American Institute of Aeronautics and Astronautics

IIT Armour College of Engineering
ILLINOIS INSTITUTE OF TECHNOLOGY

2013 HASP Proposal

Scarlet Hawk-II

HASP Student Payload Application for 2014

Payload Title: Scarlet Hawk II		
Payload Class: (check one) ☑ Small ☐ Large	Institution: Illinois Institute of Technology	Submit Date: December 20th, 2013

Project Abstract

Every year the HASP program offers the opportunity for students to design, build and flight payload for stratospheric balloon flight. After a successful mission at the end of summer 2013, IIT AIAA chapter is submitting a new application for the 2014 mission.

Our proposal include two main experiments, an engineering one involving a solar powered autonomous energy system and a biology one studying the reaction of extremophile microorganisms to the hostile stratospheric environment.

Learning from last year mission, we chose to design a stronger and more practical structure.

With the implementation of this new structural design and power system, our hope is to get closer to a CubeSat mission, our long term goal.

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Outline

1- Introduction

IlT’s Ballooning Team is formally part of the local student chapter of the American Institute of Aeronautics and Astronautics (AIAA). The Executive Board of AIAA-IIT is democratically elected by the student body and allows the allocation of funds to student-managed groups for engineering projects. The total support of this chapter to IIT’S Ballooning Team has allowed the full completion of two payloads. These efforts started back in 2012 with a couple of students, mainly with very few experience in ballooning. After two years, this initiative boiled down to Scarlet Hawk I, a small payload that flew in HASP 2013. Now, our chapter is looking forward and planning on not only further developing the high-altitude ballooning program on campus, but also getting started on NanoSatellites by 2015. The team then made the decision of going ahead with Scarlet Hawk II. Scarlet Hawk II is the result of a mixture of our past experience in ballooning and our future plans for a CubeSat program. The design of this payload involved a collaboration between two different departments of the university, Biology and Engineering, which seeks to both further the technical knowledge of our team and strengthen scientific research on high-altitude ballooning.

2- General principle of operation

2.1 Overall System Design

This payload will be divided into two main parts. The first one is an engineering experiment where solar power will be investigated as a main energy source for a future mission. The second experiment is studying the behavior of the extremophile bacteria called Deinococcus radiodurans.

For safety reasons the two experiments are kept as independent as possible. As seen in the following diagram, the interface between the 2 system is minimal and failure of one of them would not compromise the entirety of the mission. The energy produced by the solar panels will be used by 2 cameras so that it doesn't go to wast.

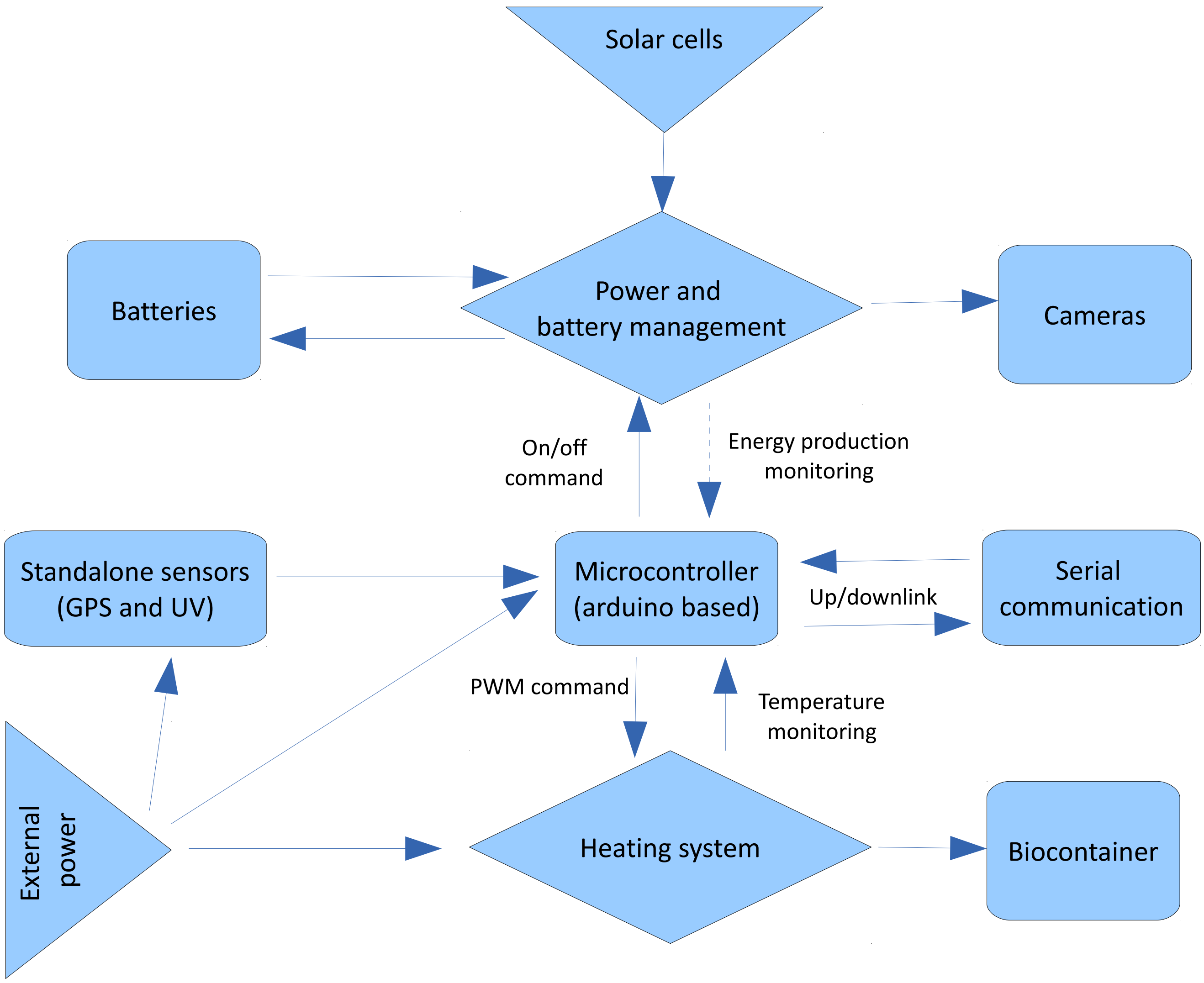


Figure 1: Overall system

The only link between the two will be an option to cut the power to the cameras if it's required for some unknown reason. Right now there is no monitoring of the energy produced by the solar cells. However, depending on PCB space and weight available this option will be considered.

2.2 Electrical Consumption

Since the IPS will be independent the only components requiring the 30V HASP power will be the microcontroller and sensors and the heating elements.

The power drawn by the assembly Microcontroller/sensors/GPS is estimated as less than 3W (estimated from previous mission). Considering that we chose to dedicate 10W to the heating system. In case the control system draws an unexpected amount of power, the heating power will be reduced.

3- Independent Power System (IPS)

3.1. Description of the System

IIT's ballooning team is planning on testing, through HASP 2014, a power system for CubeSat mission scheduled to fully start in 2015. IIT Scarlet Hawk II will have a solar powered video recording system. The idea is then to be able to run two cameras through only solar power during the entire flight. Eight solar cells will be installed in each of the 4 sides of the payload and will provide enough energy for all the flight.

The solar panels will be connected to two maximum power point trackers chips (MPPT) that will allow us to maximize the performance of the panels in the changing flight conditions. Temperature variations, solar tilt and solar intensity will be taken into account. The energy extracted from the system will charge a battery that acts as a buffer during peak production and as source of energy during moments of low solar intensity.

The cameras will be connected to the output port of the two MPPTs and the battery allowing them to work with the power of the solar panels directly while the batteries are charging. In case the solar panels and the battery do not provide enough power, the cameras can be shut down by using two autonomously controlled switches, which would then allow the battery to charge and eventually get the cameras back to record.

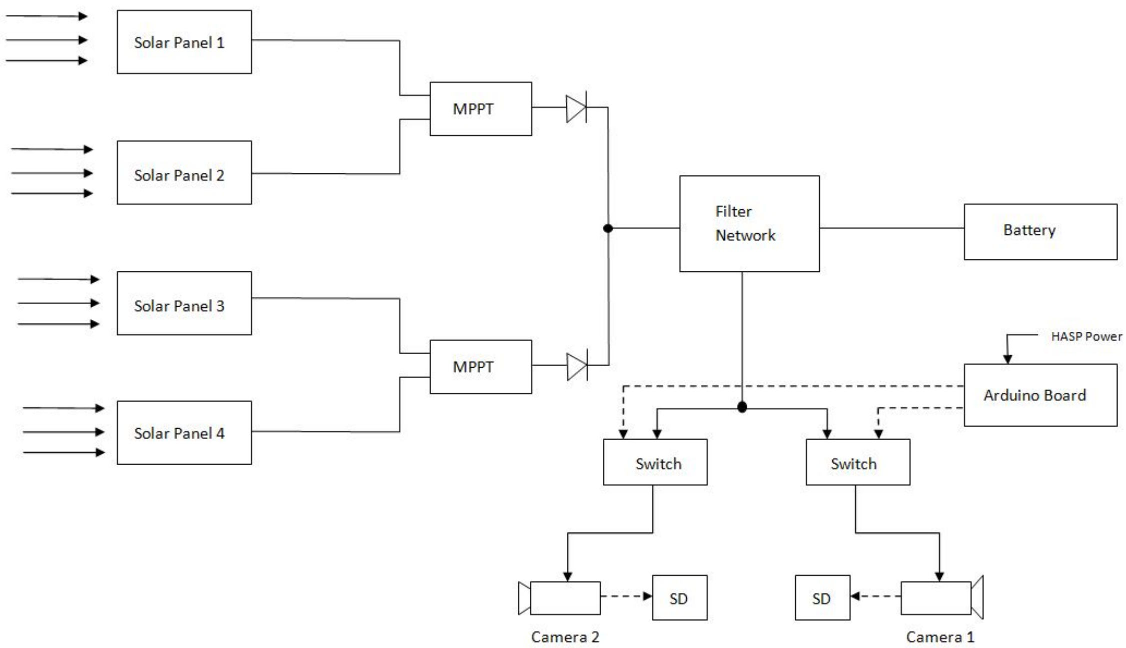


Figure 2: Scarlet Hawk II Independent Power System

3.2. Objectives

- Test an independent source of energy in space-like conditions to be used in a future CubeSat mission.
- Autonomously monitor the performance of the power production in order to make accurate predictions of power output and battery behavior in space conditions.
- Asses power efficiency ratio (Real Power/ Expected Power) for the Independent Power System for flight conditions.
- Be able to use the obtained energy to power the two cameras onboard to record video throughout the flight

3.3. Principles of Operation

Power expectation from solar panels

In order to estimate the initial output of the IPS, let us take a look at the expected values for solar radiation for a flat plate in the area of the launching site (New Mexico).

Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	3.0	3.9	5.1	6.4	7.0	7.5	7.2	6.5	5.5	4.5	3.3	2.7	5.2
	Min/Max	2.5/3.3	3.5/4.3	4.5/5.6	5.9/6.9	6.5/7.5	6.8/8.1	6.7/7.7	6.1/7.3	5.1/6.2	3.8/5.1	2.7/3.6	2.2/3.1	5.0/5.4
Latitude -15	Average	4.3	5.1	5.9	6.8	7.0	7.2	7.1	6.8	6.2	5.6	4.5	4.0	5.9
	Min/Max	3.4/5.0	4.4/5.8	5.2/6.6	6.3/7.4	6.5/7.5	6.6/7.8	6.7/7.6	6.4/7.5	5.7/7.1	4.7/6.5	3.5/5.2	3.1/4.9	5.6/6.1
Latitude	Average	5.0	5.6	6.2	6.7	6.6	6.6	6.6	6.5	6.3	6.1	5.2	4.8	6.0
	Min/Max	3.9/5.9	4.8/6.5	5.3/7.0	6.2/7.3	6.1/7.0	6.1/7.2	6.2/7.0	6.2/7.3	5.7/7.3	5.0/7.2	3.8/5.9	3.5/5.8	5.7/6.3
Latitude +15	Average	5.4	5.9	6.1	6.2	5.8	5.7	5.7	5.9	6.1	6.2	5.5	5.2	5.8
	Min/Max	4.1/6.4	5.0/6.8	5.3/6.9	5.8/6.8	5.4/6.2	5.3/6.1	5.4/6.0	5.6/6.6	5.5/7.0	5.0/7.4	4.0/6.4	3.7/6.4	5.5/6.1
90	Average	4.9	4.8	4.3	3.5	2.7	2.3	2.4	3.1	3.9	4.8	4.8	4.8	3.9
	Min/Max	3.7/5.9	4.0/5.6	3.7/4.9	3.3/3.8	2.5/2.8	2.2/2.4	2.4/2.5	2.9/3.3	3.5/4.5	3.8/5.8	3.4/5.7	3.3/6.1	3.5/4.1

Figure 3: Tucumari data, from the Renewable Resource Data Center

The solar panels have an inclination of 90º with respect to ground. It can then be expected a nominal radiation of $\frac{3,9\,Kwh}{m^2}/day$ in September. Around 13,3 hours of light per day are expected for the beginning of September in the New Mexico area. All these then yeilds a mean power of $293,33\,W/m^2$. This value represents the power expected per square meter of collection area at ground level in the launching area.

The atmosphere causes the reflexion of around 30% of the power, mainly because of the presence of clouds, and it also consumes 23% of power when it is traversed. During flight altitude, The IPS would then obtain 113% of more energy compared to ground level or $624,10\,W/m^2$.

Two solar cells will be installed on each side of the payload. Each cell will have a surface of 15625 mm² (125x125mm) and an efficiency of 19%.

$$A=2\cdot 15625=31250\text{m}\,m^2=0,03125\,m^2$$

$$PES=A\cdot RSL\cdot\eta=0,03125\cdot 624,10\cdot 0,19=3,706\,W$$

PES is the power when one side is pointing perpendicular to the sun and it is assumed the minimum power. We get the maximum power when two sides are pointing at 135º to the sun.

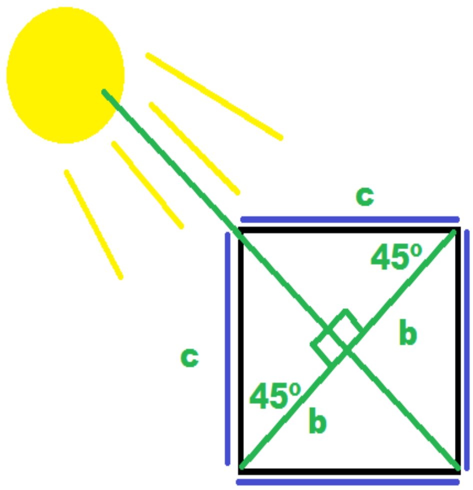


Figure 4: Sun exposure geometry

$$2 \cdot c \cdot \cos(45) = 2b$$

C, representing the area of two sides of the payload, is directly related with the output power:

$$Pmax = 2 \times 3{,}706 \cdot \cos(45) = 3{,}706 \cdot \sqrt{(2)} = 5{,}24\, W$$

If the body is rotating with a constant speed, we can calculate the mean power output with the next formula:

$$c \cdot \cos(\theta) + c \cdot \sin(\theta) = S$$

$$PES \times (\cos(\theta) + \sin(\theta)) = P(\theta)$$

$$\frac{\int_0^{\frac{\pi}{4}} PES \times (\cos(\theta) + \sin(\theta))\, d(\theta)}{\frac{\pi}{4}} = P$$

$$\frac{4\text{PES}}{\pi} = \frac{3{,}706 \times 4}{\pi} = P = 4{,}71\, W$$

This is the mean power output that can be expected. The amount will vary during the flight because of the change of sun tilt and latitude. Also, the assumption that the 53% of the energy lost by crossing the atmosphere will be reduced to 0% in conditions of almost no atmosphere is an optimistic assumption, so the mean power would be reduced.

Maximum power point tracker (MPPT)

The experiment requires us to utilize the maximum possible power that is obtained from the solar panels. In order to get the ultimate power, we use MPPTs to serve our purpose. MPPT stands for Maximum Power Point Tracking. It is a technique that grid connected inverters or solar battery chargers use to get the maximum possible power from one or more photovoltaic devices, such as solar panels. An electronic DC to DC converter that optimizes the connections between the solar arrays such as PV panels and the battery bank. Thus, it helps us to convert the higher voltage DC output from the solar panels down to the lower voltage needed to charge batteries.

<u>Working Principle:</u>

The Maximum Power Point or MPP is the working point of the photovoltaic cell or solar panel at which the product of the extracted voltage and current provides the maximum power. This MPP can also be computed from the characteristics of the PV cell curve which is as follows:

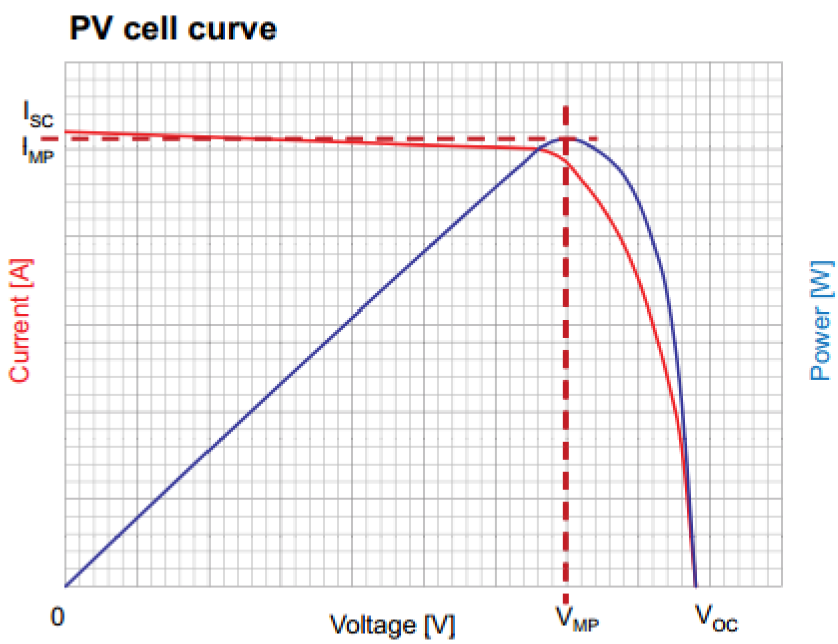


Figure 5: Power/Voltage/Current characteristics of a solar cell

Where, V_{OC} = Open Circuit Voltage

V_{MP} = Voltage at maximum power point

I_{SC} = Short Circuit Current

I_{MP}= Current at maximum power point

STEVAL – ISV006V2

STEVAL-ISV006V2 is the solar battery charger which we use as it has an embedded MPPT based on the chip SPV1040. It is a high efficiency monolithic step-up DC-DC converter. It has integrated N-channel and P-channel MOSFETs with low R_{ON} resistance. The protection from overcurrent and overtemperature; with input reverse polarity protection are considerable advantages and are to be utilized in this system. The STEVAL-ISV006V2 is a board which is supplied with the solar panels and the output load is a 220mF, 5.5V super – capacitor.

The reason for using SPV1040 in such a situation is that the MPPT algorithm assures maximum efficiency in terms of power produced from the cells and transferred to the output, even under varying environmental conditions (like temperature, dirt, irradiation). The device employs an input voltage regulation loop, which fixes the charging battery voltage via a resistor divider. The maximum output current is set with a current sense resistor according to charging current requirements. The SPV1040 protects itself and other application devices by stopping the PWM switching if either the maximum current threshold (up to 2 A) is reached or the maximum temperature limit (up to 155 °C) is exceeded.

Schematic Diagram:

The schematic circuit diagram of STEVAL-ISV006V2 is as follows:

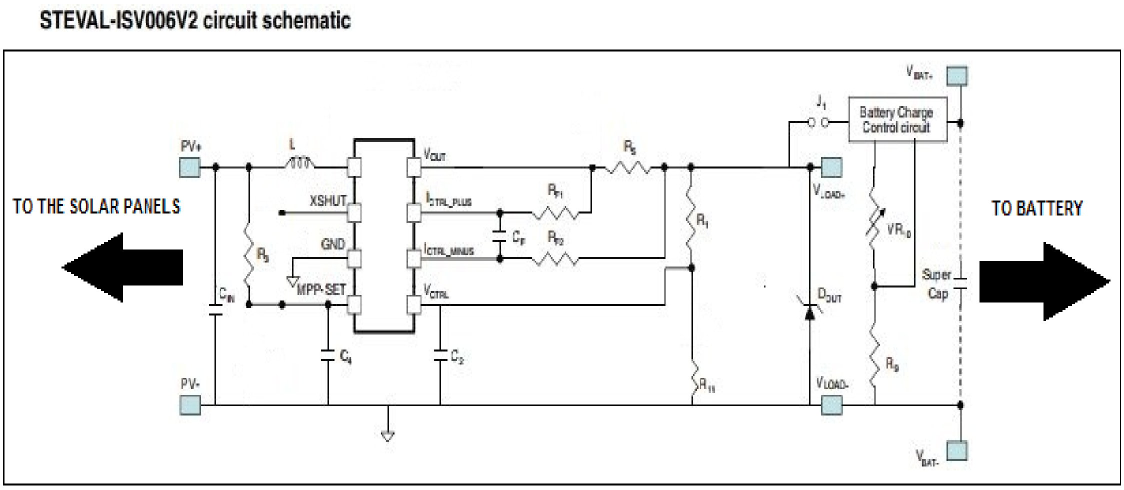


Figure 6: Electrical circuit for the MPPT chip

Here, the SPV1040 acts as an impedance adapter between the input source and output load.

Components:

The components that are required in order to implement the entire board of battery charger are shown in the following table:

Component Label	Name	Value
U25/26	Solar Battery Charger	
C_{IN}	Input Capacitor	10 µF
C_4	Voltage Sensing Capacitor	100 nF
C_2	Voltage Sensing Capacitor	1 nF
R_3	Input voltage partitioning resistor	1 kΩ
R_1	Output voltage partitioning resistor	1MΩ
L	Inductor	10 µH
	Super Capacitor	220 nF
D_{OUT}	Protection Diode	
R_S	Output Current Sense	10 mΩ
R_{F1}, R_{F2}	Noise Filtering resistors	1 kΩ
C_F	Noise Filtering capacitor	1 µF
V_{R10}	MPP- set indication partitioning resistor	0-1 MkΩ

Battery connection

Operation Principle of the circuit:

As shown in the block diagram in the General Schematics section (Fig. 1), power transmission system starts from the solar panels. The power generated is transmitted through the MPPTs and then after passing through the filtering circuit, it helps to charge the battery. This battery is responsible for the power required to run the two cameras. We have also made provision of a switch so that the whole experiment can be switched off. This switch would be activated in case there is not enough power generated through the ranks of the MPPTs to the battery.

Switches have been provided to choose which camera will be used at a particular moment. If the power is adequate, both cameras can be utilized to perform the experiment. Since Arduino board is being used, the power generated from the MPPTs towards the battery could also be monitored. This would ensures that if there is not sufficient power, the experiment can be switched off to regularize the system and would allow live feedback on the power comsuption.

The Filter Network (Fig. 1) consists of diodes which also act as switches for the MPPTs. The presence of two MPPTS provides an opportunity to switch on or off one of the MPPTs or even both of them in case the battery is fully charged. Thus, these diodes are made to act as switches in order to prevent wastage of power.

The purpose of the entire circuit is to produce the maximum possible power. In order to fulfill this objective, two solar panels on the sides, which are connected to a solar battery charger with embedded MPPT, have been connected with the MPPTs in parallel. This enables us to get an additive current from these two sources. The power transmitted helps the battery to get charged which in turn takes responsibility for the experiment.

3.4 Video Cameras

The results of our solar system will be shown in the form of pictures. The energy we obtain from these solar panels will be supplying two cameras (HD GoPro Cameras). Consequently, we expect to obtain periodic images from two sources and store them in an internal memory (SD card).

Power consumption

The two cameras on board will be constantly consuming power during the flight. The approximation of this power consumption is essential for the correct functioning of the solar set.

The main parameter we need to define is the “image captured period”, as the time between pictures. The cameras will be periodically taking pictures with a fixed interval between pictures. This interval is critical as it determines both the power consumption and the total number of pictures. If the time is too large we will have a small amount of images, but if it is too small the camera will consume much more power. Taking this two ideas into account, we set the interval period as 15 seconds.

The set period will also affect the memory size of our SD cards. With photos being taken every 15 seconds, in 1 minute 4 pictures are saved or what is the same as rate of 200pictures/h. Each image has a size between 1.5 MB and 2 MB. For one hour of recording, then, 400 MB of storage are need. Therefore, a 10 GB card will be used for the flight.

Then, we calculate the power consumption (for the worst case scenario), in case photos or videos are recorded:

HD GoPro Camera features

STATE	POWER (Watts)
Off	0.0002
Off with TL or PL	0.0006
Standby Photo	1.2
Standby Menu	1.2
Standby Video	1.2
Standby after 5 min	1.2
Recording video	1.5

We then obtain the following values:

- The aprox. Power consumption for both of the cameras:
  - Photo = 2.4 Watts
  - Video recording = 3 Watts
- Expected battery time: time for the video cameras to discharge the baterry:
  - Photo = 3.3 hours
  - Video recording = 2.4 hours

Expected pictures

GoPro cameras have a High Definition system, which will assure high resolution and detailed pictures. These images will have a size of 1592x1944 pixels or 5 Mpixels. The pictures taken will be compressed using JPEG 2000 protocol in order to maximize space. GoPro cameras will also allow to reduce the darken effect and some other common image distortions. To prevent some usual problems due to light characteristics of the atmosphere, GoPro cameras also include some basic filters to improve the image quality during very bright moments.

4- Microorganism Stratospheric Exposure (MSE)

4.1 Scientific Background

The stratosphere, the second major layer of Earth's atmosphere is a harsh environment for most organisms. For example, the low temperature (below zero Celsius), high-UV (both UV-B and UV-C), low atmospheric pressure (about 1/1000 of sea level pressure.), and the ozone limit life growth. However, some microbes have the potential to remain viable in such extreme environmental conditions. In previous research, several microorganisms, such as *Stenotrophomonas rhizophila*, *Bacillus silvestris*, *Methylobacterium chloromethanicum*, *Engyotontium album,* and *Deinococcus aetheriu,* had been observed and collected in the stratosphere. [3][5][6]

Studies are been conducted in simulated stratospheric conditions aiming at finding the environmental factors that limits microbial survival rate [4]. Since the difference between simulated condition and actual stratosphere condition (UV irradiation, ozone) can't be ignored, studies conducted in actual stratosphere should grant us more detailed and precise information in microbial survival and its limiting environmental factors.

Deinococcus radiodurans (*D. radiodurans*) is known for its resistance towards extreme radioactivity and UV radiation, geno toxic chemicals, heat, and desiccation [1]. Research has shown that this non-spore forming extremophile has a fair survival rate in a simulated Mars environment (-35°C, 83Kpa, 37 W/m^2) [2], which suggests its potential to survive in the stratosphere (-10°C, 0Kpa, 56 W/m^2 [4]). Due to *Deinococcus radiodurans'*s ability to tolerate and adapt to changing conditions, it provides us with an opportunity to investigate the influence of stratosphere environmental factors to microbial survival.

4.2 Purpose

This study aims at 1. Investigate the survival rate of *D. radiodurans* in stratosphere. 2. Evaluate the most influential environmental factors in *D. radiodurans* survival in stratosphere. 3. Discuss how these combinations of environmental factors affect *D. radiodurans* survival in stratosphere. Results may provide useful information in understanding the microbial aerosols presenting in stratosphere and other extreme environments.

4.3 Experiment Overview

In this experiment, *D. radiodurans* cultures are grouped and sent to the float altitude of 36---38 km by the payload. These samples are exposed in environments consisting of one or multiple stratosphere conditions (UV, temperature, pressure) for 15hrs. Samples are returned for cell survival rate determination and contamination analysis.

Objectives

1. Send *D. radiodurans* samples into target altitude (36 to 38 km) in stratosphere for duration of 15hrs.
2. 80 *D. radiodurans* sample groups are cultured in environments consisting of one or multiple stratospheric conditions (UV, temperature, pressure) which are controlled and maintained by the chamber.
3. Determine cell survival rate after samples are returned. Analyze the influence each factors has on *D. radiodurans* survival.
4. Analyze the microbial contamination involved in experiment preparation, flight and sample recovery.

Requirements

Environment conditions (UV, temperature, pressure) of each sample are controlled and stably maintained by the chamber according to experiment design.

(Temperature: HA, 35^{o}C; Pressure: HA, 100Kpa; UV: HA, negative)

1. Samples are cultured at target altitude (36 to 38 km) for 10hrs
2. Microbial contamination are minimized and analyzed before, during and after the flight.
3. Environment conditions (Temperature, pressure, UV radiation) are recorded during the whole flight.

Reference

[1] Battista, J.R. (1997) Against all odds: the survival strategies of *Deinococcus radiodurans. Annu. Rev. Microbiol*. 51, 203–224.

[2c] Diaz B, Schulze-Makuch D. (2006). Microbial survival rates of Escherichia coli and *Deinococcus radiodurans* under low temperature, low pressure, and UV-Irradiation conditions, and their relevance to possible Martian life. *Astrobiology.* 6(2):332-47.

[3] Shivaji, S., Chaturvedi, P., Begum, Z., Pindi, P. K., Manorama, R., Padmanaban, D. A., ... & Narlikar, J. V. (2009). Janibacter hoylei sp. nov., Bacillus isronensis sp. nov. and Bacillus aryabhattai sp. nov., isolated from cryotubes used for collecting air from the upper atmosphere. *International journal of systematic and evolutionary microbiology*, *59*(12), 2977-2986.

[4] Smith, D.J. et al. (2011). Microbial survival in the stratosphere and implications for global dispersal. *Aerobiologia* 27:319-332

[5] Wainwright, M., Alharbi, S., & Wickramasinghe, N. C. (2006). How do microorganisms reach the stratosphere?. *International Journal of Astrobiology*,*5*(01), 13-15.

[6]Yang, Y., Itoh, T., Yokobori, S. I., Shimada, H., Itahashi, S., Satoh, K., ... & Yamagishi, A. (2010). Deinococcus aetherius sp. nov., isolated from the stratosphere. *International journal of systematic and evolutionary microbiology*,*60*(4), 776-779.

4.4 Engineering Considerations

The bacterias sample are going to be tested under 3 different physical parameters: with or without temperature control, with or without pressure control and with or without UV exposure.

Pressure control

The samples we want to expose to the outside pressure will have their vial punctured near the top such that the pressure will be able to equalize without allowing the liquid to leak. The samples we want to keep at a 1 bar pressure will simply be tightly sealed. The temperature effects can be neglected as they would drop the pressure to only 0.75 bar minimum (for a perfect gas at -50C). This is considered not significant enough to affect the microorganisms.

UV exposure control

The UV exposure will be performed by storing the vials under a quartz window. Quartz is known to have a very low UV and near infrared absorption and is widely used in scientific equipment because of this property. To get the maximum amount of UV possible the top of the lids of the polypropylene tubes will be cut and the bottom part (ie the one with the threads) will glued to the surface of the window. The core of the tube will then be screwed back to the lid.

Temperature control

Half of the samples of bacteria have to be maintained at a 37C temperature. This will be done by encasing most of the vial bodies inside an aluminum rack and routing a heating element inside this rack. Since the maximum power available is 15W, we choose to use 10W for heating purposes.

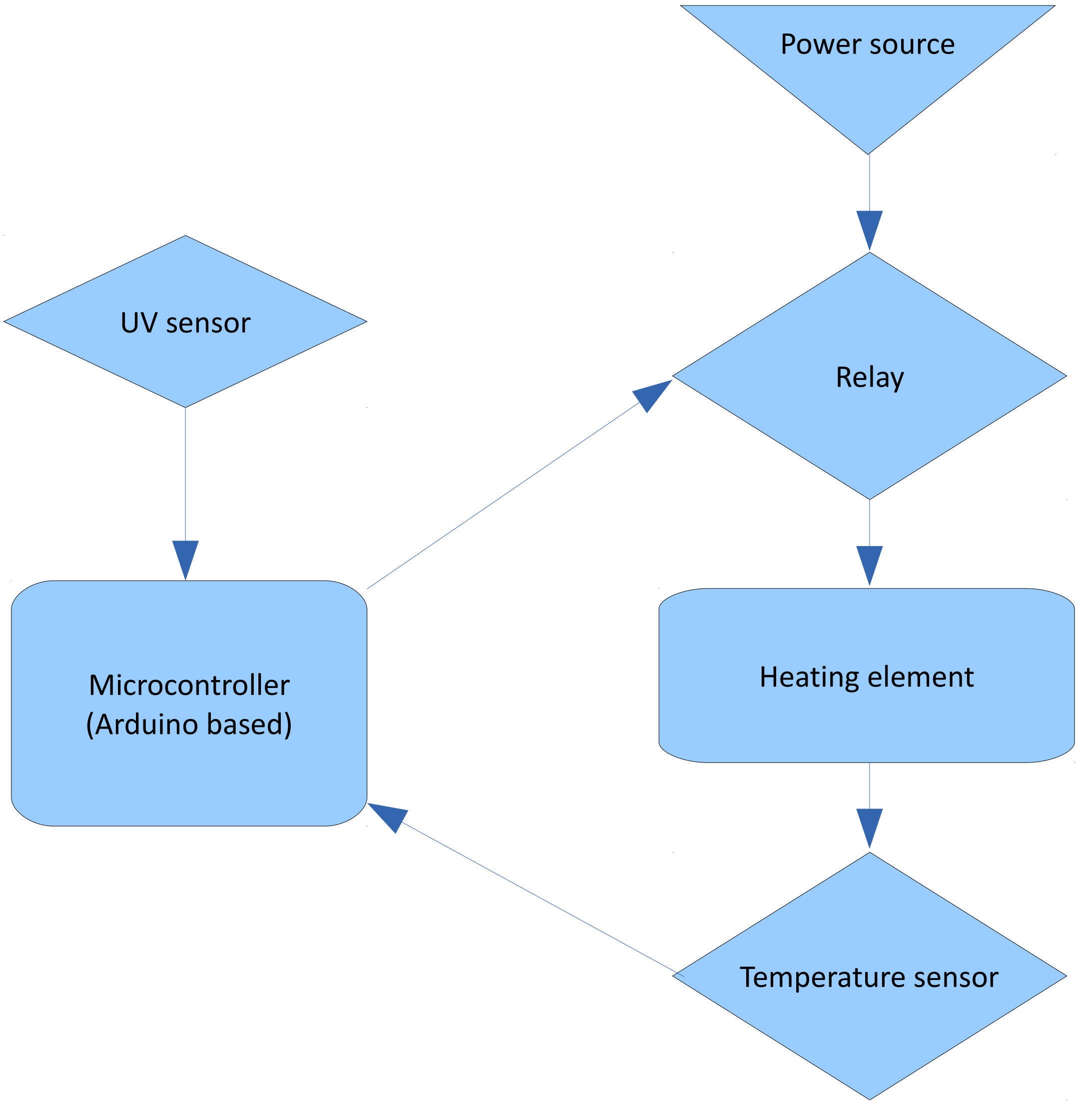


Figure 7: Temperature control system

The radiative heating loss assuming a black body radiation for a box at 37C exposed on all side is 18W. The incoming solar heat flux is around 11W for the smallest cross section and 22W for the largest. Neglecting the convection at float altitude (which seems reasonable for a pressure <10mbars) and considering some basic insulation, 10W should be sufficient to keep our samples at 37C.

The heating itself will be regulated with a solid state relay driving current through a simple cable chosen for its appropriate resistance to limit the draw to 10W (0.33A at

30V). A feedback will be provided by a thermocouple and managed by a simple microcontroller. A safety fuse will be implemented to prevent any over current or damage to HASP internal fuse.

Sensors

Since the amount of UV radiation is one of big factor in microbial growth a UV sensor will be put under the quartz window to monitor the radiation received. The altitude will also be recorded from the GPS. The pressure and temperature on the outside will be recorded by the HASP sensor as they are considered both more accurate and more reliable.

Temperature as well as the average duty cycle for the relay triggering and UV data will be send back to the ground via the serial connection. An option to purely cut the heating system will be implemented in case of malfunction.

Preliminary mechanical design

The preliminary design for the heated racks is the following:

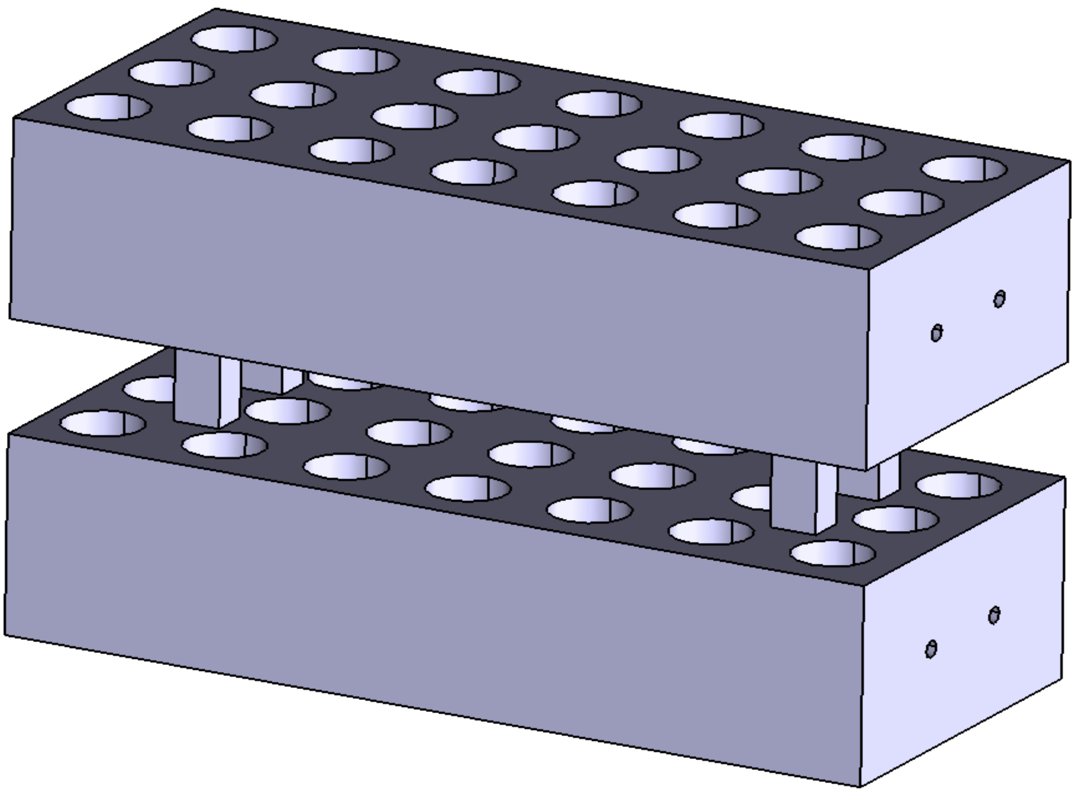


Figure 8: Heated rack concept

On the right you can see the holes going through the whole rack dedicated to the heating elements. A layer of insulation will be wrapped around it. This will be made out of aluminum to minimize weight and maximize heat transfer to the samples.

The unheated racks do not need nearly as much material and will be made out of FRP:

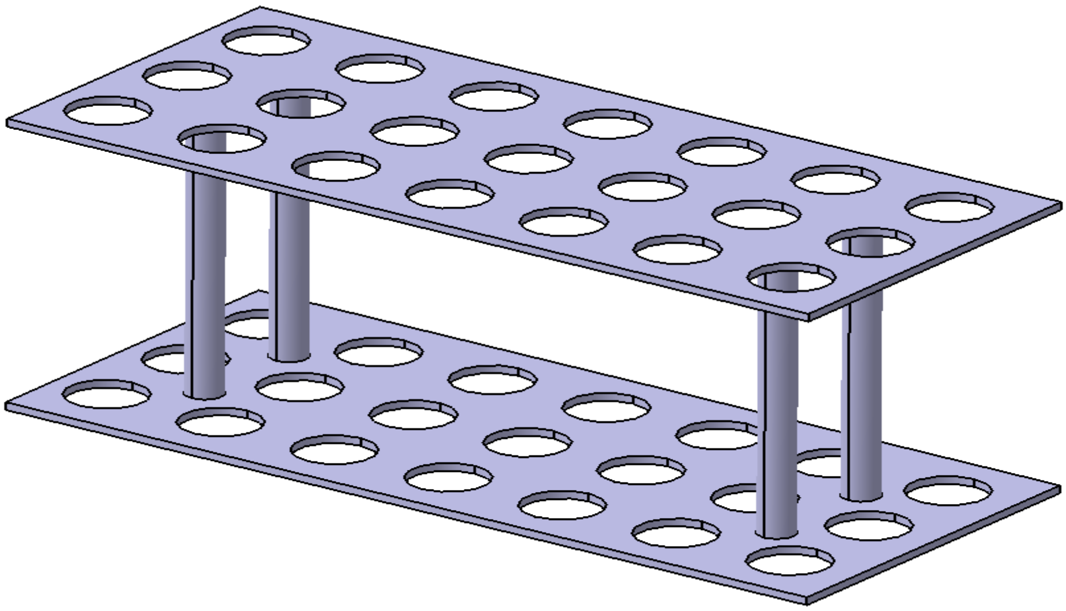


Figure 9: Unheated rack concept

The only requirement for it is to hold the tubes and protect the lower layer from direct light.

5-Structure

5.1 Description

The payload can be divided into two main structural elements: inner aluminum frame and outer FRP shell (FRP stands for Fiber Reinforced Plastic).

The aluminum frame will be responsible for providing structural support for the whole structure, and will thus have to bear the 10g/5g vertical/horizontal shocks; it is directly connected to the baseplate. The lower part of the aluminum frame will contain the main electrical components, such as the circuit boards, Arduino board, battery pack and GoPro cameras. The upper part of the aluminum frame will contain the Biology experiment with its top covered by a window made of quartz. The design of the racks used to hold the test tubes is described in the previous part. For clarity of the model, a simplified version is used in the following representations.

The attachment points will consist in small aluminum tabs spot soldered to the frame.

The FRP shell will be responsible of protecting the inner components of the payload from radiation as well as from the environment and foreign objects. The use of FRP as the main material of the shell will minimize heat absorption from the sun's rays, due to the low heat conductivity of the material. The shell will also provide support for the solar panels, and its upper part will have an opening to allow light from the sun to reach the upper part of the biology experiment. A hole will also be drilled close to the bottom on one of the sides of the shell to allow the camera to get a view from the outside.

Preliminary design drawings

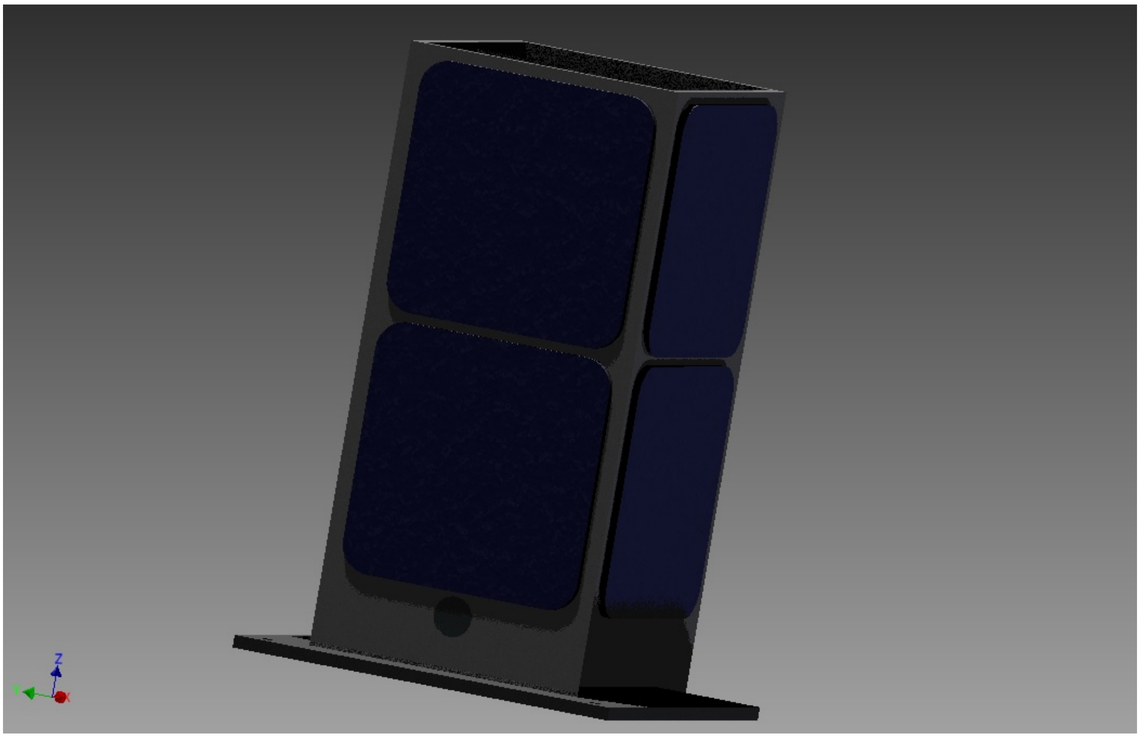


Figure 10: Payload exterior

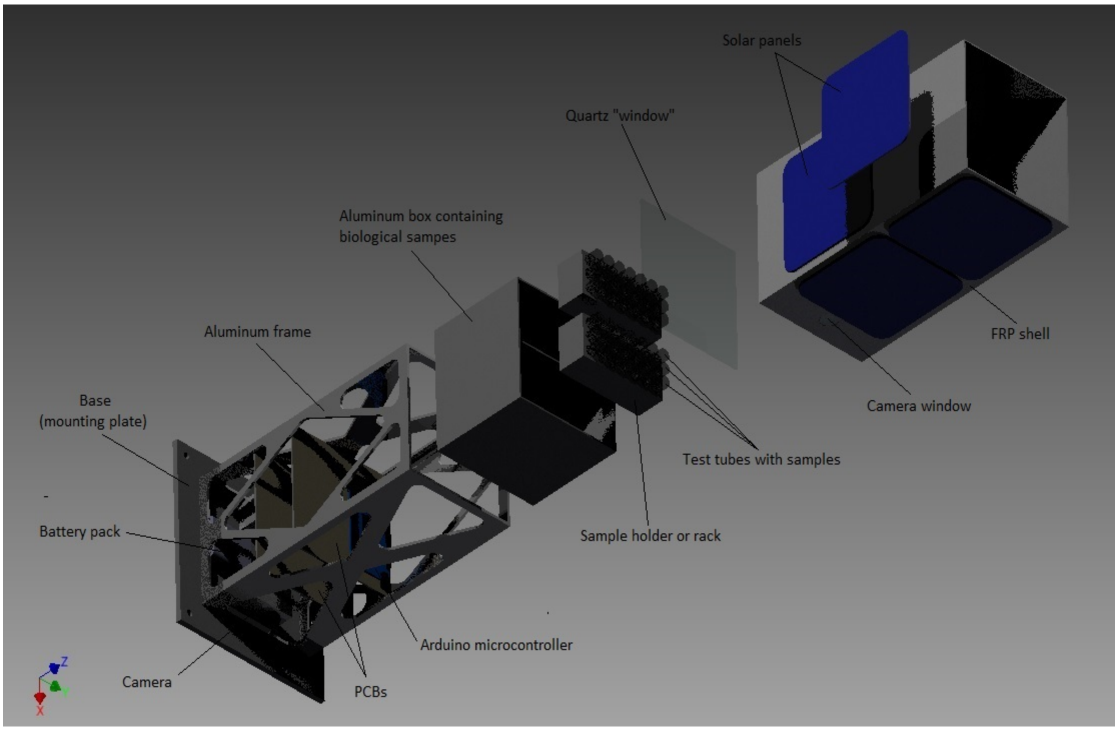
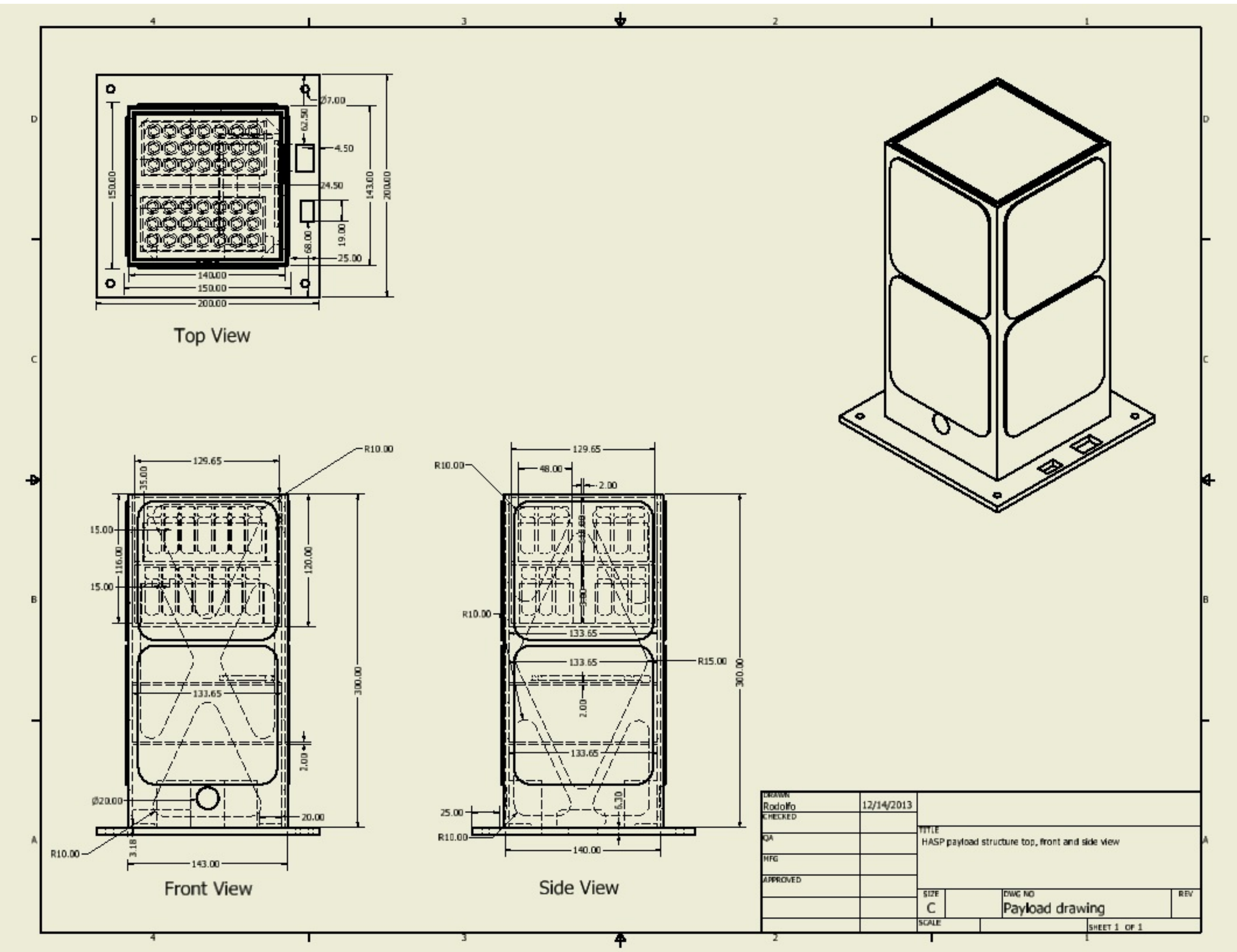


Figure 11: Payload, exploded view



5.2 Stress analysis

A preliminary stress analysis of the aluminum frame done using Autodesk Inventor as the simulation platform revealed the following results for the 10g vertical shock and 5g horizontal shock:

10g vertical shock

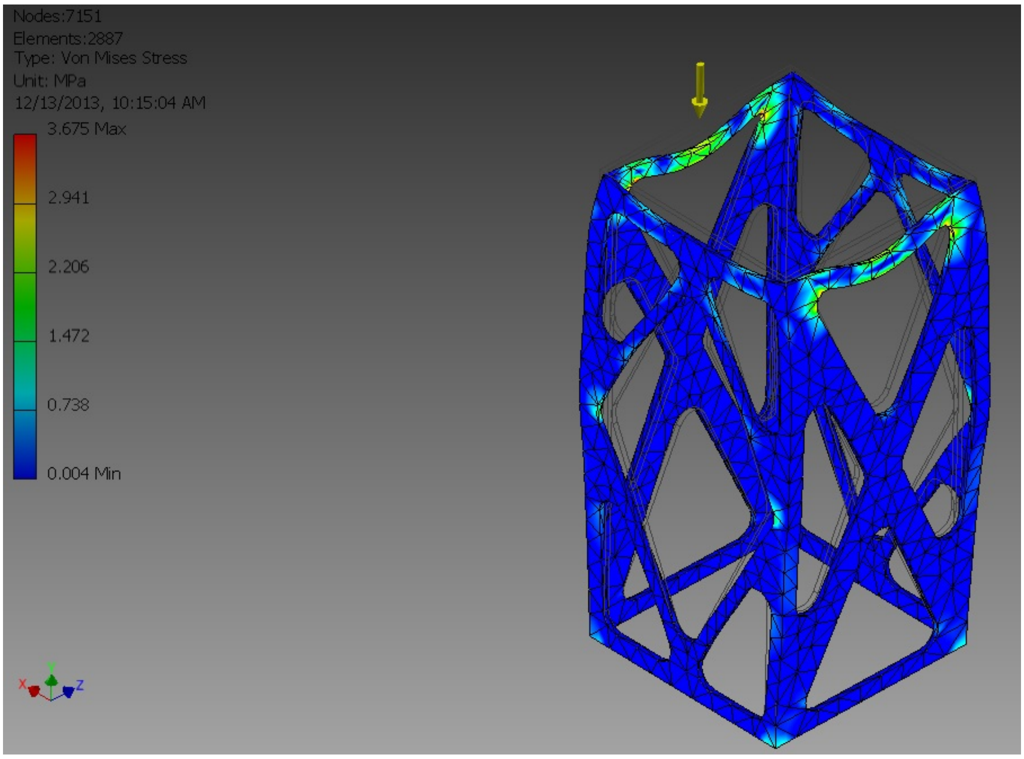


Figure 12: 30Kg vertical load

Knowing that the yield strength for pure aluminum is between 7-11 MPa, we can see that the structure should remain intact if such an event happened, since the maximum stress is of only 3.675 MPa. The yield strength of the aluminum type to be used is around 55 MPa, which gives a large safety margin. Note that these calculations are made assuming that the payload has a mass of 3kg.

5g horizontal shock

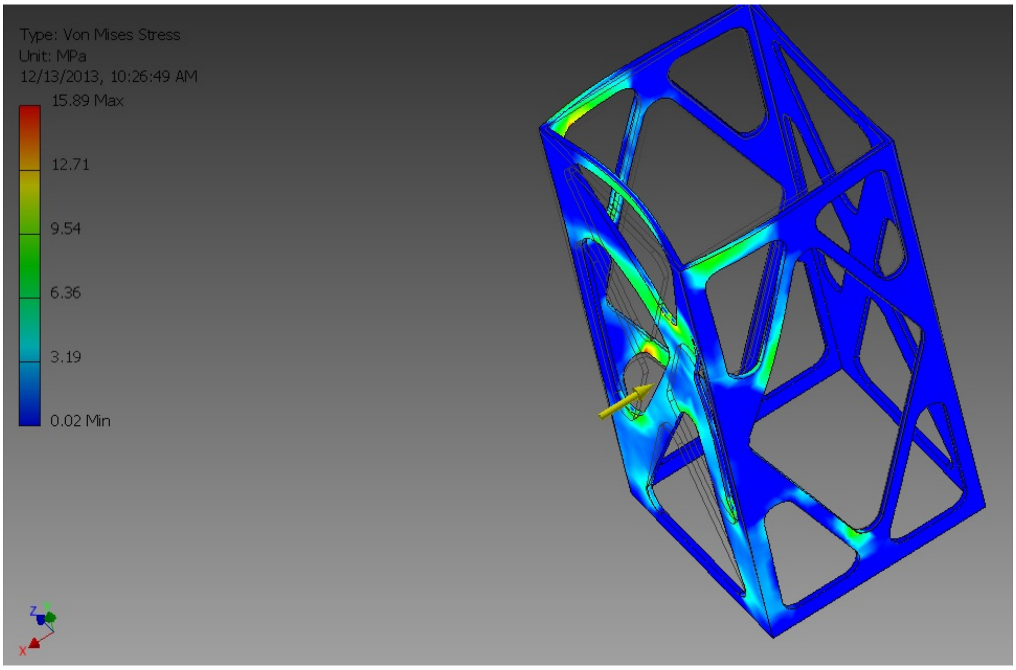


Figure 13: 15Kg horizontal load (middle section)

In the case of a 5g horizontal shock concentrated on one of the walls of the aluminum frame, the stress reaches a considerably higher maximum stress of 15.89 MPa, but is still far from being compromising.

For the worst case possible, assuming the 5g horizontal load is concentrated at the top of the frame, we get the following results:

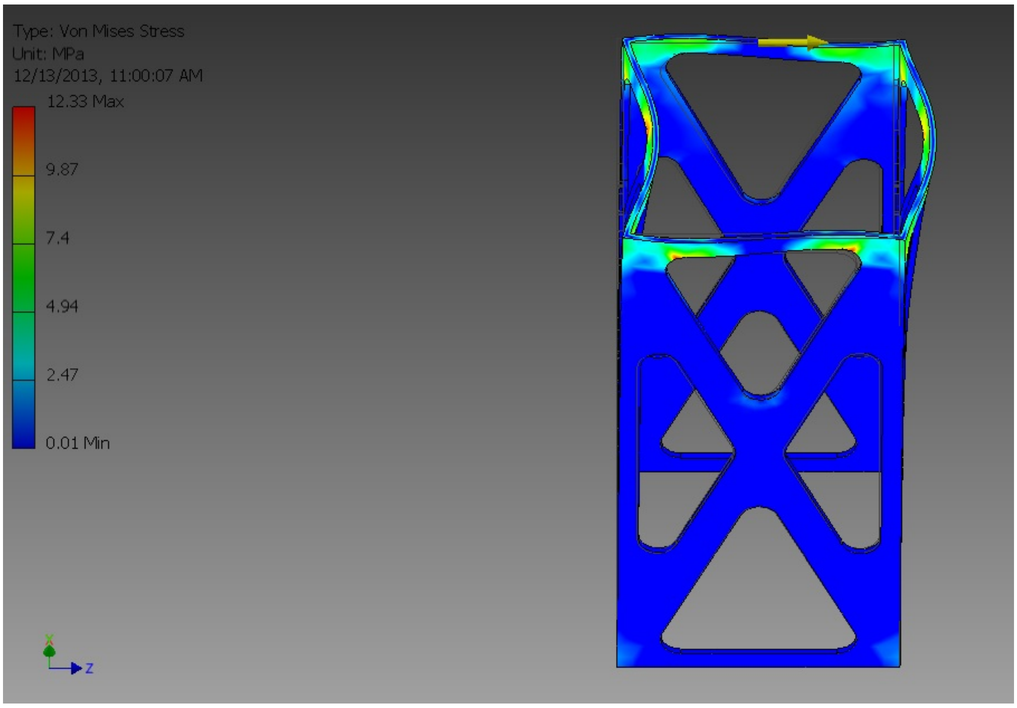


Figure 14: Figure 13: 15Kg horizontal load (top section)

5.3 Weight Budget

The list of components of the payload and their corresponding mass are as follows:

reference	unit weight	quantity	total weight (g)
batteries	80.00	1.00	80.00
gopro	75.00	2.00	150.00
PCB board	80.00	2.00	160.00
solar panels	8.12	8.00	64.92
bio container unheated	46.45	2.00	92.90
bio container heated	462.24	2.00	924.49
quartz window	152.88	1.00	152.88
tubes	5.00	84.00	420.00
frp	115.20	4.00	460.80
aluminum structure	286.74	1.00	286.74
misc			200.00
Total (g)			2992.73

The estimated total of 2792.73g puts the payload below the 3000g limit and leaves us 200g available for miscellaneous components. Further weight reduction is planned through the use of a smaller amount of FRP for the outer shell

6-Data Transmission

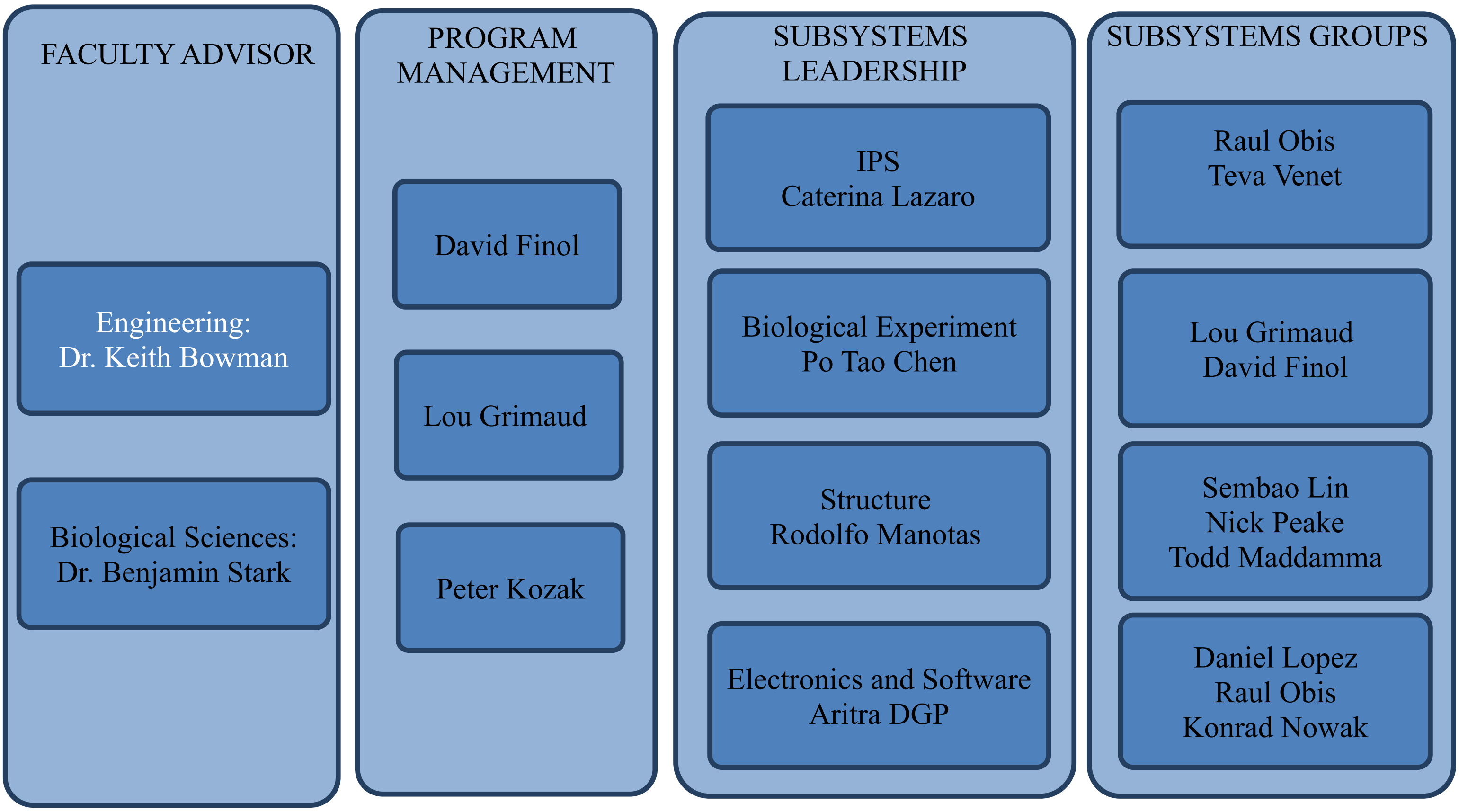
From last year flight we have determined that the data transmission is very reliable and therefore we do not feel the need to include any on-board data storage. The data transmitted will be:

- GPS position and altitude
- Temperature
- Heating system duty cycle
- UV exposure
- Energy production

This small quantity of information will easily fit within the 1200 baud bandwidth.

A few safety commands are planned. These are cutoff commands to ensure that a failing system will not compromise the entire mission. These commands will include cameras shutdown and heating system shutdown as well as a software reset.

7- Team Management, Funding and Schedule



IIT's Ballooning Team is mainly supported by Armour College of Engineering and IIT Student Government Association. Our team has been awarded more than $15,000 in the last two years and our two main sources of funding has already allocated funds for Scarlet Hawk II. The Scarlet Hawk II mission will be led by David Finol with guidance from Dr. Bowman and Dr. Stark. Lou Grimaud is going to lead the overall design of the payload and Peter Kozak is taking care of the expansion for new sources of funding and marketing. Dr. Bowman will provide advisory for the engineering systems while Dr. Stark will be mainly working with the Biological Experiment.

Half of the students currently involved in project are graduates students or are in the last year of a joint program and the other half are mainly undergraduate students. The vast majority of the students are going to be attending IIT in 2014 and more students are going to be added throughout the spring semester.

Schedule

There are nine main critical dates for the entire group but each subsystem has its own internal deadlines. Important dates from both HASP and IIT Calendars are taken into account, such as final exams period and flight date. Using Scarlet Hawk I recommendations (HASP 2013), the schedule was done in such a way to reduce excessive workload and stress on each team as much as possible.

- Research topics and experiment definition(Done by November 15th, 2013)
- Mission Definition and Requirements (Done by December 1st, 2013)
- Final design (Done by December 14th, 2013)
- Application writing (Done by December 18th , 2013)

➢ Biological Experiment
  - External Structure Building (Done by January 31st, 2014)
  - Internal Holding mechanism building (Done by Febrary 28th, 2014)
  - Temperature Control System Building (Done by March 28th, 2014)
  - Independent Subsystem Testing (Done by April 18th, 2014)

➢ Independent Power System
  - Solar cells size adjustment and distribution (Done by January 31st, 2014)
    - ✓ Maximum Power Point Tracker building(Done by February 21st, 2014)
    - ✓ Prototype circuit building(Done by March 7th, 2014)
    - ✓ Assembly of final subsystem (Done by March 28th, 2014)
    - ✓ Independent Subsystem Testing (Done by April 18th, 2014)

➢ Structure
    - ✓ Main Aluminum Frame Building (Done by February 21st, 2014)
    - ✓ FRP Shields Building (Done by March 7th, 2014)
    - ✓ Internal Structure Building (Done by April 4th, 2014)
    - ✓ Heating Management Testing (Done by June 6th, 2014)

➢ Electronics and Software
  - Preliminary design of the code for each subsystem (Done by Febrary 7th, 2014)
  - Data Storage, downlink and uplink (Done by Febrary 14th, 2014)
  - PCB manufacturing for each subsystem (Done by Febrary 28th, 2014)
  - Independent code testing for each subsystem (Done by Febrary 28th, 2014)
  - PCB Testing (Done by March 7th, 2014)
  - Integration of PCB with electrical components(Done by March 14th, 2014)
    - ✓ Final code for the Payload (Done by March 28th, 2014)
    - ✓ Code Testing and Improvement (Done by June 27th, 2014)
  - ➢ Preliminary Payload Integration (Done by June 15th, 2014)
  - ➢ Testing and Improvement of the entire payload (Done by July 15th, 2014)
  - ➢ Target launch date and flight operations (On September 1st, 2014)
  - ➢ Data analysis (Done by November 1st, 2014)

➢ Final Science Report (Done by December 12th, 2014)