HASP Student Payload Application for 2012

Payload Title: ARIES-DYNAMICS		
Payload Class: (check one) X Small ☐ Large	Institution: Inter-American University of Puerto Rico Bayamon Campus	Submit Date: December 16, 2011

Project Abstract

The purpose of the ARIES-DYNAMICS experiment is to increase the knowledge of aerospace engineering specialized in CubeSat technology. In addition, the project allows the students to gain knowledge and experience in attitude determination and control systems (ADCS) of a payload. Through Kalman filtering the attitude determination system (ADS) will be used to determine the flight dynamics. Then, an attitude control system (ACS), using a Proportional-Integral-Derivative (PID) control scheme, will be used to maintain the correct orientation of the upper part of the payload. The team currently consists of approximately 12 undergraduate students from many disciplines from the IUPR-Bayamon campus.

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ARIES-
DYNAMICS
Proposal for the High Altitude Student Platform
(HASP), 2012

Advanced Research and Innovative Experience
for
Students Laboratory
ARIES Labs

UNIVERSIDAD INTERAMERICANA DE PUERTO RICO
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Mission Goal

To gain knowledge in aerospace engineering by developing a prototype of the Puerto Rico SWIM CubeSat as a balloon payload, and to test the attitude determination and control system during the 2012 flight of the HASP balloon.

Payload description

Science Objectives

The purpose of the ARIES-DYNAMICS experiment is to increase the knowledge of aerospace engineering specialized in CubeSat technology. In addition, the project allows the students to gain knowledge and experience in attitude determination and control systems (ADCS) of a payload. Through Kalman filtering the attitude determination system (ADS) will be used to determine the flight dynamics. Then, an attitude control system (ACS), using a Proportional-Integral-Derivative (PID) control scheme, will be used to maintain the correct orientation of the upper part of the payload.

In the experiment, the global positioning system (GPS) is used to determine the position and the time of flight of the payload. The internal and external temperature during flight is measured to understand the temperature gradient effect on the MEMS IMU. To understand the flight dynamics of the balloon platform, a camera will be used to store images of the surrounding environment of the platform. Post flight, stored images will be analyzed to verify correct operation of the ADCS.

Principal of Operation

The ARIES-DYNAMICS payload will test commercial-off-the-shelf (COTS) inertial measurement units (IMU's) that could be used for a future CubeSat project. Once the payload is turned on, the system and the ADCS board in the bottom box will reset all the motors to their initial position. There will be several boards on the top of the cube: 1) an ADS board that will read the data from all the sensors and will store it in a micro SD card for post analysis; 2) a solar panel voltage-current measurement board will be used to obtain the current and voltage of the five solar panels made for the NSF CINEMA UC Berkeley which are placed along the external wall. In the bottom box, there is an ADCS board that will collect attitude information and perform all the necessary calculations to obtain the attitude quaternion. The attitude quaternion is used to correct the pitch and yaw orientation of the top cube by using the motors. In general, the main objective of the project is to keep the top cube aimed at a reference point with respect to the body frame of the balloon payload. To measure the thermal environment of the ARIES-DYNAMICS payload, the temperature sensors will be placed in different areas of the payload.

Thermal Control Plan

To be thermally stable, the payload aluminum structure needs to be insulated to prevent damage to the electrical components. Kapton and Multi Layers Insulators (MLI) are selected as the main insulators materials due to its temperature resilience. Kapton and MLI are useful in these applications due to its thickness and its low conductivity for temperatures between -80 to 80 degrees Celsius. The Kapton layers and MLI are determined by considering the external vs. internal temperature produced by the power of the electrical components. For this reason, this project will use Finite Element Analysis software as Ansys and Comsol Multiphysics to validate the expected data.

Mission Justification

The ARIES-DYNAMICS project is a low cost, low medium-risk test flight to prove new technologies that are critical to the success of the Puerto Rico SWIM CubeSat mission. A flight in the HASP environment allows for a cost effective method to reduce the risk factors to the CubeSat mission. This flight allows the development of new technology and proves the flight software operation in an environment similar to Space. The ARIES-DYNAMICS payload is the next step to obtain a full attitude determination and control system, to characterize the solar panels for the upcoming NSF CINEMA CubeSat project from UC Berkeley, and to validate the usage of MEMS IMUs for future CubeSat project.

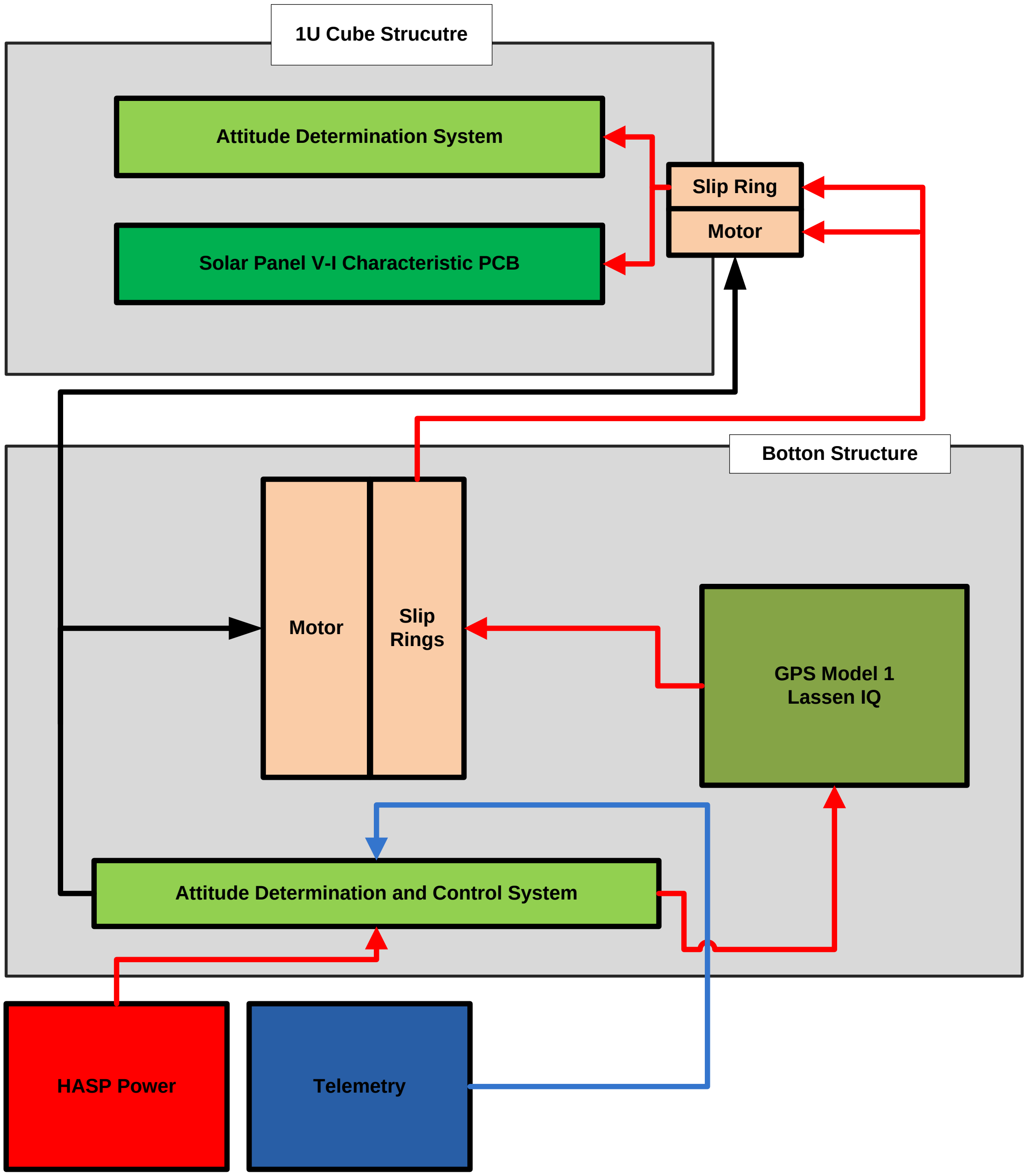

Figure 1: System Diagram

A general description for a system design of the ARIES-DYNAMICS payload is shown in **Figure 1**. The 30V and 0.5A power supply from the HASP platform is connected to a step down circuit on the Attitude Determination and Control System (ADCS) board. This circuit will supply the voltage and current required for the GPS. The top cube (a 1U freely moving structure) has an ADS board with an earth horizon camera and the solar panel V-I characteristic board. The data from the ADCS will be sent through telemetry to be used in the post-processing flight. The ADCS will control two motors according to the data received from the sensors to adjust the pitch and yaw angle of the top cube.

Attitude Control System

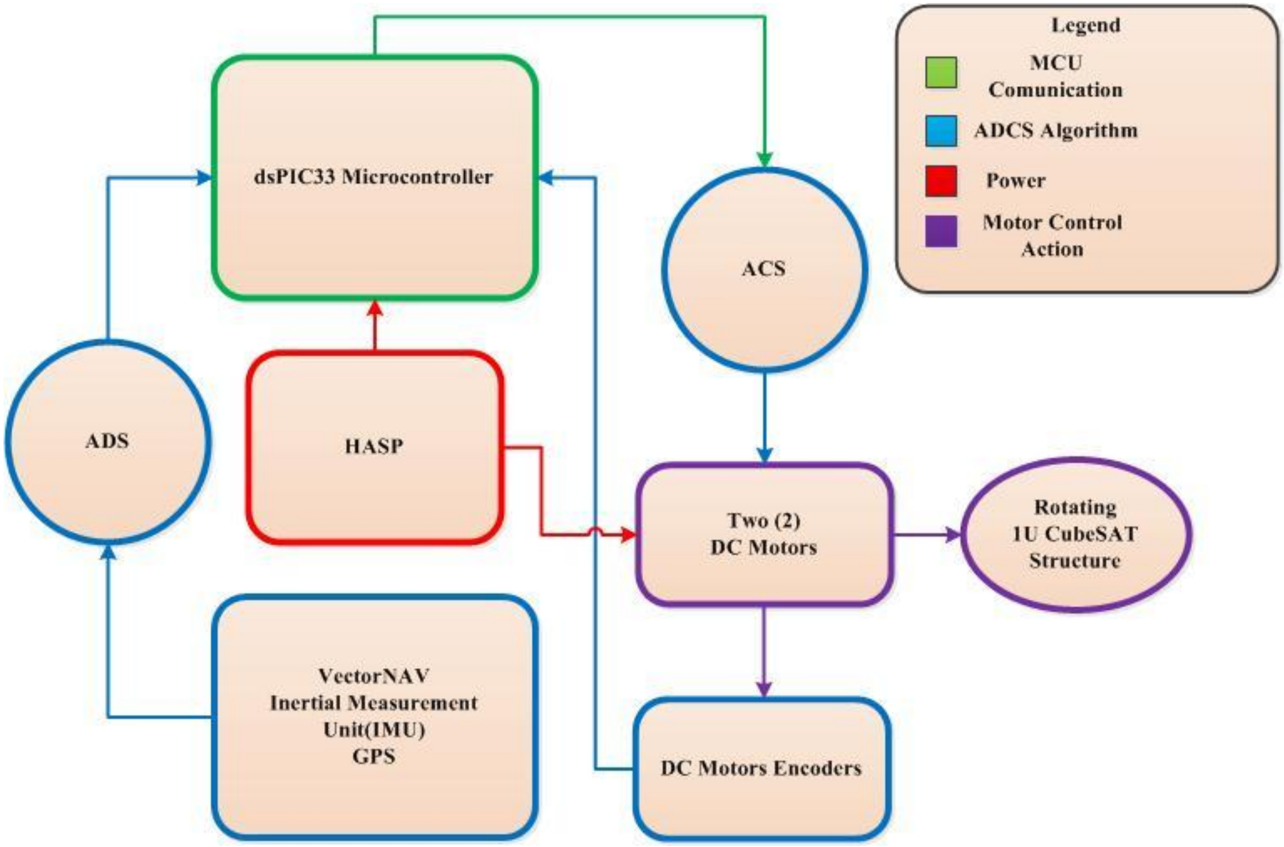

Figure 2: Control System Diagram

An extensive research for the previous Puerto Rican HASP 2011 payload has been done to design an Attitude Control System (ACS) to test various sensors. To obtain the orientation of the payload, the angular velocity, Earth's magnetic field, and the acceleration will be used to obtain the Euler's angles from the quaternions calculated by a Kalman filter.

The objective of the control system is achieved by two DC motors that control the pitch and yaw orientation of the top cube. These two angles are determined by the microcontroller with two encoders which receive the actual yaw and pitch angles. Then, these angles are used to compare the measurements to the set points such that the error between the measurement and the set point becomes a minimum. It is important to note that all the signals coming in or out of the microcontroller are sampled and hold to serve the control objective.

Payload Specifications

HASP Power Supply

The primary available power source during flight is a 30V at 0.5A from HASP. The main purpose of the project is to test the functionality of the ADCS; therefore the HASP will provide the necessary power for these critical components during the (approximately) 17hr flight.

HASP Power Interface

The HASP mounting plate provides two connectors: one connector is the DB9 serial connector used for uplink and downlink of data; and the other connector is the EDAC 16 connector which provides the connections for power, the discrete commands to the HASP platform, and the analog outputs. **Figure 3** shows the platform and the location of both connectors.

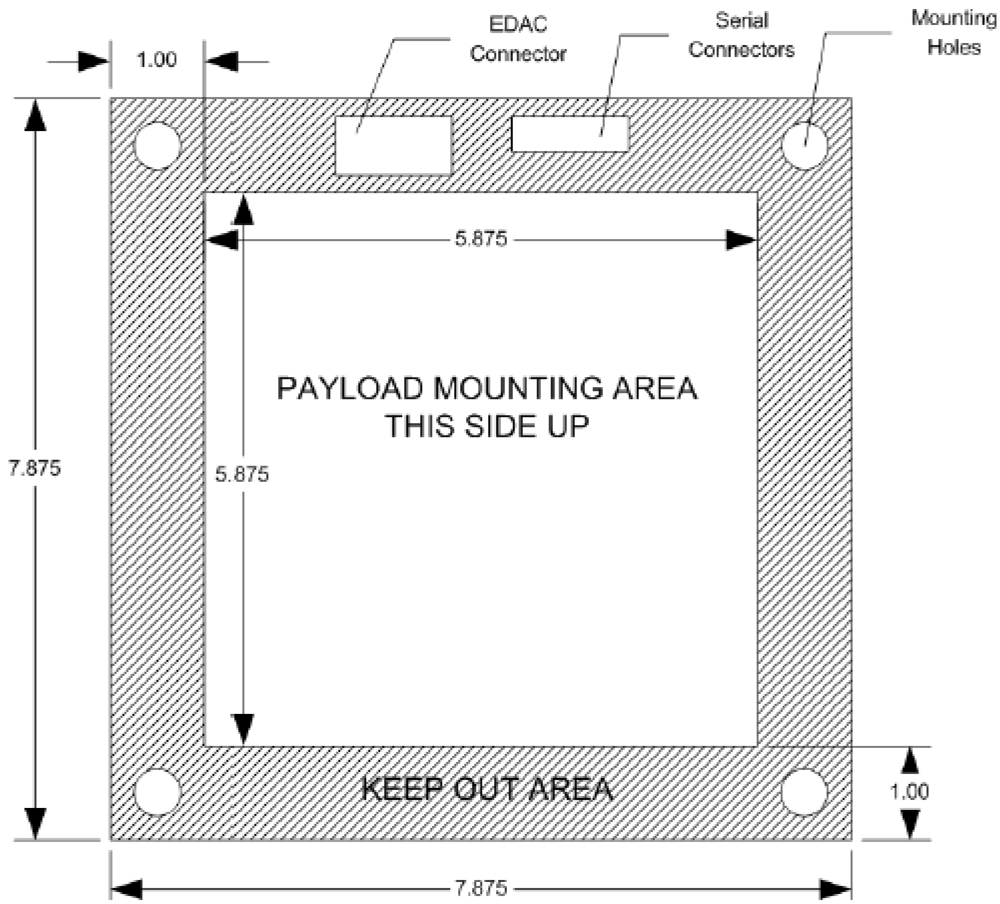

Figure 3:- HASP Mounting Area Layout

The EDAC is a 20 pin connector used to interface our system to the HASP 30V power. The HASP already provides this connector in its platform, and the wires are labeled with a specific color to identify its function. The following table describes the wire 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 1:- EDAC 516-020 Pin Layout

The table shows four wires that provide +30VDC; these wires are labeled as A, B, C, and D. These wires are required to be connected in parallel to allow the maximum current (0.5Amps) from the HASP. The parallel connections between the wires should be connected properly to the step down circuit on the ADCS board.

Payload's Power Budget

Sensors	Voltage (V)	Current (A)	Power (W)	Power Source
Digital Temperature Sensor DS18B20	3.3	0.006	0.0198	HASP
DSPIC33F256MC710 Microcontroller	3.3	0.05	0.165	HASP
MPU 6000 IMU	3.3	0.0038	0.01254	HASP
Real Time Clock DS1306	5	0.00128	0.0064	HASP
SD card circuit	3.3	0.038	0.1254	HASP
CMOS Camera	5	0.025	0.125	HASP
Solar Panels Electrical Components	5	0.114	0.57	HASP
RS232	3.3	0.03	0.099	HASP
Honeywell Magnetometer	3.3	0.0008	0.00264	HASP
Atmega 2560 Microcontroller	5	0.05	0.25	HASP
GPS Lassen IQ	5	0.32	1.6	HASP
Antenna	5	0.05	0.25	HASP
	Total	0.69	3.22578	

Table 2: Power Budget for Bottom Cube structure

The total current consumption in the payload is delivered by the HASP platform. This voltage is then converted by a DC to DC voltage converter from a 5V to 3.3V power source depending on the sensors configuration.

Data Format & Storage

The system will have six primary sensors: a magnetometer (HMC5863), two IMU's (MPU-6000 and the VectorNav), one GPS (Lassen IQ) and five solar panels.

The stored sensor data consist of an 18 byte timestamp followed by 94 byte showing the axes for each of the sensors. Finally, the quaternion will be stored taking up to 5 bytes. The length of the data is 90 bytes with a carriage return, linefeed and null character appended to the end of it. This information is without the CMOS camera because the camera uses 307.2 Kbytes and is stored once each minute. The sample rate of the complete code will be of approximately 1 second.

Downlink and Uplink

The ARIES-DYNAMICS payload plans to use the serial telemetry downlink at a baud rate of 1200. A baud is 1200 bits per second; dividing this by 8, the maximum number of bytes rate per second is 150. The priority is to understand the behavior of the payload during flight; for this reason the attitude data will only be downlink. This data will be downlinked (with the provided RS232 connector from the HASP platform) every min according to the Interface manual.

Discrete commands will be used to change the state of the payload during flight. The commands that will be required are:

- OFF- to turn off the payload in case of a problem (will reply with an accept command).
- ON- to turn the payload on in case it was turned off (will reply with an accept command).

Weight Budget

The ARIES-DYNAMICS payload has a weight limit of 3kg for all the components; therefore, it is required to develop a weight budget to monitor the weight of the entire payload. The approximate weight of each one of the components for the payload is described in **Table 5**. Since this project is currently in the preliminary phases, there are several weights that are to be determined. Nevertheless, more detailed weight information is present in the CDR document for this project and the final weight information of the components will be included in the FRR document.

Total Weight of HASP Components	
Weight (g)	*Instruments/Components*
157	Panel Solar
80	Caps Superior and Inferior
146.4	ADS Board
186.4	ACDS Board
550	Payload platform
354.8	Bottom Box
308.2	Two Motors
42	Two Pitch Towers
89	Damper
47	Side Cage
40	Motor Cage
43	Servo Motor
117.13	CubeSat
283.8	Slip Ring + Bottom Damper
7.8	Pulley
3.1	Bottom Pulley
9.5	Two Bearing in Columns
86.89	Platform for Columns
19	Two Bearing in Bottom Box
122.24	Heating Palate + Empty Board
13.3	Principal Rod
2706.56	Total

Table 3: Weight Budget

Preliminary drawings

Payload Dimensions and Design

The ARIES-DYNAMICS experiment must comply with various requirements such as weight and power. This size must be met since the payload should not exceed a 15x15 cm footprint, a height of 30cm, and the ability to survive the landing loads. The weight, the yield strength, and the size are taken into account in the design process. The ARIES-DYNAMICS payload is mounted to the interface plate with four bolts from below. The design in **Figure 4** is developed to allow movements in two dimensions (yaw and pitch motion).

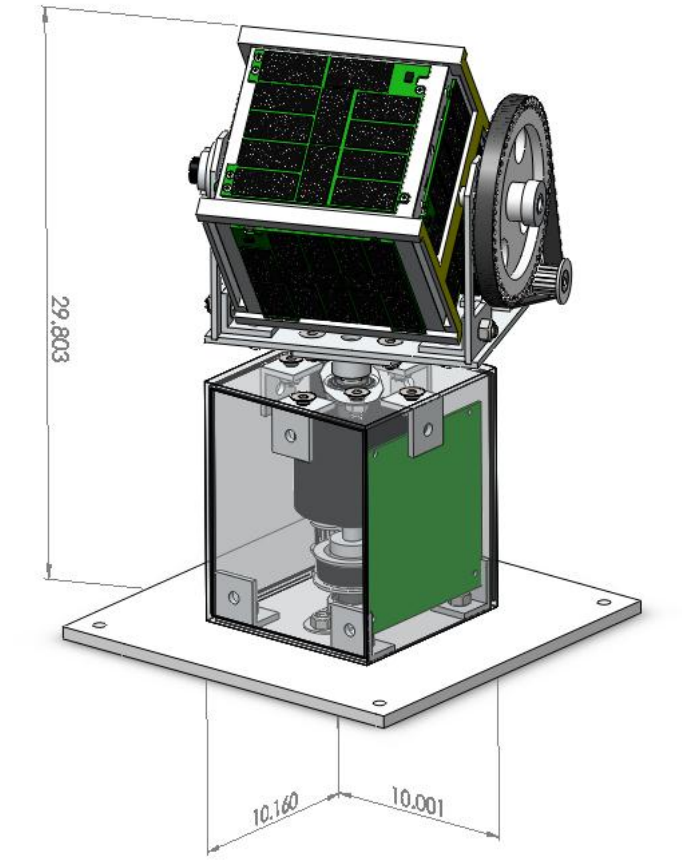

Figure 4: Mechanical Design

Testing and Integration Procedures

Testing at Inter American University of Puerto Rico Bayamón Campus

The ARIES-DYNAMICS payload requires environmental testing to perform instrument calibration and flight system validation. This project will be tested in extreme temperatures to ensure that the payload will perform successfully throughout the entire flight. According to the temperature profile of previous IUPR HASP payloads (EQUIS and TigreSAT); it is necessary to perform these tests in a temperature range of -80°C to +60°C for a 6 hour period. A physical prototype of the experiment will be developed and tested in a thermal vacuum chamber at the Inter American University of Puerto Rico. The test will simulate the cold and hot environments to do any adjustments with time if it is necessary. By doing this, the team will be prepared to pass and complete the integration process as efficiently as possible in the NASA Columbia Scientific Balloon Facility.

Project Managers:

Jorge Quiñones — Student Project Manager
(787) 241 7525

Dr. Hien Vo — Faculty Advisor, Principal Investigator
(787) 241 8046

The administrative planning, organizing, directing, coordinating, analyzing, controlling, and approving processes is used to accomplish the overall project objectives. The specific hardware or software elements include project reviews and documentation, and non-project owned facilities. It excludes technical planning, management, and delivering specific engineering, hardware and software products.

The personnel that might be traveling to the integration for the HASP payload will be the following:

Jorge Quiñones
Email: jorgej1609@gmail.com
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This management element includes the efforts to define the project flight instrument and ground system, the conducting trade studies, the planning and control of the technical project efforts of design engineering, the software engineering, the integrated test planning, the system requirements writing, the configuration control, the technical oversight, the control and monitoring of the technical project, and the risk management activities. Documentation products include the PDR, CDR, and FRR documents, the interface control documents, and the master verification and validation plan.

Management

This project will operate under the supervision of Dr. Hien Vo as shown in **Figure 5** at the Inter American University of Puerto Rico. Professors and a NASA engineer are supervising the work done by the student groups. The focus of the Aerospace Research and Innovative Experience for Students (ARIES) is to allow students to participate in a real space engineering project and to better prepare the student for careers in aerospace engineering. Additionally, the main motivation is to create an environment where creativity and independence is encouraged, allowing to apply the theory from the classroom to a real hands on work.

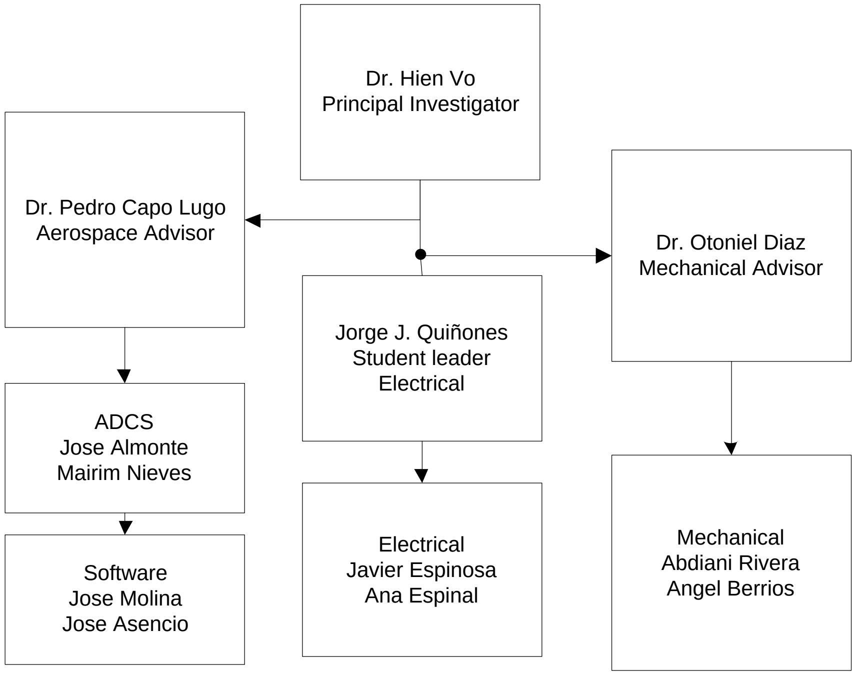

Figure 5: ARIES-DYNAMICS ARIES-DYNAMICS Students and Faculty

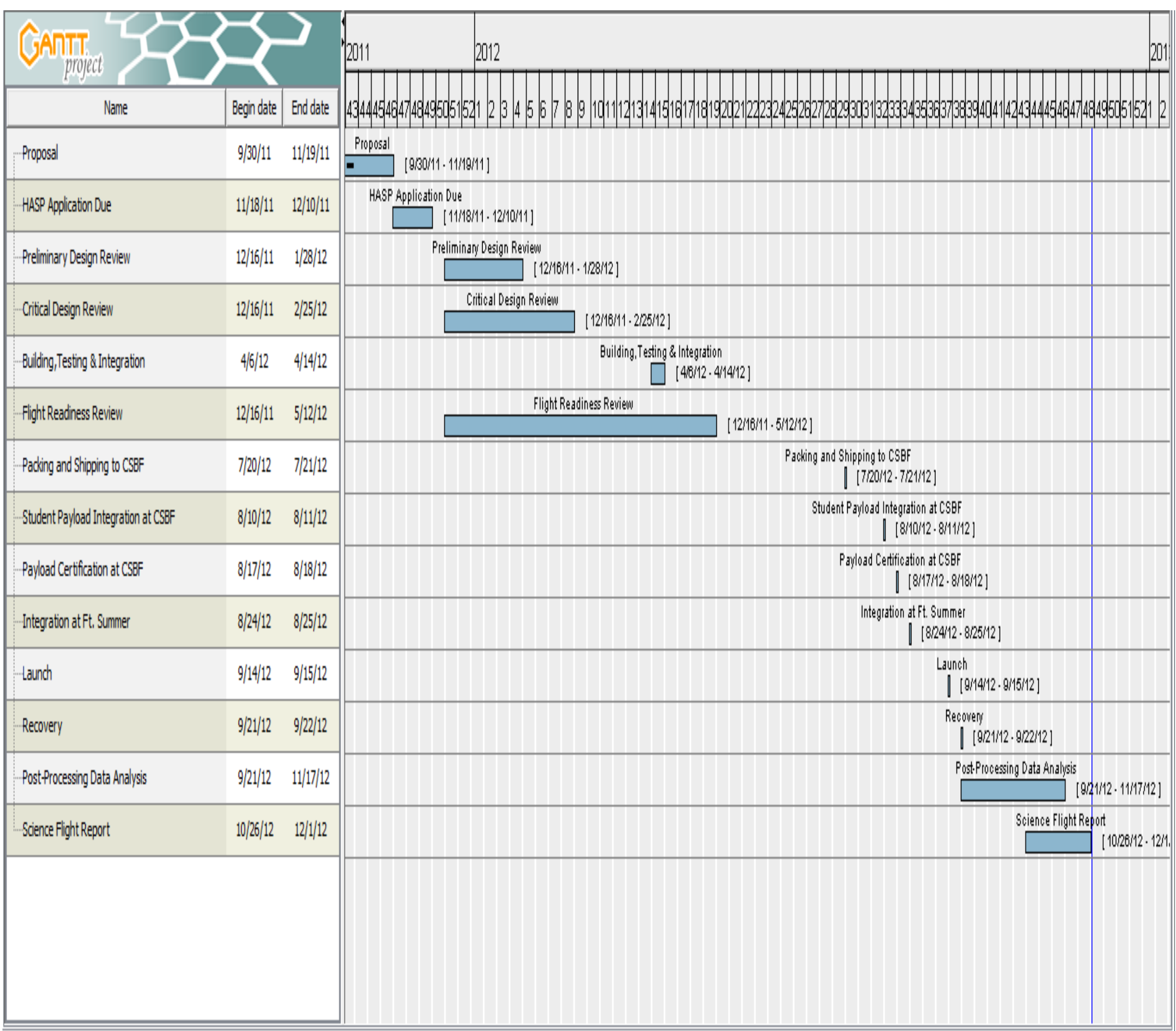

Figure 6: Timeline of ARIES-DYNAMICS project