



2014 HASP Proposal: Scarlet Hawk - III





HASP Student Payload Application for 2015

Payload Title:		Scarlet Hawk III	
Payload Class: (check one) <input checked="" type="checkbox"/> Small <input type="checkbox"/> Large		Institution: Illinois Institute of Technology	Submit Date: 12/19/2014
<p>Project Abstract</p> <p>Every year, the HASP program offers an opportunity for students to design, build and test a payload for stratospheric balloon flight. After a successful mission at end-of-summer 2014, IIT's AIAA chapter is submitting a new application for the 2015 mission. Our proposal includes a main engineering experiment: a communication system between our payload and a ground-station. Learning from last year's mission, we also designed a new version of the same structure. Adding some elements into the structure, we came up with a more robust and reliable frame. Furthermore, we chose to implement a compartment to both secure locate all electronics boards but also allow an easy access to any of their components (in case a replacement is needed). We hope to have found a structure to be used in our future missions. With the implementation of this new structural design and an autonomous communication, we hope to get closer to a CubeSat mission—our long-term goal.</p>			
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Outline

Outline	4
Introduction	4
General Principle of Operations	5
Overall System Design	5
Objectives	6
Technical Experiment: Communication System	7
Description of the system	7
Principles of operation	7
Implementation	11
Electronic System	16
Description	16
Schematics	16
Power Consumption	17
Power budget	17
Structure	18
Description	18
Stress analysis	22
Weight budget	26
Data Transmission	27
Serial Port	27
Communication System	28
Team management, Funding and Schedule	30

Introduction

IIT's Ballooning Team is formally part of the local student chapter of the American Institute of Aeronautics and Astronautics (AIAA). AIAA-IIT's executive board is democratically elected by the student body and allocates funds to student-managed groups for engineering projects. This chapter's support has allowed IIT'S Ballooning Team to complete three full payloads.

These efforts began in 2012 with only a couple students, both of whom had very little ballooning experience. Two years of work yielded the Scarlet Hawk I, a small payload that flew in HASP 2013.

After that successful mission, our chapter decided to look toward bigger goals. Not only did we further develop the high-altitude ballooning program on campus, but we began work on CubeSats for the near future. This led to the building of Scarlet Hawk II, which mixed our past experiences in ballooning with our future plans for a CubeSat program. This small payload implemented a solar powered autonomous energy system, which flew in HASP 2014. The Scarlet Hawk III is our follow-up to those projects. We will be building a communication system to connect our payload to a ground station, through which we can monitor and control its functions—gathering general telemetry data, taking pictures, etc.

The design of this payload involved the collaboration of students from two different departments—the Mechanical, Materials department and Aerospace Engineering department, and the department of Electrical and Computer Engineering. We seek to further the technical knowledge of our team and strengthen research and implementation abilities on future high-altitude ballooning and CubeSat missions.

General Principle of Operations

Overall System Design

As mentioned, this mission will include the implementation of a communications system, based in satellite communications, able to connect to our ground station (located in the launching point) throughout the whole flight. Furthermore, the system will be testing the performance of various frequencies and modulations, the best combination of which will be chosen at each given moment. The information transmitted will come from a collection of sensors, recording the environmental conditions of the payload—temperature, pressure, humidity, etc.). There will also be a camera taking pictures throughout the flight.

Additionally, we have implemented a control system, which will monitor and secure the integrity of the experiment. The payload will continuously control the components of the system and send necessary information through the downlink. If some failure is detected, we can correct the behavior, or shut it down completely if necessary. This control system will allow us to change the parameters of the communication system in case no connection can be established.

In the following figure, we see the connection block diagram of our system. It presents a receiver/transmitter configuration, where the payload acts as a passive receiver. That said, both the payload and the ground station will be configured so that each may act as receiver and transmitter.

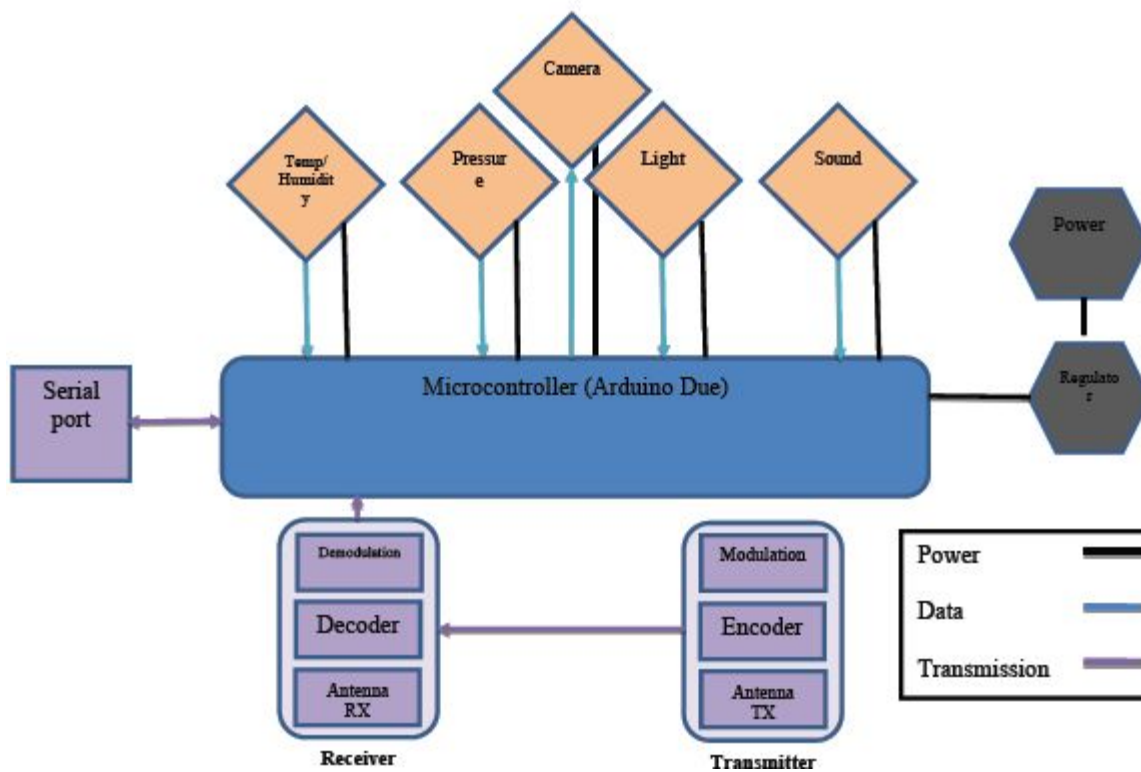


Figure 1. Connections block diagram

Objectives

- Test performance of modulations commonly used in CubeSat missions.
- Check results when using other modulations.
- Implement FEC (Forward Error Correction) techniques and get BER (Bit Error Rate) improvement while using this feature.
- Measure antenna radiation pattern and gain and compare them with the theoretical values.
- Provide reliable communication with an acceptable BER between ground station and the payload.
- Autonomously monitor the performance of the power consumption and behavior of every critical component of the system. Be able to shut down any malfunctioning device which might compromise the results of the whole mission.
- Monitor the environmental conditions of our payload (temperature, pressure and humidity values).

Technical Experiment: Communication System

1. Description of the system

IIT will implement its own communication system in the HASP 2015 venture. The purpose of this experimental subsystem is to test a communication link between IIT's payload, but it also reaches to a higher objective: a future autonomous CubeSat mission. The communication system is one of the essential parts in any satellite mission, its main objective to provide data exchange between the satellite and ground station, all this with minimum reliability on the NASA system.

In this experiment we would like to use varied frequencies and communication channel configurations. We will obtain assorted data from the performance of each configuration in all frequencies assigned to our project; this will help us select the configurations best suited to a future mission.

2. Principles of operation

The prospective communication channel is OFDM (Orthogonal Frequency Division Multiplex). Not many CubeSat satellites implement OFDM, which makes it ideal for such an experiment. It provides great bandwidth efficiency and is optimized for different data-sending channels. Along with OFDM, we've opted for 4-QAM (Quadrature Amplitude Modulation) as the main configuration.

For other channel conditions—such as high frequency noise frequencies or attenuation—we would remain on 4-QAM, or change to a DBPSK (Differential Binary Phase Shift Key) and remove the OFDM system. This would help prevent possible interference between channels. The aim of such a change is to maintain the communication between the payload and the ground station (when noise conditions are worse, changes have to be made in order to gain reliability on the link by losing efficiency). Also by using a differential phase modulation we can avoid inadvertent phase shifts.

For each data stream we will perform a channel coding before modulation. By performing FEC techniques at the receiver, we can decrease the BER, thereby adding redundant bits to the original stream and protecting it from possible errors. Again, various coding schemes will be tested to register experimental data about the error rate difference, specifically between raw data (that is, without channel encoding) and coded data.

As we stated, our main objective is to check the efficiency of OFDM in this setting, specifically its reliability for such FEC techniques. The data transmitted will be twofold: telemetry read from sensors within the payload, and bit streams testing, both to provide useful information about our communication link.

Our modulation scheme decisions are rooted in simplicity; the power of the signal emitted by the antenna could be low (below 2W), and depending on height and atmosphere conditions, a dense modulation could cause high error rate. Since this experiment is a predecessor for a future CubeSat communication system, we must take into account the operational factors of that mission, such as actual height and power conditions. Apart from the two modulations mentioned before, we would use a few additional for the two schemes provided (with and without OFDM), for the purpose of testing. We will try to use modulations with even more symbols, if the power and noise restrictions allow it.

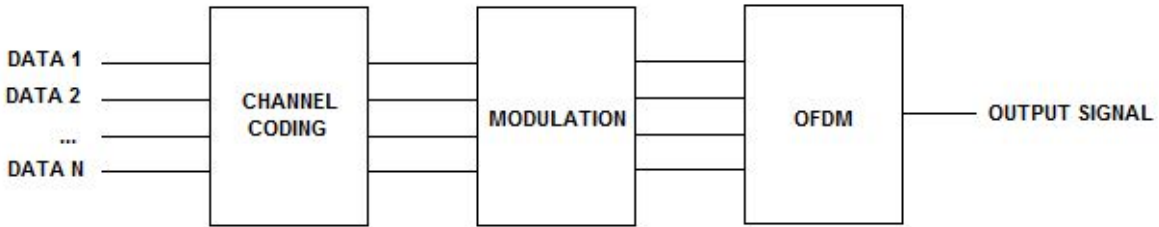


Figure 2. Main Configuration

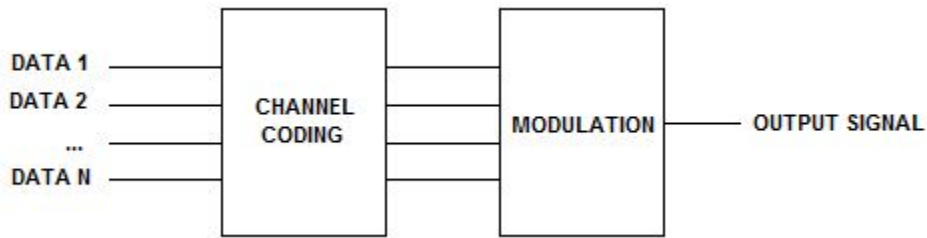


Figure 3. Secondary configuration

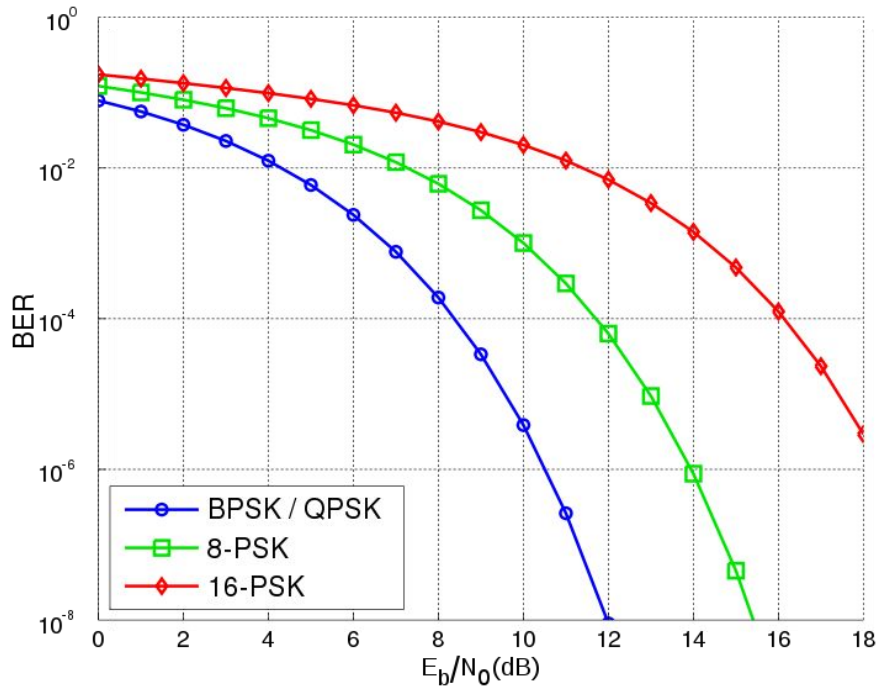


Figure 4. Theoretical BER for different PSK modulations

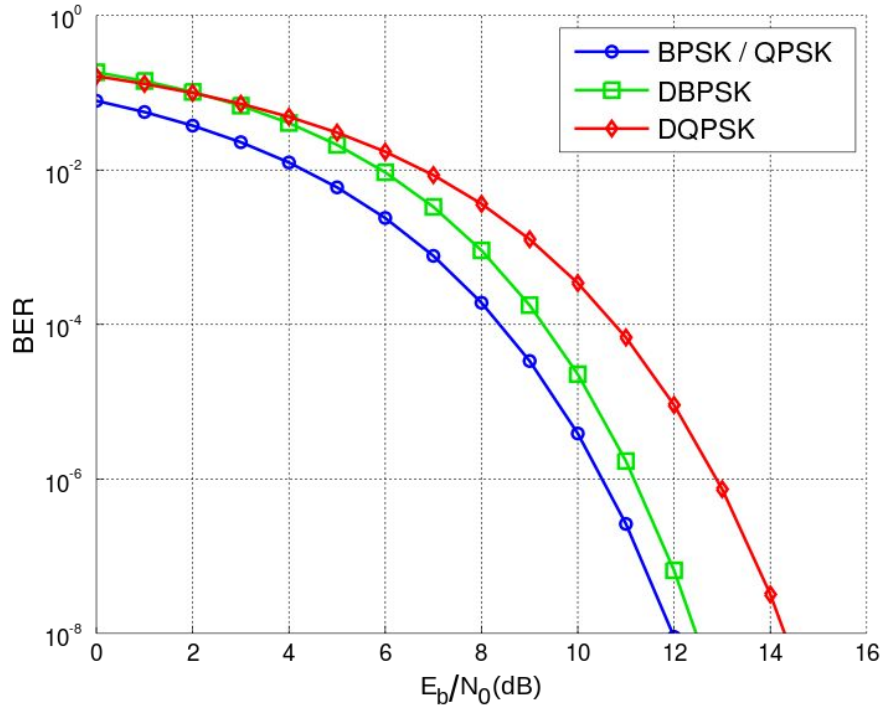


Figure 5. Theoretical BER for BPSK, QPSK and their differential versions

2.1. Propagation analysis

In this section, we will approximate the receiving power, which can be used to adjust the sensibility and transmission power of our system. Generally, we want to maximize sensibility and to minimize transmission power. To obtain this received power, we need to first analyze the surrounding environment and general conditions of the flight, set an initial transmitting power and perform some basic propagation calculations.

General Conditions

Using data from prior missions, we aim to approximate the surrounding and general conditions of the payload during flight. With this analysis we will obtain the altitude, maximum horizontal distance and general location.

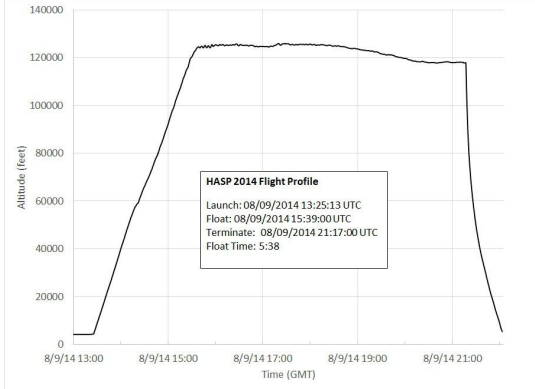


Fig. 6. HASP 2014 Flight Profile

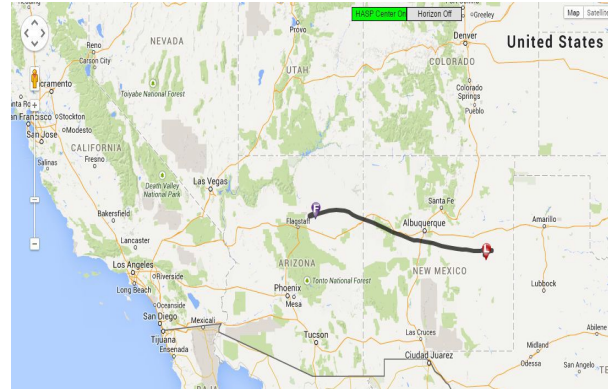


Fig. 7. HASP 2014 Flight Map

The general flying altitude, as shown in Fig. 6., is 120,000 ft (equal to 36.576 km). From Fig. 7, we see that the regions we need to consider during the flight are New Mexico, Arizona and Colorado. We will also approximate maximum horizontal distance, as judged from mobile payload and the static ground station. This horizontal maximum distance is reached at the end of the flight. Our prior flight data indicates a the total flight distance of 465.83 miles (749.680716 km) and 520.41 miles (837.51871km) in 2014 and 2014 respectively. We will use the greater value.

Combining the flying altitude and the maximum distance, we obtain a maximum distance, which will be used in the propagation analysis

$$\text{Maximum Distance} = \sqrt{\text{Flying Altitude}^2 + \text{Horizontal Distance}^2} = 83.2 \text{ km}$$

Transmitter

To characterize the transmitter antenna, we will set a transmitting frequency and power. For the frequency, we will be working in the 70cm-band (420–450 MHz). Among those values, we chose the 437MHz frequency. For power, we chose 1W.

Power balance

A Line Of Sight (LOS) is secured during the entire flight. Consequently, we will be studying the propagation of a radio signal. First, we will consider the free space Losses. Its behavior is determined by the equation:

$$L = \frac{P_t}{P_r} = \frac{(4\pi d)^2}{\lambda^2} = \frac{(4\pi f d)^2}{c^2}$$

$$\begin{aligned}
 L_{dB} &= 10 \log \frac{P_t}{P_r} = 20 \log \left(\frac{4\pi d}{\lambda} \right) \\
 &= -20 \log(\lambda) + 20 \log(d) + 21.98 \text{ dB} \\
 &= 20 \log \left(\frac{4\pi f d}{c} \right) = 20 \log(f) + 20 \log(d) - 147.56 \text{ dB}
 \end{aligned}$$

Next, we will consider the gain of our communication system over highly directive antennas (this gain is represented by the receiver antenna Gain, Gr, and the transmitter antenna gain Gt). The ratio Pt/Pr is now:

$$\frac{P_t}{P_r} = \frac{(4\pi)^2 (d)^2}{G_r G_t \lambda^2} = \frac{(\lambda d)^2}{A_r A_t} = \frac{(cd)^2}{f^2 A_r A_t}$$

$$\begin{aligned}
 L_{dB} &= 20 \log(\lambda) + 20 \log(d) - 10 \log(A_r A_t) \\
 &= -20 \log(f) + 20 \log(d) - 10 \log(A_r A_t) + 169.54 \text{ dB}
 \end{aligned}$$

The atmospheric absorption has not been taken into consideration. It is only relevant for frequencies greater than 5GHz (not our case). Other attenuation factors not considered are the atmospheric absorption, atmospheric refraction, the terrain factors and obstacles.

As a result, we can now express the received power using Friis equations. We only need to satisfy that the distance is much greater than the wave-length. In our model, the distance is 80km, and the wavelength 70cm (80km >> 70cm).

$$\begin{aligned}
 \frac{P_r}{P_t} &= G_t G_r \left(\frac{\lambda}{4\pi R} \right)^2 \\
 P_r &= P_t + G_t + G_r + 20 \log_{10} \left(\frac{\lambda}{4\pi R} \right)
 \end{aligned}$$

Where:

- Pt (power delivered to the transmit antenna) = 1W
- R (distance) = 83.2*10³ m
- f = 437MHz
- λ = 68.65 cm

As the antennas are not fully implemented, Gr and Gt values are still unknown. However, we have calculated the power we will have at reception in two typical cases:

In the first case, we have no antenna gain ($G_t = G_r = 1$). Then, the received power is $P_r = -113.71 \text{ dBm} = 4.25 \times 10^{-15} \text{ W}$

In the second case, we use typical gain values ($G_t = G_r = 44 \text{ dB}$), with a $P_r = -25.7 \text{ dBm} = 2.68 \times 10^{-6} \text{ W}$

We are expecting a received power of around $2.68 \times 10^{-6} \text{ W}$, though we will have the exact theoretical value once the antenna is implemented.

3. Implementation

3.1. Block diagram

The transmit data is received from the Arduino—our data source—through the serial interface of the FPGA. For the Tx operation, the FPGA handles the channel encoding, modulation, and IDFT in order to perform OFDM. The data from the FPGA is output through the serializer to the AD9364, which handles the digital-to-analog conversions and the passband modulation. The output of the AD9364 is sent to a driver/RF Amplifier circuit and is connected to the antenna via Tx/Rx switch. The received signal is passed from the antenna to the Low Noise Amplifier block via the Tx/Rx switch. The output of the LNA is sent to the AD9364 for the passband demodulation and analog-to-digital conversions, and passed to the deserializer of the FPGA. The Rx operation in the FPGA includes the DFT block, demodulators and channel decoding that performs error corrections. The final received data is sent to the Arduino through the serial interface.

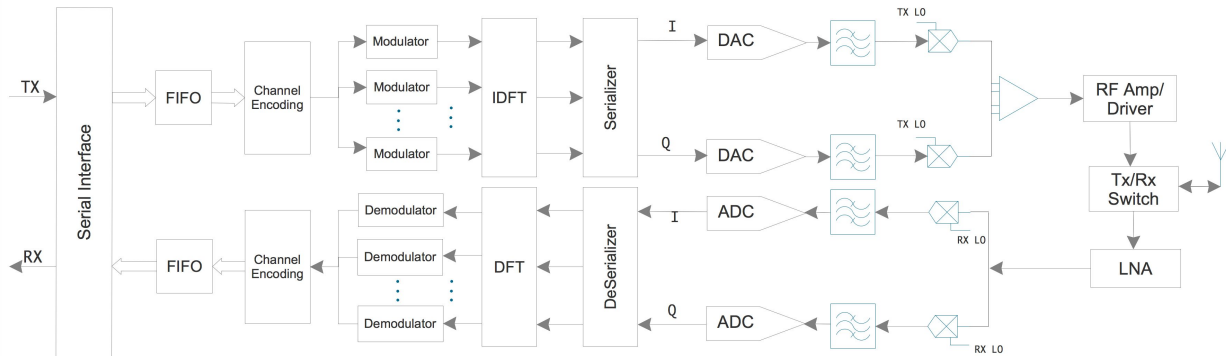


Fig 8. Detailed block diagram

3.2. *Antenna*

CubeSat communications occurs at UHF amateur frequencies because of the readily available worldwide coverage and infrastructure. This provides a reliable method of communication between CubeSat and ground stations, and allows students to focus on other aspects of the CubeSat Project.

A low gain, nearly isotropic antenna is being designed to provide communication regardless of orientation. A dual quarter-wave monopole antenna is selected for its simplicity. It is hoped that by placing two monopoles on perpendicular faces of the cube, a nearly isotropic radiation pattern will be obtained. Monopoles were selected, as they require fewer deployable wires than dipole antennas, while providing roughly the same coverage.

Design and fabrication

The dual quarter-wave monopole antenna is modeled mounted on the CubeSat as shown in Fig 9. This setup is found to have a rather omni-directional radiation pattern, as shown in Fig 10.

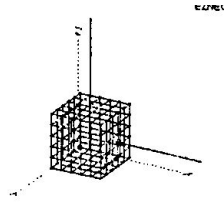


Figure 1: Two quarter-wave monopoles are mounted on the cube to provide a more isotropic radiation pattern.

Fig 9. Two quarter-wave monopoles

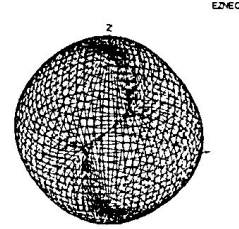


Figure 2: The radiation pattern of two quarter-wave monopoles mounted on perpendicular cube faces has an omnidirectional radiation pattern.

Fig 10. Radiation pattern

The antenna will be constructed using measuring tape, because its elasticity will allow for easy deployment after launch. Since the entire CubeSat must fit in the dimensions 15x15x30cm, a bit of elastic line will be used to secure the antennas around the CubeSat. Then, during deployment, the plastic line will be melted, so that the quarter-wave monopole springs away from the CubeSat and into its operational position. The tape will be stemmed to tune the antenna to 437 MHz. The measuring tape will be rounded at its ends to prevent charge buildup in the vacuum of space.

The final mounting structure for the antenna should be like as shown in Fig 11 and Fig 12. The antennas are recessed behind the cube walls to reduce the stress placed on the SMA-antenna connection when the antennas are wrapped around the CubeSat for launch. The SMA connectors are bolted into aluminum pieces that are also bolted into the CubeSat wall. The antennas were soldered to the SMA inner conductor, and passed through the cube wall. Epoxy will be used to fill the gap between the antennas and the aluminum pieces to prevent the antennas from shorting to the ground plane.

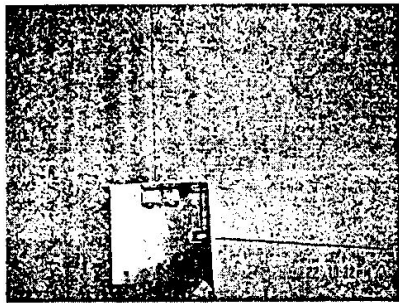


Figure 3: Two quarter-wave monopoles were mounted on perpendicular faces.

Fig 11. In perpendicular faces

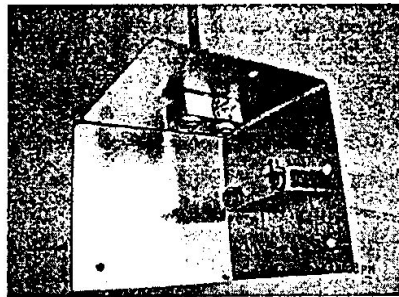


Figure 4: The mounting structures were designed to provide a solid ground connection.

Fig 12. Mounting structure

The two antennas will be connected on perpendicular faces of the cube utilizing a Mini-Circuits SBTC-2-10, 2-way-0° power-splitter.

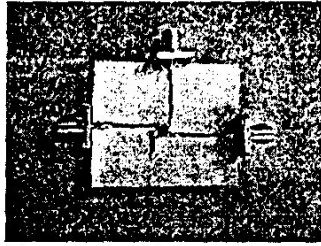


Figure 5: Power is split equally between both antennas with a 0° phase shift.

Fig 13. In perpendicular faces

This type of deployment of monopole antennas is commonly used in all the CubeSat applications. The main reason for this is the easy deployment and better coverage we get.

Reference

[1] Tamamoto, M.A.M., Shiroma, W. Active antennas and UHF antennas for CubeSat applications. University of Hawaii at Manoa.

Electronic System

Description

As we can see in Figure 1, the Arduino Due electronic circuit will be used to manage all the sensors, as well as the data transmission experiment. The four sensors are as follows: temperature and humidity, pressure, light and sound. Through these, we can obtain a complete analysis the payload's surrounding environment. We will also control the temperature and the current of our circuit to avoid internal damages. Apart from the sensors, there is also a HackHD Camera, which will capture photos throughout the trip.

The power provided by NASA is converted with a voltage regulator and connected to Arduino, which will distribute it later to the sensors. To supply the power from Arduino, we will use both, the 3.3 V and the 5V pins, each used respectively depending sensor demand.

Schematics

The next figure is the schematic of the circuit, where you'll find a representation of all connections:

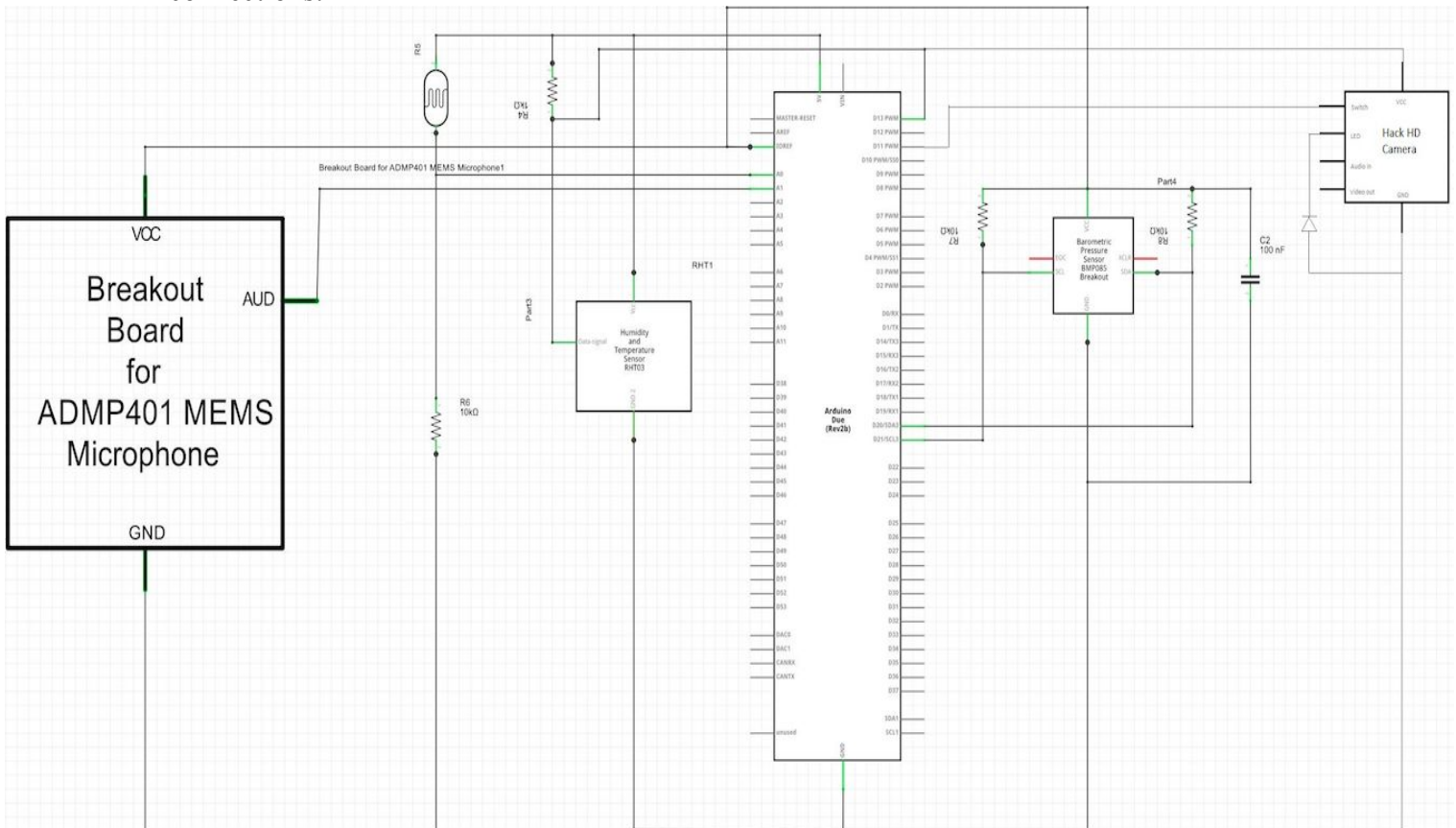


Figure 14. Electronic circuit schematic

Power Consumption

The power budgets for individual components (sensors and camera) were calculated by finding the voltage usage of each component, and thus the constant current in amperes. Multiplying the amperes of current by the volts gave us an approximation for hourly power consumption (watts). We used a current cost of 1000 watts an hour, finding the cumulative cost for all the components running simultaneously for one hour. And using the range for some components of possible voltage and current values, a maximum and minimum power consumption value was found. It is now also known which components are the most and least cost- and power-efficient. Table 1 on the following page shows the overall power consumption:

Sensors	Voltage	Current	Power
Temperature & Humidity (RHT03)	2.3-5.5 V	Sleep: 0.6 uA Supply: 0.65 mA	Min: 1.38 uW Max: 3.575 mW
Camera (Hack HD)	3.7-5.5 V	1.1 Ah	Min: 1.13 mW Max: 1.68 mW
Light sensor (LDR)	3.3-5 V	0.07-4.5 mA	Min: 0.231 mW Max: 22.5 mW
Sound sensor (ADMP401)	1.5-3.3 V	250 uA	Min: 0.375 mW Max: 0.825 mW
Pressure sensor (BMP085)	1.8-3.6 V	Low power: 3 uA High resol.: 12uA	Min: 5.4 uW Max: 43.2 uW
Arduino Due	7-12 V	0.2 mA	Min: 0.14 mA Max: 2.4 W
LNA	3V 5V	30mA 60mA	Min; 0.9 mW Max: 3 W
Power Amplifier	-	-	Disipation: 1.9 W
FPGA board	-	-	1.9 W
Transceiver board (ADC)	1.3V	490mA	0.637 W
Antenna	-	-	5 W
TOTAL	-	-	Min: 6.411 W Max: 43.46 W

Table 1. Overall power consumption

Structure

Description

The payload can be divided into three primary structural elements—the outer shell, the aluminum frame, and the component housing case. The outer shell will be composed of CFRP (Carbon Fiber Reinforced Plastic), a material with low thermal conductivity to minimize heat absorption under high-altitude conditions. The shell will also protect the inner components against radiation, frigid temperatures, and debris.

The metal frame is composed of extruded aluminum 6061 L-brackets, all attached with 2-64 screws (the welding together of last year's aluminum plates was a real struggle and we're trying to prevent similar issues). The L-brackets provide shelving for internal X-plates, which offer additional support against horizontal shock; they also subdivide the frame into three internal compartments—the top and bottom for cameras, sensors, and antenna adapters, and a middle section, where the removable housing case lives. The housing case, composed of glued ABS plastic, includes shelving for the various circuit boards.

The aluminum frame is constrained to the baseplate by small aluminum tabs spot-soldered to the frame.

Attached to the outer frame will be the two antennas of the communication system. They will be located in two adjacent faces, in the middle. Each antenna is perpendicular to its face and has a length of 17cm (exceeding the maximum dimensions of a small payload). Both the side and the orientation are required in order to guarantee a correct communication payload-ground: the 17 cm are given by the frequency range whereas the orientation generates the optimal propagation diagram.

For clarity of the model, a simplified version is used in the following representations (not including the antennas, for instance).

Preliminary Design Drawings

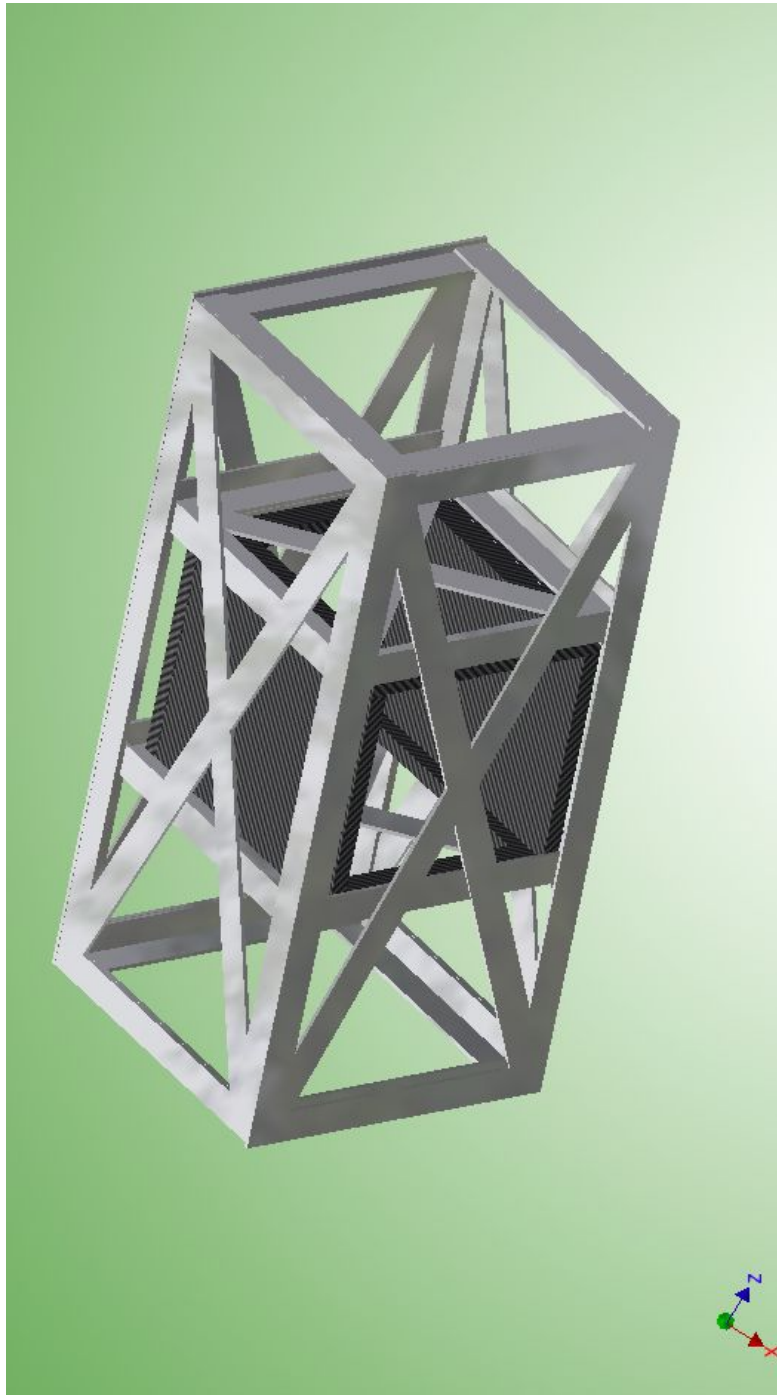


Figure 15. Frame, full view

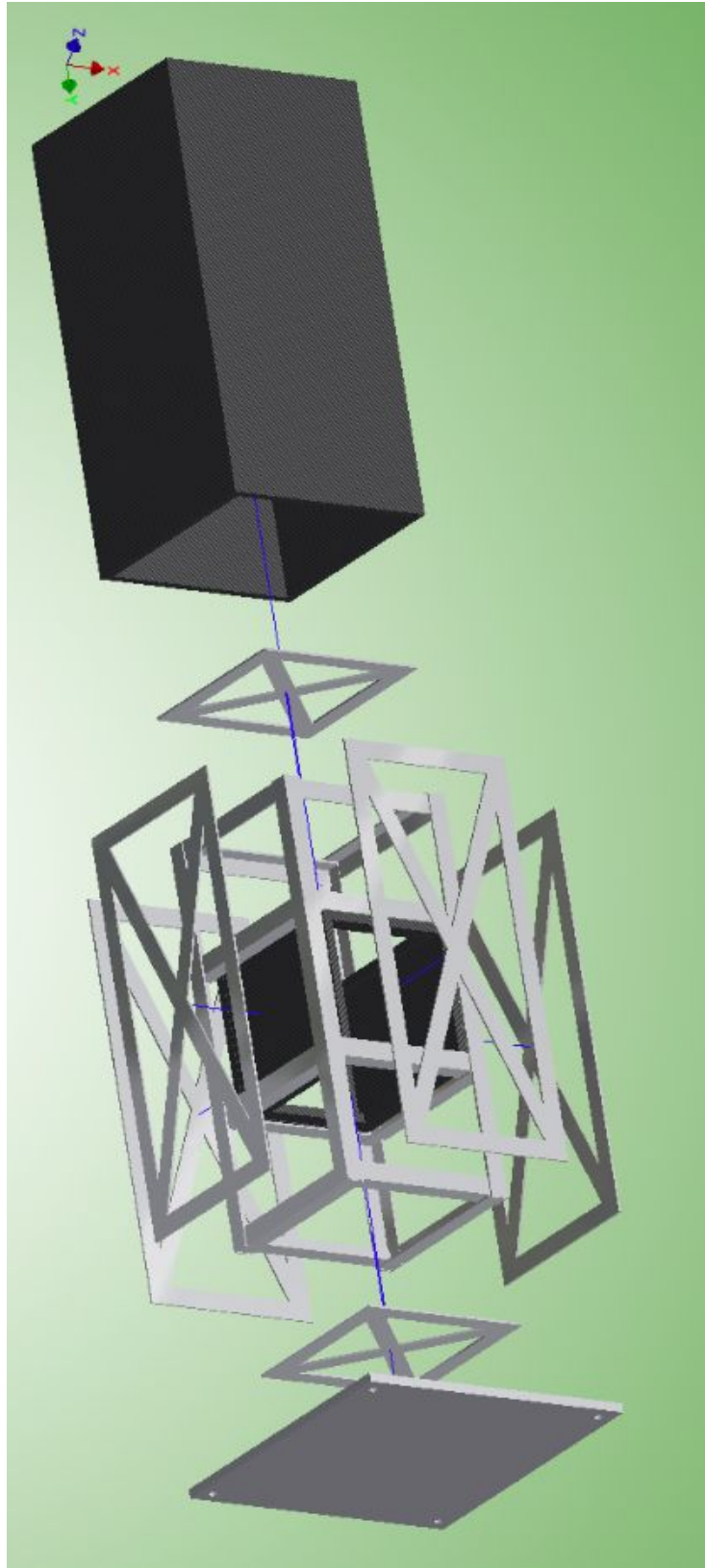


Figure 16. Full structure, exploded view

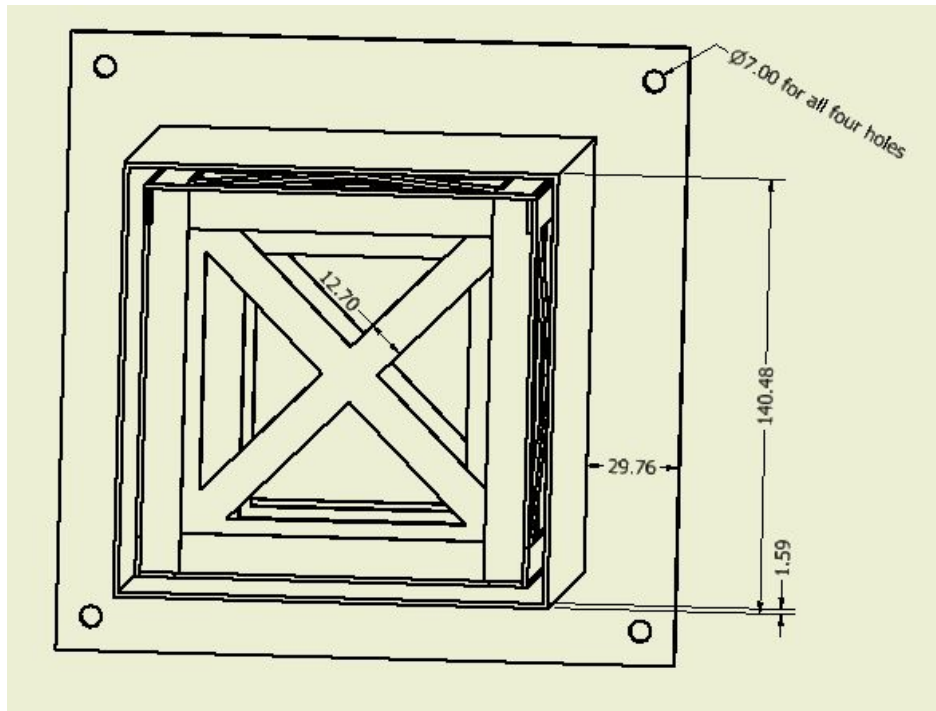


Figure 17. top 2D representation w/ dimensions (mm)

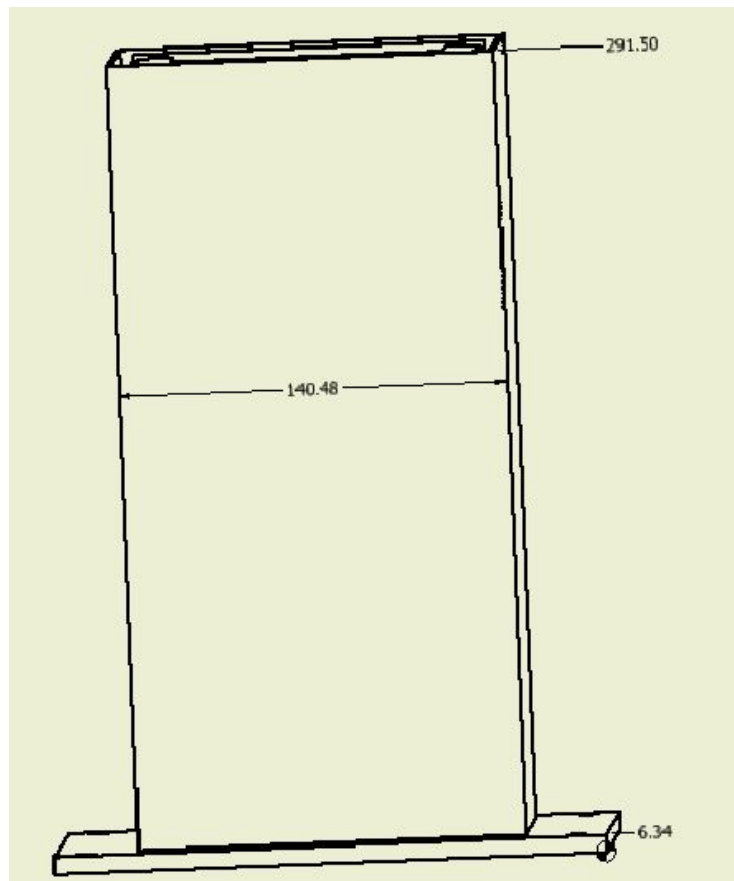


Figure 18. side 2D representation w/ dimensions (mm)

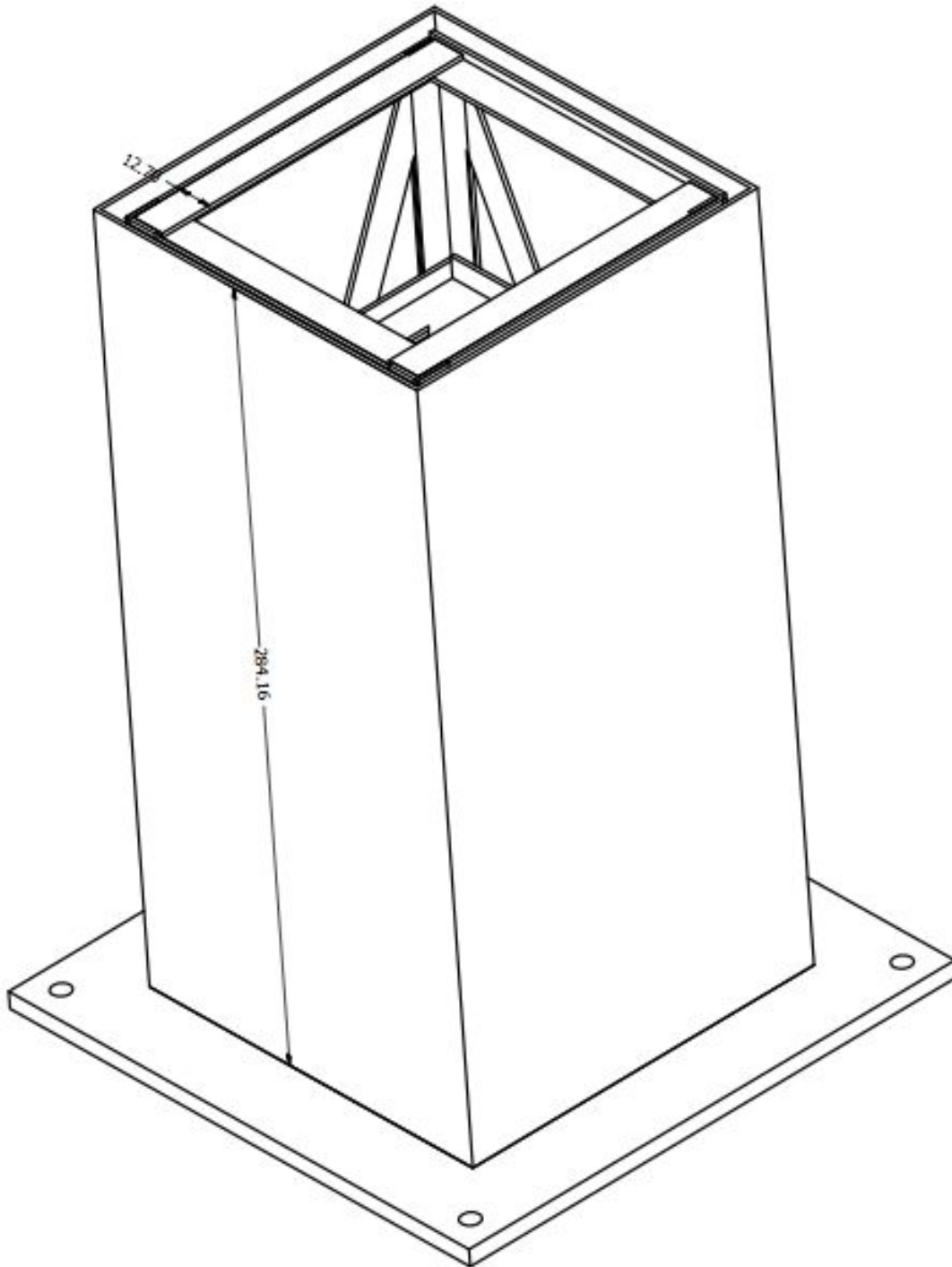


Figure 19. angled 2D representation w/ dimensions (mm)

Stress analysis

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

5 G Horizontal Stress (150 N, 15 kg):

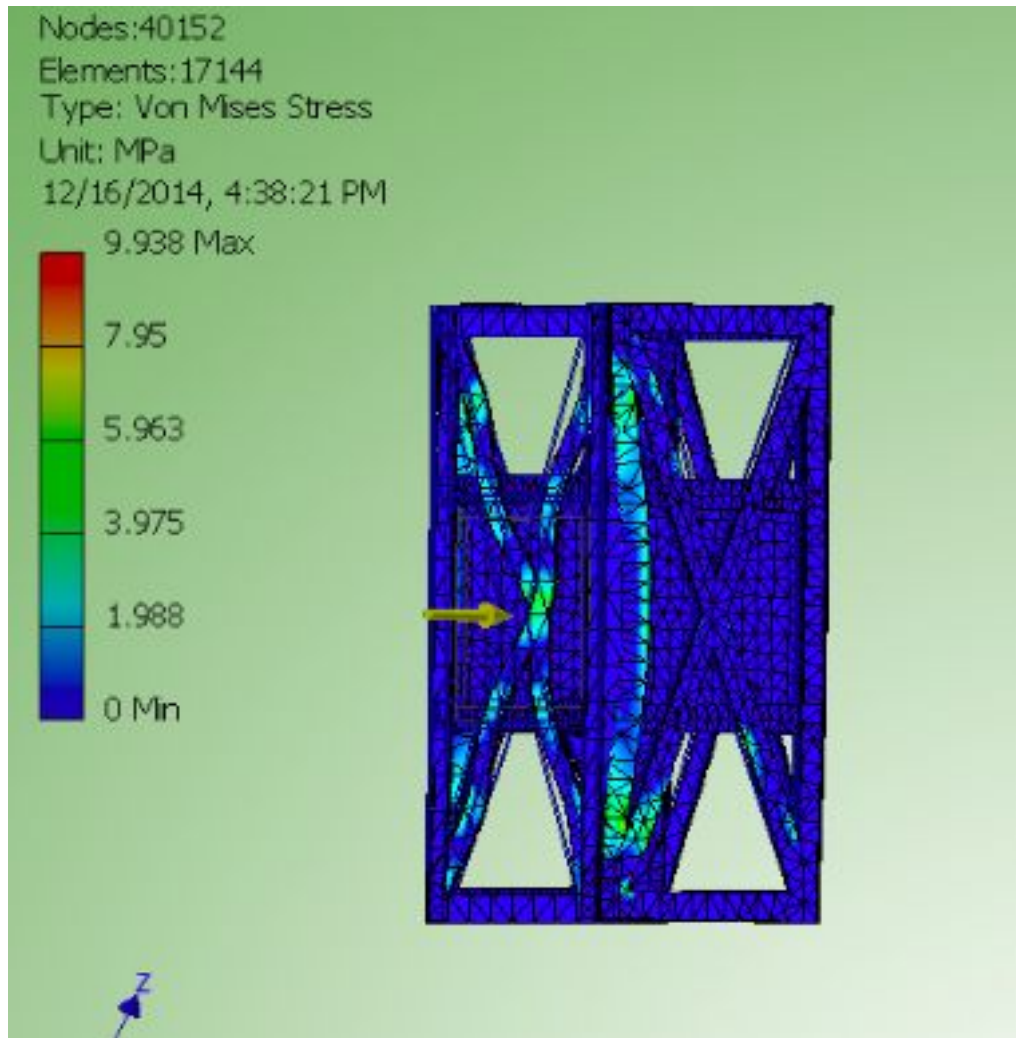


Figure 20. Horizontal stress

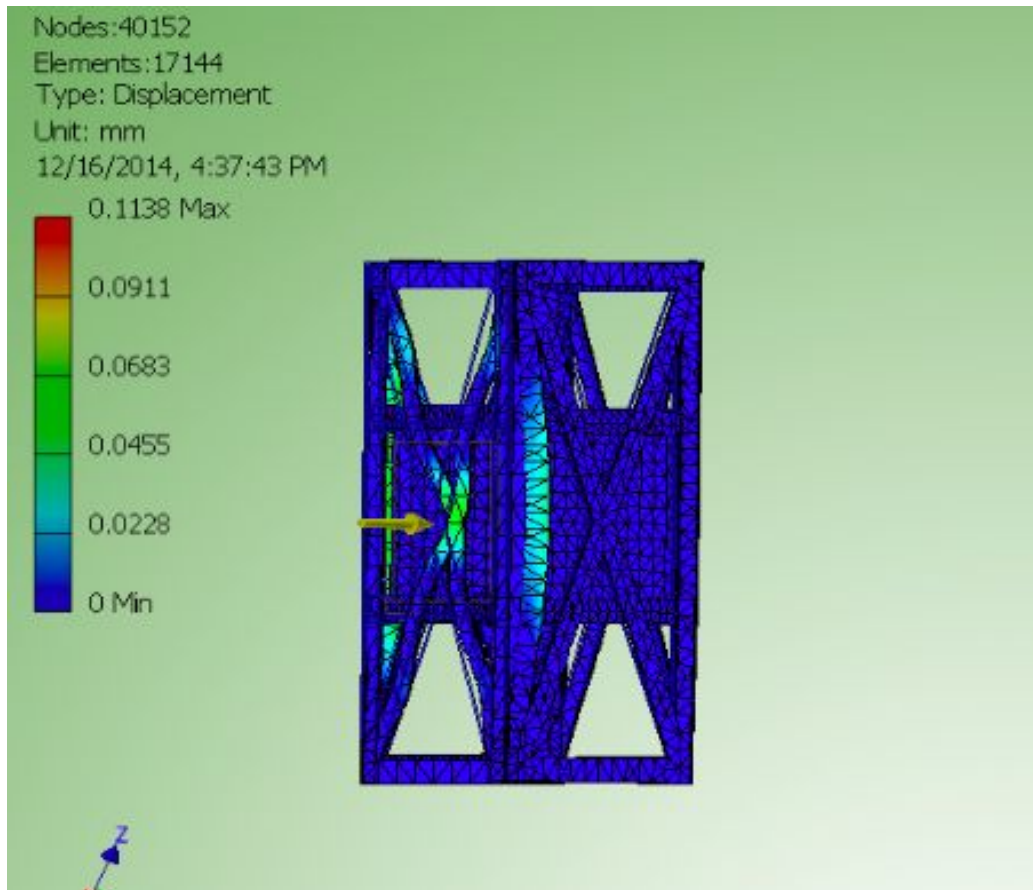


Figure 21. 5G Horizontal Stress Displacement

10G Vertical Stress (300 N, 30 kg)

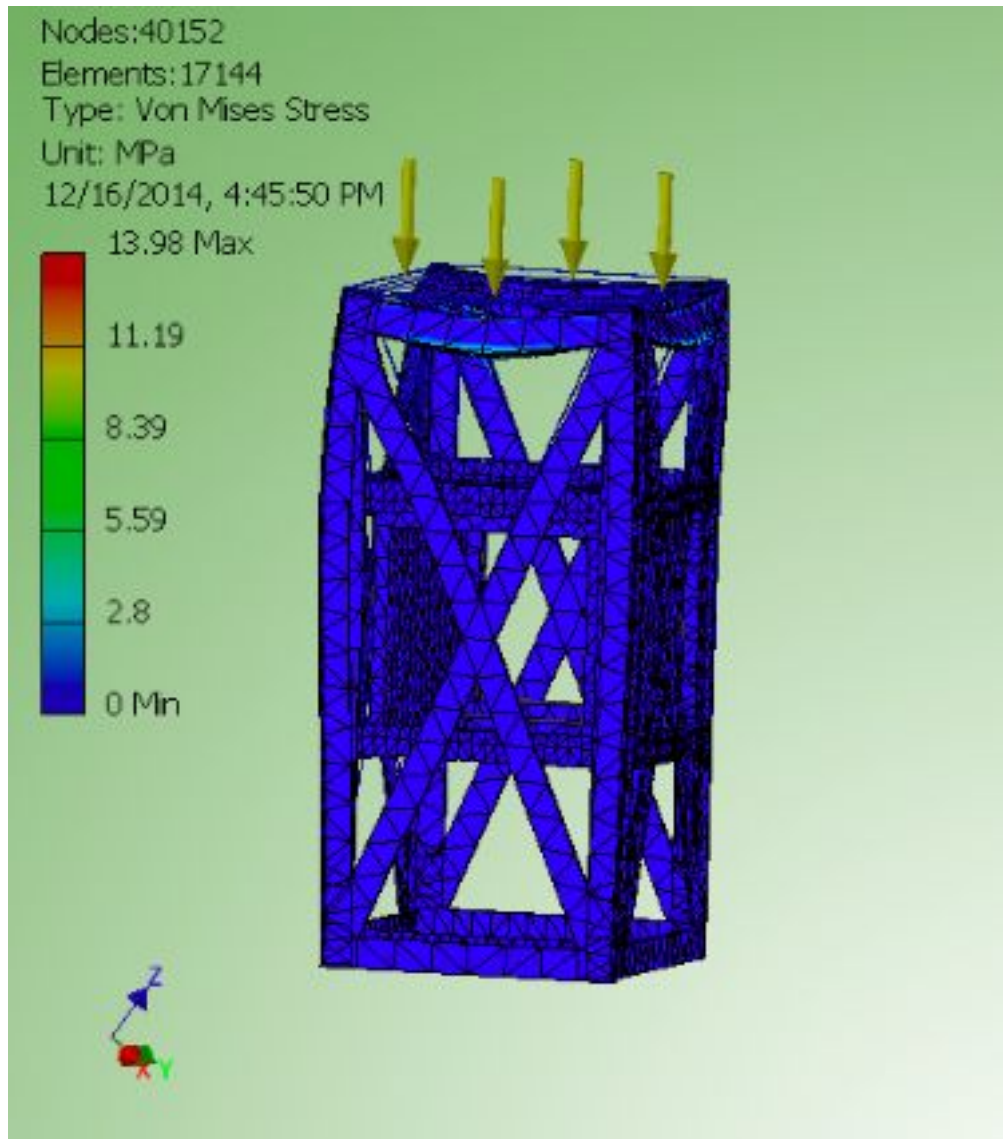


Figure 22. Vertical stress

The yield strength of this aluminum type is around 55 MPa. As can be seen, the max stress doesn't exceed 14 MPa, so we have a large safety margin. The structure should remain intact in the event of a substantial shock. Note that calculations are made assuming that the payload has a mass of 3 kg.

Weight budget

Reference	Weight (kg)
Outer Shell w/Lid	.402
Aluminum Frame	.661
Housing Case	.220
Base Plate	.268
Arduino Due	.036
FPGA board	.165
Transceiver board (ADC)	.165
Misc. Electronics	.5
TOTAL	2.417

Table 2. Weight budget of the payload

Data Transmission

Serial Port

We will use the serial port to transmit data and receive some basic commands. The transmission will include the values gathered by the sensors. These values are:

- Temperature
- Humidity
- Pressure
- Light and sound
- Energy values at different points of the system

This small quantity of information will easily fit within the 1200 baud bandwidth. Regarding the uplink, few safety commands are planned. These are cutoff and control commands to ensure that a failing system will not compromise the entire mission. These commands will include cameras shutdown and communication system control commands (change of frequency and modulation).

Serial communications use a DB9 connector with pins 2 (receive / transmit), 3 (transmit / receive) and 5 (signal ground) connected. The protocol is RS232 and the port setup is 8 data bits, no parity, 1 stop bit and no flow control. The serial port is set to 1200 baud for small payloads. [Note that the term “baud” is used to designate the timing between bits on the serial link and is not necessarily your “bit rate”. Your “bit rate” is determined by the amount of data (the number of bits) you are transmitting on the serial line per unit time. In addition, your “bit rate” cannot exceed the “baud” rate. For example, suppose you have a small payload and are sending to HASP a data record of 45 bytes each minute. Your bit rate would be 6 bps (bits per second) and each bit would be sent at a “speed” of 1200 baud. HASP will collect data from the student payload as a bit stream: listening for, and receiving, data.

D-sub 9

In/out and diagram of DE9 connector (DB9 connector), commonly used for serial ports (RS-232).

Pin	SIG.	Signal Name	DTE (PC)
1	DCD	Data Carrier Detect	in
2	RXD	Receive Data	in
3	TXD	Transmit Data	out
4	DTR	Data Terminal Ready	out
5	GND	Signal Ground	-
6	DSR	Data Set Ready	in
7	RTS	Request to Send	out

8	CTS	Clear to Send	in
9	RI	Ring Indicator	in

Table 5. In/out diagram of DE9 connector

The DTE (PC) has the male connector (shown below), and the DCE (peripheral) has the female.

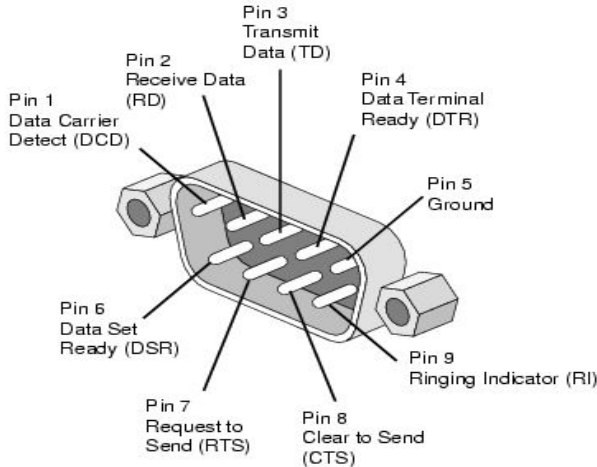


Figure 23. Male connector

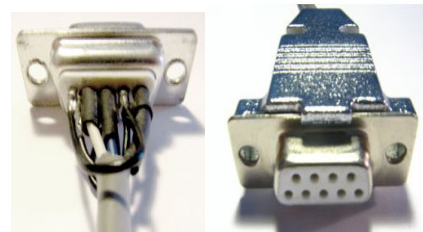


Figure 24. Female connector

RS-232 Maximum Cable Length

The maximum cable length for RS-232 is 50ft, but in practice depends on baud rate, cable-specific capacitance and ambient noise. The table below contains some rules-of-thumb from experiments done by Texas Instruments years ago.

Baud rate	Maximum range / cable length
19200	50ft
9600	500ft
4800	1000ft
2400	3000ft

Table 4. Baud rates and range relations

Communication System

For the data encoding, which will be sent to the communication system, we chose the AX.25 protocol. It is the most used protocol for other CubeSat projects around the world.

FLAG (0x7E)	ADDRESS (14 Bytes)	CONTROL (1 Byte)	PID (1 Byte)	DATA (0 – 256 Bytes)	FCS (2 Bytes)	FLAG (0x7E)
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Figure 25. AX.25 packet

Some characteristics of the protocol include a bit stuffing (add a 0 each 5 consecutive 1s) to avoid having the flag within the frame, and the implementation of several modes using the CONTROL and PID fields. This protocol will also be implemented in the Arduino.

Funding, Team management and Schedule

IIT’s Ballooning Team is mainly supported by Armour College of Engineering and the 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 have already allocated funds for Scarlet Hawk III. The Scarlet Hawk III mission will be led by Caterina Lazaro, with guidance from Dr. Bowman. As a result, Caterina Lazaro will be taking care of the design of the payload and the sources of funding and marketing, while Dr. Bowman will provide advisory services for the engineering systems.

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 undergraduate students. The vast majority of the students are going to be attending IIT in 2015 and more students are going to be added throughout the spring semester.

This year’s students come mainly from two departments: the Mechanical, Materials and Aerospace department, and Electrical and Computer Engineering department.

Teams Structure

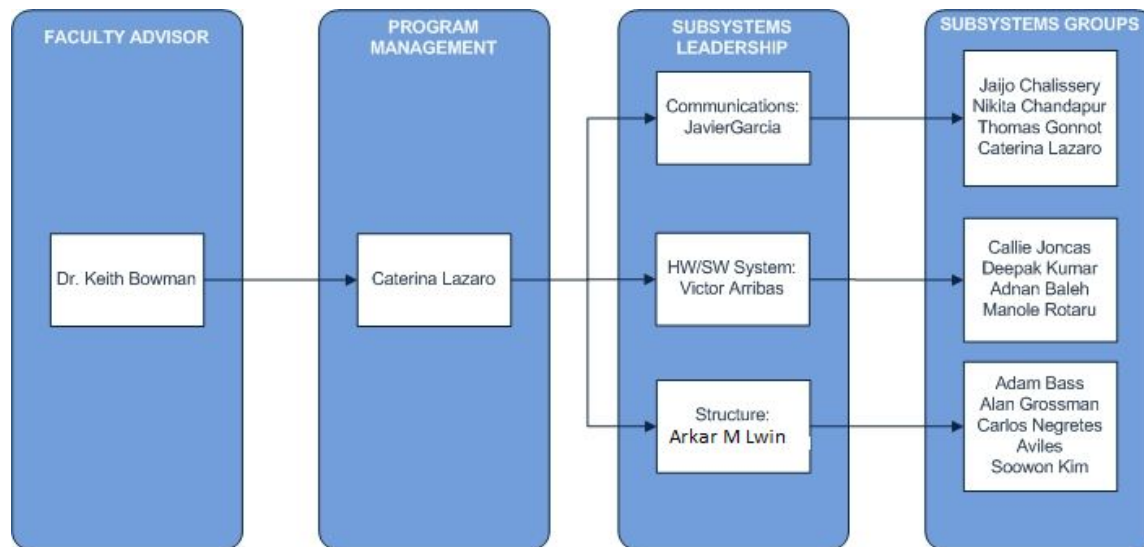


Fig 26. Distribution of students in teams

Schedule

There are nine main critical dates for the entire group, but each subsystem has its own internal deadlines. Important dates from the HASP Calendar (such as Integration Plan or Flight date) have served as guidance for the schedule elaboration. Using Scarlet Hawk I recommendations (HASP 2013), the schedule was done in such a way to reduce excessive workload and stress on each team wherever possible.

The workload will be organized bi-weekly or monthly, depending on the difficulty and dedication required for the task. Each subsystem is responsible for the completion of their milestone by the last Friday of each period. This will allow some time for the teams to exchange information, organize their next week's workload and, especially when two or more subteams need to collaborate, arrange new schedules.

NOTE: special weeks of IIT, such as the Spring Break (March 16th) and final exams (May 4th), have been respected.

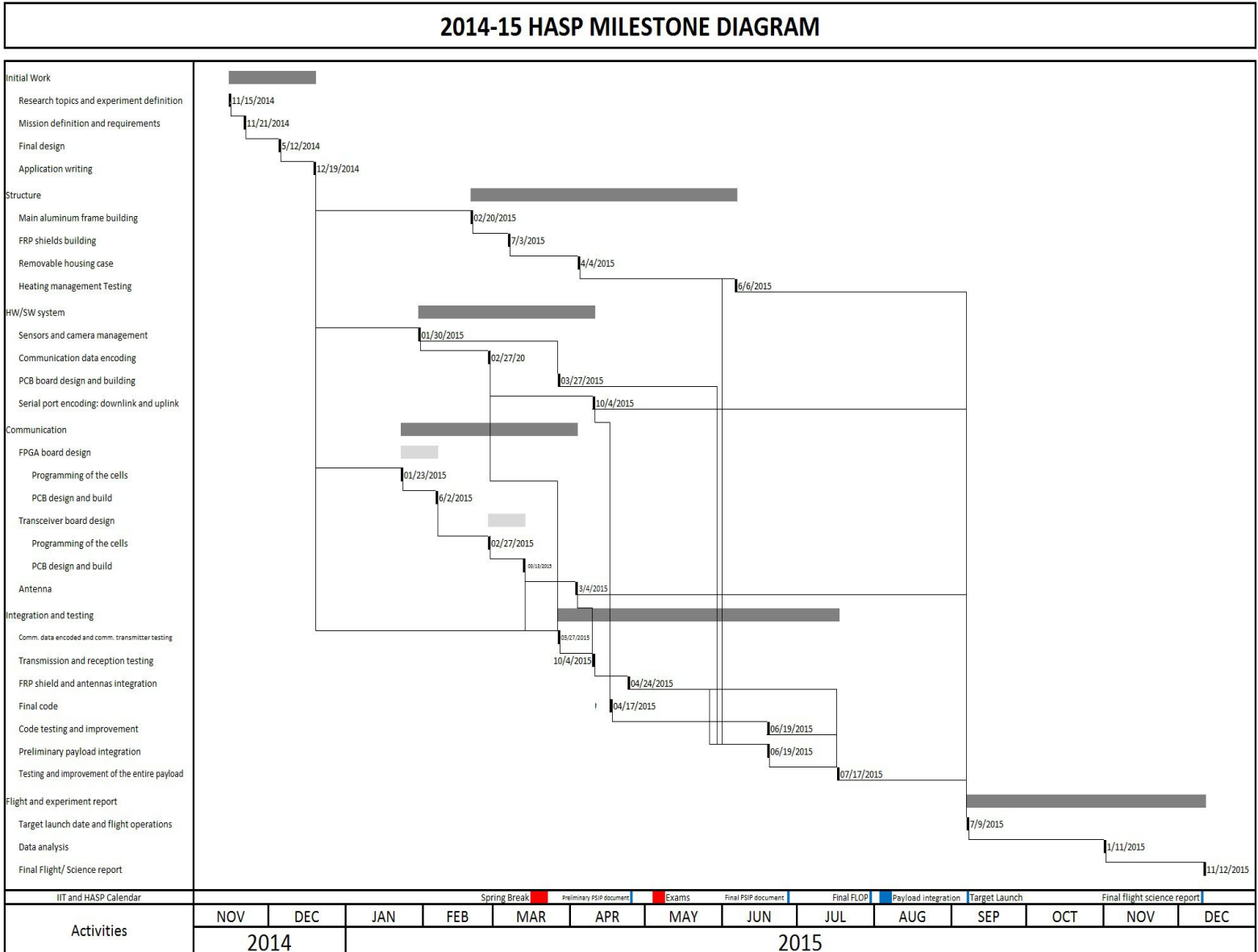


Fig 27. Tasks milestones diagram

- Initial Work:
 - Research topics and experiment definition(Done by November 15th, 2014)
 - Mission Definition and Requirements (Done by November 21st, 2014)
 - Final design (Done by December 5th, 2014)
 - Application writing (Done by December 19th, 2014)
- Structure:
 - Main Aluminum Frame Building (Done by February 20th, 2015)
 - FRP Shields Building (Done by March 7th, 2015)
 - Removable housing case (Done by April 4th, 2015)
 - Heating Management Testing (Done by June 6th, 2015)
- HW/SW System:

- Sensors and camera management (Done by January 30th , 2015)
- Communication data encoding (Done by Feb 27th , 2015)
- PCB board design and building (Done by March 27th , 2015)
- Serial port encoding: downlink and uplink (Done by April 10th , 2015)
- Communication:
 - FPGA board design (Done by February 6th , 2015)
 - ◆ Programming of the cells (Done by January 23rd , 2015)
 - ◆ PCB design and build (Done by February 6th , 2015)
 - Transceiver board design (Done by March 20th , 2015)
 - ◆ Programming of the cells (Done by Feb 27th , 2015)
 - ◆ PCB design and build (Done by March 13th , 2015)
 - Antenna (Done by April 3^h , 2015)
- Integration and testing:
 - Communication data encoded and communication transmitter testing(Done by March 27th , 2015)
 - Transmission/Reception testing (Done by April 10th , 2015)
 - FRP shield and antennas integration (Done by April 24th , 2015)
 - Final code (Done by April 10th , 2015)
 - ◆ Testing and improvement (Done by June 19th , 2015)
 - Preliminary Payload Integration (Done by Jun 19th , 2015)
 - Testing and improvement of the entire payload (Done by July 17th , 2015)
- Flight and experiment report:
 - Target launch date and flight operations (Done by September 7th , 2015)
 - Data analysis (Done by November 1st , 2015)
 - Final Science and Technical Report (Done by December 11th , December 2015)