

ARIES-GPS
Proposal for the High Altitude Student Platform
(HASP), 2013

Advance Research and Innovative Experience for
Students Laboratory
ARIES Labs



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1. Mission Goal

To develop the aerospace workforce in Puerto Rico through the HASP platform. The use of HASP as a test platform for Cubesat technology we plan to perform a radio occultation experiment using GNSS receiver. In addition we would test and compare two different GPS's performance in a hostile space environment.

2. Objectives

2.1 Science Objectives

The following are several science objectives that are related to the ARIES-GPS experiment:

1. Increase the understanding of aerospace sciences specialized in CubeSAT technology.
2. Provide the student team experience in systems engineering and scientific data analysis concepts.
3. Help the student team learn critical skills in utilizing GPS signals to develop position solutions and the time of flight of the payload.
4. Data acquired from the GPS receiver will be used for characterization of line-integrated electron density between the receiver and the GPS satellite being tracked.
5. Learn, test, and calibrate different sensors to measure the Earth's gravitational, and magnetic fields, also the Sun intensity, and the angular momentum of the ARIES-GPS payload.
6. Measure the internal and external temperature during flight to determine the potential impact to the structure and the components of the structure.
7. Determine the position and the time of flight of the payload by using a global positioning system.
8. Characterize the line-integrated electron density from the ASTRA CASES GPS receiver.
9. Compare GPS derived total electron content (TEC) to state of the art space environment models, such as the Thermosphere-Ionosphere-Mesosphere Energetics General Circulation Model.

10. Use the radio occultation profiles for verification to improve the assimilation of space-borne atmospheric sounders
11. Observe gravity waves for the parameterization of momentum flux into the stratosphere.
12. Learn about flight characteristic such as angular rate rotation, and orientation with respect to different reference frame.
13. Allow a demonstration of atmospheric profiling with GPS radio occultation profiles.
14. Increase the TRL (Technology Readiness Level) of the GPS receivers for future space application.
15. Acquire knowledge of post flight data analysis.

2.2 Technical Objectives

The technical objectives presented here are necessary to accomplish the science objectives. These objectives will be completed during the development of the prototype:

1. Design and connect the sensors located in a PC/104 board inside the body frame of 10cm cube to determine the attitude motion of the payload.
2. Interpret the graphs and charts obtained from the output of the different sensors as well as the attitude of the vehicle.
3. Integrate the CASES GPS receiver and the antenna with the ARIES-GPS payload.
4. Demonstrate CASES capability for fast signal acquisition upon cold start.
5. Increase the Technical Readiness Level (TRL) of the CASES GPS, and
6. Implement a precise position solution using the GPS carrier phase measurements.
7. Compare the performance of ASTRA CASES GPS receiver to the dual-frequency Novatel OEM GPS receiver.
8. Obtain the platform's orientation with respect to the inertial reference frame of the ARIES-GPS project.
9. Implement a thermal system in the range of 0°C to 80°C to maintain the components in the nominal operating temperature range.

10. Analyze the behavior of an external temperature sensor to see the platform thermal reaction during the flight. Data obtained will be used as our requirements heritage
11. Maintain the dimensions of the package within 15 cm x 15 cm x 30 cm area.
12. Test two possible GPS models to compare accuracy and precision, to obtain the appropriate one for the SWIM satellite.

3. Requirements

3.1 Science Requirements

To accomplish the development of a robust ARIES-GPS prototype, that will be used to define the requirements that are needed to obtain the mission success. These requirements are:

1. Receive signals from occulting GPS satellites, which are essential to perform the TEC calculations of the mission.
2. The maximum inaccuracy of ± 5 degree for the heat transfer rate into or out of the payload.
3. The inaccuracy of the Inertial Measurement Unit (IMU) with respect to the position GPS data should be less than 10 degrees.
4. Gather knowledge about the attitude motion and control of the payload and provide recommendations for future HASP and CubeSAT projects.
5. To interpret the data given from the ADS and GPS (e.g. position, angular velocity, the magnitude of the Earth's magnetic field, and acceleration) to allow a proper TEC calculation from the given data.
6. Protect the electronic devices from the temperature fluctuations from the environment, using an insulating material.
7. Complete PDR, CDR, FRR, Integration plan, CSBF Thermal/Vac certification, FOP and Final science report (post flight).

3.2 Technical Requirements

The requirements for the technology necessary to determine the orientation, position, and control of the ARIES-GPS payloads are:

1. To develop a payload that requires less than 30V at 0.5Amps, provided by HASP, and as well to meet the CubeSAT power requirements.
2. Develop a mechanical structure that can withstand all the stresses during the payload's flight, such as 10g vertical and 5g horizontal.
3. Design and select the proper elements to allow full operation, and do not exceed the 3kg weight limit.
4. Obtain the data at a sampling rate of 8s.
5. An Linux ARM processor as our main processor unit, which is intended to interact with the sensor and the GPS data.
6. Position the GPS antenna on the HASP PAYLOAD with an inclination angle of 30 degrees in order to obtain signal from occulting GPS in the horizontal line.
7. Transmit a sensor data with a maximum telemetric rate of 1200 baud.
8. Implement a structure having a weight limit 3 Kg.

4. Principal of Operation

The ARIES-GPS experiment will compare the performance of two different dual frequency GPS receivers. Once the payload is turn on the system, the CASES and Novatel L1/L2 GPS receivers will begin to collect data from the available GPS satellites. There will be several boards on the payload; a control board that will be monitoring the external and internal temperature of the payload and stored in the SD card. In addition to convert the HASP power source to the respectively voltage range required to power up the CASES and Novatel L1/L2 GPS receivers , a dual frequency active GPS antenna, and the temperatures sensor.; an CASES receiver board will obtain power from the control board and it will read data from the GPS satellites and store it in its internal SD card for post analysis; Also a Novatel receiver board will be placed on top of the CASES receiver, the Novatel will also take the data form the GPS satellites and store it in the control board SD card. In general, the overall objective is to collect data from two different GPS receivers. Data will be post-process to obtain the line-integrated electron density between the ARIES GPS 2013

receiver and GPS satellites, retrieve atmospheric profile below the balloon height. To ensure proper operation environment on the ARIES GPS temperature sensors will be placed in different areas of the payload. These temperature sensors will be used in specific locations to monitor and maintain the temperature with the heater.

5. Mission Justification

The ARIES-GPS project is a low cost, low medium-risk test flight to prove new technologies that are critical for the success of the SWIM satellite mission. Obtaining a flight on the HASP environment allows a cost-effective method of reducing risk factors for the future CubeSAT mission by permitting the development of new technology and proving prosperous operation in an environment similar to space.

6. ASTRA and Novatel GPS Technologies

ARIES-GPS experiment onboard the NASA HASP program will demonstrate the capability of operating a GPS receiver to monitor ionospheric scintillations. ASTRA's CASES GPS receiver, developed under Air Force funding, is an ideal candidate for the ARIES-GPS experiment due to its dual frequency receiver GPS and compact size.

6.1 ASTRA CASES

The new CASES GPS sensor developed by ASTRA, Cornell and UT Austin represents a revolutionary advance in dual frequency GPS space-weather monitoring. CASES is a smart, dual-frequency GPS software receiver with robust dual-frequency tracking performance, stand-alone capability, and complete software upgradability. CASES consists of a real-time GPS software receiver for the L1 C/A and L2C codes, as well as a custom hardware platform on which to run this receiver. This receiver was developed as a low-cost space weather instrument for monitoring ionospheric scintillation and total electron content.

The receiver software includes several novel additions that make this instrument ideal as a space weather monitoring tool: advanced triggering techniques to accurately determine the onset of ionospheric scintillation, buffering of data to allow for observation of the onset of scintillation, data-bit prediction and wipe-off for robust tracking, and eliminating local clock effects by differencing. The custom hardware platform on which the software runs is very compact while

still remaining quite flexible and extensible.

As this receiver is software-defined, it is possible to remotely reprogram the entire receiver via the Internet or another communications link. The CASES receiver operation is defined by two things: the actual executable code, and various configuration files. Should the user desire to change the executable code, this is accomplished by commanding it to write the new image to flash storage. In this manner, the entire structure of the receiver can be changed, and this can be done remotely. A set of these receivers deployed in Antarctica as part of a University of Michigan instrument suite has recently been reprogrammed via the Iridium satellite communication system that connects the suite's infrastructure (buried in the snow) to the outside world. It has also been demonstrated repeatedly over the internet to receivers deployed in less remote locales. Receiver configuration files are stored on the local file system, and allow the user to redefine such things such as tracking loop bandwidths, data logging cadence, scintillation thresholds, and more. These files can be changed by editing or replacing the existing copies on the receiver files system, accessible by SSH over the Internet.

The receiver implements a data bit prediction algorithm that makes operation of the receiver phase-locked loop more robust under ionospheric scintillation or similarly adverse conditions. By recording previously observed data bits, the receiver can guess with a high degree of certainty what future data bits will be (or it can calculate them, for example in the case of time-of-week data, where it is known how the data changes). This processing technique also improves performance under nominal operating conditions. This technique naturally fails right after switching to a new ephemeris data set, in which case data bit prediction is suspended until the new data have been observed.

The CASES receiver software is designed to sample the GPS signals at 100Hz, and to output TEC at this high rate. The scintillation parameters S_4 , τ_0 , and sigma phi are computed inside the receiver and output at a cadence that can be adjusted in the configuration file. S_4 and sigma phi are standard deviation measures of received signal power and received signal phase, respectively. τ_0 is the decorrelation time of amplitude fluctuations. Processing periods may vary, but are commonly 1-minute periods.

The study of scintillation requires high data logging rates (e.g., 100 Hz) but it is often impractical to store this high-rate data all of the time due to size constraints and/or bandwidth constraints (in

the case of remote receivers). In bandwidth-limited or storage-limited situations, it is extremely important to have a robust method for detection of scintillation, so that the user can record high-rate data only when the signal is actually scintillating. In light of this, a new measure of scintillation intensity has been implemented that makes use of the wide-band power spectrum of the in-phase and quadrature accumulations. In contrast to the S4 or sigma phi scintillation indices, which look at only amplitude or phase, respectively, this technique weighs both simultaneously. Once the signal fluctuations exceed a user-set threshold (i.e., an amount of power in a specific frequency band), they are judged to be scintillating.

The CASES hardware platform consists of several components: a Texas Instruments Digital Signal Processor (DSP) on one circuit board, an Atmel ARM microcontroller with several associated peripherals on another board, a custom-built narrow-band dual-frequency front end on a third board, and a connecting backplane. Hardware capabilities include USB, SD card storage, WiFi, Ethernet, RS-232 serial port, the ability to use an external oscillator, and more. The receiver has 128 MB of on-board storage for data logging and uses a Linux operating system.

The combination of a flexible software-based receiver, novel techniques aimed at producing quality observations of scintillation and TEC, and a capable, extensible hardware platform make this receiver an ideal instrument for space weather monitoring or other specialized scientific or engineering applications.

The following Figure shows the ASTRA's low SWAP version of the CASES receiver.

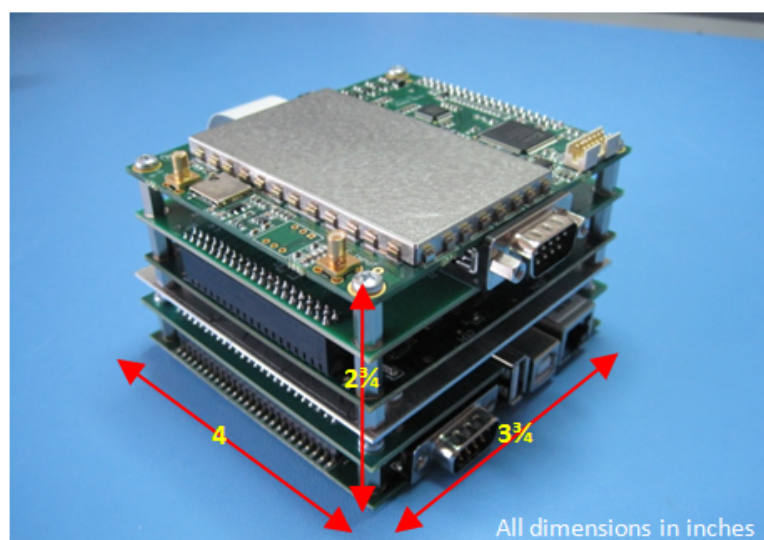


Figure 1. CASES receiver showing the RS-232 and Ethernet

We anticipate testing the Antarctic version of the CASES receiver, shown in Figure 1, with the Wave Glider vehicle and store the data locally on a USB external hard-drive. Specifications of the CASES receiver that we plan to test on the Wave Glider are given below:

Form factor/dimensions	4×3¾×2¾ inches (approx W x D x H).
Weight	Approx. 2 lbs
Power	7 Watts
Supply voltage	+5V or +12V (+/-10%)
Temperature range	-20°C to +40°C
Communication interfaces	RS-232 (DB9) and Ethernet (RJ45)
Data Rate	On-board data storage using micro-SD card

Table 1. CASES Specifications

6.2 Novatel OEMV-1DF

The OEMV-1DF is a dual frequency GPS receiver capable of receiving and tracking the GPS L2C and L2 P(Y). It has a Patented Pulse Aperture (PAC) with multipath mitigation technologies, and a 32 bit processor. This allows the OEMV-1DF receiver to offer multipath-resistance processing at a high data rate. Also has a good acquisition and re-acquisition times allow the receiver to operate on environment where the interruption of signals is expected. In addition the OEMV-1DF is supported by the Advance RTK engine, this means a lower ambiguity error rate, faster narrow lane convergence and more fixes in a wider range of condition. Moreover the OEMV-1DF is flexible because multiple software models are available, allowing you to fit the receiver performance to the decided application while maintaining the option for a compatible upgrade path.

Form factor/dimensions	46 W X 71 L X 13H (mm).
Weight	21.5g
Power	1.1W
Supply voltage	3.3V (+5%/-3%)
Communication interfaces	20-pin dual row male header
Temperature range	-40°C to +85°C
Data Rate	On-board data storage using micro-SD card

Table 2. Novatel Specifications

Both GPS antennas will use the Antcom 1.9G1215A-XCS-1, an active L1/L2 GPS antenna.

Dimension	50.80 L X 50.80 W X 13.54H
Weight	74g
LNA voltage	5V
LNA current	50 mA
Temperature Range	-55°C to +85°C

Table 3. GPS Antenna Specifications

7. HASP Power Supply

The primary power source that will be available during the flight will be the 30V @ 2.5A from HASP. The main purpose of the project will be to test the functionality of the ASTRA GPS therefore the HASP will provide the necessary power for these critical components located in the bottom cube structure during the approximately 17hr flight.

7.1 HASP Power Interface

The HASP mounting plate provides two connectors; one is a DB9 serial connector used for uplink and downlink of data, and the other is an EDAC 16 connector, which provides connections for power, discrete commands to the HASP platform and analog outputs. **Figure 2** shows the platform and the location of both connectors.

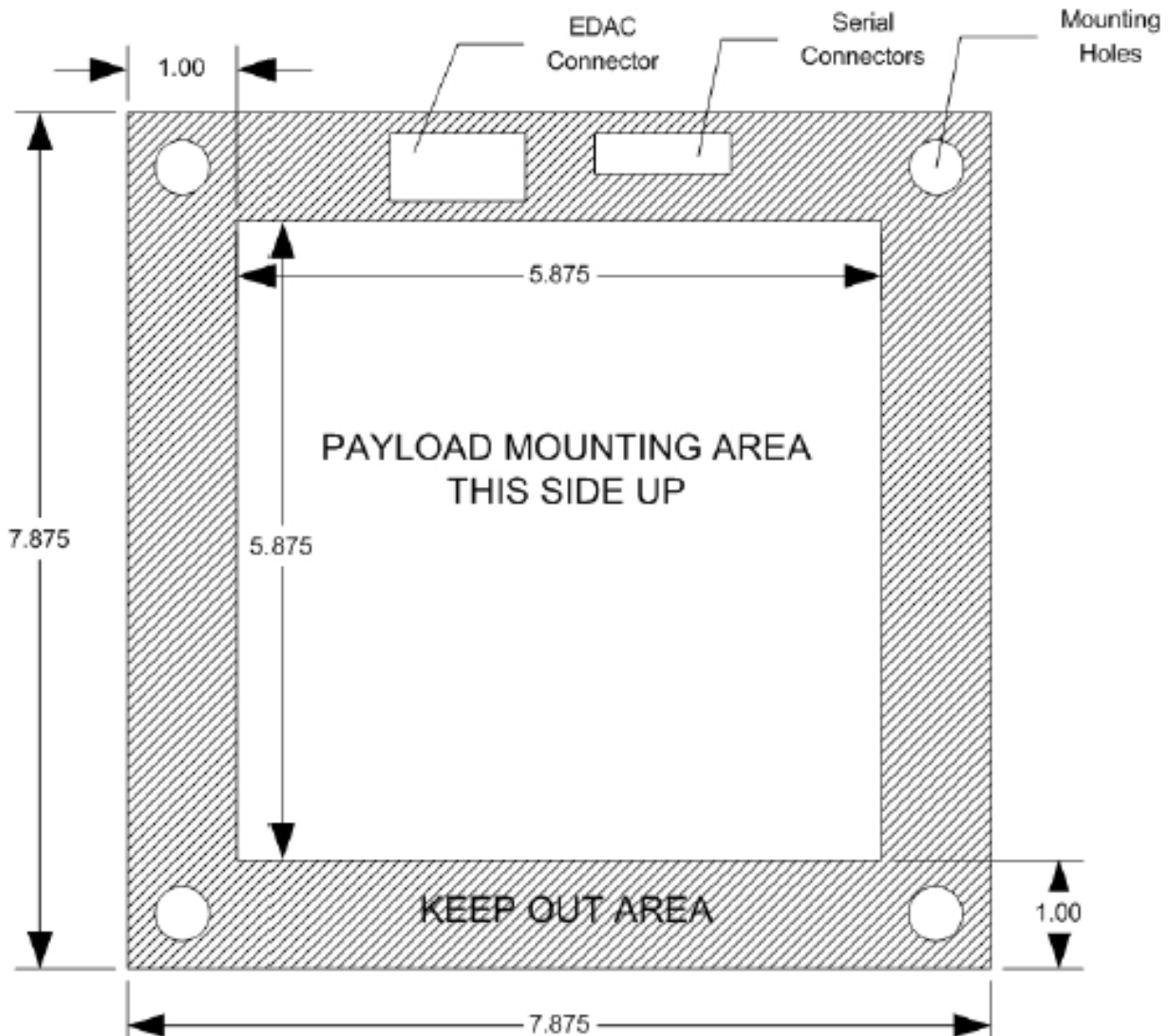


Figure 2. HASP Mounting Area Layout

Since the EDAC connector is the one that provides the 30V to our system, this is the one going to be discussed in this section. The EDAC is a 20-pin connector used to interface with the HASP power. The HASP already provide this connector in its platform each one is labeled with a specific color to identify its function. The following table describes its wire with its color label and its function (taken from HASP Interface Manual).

Function	EDAC Pins	Wire Color
+30 VDC	A,B,C,D	White with red stripe
Power Ground	W,T,U,X	White with black stripe
Analog 1	K	Blue
Analog 2	M	Red
Signal Return	L, R	Black
Discrete 1	F	Brown
Discrete 2	N	Green
Discrete 3	H	Red with white stripe
Discrete 4	P	Black with white stripe

Table 4. EDAC 516-020 Pin Layout

As it can be seen from the table there are four wires that provide +30VDC; these are labeled as A, B, C, and D. From the manual these wires need to be connected in parallel to allow the maximum current, 2.5Amps in our case, to be drawn from the HASP. This parallel connection between the wires needs to be done properly and connected to the step down circuit on the ADCS board.

7.2 Payload's Power Budget

ITEM	Voltage (V)	Current (mA)	Watts (mW)
MBS-GPS-OEMV -1DF PC/104PC	5	320	1600
Flight Computer	5	200	1500
Antenna	5	50	250
CASES GPS Computer board	12	500	6000
CASES GPS acquisition board	5	200	1000
ASTRA GPS RF front end board	5	300	1500
Razor IMU	3.3	6.86	22.64
External Temperature Sensor	5	2	10
Total Power Consumption	30	396.6	11882.64
Power Limit	30	500	15000
Power Margin	30	103.4	20.78%

Table 5. Power Budget for Top 1U Cube structure

The payload total power consumption will be delivered entirely by the HASP platform at 30V and 0.5A giving a 15W source. This will be then down-converted by a DC to DC to a 5V, and another DC to DC converter to 12 V, depending on the sensors. The new ratio will give us an increment in

current and keeping the same power 15W (5V, 3A with 15W and 3.3V, 4.54A and 15W) from the HASP platform. The power for the boards on the 1U will be 11.9W. The **Tables 5** describe the total power consumption for the boards on the 1U payload. The heater is not included in the payload because from our previous experience with HASP flight in 2011, the heater is not needed.

This payload will employ power from the HASP platform. A source of 30V at 0.5A will be supply by the HASP platform to the payload through the EDAC 516 connector. Wires A, B, C and D are connected together to obtain a positive 30V at 0.5A from the platform. Wires T, W, U and X are connected together for ground.

As shown in Table 5, we have devices that vary in voltage. For this reason we need to place two DC to DC converters. Used in past test the LM2576 DC/DC converter will step down the 30V from HASP to 12V, supplying power to the 12V devices. Another LM2576 DC/DC converter will step down the 12V to 5V and supply voltage to all the 5V devices. The Razor IMU will be powered from the digital pins of the Flight Computer, which are able to output 3.3 VDC.

7.3 Electronics Design Inrush Current

The HASP platform to make sure that any payload exceeds the limit set, each power line has a thermal fuse of 0.75A; also they monitor the current draw through a computer in real time. Before the payload is mounted on the platform, the payload has to pass the “pre-integration” test. This test consist of weighting the payload to ensure that it do not weight more than 3kg, and then they power up the payload (with the fuse) to measure the current draw of each individual payload. The ASTRA GPS payload passed, for several times, the pre-integration test successfully. Once the payload was mounted in the HASP Platform for the thermal test, the fuse started to blow up. In the first thermal test we talked with the LSU scientists and they provided us a bigger fuse (the one used for large payloads) and the thermal test was successfully achieved.

Then to make the “pre-integration” test again, and as expected the payload did not blew up the fuse at start up and neither the current draw was more than 500mA. Unfortunately in the final thermal test (when mounted in the platform with the other payloads) the fuse blew up again and the LSU people did not let us to use the bigger fuse previously used. After this the payload was sent to Puerto Rico for test purposes.

An oscilloscope was used to monitor the current draw of the payload. A 1Ω 10W resistor placed in series with the power supply provides a voltage drop, read by the oscilloscope, which is proportional to the current draw of the payload. The following capture was obtained during that test:



Figure 2 Transient current of the payload

The peak current during startup of the payload is shown in **Figure 2**. Here the maximum current draw goes above 1A for approximately 40ms, having a maximum peak of 1.56A. After this peak, the current draw stabilizes between 0.42A and 0.47A for the rest of the process.

This type of thermal fuses present up to 20% more (in some cases) than the rated current for a specific range of time. In this case HASP uses a 3/4A fuse, which leads us, with the 1.56A draw for 40ms, to the limit of the fuse.

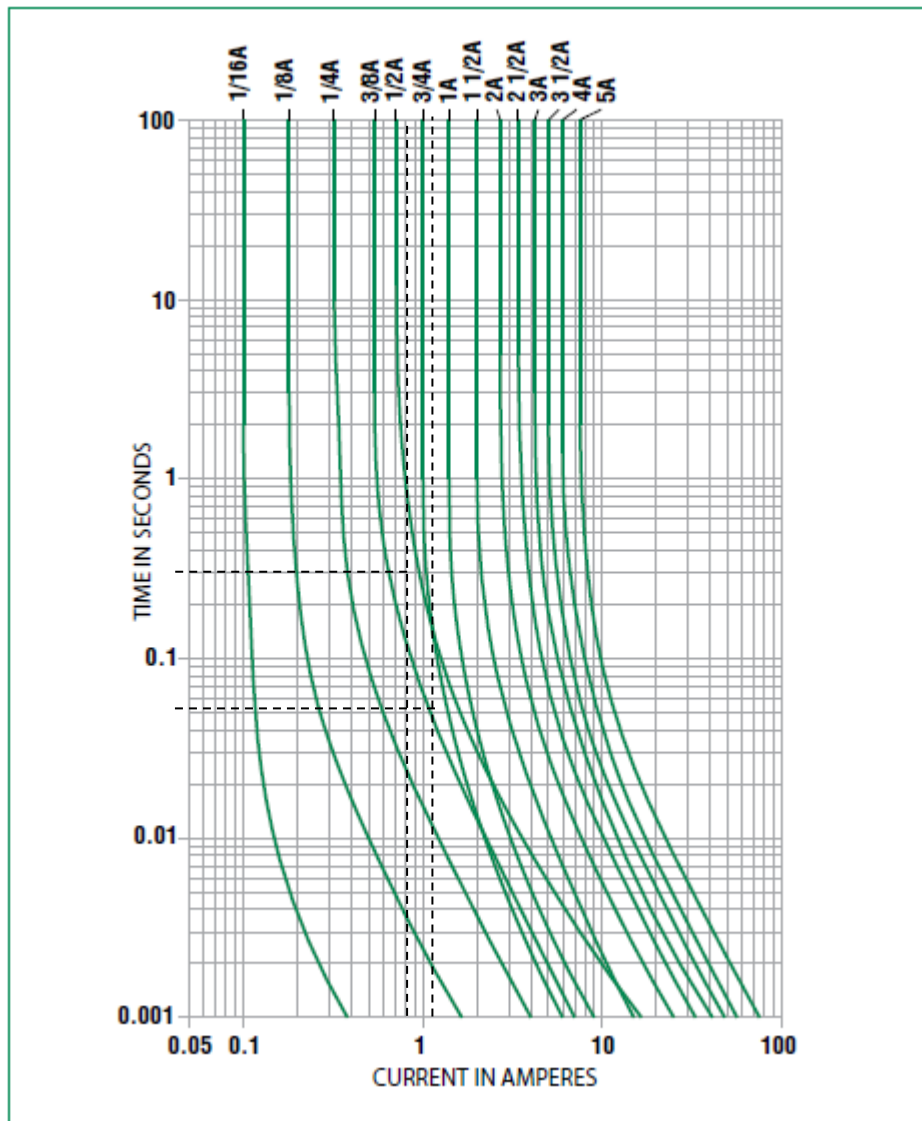


Figure 3. Rated current of the fuse during different range of time

The fuse can withstand a current draw of 1A for ~300ms, and ~50ms for 1.5A. When the current draw goes to 1.56A, the fuse gets to the limit and blowup. The little time edge, explain why the fuse do not blew up in some “pre-integration” tests, but blew up when mounted in the platform.

This phenomenon is called inrush current, which is nothing more than a current generated during a given time. After several trials to reduce the peak current, realized that the transient current depends on the load so we decided to design a circuit where the voltage is at different times, avoiding sudden rush of power. The result is shown in Figure 3. Which shows that the current is 880 mA max.

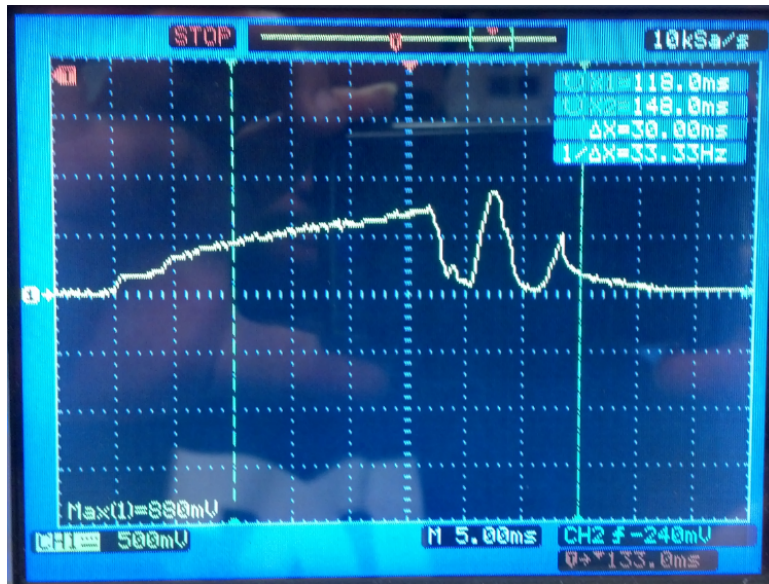


Figure 4. Transient current with the load at different times

To make this possible solution, was created the following system:

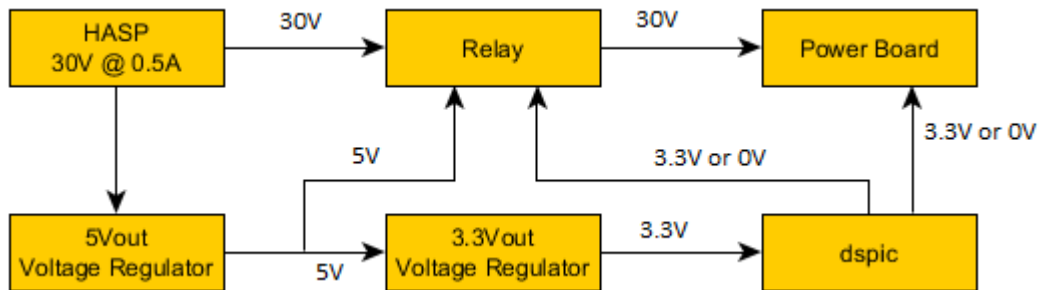


Figure 5. Wiring diagram of the switching board

In **Figure 5** is shown a representation of the circuit created to make the switching at different times. The purpose of this circuit is to turn off the DC/DC converters when the power supply is on, and turn on the converters a couple of seconds later at different times. The 30V from HASP is supplied to a 5V voltage regulator and a relay that is normally open. The 5V from the first regulator goes to another regulator to step down that voltage to 3.3V and feed a dspic. The dspic will send through a digital line, a logic high to the DC/DC converters. These converters come with a feature pin that let you turn ON or OFF the converter when the pin is high or low. When the pin is high the DC/DC is OFF, and when the pin is low (or connected to ground) the converter is ON. So the dspic send 3.3V to the relay and the two converters. At this stage the relay switch and the 30V goes to the power board, but because the converters are at OFF state, there is no power consumption. Five seconds later the dspic send a logic low to the 12Vout converter to turn it on, and ten seconds later the same

signal is send to the 5Vout converter. Thus the desire switching behavior is obtained. The oscilloscope and HASP fuse test was made with this circuit and the transient current was exactly the same as the one in **Figure 4**.

We decided to implement two possible solutions because of the problems presented with the additional board. This problem is mostly for space because the additional board in the platform. The first is to implement a new card where you put the equivalent components but in smaller size and the second solution is to change the existing converters. These converters will be exchanged for converters with soft start.

In our research, we found a DC to DC converter with special feature. This feature is the possibility to configure an internal soft start. The soft start circuit charges the capacitor through a current limiting resistor located in series with a coil, when you load has occurred, is shorted by a relay and amplifier can operate at full power. Eliminating abrupt current changes caused by overvoltage present during the application of an input voltage.

The soft start pin is connected to a capacitor between the pin and the ground to allow a slow switching power regulator. The capacitor sets a time delay interval and gradually increases the duty cycle of the internal power switch. This can significantly reduce the amount of current required on the input voltage supply during a sudden application of the input voltage. This capacitor controls the rate at which the converter starts up at power on. The capacitor is charged linearly by an internal current source. This voltage ramps gradually increases the duty cycle of the power switch until it reaches the normal operating duty cycle defined primarily by the ratio of the output voltage to input voltage. The soft start turn on is programmable by selection the capacitor.

8. Software Design

The data will be retrieved from the sensors and thus the software will be designed to read the data, store the data in the micro SD card, and perform all necessary calculations and all the necessary controls to allow stabilization of the CubeSAT. **Figure 6** shows the general flow chart for the HASP 2012 Flight Software:

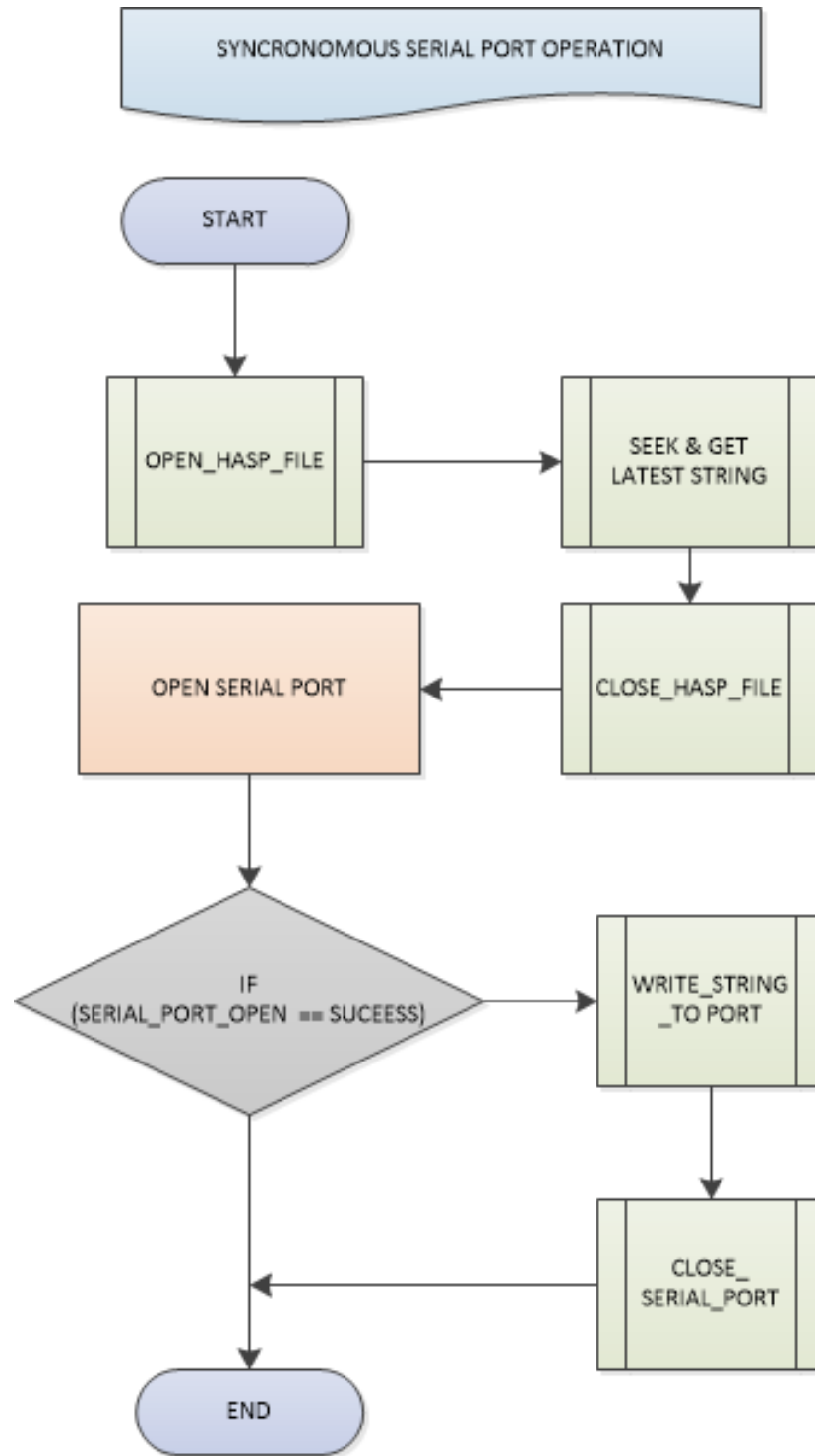


Figure 6. Data Format & Storage

8.1 Data Storage Specifications

The ARIES GPS payload will generate 4 files for the data storage according to the data type. The mission organizes the data according to the data source, which can be defined below

1- HASP downloaded data.

2- GPS data

3- Experimental data

4-Tec data

Each of these files created are stored in an SD card formatted as FAT16. All the files are stored with .csv extension for post-processed data analysis. The files are stored with a header defined for each of the specific data files as described below, the header informs clearly the parameters that will be storing during the whole mission process.

File name	Data Header
hasp.csv	PRN, LONGITUDE, LATITUDE, HEIGHT, PSEUDORANGE_L1, PSEUDORANGE_L2, PHASE_L1, PHASE_L2, ELEVATION\n
exp.csv	PRN, LATITUDE, LONGITUDE, HEIGHT, YEAR, MONTH, DAY, HOUR, MINUTE, MILLISECOND S, ITEMP, ETEMP, AX, AY, AZ, GX, GY, GZ, MX, MY, MZ\n
tec.csv	"PRN, SCTEC, SCTECdelay, SPTEC, ASTEC, ASTECcor, VTEC\n
gps.csv	#, YEAR, MONTH, DAY, HOUR, MINUTE, MILLISECOND, PRN, PSEUDORANGE_L1, PSEUDORANGE_L2, PHASE_L1, PHASE_L2, LONGITUDE, LATITUDE, HEIGHT, ITEMP, NUMBER, CRC\n

Table 6. Data Storage Specification

8.2 Downlink Telemetry Specifications

The ARIES-GPS team will send scheduled health and status packages through the downlink at regular intervals. These packets are used for monitoring the payload performance, at almost real time. The amount of data generate by our experiment is extensive and we are unable of downloading all the data recompiled. However some packages will be downloaded as a Housekeeping data. The almost real time analysis of the data will provide the experiment of a method for knowing the experiment health. Each packet, stored and down linked will be time-stamped. In addition these packets will follow a custom made format developed by our team members, and will be composed of the bytes

BYTE	NAME OF BYTE
0	Start of header ('#' -ASCII character)
1-4	UTC year
5	Comma separator
6	UTC month (0-12)
7	Comma separator
8	UTC day (0-31)
9	Comma separator
10	UTC hour (0-23)
11	Comma separator
12	UTC minute (0-59)
13	Comma separator
14-17	UTC millisecond (0-60999)
18	Comma separator
19-22	GPS pseudorangeL1
23	Comma separator
24-27	GPS pseudorangeL2
28	Comma separator
29-32	GPS carrier_phaseL1

33	Comma separator
34-37	GPS carrier_phaseL2
38	Comma separator
39-42	GPS Latitude
43	Comma separator
44-47	GPS Longitude
48	Comma separator
49-52	GPS Height
53	Comma separator
54-57	SBC temperature
58	Comma separator
59-60	Packet number(0-65536)
61	Comma separator
62-63	16 bits CRC

Table 7. Downlink Telemetry Specifications

8.3 Uplink Telemetry Specifications

After every power off the system will go up and will take around two minutes before sending command to the HASP platform. It is always recommended to send the commands until the systems send and acknowledge answer of the action performed. The systems Status's flags package are the response upon command received.

8.4 List of executed commands

1. Start Mission Command:

Command Name:	ON
Hex Command Byte:	4F
Criticality	HIGH
Payload Response Message:	Status's flags package
Command (HEX)	Example 0102084F030D0A

Table 8. List of executed commands

Brief Description:

The command should be sent immediately after the payload is in secure flight. At power up the payload will initialize all the drivers and prepare the system for mission's objectives. The command will enable the modules related to the payload mission requirements.

Contingency Plan:

The start of mission command will determine the mission success. If response is not received upon command execution a “**reboot command**” shall be sent to ensure a restart of mission operation.

Command Name:	RBT
Hex Command Byte:	42
Criticality	MEDIUM
Payload Response	Status's flags package

Message:	
Command Example(HEX)	01020842030D0A

Ramifications to flight success:

The command’s criticality is HIGH. The flight success will be determined in the proper execution of this command by the flight computer and in the response message issued by the system.

2. Reboot Command:

Table 9. Reboot Command

Brief Description:

The Reboot command will reset the payload flight computer operation if something goes wrong. This command will be executed upon reception with a previous package flag downloaded.

Contingency Plan:

There is no contingency plan for this command other than the re-send process.

Ramifications to flight success:

The command’s criticality is MEDIUM. The flight success will be determined in the proper execution of this command by the flight computer and in the response message issued by the system.

3. End Mission Command:

Command Name: OFF

Hex Command Byte: 60

Criticality	MEDIUM
Payload Message:	Response Status's flags package
Command Example(HEX)	01020860030D0A

Table10. End Mission Command

Brief Description:

The OFF command will shut down the system once it is executed. This command should be executing at the end of the mission for a more secure end of mission process. Before execution of the command a set of the current systems flags will be downloaded to the HASP platform.

Contingency Plan:

There is no contingency plan for these commands other than the re-send process.

Ramifications to flight success:

The command's criticality is MEDIUM. The flight success will be determined in the proper execution of this command by the flight computer and in the response message issued by the system.

4. IMU ON Command:

Command Name: ION

Hex Command Byte: 49

Criticality LOW

Payload Message: **Response** Status's flags package

Command Example(HEX) 01020849030D0A

Table 11. IMU ON Command

Brief Description:

The command will turn on only the IMU, if required in some point of the experiment.

Contingency Plan:

There is no contingency plan for this command.

Ramifications to flight success:

The command's criticality is LOW. No critical repercussion upon failure of the command.

5. IMU OFF Command:

Command Name: IOFF

Hex Command Byte: 50

Criticality LOW

Payload Response Status's flags package
Message:

Command Example(HEX) 01020850030D0A

Table 12. IMU OFF Command

Brief Description:

The command will turn off only the IMU, if required in some point of the experiment.

Contingency Plan:

There is no contingency plan for this command.

Ramifications to flight success:

The command's criticality is LOW. No critical repercussion upon failure of the command.

6. GPS OFF Command:

Command Name: GOFF

Hex Command Byte: 75

Criticality LOW

Payload Response Status's flags package
Message:

Command Example 01020875030D0A
(HEX)

Table 13. GPS OFF Command

Brief Description:

The command will turn off only the GPS, if required in some point of the experiment.

Contingency Plan:

There is no contingency plan for this command.

Ramifications to flight success:

The command's criticality is LOW. No critical repercussion upon failure of the command.

7. GPS ON Command:

Command Name: GON

Hex Command Byte: 71

Criticality	LOW
Payload Message:	Response Status's flags package
Command (HEX)	Example 01020871030D0A

Table 14. GPS ON Command

Brief Description:

The command will turn on only the GPS, if required in some point of the experiment

Contingency Plan:

There is no contingency plan for this command.

Ramifications to flight success:

The command's criticality is LOW. No critical repercussion upon failure of the command.

8. Stop Running Mission Command:

Command Name:	STOP
Hex Command Byte:	90
Criticality	HIGH
Payload Message:	Response Status's flags package
Command (HEX)	Example 01020890030D0A

Table 15. Stop Running Mission Command

Brief Description:

The stop command will stop the system from running in an infinitely loop. Program code will be loaded in flash memory and will start running once the board is powered up. However on this Linux environment the program will not allow access to user space platform until it ends running. The command will stops infinitely while with a sentinel value that will be sent with the command.

The command is not related to the mission performance as it is a post mission command. However is listed as part of the software environment of the platform.

Contingency Plan:

Kill the process using Linux tools.

Ramifications to flight success:

None. Command will not be executed on Flight.

Example of Command Transmission String

As part of the uplink command format below is an example on how the commands will be formatted for future uploading.

Byte	Hex Value	Description
1	01	Start of Heading (SOH)
2	02	Start of Text (STX)
3	08	Payload ID
4	XX	Hex Command Byte
5	03	End of Text (ETX)
6	0D	Carriage Return (CR)

7	0A	Line Feed (LF)
---	----	----------------

Table 16. Example of Command Transmission String

8.4.1 Example of Status flags packages

The status flags packages will be downloaded once commands are received. It is also a method of knowing system health apart from the telemetry data:

Byte	Name of byte
1-3	On:
4	flag
5-8	rbt:
9	flag
10-13	gon:
14	flag
15-19	goff:
20	flag
21-24	ion:
25	flag
26-30	ioff:
31	flag

32-36	stop:
37	flag
38-41	off:
42	flag
Flag value	SET = 1 CLEAR = 0

Table 17. Example of Status flags packages

8.5 Sensor Interfaces

The interface between the sensor will be Serial Peripheral Interface (SPI) and Inter Integrated Circuit (I2C). The magnetometer, accelerometer, micro SD card, and the real-time clock use the SPI to communicate with the microcontroller. SPI is a synchronous serial communication with one microcontroller (master) and several devices (slaves). The master provides the clock signal and activates which device (slave) to receive data from. The SPI uses 4 lines, the slave select line to activate the device, the serial clock line to synchronize the data communication, the master-in-slave-out (MISO) line to send data from the slave to the master, and the master-out-slave-in (MOSI) line to send data from the master to the device. The gyroscope (ITG 3200) uses I2C to communicate with the microcontroller using two lines the serial data line (SDA) and the serial clock (SCK). The commands from the microcontroller and the data sent use the same line, SDA.

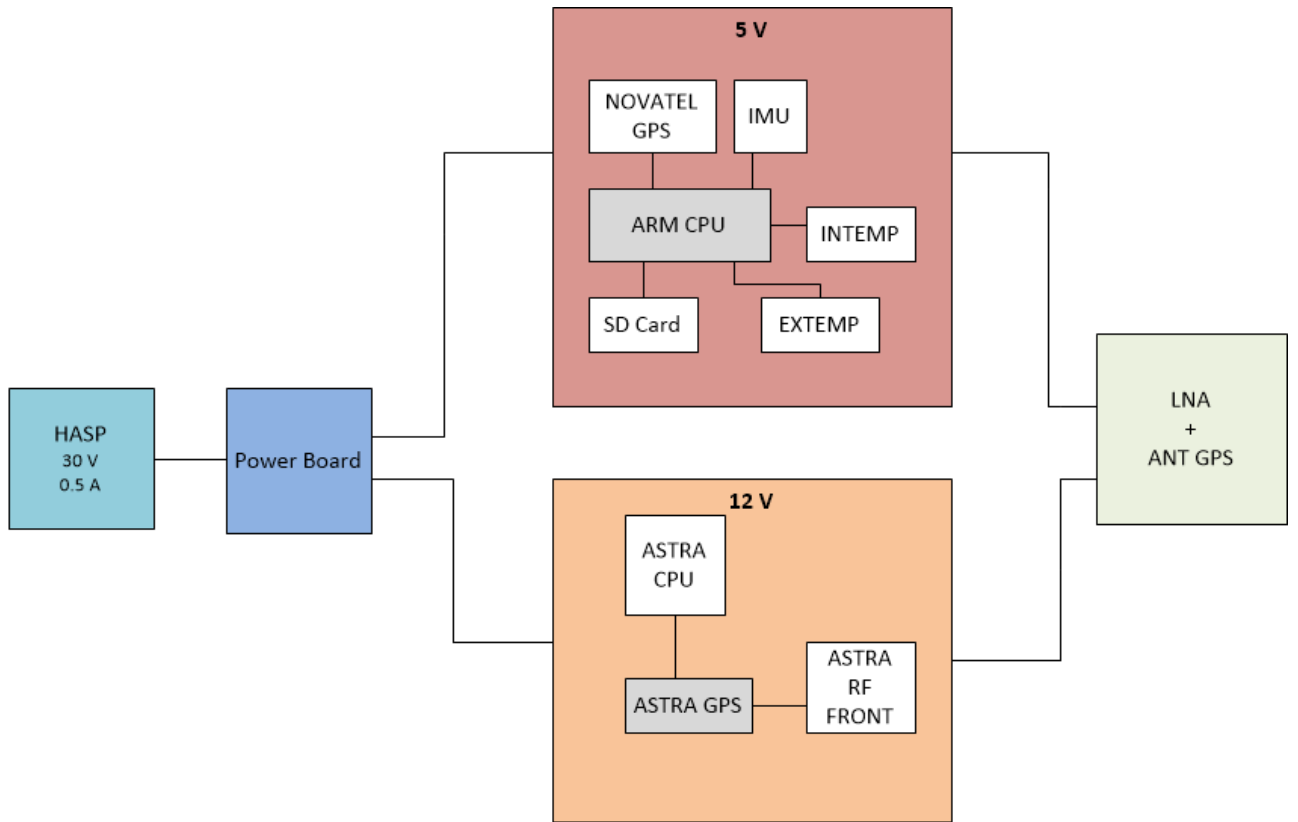


Figure 7. System Diagram

9. Desired Position and Orientation

Payload position #8 is requested. The GPS antenna should have a clear line of sight to the sky above to be able to lock in the GPS satellites.

10. Integration Procedures

Integration of ARIES-GPS payload to HASP will consist of fastening the mounting plate to HASP and connecting the power and data cable to the provide connections. The power on command will be given to verify that the payload turn on correctly.

11. Mechanical Design

11.1 Weight Budget

The ARIES-GPS payload has a weight limit of 3kg for the entire system. It is required to develop a weight budget in order to monitor the weight of the entire payload to ensure the entire system will be within the weight limits mentioned in the technical requirements section. The approximate weight of each one of the components for the payload is described in **Table 8**. Since this project is currently in the preliminary phases, there are several weights that are to be determined. Nevertheless, a more detailed weight will be present in the PDR and CDR document of this project and the final weight information of the components will be included in the FRR document.

ITEM	WEIGHT
MBS-GPS-OEMV -1DF PC/104	89g
Flight Computer	113.53g
Temperature Sensors DS18B20-TO-92	1g
Payload Structure	555.85g
Mounting Plate (estimated)	329.15g
Antenna Bracket	224.41g
Antenna	100g

RF splitter+ board	333g
CASES GPS	453.6g
Power Board	239g
External Temperature Sensor	2g
Cables & Connectors (estimated)	50g
Total Weight (without payload plate)	2161.39g
Total Weight (with payload plate)	2490.54g
Weight Limit	3kg
Weight Margin	16.982%

Table 18. Weight Budget

11.2 Payload Dimensions and Design

The ARIES-GPS experiment must comply with various requirements such as weight and power as mentioned previously. In addition, the ARIES-GPS experiment must also comply with the size requirement, which states that the payload must not exceed the 15cm x15cm footprint, a height of 30cm, and the ability to survive the landing loads. For this weight, yield strength and size are taken into account in the design process. The ARIES-GPS payload design is shown in **Figure 8 and 9**.

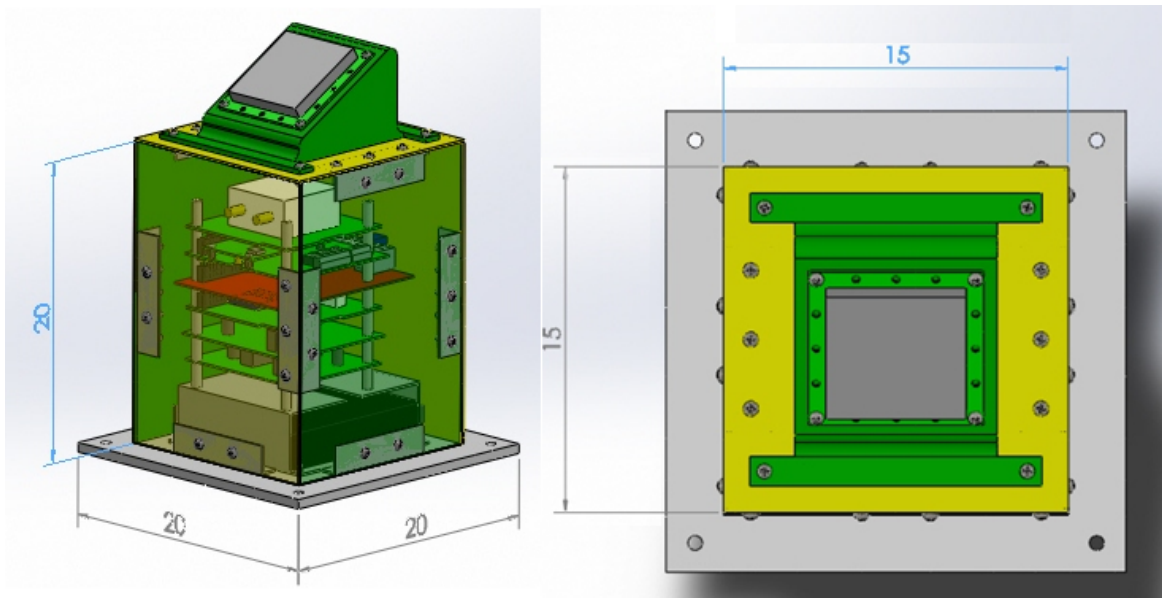


Figure 8 & 9: ARIES GPS payload design and dimensions.

11.3 Vector Analysis

Since the payload will be exposed to a vertical force of 10g vertical and 5g horizontal a vector analysis was performed on the areas that are considered critical and vulnerable for now, but this analysis will be performed to the complete structure. The preliminary results are shown in the **Figures 9 and 10**.

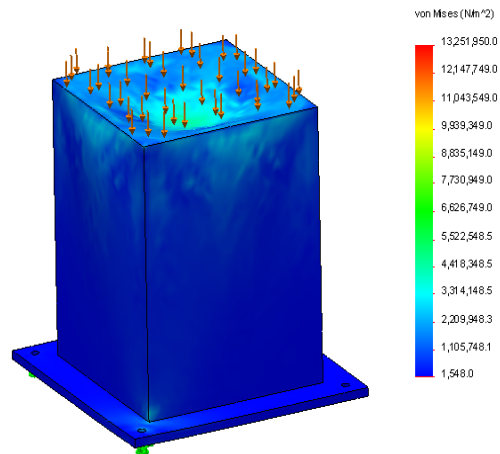


Figure 9: 10g vertical force

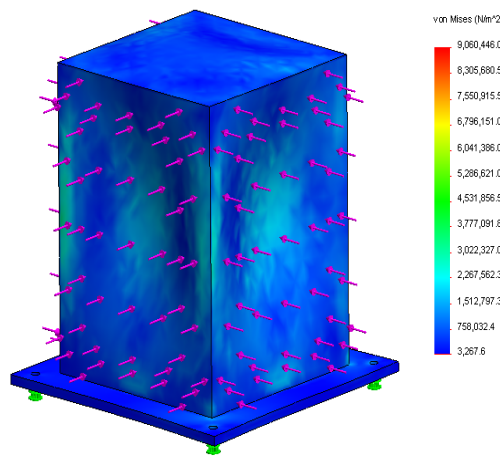


Figure 10: 5g horizontal force

12. Testing and Integration Procedures

12.1 Thermal Analysis

For the thermal issue, the structural aluminum payload needs to be insulated with kapton and MLI (multi-layer insulation) material due to this high conductivity. The use of kapton and MLI is useful in this due to this thickness in less space consuming and its low conductivity for electrical component protection from temperatures about -80 Celsius to 60 Celsius degrees, data obtained

from previous projects. To design how many kapton of layers and thickness of MLI are going to be used, the analysis will be considering external temperature vs. internal temperature produced by the electrical components power. For that reason, in this project will be use Heat Transfer Analysis in FEA software as Ansys and Comsol Multiphysics to validate the data. Finally, to generate more internal heat in cold case at temperature of -80 Celsius degrees is necessary increase the taking of samples in the microcontroller to increase the temperature and in hot case samples need to be decrease or be standby in critical event.

12.1.1 Worse Hot Case Scenario Simulation

In this case we assume the initial temperature being 10C, the radioactive environment -50C, the internal heating 13.5W.

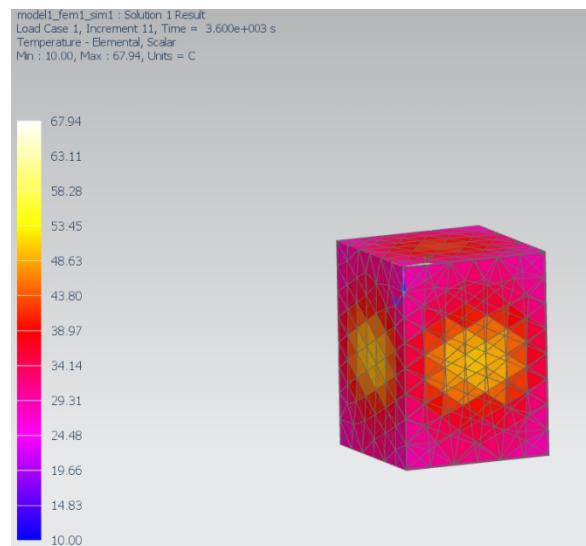


Figure 11. Worst hot case scenario simulation

The internal temperature became steady at $T=67.94C$.

12.1.2 Worse Cold Case Scenario

In this case we assume the initial temperature being 10C, the radioactive environment -60C, the internal heating 13.5W.

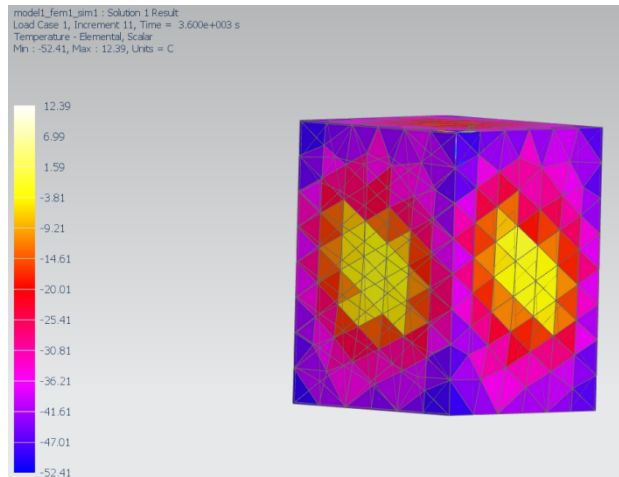


Figure 12. Worst cold case scenario simulation

The internal temperature became steady at $T=12.39^{\circ}\text{C}$.

13. Payload Student Team Structure at Inter American University of Puerto Rico Bayamón Campus

The personnel that might be traveling to the integration for the HASP payload will be the following, but this is subject to change at any time, with someone with the proper knowledge to deal with the payload will replace any personnel.

Stephanie Miranda Nieves

Email: ingstephmirand@gmail.com

Contact Number: 787 300 0528

Rosemily Diaz Montoya

Email: rosemily@live.com

Contact number: 787 597 7427

The technical and management efforts of directing and controlling an integrated engineering effort for the project. This element includes the efforts to define the project flight instrument and ground system, conducting trade studies, the planning and control of the technical project efforts of design engineering, software engineering, integrated test planning, system requirements writing, configuration control, technical oversight, control and monitoring of the technical project, and risk management activities. Documentation products include requirements documents, interface control documents, and master verification and validation plan.

14. Management

This project will operate under the supervision of Dr. Vo, Hien as shown in **Figure 13** at the Inter American University of Puerto Rico. Professor of different discipline are working in this experiment to supervise the student groups. The focus of the Aerospace Research and Innovative Experience for Students (ARIES) is to allow students to participate and be become part of a real-world space-systems project. To better prepare the student for careers in space science and engineering. An additional motivation is to create an environment where creativity and independence is encouraged, thus allowing to apply the theory from the class room to real hands on work.

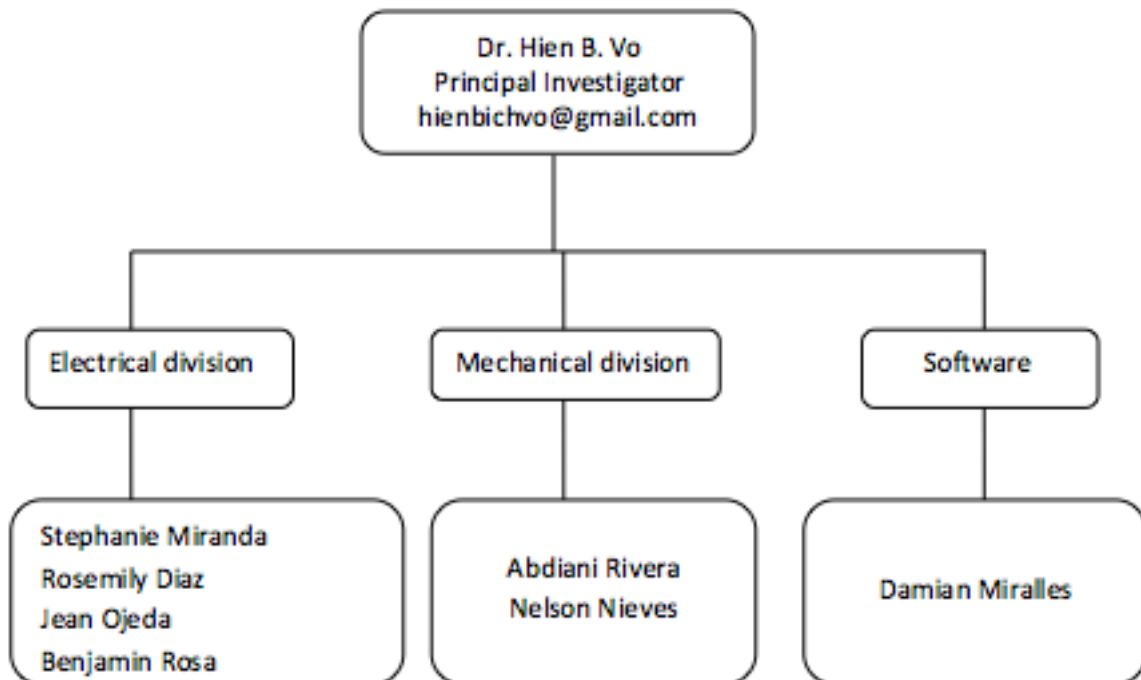


Figure 8. Team Structure

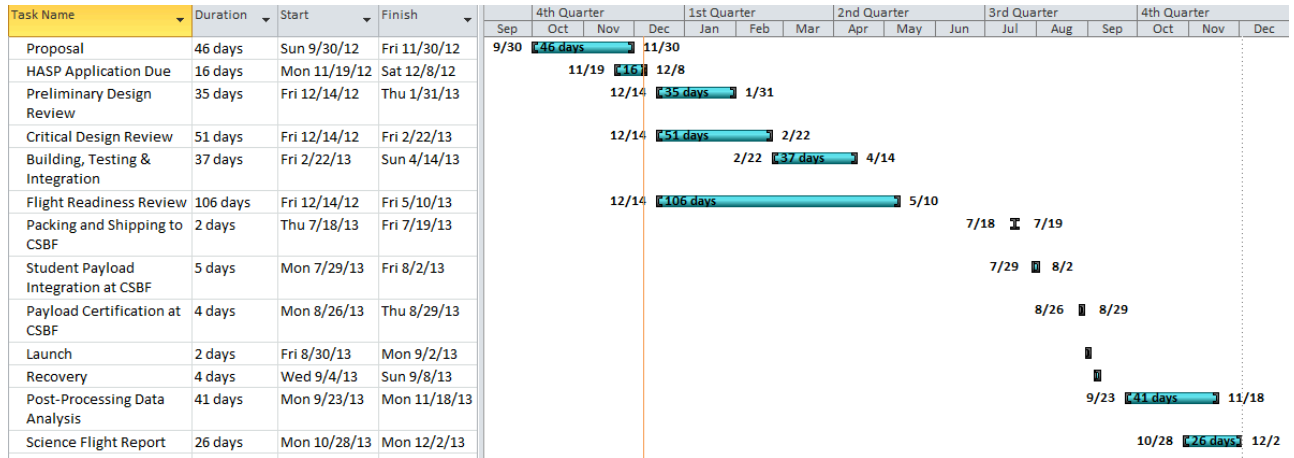


Figure 16: Preliminary Gantt Chart