HASP Payload Integration Plan

Payload Title: ARIES-DYNAMICS

Payload Class: [✓ Small] Large (circle one)

Payload ID: TBD

Institution: Inter-American University of Puerto Rico

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Submit Date: 6/21/2012

I. Mechanical Specifications:

A. Measured weight of the payload (not including payload plate)

The total measured weight of the payload and its individual parts and components are as listed below. The bottom assembly (shown in detail in the next section) was obtained as a whole and is therefore treated as a single part of measured mass as shown.

Table 1: Tabulated mass budget for the CubeSat unit, frame, and base along with their individual components. Note the Circuit Boards, and bottom assemblies are included as wholes.

Part	Component	Qty.	Item Weight (g)
CubeSat			275.52
	Large Smooth Face	1	41.88
	Small Smooth Face	2	40.54
	Shelved Face	2	55.51
	Perforated Face	1	41.54
CubeSat Frame			**583.43**
	Side Panels	2	175.34
	Support Rods	4	58.19
Frame Base			**871.81**
	Base Panel	1	215.60
	Base Support	1	76.86
	Motor Flange	1	21.48
	Slip Ring Mount	1	28.38

	Frame Support	2	125.15
	Grooved Shafts	2	6.76
	Ball Bearings	2	4.75
	Pitch Pulley	1	65.20
	Motor Pulley	1	8.51
	Slip Ring	1	28.35
	Motor	1	154.10
Payload			**187.11**
	ADS Board	1	76.54
	ACS Board	1	76.54
	Heating Circuit	1	34.02
Bottom Assembly			**847.65**
Total			**2765.52**

B. Provide a mechanical drawing detailing the major components of your payload and specifically how your payload is attached to the payload mounting plate

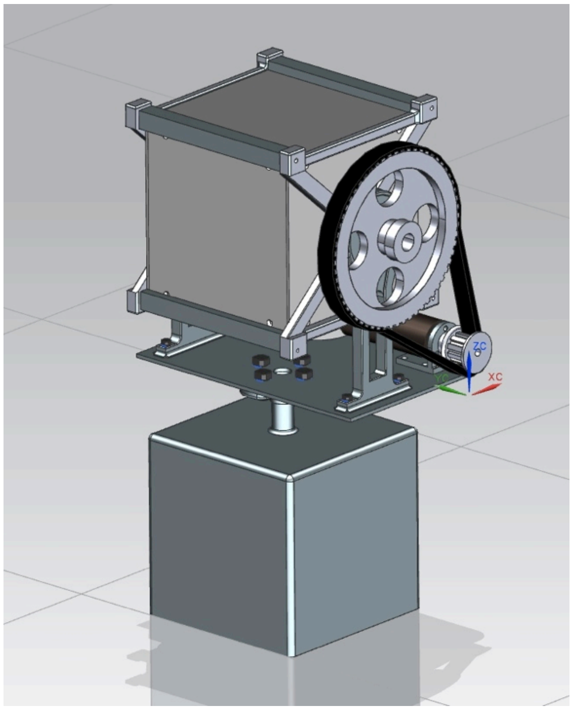


Figure 1: Entire payload assembly without mounting plate.

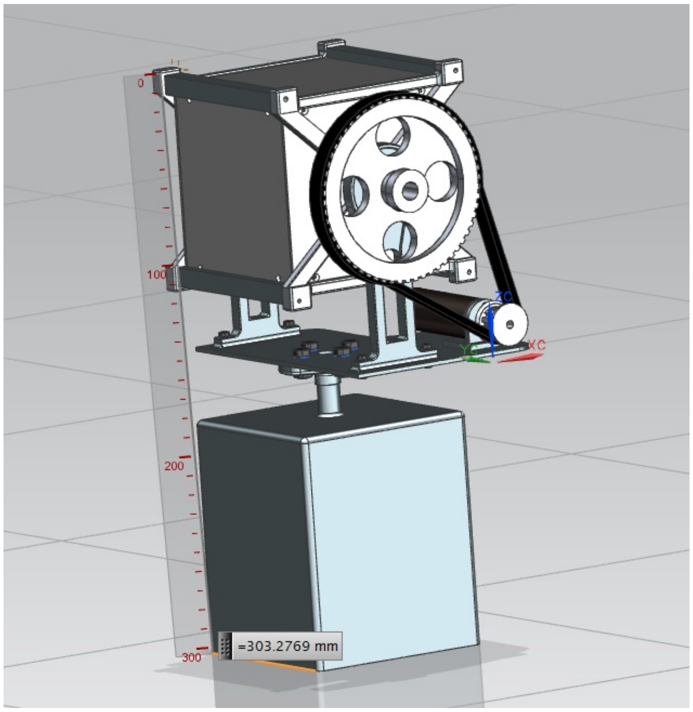


Figure 2 : Entire payload assembly showing its total height. Note: 303.27mm is the maximum height, during operation the middle shaft sinks into the bottom box for a total height of 298mm.

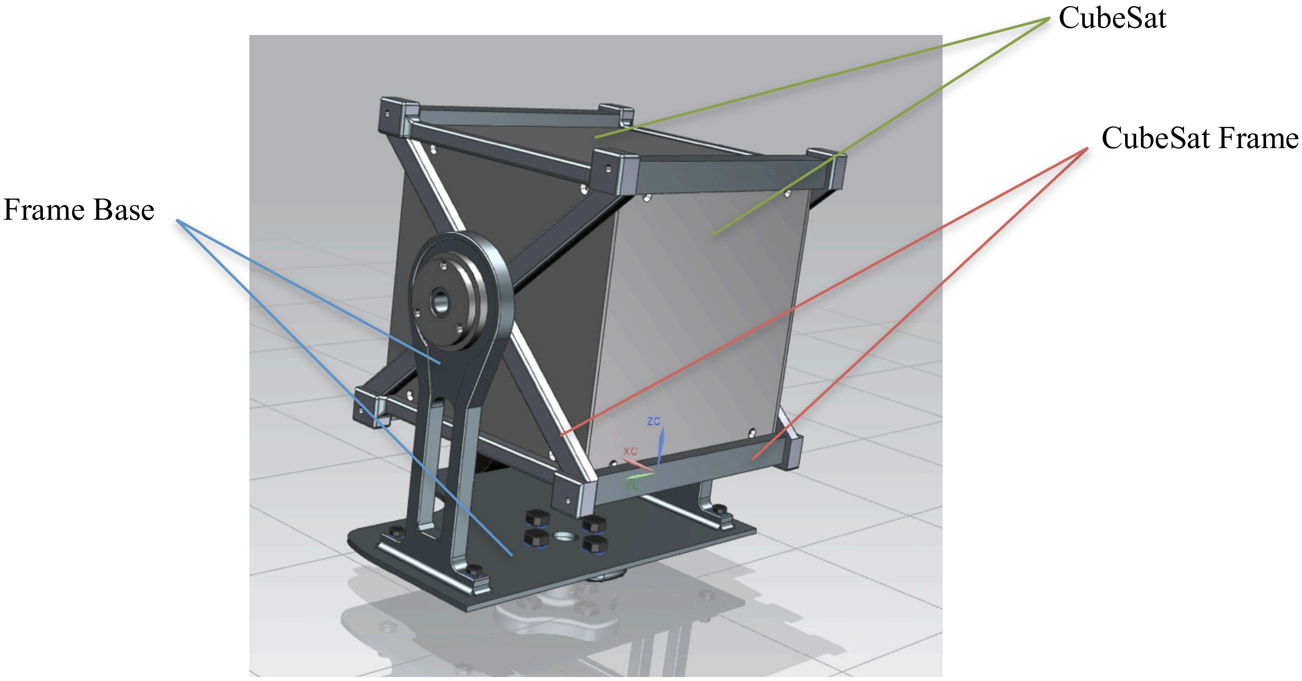


Figure 3: Three-dimensional rendering of aluminum CubeSat unit with its frame and base (top assembly).

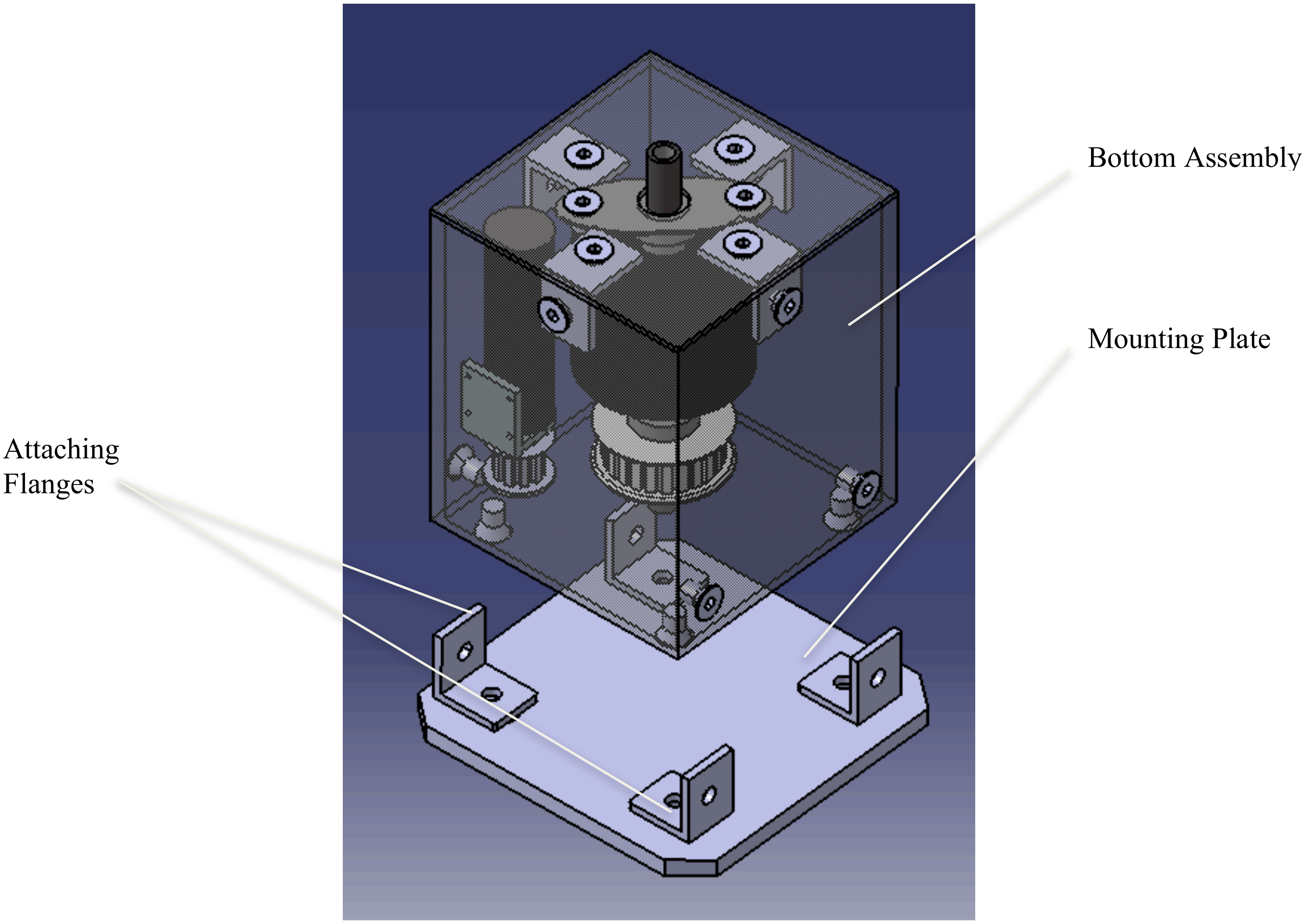


Figure 4: Half exploded, transparent view of the structure's bottom assembly showing the payload mounting plate and the four flanges by means of which it is attached.

C. If you are flying anything that is potentially hazardous to HASP or the ground crew before or after launch, please supply all documentation provided with the hazardous components (i.e. pressurized containers, radioactive material, projectiles, rockets…)

The Aries-Dynamics team is not flying anything that is potentially hazardous to HASP or the ground crew.

D. Other relevant mechanical information

Design Description

The model displayed **Figure 2** was designed specifically to meet and exceed the standards set forth for the HASP payloads. The material chosen for the payload is Aluminum 6061-T6 since its high yield strength combined with its low density allows us to enforce certain safety factors without exceeding mass limits and requirements.

The main purpose of the frame, apart from simplifying the maneuverability of the control system, is to provide a sturdy yet unobtrusive casing for the 1U structure capable of withstanding all the requires loads while sparing the CubeSat itself from harm.

For this purpose, the frame consists of a simple design which relies more on a combination of its own geometry and material properties rather than a complex support system. The sides of the frame (shown below) are capable of effectively withstanding loads in both horizontal and vertical directions due to its truss-like design while using small amounts of material. Four simple flanges with enough thickness to provide structurally significant support complete the frame.

The rest of the frame consists of a flat plate to which two towers that hold the CubeSat frame are attached. Another piece that allows the entire frame to rotate (yaw) about a shaft connected to the bottom assembly is attached to the underside of the plate.

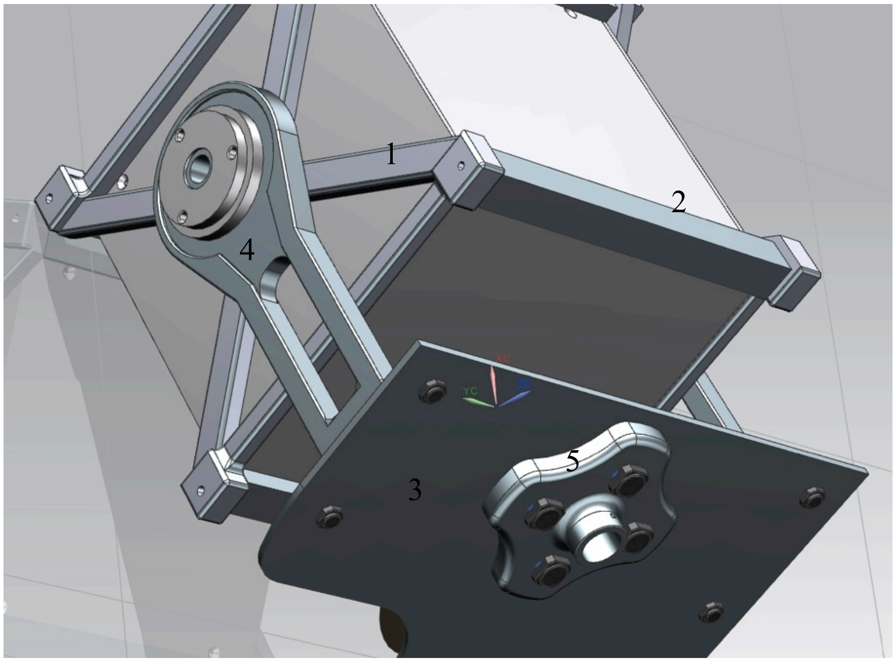


Figure 5: Complete view of the top assembly (frame) showing all its individual components: side panels (1), support rods (2), base plate (3), supporting towers (4) and yaw support (5).

Structural Analysis

The structural requirements for HASP payloads include the structure being able to handle a 10g load in the vertical direction, 5g in the horizontal direction, and 5g in torsion and shear. As part of the mechanical design process, extensive stress calculations were carried out which were then compared to several simulations to verify their accuracy. The following is a brief overview of the final results for a Von-Mises stress simulation.

The following diagrams show minimum and maximum stresses and deformation when subjected to the aforementioned loads. To avoid multiple simulations on the selected structure and loads, the loads were placed on the weakest locations determined. This method ensures the structure's survival throughout the flight.

As a general result for all loadings, all possible deformations are limited to the elastic range, therefore no permanent deformation occurs anywhere in the structure even at the critical areas the loads were applied on. The following pictures also provide an exaggerated deformation for each load in order to demonstrate how the part would fail under continued (higher) stress. A more detailed explanation of each result can be found attached to each figure. As reference, Aluminum 6061-T6 material properties are provided:

Table 2: Material Properties of Aluminum 6061-T6

Properties	SI units	English Units
Density	2.7 g/cc	0.0975 lb/in³
Ultimate Tensile Strength	310 MPa	45000 psi
Tensile Yield Strength	276 MPa	40000 psi
Elongation at Break	12 %	12 %
Elongation at Break	17 %	17 %
Modulus of Elasticity	68.9 GPa	10000 ksi
Ultimate Bearing Strength	607 MPa	88000 psi
Bearing Yield Strength	386 MPa	56000 psi
Poisson's Ratio	0.33	0.33
Fatigue Strength	96.5 MPa	14000 psi
Fracture Toughness	29 MPa-m½	26.4 ksi-in½
Shear Modulus	26 GPa	3770 ksi
Shear Strength	207 MPa	30000 psi

NOTE: All displacements depicted in the following simulations are largely exaggerated. While it may appear the structure is failing due to deformation, most deformations are in the order of 10^{-3} mm.

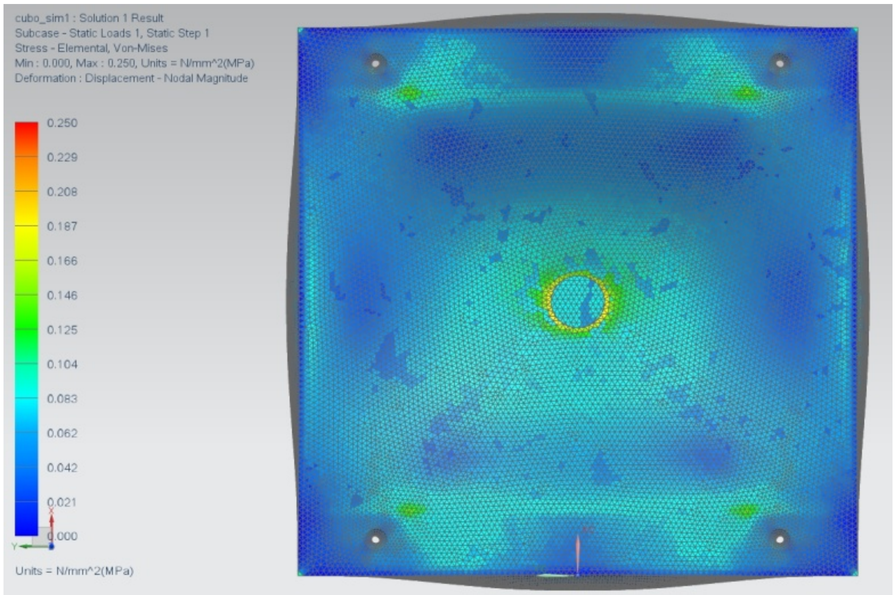


Figure 6: Front view of horizontal 5g load on 1U structure alone. Notice the simulated deformation (outward bowing of the plates) and the stress concentration around the thread holes.

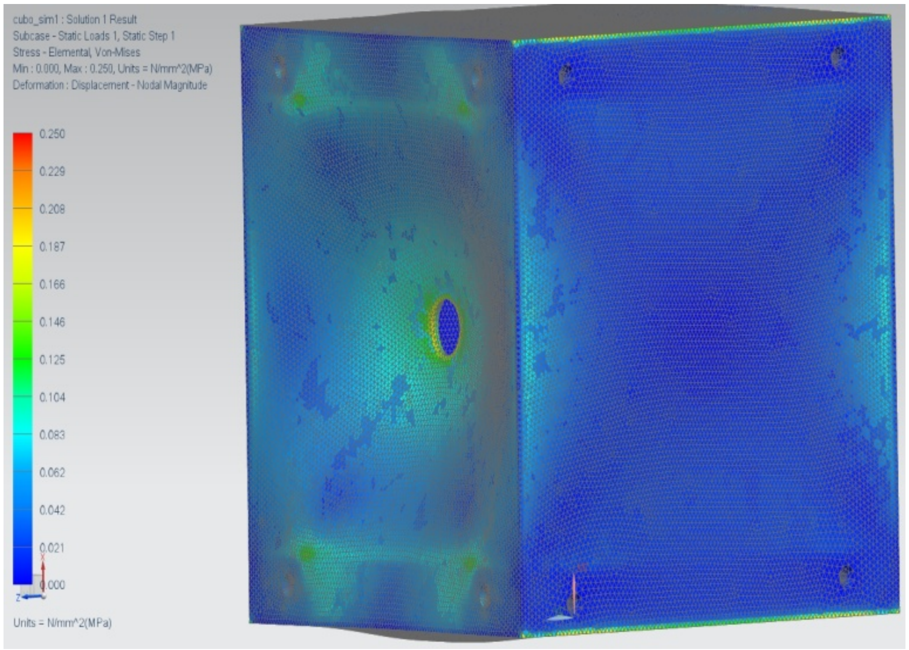


Figure 7 : Angled view of horizontal 5g load on 1U structure alone. Note the bowing inward of the face where the load is applied.

In the horizontal loading simulations for the cube alone (Figures 6 & 7) stress levels are much lower in the other faces (the ones not experiencing the direct load) yet stress concentrations are still higher at the corners regardless of the face. The maximum stress was on the order of 197 kPa and occurred at the perforated center of the loaded face. The maximum displacement occurred at the same location and took a value of $1.165*10^{-3}$ mm.

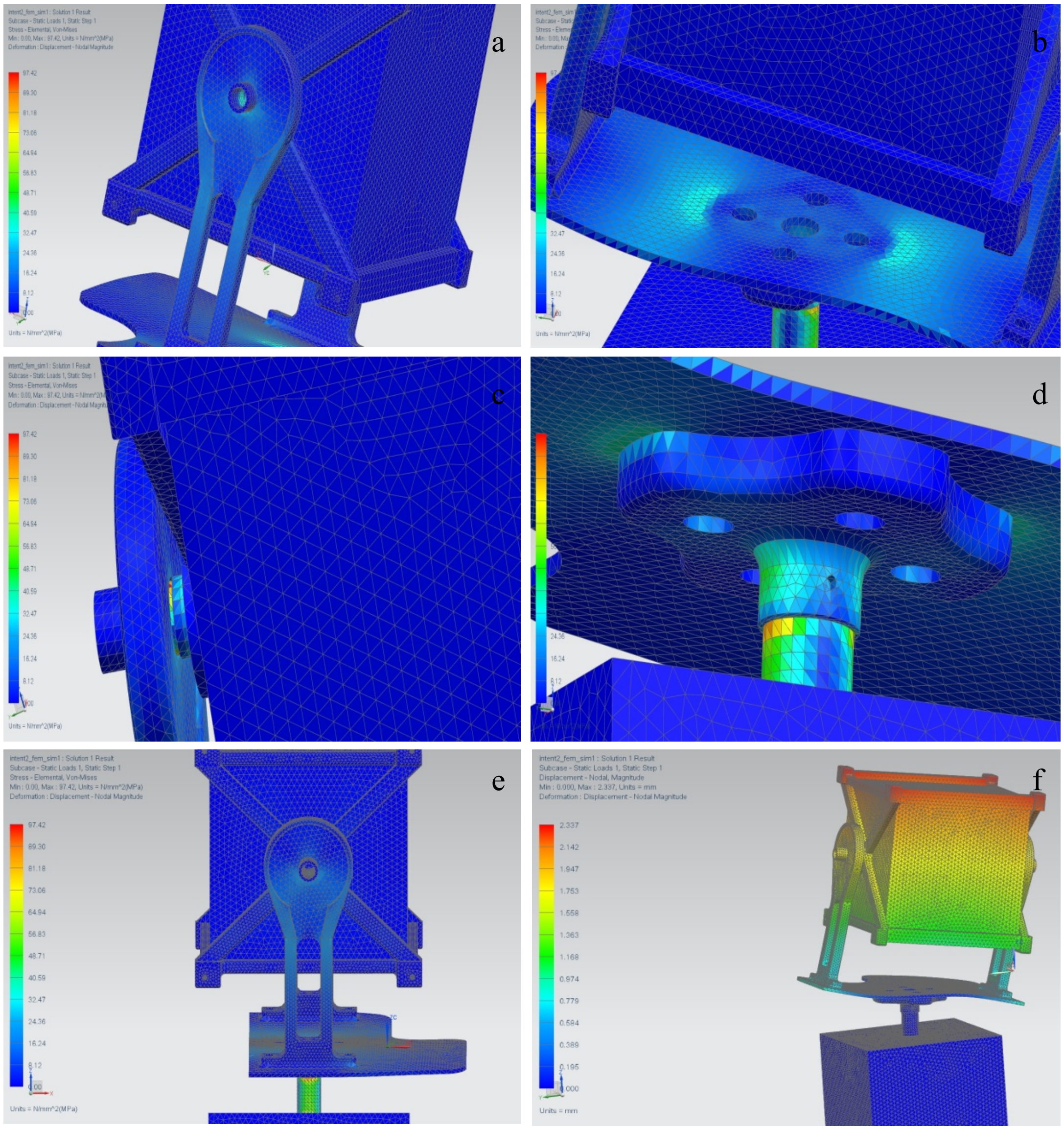


Figure 8: Horizontal 5g load on entire assembly. Note how when subjected to a load the 1U structure experienced almost no loads whereas almost the entire stress concentrates on the shaft uniting the top and bottom assemblies.

In the horizontal load simulation shown in **Figure 8**, instances a. through e. offer different angled views where one can appreciate the nuances of the stress distribution along the shaft as well as in those parts directly in contact with it. In instance f. we can see a representation of continued displacement in contrast to the stress distribution. In this case, the maximum displacement would take place at the top of the frame and would have a magnitude of 2.337mm. Also note that the maximum stress experienced by the structure in this scenario is 97.42 MPa (still much lower than the material yield strength).

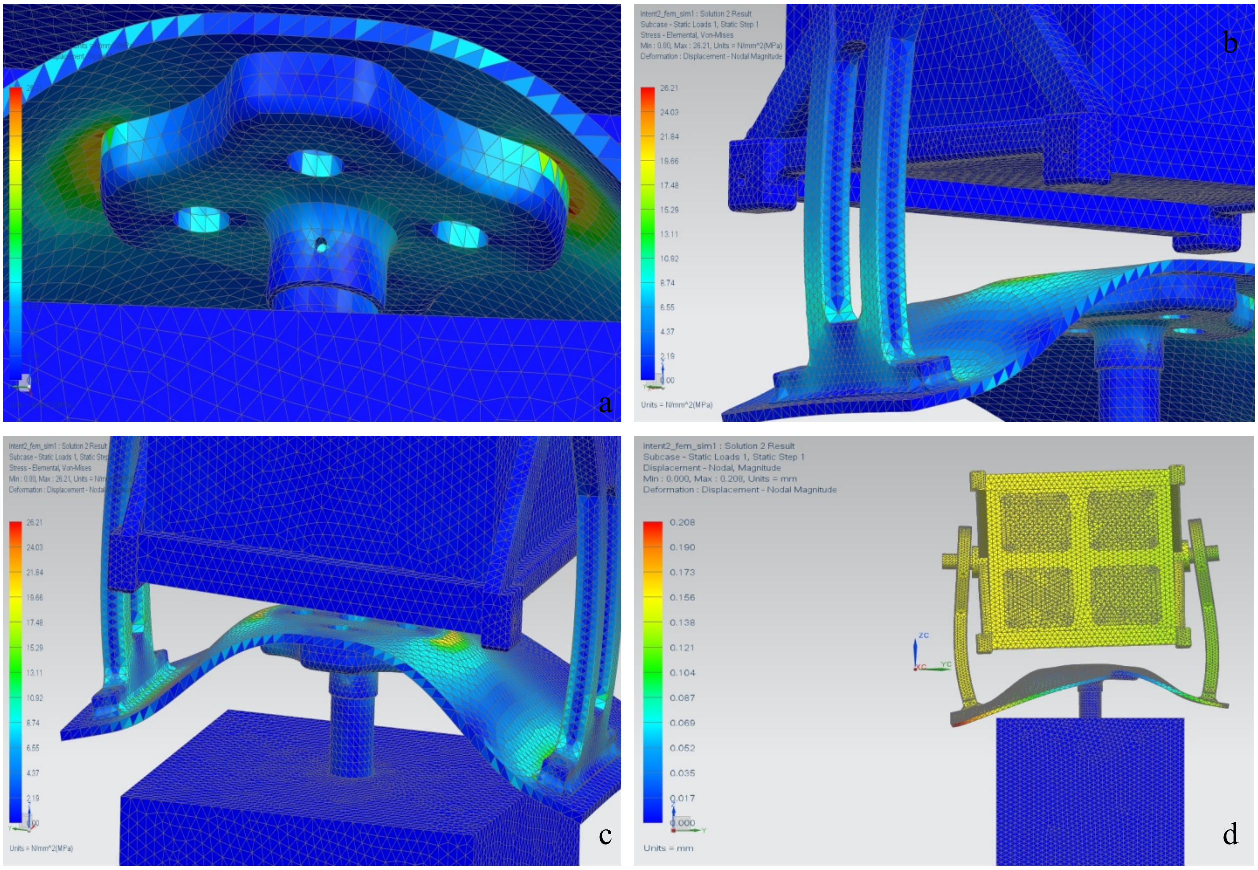


Figure 9: Vertical 5g load on entire assembly. Notice that as before the stress concentration is largest at the around the base plate.

In the veritical loading scenario (**Figure 9**) instead of at the shaft, (as was the case with the horizontal loading) the stress is largest at the supports (the two towers and central support). See again from the stress distribution that the 1U structure carries almost no stress, as it is free to yaw about the shaft. The maximum stress in this case is 26.9 MPa, which again is far below the material's yield strength. As before, instances a. through c. are stress distributions while the last (instance d.) is a displacement simulation. The maximum displacement for this loading occurs at the border where the tower meets the base and has a magnitude of 0.208mm.

From the previous diagrams it is clear that the material will not fail with the current design. It should also be considered that the degrees of freedom of the full assembly make it unable to resist torsional loading, in this situation the top assembly would simply rotate and then reposition itself via its control system, therefore no stress concentration or deformation occurs from such a load.

However, even if the design is sound failure could still occur at the joints where the structure must rely on its various connections, in this case screws and nuts. The next diagrams show how the M5 and M8 screw utilized in the frame base react when subjected to the loads seen above. Note that while the simulation does not show the screw's threads they have been included and accounted for in the modeling.

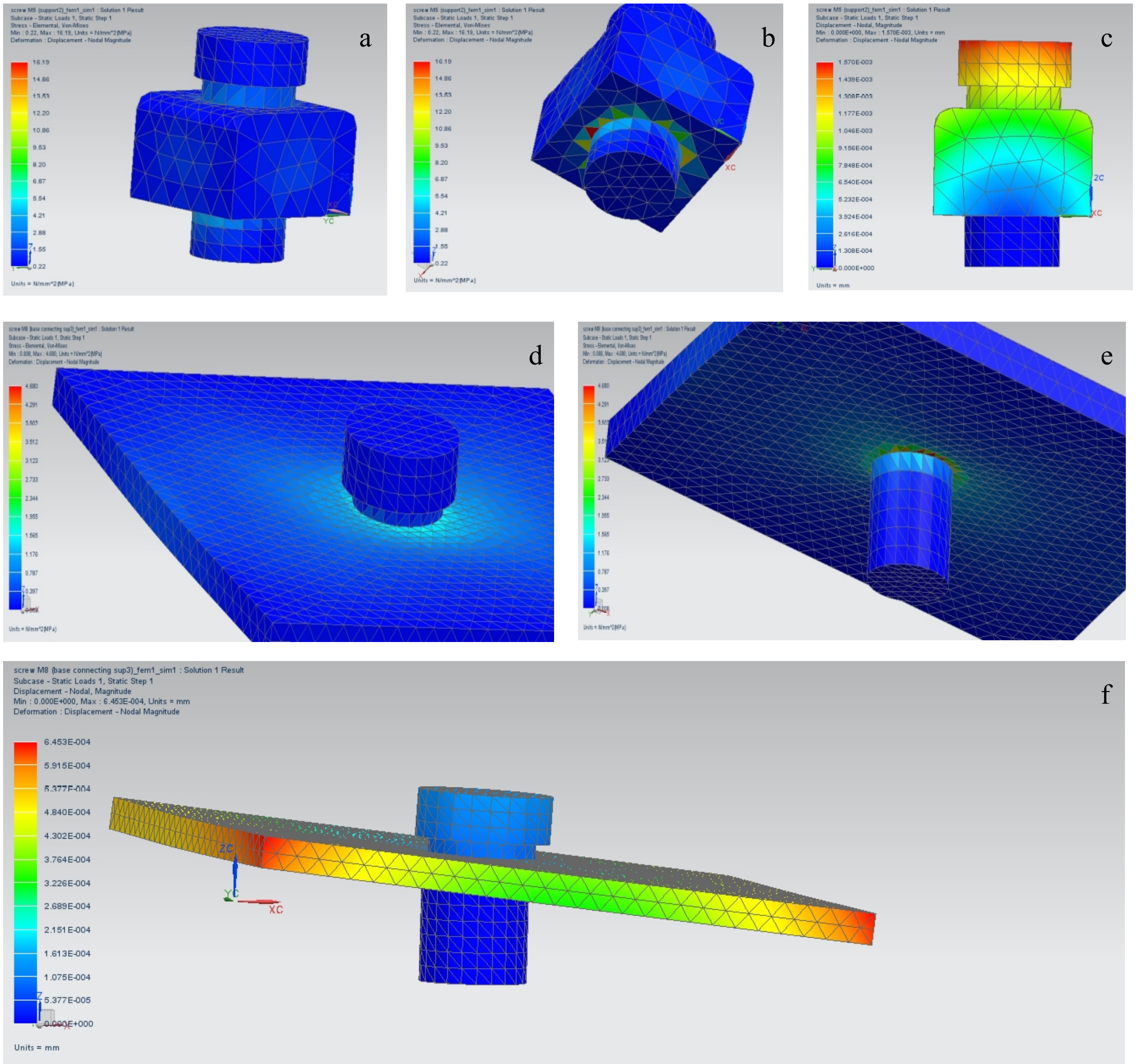


Figure 10: Standard M5 and M8 screws subjected to a 5g load while attached to nuts and plates.

In the M5 and M8 screw analysis (**Figure 10)** it can be seen that for both screws the stress distribution (instances a, b, d, e) is higher at the bottom of the attached plate or nut but still remains very mininal 16.19 MPa and 4.68MPa respectively. From instances

c. and f. (the displacement diagrams) we can see the threads did not fail since the displacement remained extremely small (between three and four orders of magnitude smaller than the utilized unit: mm).

Thermal Analysis

For the CubeSat project, performing the thermal analysis is crucial for determining if the payload can function properly under the extreme conditions it will be facing. To start off the analysis, the following assumptions have been made:

- The CubeSat is a perfect cube with uniform properties.
- The heating circuit generates constant uniform heat in all directions.

With these two assumptions the case can be simplified down to a one-dimensional analysis with heat conduction and generation. The given data is the following:

- Length of the cube: 10cm
- Thickness of the cube: 1.6mm
- Outside temperature: -60°C
- Minimum allowable temperature on the inside: -20°C
- Heat generated by the circuit: 9W

Through the use of an excel spreadsheet and the equations for heat transfer due to conduction and generation we have approximated a value for the required thickness of the insulation that is to be used to help keep the CubeSat up and running. As a first attempt, calculations were done assuming the only insulation available would be regular household foam with a thermal conductivity of 0.0033W/(m*K) and the only heat produced would be that of the heating circuit, 9W. With these parameters we obtain that the needed insulation thickness would be close to 4cm, which is much thicker than our mission allows.

The next step in the procedure is carrying out these calculations with various materials in order to quickly rule out those which are unacceptable. We will also account for the possible reflective properties of the insulating material, as the use of many insulators (such as Kapton and Mylar) relies heavily on their reflective properties. This will allow us determine the material needed to reduce the required insulation thickness and maintain a steady heat flow inside the CubeSat.

II. Power Specifications:

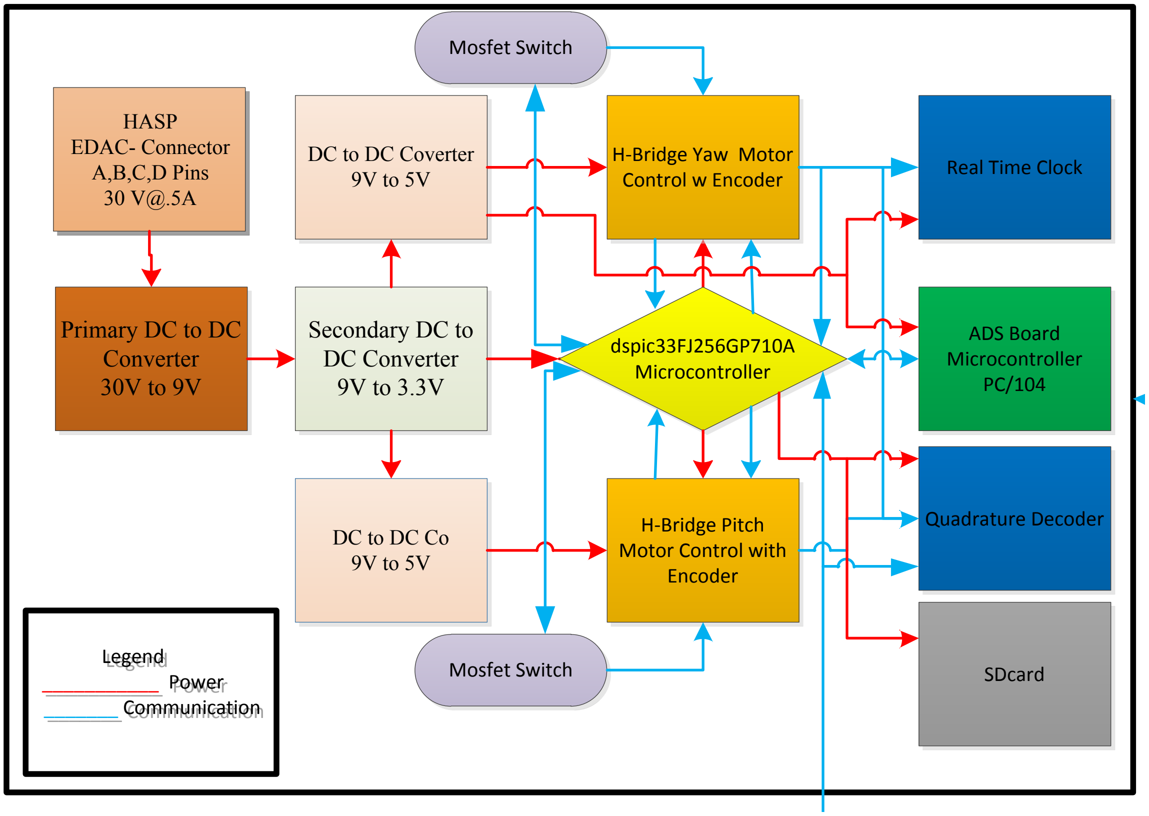
A. Measured current draw at 30 VDC

The primary available power source during flight is the 30V at 0.5A from HASP.

ADCS/Flight Computer Board, Run on HASP power				
Sensors	Voltage (V)	Current (A)	Power (W)	Power Source
Digital Temperature Sensor DS18B20	3.3	0.012	0.0396	HASP
2 x DSPIC33F256GP710A Microcontroller	3.3	0.1	0.165	HASP
Real Time Clock PCF2127AT	3.3	0.00013	0.000429	HASP
SD card circuit	3.3	0.038	0.1254	HASP
Razor IMU	3.3	0.025	0.0825	HASP
MAX3232 Converter	3.3	0.014	0.0462	HASP
SPI to UART Converter SC16IS750	3.3	0.006	0.0198	HASP
FT232R USB UART	5	0.015	0.075	HASP
2 x H-Bridge L293DD	5	0.24	1.2	HASP
Motor Encoders	5	0.01	0.05	HASP
Current Sensor ACS712	5	0.028	0.14	HASP
Solar Panels Electrical Components	5	0.114	0.57	HASP
Heater Circuit	9	1	9	HASP
GPS Lassen IQ	5	0.026	0.13	HASP
Antenna	5	0.05	0.25	HASP
Total		1.678	11.894	

The total current consumption in the payload is delivered by the HASP platform. The resulting power consumption will be around 3.026 W, which is acceptable since the HASP can provide a total power of 15W.

B. If HASP is providing power to your payload, provide a power system wiring diagram starting from pins on the student payload interface plate EDAC 516 connector through your power conversion to the voltages required by your subsystems.



The Attitude Control system / flight Computer Board will consist of a Primary and Secondary DC to DC converter to regulate the power from 30V to 9V and from 9V to 3.3V, 5V respectively. In addition this board will have a microcontroller which is in charge of processing the data received from the ADS microcontroller connected through the PC/104 Bus. The data obtained will be used to determine the proper control action for the DC motor to make the required corrections to the payload motors and monitor all the systems.

C. Other relevant power information

None

III. Downlink Telemetry Specifications:

A. Serial data downlink format: Stream [✓ Packetized] (circle one)

B. Approximate serial downlink rate (in bits per second)

The amount of bytes to sent will be of 68 *8 = 544 bits, at 5 seconds of intervals is 108 bits/s

C. Specify your serial data record including record length and information contained in each record byte.

The system has two main sensors: a 9-degree precision IMU and a GPS receiver. Each of these sensors will be used on the payload for accomplishing the mission requirements. However, the amount of data below is downlinked as a method of housekeeping. The downlinked data will be checked at almost real time, and commands will be uploaded according to the experiment performance. The sample rate will be of approximately 5 seconds and **Table 3** shows each field of the packet.

Table 3: Bytes Description.

Byte	Description
1-19	Time Stamp
20	Comma Separator
20-23	Accelerometer: X axis
24	Comma Separator
25-28	Accelerometer: Y axis
29	Comma Separator
30-33	Accelerometer: Z axis
34	Comma Separator
35-38	Gyroscope: X axis
39	Comma Separator
40-43	Gyroscope: Y axis
44	Comma Separator
45-48	Gyroscope: Z axis
49	Comma Separator
50-53	Magnetometer: X axis
54	Comma Separator
55-58	Magnetometer: Y axis
59	Comma Separator
60-63	Magnetometer: Z axis
64	Comma Separator
65-66	Internal Temperature Sensor
67	Comma Separator
68	End of Line

D. Number of analog channels being used:

ZERO

E. If analog channels are being used, what are they being used for?

No analogs lines are being used

F. Number of discrete lines being used:

ZERO

G. If discrete lines are being used what are they being used for?

No discrete lines are being used

H. Are there any on-board transmitters? If so, list the frequencies being used and the transmitted power.

No onboard transmitter

I. Other relevant downlink telemetry information.

None

IV. Uplink Commanding Specifications:

A. Command uplink capability required: [✓ Yes] No (circle one)

B. If so, will commands be uplinked in regular intervals: Yes [✓ No] (circle one)

C. How many commands do you expect to uplink during the flight (can be an absolute number or a rate, i.e. *n commands per hour*)

The uplink command will be sent only when necessary, such as when a sensor stops receiving data properly or a function needs to be re-configured (sensor registers). To do so, a specific command can be sent where *if* it is HIGH then re-initialize function *x else* do nothing.

D. Provide a table of all of the commands that you will be uplinking to your payload.

Wake Up Command:

Command Name:	**ON**
Hex Command Byte:	4F
Description:	Wakes up the payload from sleep
Critical?	Yes
Payload Response Message:	"Command Received: ON"

Sleep Command:

Command Name:	**OFF**
Hex Command Byte:	46
Description:	Puts the payload on sleep mode
Critical?	Yes
Payload Response Message:	"Command Received: OFF"

Heater On Command:

Command Name:	**HON**
Hex Command Byte:	48
Description:	Turns on the heater
Critical?	No
Payload Response Message:	"Command Received: HON"

Heater Off Command:

Command Name:	**HOFF**
Hex Command Byte:	68
Description:	Turns off the heater
Critical?	No
Payload Response Message:	"Command Received: HOFF"

NULL Command:

Command Name:	**NULL**
Hex Command Byte:	00
Description:	Terminates listening mode
Critical?	No
Payload Response Message:	"Unrecognized or NULL command"

Example of Command Transmission String

Here is an example of the TON command string in hexadecimal format:

“01028054030D0A”

Byte	Hex Value	Description
1	01	Start of Heading (SOH)
2	02	Start of Text (STX)
3	80	Payload ID + Checksum
4	54	Hex Command Byte
5	03	End of Text (ETX)
6	0D	Carriage Return (CR)

E. Are there any on-board receivers? If so, list the frequencies being used.

The Lassen IQ GPS is the sole receiver and runs as follows: L1(1575.42 Hz) frequency, C/A code, and 12 channel receiver.

F. Other relevant uplink commanding information.

None

V. Integration and Logistics

A. Date and Time of your arrival for integration:

August 1, 2012.

B. Approximate amount of time required for integration:

The approximate amount of time required for the integration of the ARIES-DYNAMIC payload is no more than four hours.

C. Name of the integration team leader:

Francisco Franquiz Maldonado

D. Email address of the integration team leader:

franciscofranquiz@live.com

E. List **ALL** integration participants (first and last names) who will be present for integration with their email addresses:

Leader:

Francisco Franquiz Maldonado

franciscofranquiz@live.com

Others:

TBD

F. Define a successful integration of your payload:

A successful integration of the ARIES- DYNAMIC payload will consist of a proper functional payload and retrieval of the data.

G. List all expected integration steps:

1. Mount payload to HASP platform.
2. Connect the payload bottom box slip ring, to the HASP power (30V@.5A) and serial data pins from the EDAC connector. To provide connection to the other slip ring on the top cube to power on the systems.
3. Verify that the power system is working properly and supplying the require operating voltage of every subsystem.
4. Verify the communication to and from HASP platform.
5. Turn on flight computer and run the initial setting configuration.
6. Verify the flight computer performance and enable all subsystems.
7. Verify and monitor temperature sensors readings and turn on/off heater if necessary.
8. Verify motor functionality and encoders readings.
9. Perform thermal and vacuum test.
10. Troubleshoot for any faults on electrical or communication systems.

H. List all checks that will determine a successful integration:

STEPS	CHECKS
Successfully complete mechanical check and integration	
Payload current and voltage composition to ensure proper functionality.	
Verify the uplink and downlink commands with the HASP ground station.	
Check all the sensors to gather data and functionality of ADS.	
Verify the functionality of DC motors orientation and control algorithm.	
Verify that other payload do not interfere with ARES-Dynamics payload orientation.	
Complete thermal and vacuum checkout	
Check the functionality after thermal and vacuum test.	

I. List any additional LSU personnel support needed for a successful integration other than directly related to the HASP integration (i.e. lifting, moving equipment, hotel information/arrangements, any special delivery needs…):

None additional support is requested.

J. List any LSU supplied equipment that may be needed for a successful integration:

Adjustable power supply (or supplies) that can provide output voltages:

3V, 5V, and 30V, Oscilloscope and soldering station for any modifications