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Abstract

In keeping with Embry-Riddle's history of balloon satellite flights as well as the goal of putting a satellite in orbit within the next four years, *Hatchling II* seeks to be the latest in testing the design prowess of the undergraduate engineers at ERAU. *Hatchling II* consists of two parts: *Phoenix*, an atmospheric sampling mission; and *EagleSat*, Embry-Riddle's first cubesat. *Phoenix* is an exploration of the effects of wildfire on the stratosphere, consisting of multiple gas and particle sensors to investigate the presence of smoke and soot and how long they prevail at 120,000 feet. *EagleSat* seeks to test a crystal radio, a student-built electrical power system, and solar panels for later use on a space-ready model.

Payload Description

Phoenix

Wildfires are a mixed benefit for the land they touch: grasslands are destroyed, but can return within months; and forests are often cleared of smaller trees while the big trees soldier on. But what is the effect of wildfire on a larger scale? What happens to all the smoke? Does the smoke stay contained within the troposphere, or does it burst into the stratosphere? *Phoenix* seeks to investigate the presence of smoke in the stratosphere by sensing for gaseous indicators as well as physical particles. By flying *Phoenix* on HASP during the peak of fire season, it will be possible to compare the data generated with data collected during the offseason to see the influence of wildfire-generated smoke on the stratosphere both during and after fire season.

The tropopause - the boundary between the troposphere and stratosphere - was long considered to be an incredibly stable section of the atmosphere. It kept most pollutants within the troposphere, save for some chemicals small enough to be whisked into the stratosphere. The tropopause is such an efficient barrier that volcanoes were thought to be the only source of smoke in the stratosphere, due to their violent nature of ejection. But in the later years of the 20th century, it was discovered that wildfire smoke, when generated by especially energetic fires, could in fact make its way through the tropopause, where it was soon distributed around the globe via stratospheric air currents. Once in the stratosphere, the smoke can affect the global environment: it can reflect solar radiation, causing a cooling effect; or it can cause pryocumulonimbus clouds, which are thunderstorms either caused or influenced by wildfire smoke. The most common way of sensing for smoke particles is through satellite imaging or ground-based radar, but with *Phoenix*, the data will be collected where the smoke should be present, giving an actual picture of the atmospheric composition.

To collect the necessary data, *Phoenix* will contain a series of gas sensors and particle collectors. The gas sensor will detect elevated amounts of carbon dioxide, carbon monoxide, nitric oxide, and ozone, all byproducts of smoke. Other sensor will include: humidity, to look for any water vapor associated with a smoke plume; as well as temperature and pressure. These sensors will all be flight tested earlier in the year to check their accuracy at flight altitude, as well as to get a baseline reading for the stratosphere outside of fire season. *Phoenix* will also have a particle sensor onboard to look for actual soot in the atmosphere: an optical dust sensor. This sensor will continually sample the surrounding air by searching for dust refraction, an action that requires it to have exposure to the elements.

The overall structure of *Phoenix* will be an incremental development over past structures, incorporating elements from past HASP flights as well as other balloon flights. There will be an inner skeleton made from 6061 aluminum, covered with a composite shell for thermal insulation. This structure is being designed from scratch by the members of the *Phoenix* team, allowing for hands on exercise in CAD and assembly work. The structure itself will be relatively small, with the outer shell standing a mere 5 centimeters tall, while the base will take up the full fifteen centimeter square as allowed by the HASP specifications. Through tests on the old *Hatchling I* payload, it was revealed that the E-Glass/foam composite used to form the outer shell was incredibly efficient as a thermal insulator, making it so the heating system inside the payload would have to do little work to maintain a reasonable environment while at flight altitude.

Phoenix will be flown several times over the course of the year to generate data that can be used to get an idea of how much smoke is in the stratosphere. Most flights will occur on short duration balloons from Arizona; it is estimated that these flights will only allow for half an hour of stratospheric sampling before the balloon pops and begins its descent. By flying on HASP, however, *Phoenix* would be able to gather data for up to 10 hours, a vast improvement over any other flight opportunity. The extra data generated during the HASP flight would allow for a much detailed sampling over a larger region, thus creating a more detailed picture of the atmosphere. Also, HASP flies at the peak of fire season, which would make for an incredibly sample-rich period in the stratosphere, and an opportunity that would help generate the clearest picture of just how much smoke can make it past the tropopause during fire season.

EagleSat

It is the shared goal of a dedicated group of students at Embry-Riddle's Prescott campus to launch a cube satellite into space within the next four years; this satellite, called *EagleSat*, seeks to investigate the effects of solar radiation on bit flipping in different types of commercially available memory, as well as mapping the extent of the Air Force's Space Surveillance System (colloquially referred to as the Space Fence) as it passes through the radar beam. In addition to this mission, *EagleSat* also serves as a learning experience for the many underclassmen on the team, who would otherwise have to wait until the last years of their time at Embry-Riddle to build such a project. Flying the *EagleSat* test article on HASP would allow for the flight testing of several components over a long duration in a near-space environment, allowing the project members to see just how well their components would hold up in orbit.

To accomplish its primary mission, *EagleSat* will be using various forms of commercially available memory - FRAM, MRAM, and PRAM - to look for the prevalence of bit flipping as caused by Single Event Upsets or SEU, events in which solar radiation is interfering with electronic systems. The occurrence and rate of any bit flipping will be recorded and then compared to any spikes in solar radiation recorded by an onboard radiation detector. It is believed that a correlation can be found between the two, given that solar weather cooperates for the duration of the mission.

One of the main developments in the early stage of *EagleSat*'s development has been the design and construction of the Electrical Power System (EPS) that will be in control of power distribution onboard the satellite. During flight operations, the EPS will take in the power from the solar panels; use it to charge up the satellite's lithium polymer batteries; as well as distribute power at 3.3v, 5v, and 13.8v to meet the needs of onboard sensors. As a part of the overall HASP payload, the EPS will do all these duties, as well as use its onboard microprocessor to manage the data generated by *Phoenix* and *EagleSat* components.

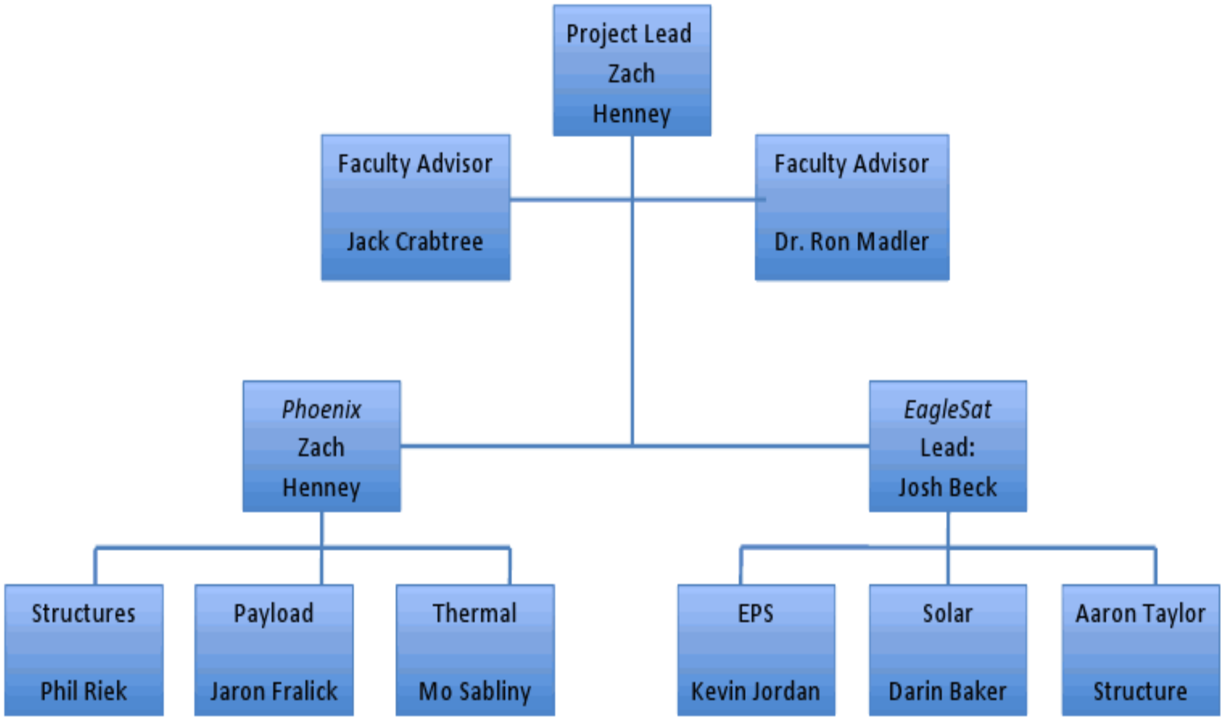
To generate power in orbit, *EagleSat* will need to have solar panels onboard, which team members are developing from an array of Triangular Advanced Solar Cells (TASC). These small, high efficiency cells are designed for use in space, and will be mounted to larger PCBs, creating a larger solar panel to cover each side of the satellite. In the final design, the plan is to have the solar panels be deployable, thereby increasing the amount of surface area for power generation, but for HASP the panels will be fixed. Testing these panels at float altitude will allow for the team to get an idea of just how well the panels will be able to generate power in a near vacuum, as well as testing their thermal resiliency.

EagleSat will measure the extent of the Space Fence by sensing via a crystal radio when it crosses through its radar band, which is unfortunately an asset that cannot be guaranteed to be on the HASP flight plan. To circumvent this, it has been proposed that the crystal radio will instead be triggered by sending a transmission towards the payload while in flight on the 200 MHz band. Rather than trying to determine a period of travel, the crystal radio would instead be used in a verification manner, making sure that it can operate correctly in the conditions of near-space.

All of the components for *EagleSat* need a structure, therefore, Embry-Riddle's Senior Detail Class is engaged in developing what may end up being the final structure for the satellite. However, should the decision be made that the structure will not be up to par when compared to a pre-made structure, the ERAU-built structure will be passed upon for a commercially available one. It is anticipated that the structure flying on HASP will be the one designed on campus, as it would be an excellent opportunity for flight testing an innovation of some of Embry-Riddle's own engineers. The structure will be a 1u cubesat, with dimensions of 10 cm by 10 cm by 10 cm, and will be mounted directly on top of *Phoenix.* The structure will be insulated against the elements, both by the solar panels sealing the payload as well as internal insulation aided by the heat generated by the electrical components within.

Team Management

Hatchling II is a project under Embry-Riddle's NASA Space Grant, and all work being done is extracurricular and reflects the interests of a group of dedicated engineering students. Currently the team is of a modest size, as reflected in the organization chart below.



It is anticipated that of the team members, at most there will be five people in attendance for integration at the Columbia Scientific Balloon Facility and flight operations at Ft. Sumner.

Contact information for the team leads and advisors are as follows:

Project Lead	Zach Henney	Embry-Riddle Aeronautical University 3700 Willow Creek Rd Prescott, AZ 86301	henneyz@my.erau.edu 707-570-6111
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Faculty Advisor	Jack Crabtree	Embry-Riddle Aeronautical University 3700 Willow Creek Rd Prescott, AZ 86301	crabtrej@erau.edu (928) 777-6916
Faculty Advisor	Dr. Ron Madler	Embry-Riddle Aeronautical University 3700 Willow Creek Rd Prescott, AZ 86301	madler@erau.edu (928) 777-3896

Given that the development of *Hatchling II* is done by students, design, construction, and testing will be completed by the end of April. Below is a chart detailing anticipated milestones for the development of *Hatchling II.*

January
- Acquisition of hardware components
- Finalizing designs
- Begin construction on *Phoenix* module
- Continue construction of *EagleSat* structure

February
- Integration of both *Phoenix* and *EagleSat* into *Hatchling II*
- Begin construction of *Phoenix* test module for balloon flight.

March
- Completion of construction for *Hatchling II*
- Sample gathering flights for *Phoenix* test module

April
- Thermal and vacuum tests for *Hatchling II*
- Completion of Payload Integration and Flight Operation documents
- More flights for *Phoenix* test module

July/August
- Payload integration with HASP

August
- Correct any issues that may have arisen during payload integration

September
- HASP Flight

Payload Specifications

When integrated with HASP, *Hatchling II* will have a base dimension of 15 by 15 centimeters, fitting within the constraints for a small payload. The *Phoenix* payload will stand 5 centimeters tall, and *EagleSat* have a height of 10 centimeters; when stacked on top of each other in their proper configuration within *Hatchling II*, the overall payload height will come to 15 centimeters, again within the constraints for a small payload. *Phoenix* will consist of an aluminum frame encased in a composite shell for insulation, with resistive heaters working in tandem with a temperature probe to maintain a proper working environment for the various sensors inside. *EagleSat* will also consist of an aluminum frame, but will have solar panels on each of the five outwards-facing sides. For thermal management, *EagleSat* will not have an external sheath due to the presence of solar panels on its exterior. It will instead have internal insulation in the gaps between components, as well as an on board resistive heating system. The anticipated mass budget for the payload can be seen in the table below.

Component	Part Name	Mass (g)
Phoenix	Optical Dust Sensor	30
	CO2 sensor	9
	O2 sensor	9
	CO sensor	9
	GPS Antenna	18
	GPS Logger	9
	NO sensor	9
	Ext. Temp/Humidity	0.1
	Int. Temp/Humidity	0.1
	Ext. Pressure	0.09
	Structure	200
	Thermal Mgmt.	100
EagleSat	Overall	1000
Hatchling II	Total	1393.29

Mass Budget for *Hatchling II*

As for the use of power from HASP, only the *Phoenix* payload will be utilizing the power delivered via the EDAC 516 connector, as *EagleSat* will be running off internal batteries as part of the parameters of its flight test. Due to the nature of the data being collected, *Phoenix* will only require power at flight altitude, and will most likely be powered off during ascent and descent. As such, it is anticipated that there will only need to be commands to turn the payload on, off, and to reset it in case of an error in data collection. The collected data will primarily be stored internally, but every fifteen minutes *Phoenix* will use the downlink capabilities provided by HASP to give a status update and a sampling of the collected data. Below is a table with the anticipated power budget for *Phoenix.*

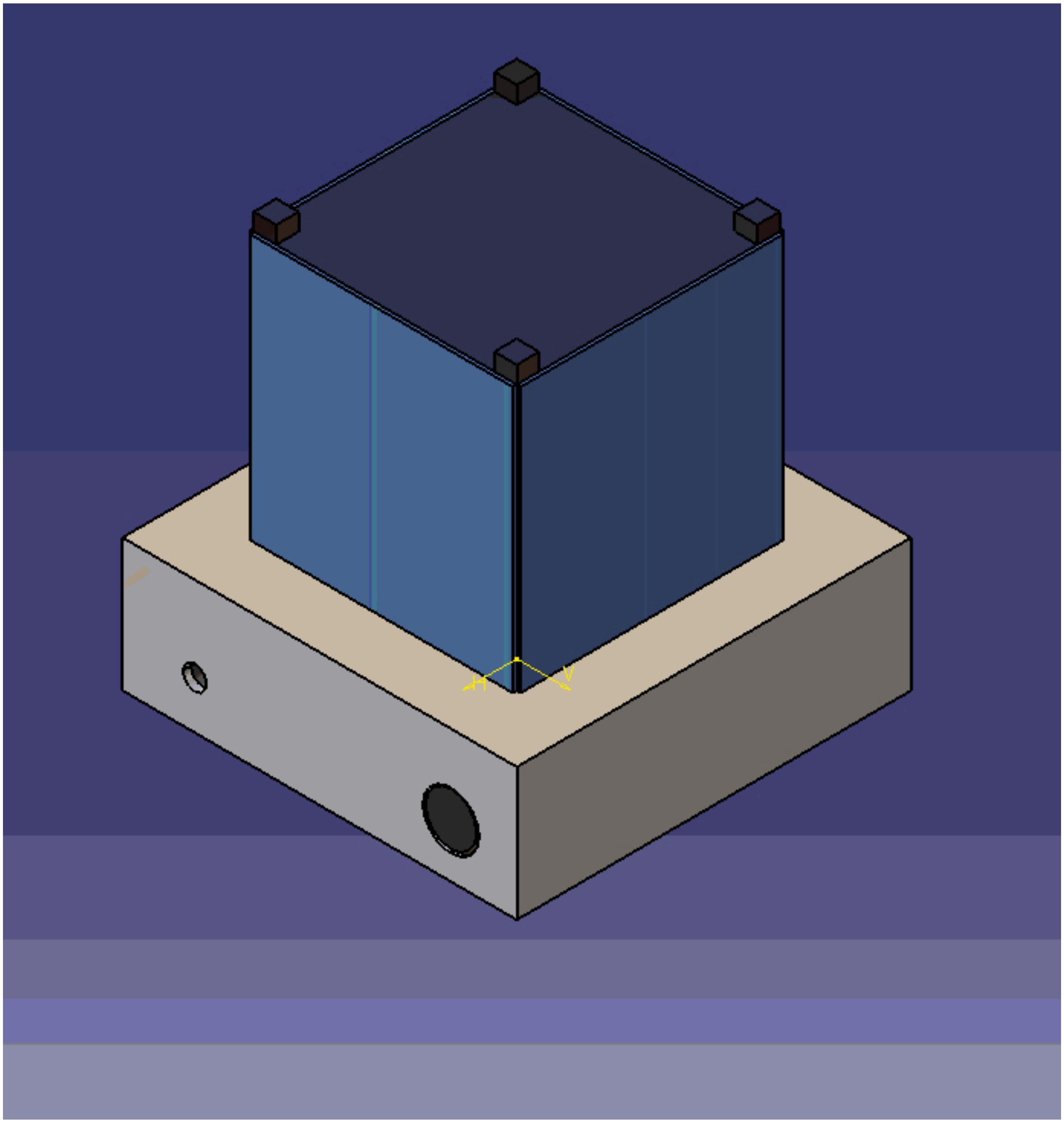
Part Name	Current (mA)	Volts	Watts
Optical Dust Sensor	11	3.3	0.0363
CO2 sensor	50	5	0.25
O2 sensor	50	5	0.25
CO sensor	50	5	0.25
GPS Antenna	12	3.3	0.0396
GPS Logger	28	3.3	0.0924
NO sensor	50	5	0.25
Ext. Temp/Humidity	0.028	3.3	0.0000924
Int. Temp/Humidity	0.028	3.3	0.0000924
Ext. Pressure	0.005	3.3	0.0000165
Total			1.17

Anticipated *Phoenix* Power Budget

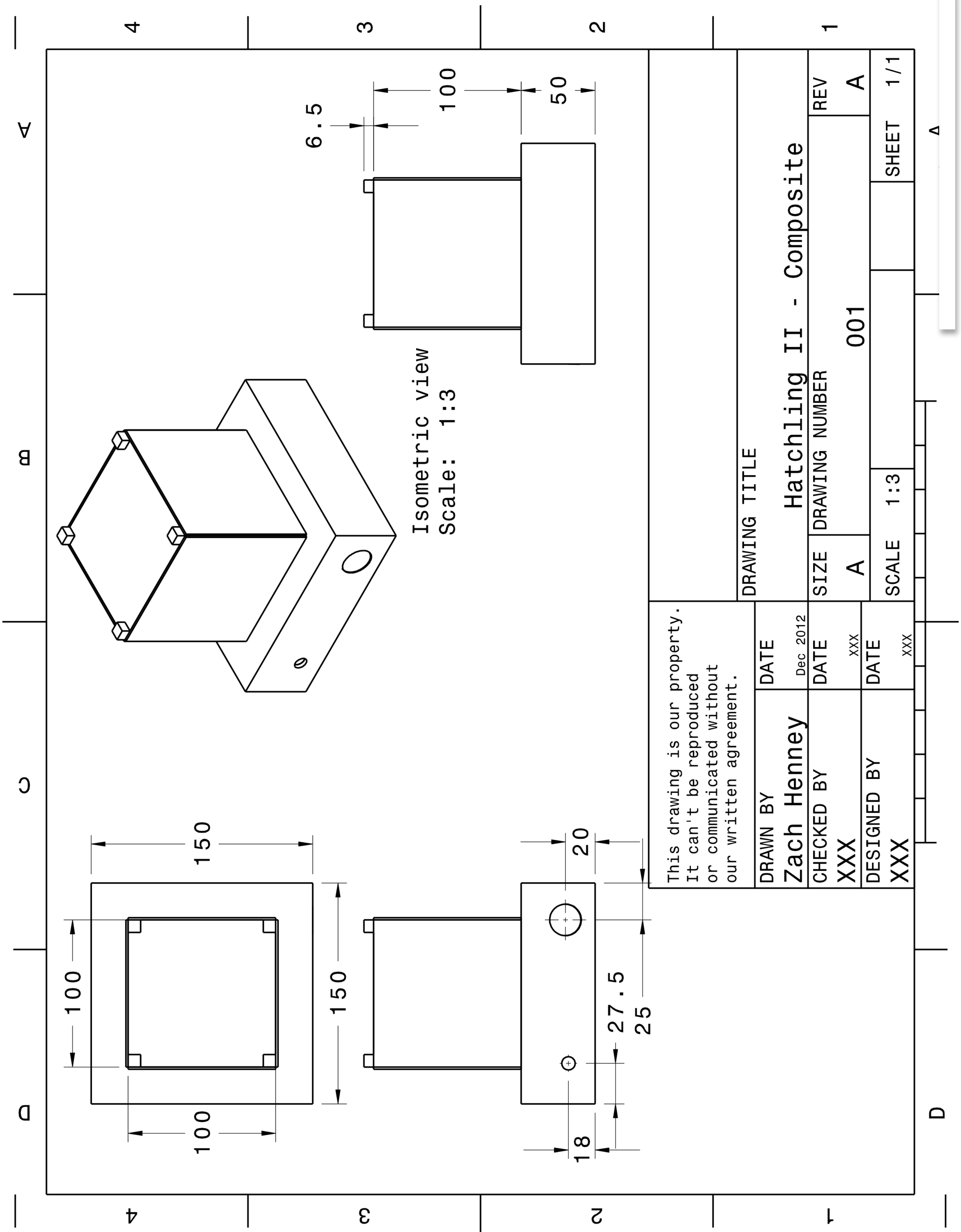
Due to the positioning of the sensors onboard *Hatchling II*, any of the small payload slots will fit the requirements for both *Phoenix* and *EagleSat.* All of the sensors of *Phoenix* will be able to sense the atmosphere no matter where the location, and as long as the solar cells onboard *EagleSat* can receive sunlight then that payload will function as well.

For integration procedure, it is planned to test the payload interfaces between *Hatchling II* and HASP to make sure that the two can communicate and that power is delivered properly. Thermal and vacuum-readiness testing will be done, in addition to that done in the thermal and vacuum chambers in the Aerospace Experimentation and Fabrication Building on campus at Embry-Riddle. Vibration and shock testing will also be done, to ensure that *Hatchling II* will not suffer any undue stress that may compromise the overall structure. If all goes well during integration, flight readiness will simply consist of plugging the payload into HASP for flight operations.

Preliminary Drawings



Screenshot of *Hatchling II* from CATIA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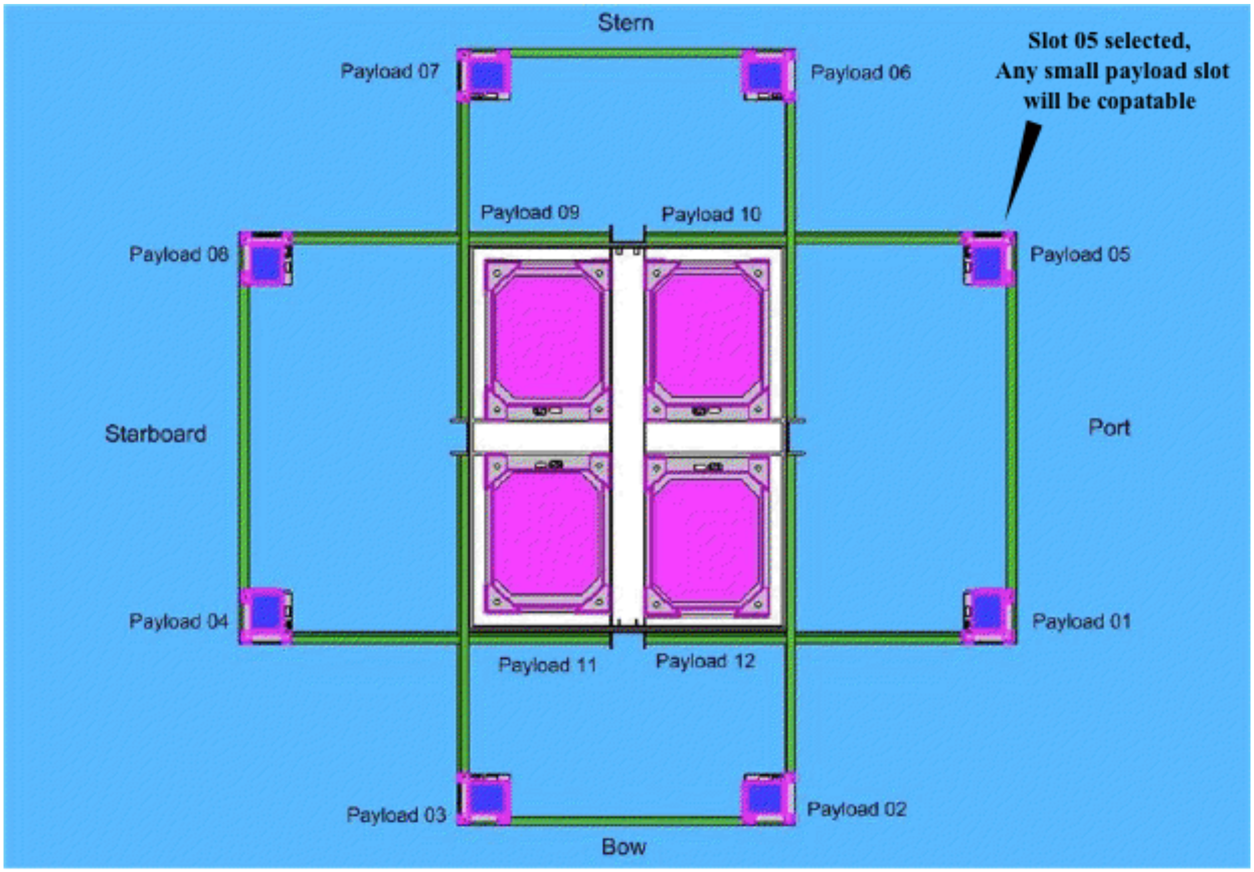
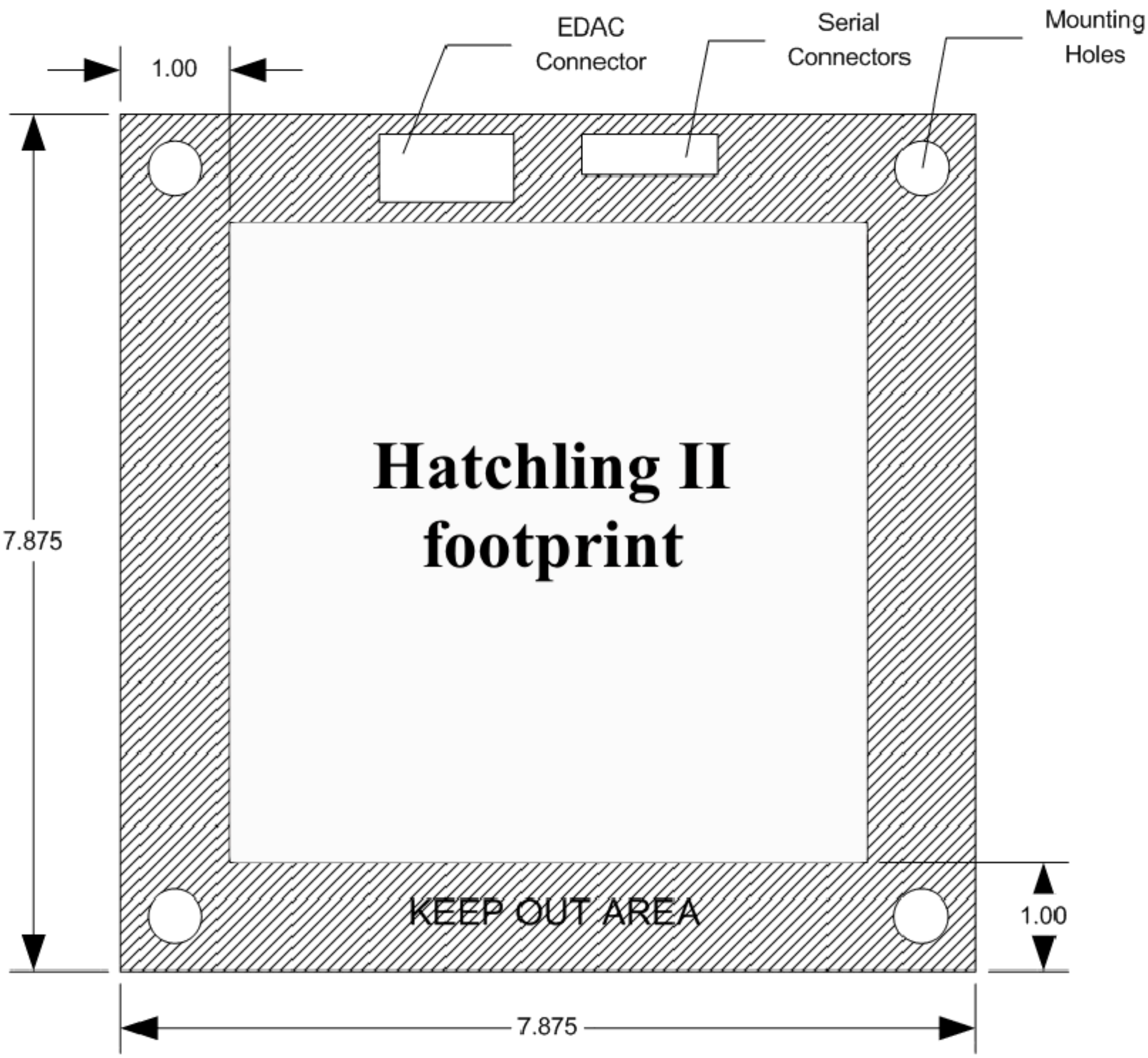


Selected slot for *Hatchling II*



Hatchling II will take up the full 15 by 15 centimeter area allowed for small payloads.