HASP Student Payload Application for 2008

Payload Title:
High Energy Monitoring Instrument (HEMI)

Payload Class: (circle one) [✓ Small] Large	Institution: The Pennsylvania State University	Submit Date: 12/17/07

Project Abstract

The High Energy Monitor Instrument (HEMI) is being developed by students at The Pennsylvania State University to detect when a gamma ray burst (GRB) occurs and record data on the event. Ultimately, HEMI is intended to be a student instrument for measuring GRBs on a future satellite. As the challenges for developing student satellite hardware are significant, a precursor balloon flight will provide the necessary heritage to enable a more costly and complex project.

As GRB events are rare, on this flight, the instrument will be used to study cosmic showers as a precursor to studying GRBs. HEMI will collect information as to the number of particles and their energies that it intercepts per time interval. When this number increases dramatically, this indicates a cosmic shower. HEMI will record data in a similar manner as if this were a GRB to prepare for future GRB instruments.

There are currently 10 undergraduates and one graduate student participating on this project from physics, astronomy and astrophysics, and aerospace, mechanical, and electrical engineering. The project is managed by the Penn State Student Space Programs Laboratory.

HEMI conforms to all of the requirements specified in the Call for Proposals and requires no additional resources beyond those already allocated by the program.

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High Energy Monitor Instrument (HEMI) Proposal for High Altitude Student Platform (HASP), 2008

HEMI-HASP, 2008

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17 December 2007

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REVISION HISTORY

Version	Date	Author	Description
Rev 1	12/17/07	Brian Schratz	Initial Release

RELEVANT DOCUMENTS

Doc. Number	Title	Rev
n/a	HASP Call for Payloads 2007–2008	15 Sept 2007
n/a	HASP – Student Payload Interface Manual	09.07.07

*Relevant documents are available on the SSPL web server when available

ACRONYMS

BAT	Burst Alert Telescope
BATSE	Burst And Transient Source Experiment
BeppoSAX	Satellite per Astronomia X
CBE	Current Best Estimate
CGRO	Compton Gamma Ray Observatory
CSBF	Columbia Scientific Balloon Facility
DAU	Data Archive Unit
DC/DC	Direct Current to Direct Current Converter
EMC	Electromagnetic Compatibility
EPO	Education and Public Outreach
eV	Electron Volt
FCU	Flight Control Unit
GBM	GLAST Burst Monitor
GDS	Ground Data System
GLAST	Gamma Ray Large Area Space Telescope
GRB	Gamma Ray Burst
GRBM	Gamma Ray Burst Monitor
GSE	Ground Support Equipment
HASP	High Altitude Student Platform
HEMI	High Energy Monitor Instrument
HV	High Voltage
ICD	Interface Control Document
Mini-SIP	Mini-Support Instrument Package
MOS	Mission Operation System
NASA	National Aeronautics and Space Administration
PMT	Photomultiplier Tube
PSU	Pennsylvania State University
PVC	Polyvinyl Chloride
SCU	Serial Control Unit
SSPL	Student Space Programs Laboratory
UV	Ultraviolet
V&V	Verification and Validation
WBS	Work Breakdown Structure

HIGH ENERGY MONITOR INSTRUMENT (HEMI) PROPOSAL FOR HIGH ALTITUDE STUDENT PLATFORM (HASP), 2008

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1.0 Payload Description

1.1 Science Objectives

Since their discovery in the early 1970s, little information has been gathered about Gamma Ray Bursts (GRB). GRBs release a tremendous amount of energy, up to the order of GeV. Despite the allure of these phenomena, much of the physics behind them still remains unknown, including their origin. The three leading theories are 1) the collapse of two neutron stars upon one another forming a black hole; 2) an extremely violent explosion of a supernova forming a black hole; and 3) a neutron star collapsing into a black hole. All three of these theories center on the turbulent activity of a black hole. Most meaningful data on GRBs have been collected within the past 20 years with the CGRO, BeppoSAX, and Swift satellite projects.

BATSE on CGRO collected an array of data from over 1350 GRBs. It measured the particle flux, fluence, and duration of each GRB. This served as a good basis for the further study of GRBs. BeppoSAX discovered that GRBs also emitted radiation in the form of X-rays. Swift took lessons learned from both CGRO and BeppoSAX, and studied information on the X-ray, UV, and optical portions of GRB afterglows.

The science behind GRBs is essential to the understanding of larger astrophysical phenomena and the history of our universe. Based on the three theories of GRB formation mentioned above, data from GRBs could help explain what physical processes are happening within a black hole. This is an area of astrophysics where still little is known. Many GRBs that are detected originate from such great distances that the information we are recording from them is actually billions of years old. Additional information can help us further understand the beginnings and origin of the universe around us.

The High Energy Monitor Instrument (HEMI) is being developed by students at The Pennsylvania State University to detect when a GRB occurs and record data on the event. Ultimately, HEMI is intended to be a student instrument for measuring GRBs on a future satellite. As the challenges for developing student satellite hardware are significant, a precursor balloon flight will provide the necessary heritage to enable a more costly and complex project.

Because GRBs are not very frequent—on average there are one to two per day—and the HASP balloon launch duration is roughly 20 hours, it is not likely that a GRB will be detected by HEMI during the HASP flight. Taking this into account, and keeping in mind the ultimate goal of studying GRBs, this first flight will be a test of preliminary hardware as well as the student organization. On this HASP flight, the instrument will be used to study cosmic showers as a precursor to studying GRBs. HEMI will collect information as to the number of particles and their energies that it intercepts per time interval. When this number increases dramatically, this indicates a cosmic shower. HEMI will record data in a similar manner as if this were a GRB to prepare for future GRB instruments.

Scientifically, the study of cosmic rays provides relevant and meaningful science questions for the students to study and investigate. The data products for cosmic rays and gamma rays will be similar and the analysis of cosmic rays will allow students to gain hands-on experience in data analysis that will prepare them for future efforts.

Through the study of cosmic rays, we can further our knowledge about the origins and distribution of matter throughout the universe. The particles that we intercept can be billions of years old. Information gathered from the analysis of these particles can help scientists understand what was happening in the universe in its early stages of formation. Many projects are still underway to gather more data on the composition of outer space. However, their results are still unclear. More data in this area is still needed to be able to have a full understanding of the composition of the universe.

1.2 Instrument Design and Operation

The HEMI will be similar in design to burst detector instruments such as CGRO's BATSE, BeppoSax's GRBM, GLAST's GBM, and Swift's BAT. As a student-developed component, the emphasis of this design is a simple instrument that is still able to return meaningful science.

The proposed design consists of a scintillating crystal approximately three inches in diameter and between one to two inches thick (~7.5 cm diam by 2.5–5 cm thick). The crystal will attach to the top of a head-on linear-focused type photomultiplier tube (PMT). The PMT cathode will be grounded and the anode connected to a high voltage power source.

Illustrated in the Preliminary Drawings section below, the scintillating crystal extends beyond the instrument box. The box itself will mount on top of the PVC plate provided by HASP. The remainder of the instrument will be self-contained within the HEMI instrument box.

To maintain the simplicity of the design, only the signal from the anode will be used. No intermediate dynodes will be sampled. However, to reduce power consumption, the proposed design will utilize active biasing of the dynode network rather than the typical resistive voltage divider.

The signal from the anode will pass through a current-to-voltage converter and pre-amplifier. The amplified signal will be analyzed by on-board electronics where the data will be time-stamped and passed on to the HASP data handling system.

The HEMI will use a particle-counting technique. To satisfy the data volume requirements, the instrument will bin the particle counts into discrete energy levels. The data product will then be the spectrum of data showing counts as a function of energy level. In order to detect events of varying duration, the instrument will record time-averaged values spanning various periods.

The thermal plan is addressed in Section 3.6 below.

1.3 Project Justification

This project's intent is to use the lessons learned from the HASP flight to build the next generation HEMI detector and to fly it on a long-duration balloon and eventually a satellite. The second balloon flight is planned to last for a few weeks, so it is certain that we will be able to detect at least a few GRBs. HEMI will be adjusted from studying cosmic showers, as on this upcoming balloon flight, to the study of GRBs. With the second-generation proven on a long duration balloon flight, the next phase will be to adapt the instrument for a satellite mission.

The transition from studying cosmic showers to studying GRBs should be straightforward. The range, sensitivity, triggers, and conditioning of the detector will have to be adjusted to a higher energy setting to focus on GRBs. This is the only anticipated major payload change between balloon flights.

This project will provide hands-on experience for at least a dozen students at Penn State. These students are already working on prototypes and models for this instrument and the opportunity to see an entire lifecycle from concept through analysis will provide invaluable experience for their future science and engineering endeavors. In addition to demonstrated flight hardware, the team fully expects to publish their results and have already submitted an abstract for a research symposium at Penn State in the spring.

2.0 Team Organization

2.1.1 Management

This project will operate under the auspices of the Student Space Programs Laboratory (SSPL) at The Pennsylvania State University. The lab is managed and lead by a core group of students under its Director, Dr. Sven Bilén, and advised by a group of faculty members. This project will be a project under the Flight Program, illustrated in Figure 1 below, and will have the support of the lab's resources.

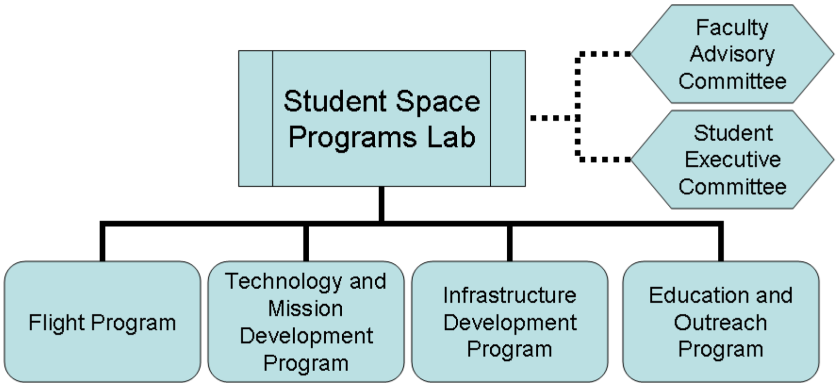
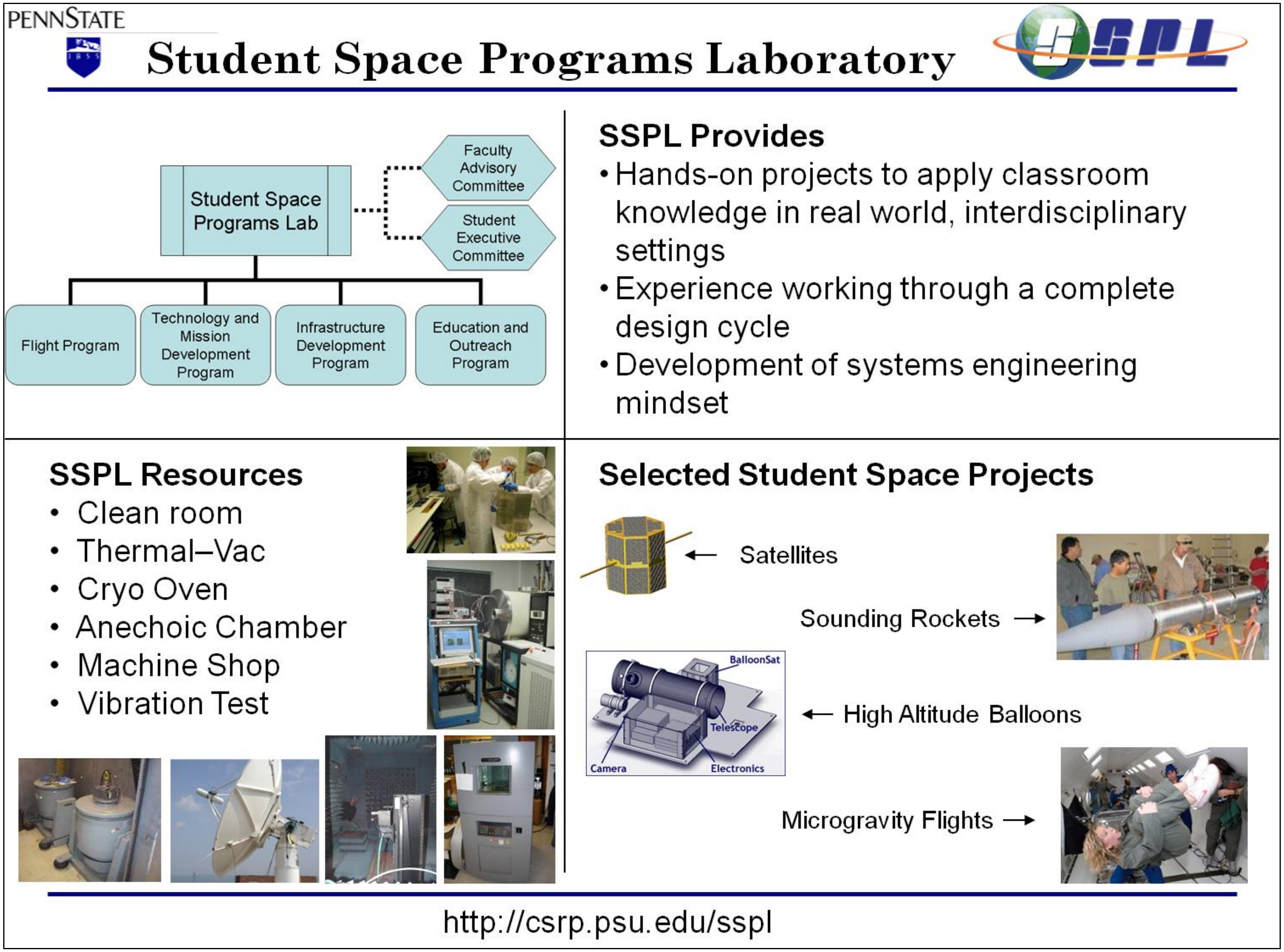


Figure 1 SSPL Organizational Structure

The primary focus of the SSPL (see Figure 2 below) is the integration of real-world space-systems project work with the traditional curriculum to better educate students and prepare them for careers in space science and engineering. SSPL is integrated into the engineering curriculum, giving its students many ways of receiving credit and recognition for their efforts. SSPL projects provide senior capstone projects, independent study projects, undergraduate honors theses, and graduate theses. SSPL student present the results of these projects at national and international conferences.

The HEMI, in particular, is the topic of a current Master's thesis where results from this flight will be a significant part of its completion. Although lead by the M.S. student, significant undergraduate student involvement is part of the HEMI project.

SSPL enriches the students' experience by introducing them to the resources, faculty, projects, opportunities, and other students that they otherwise might never meet. By participating in, and often leading in some way, the lifecycle of a complex project, students are better prepared for the challenges ahead, whatever field they may pursue. By creating an environment where creativity and independence is encouraged, and by giving students access to other experienced students and exciting projects to work on, the students can grow faster than in any classroom.



PENNSTATE

Student Space Programs Laboratory

SSPL

Student Space Programs Lab

Faculty Advisory Committee

Student Executive Committee

Flight Program

Technology and Mission Development Program

Infrastructure Development Program

Education and Outreach Program

SSPL Provides

- Hands-on projects to apply classroom knowledge in real world, interdisciplinary settings
- Experience working through a complete design cycle
- Development of systems engineering mindset

SSPL Resources

- Clean room
- Thermal–Vac
- Cryo Oven
- Anechoic Chamber
- Machine Shop
- Vibration Test

Selected Student Space Projects

← Satellites

Sounding Rockets →

← High Altitude Balloons

Microgravity Flights →

http://csrp.psu.edu/sspl

Figure 2 Overview of the Penn State Student Space Programs Lab (SSPL)

2.1.2 Work Breakdown Structure (WBS)

This project will be organized according to the project Work Breakdown Structure (WBS) illustrated in Figure 3 and defined in the WBS dictionary below.

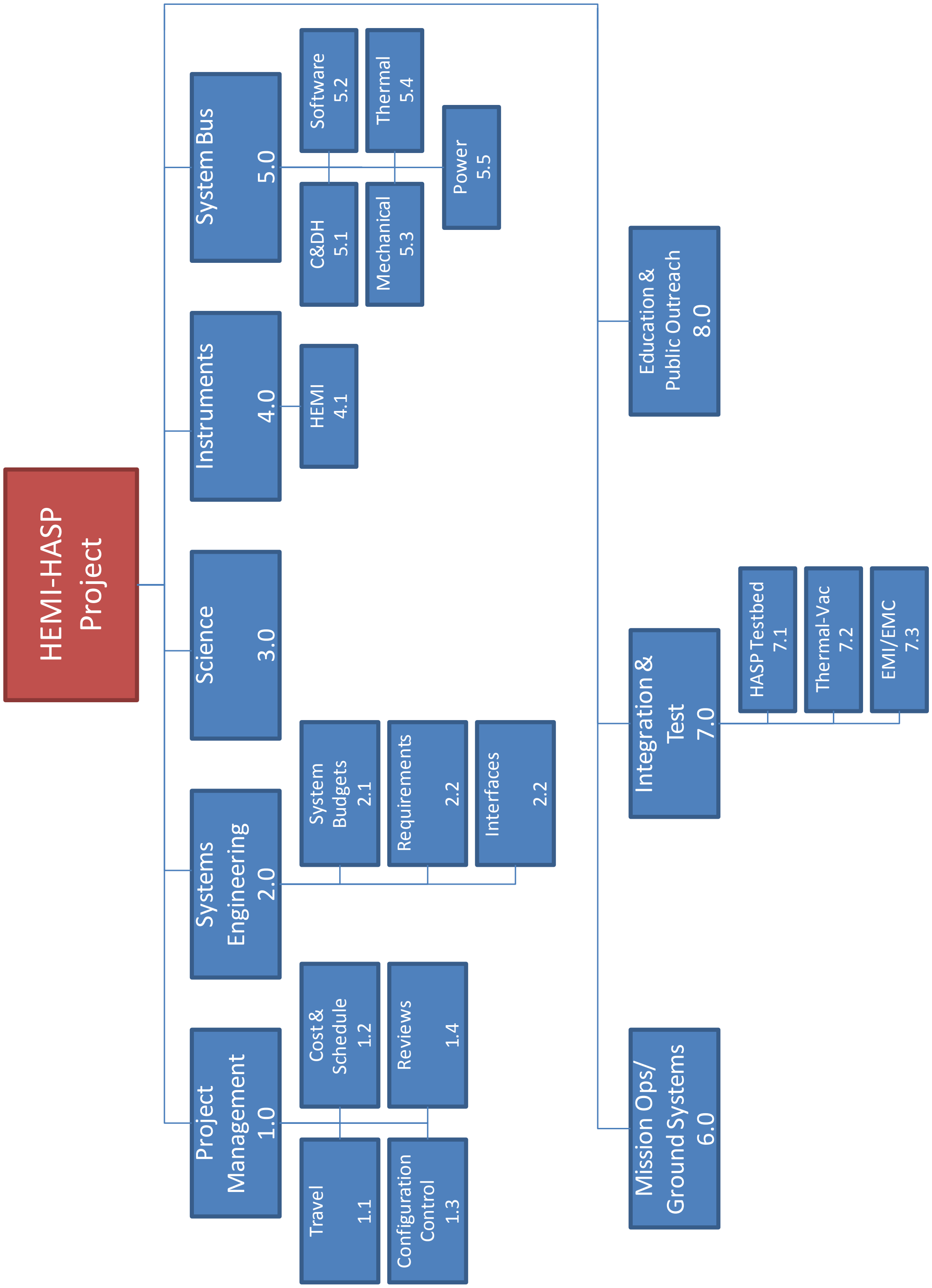


Figure 3 HEMI-HASP Preliminary WBS

HEMI-HASP Work Breakdown Structure (WBS) Dictionary

1.0 – Project Management: **Brian Schratz** *Student Project Manager*
schratz@psu.edu (814) 441-0820

Dr. Sven Bilén *Faculty Advisor, PI*
sbilen@psu.edu (814) 865-1526

The administrative planning, organizing, directing, coordinating, analyzing, controlling, and approval processes used to accomplish overall project objectives, which are not associated with specific hardware or software elements. This element includes project reviews and documentation, and non-project owned facilities. It excludes technical planning, management, and delivering specific engineering, hardware and software products.

2.0 – Systems Engineering: **James Whites**
jaw5020@psu.edu (610) 416-0313

The technical and management efforts of directing and controlling an integrated engineering effort for the project. This element includes the efforts to define the project flight instrument and ground system, conducting trade studies, the planning and control of the technical project efforts of design engineering, software engineering, integrated test planning, system requirements writing, configuration control, technical oversight, control and monitoring of the technical project, and risk management activities. Documentation products include requirements documents, interface control documents (ICDs), and master verification and validation (V&V) plan.

3.0 – Science: **Thomas Wright**
tsw5017@psu.edu (484) 643-3995

This element includes the managing, directing, and controlling of the science investigation aspects of the Project. Specific responsibilities include defining the science requirements; ensuring the integration of these requirements with the payloads, spacecraft, ground systems, and mission operations; providing the algorithms for data processing and analyses; and performing data analysis and archiving. This element excludes hardware and software for onboard science investigative instruments.

4.0 – Instrument: **Kyle Holmes**
kmh5139@psu.edu (610) 220-2595

This element includes the equipment provided for special purposes in addition to the normal equipment (i.e., GSE) integral to the flight system. This includes leading, managing, and implementing the hardware and software payloads that perform the scientific experimental and data gathering functions placed on board the flight instrument.

5.0 – System Bus: 5.1 **Brian Schratz** *Command and Data Handling*
schratz@psu.edu (814) 441-0820

5.2 **TBD** *Software*

5.3 **Jack Quindlen** *Mechanical*
jfq5000@psu.edu (610) 574-1389

5.4 **Michael Dollinger** *Thermal*
mdd5018@psu.edu (814) 512-1704

5.5 **Dave Ydoate** *Power*
djy5005@psu.edu (908) 938-2395

The system bus that serves as the platform for carrying the instrument on the balloon to achieve the mission objectives. The system bus includes the following subsystems: Command & Data Handling, Communications, Mechanical, Thermal, Wiring Harness, and Flight Software. This element also includes all design, development, production, assembly, test efforts, and associated GSE to deliver the completed system for integration with the host balloon and detector instrument. This element does not include integration and test with payloads and other project systems.

6.0 – MOS/GDS: **Alex Hackett**
alh5017@psu.edu (610) 999-4764

Mission Operations System and Ground Data System (MOS/GDS). MOS is the management of the development and implementation of personnel, procedures, documentation, and training required to conduct mission operations. This element includes tracking, commanding, receiving/processing telemetry, and analyses of system status.

GDS is the complex of equipment, hardware, software, networks, and mission-unique facilities required to conduct mission operations of the instrument. This element includes the design, development, implementation, integration, test, and the associated support equipment of the ground system, including the hardware and software needed for processing, archiving, and distributing telemetry data.

This element will coordinate with the HASP program to develop an appropriate interface as HASP is providing command and control of the instrument during flight. This element does not include integration and test with the other project systems or conducting mission operations

7.0 – Integration and Test: **Jessica Tramaglini**
jkt5010@psu.edu (412-335-9658)

This element includes the hardware, software, procedures, and SSPL-owned facilities required to perform the integration and testing of the System Bus, Detector Instrument, and mission operations.

8.0 – EPO:	**Dhurata Stroni**	*Leader, SSPL EPO Program*
	dus142@psu.edu	(814) 441-3709

Education and Public Outreach (EPO) Includes management and coordinated activities, formal education, informal education, public outreach, media support, and website development.

2.1.3 Preliminary Timeline

The schedule for this project is illustrated in Figure 4, which illustrates the estimated dates for the mission phases leading up to integration with HASP and through flight operations and post-flight analysis. Based on past projects' experience with travel costs and student schedules, likely 4–6 students will support the integration with HASP in person and flight. In addition, several students will likely support the integration and launch operations remotely from Penn State.

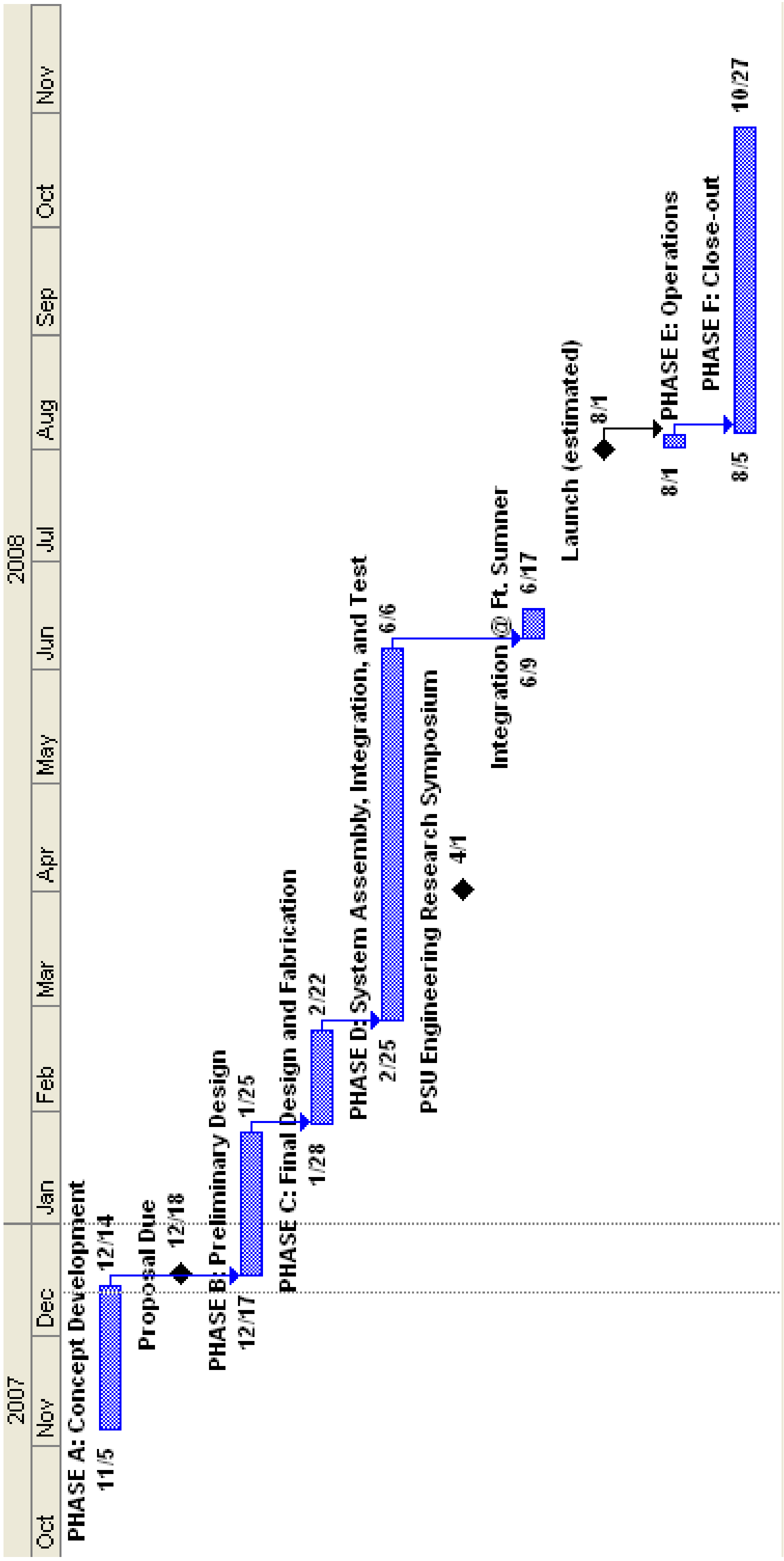


Figure 4 Project Schedule

3.0 Payload Specifications

This section describes what HASP resources the HEMI will use and how it will fit within the HASP constraints.

3.1 Mechanical

The HEMI instrument must fit a number of requirements restricting it to a mass of 3 kg, a 15×15-cm footprint, a height of 30 cm, and ability to survive the landing loads.

With the mass of the HEMI restricted, the total mass includes a 30% contingency on all current best estimates (CBEs). After calculating mass properties either by analysis or manufacturer's specifications, the total mass of the HEMI instrument, including contingency, is 2.61 kg, well under the mass budget. Table 1 provides the detailed mass budget.

Table 1 Mass budget

Item	Qty	Mass, CBE (kg)	Contingency (%)	Mass, CBE + Cont. (kg)
High Voltage DC/DC	1	0.284	30	0.369
Photomultiplier Tube	1	0.240	30	0.312
Circuit Board	2	0.125	30	0.325
Aluminum Box	1	0.740	30	0.962
Mounting Bracket	2	0.020	30	0.052
Wiring and Connectors	1	0.250	30	0.325
PVC plate	1	0.201	30	0.261
			Total HEMI Mass:	**2.61 kg**

Lastly, the HEMI instrument has a 9×9-cm footprint with two mounting brackets extending out to connect the instrument to the base plate. The box height is approximately 21 cm with 3.5 cm of scintillating crystal protruding above. The instrument itself will be contained in an aluminum box, which will be mounted to the ¼″ thick PVC plate using the two mounting brackets mentioned above. Figure 5 below is a dimensioned drawing of the footprint of the aluminum box and mounting brackets on the 15×15-cm PVC board.

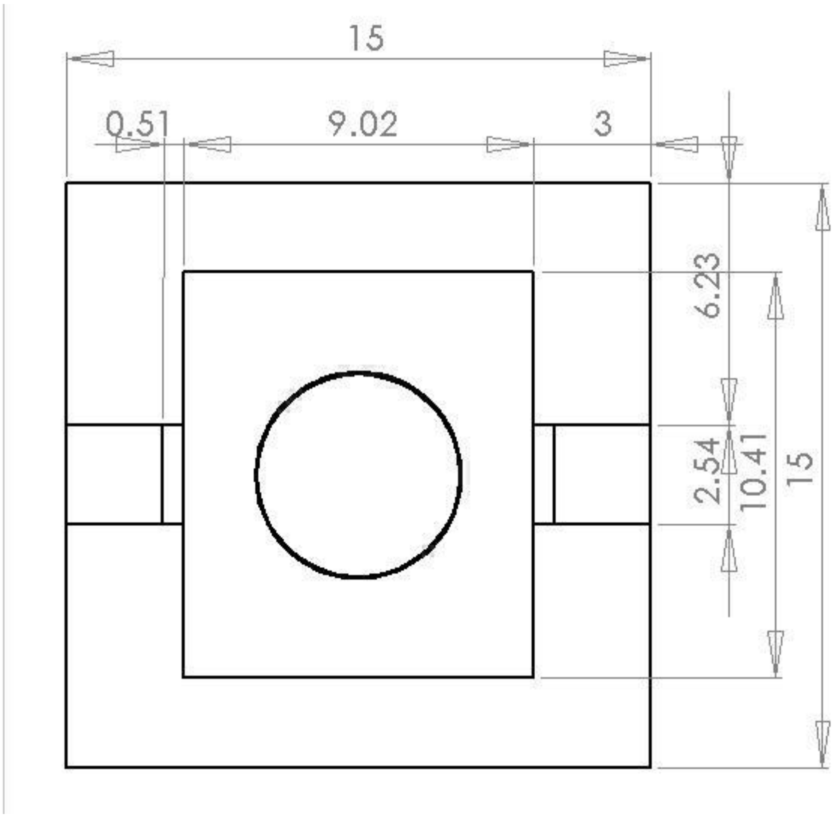


Figure 5 Mounting footprint (Note: all units in centimeters)

Figure 6 below is a dimensioned drawing of the side view of the box and mounting brackets on the ¼″ thick PVC board.

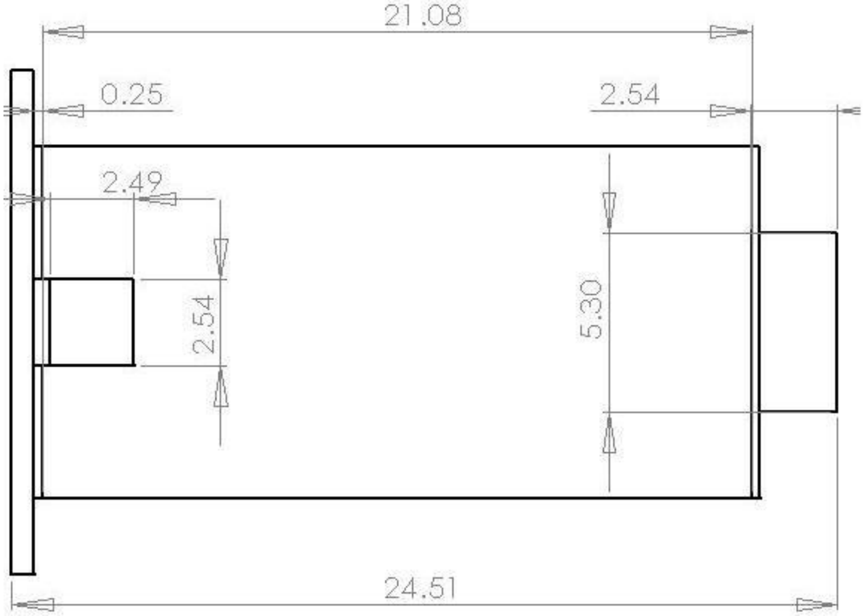


Figure 6 Height dimensions (Note: all units in centimeters)

3.2 Operational Modes

The HEMI instrument will operate in the following modes:

3.2.1 Safe Mode

Safe mode allows for the power-on of the HEMI control circuitry and housekeeping, including thermal control. This mode allows for bidirectional communication of the instrument and verification of the operational environment.

3.2.2 Standby Science Mode

In standby mode, the HEMI will constantly monitor and record the background energy levels. The HEMI will transmit 1-second averages of the ambient energy to the ground for post-flight analysis and near real-time monitoring.

When the monitored energy level exceeds a predefined threshold, the instrument will switch into Burst Mode, defined in Section 3.2.3 below.

3.2.3 Burst Science Mode

When the instrument determines that an energetic event is occurring, the instrument will record various time-averages of the energy levels spanning a range of averaging durations. The HEMI will transmit each of these averages to the ground for post-flight analysis and limited real-time monitoring. The averaging durations are described in Section 3.3.1 below.

3.3 Command and Data Handling

Currently, HEMI plans to use the serial telemetry downlink at the specified 1200-baud rate for all of its data. The current design does not need the extra analog downlink, but the team may decide to include these as redundant housekeeping sensors. In that event, they would require a slow sampling rate (<<1 Hz) and course resolution (~8 bits). The discrete commands will be used only for on/off control to the instrument power supply (discussed further in Section 3.5 below).

3.3.1 Downlink Data Format

The downlink data will be in one of two formats depending on which of the modes described in Section 3.2 the instrument is in. Both data formats begin with the standard header as suggested in the Student Payload Interface Manual and reproduced in Table 2 below. At no time will the data rate exceed the capacity of a 1200-baud channel. During the high data rate burst mode, data will be time-stamped and stored on board to be transmitted down during the low data rate stand-by mode. The volume of data will be designed based on our best expectations of in-flight events to not exceed the channel capacity of HASP including contingency. In the event that more data is gathered than can be transmitted, we will accept lost data.

Table 2 Downlink Header Data

Byte(s)	Description
1	Record Type Indicator
2–5	Timestamp (seconds since January 1, 1970)
6–9	Timestamp (nanoseconds past the last second)
10–11	Record size
12	Least significant 8 bits of the record checksum
13–n	Data Bytes as needed

In addition to the standard header, the second part of each data packet will vary depending on what mode the instrument is in, either safe, standby, or burst mode. Table 3 below shows the format for both safe and standby data. After the 12-byte header, the data contains 1-second measurements of the background radiation, echoes of the most recent uplink command received, general purpose flags for system monitoring, and various temperature, voltage, and current housekeeping sensors. If the instrument is in safe mode, the Background Energy bytes will be zero.

Table 3 Stand-by Data Downlink Format

Byte(s)	Name	Description
1–12	Header	Defined in Table 2
13	BgLSB	Background Energy LSB
14	BgMSB	Background Energy MSB
15	CmdLSB	Command Acknowledge LSB
16	CmdMSB	Command Acknowledge MSB
17	GPFB	General Purpose Flag Bits
18	Temp1	Temperature Sensor 1
19	Temp2	Temperature Sensor 2
20	Temp3	Temperature Sensor 3
21	Temp4	Temperature Sensor 4
22	V1	Voltage Monitor 1
23	V2	Voltage Monitor 2
24	V3	Voltage Monitor 3
25	V4	Voltage Monitor 4
26	I1	Current Monitor 1
27	I2	Current Monitor 2

The burst-mode data format is still to be determined pending studies to predict what energetic events the instrument will experience and what data should be its focus. Currently, HEMI will record time-averages of the measured energies, producing value of counts (number of particles) per specified energy range. Various time-averaged periods will provide information of different types of events. The final data package will be an optimization of science return given the constraints of the mission (specifically a 1200-baud downlink).

3.3.2 Uplink Commands and Data Format

HEMI is designed to require no uplink commands from the ground during flight. However, as this is a prototype, this instrument may allow for limited commands to force the instrument into safe, standby, or burst modes as described in the following sections. In the event that these commands are required, they should occur infrequently (every few hours) and do not have a required uplink data rate—HEMI can adjust to the resources the HASP system has to offer. The planned uplink format is described in Table 4 below.

Table 4 Command Uplink Format

Byte	Hex Value	Description
1	0x01	Start of Heading (SOH)
2	0x02	Start of Text (STX)
3	CmdLSB	Command Uplink LSB (checksum and payload ID)
4	CmdMSB	Command Uplink MSB
5	0x03	End of Text (ETX)
6	0x0D	Carriage Return (CR)
7	0x0A	Line Feed (LF)

3.4 Configuration

The HEMI instrument will be completely contained within the allocation set forward in the Call for Proposals. The active part of the detector will be pointed vertically up and likely slightly away from the HASP system. The effective field of view is approximately 2π steradians. The field of view should be kept clear, although minor obstructions should not significantly affect the validity of the science results. Based on illustrations of previous integrated HASP instruments on the program website, any small payload location will be suitable for HEMI. Illustrations of the full instrument and its interface to HASP can be found in the Mechanical section above or the Preliminary Drawings section below.

3.5 Power

The HEMI instrument will use a single DC/DC converter to convert the nominal 30 V supplied by HASP to a regulated 5-V supply for instrument use. A mechanical relay will be used to turn the HEMI on and off through the discrete commands provided by the HASP system. Table 5 below shows the estimated power budget detailing the consumption of each assembly in the HEMI system.

Table 5 Power Budget

Assembly	V_{in} (V)	I_{in} (mA) CBE	Contingency (%)	Power (mW)	Mode
Power Distribution	7.5–36	72 (@ 30V)	30%	63	Safe, Standby, Burst
HV DC/DC	5	140	30	910	Standby, Burst
Control Unit	5	120	30	780	Safe, Standby, Burst
Sensor Electronics	5	50	30	325	Standby, Burst
Heaters	5	variable	0	0–3000	As needed; above calculations assume no heater power

**Includes power for all assemblies; assumes worst-case 71% efficiency, 5 V and 310-mA output, 30-V input*

At a nominal current draw of 72 mA including contingency from a 30-V supply, HEMI is only requiring approximately 14% of its allocated power. As a safety precaution, the power distribution design will include a 0.5-A slow-blow fuse to prevent exceeding the HASP allocation and to prevent damage to the DC/DC converter during testing and integration.

3.6 Thermal

The HEMI thermal system assumes that all components are able to operate within the industrial temperature range of −40 to +85 °C except for specific temperature-sensitive components specified in Table 6 below.

Table 6 Temperature-sensitive components

Component	T_{min} (°C)	T_{max} (°C)	$T_{storage}$
7805SR DC/DC	−40	+70	−40 to +85
EMCO 10077 HV DC/DC	−10	+60	−20 to +90

Ambient temperatures are assumed to correspond to the temperature profiles specified in the HASP Call for Proposals, reproduced as Figure 7 and Figure 8 below.

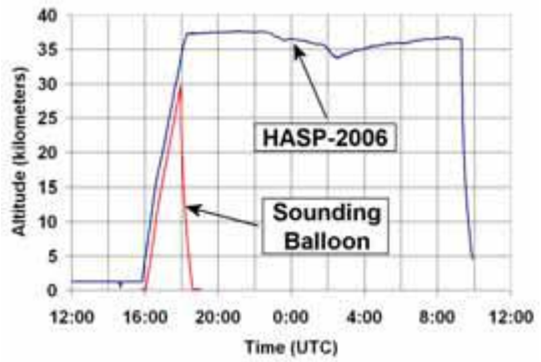


Figure 7 The HASP flight profile

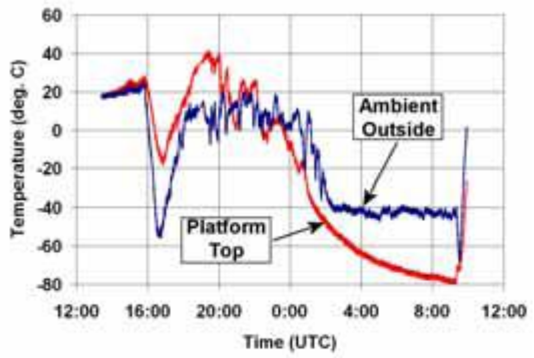


Figure 8 Typical temperatures during flight.

In order to ensure that all components operate within the specified range of temperatures, the thermal team is developing a mathematical model to simulate the system within anticipated environmental conditions. The data from this model will then be compared to a physical model to be tested as described in Section 3.7. The results will be used to determine the use of passive controls (e.g., coating of the structure) to regulate heat flow and maintain the desired temperature range. If extra heating is deemed necessary, patch heaters will be used for necessary components.

3.7 Testing and Integration Procedures

3.7.1 Testing at Penn State

The HEMI will require testing and environmental procedures for both science calibration and engineering survival. This project will assume environmental extremes from temperature data provided by the HASP Call for Proposals document, illustrated in Figure 8 above.

The detector will have to be calibrated across the expected temperature ranges in the presence of an energetic particle source. This calibration will be performed only at Penn State in a controlled facility. The Penn State Department of Astronomy and Astrophysics has extensive experience with this procedure.

For engineering analyses and test, the following procedures will be performed <u>at Penn State</u>:

- <u>Thermal Analysis</u>: To determine if active or passive thermal control is required in order to maintain operating temperatures for all instrument components

  The mathematical model described above in Section 3.6 will be used to determine the necessary control systems to maintain desired temperatures. Based on the results, various thermal controls will be chosen to maintain experiment components within the desired temperatures.

- <u>Thermal–Vacuum Test</u>: To validate the thermal analysis in a relevant environment

  A physical model of the experiment will be fabricated to test within a thermal–vacuum chamber at Penn State University. The chamber will simulate calculated heat sources, and sensors placed around the model will be used to create a temperature profile around the model that can be compared with data from the mathematical model.

- <u>Electromagnetic Compatibility Test</u>:

  To ensure that the HEMI will not produce intolerable electromagnetic noise into the HASP system

- <u>Vibration/Structural Analysis</u>:

  To ensure that the HEMI instrument is mechanically robust to survive all phases of the HASP flight (vibration test is not warranted given the funding levels and requirements of the project)

3.7.2 HASP Testing and Integration

Significant preliminary testing will be done at Penn State prior to integration. Therefore, the instrument-level validation will already be complete by integration at Ft. Sumner. The procedures remaining for Ft. Sumner will be a validation of successful interfaces between HEMI and HASP. Specifically, we will validate:

- the command telemetry interface to ensure we can both transmit and receive data
- the mechanical interface to ensure a reliable mounting
- power interface to ensure electromagnetic compatibility
- the discrete event interface to ensure that we can turn our instrument on and off remotely

3.8 Flight Operations

The HEMI instrument will operate autonomously during flight with minimal or no uplink commands from the ground station during flight.

Under normal conditions, the HEMI will operate in standby mode measuring the background energy levels and monitoring the data for high-energy events. When detected events exceed pre-set thresholds, the instrument will autonomously switch into burst-mode during which high speed data collection will occur. Once energy levels fall below the preset threshold levels, the HEMI will return to standby mode until the next event.

In the event that flight data indicates a fault event, the instrument will enter into safe mode where all science operations cease and the only available HEMI functions are thermal management (if required) and command receiving for enabling or disabling select HEMI components. Only a command from the ground can place the HEMI back into normal standby mode.

3.9 Additional Resources

As planned, the HEMI will not require additional resources beyond those allocated in the HASP Call for Proposals and the HASP Student Payload Interface Manual. Increased data volume will always enhance the science return, but is not required.

4.0 Preliminary Drawings

Below are preliminary drawings of the HEMI instrument mounted to the HASP base-plate. Section 3.4 above provides specific descriptions of the instrument configuration with HASP.

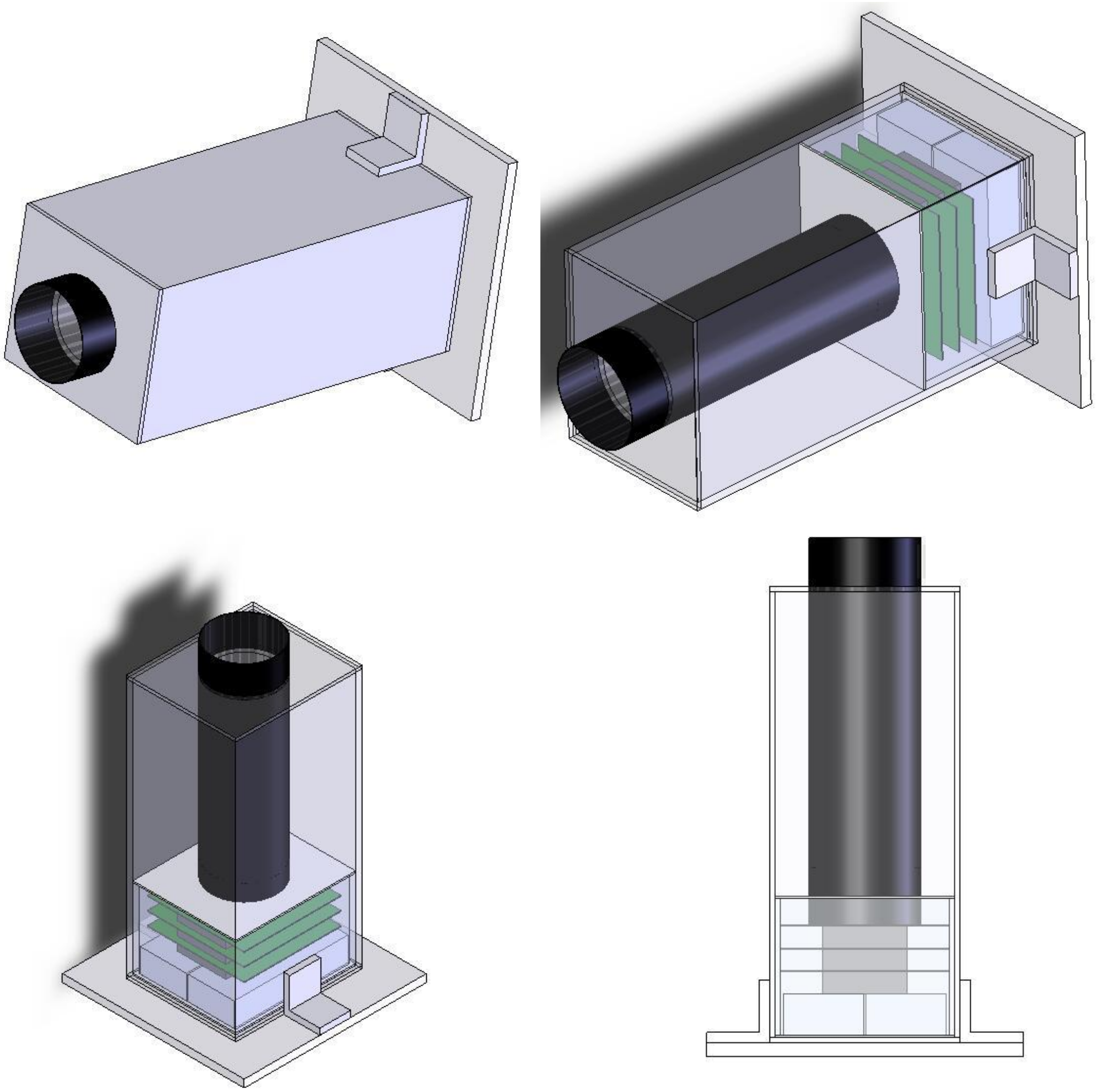


Figure 9 Illustrations of payload and component orientation

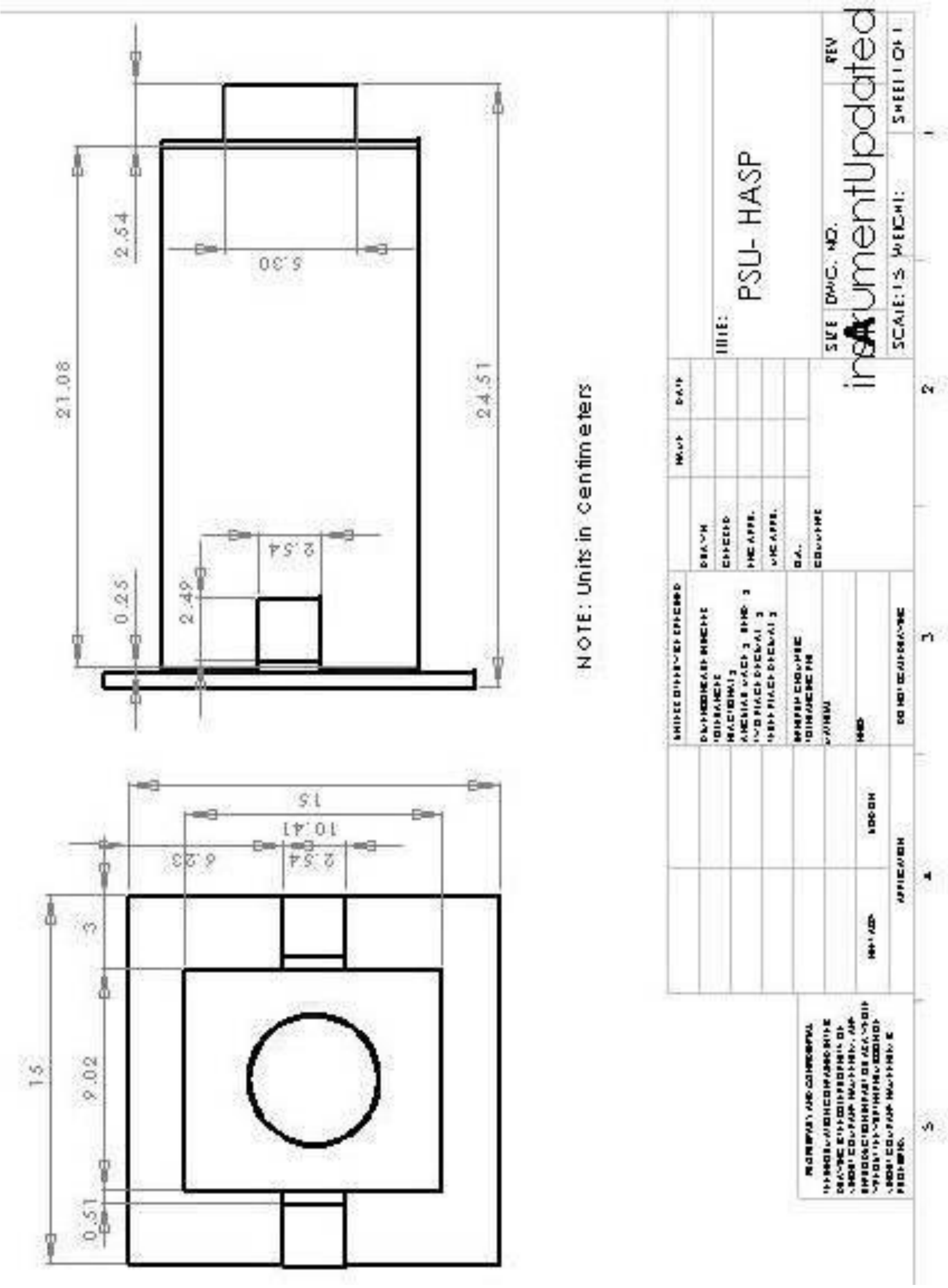


Figure 10 Dimensioned 2-view drawings of HEMI Instrument