HASP Student Payload Application for 2015

Payload Title: EagleSat

Payload Class: (check one)	Institution:	Submit Date:
☒ Small ☐ Large	Embry-Riddle Aeronautical University	19 December 2014

Project Abstract

Designed by undergraduate engineering students at Embry-Riddle Aeronautical University's Prescott, Arizona campus, EagleSat is the first CubeSat designed on campus with an agreement with NASA to launch before the end of 2016. EagleSat seeks to test the effect of solar radiation on flash computer memories, as well as how a CubeSat deorbits over time. Testing EagleSat on HASP will allow the team to continue to test all systems for a long duration flight in near-space environment, following tests on HASP in 2013 and 2014.

Team Name:	Team or Project Website:
ERAU NASA Space Grant	theeaglesatprogram.org

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1. Payload Development

Developed by students at Embry-Riddle Aeronautical University's Prescott, Arizona campus, EagleSat is the university's first attempt at launching a satellite into orbit. EagleSat is a 1U CubeSat, or a small, cubed satellite with dimensions of 10 centimeters per side. EagleSat was developed to measure the effects of solar radiation on various off-the-shelf flash memories, with the use of radiation-hardened memory as the control experiment. The satellite will also be using the GPS constellation to measure its position over time; by analyzing the trends within this data, it is hoped that the Embry-Riddle team will be able to develop a model for the re-entry of small satellites. This model could prove to be incredibly useful with the growing prevalence of CubeSats on orbit, and the threat they pose if they become orbital debris.

EagleSat test articles have flown as a payload on HASP flights in 2013 and 2014, and the development of the articles have increased each year. The 2013 test article was rudimentary, utilizing a student-designed structure to support an early solar panel design as well as a student-designed antenna. This flight allowed the Embry-Riddle team to study the feasibility of the solar panel design, which was determined to be feasible and continued into further production for HASP 2014 and EagleSat's orbital operations. The student-designed antenna was determined to be overcomplicated during HASP assembly, and necessitated a further redesign before it would be tested again, but also opened the door for further trade studies before the redesign would continue. And though the antenna was able to transmit data from HASP to the team on the ground, it did not perform as well as had been expected, and in fact was incredibly directional. This also led to a second trade study period as the communications team began their redesign of the antenna.

The design of the EagleSat test article for HASP 2014 addressed the issues noted during the previous year's flight, and introduced more advanced EagleSat elements into the test. The student-designed structure was replaced with a Pumpkin CubeSat structure, one of the most common structures used in CubeSat operations. Due to an issue with the antenna redesign, the student design, a phase shifted circularly polarized antenna, was abandoned late in the testing process for a simple monopole, as the team needed a functional antenna to receive data during testing. The 2014 test article also saw the inclusion of the on-board computer (OBC) and power elements that will be used on the final model, bringing the test one step closer to the final product. The 2014 test article performed as expected, and served to confirm the viability of the capacitor-based energy storage array the EagleSat will be using in place on a battery array.

For 2015, the Embry-Riddle team is proposing to fly a test article of the final version of EagleSat on HASP. While the past two iterations have allowed the team to develop and test possible components for EagleSat, this final iteration will be launched close to the anticipated delivery-to-NASA date, so both the test article and the actual EagleSat will need to be completed. Testing once more on HASP will allow the team to perform a near-space systems verification, as well as to test the ground station hardware and software developed after HASP 2014. Since the maximum range between EagleSat and the Embry-Riddle ground station is similar to the range expected during orbital operations, it is critical that the ground station be able to contact EagleSat during HASP operations as well. The payload would consist of two main parts – EagleSat, and the Nest integration module. The EagleSat portion will consist of five main systems: the on-board computer, the communications system, the power system, the payload boards, and the structure.

The on-board computer (OBC) is based off a PIC24 architecture, and manages all operations within EagleSat. The OBC will be controllable with commands from either HASP or those received over the radio, and will also transmit operational data through both methods. On past HASP flights, the OBC logged data at a frequency of four times per minute, which led to large amounts of data over the period of the flight. For the 2015 HASP flight, the data logging frequency is being investigated, and may be set to a lower amount, depending on the resolution of data needed over the period of the flight. The power system consists of two main parts: the solar power system, and the capacitor energy storage array. Both elements were tested on the 2014 HASP flight, and proved to perform well within expectations. However, a longer test in the near-space environment would help ensure strong performance for orbital operations. The capacitors utilize an Electrical Power System (EPS) in the Nest integration module to limit the amperage they can draw in order to prevent shorting the HASP electronics.

The payload boards contain the equipment needed to complete EagleSat's primary and secondary missions: investigating how flash memory handles solar radiation on orbit, and how a small satellite deorbits. The primary mission involves testing the effects of solar radiation on various forms of commercially available computer memory, including Static RAM (SRAM), Ferroelectric RAM (FRAM), Magneto-resistive RAM (MRAM), Phase Change Memory (PCM), and Radiation Hardened RAM (RADHARD). Satellites and space probes must use costly radiation hardened memory to avoid Single Event Upsets (SEU) in which the onboard memory is damaged as a result of solar or cosmic radiation. This experiment seeks to discover any correlation between SEU and periods of high solar activity, and also to examine the possible strengths of using non-radiation hardened memories in low earth orbit. On HASP 2015, this module isn't expected to experience any SEU, but as part of the overall EagleSat system, its presence will be vital to ensuring perfect performance of the entire system, and including in on the final testing opportunity will deliver that data. The secondary mission will be accomplished through a GPS module, which would be installed on the bottom of EagleSat for orbital operations. For HASP 2015, the GPS will be mounted to the Nest module instead, as the bottom of the EagleSat article will be mounted to Nest for the duration of the flight.

The radio for EagleSat's communications subsystem has been verified to be effective on 436.5 MHz over the past two HASP flights, but the final orbital antenna has yet to be decided upon. Given the potential for success in the phase shifted circularly polarized antenna utilized on HASP 2013, a redesign of the antenna is ongoing and may be utilized for HASP 2015. However, trade studies are ongoing alongside the redesign, so the payload design drawings for this proposed payload still reflect the phase shifted circularly polarized antennas.

The structure used for EagleSat will be the Pumpkin CubeSat structure, last utilized for HASP 2014. The structure is a ten centimeter cube, and will have solar panels mounted on all sides for additional testing as well as thermal protection. One of the issues noted during HASP 2014 was the potential for the EagleSat electronics to overheat during periods of intense solar radiation; for HASP 2015, there will be attempts to allow the Pumpkin structure to better radiate heat for the safety of the enclosed electronics.

The Nest integration module has been designed to integrate EagleSat onto the HASP platform, and contain all electronics to connect the two systems. The Nest module is an aluminum structure 13 centimeters on a side and 5 centimeters tall, with ports for the power and serial lines to run through the payload. The top plate of the Nest module contains mounting holes to fit the EagleSat test article. The Nest module contains the EPS needed to regulate power to EagleSat, as well as an Arduino Mega to pass EagleSat data down through the HASP serial line.

2. Team Structure and Management

Embry-Riddle's HASP initiative began as a separate program from the EagleSat program, but over the years it has become the most critical flight testing opportunity available to the program, and has in turn become part of the EagleSat program. The EagleSat program is managed by Clayton Jacobs, a senior Electrical Engineering student, and is overseen by faculty mentors Prof. Jack Crabtree and Dr. Gary Yale. The HASP initiative is led by Zach Henney, a senior Aerospace Engineering student, and is supported by the many team leads and members of the EagleSat program. As the EagleSat program contains nearly 50 active members, the team organization chart below lists only the team leads responsible for mission success during HASP.

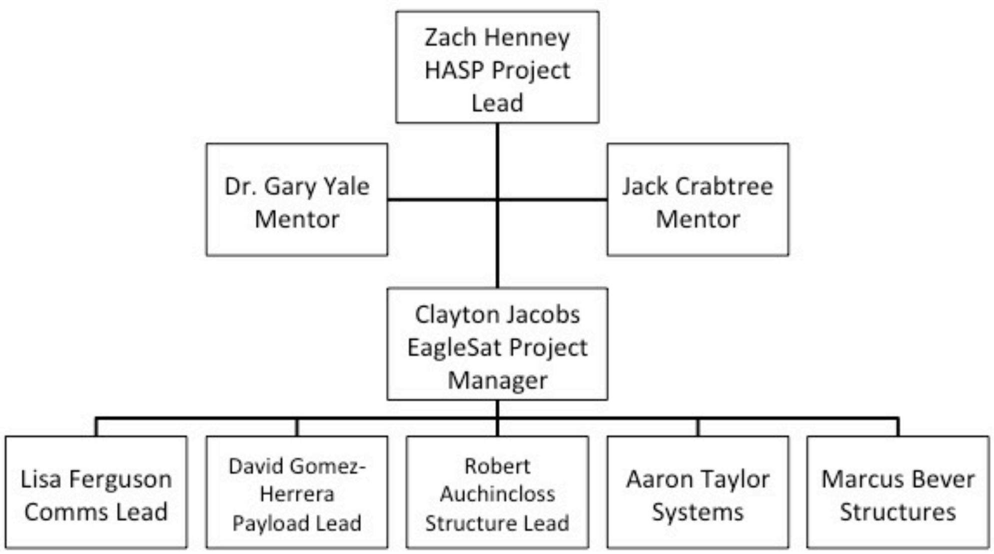


Figure 1. ERAU HASP Organization

The contact for the Project Lead and Manager, as well as the faculty mentors, is given below:

Title	Name	E-mail Address	Contact Information
Project Lead	Zach Henney	henneyz@my.erau.edu	707-570-6111
EagleSat Lead	Clayton Jacobs	jacobsc6@my.erau.edu	661-492-4814
Faculty Advisor	Jack Crabtree	crabtrej@erau.edu	928-777-6916
Faculty Advisor	Gary Yale	yaleg@erau.edu	928-777-3896

Table 1. ERAU Contact Information

Of the members involved with the project, it is anticipated that anywhere between two to four members and one or two mentors will travel to Palestine, TX, and Ft. Sumner, NM for flight operations.

The development schedule for the Embry-Riddle payload is centered on the academic calendar, as all major payload work has a deadline of the end of the spring semester. Minor work, such as small fixes and aesthetic work, can continue over the summer semester, but is not vital to payload success. A graphic of the preliminary development, fabrication, and testing schedule is given below.

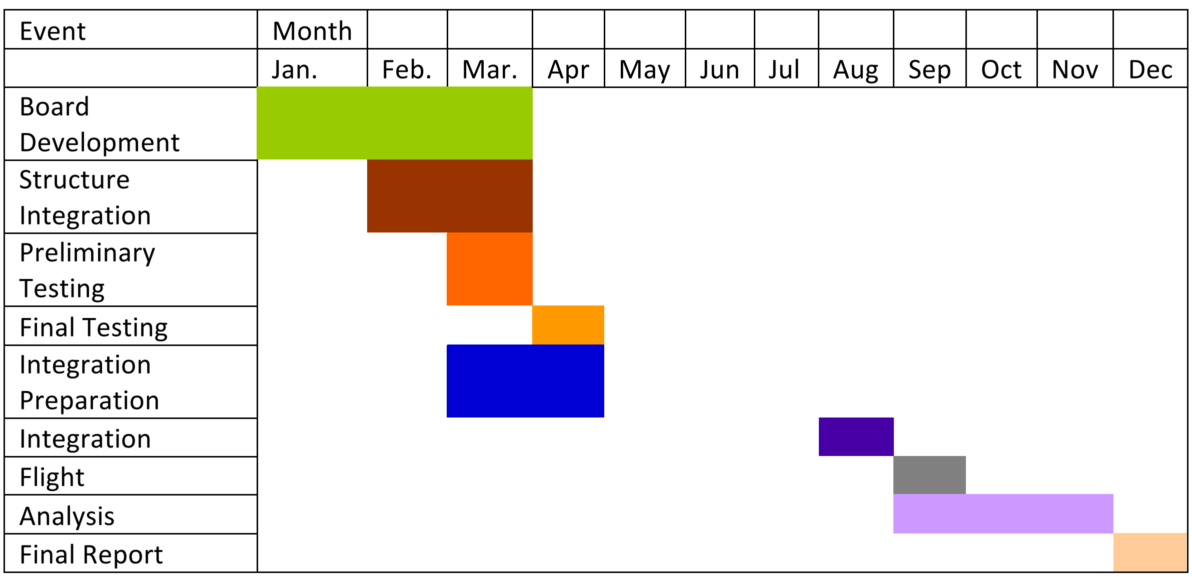


Figure 2. Preliminary EagleSat HASP Development Schedule.

As seen in this schedule, all work aims to be completed by the end of April, when the spring semester wraps up and most students will be leaving. Testing may continue past the end of April in order to ensure success during HASP, but completing it during the spring semester is the ideal situation for the Embry-Riddle team.

3. Payload Specifications

On HASP, EagleSat and the Nest module will be 15 centimeters tall, with a base filling all of the 15 centimeter square on the mounting plate. The phase shifted circularly polarized antennas have the potential to extend nearly 12.5 centimeters outside of the envelope allotted by the mounting plate, however, testing on the 2013 HASP flight proved that they did not physically interfere with any other payloads. The Nest module will contain insulation to protect the electronics from the cold temperatures experienced during ascent and descent, while the EagleSat article will remain relatively uninsulated. However, given the thermal anomalies experienced during the 2014 flight, better heat sinks are needed for both parts of the payload to prevent any issues related to overheating. It is anticipated that the total mass of the payload, with a margin, will be 1794 grams, well within the 3000 gram requirement. This mass allows for a margin of 175 grams, which makes for a safe buffer should any additional components be added.

	Component	Mass (g)	Margin (g)	Measured	Estimated
EagleSat	Payloads	79	50		yes
	Electrical Power System	60	30		yes
	Super Capacitors	174	50		yes
	Communications	136	20		yes
	On-Board Computer	98	10		yes
	Solar Panels	228	0	yes	
	Antennas	192	0	yes	
	Structure	200	0	yes	
Nest	GPS	27	0	yes	
	Thermal Management	50	0	yes	
	Arduino	35	0	yes	
	Electrical Management	50	15		yes
	Structure	290	0	yes	
	Total	1619	175		
	Total, with margin	1794			
	Mass allowance	3000			

Table 2. Estimated Mass Budget for Embry-Riddle Payload.

The EagleSat article will rely on both HASP and its solar panels for power, but will only charge from the sun when capable of producing enough current to raise the voltage within the capacitor array above 11 V. To address this issue, the Nest Arduino has the ability to cut EagleSat off from

HASP power, which will allow the Embry-Riddle team to better test the abilities of the solar panels in sustaining long-duration operations. An estimated power budget is provided below.

	Compenent	Current (mA)
EagleSat		
	System	250
Nest		
	Arduino	120
	Total	370
	Allowable Current Draw	500

Table 3. Estimated Power Budget for Embry-Riddle Payload.

Due to the closed nature of the EagleSat system, it is difficult to measure the current draw of individual components. However, the 250 mA draw is a maximum draw, and is only experienced when the capacitor array is charging. The Nest EPS is designed to ensure that value is never exceeded, allowing the payload to remain within the constraints of a small payload.

The EagleSat article will be receiving its commands through the Arduino within the Nest module, which is a critical part of operations on HASP. These commands can be mirrored through the ERAU ground station, but some, such as disabling power to EagleSat, can only be sent through HASP. The anticipated command list is given below.

Name	Bytes	Description	Critical	Determination	Contingency	Ramification
TRANSMIT INHIBIT	A 0	Deactivates EagleSat radio	Yes	Radio shuts off	Resend command	If interrupting CSBF radios, payload must be disabled
TRANSMIT ENABLE	A 1	Activates EagleSat radio	Yes	Radio begins broadcasting	Resend command	Radio remains off for duration of flight.
ACTIVATE RELAY	B 1	Sends power to EagleSat	Yes	EagleSat reports full voltage	Resend command	EagleSat may power down during the flight.
DEACTIVAT E RELAY	B 0	Switches EagleSat to solar	Yes	EagleSat displays non-standard voltage drop	Resend command	EagleSat remains on HASP power.
STATUS	C 1	Asks payload for status	No	Payload responds "Still working"	Resend command	Payload will only send data updates.

Table 4. Anticipated EagleSat commands list.

Data from the EagleSat article will also be downlinked through the Arduino to HASP, and based on testing will be split into two formats: EagleSat status update, and GPS updates. The expected EagleSat status update is seen below, with explanations for each section.

Byte	Value	Description
1-18	OBC Time	Time as reported by the on-board computer
19-36	OBC Date	Date as reported by the on-board computer
37-59	EagleSat Voltage	Voltage of the EagleSat capacitor array
60-64	Checksum	Checksum for data string

Table 5. Expected EagleSat Status Update Format.

As seen from this format, the EagleSat status updates focus largely on the health of the OBC and capacitor array. If the time or date slip, it is an indication of an error within the OBC, and can be addressed by sending a command to reset the internal clock over the radio. Monitoring the voltage within the capacitor array allows the team to see the effectiveness of the solar power system: if the voltage reaches values above 11 V, the power system is working at high efficiency. If not, it is indicative of a draw larger than the solar panels can handle, which would cause EagleSat to power down during orbital operations.

The second source of downlinked data comes from the GPS, and is linked to the success of EagleSat's secondary mission. The GPS data is expected three times a minute, and comes with a much different format than the EagleSat status updates. However, the GPS data is not as easily interpreted by examination, so the following format is key to understanding the data.

Byte	Value	Description
1-7	GPS Format	Reports the format of GPS data
8-19	UTC Time	Record time, in UTC, with checksum
20-32	Latitude	Latitude, in format DEG MIN.MIN
32-45	Longitude	Longitude, in format DEG MIN.MIN
46-47	GPS Fix	Reports the status of GPS fix
48-50	Satellilte	Number of Satellites in View
51-54	HDOP	Relative accuracy of horizontal position
55-64	Altitude	Altitude above sea level, meters
65-73	Geoid height	Height of geoid above WGS84 ellipsoid
74-87	Checksum	Checksum

Table 6. Expected EagleSat GPS Format.

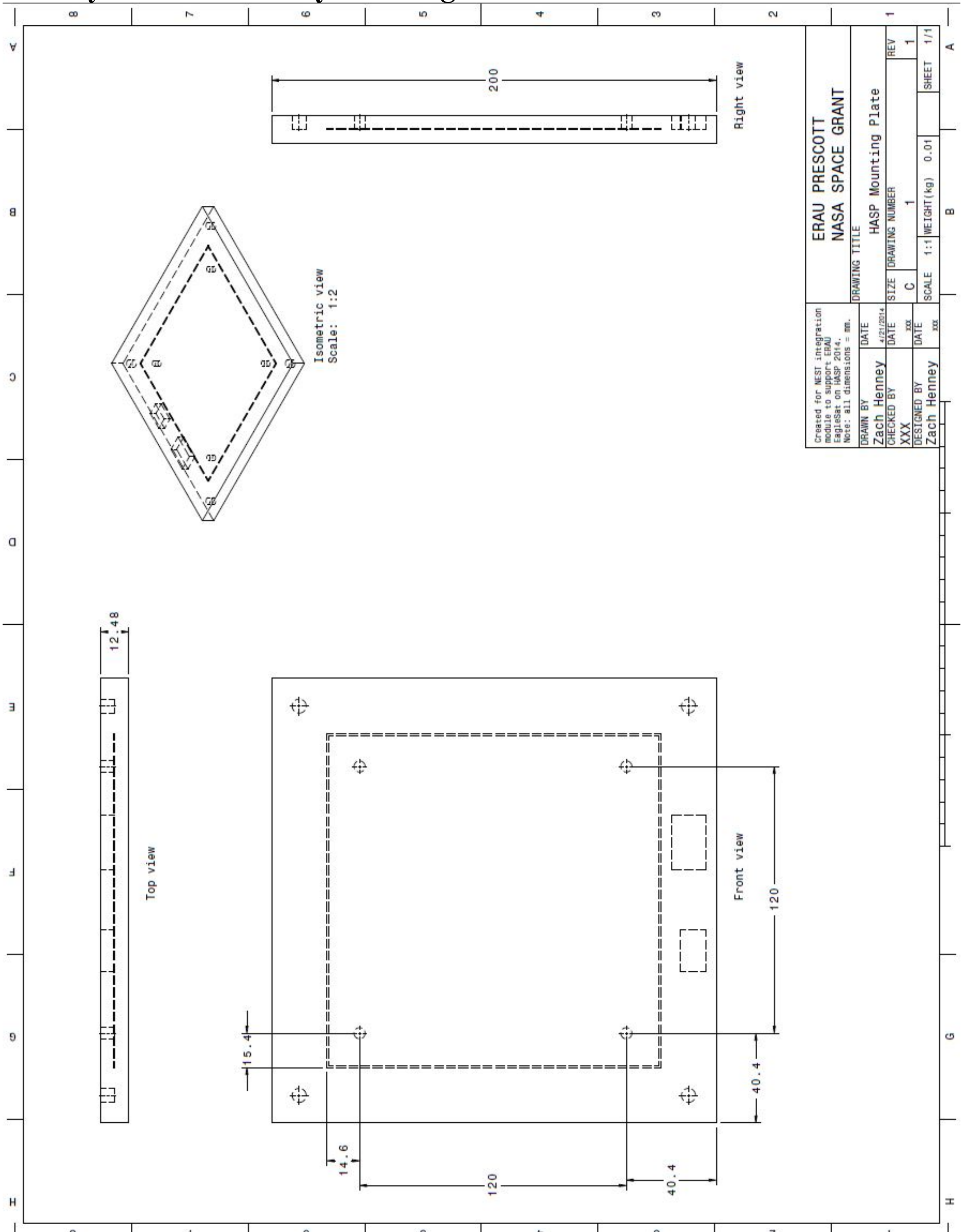
Again, this format is not easily understood, but utilizing the format description can enable any user to decode the information being downlinked. The data is incredibly useful for tracking the payload, and the altitude provided gives an excellent impression of the extremes experienced by the payload.

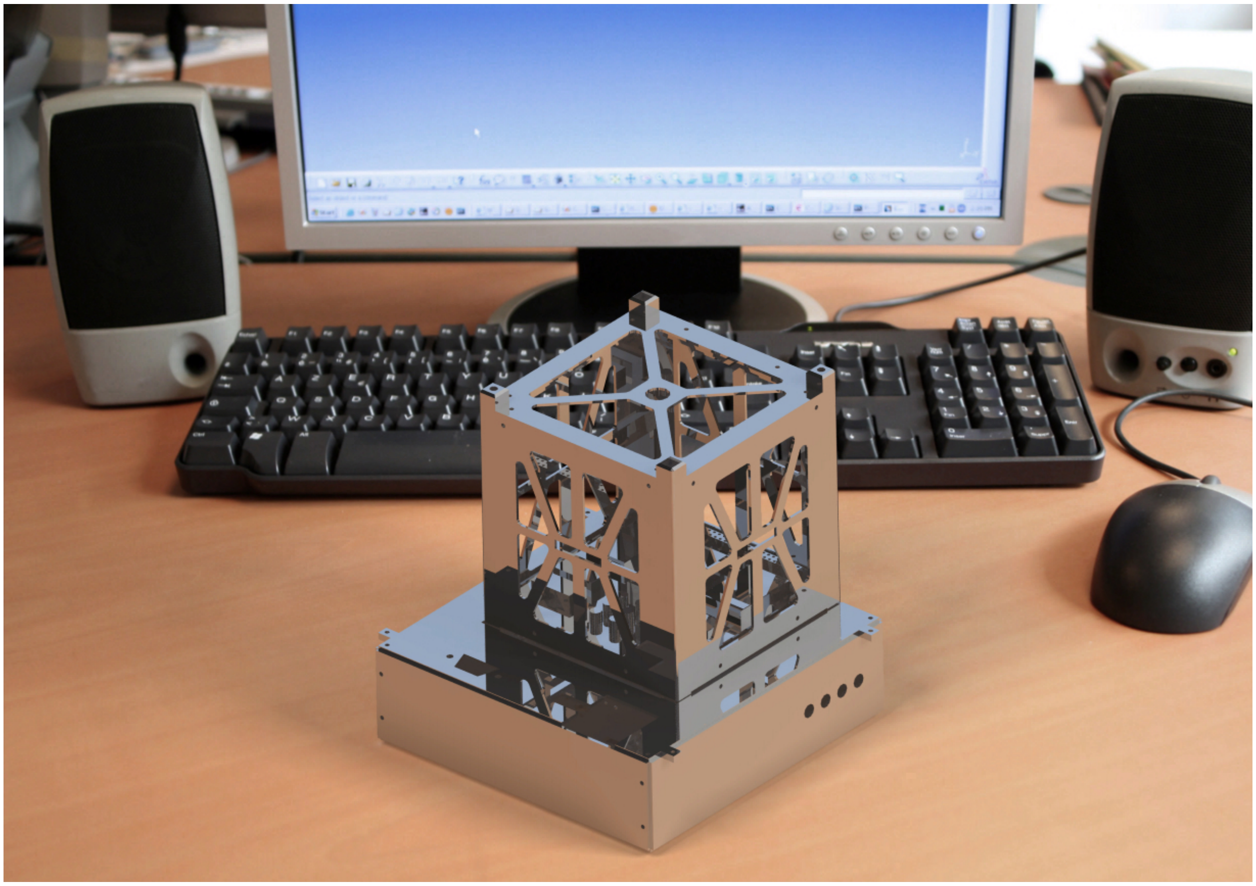
4. Integration and Flight Procedures

Prior to HASP Integration, the EagleSat test article and the Nest module will have been tested rigorously using the facilities available at the Embry-Riddle campus. Once this testing phase has ended, the payload would be brought to the CSBF facility in Palestine, TX for further testing and integration with HASP. Integrating the payload will simply be a matter of connecting the power and serial lines, as well as firmly attaching the mounting plate. During the thermal vacuum tests, data will be relayed through the serial line to verify the payload's ability to handle the provided conditions, as well as to verify that data can be successfully received by the HASP hardware. Also of note during the testing process is that the radio on-board EagleSat does not interfere with HASP or CSBF hardware. Given the performance over the past two years, it is not anticipated that this issue would occur, but it something that would require verification during this phase. It is expected that the Embry-Riddle team present for integration would range between two and six people at CSBF.

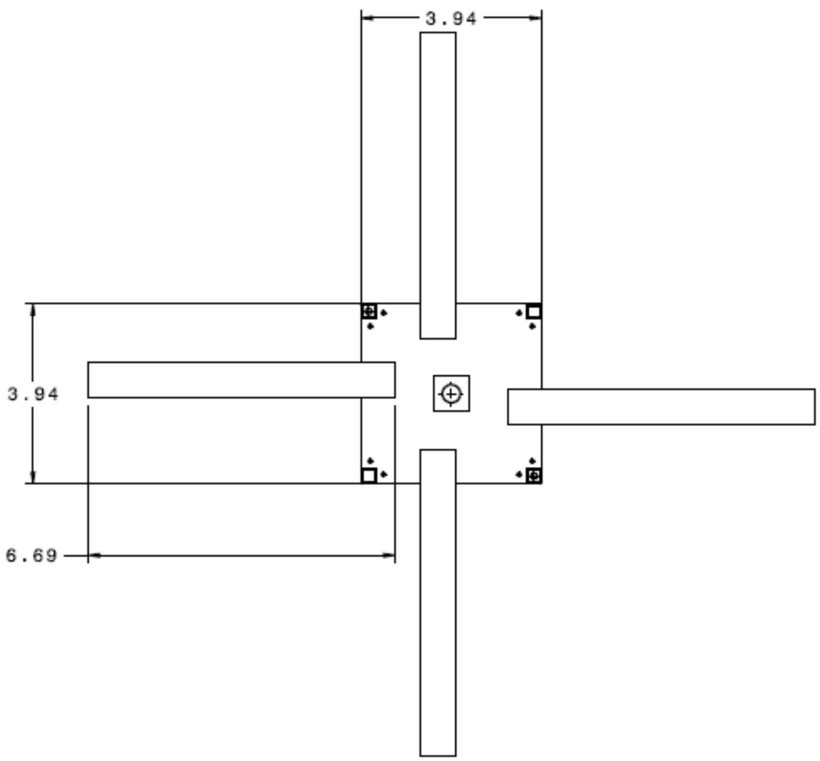
Flight operations would be slightly more involved than they have been in the past, due to a desire to let the EagleSat systems operate on their own. Since the EPS in the Nest module has the ability to isolate EagleSat from HASP power, it is desired that EagleSat would rely on its solar power system for most of the flight. However, in a situation when the power needs to be toggled, this would require a large amount of monitoring on the Embry-Riddle side, and possibly multiple commands an hour being sent over serial to the payload. Such a scenario depends on the prevalence of solar power during the flight, and will ultimately depend on the performance of the payload. Monitoring data will be a crucial aspect of the flight, especially for those manning the ground station at the Embry-Riddle campus. At this time, it is anticipated that at least three members of the Embry-Riddle team will travel to Ft. Sumner for flight operations, and depending on the direction of the flight path, the team would like to once again take part in recovery of the balloon, and the payload.

5. Payload Preliminary Drawings

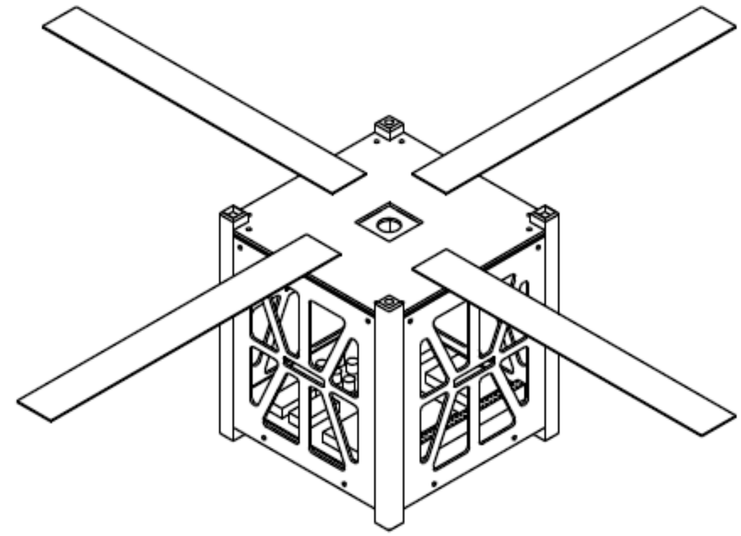




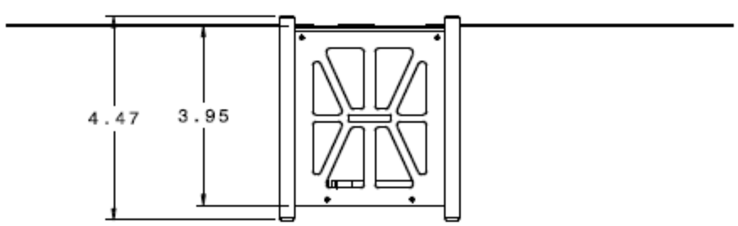
Scale rendering of EagleSat and Nest.



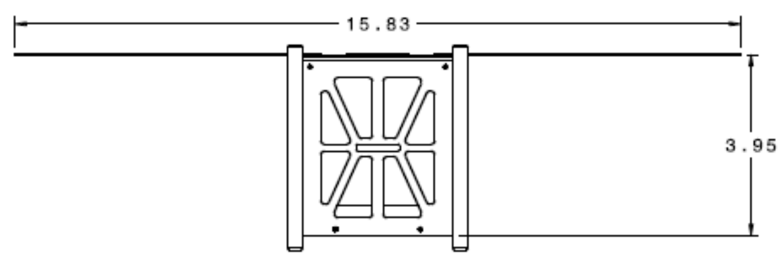
Top view
Scale: 1:2



Isometric view
Scale: 2:3



Front view
Scale: 1:2

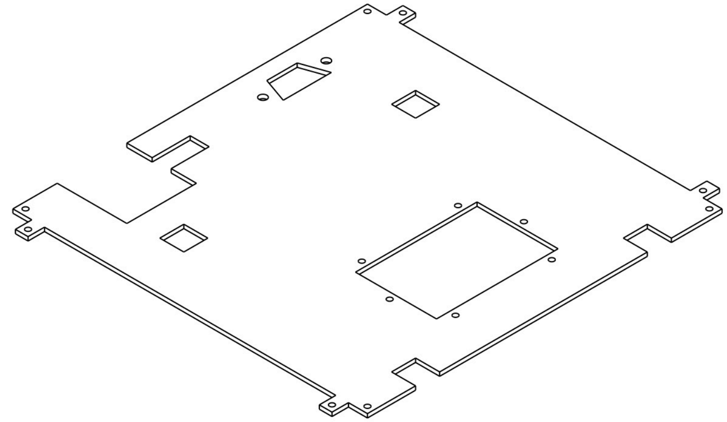


Right view
Scale: 1:2

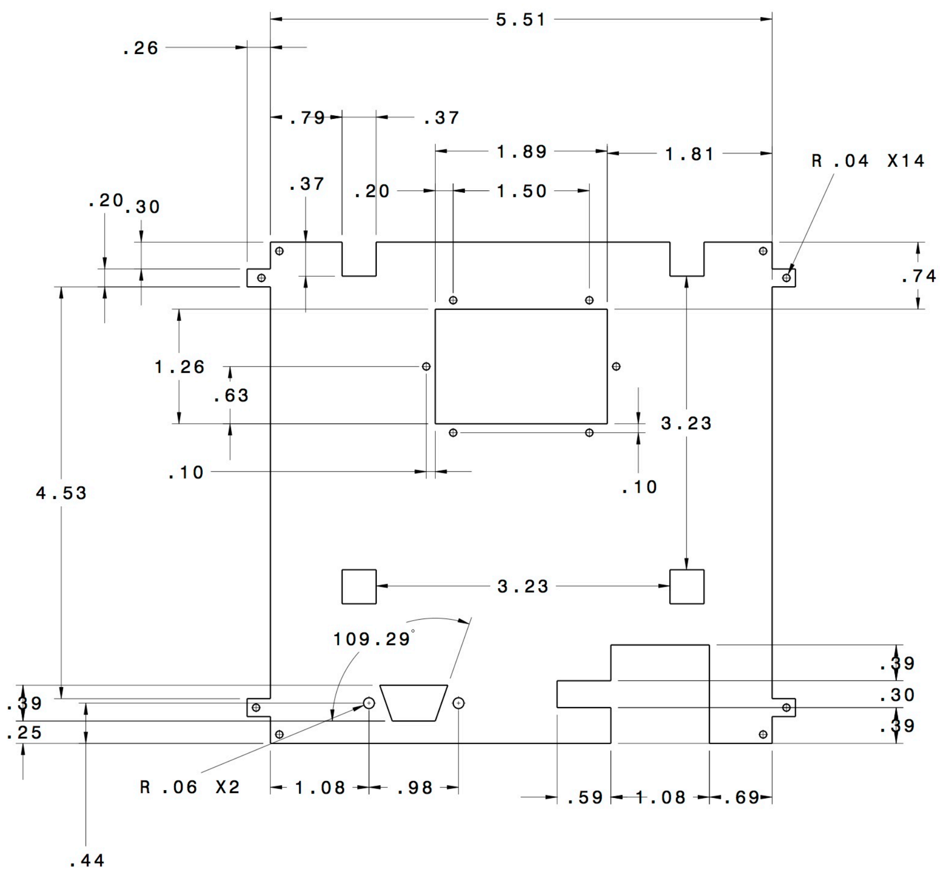
All units in centimeters

This drawing is our property. It can't be reproduced or communicated without our written agreement.		ERAU NASA SPACE GRANT			
DRAWN BY Mo Sabliny	DATE 5/21/2013	DRAWING TITLE EagleSat			
CHECKED BY Zach Henney	DATE 5/21/2013	SIZE C	DRAWING NUMBER 002		REV B
DESIGNED BY	DATE	SCALE 1:2	WEIGHT(kg) XXX		SHEET

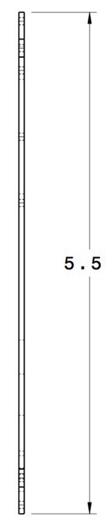
Top view
Scale: 1:1



Isometric view
Scale: 1:1



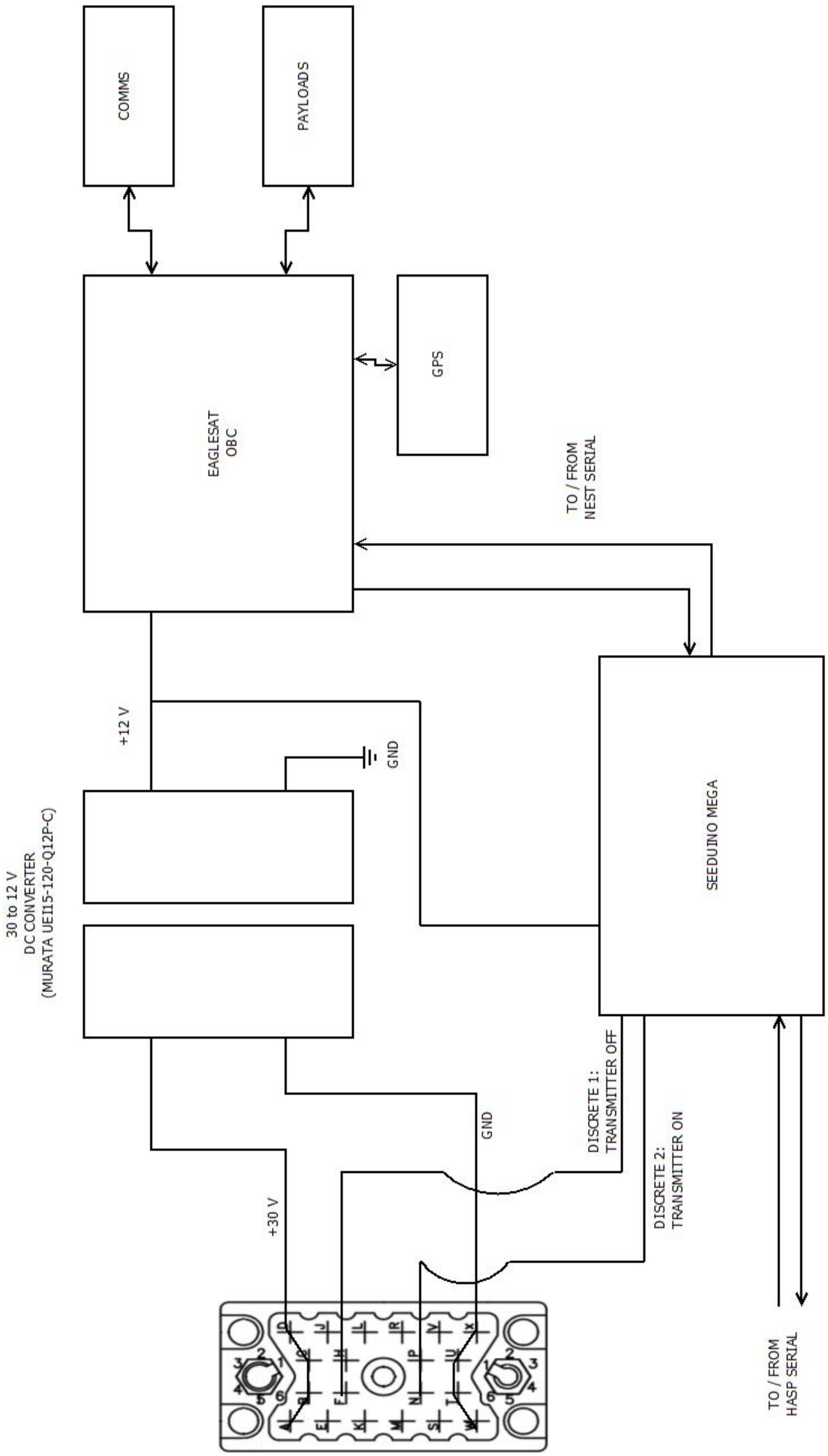
Front view
Scale: 1:1



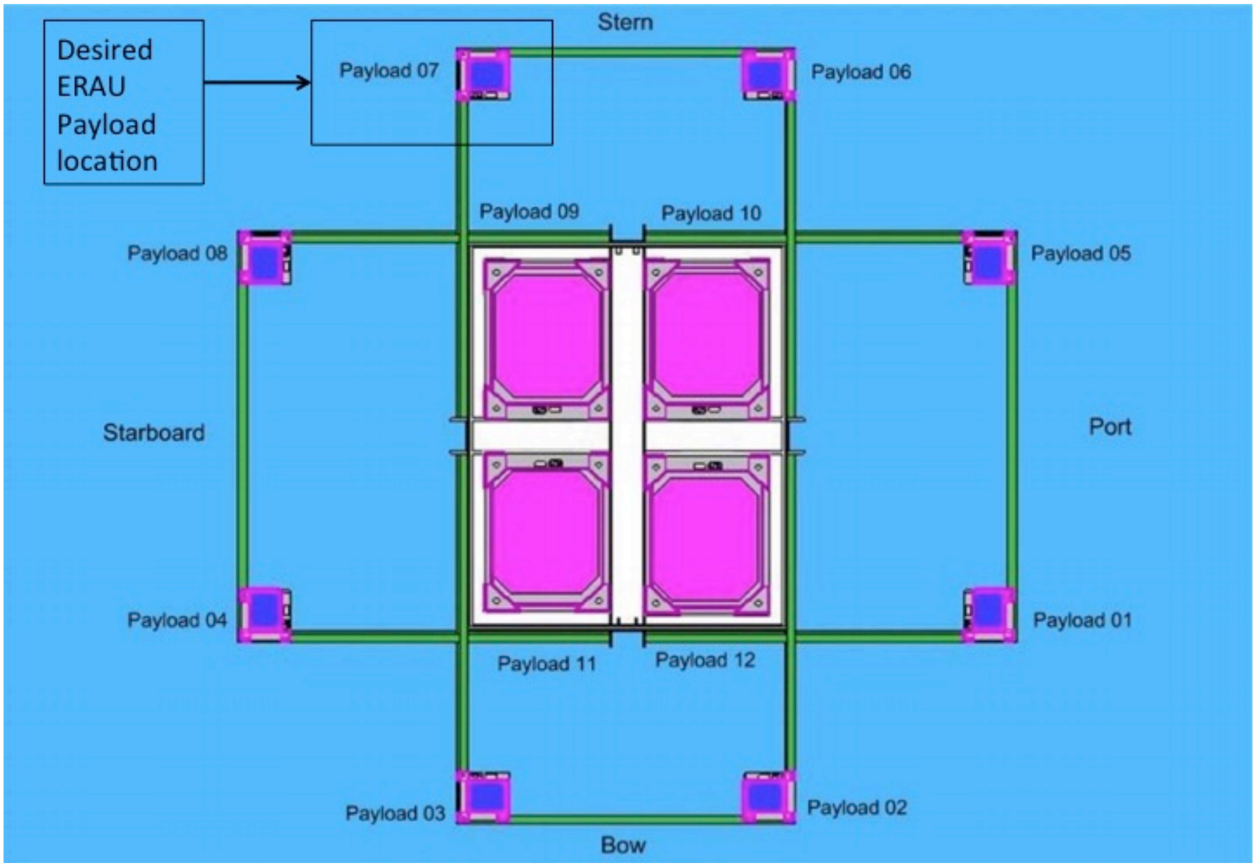
Right view
Scale: 1:1

Created for NEST integration module to support ERAU EagleSat on HASP 2014.
Note: all dimensions = in.

DRAWN BY Zach Henney	DATE 3/28/2014	ERAU PRESCOTT NASA SPACE GRANT			
CHECKED BY XXX	DATE XXX	DRAWING TITLE Nest Top			
DESIGNED BY Zach Henney	DATE 2/20/2014	SIZE C	MATERIAL 5052 Aluminum		REV X
		SCALE 1:1	WEIGHT(kg) 0.03		SHEET 1/1



EagleSat wiring diagram, showing interconnected nature of Nest and EagleSat systems.



Desired ERAU payload location.