PUERTO RICO
CubeSat

HASP Student Payload Application for 2016

Payload Title: EVALUATION OF ATMOSPHERIC PARTICLE COLLECTION PERFORMANCES OF THREE SAMPLING SUBSTRATES AT DIFFERENT LAYERS OF THE ATMOSPHERE.		
Payload Class: (check one) ■ Small ☐ Large	Institution: Inter-American University of Puerto Rico	Submit Date: 18/12/2015

Project Abstract:

The composition and size distribution of atmospheric aerosol particles are temporary and spatially highly variable. Their occurrence, residence times, physical and chemical properties, such as size distributions and chemical composition, all vary greatly of many orders of magnitude. Therefore, the vertically resolved measurement of physical properties of particles is of great interest. In this study, we would like to determine and interpret the changes in the size and shape of the atmospheric particles and concentrations of trace metals and persistent organic compounds along three altitudinal gradients. We hope to gain experience and insight into the aerosol particle size distribution and atmospheric contamination with metals and POPs, and use this experience for a near future study to be conducted in the tropical atmosphere of Puerto Rico.

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ABSTRACT

The composition and size distribution of atmospheric aerosol particles are temporary and spatially highly variable. Their occurrence, residence times, physical and chemical properties, such as size distributions and chemical composition, all vary greatly of many orders of magnitude. Therefore, the vertically resolved measurement of physical properties of particles is of great interest. In this study, we would like to determine and interpret the changes in the size and shape of the atmospheric particles and concentrations of trace metals and persistent organic compounds along three altitudinal gradients. We hope to gain experience and insight into the aerosol particle size distribution and atmospheric contamination with metals and POPs, and use this experience for a near future study to be conducted in the tropical atmosphere of Puerto Rico. Additional it will be collecting data on the performance of Electronic Power Systems (EPS) that was designed for Puerto Rico CubeSat.

MISSION OVERVIEW

A. Mission Objectives

The main objective of this study is to evaluate particle collection performances of porous and nonporous substrates in the troposphere and stratosphere with the help of physical and chemical characteristics of atmospheric aerosols.

Specific goals of the study are given below:

1. To evaluate particle collection performances of aerogel, polyurethane foam (PUF) and Mylar discs at different atmospheric layers,
2. To obtain aerosol size distribution at different altitudes,
3. To quantify atmospheric concentrations of trace metals and persistent organic compounds in the troposphere and stratosphere. .

A secondary objective will be to characterize the EPS which is designed for Puerto Rico CubeSat.

B. Theory and Background

Aerosols Experiment.

Aerosols are of major importance for atmospheric chemistry and physics, the hydrological cycle, climate, and human health. The primary parameters that determine the environmental and health effects of aerosol particles are their concentration, size, structure, and chemical composition. However, these parameters are spatially and temporally highly variable due to different sources and meteorological processes. In the troposphere, the total particle number and mass concentrations typically vary in the range of about 10^2–10^5 /cm^3 and 1–100 mg/m^3, respectively [Raes et al., 2000, Williams et al., 2002, Krejci et al., 2005]. In general, the predominant chemical components of air particulate matter (PM) are sulfate, nitrate, ammonium, sea salt, mineral dust, organic compounds, and black or elemental carbon, each of which typically contribute about 10–30% of the overall mass load. However, the relative abundance of each components can vary by an order of magnitude or more at different locations, times, meteorological conditions, and particle size fractions [Raes et al., 2000, Han et al., 2007].

The physical and chemical properties of atmospheric particles in the troposphere are highly diverse, due to different sources and meteorological processes. Atmospheric aerosol particles originate from a wide variety of natural and anthropogenic sources. Meteorological conditions such as wind speed, temperature and relative humidity influence aerosol shape and size distributions, and chemical levels. Measurements of size distributions and chemical composition of atmospheric aerosols are crucial in advancing our understanding of their fate and transport.

EPS

The **EPS** prototype is a one sided Printed Circuit Board (PCB), printed on a single layered 9cm x 9cm copper clad with a total weight of 0.071 kg. The developed **EPS** satisfies the following standard conditions for a standard small satellite: capability of handling up to 5A, output voltage levels should be 3.3V and 5V, support a photovoltaic input as well as an 8.4V battery input, energy management capabilities, size and weight restraints. Fig. 1 illustrates the constructed 9cm x 9cm prototype for the CubeSats **EPS**.

The **EPS** is backed up by a battery that supplies power when the sun irradiation is not enough to power the satellites. The **EPS** also makes use of the Optimal Duty Ratio algorithm for **Maximum Power Point Tracking (MPPT)** that facilitates the conversion/transmission of maximum power extracted from the solar cells. This algorithm helps determine the maximum power, current, and voltage that can be extracted from the **EPS**. Below is a list of features integrated into the CubeSats **EPS**. The figure 1 shows the second prototype of the CubeSat EPS.

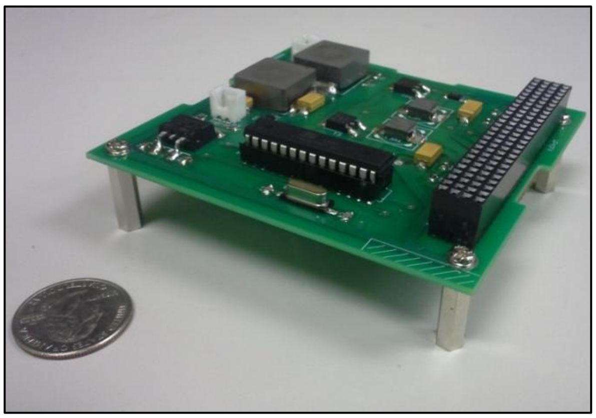


Figure 1. Electronic Power System Board

C. Concept of operations (Con-Ops)

The scientific payload will be running once the launch begins. The payload will depend in the altitude of the satellite. Form point 1 to 2 the first collector assembly 1 is exposes to atmosphere using a slider box and will allow us to obtain the samples. From point 2 to 3 the first assembly closes and the second collector assembly will allow us to obtain the samples. From point 3 to 5 the second assembly will close and the third assembly opens. Once the payload reaches the maximum altitude, the mission for the EPS will starts. The experiment of the EPS will run from point 4 to 5. From point 5 to 6 the system will shut down at the descent. The figure 2 shows the concept of operations.

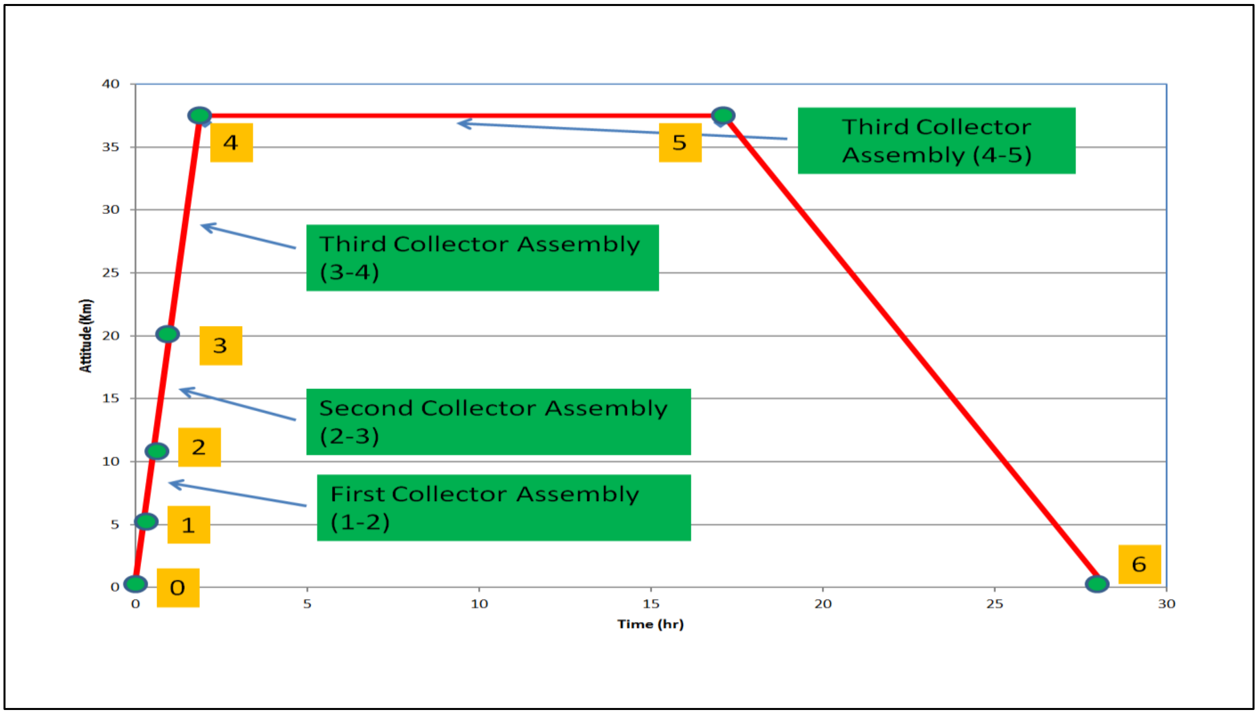


Figure 2. Concept of Operations

D. Payload Design Details

In this study, aerogel, PUF and Mylar discs will be used to collect atmospheric particles at three different layers of the atmosphere (Figure 3). Unlike Mylar discs, aerogel and PUF have porous surface. Aerogels are highly porous materials made by removing the liquid phase of a dilute suspension of solids by taking off the vapor under super-critical temperature and pressure conditions. The aerogel structure has a skeleton of nanometer-size elements forming pores that are tens of nanometers in dimension. NASA used aerogels to trap space dust particles aboard the Stardust spacecraft.

PUF disks of 5 cm diameter and 1.2 cm thickness are proposed to use in this study and they have been previously tested as passive samplers (Jaward et al, 2004; Pozo et al., 2009). The use of PUF as a substrate has several advantages such as having very high particle collection efficiency over a large range of particle sizes, being chemically inert, minimizing interference with any of the tests. A large amount of particles can be collected on a relatively small collection surface of PUFs and easily extracted with small amounts of water or organic solvents.

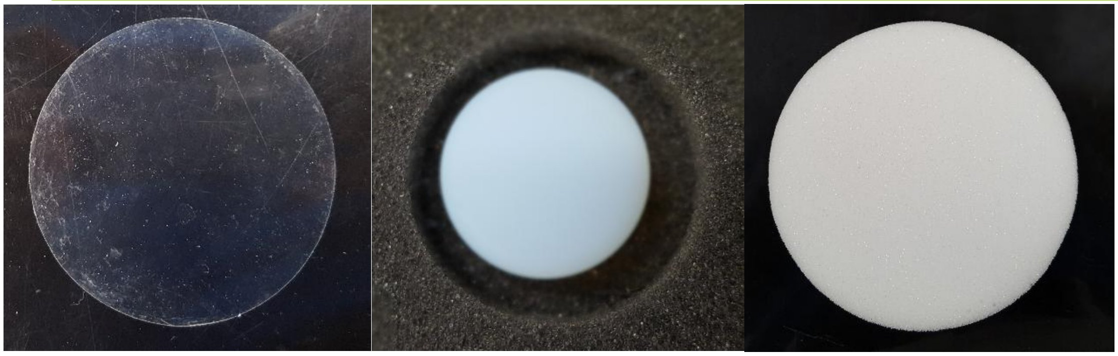


Figure 3. Particle collection media: Mylar disc, aerogel, and PUF disc (from left to the right).

Mylar strips have been extensively used as a surrogate surface for atmospheric dry deposition studies. Particle bouncing form the strips have been prevented by coating the surface of the strips with grease. In this study, instead of strips, Mylar discs will be used in order to have same geometric shape with the other two sampling substrates.

Mylar discs will collect total suspended particles whereas PUF and aerogels will entrap only for fine particles. Since aerogels have nanopores, only particles lees than 100 nm might be captures by those pores.

MATERIALS AND METHOD

Sample Collection

In this study, aerogel, PUF and Mylar discs will be used to collect atmospheric particles at three different layers of the atmosphere. An air-tight sample box made of PVC will be prepared to house the sampling substrates. The sample box will have three compartments and each compartment will include discs of aerogel, PUF and Mylar. Ambient particles will be captured by the aerogel and PUFs in their pore structures.

Preparation of Sampling Media

Mylar strips have been extensively used as a surrogate surface for atmospheric dry deposition studies. In this study, instead of strips, Mylar discs will be used in order to have same geometric shape with the other two sampling substrates. The collection area to be greased on Mylar (0.002 inches thick) disc will be marked with a scratch pen. Prior to being coated with grease the discs will be cleaned. The first step in the cleaning procedure involves dipping the discs in glass petri dish containing double distilled methanol and scrubbing both sides with particle free wipe (S/P Brand S/Pec-Wipe). The discs will be subsequently dipped in a second petri dish containing deionized water and both sides are again scrubbed with a particle free wipe. The third and fourth steps involve dipping the discs again in deionized water. However, in these steps the discs will not be scrubbed. Finally, the discs will be placed in a storage box for drying. After the discs dry, they will be given a thin coat of Apiezon-N grease on the marked area. This will be accomplished by melting the grease in a small glass petri dish on a hot plate. A small paint brush will be used to coat the discs, which will also be warmed on the hot plate. The brush will be cleaned prior to use with pure Hexane, followed by double-distilled-Methanol. After the discs are coated with the grease, they will be put into a dust-free storage box to equilibrate for at least 24 hours before weighing. The storage box will be not opened until all the other preparations are made for field measurements. The discs will be handled with particle free gloves to ensure that there is no physical contact with the greased surface.

Porous materials are of immense importance in various applications such as adsorption, sensing, and catalysis, owing to their high surface area, porosity, adjustable framework, and surface properties. Out of all known solid porous materials, aerogels have drawn a lot of interest in recent years because of their low bulk density, hydrophobicity, low thermal conductivity, and high surface area. Aerogel is a nanoporous material consists of 99.8% of air and can be used at temperatures ranging from - 200°C to + 650°C. The particles vaporize on impact with solids and pass through gases, but can be trapped in aerogels. Therefore, aerogels will be employed in this study for the purposed of trapping aerosols at different layers of the atmosphere. Since aerogels have large specific surface area but small pore size, it is expected that mostly nanoparticles (aerosol diameter less than 100 nm) will be trapped in those pores.

Mylar strips will be used for mass size distribution measurements, and to minimize particle bouncing, the discs will be coated with Apezion-N grease. Apiezon L, M and N greases have been specifically developed for vacuum use, but are also extensively used for nonvacuum purposes in a variety of industrial and scientific applications. Apiezon N grease is also widely recognized and recommended as the cryogenic vacuum grease of choice. It's working temperature range from -269 to 30 °C. The net mass on the disc samples will be determined from the weight difference of the discs before and after sampling.

Each compartment will be activated at different times and altitudes during the flight. The Mylar disc will have only particles whereas the porous substrates, aerogel and PUF, will have both particle and gas phase of the pollutants. This first compartment will be opened from near ground until the tropopause (approximately10km) where temperature decreases with altitude. The compartment will stay open between tropopause and the stratosphere where there is no significant temperature change (approximately 10-20km). Finally, the third compartment will stay open at 35km and collects the particles as well as gas phase of the pollutants.

Analysis of the Samples

Following table summarize the sample analysis procedure.

Substrate	**Instrument**	**Instrument**
Mylar disc	Particle size and shape Particle size Elemental composition	SEM IZON qNano SEM-EDX
PUF disc	Particle size POPs	IZON qNano Varian GC/MS
Aerogel	Particle size Elemental composition	IZON qNano

Particles collected on surface of PUFs will be easily extracted with small amounts of DI water for size distribution and with organic solvents for chemical analysis. The captured particles by aerogels will be transported in the nano DI water from the sampler by sonication. The extract will be used for size and elemental composition analysis.

Particle size distribution will accurately be determined by measuring individual particles with IZON qNano instrument. Unlike other size analysis technologies such as Dynamic Light Scattering, where measurement includes intensity-weighted averaging effects, the IZON qNano measures individual particles. Particle-by-particle measurement allows an accurate size distribution to be obtained with high precision.

The shape and elemental composition of the particles collected at three different altitudes will be analyzed using a TESCAN scanning electron microscope (SEM) Model VEGA 3 XMU. The elemental composition of the collected particles will be determined with an energy dispersive X-ray system (EDX).

The large portion of the PUF disc samples will be Soxhlet extracted with a 20:80 dichloromethane (DCM): petroleum ether (PE) solution for 24 h. The samples will be spiked with POPs surrogate standards prior to extraction. The analysis of the samples will be performed using a Varian 450-GC coupled to an ion trap mass spectrometer Varian 240 MS.
All the instruments are available at the Bayamon campus of Inter American University.

Benefits of the Study

Aerosol particles affect climate directly by interacting with solar and terrestrial radiation and indirectly by their effect on cloud microphysics, albedo, and precipitation. Aerosol properties at high altitudes are an important element of intercontinental transport. Vertical concentration gradients of aerosol size distribution are crucial in advancing our understanding of aerosol fate and transport. Study of the size distributions of aerosol will give us important information about their origin and atmospheric behavior. With this, study new scientific information related to physical and chemical properties of atmospheric aerosols will be developed. The study results will be a source of valuable information that can be used in various atmospheric investigations, including studies of air mass modification, climate change and models validation.

EPS TEST

Figure 4 show the block diagram for the proposed CubeSat EPS. The proposed design for the EPS of the CubeSat mainly consists of: a DC/DC converter that performs the maximum power point tracking (MPPT), two load regulators that will supply the 3.3V and 5.0V loads. The DC/DC converter is an electronic circuit that has the capacity to regulate the DC voltage from a DC source in order to transfer energy to the different loads. Regulators will control the output voltage to 3.3V and 5V directly from the DC/DC converter or from the batteries. The EPS must provide power to the CubeSats peripherals so it can maintain its functionality. HASP platform will be used to characterize the operation of the EPS in extreme conditions.

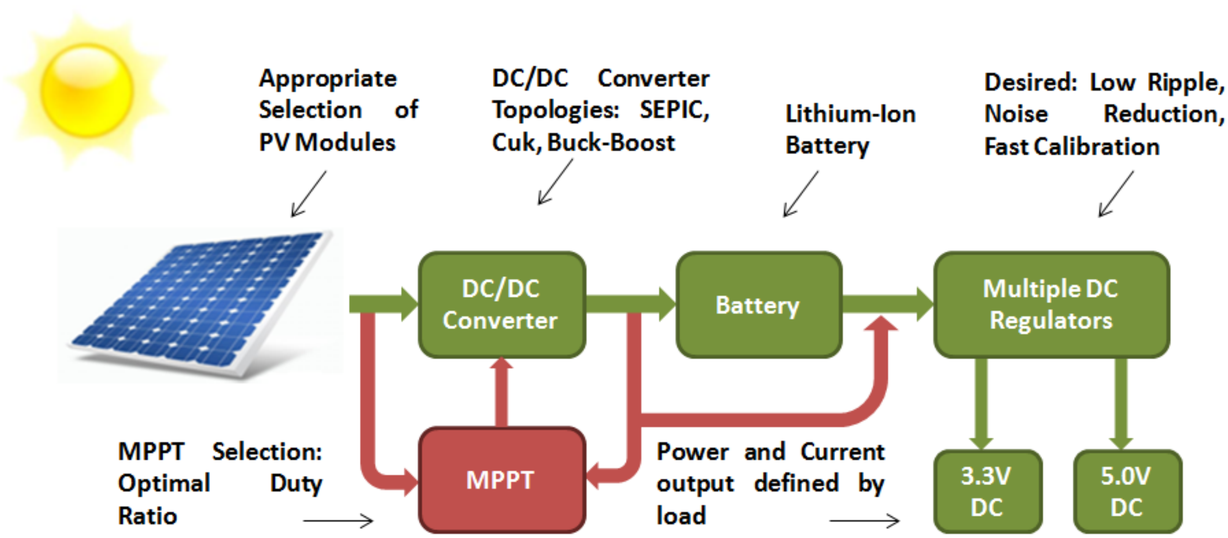


Figure 4. Proposed CubeSat electrical power supply (EPS) design. This design utilizes DC/DC converters to perform the MPPT and to regulate voltage at the EPS outputs. The green blocks show the power flow while the red blocks illustrate the control flow of the EPS.

E. Electrical Power Sub-System

The electrical power subsystem shall regulate the incoming (30V/0.5A) coming from the HASP platform. This sub-system will consist of a single PCB that will collect, regulate and distribute the power necessary for all of payload active components. Power from HASP will be regulated by a series of different buck DC-DC converters that will regulate all needed outputs. In general a 5V and a 3.3V standard buck DC-DC converter will be required and other voltages will be added to design as requested by other sub-system requirements. Input Power from HASP will be in parallel to all output buck converters. If necessary current limiters will control current peaks in order to asses power consumption standardization.

Power regulated will be passed down to all components of the payload and all grounds will be returned to the power distribution and control board (PDCB). The PDCB will pass grounds through a series of transistor switches that will control all component grounds.

The microcontroller will automatically turn on and off electrical components depending on functionality procedures dictated by the software algorithms inside the microcontroller.

F. Data Handling and Command Sub-System

The DHCS will consist of a PCB containing a microcontroller and power distribution transistors switches (PDCB). This subsystem will control the switching power of all components and will acquire data from all sensors. This data will be process and parsed toward a storage component in the meantime an SD card. The temperature array analog data will be processed and parsed by the microcontroller through the ADC ports of the microcontroller. All temperature parsed data will be stored on a SD card for post flight data collection.

The barometer data will determine altitude of HASP on order to digitally activate collectors' box. The first collector will be activate from 5km as system activate servomotor 1 in order to open collector 1 and acquire aerosol particles until HASP reaches the tropopause at 10km of altitude. Barometer lecture of 10km of altitude will make microcontroller close the collector 1 servo and open collector box 2 that will collect aerosol particles from the tropopause until stratosphere. Reaching the stratosphere will activate the servo from collector 2 close and open collector box 3 until reaching the 35km. Any other command or data collection should be added as requested or determine by other sub-systems.

The EPS experiment began at 35km, acquiring voltage and current and this data will be process and parsed toward a storage component in the meantime an SD card.

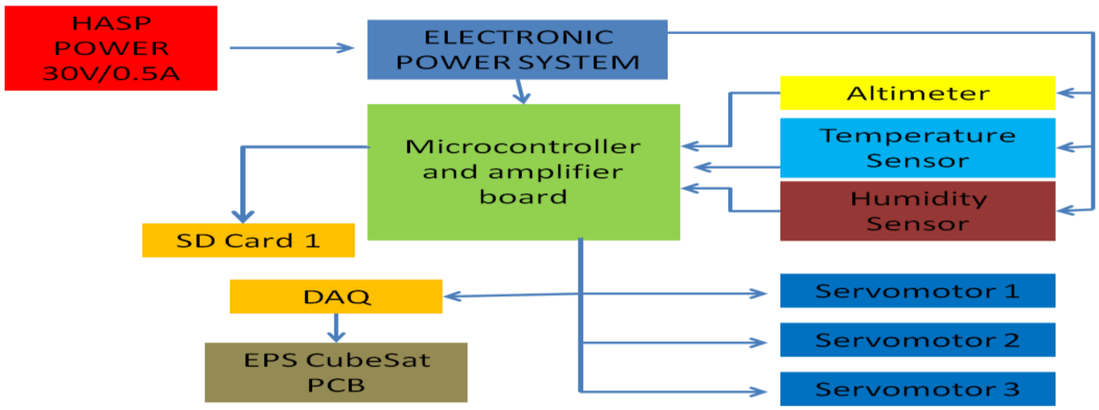
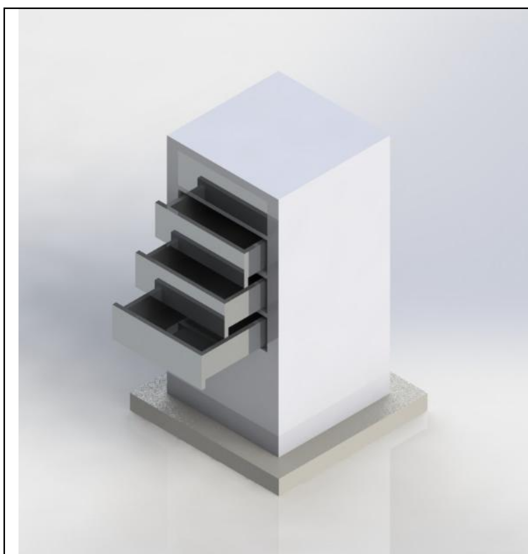
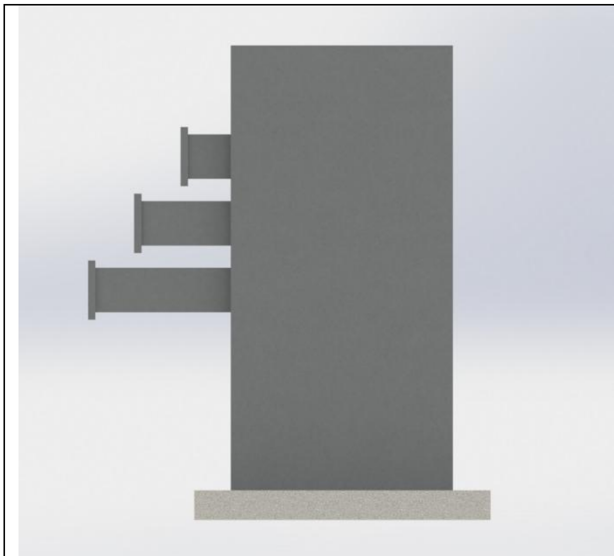
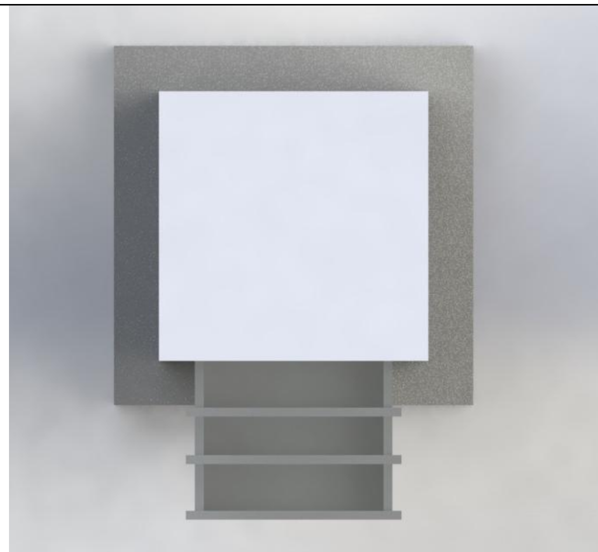


Figure 5. Data handling and subsystems

G. Structure

	
Isometric View	Front View

	
Lateral View	Top View

The base of the structure has dimensions of 15cm x 15cm, the total height of this prototype is approximately 30cm. This is a preliminary structure; further studies are being done to optimize and change the structure if needed. The body has dimensions of around 12cm x12cm. The structure is made of aluminum 6160, for CubeSat applications, the same material is used.

H. Mass and Power Budget

Components	Mass (kg)	Voltage(V)	Power (W)
3 Servo Motors	0.050	5	3.3
Boards and micro	0.035	3.3	0.2
EPS Board	0.097	5	
DAQ Board	0.035	5	0.5
Structure	0.250		
Total	**0.467**		**4.0**

The maximum power was calculated considering that there will be at most 3 servo motors at a single time as well as the microcontroller and the circuitry. When these components are in use they will consume the most power, they were taken into consideration for the maximum power. The total mass is calculated considering that the system will contain 3 servos, micro, pbc boards, the circuitry, connections and the structure, fasteners and test plates. All the mass measured is preliminary since the components may change in order to improve the design.

I. Project Management Plan

The payload has the need of incorporating the structure and thermal analysis team together, as well as, the power team. As such, the organization of the team is as shown at figure 5:

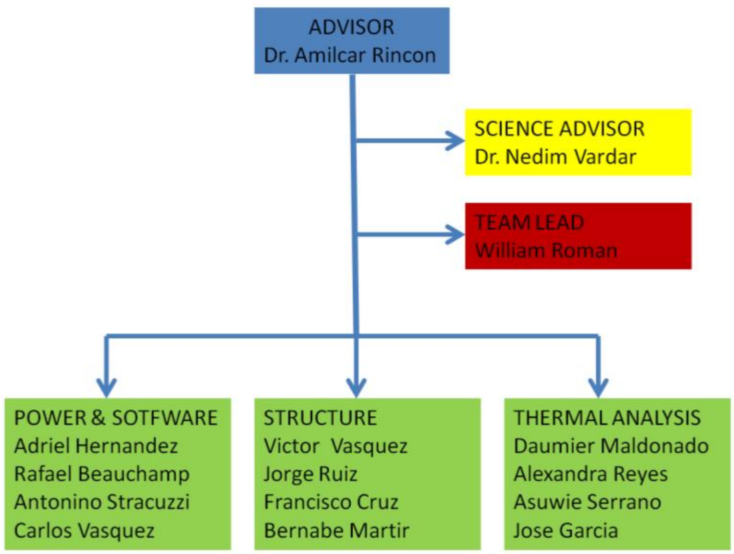


Figure 6. Organization of the Team

Subsystems

The payload consists of 3 critical subsystems. Each subsystem will be tasked to a group member who will report directly to the team lead of the project.

Thermal Analysis: Temperature control, and weather conditions change.
Power and software: voltage regulation, wiring, circuit components, and the electrical integration and coordination of all sensors and controllers.
Structure: Case design, structure material, and structure incorporation.

There will be a total of 13 students working on the project.

J. Waiver Request

In order to acquire the samples of the atmospheric particle at high altitudes, a payload on the HASP gondola is needed. This is necessary to accurately obtain aerosol mass and size distribution at different altitudes and to quantify atmospheric concentrations of persistent organic compounds in the troposphere and lower stratosphere. Since the equipment required to simulate the conditions at high altitudes is available at the university at the time, we plan to use this opportunity as a stepping stone to acquire external fund in the future.

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