HASP Student Payload Application for 2007

Payload Title:
High Altitude Cosmic Radiation Detector

Payload Class: (circle one) [✓ Small] Large	Institution: West Virginia University	Submit Date: December 15, 2006

Project Abstract:

Studying the intensity of cosmic radiation at higher altitude is impossible from the ground level. Many commercial and military pilots alike have experienced increased eye cancer from little apparent cause. Several studies suggest that exposure to theoretically increased cosmic radiation at higher altitudes is to blame. HASP and other balloon satellite launch programs provide opportunity to study, quantitatively, the levels of cosmic radiation in the upper atmosphere, where aircraft operate. These programs also provide an opportunity to study cosmic radiation in altitudes normally only seen by spacecraft.

The proposed payload will study the variation of cosmic radiation with altitude and time in the atmosphere. Quantitative measurement of cosmic radiation can be conducted similarly to any type of radiation measurement. Such a detection device will generally consist of a light amplifying structure used in conjunction with a counting device. The resultant measurement is only the number of counts of photon strikes given a surface area and amount of time the strikes were counted during. This payload will study the variance of cosmic radiation with altitude and time in the atmosphere.

The team is comprised of two West Virginia University, Mechanical and Aerospace Engineering faculty members and three undergraduate WVU, MAE students. Once of these students will act as project coordinator amongst the other two students and faculty.

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West Virginia University Proposal
High Altitude Cosmic Radiation (HACR) Detector

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12/15/2006

Submitted by: WVU Team HACR

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Justification of Proposed Experiment

Over the past several years, there have been a number of studies on the negative effects of prolonged cosmic radiation exposure among military and commercial pilots. The majority of these studies have involved statistical analyzes comparing the occurrence of cancers and nuclear cataracts in pilots compared to those of the average person of the same statistical risk group. Studies such as those conducted by Rafnsson (2000), Pukkala (2002), and Buja (2005), found that the incidences of melanoma and other skin cancers were significantly higher among military and commercial pilots than the number of cases expected for the general public, even after adjusting for habits such as sunbathing and socio-economic status. However, it is stated in the studies that ultraviolet radiation cannot be ruled out as the cause of the increased cancer incidences, and thus the role of cosmic radiation exposure is still unknown. Therefore, it is proposed to conduct a quantitative study of cosmic radiation levels over the altitude range covered by the High Altitude Student Platform. The extended flight duration time of the HASP will allow for more extensive measurements of cosmic radiation strikes than has previously available using the balloon launch platforms available at West Virginia University, where flight durations are typically no more than a couple of hours.

Payload Description

The proposed payload for the small student package category of the HASP program will consist of the detectors and electronics necessary to detect and record the time, altitude, and location of cosmic radiation strikes. In order to accomplish this, two separate scintillation plates that are photo-luminescent to cosmic radiation will be placed in a vertical stack inside the payload package, with the two plates aligned with the gravity gradient. This stacked configuration will allow for detection of coincident photon strikes between the two plates. Since essentially all of these coincident photon strikes will be aligned vertically, this data can be interpreted as a measurement of the incoming cosmic radiation from deep space. Each scintillation plate will then be coupled to a photomultiplier tube (or similar photo-amplifying device), which will react to the blue light emission from the adjoined plate and convert the signal into an amplified electrical pulse.

In order to detect coincident photon strikes between the two plates, the photomultiplier tubes (PMTs) will be connected to circuitry that will shape the pulses from the PMTs. The on-board memory will store the system clock to record the number of counts for each PMT recorded periodically; as well as, the coincident events recorded, and the number of accidental coincident events recorded periodically. This data will be reduced to the number of true coincident events observed per unit time. This system can be seen in Figure 1. As connection from the ground system permits, the data stored on-board will be transmitted over the provided air-to-ground link. The payload will also be heated using a system, described later in further detail, to ensure that the internal payload temperature is controlled.

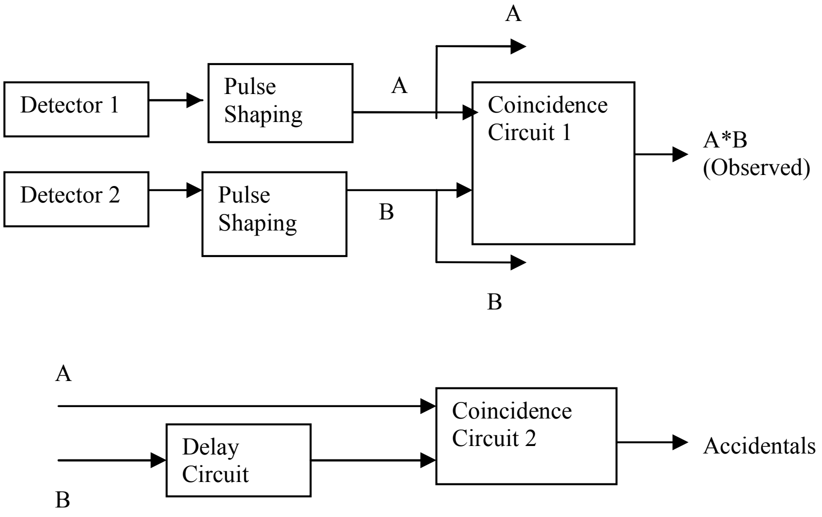


Figure 1: Schematic of the Proposed Coincidence Detector

Team Structure and Management

The West Virginia University team "HACR" (High Altitude Cosmic Radiation) will be comprised of three undergraduate dual major Aerospace Engineering/Mechanical Engineering students and will have two advisors. The project team will be organized, as shown in figure 2, with the advisors, Drs. Kuhlman and Palmer, along with one team member, John Brewer, being the contact points for HASP management. Brewer and the other two team members will also report directly to Drs. Kuhlman and Palmer, as we have been doing for the past two months during the development of the current project proposal. Tasks involved in the development, testing, and data analysis will be evenly distributed among the team members. A timeline for the completion of tasks is included below. It is anticipated that the entire team, including the advisors, will attend the payload integration at LSU in July, 2007, as well as the September launch from Ft. Sumner, NM. Budget estimates have been made for all materials and travel by the team to LSU in July 2007 for payload integration with HASP, as well as to attend the launch in August. This budget estimate has been submitted to the Director of the West Virginia NASA Space Grant Consortium. It is hoped that all expenses incurred from this project will be covered by the Consortium. The team expects to hear a decision about funding from Dr. Majid Jaraiedi, Space Grant Consortium Director, shortly after the submission of this document.

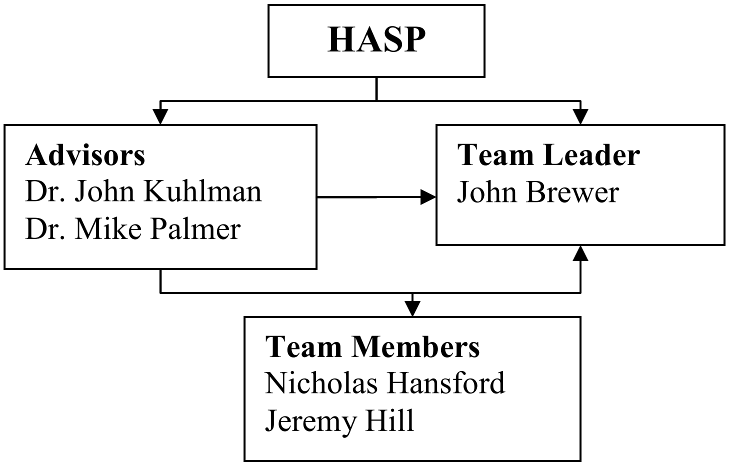


Figure 2: Management Structure for WVU Team

Project Timeline

Dec. 2006: Submit proposal, complete final theoretical development

Jan. 2007: Receive notification of seat award; commence component selection and purchasing

Feb.-Mar.: Construct and develop electronics and payload enclosure

Late Mar.-May: Testing, inclusive of test flight with WVU Balloon Satellites Course

May/June: Analyze test flight data and other testing results

July: Finalize payload construction and corrections, integrate with HASP platform at Louisiana State University

August: Complete final interface corrections, if necessary

September: Attend launch at Ft. Sumner, NM, make last minute changes, if necessary

Post-Launch: Analyze data; report results.

Payload Specification

The project will be designed to meet all of the HASP small payload requirements. Having designed a similar device for launch with the existing West Virginia University "Balloon Satellites" course in Spring 2006, it is expected that the project will weigh approximately 2 pounds (0.9 kg), and definitely no more than the small payload maximum weight of 2.2 lbs (1 kg). This will be an easy design constraint to meet, since the project is not required to carry its own power source as was the case for the previous payload developed at WVU. The proposed payload will also meet the maximum footprint specifications of a 15 cm (6 in) square. It may be desired as construction begins that the payload box include an overhang on two sides beginning approximately 2 in. (5 cm) above the mounting plate, as allowed in the HASP-Student Payload Interface Manual. It is planned that the payload will also be significantly shorter than the 30 cm maximum height limitation. Epoxy and a bracketing assembly will be used to attach the project to the mounting plate as shown in Appendix 1. It is clear from these drawings that the payload will be mounted such that it is compressively restrained to the mounting plate. The material used for the bracketing assembly will be determined later as it is critical that the payload not be further restricted on weight unnecessarily. Appendix 1 also shows drawings of the payload outer shape, assuming that the 5 cm (1 in) overhang is utilized on two sides, and assuming a payload height of 15 cm. Other critical drawings of the payload, assembly and mounting location on the HASP platform are included in Appendix 1.

The payload will use the allotted 28 V DC voltage and current limitations supplied from the HASP bus to power the detector, data collection unit, onboard electronics, and a thermal management system. Each of these subsystems will require different input voltages; therefore the supplied voltage will be run through voltage switchers, which will be integrated in the payload electronics stack. One of the main power consumers in the payload will be the detector, which requires a 1000V input. This voltage will be achieved using a stepping power supply. Figure 3 shows a schematic diagram of the planned electronic layout for the payload including interface paths. As the schematic shows, all payload operations will be managed by a CPU embedded with executable commands. The diagram also shows that an onboard GPS unit will be used. This will allow for the data recovered from the detector circuit to be associated with the altitude and position of the coincident strike.

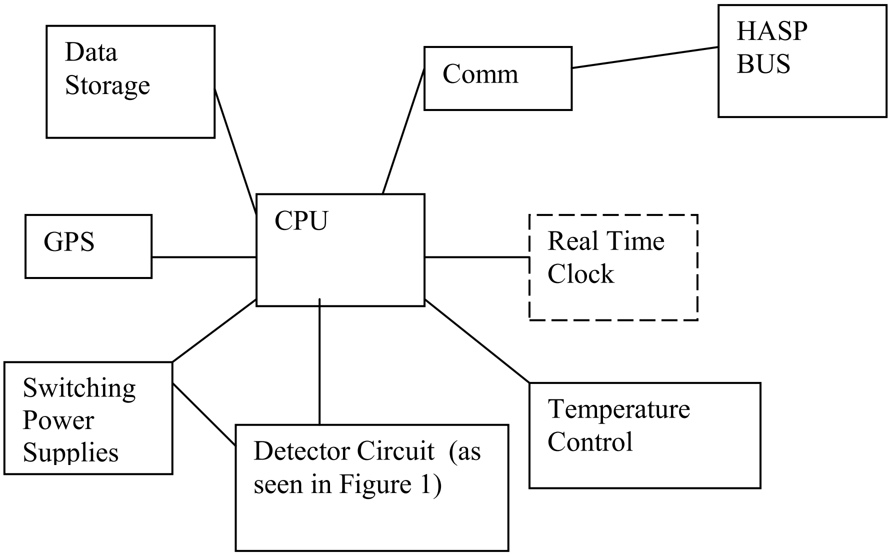


Figure 3: Schematic of Payload Electronics

The payload will use the standard DB9 and EDAC 516 connectors to interface with the HASP, as specified in the HASP-Student Payload Interface Manual. It is planned that data will be transmitted to the HASP for downlink approximately every 3 to 5 minutes. This downlink data will allow the team to confirm the proper operation of the payload throughout the flight. Transmitted data will include HASP package identification, data point number, a GPS time stamp, payload temperature, power supply voltages, and detector counts, using a checksum or CRC format. Data packet length will conform to the HASP packet and a package size of 1400 bytes. This size will allow multiple records to be packaged together. The payload will have enough data storage capability to also record all data acquired during the entire flight. There are currently no plans to uplink commands to the payload, however, it may be desired in the future as development continues.

The inside temperature of the payload will be managed by the use of Minco Thermofoil™ heaters; this thermal control system is likely to be the second major electrical load in our experiment. These heaters will be controlled using an onboard routine that will switch them on and off according to the internal payload temperature measured using either solid-state temperature sensors or thermistors. The devices used in the temperature system will not add significantly to the payload weight, as the heaters are slightly thicker than a sheet of paper. The trade off between the weight of additional insulation and heater power will be closely managed to ensure that the overall payload power requirement stays under the 0.5 Amp current limit for a HASP small payload.

Since the payload will be detecting the density of high-energy gamma radiation as a function of altitude, the mounting location on the HASP platform is not critical. The mounting direction, however, is critical, as the detector must be oriented with the scintillant paddles nearly parallel to the sky plane to maximize the number of detections of cosmic origin.

It is planned that the payload construction and preparation will be completed prior to the integration at LSU in July 2007. At the time of integration with the HASP platform, the team will attach the payload and verify proper communication and supplied power. This will involve providing a test pulse to the detector as well as running the payload for a short period of time with all systems operational. The team members and advisors will also attend the launch in August. At this time, the team will once again verify communication and payload attachment. During the course of the flight, the team will examine the transmitted data to confirm proper payload operation. Data analysis and a formal report will be completed by the team after their return to West Virginia University.

Payload Testing and Verification

While the utmost care will be taken during the payload design phase to assure the project's safety in flight, it is possible that any number of things can go awry due to unanticipated events during the mission. During the failure of the balloon and during landing, the project can experience very high shock loading on the order of up to 10 times the magnitude of gravity. The project may also experience shock loading during encounters with atmospheric turbulence in flight.

While shock loading from landing is not as critical, shock loading due to the failure of the balloon or atmospheric turbulence are both important concerns. As of such, the project will be shock tested. The team plans to purchase accelerometers of some form, most likely the disposable type, which act similar to litmus paper by changing colors when the g-load has been exceeded. The team also will attempt to borrow electronic accelerometers (which can accept loads up to plus/minus 50 times the force of gravity) from other members of the faculty who routinely perform vibrations analysis and testing. Simple drop testing will be used in conjunction with these meters to establish the survivability of the project up to a shock loading of 10 times the magnitude of gravity in the vertical direction and 5 times in the lateral direction.

The West Virginia University HASP Team "HACR" has access to a vacuum chamber capable of almost complete evacuation for use in our testing program. This pressure chamber will allow the team to test pressure conditions that the project will experience during prolonged flight in the upper atmosphere. The chamber is approximately 2 feet in diameter by 2.5 feet in depth. The chamber has been used for upper atmosphere simulation in the past for similar projects.

Previous experience by Drs. Palmer and Kuhlman has shown that the high-voltage, low current electronics necessary for our project are very susceptible to damage from arcing due to the higher spacing of air molecules in the upper atmosphere. A large portion of the pressure testing will be centered on ensuring the safe operation of such electronics. The pressure testing will also verify that the sustained low pressure does not adversely influence all of the electronics, especially the high-voltage power supply required for the operation of the PMTs. For example, a prior WVU Balloon Satellites project team discovered that the enclosure of a Geiger-Mueller tube came apart at high altitude due to the low pressure.

West Virginia University does not possess facilities to directly test the effects of temperatures in the rage of -50 Celsius. The team plans to simply pack the payload in dry ice to lower the temperature. Temperature testing has two primary concerns – condensation and direct failure of the electronics. Temperature-produced failure of the electronics will be addressed during long test periods of sub-zero temperature testing. Condensation should be negligible because all of the electronics will constructed using extended temperature range components.

Also, the electronics will be located inside of the box where the air should not be able to condense as easily.

Since the project's main purpose is to measure the variations in radiation in the upper atmosphere versus altitude and time, testing of the proper operation of the sensing electronics will be of the utmost importance. The radiation testing will be comprised two parts. The first part will verify whether the sensors work as designed, and the second part will test the coincidence measurements from the redundant PMTs. The radiation testing will also establish a baseline of how many radiation counts per hour the project receives in the natural atmosphere. This baseline can then be used to estimate (with some certainty) how much data the team will need to store during the planned nominal 12 hour mission.

The testing will require a source of radiation. The team plans to procure either a Sodium 22 source (two 0.5 MeV gammas) or a Cobalt 60 source (two gammas rays with 2.5 MeV total). The Sodium 22 source would be better to have, but it may be difficult to acquire. The Cobalt 60 source will be easier to get but less desirable for testing purposes. The WVU Nuclear Medicine program has been helpful in the past by providing temporary use of a Sodium 22 source. However, the extended testing required for this project may be prohibitive to Nuclear Medicine. One of our advisors, Dr. Palmer, feels confident he will be able to secure a Cobalt 60 source and possibly even a Sodium 22 source.

Once a source has been acquired, the team can also then test the coincidence timing and tune the coincidence timing of the electronics. The team will need a device known as a time delay box for this purpose. While the required time delay box may not be readily available, the team can build one if necessary. The delay box is essentially a series of variable length cables to measure signal arrival time differences in branches of the coincidence gates. Dr. Palmer's vast experience with this device will be invaluable to this phase of testing.

Because of the projects extreme sensitivity to light, tests for light leakage will also be part of the radiation testing. Light leakage is extremely difficult to test for, and generally only manifests itself in overflow of the sensing electronics. If the project returns more counts than expected (by comparison of similar studies), then the most likely cause if light leakage. Testing for light leakage can also be accomplished by checking each part of the circuitry with an oscilloscope.

In the spring semester of 2006, all three members of the current team were enrolled in a one-credit elective Balloon Satellites course offered by the Mechanical and Aerospace Engineering department at WVU. This class had a similar goal of a balloon satellite launch, but the WVU balloon flight did not achieve either the altitude or duration proposed by the HASP. The team launched a project that attempted to measure cosmic radiation through a system similar to the one proposed here; however, the project was not as complex and not as much testing had been performed prior to the launch date. Another payload that was part of the WVU flight required a similar heating system to the one proposed for use with the current HASP experiment. Examining data from this payload proved that the heating system worked without error. It is planned that the team further refine the circuitry used in this course for the HASP. This circuitry, seen in Figure 4, currently includes a GPS receiver, voltage switching devices, and controllers that will be required by the proposed HASP payload.

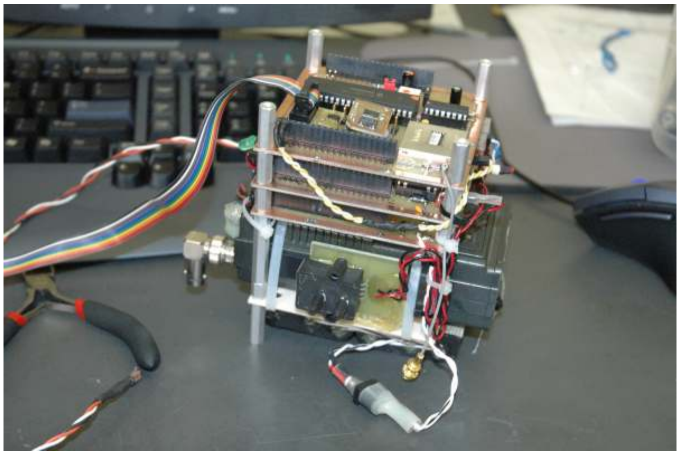


Figure 4: Electronics Stack Used in WVU MAE Balloon Satellites Course

Unfortunately, the proposed WVU HASP team's original cosmic ray payload from spring 2006 was destroyed through circumstances completely outside the control of the team during the initial flight. (In fact, the entire WVU balloon flight was completed successfully, but the parachute and payload stack landed in telegraph wires, suspended directly above an active railroad track. The team's previous payload was destroyed by an impact with a passing train.)

As a result, no data could be analyzed, and the project could not be further refined for a second flight. It is hoped that the experiences gained by the team from the previous attempt, and the knowledge of the technical issues facing this project, will allow for a greatly successful project. This previous knowledge will aid the team greatly in the testing phase. Problems that were encountered late in this previous attempt can be checked for during the testing phase of the development of the WVU cosmic ray detection payload that is proposed for the HASP.

References

Buja, A., Lange, J., Perissinotto, E. Rausa, G., Grigoletto, F., Canova, C., Mastrangelo, G., "Cancer Incidence Among Male Military and Civil Pilots and Flight Attendants: An Analysis on Published Data". *Toxicology and Industrial Health*, Vol. 21, No. 9, 2005, pp. 273-282

Pukkala, E., Aspholm, R., Auvinen, A., Eliasch, H., Gundestrup, M., Haldorsen, T., Hammar, N., Hrafnkelsson, J., Kyyronen, P., Linnersjo, A., Rafnsson, V., Storm, H., Tveten, U., "Incidence of Cancer Among Nordic Airline Pilots Over Five Decades: Occupational Cohort Study." *British Medical Journal*, Vol. 325, 2002, pp. 567-569.

Rafnsson V, Hrafnkelsson J, Tulinius H. "Incidence of Cancer Among Commercial Airline Pilots". *Occupational Environmental Medicine.* Vol. 57, 2000 pp.1759.

Appendix 1: Critical Payload Drawings

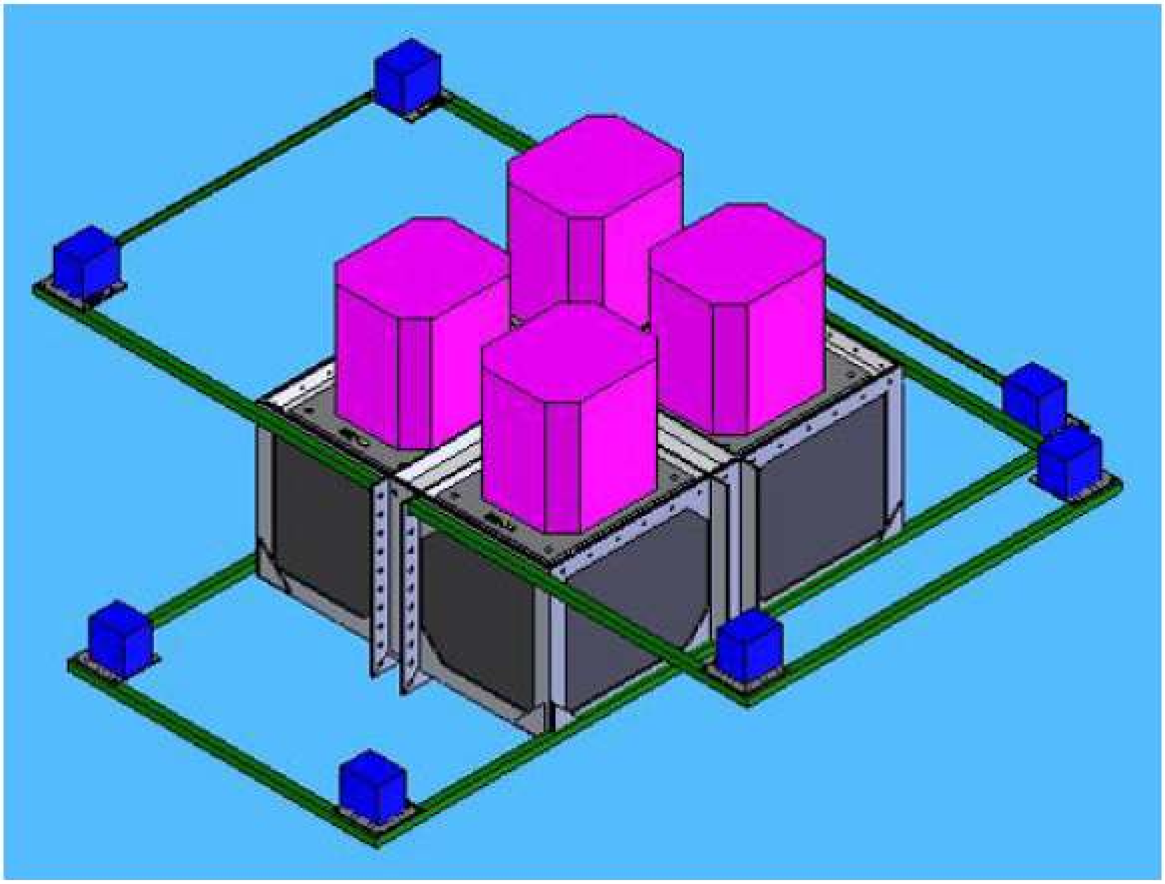
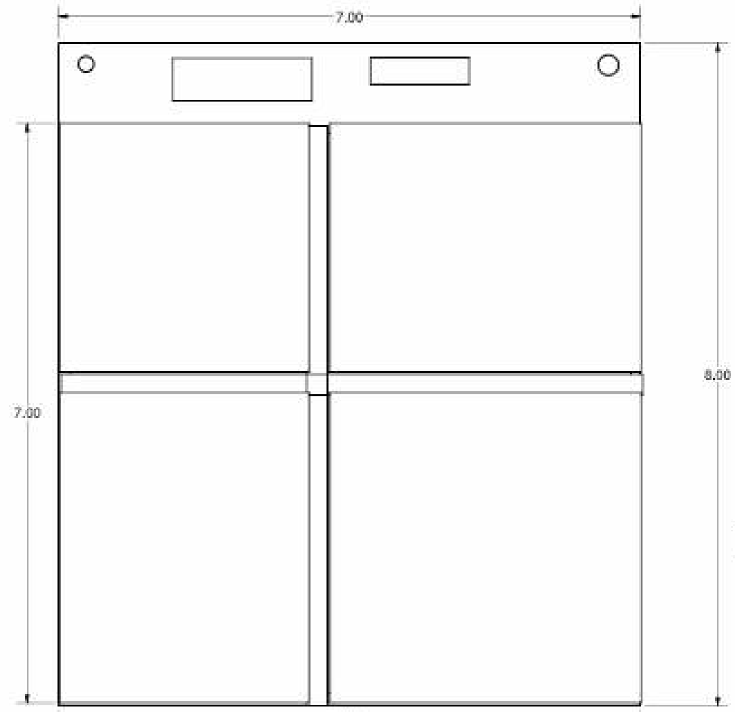
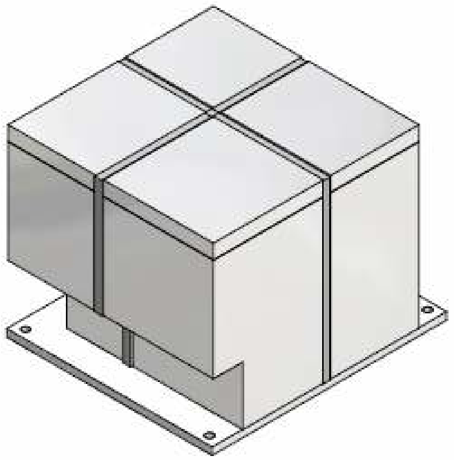


Figure A. HASP Configuration (from HASP Call for Payloads, page 2)

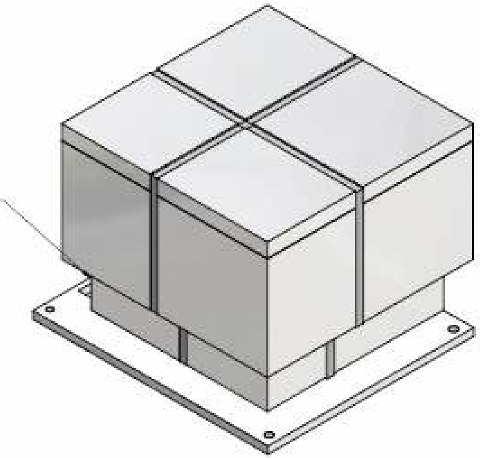
The WVU small payload could be mounted in any of the small payload locations on the HASP platform. It must, however, be oriented such that the top of the payload is oriented perpendicular to the gravity gradient.



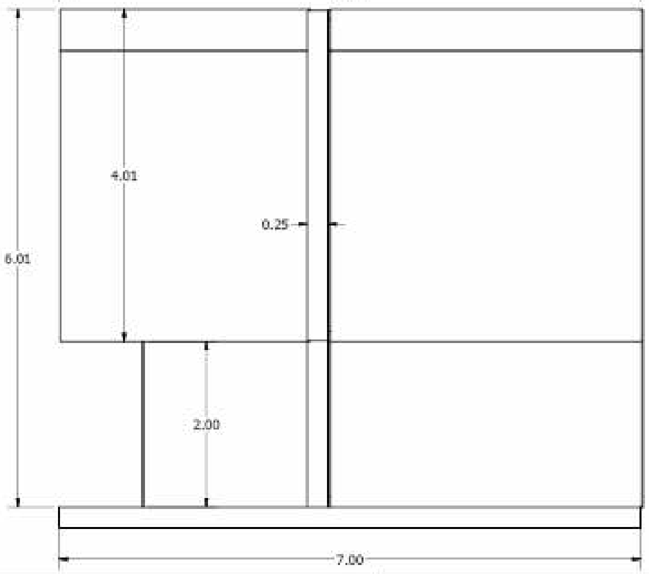
Top View of Payload Assembly



Looking from Right of Payload with DB9 and EDAC 516 Connections In Rear



Looking from Left of Payload with DB9 and EDAC 516 Connections Slightly Visible



Side View of Payload Assembly

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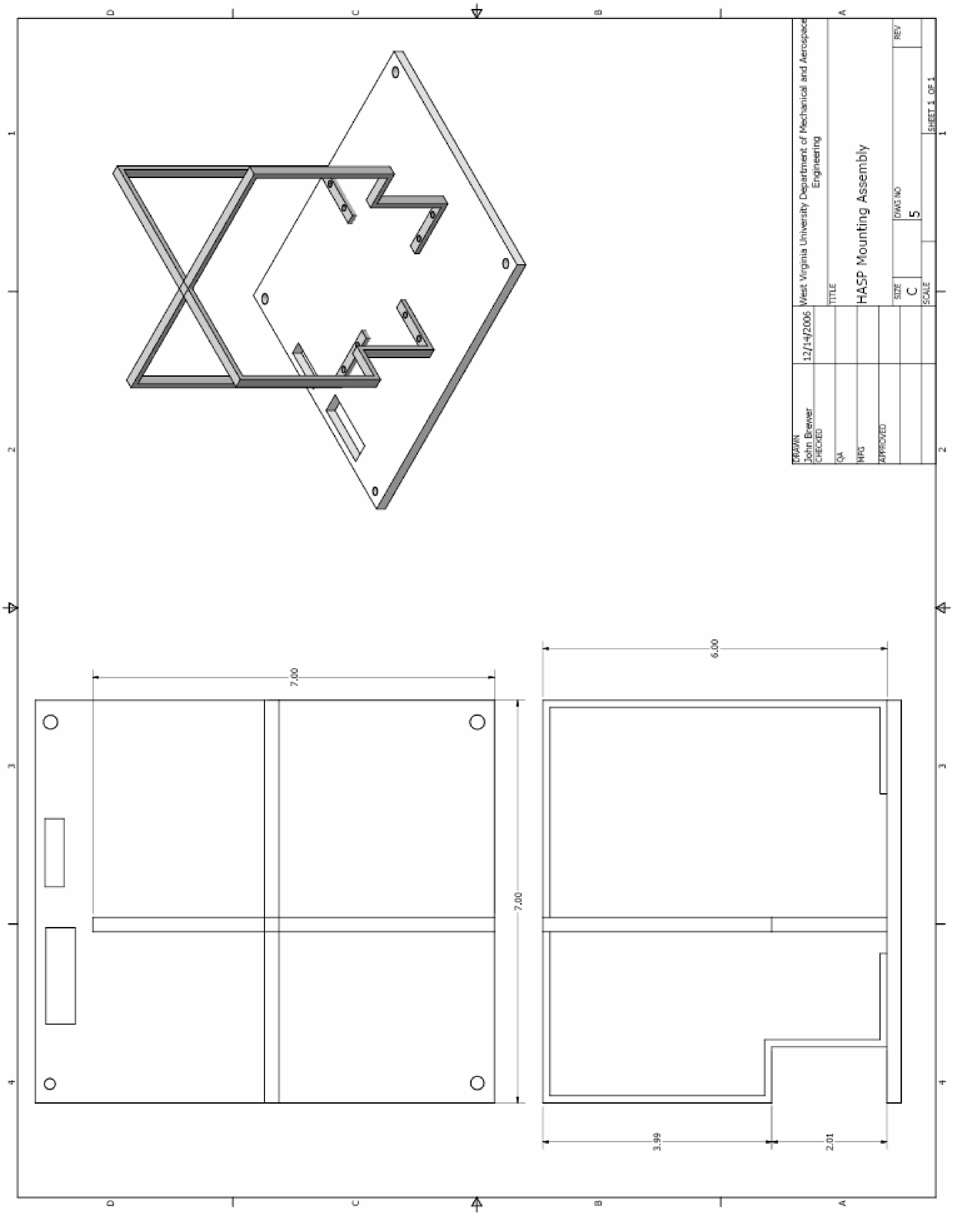
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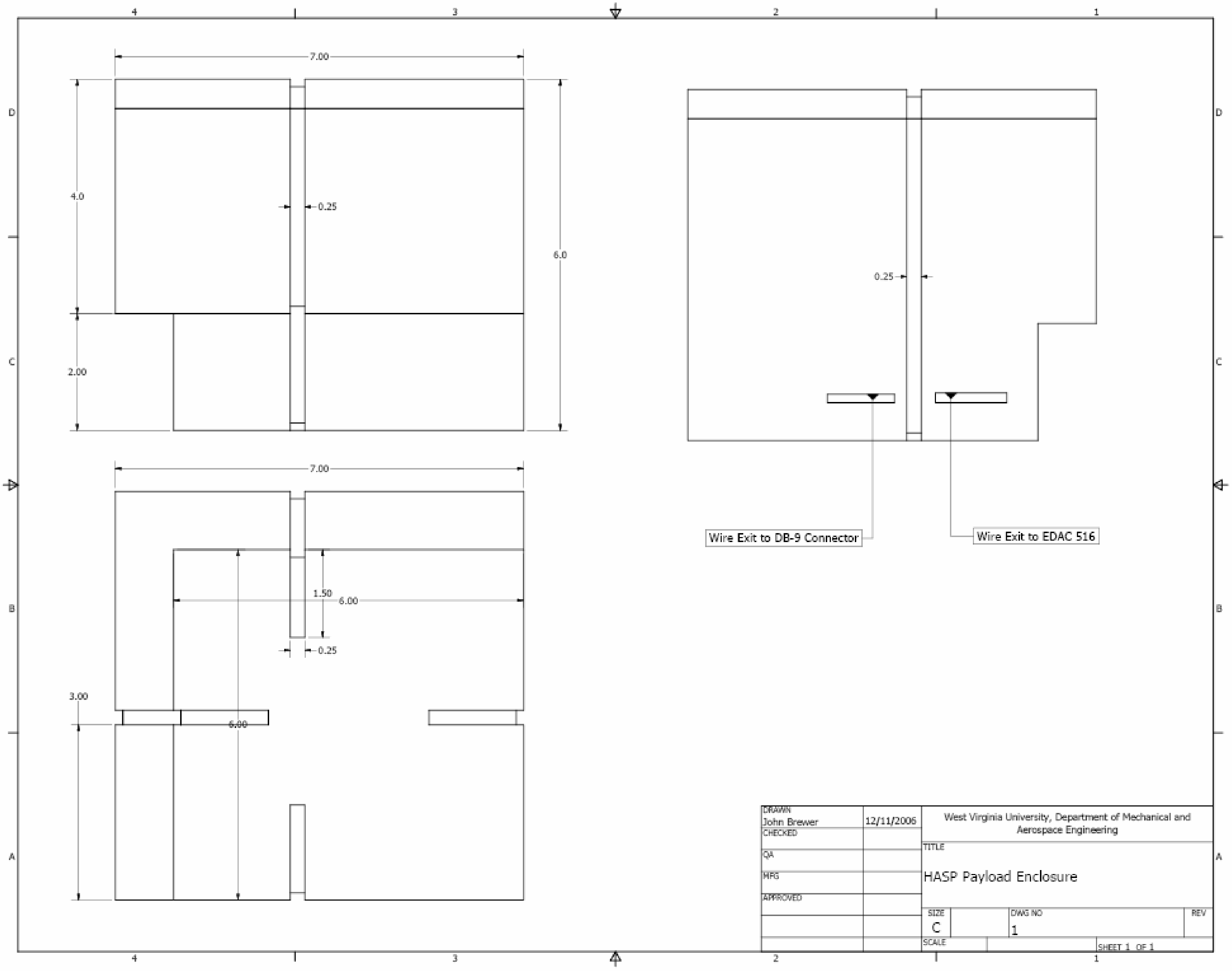

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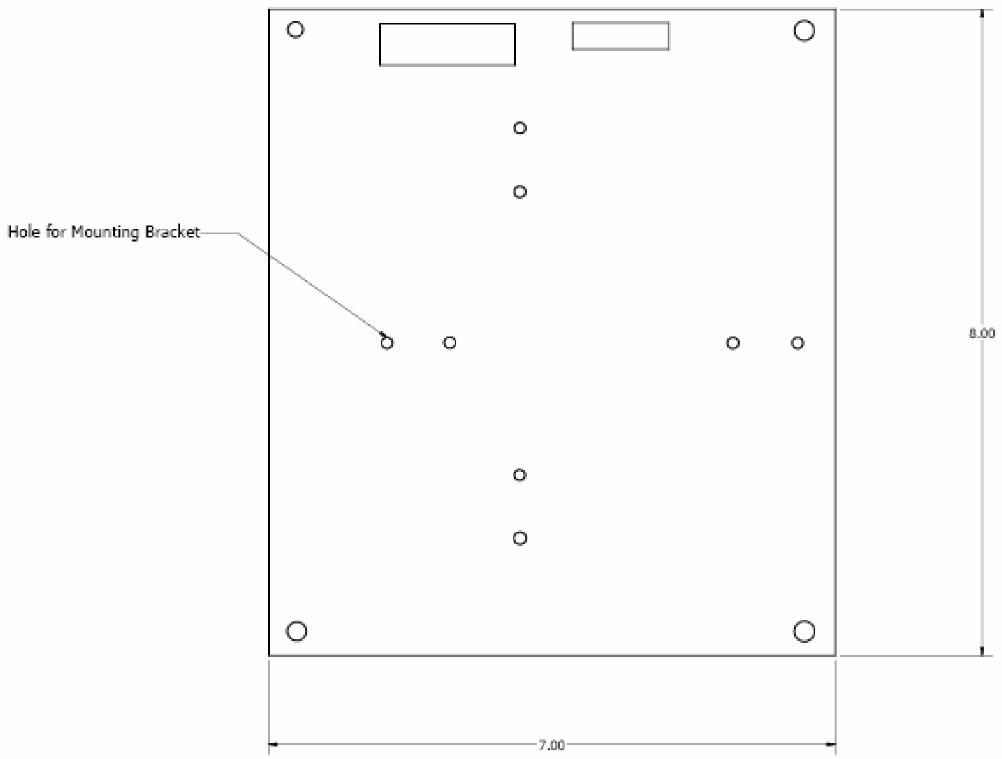

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