. The sensors will require a minimum of twelve ADC channels and eight I/O pins from the controller.

3.6 Thermal

From ground to 120,000 ft, the temperature in the atmosphere can reach values as low as -70°C. All electronic components included in the payload have a restricted temperature range out of which they may not perform properly. For this reason, it is important that all the electronics are properly insulated. Table 7 associates the main components with their respective ranges.

Table 7: Thermal Summary

Component	Temperature Range
Motors	-40°C - 85°C
Controller	-40°C - 85°C
Memory	-40°C - 85°C
ADC chip	-40°C - 85°C
Door Sensors	-40°C - 85°C
Reel Sensors	-40°C - 80°C
Temperature Sensors	-65°C - 150°C
Pressure Sensor	-40°C - 125°C
Humidity Sensor	-40°C - 85°C
Ultraviolet Sensors	-30°C - 80°C
Ozone Sensors	-30°C - 80°C
Current Sources	-25°C - 100°C
Operational Amplifiers	-40°C - 85°C

Most of the components in Table 7 will be placed inside the electronics chamber where the temperature is expected to remain warm due to heat dissipated for components. The electronics chamber will have insulation lining the inner walls of the chamber. Thermal tests will be performed after fabrication to confirm the temperatures stay in range. If the testing results show that temperature inside the electronics chamber will drop lower than desired, an additional heater will be added.

The door motors will be exposed to extreme temperatures and may lead to the door and sampling failure during the flight. If door motors do not operate properly, due to low temperatures, then the mission will fail. For this reason, a temperature sensor and a heater will surround each door motor to keep it at acceptable temperatures all time. A 2.5W/in^2 Kapton heater is appropriate for this task. Kapton heaters can perform at extreme temperature conditions with an operating temperature range of -200°C to 235°C and they are useful in a vacuum. Kapton heaters exist in two different configurations: rectangular and round. The door motors will be heated with a rectangular heater for a more uniform distribution of heat through the device.

Measurements of conduction heat transfer and radiation will help determine the best type of material to insulate the components outside the electrical chamber. These components include reel motors, humidity, ozone and ultraviolet sensors.

4.0 DATA INTERFACE

4.1 Command and Data Handling

A controller is required to handle the communication between HASP and our payload. The controller must have a serial RS-232 connector. We will require twelve ADC channels to accommodate the seven environmental sensors five onboard monitoring temperature sensors aboard SMITH. Eight bit ADC channels will suffice for our environmental sensors. Ten I/O pins will be required to interface with the heaters, the door sensors, and the rotational sensors.

Table 8 shows the format of the record that we will store and downlink during flight. The real time clock needs a total of 4 bytes. The temperature sensors will need a total of 5 bytes, 1 byte per sensor. The doors sensors and including the heaters will all need a total of 8 bytes. The rotational sensor for our sampling device will need an estimated of 4 bytes total. The environmental sensors will need a total of 7 bytes, 1 byte per sensor. The record will be stored once per minute as per technical requirements. For a flight of 30 hours, a maximum of 47 KB of storage will be required.

Table 8: Record Format

Records	**Bytes**
Real Time Clock - day	1
Real Time Clock - hour	1
Real Time Clock - minute	1
Real Time Clock - second	1
Temperature Sensor 1	1
Temperature Sensor 2	1
Temperature Sensor 3	1
Temperature Sensor 4	1
Temperature Sensor 5	1
Door Sensor – close (sampling chamber)	1
Door Sensor – open (sampling chamber)	1
Door Sensor – close (control chamber)	(if operation) 1
Door Sensor – open (control chamber)	(if operation) 1
Rotational Sensor (sampling chamber)	(estimated) 2
Rotational Sensor (control chamber)	(estimated: if operation) 2
Heater: Door (sampling chamber)	1
Heater: Door (control chamber)	(if operation) 1
Heater: Reel (sampling chamber)	1
Heater: Reel (control chamber)	(if operation) 1
Environmental Temperature Sensor	1
Environmental Pressure Sensor	1
Environmental Humidity Sensor	1
Environmental UV-A Sensor	1
Environmental UV-B Sensor	1
Environmental UV-C Sensor	1
Environmental Ozone Sensor	1
Total:	**26 (estimated: if all operational)**

4.2 Downlink Data Format

The data will transfer from HASP via a RS-232 serial connection that will use 8 data bits, no parity bit, 1 stop bit, and no flow control. The serial connection will be a DB9 DTE (Data Terminal Equipment) connector. Figure 16 shows the DB9 DTE pin layout. SMITH will downlink sensor data every 10 seconds. This provides near real time status of the payload. The

SMITH team can then mitigate any problem if they occur. A current estimate is 21 bits per second (bps) for SMITH.

4.3 Uplink Command and Data Format

The serial connection to HASP provides the ability to uplink 2 byte commands. The first byte is used to ensure that the complete and correct command has reached the payload. The second byte offers 256 possible unique commands for the payload. Table 9 is the current list of commands we uplink.

Table 9: Total Commands

Commands
Sampling Chamber:
• Start sampling protocols
• Stop sampling protocols
• Reel in x distance
• Reel out x distance
• Open sampling chamber door
• Close sampling chamber door
• Reel in all the way and stop
• Real out all the way and stop
• Start door heater
• Stop door heater
• Start reel heater
• Stop reel heater
• Stop all operation
Control Chamber:
• Start sampling protocols
• Stop sampling protocols
• Reel in x distance
• Reel out x distance
• Open control chamber door
• Close control chamber door
• Reel in all the way and stop
• Real out all the way and stop
• Start door heater
• Stop door heater
• Start reel heater
• Stop reel heater
• Stop all operation
Total Commands: 26

By default, the sampling process is automated once the start command is issued. The stop is an automated process to re-seal the system. The heater commands enable the heaters to operate. Additional commands can be used to manually control key SMITH functions. These functions include reeling the sample chamber in and out x distance, open and close doors, and reeling in and out completely. The flight control chamber has the ability to receive the same sets of commands as the sampling chamber. This is in case of a failure in the primary sampling chamber. As the design progresses, additional commands will be added if necessary.

A twenty pin EDAC 516 will be used to interface with HASP's analog, downlink channels, and discrete commands. Table 10 describes the function of each pin and the wires from the connector are color coded respectively.

Table 10: EDAC Pin Functions

Function	EDAC Pins	Purpose
Discrete 1	F	Sample bay door heater
Discrete 2	N	Sample bay reel heater
Discrete 3	H	Flight control bay door heater
Discrete 4	P	Flight control bay reel heater on/off

There are two discrete lines that directly control power to the heaters. Discreet line 1 controls sample bar door and reel heater. While discreet line 2 controls flight control bay door and reel heater. This is a safety feature in case the manual control fails. There is currently no plan to use analog channels.

5.0 TESTING AND INTEGRATION PROCEDURES

5.1 Testing at LSU

- Calibrate Temperature sensors
- Calibrate Door sensors
- Test door motors for opening and closing doors
- Test reel motors with the chamber attached
- Test individual motor at low pressures in vacuum chamber
- Test individual motor at cold temperatures using refrigerator, freezer, and dry ice
- Test the strength of the reel at cold temperatures
- Run the flight software and do a complete system test
- Use terminal to test serial communication

5.2 HASP Testing and Integration

- Mount payload to HASP platform
- Connect HASP power and serial connectors
- Run flight software
- Perform thermal test
- Perform vacuum test
- Perform 10g vertical and 3g horizontal impact test
- Troubleshoot for any faults

6.0 TEAM ORGANIZATION

6.1 Management

The SMITH project for HASP will be developed and operated under the support of the NASA EPSCoR MARSLIFE project at Louisiana State University (LSU). The SMITH project is led by faculty advisors Jim Giammanco, Brad Ellison, and Michael Stewart, under the direction of Dr. T. Gregory Guzik. Principle Investigator, Dr. Brent Christner will serve as overall administrator and lead scientist.

Several of the students involved in the SMITH project (Noelle Bryan, Allen Bordelon, Ravneet Singh, and Cedric Toguem) have completed the Louisiana Aerospace Catalyst Experiences for Students (LaACES) program at LSU. After completing the LaACES project, students gained first-hand experience with project management, life-cycle, experiment construction, data collection, analysis, and interpretation. The skill set learned will be further developed on the SMITH project. This program provides four students (Allen Bordelon, Ravneet Singh, Cedric Toguem, and Jingbo Zhou) with a senior design project. The information on the concentration of cells in the stratosphere gained from the SMITH project will also serve as Noelle Bryan's graduate thesis.

6.2 Project Organization

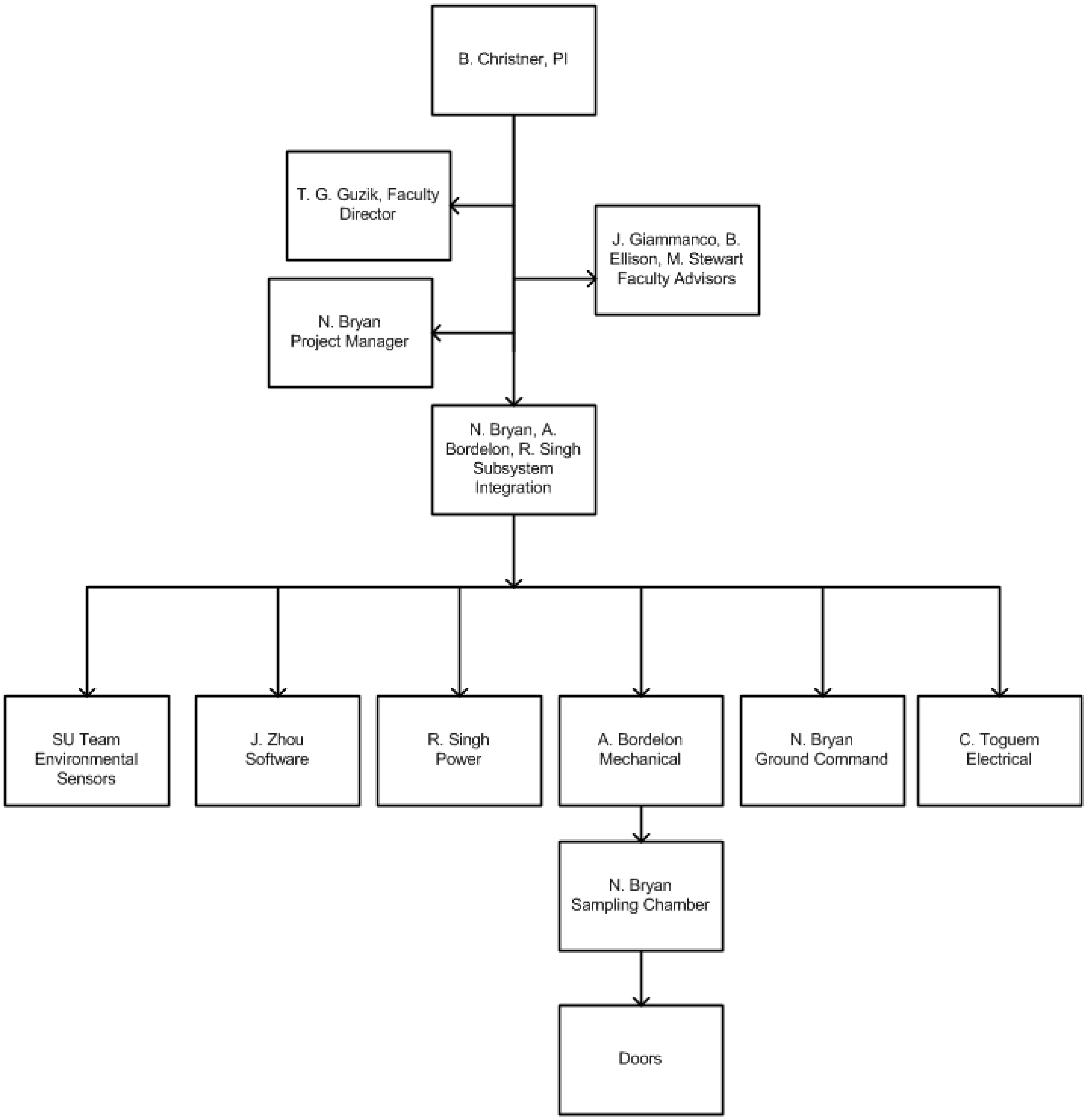

Figure 16: Project Organization

Project Management:	Noelle Bryan	Student Project Management
	Nbryan5@tigers.lsu.edu	(225) 326-4628
	Dr. Brent Christner	Principle Investigator
	xner@tigers.lsu.edu	(225) 578-1734
	Dr. T. G. Guzik	Faculty Advisor
	guzik@phunda.phys.lsu.edu	(225) 578- 8597

The administrative procedures of planning, organizing, coordinating, analyzing, and approval processes that direct the SMITH project are under the control of the project management. It excludes technical planning, management, and delivering specific engineering, hardware, and software products.

Systems Integration: Noelle Bryan
nbryan5@tigers.lsu.edu
Allen Bordelon
abord23@tigers.lsu.edu
Ravneet Singh
rsingh5@tigers.lsu.edu

Systems Integration team members are responsible for directing and controlling the integration efforts of the payload. This includes subsystem interfacing as well as integrating with the HASP platform. The Integration team also defines the project flight instruments, and planning and control of the technical project efforts of design engineering, software engineering, integrated test planning, system requirements writing, control and monitoring of the technical project, and risk management.

Subsystems: Allen Bordelon
abord23@tigers.lsu.edu
Ravneet Singh
rsingh5@tigers.lsu.edu
Cedric Toguem
ctogue1@tigers.lsu.edu
Jingbo Zhou
jzhou2@tigers.lsu.edu

Subsystems team members are responsible for their respective subsystem as described in Figure 16. The functioning subsystems will be integrated to achieve the overall mission objectives. This element also includes development, design, production, assembly, revisions, testing, and relevant documentation.

6.3 Preliminary Schedule

ID	Task Name	Start	Finish
1	**Preliminary Design**	**Wed 9/1/10**	**Fri 8/26/11**
2	Mission Definition Review	Wed 9/1/10	Fri 9/24/10
3	System Requirement Review	Mon 9/27/10	Fri 10/29/10
4	**Definition of Preliminary Design**	**Mon 12/6/10**	**Fri 12/10/10**
5	Trade Study of Pump vs. Yo-Yo	Fri 12/10/10	Fri 12/10/10
6	Trade Study of Rods vs. Filter	Mon 12/6/10	Fri 12/10/10
7	**Final Design**	**Mon 12/6/10**	**Fri 1/28/11**
8	HASP Proposal	Fri 12/17/10	Fri 12/17/10
9	Selection Announcement	Sat 1/15/11	Sat 1/15/11
10	**Electronic Design**	**Mon 12/6/10**	**Fri 1/7/11**
11	Environmental Sensors	Mon 12/27/10	Fri 12/31/10
12	Door Sensor	Mon 12/6/10	Mon 12/6/10
13	**Software Design**	**Mon 12/13/10**	**Fri 1/7/11**
14	Data Storage	Mon 12/13/10	Fri 12/17/10
15	Downlink	Mon 12/13/10	Fri 12/17/10
16	Uplink	Mon 12/13/10	Fri 12/17/10
17	Write Preliminary Program	Mon 12/20/10	Fri 1/7/11
18	**Mechanical Design**	**Mon 1/3/11**	**Fri 1/28/11**
19	Yo-Yo System	Mon 1/3/11	Fri 1/14/11
20	Door System	Mon 1/17/11	Fri 1/21/11
21	Mounting	Mon 1/17/11	Fri 1/21/11
22	Rod Chamber	Mon 1/24/11	Fri 1/28/11
23	Status Report Due End of Months	Mon 1/31/11	Fri 8/26/11
24	**Subsystem Integration Phase**	**Mon 1/3/11**	**Fri 3/11/11**
25	Order Materials	Mon 1/3/11	Fri 1/28/11
26	IntegrateTemperature Sensors	Mon 1/31/11	Fri 2/4/11
27	Calibrate Temperature Sensors	Mon 2/7/11	Fri 2/11/11
28	Build Mechanical Housing	Mon 2/14/11	Fri 3/11/11
29	Status Report Due	Fri 2/25/11	Fri 2/25/11
30	**Preliminary PSIP document**	**Mon 3/14/11**	**Wed 6/1/11**
31	Exact Power and Weight Budget	Mon 3/14/11	Wed 3/16/11
32	Determine exact downlink data format	Wed 3/16/11	Fri 3/18/11
33	List Uplink Commands	Mon 3/21/11	Tue 3/22/11
34	Discreet Command and Analog Output Usage	Tue 3/22/11	Wed 3/23/11
35	Write Rough Draft	Thu 3/24/11	Fri 4/1/11
36	Edit Rough Draft	Mon 4/4/11	Thu 4/21/11
37	Preliminary Version Due Date	Fri 4/22/11	Fri 4/22/11
38	Edit Preliminary Version	Mon 5/2/11	Tue 5/31/11
39	Final Document Due	Wed 6/1/11	Wed 6/1/11
40	Preliminary HASP thermal / vacuum testing	Mon 5/23/11	Fri 5/27/11
41	Final testing and payload adjustments	Mon 7/4/11	Sun 7/31/11
42	**FLOP**	**Thu 6/2/11**	**Sun 7/31/11**
43	Write Detailed Timeline for Launch Day	Thu 6/2/11	Mon 6/6/11
44	Write Detailed procedures for Flight Line Setup	Mon 6/6/11	Fri 6/10/11
45	Write Rough Draft	Mon 6/13/11	Thu 6/30/11
46	Edit Rough Draft	Mon 7/4/11	Fri 7/29/11
47	Final Document Due	Sun 7/31/11	Sun 7/31/11
48	**Student payload integration at CSBF**	**Mon 8/1/11**	**Fri 8/5/11**
49	Mount Payload to HASP Platform	Mon 8/1/11	Mon 8/1/11
50	Test and Debug Flight Software	Tue 8/2/11	Tue 8/2/11
51	Perform Thermal Test	Wed 8/3/11	Wed 8/3/11
52	Perform Vacuum Test	Thu 8/4/11	Thu 8/4/11
53	Perform Shock Test	Fri 8/5/11	Fri 8/5/11
54	HASP flight preparation	Mon 8/29/11	Thu 9/1/11
55	Target flight ready	Fri 9/2/11	Fri 9/2/11
56	Target launch date and flight operations	Mon 9/5/11	Mon 9/5/11
57	**Flight/Science Report**	**Tue 9/6/11**	**Tue 12/6/11**
58	Analysis of Data	Tue 9/6/11	Fri 9/30/11
59	Rough Draft	Mon 10/3/11	Fri 10/28/11
60	Edit Rough Draft	Mon 10/31/11	Mon 12/5/11
61	Final Draft	Tue 12/6/11	Tue 12/6/11

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