HASP Student Payload Application for 2012

Cover Page

Payload Title: ***Student Payload First Flight***

Payload Class: (check one)	Institution:	Submit Date:
☐ Small x 2 ☐ Large	Boston University/Georgia Institute of Technology/New Mexico Tech	16-Dec-2011

Project Abstract

The BUSAT program, in conjunction with development teams from Georgia Institute of Technology (GA Tech) and New Mexico Institute for Mining and Technology (NMT) intends to fly the Satellite Platform Integrated First Flight (SPIFF) aggregate instrument platform to gather baseline data on the fair-weather electric field, monitor the high-altitude magnetic field, and record changes in the structural integrity of a high-altitude scientific instrument. SPIFF will also advance the technology readiness of three student-built instruments as well as a central support module, enabling future development and use in the scientific spaceflight community. Experiments include an Electric Field Mill (EFM), a piezoelectric structural health monitoring sensor array (SHM), and a magnetometer (MAG). The central support module (the "Hub") will interface with peripheral payloads using Space Plug-and-Play (SPA-1) software developed by AFRL. Each team will include a project manager and engineer responsible for overall development. Interface between BUSAT, NMT and GA Tech teams will be the responsibility of each team's project manager. Interfaces require ***one small payload position*** with minimal mounting plate modification, ***one analog downlink*** via EDAC 516 connector and ***one RS 232 data line*** via DB9 connector.

Team Name:	Team or Project Website:
Student Payload First Flight	N/A

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1. INTRODUCTION

Student Payload First Flight (SPIFF) Payload Description: Scientific Objectives, High Level Review of Payload Systems, Statement of Principle of Operation of Experiments
The Student Payload Integrated First Flight (SPIFF) mission seeks to unify diverse scientific instrumentation aboard a high altitude balloon flight for the dual purpose of recording pertinent high-altitude scientific data for university research, and for furthering the impact of current plug and play technologies in scientific remote sensing for extreme environments. The SPIFF mission has four components in ***a single payload module:*** *The Hub, a Magnetometer, the EFM and the SHM.*

2. PROJECT DESCRIPTION

2.1 The Hub

Principal Investigator: Professor Theodore Fritz
Project Manager: Nate Darling
Project Engineer: Christopher Hoffman

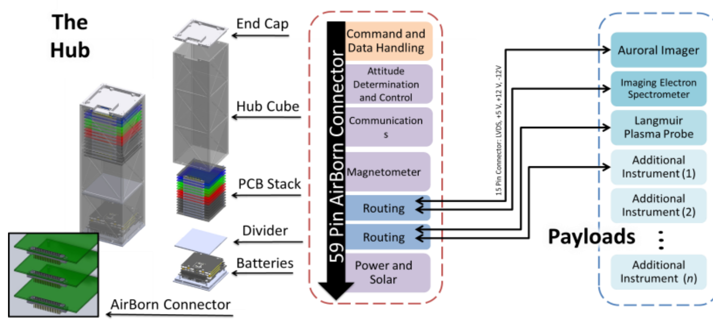


FIGURE (1): The BUSAT Hub showing peripheral payload capabilities

The Boston University Student satellite for Applications and Training (BUSAT) program is a grassroots spaceflight hardware development program for students of engineering, physics, astronomy, and computer science. While professional and academic mentorship is essential to the program, ***BUSAT is entirely staffed and directed by students of Boston University and Boston University Academy***. Cooperative efforts by students at Georgia Institute of Technology and New Mexico Institute of Mining and Technology also contribute considerably to the BUSAT effort. The SPIFF mission will serve as a milestone in hardware development and qualification of BUSAT's space weather satellite development project by advancing the technology readiness of its fundamental components. In addition to the scientific mission, the BUSAT and SPIFF missions address the high cost, long development schedule, and challenging interface environment that characterize current space hardware development projects, thereby impeding collaboration efforts and access to space and other hazardous regimes as scientific sampling environments. This is accomplished by compartmentalizing the satellite's diverse instrumentation into 10cm cubic modules and reducing every interface (mechanical, electrical

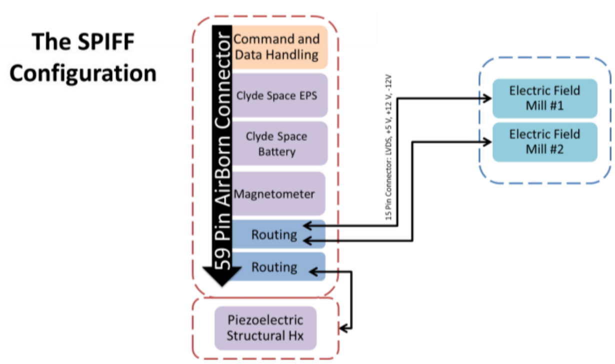


FIGURE (2): The BUSAT Hub configured for the SPIFF / HASP mission

and software) to a common standard, effectively allowing a local or remote development team to deliver an instrument that can be integrated and ready for testing in minutes and hours, rather than days or months.

2.2 "The Hub" and SPIFF

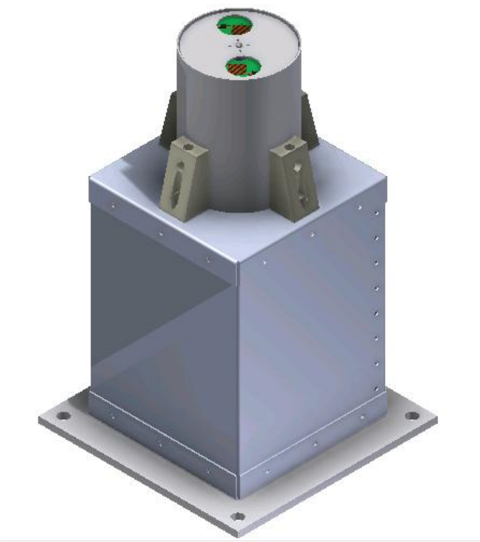


Figure 3: The integrated SPIFF payload shown here mounted on the small HASP payload interface plate

The mechanical, electrical and software core of the BUSAT satellite is referred to as "the Hub" and comprises all of the subsystems essential to the functions of a scientific satellite mission, including a central single-board computer, electric power supply and batteries, radio, attitude determination and control, a magnetometer, and several routing boards for interface with peripheral scientific subsystems. **Succinctly, the Hub has the ability to function independently as a single 3-unit CubeSat, but can also be easily expanded to accommodate other instruments.** Using Space Plug-and-Play Architecture (SPA-1) protocols (developed for rapid space response by AFRL) to standardize the interface between the Hub and those other peripherals, we aim drastically simplify the effort required to integrate large scientific instrumentation systems. While SPA-1 was designed primarily for space-directed development efforts, this mission, (which integrates a diverse set of instruments) will demonstrate that we are able to expand the BUSAT standard to terrestrial applications, including volcanic ash monitoring. The Hub will function as the central node of the SPIFF mission, interfacing with the EFM and the SHM via SPA-1.

The SPIFF hub will differ from the BUSAT hub 3-U form factor in order to fit within a single small payload seat. Additionally, this design choice allows a far simpler fabricated housing made up of 1/16 inch 5052 aluminum bent and fastened into a cubic structure see (Figure 3).

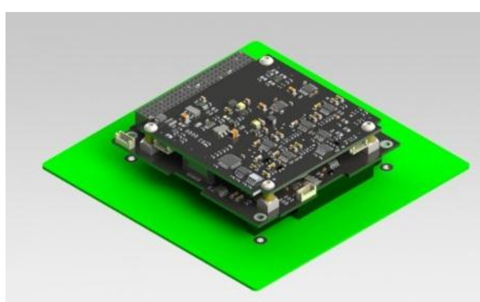


Figure 4: The SPIFF 5.4" PCB shown mated with the FlexUEPS from Clyde Space.

While BUSAT's form factor accommodates the PC/104 embedded systems form factor specification as well as the (nominal) CubeSat form factor, the SPIFF mission will implement a custom 5.4" x 5.4" stackable printed circuit board. This will not only allow the SPIFF mission to fit within one small payload seat, it also optimizes debugging and test point features while remaining within the HASP footprint.

2.3 Magnetometer

Magnetic field measurements make up a large part of the data collected during studies of natural phenomena in space physics , terrestrial geology and many other diverse fields. Space-borne magnetometers are limited in their ability to resolve natural magnetic fields by the time varying magnetic fields induced locally as a satellite mission platform shifts between operational modes. The SPIFF mission will implement an approach to magnetometer measurements appropriate for pico- and nano-satellite missions that are not able to use a deployment boom to eliminate the effect of artificial fields. Using dual HMR-2003 fluxgate magnetometers will allow averaging and comparison between the orthogonal components of each sensor to separate local magnetic effects from variations in the Earth's field. A preliminary calibration of the SPIFF payload will be performed by rotating the entire payload about three axes in each of its operational modes. While rotating only the payload structure (with magnetometer) in a relatively magnetically "well-behaved" environment, the resulting data will fall on a spherical surface because:

$$\left|\vec{B}\right|^2 = B_x^2 + B_y^2 + B_z^2$$

Where $\vec{B}$ is the ambient magnetic field vector. While rotating the payload with subsystems drawing current from the EPS, a distorted ellipsoid will be formed as a result of local magnetic effects. The distorted ellipsoid will be characterized by a set of linear coefficients corresponding to misalignment errors, offset values and scale factors inherent to the system. This distortion will allow offsets to be extracted based on the modes of the SPIFF payload, the orientation of the payload with respect to the field, and misalignment of the magnetometer axes. This calibration will be performed prior to integration with the HASP vehicle.

Reference:

Clavier, O. , Beach,T, Davis, B. Chepko, A., "Enabling low-cost, high accuracy magnetic field measurements on Small Sats for space weather missions," Proceedings of the 25th Annual AIAA/USU Conference on Small Satellites, Logan, UT, 2011.

2.4 Miniature Electric Field Mill (EFM) for volcanic plume research

Principal Investigator: Josef Dufek
Project Manager/Project Engineer: Joshua Mendez
Co-Investigator: John Trostel

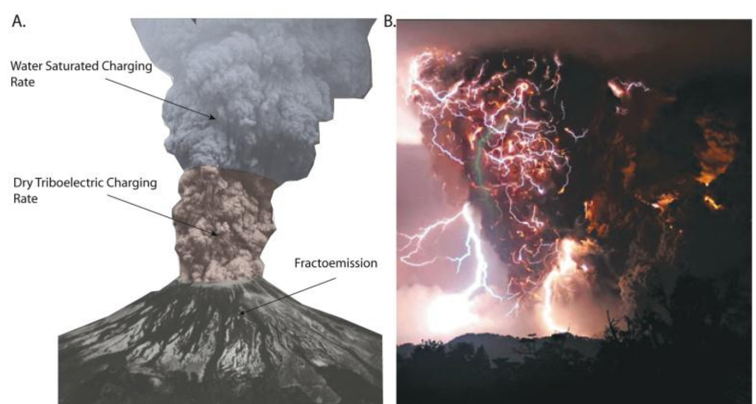


FIGURE (5): Regions of plume electrification B. Strong electrical fields result in the dielectric breakdown of air. Both the static field and lightning can be detected with relatively simple technology

The spectacular electrostatic discharges that occur during eruptions testify to the huge potentials that are generated within plumes as ash becomes charged. Since the production and movement of charged particles are

closely coupled to the updrafts in an eruptive column, the electromagnetic signals they produce must reflect the physics of the plume itself. In other words, we hypothesize that the proximal plume dynamics can be inferred from measured electric fields and lightning observations.
The need to characterize plume dynamics in the near-field was clearly demonstrated when key airways were paralyzed by the eruption of Eyjafjallajökull in 2010. As stated in the International Civil Aviation Working Paper (July, 2011), two important sources of uncertainty in current models are the proximal dynamics of particle sorting and aggregation, both of which determine how long these remain in a plume. While it is nearly impossible to directly probe the dynamics in a plume, the resulting electrical signals can be measured with relatively simple technologies like field mills (EFM).

Interconnected with Space-Plug-and-Play (SPA-1), we hope to expand this architecture to earth-based systems in extreme environments. Our goal is to realize a self-configuring wireless network of EFMs which can be integrated and deployed around a cone within days of the start of activity. Using the technique described by Renno *et al* [2007], our EFM can measure both the ambient field and the charge on precipitating ash particles. Once deployed, this network will allow us to closely monitor the evolution of the overhead E-field as ash becomes charged and is advected above the volcano. By flying one EFM on HASP, we will be able to test the operation of the instrument as well as our novel implementation of the SPA-1 protocols. Furthermore, the relative simplicity of field mills presents a great introduction to practical electronics and how to use technology to network the physical world. Over the course of the next year we will involve students at the high school level in constructing and testing the field mills.

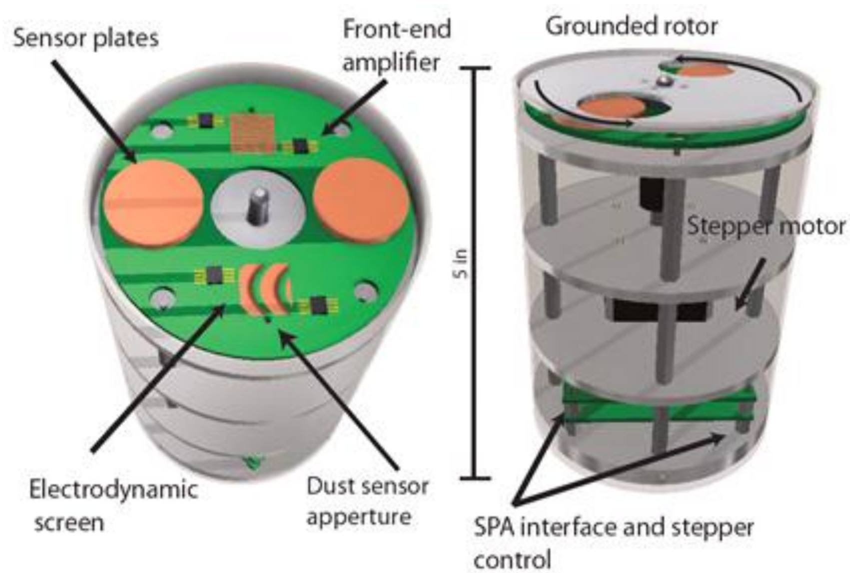


FIGURE (6): The EFM Instrument showing basic PCB and mechanical design

2.5 Structural Health Monitoring: SHM

Principal Investigator: Professor Anders Jorgensen
Project Manager: Jordan Klepper
Project Engineer: Mathew Landavazo

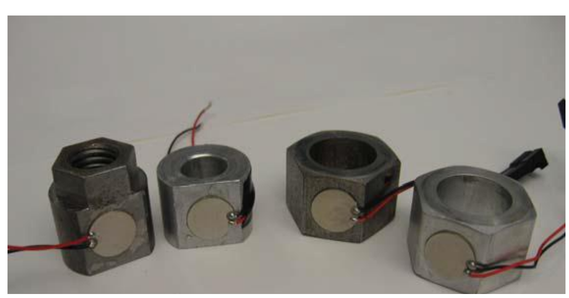


FIGURE (7): Piezoelectric wafer sensor / actuators

The SHM instrument utilizes multiple piezoelectric actuator / sensors to provide onboard structural health monitoring for platforms operating in extreme environments such as low-Earth orbit, near space, and even during delivery and integration stages. In this way the structural integrity of expensive and often one-of-a-kind instrumentation can be monitored to mitigate risk of failure during critical mission phases. Piezoelectric actuator / sensor "wafers" (PZTs) are placed strategically on jointed elements such as bolts (see FIGURE (7)) and driven by an alternating electric field. The resulting mechanical vibration excites the structural element, which in turn transfers back to the PZT, producing an electrical response. Electrical impedance can then be correlated to structural impedance, allowing a baseline structural health response to be measured. Any future change in electrical impedance indicates a change in mechanical impedance and therefore also a change in the structural element such as loosening or plastic deformation. Also included with the EFM is an auxiliary sensor placed in a "free-boundary" condition, in which the sensor is held with a minimal amount of force so that little or no damping is induced. This will further characterize the PZT sensor concept in the near-space environment.

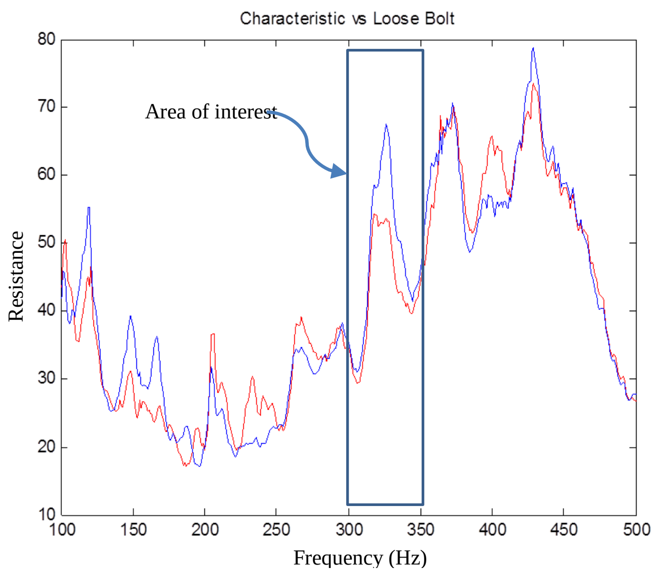


FIGURE (8): Characteristic vibration response (blue) with loose bolt response (red)

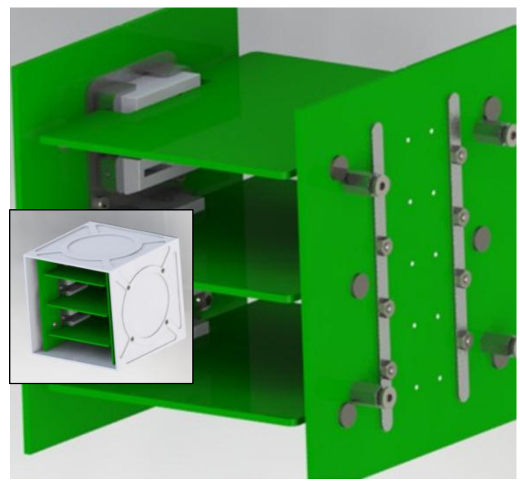


FIGURE (9): SHM printed circuit board configuration showing detail of cube housing and slot connector design.

2.6 Thermal Control Plan

While the thermal characteristics of the SPIFF payload are not yet known, both hot and cold cases will be identified by thermal modeling early in the design process and appropriate action will be taken to ensure a successful flight. All instruments will be contained within cube elements that conform to the BUSAT standard form factor (although 6063-T6 aluminum will be substituted with lighter prototyping structural materials). This will not afford much insulation or

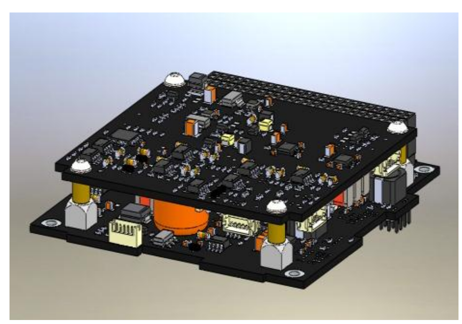


FIGURE (10): Clyde Space FlexUEPS Electronic Power Supply (EPS)

thermal control. Passive thermal control in the cold case can be provided with a light foam thermal barrier. Additionally, the Clyde Space FleXUEPS includes an internal heatin system that activates at 0˚C. Although the need for active heating is not anticipated, additional thermal resistors could be implemented if their use is warranted by results of thermal / vacuum chamber testing at Boston University. Passive control for the hot case will be provided in the form of copper braid and plate integrated within the instrument cases and routed externally to the launch vehicle structure. Additional protection from overheating can be provided by an appropriate choice of exterior surface coating, whether paint or reflective film.

3. TEAM STRUCTURE AND MANAGEMENT

3.1 Boston University

Theodore Fritz: Principle Investigator (BUSAT)
Theodore Fritz is a Professor in the Astronomy Department at Boston University and member of the BU Center for Space Physics. Dr. Fritz brings rings to the project 40 years of experience in spacecraft and instrument design and will oversee the HUB development effort at BU.

Nathan Darling: Project Manager (SPIFF and BUSAT)
Nathan Darling is a graduate mechanical engineering student studying the vibration and environmental testing of small satellite structures. He has several years of team leadership through outdoor education and has applied much of this experience to the BUSAT effort since beginning work on the project in January, 2011. Nathan will oversee structural design, logistical issues, and act both as the SPIFF Project Manager and as point of contact and coordinator for BU, GA Tech, and NMT.

Christopher Hoffman: Project Engineer (BUSAT) Christopher Hoffman is a junior electrical engineer at Boston University. As BUSAT's project manager and power systems engineer, Chris designed BUSAT's modular solar panels and electronic power system. Chris will oversee the SPIFF power system development and other electrical aspects of the system.

3.2 Georgia Institute of Technology

Josef Dufek: Principal Investigator (Georgia Institute of Technology)
Josef Dufek is an Assistant Professor of volcanology and multiphase fluid dynamics in the

School of Earth and Atmospheric Science at Georgia Tech. Joe Dufek is well known in the geophysics community for his transformative science and innovative computational methods. Dr. Dufek will oversee the development and deployment of the field mill sensor network in the context of volcanic processes.

Joshua Mendez: Project Manager and Project Engineer (Georgia Institute of Technology)
Josh Mendez is a first year graduate student at Georgia Tech. He worked on both BUSAT I and II as an undergraduate. With experience in embedded systems and analog circuit design, he will lead the construction of the field mill, in addition to a semester-long course on the design of sensor systems for hazardous environments during the spring of 2012. Josh will act as the SPIFF Project Engineer, overseeing the integration of the constituent subsystems.

John Trostel: Co-Investigator (Georgia Tech Research Institute)
John Trostel is the director of the Severe Storms Research Center (SSRC) at the Georgia Tech Research Institute. Working with students at the college and high school levels, he is engaged in developing novel ways to forecast storms, as well as instrumentation.

3.3 New Mexico Institute for Mining and Technology

Anders Jorgenson: Principal Investigator
Anders Jorgensen's research interests span a wide range of topics from astronomical instrumentation and techniques through space plasma physics and space weather to sensor networks and machine learning algorithms. Dr. Jorgensen received his PhD in Astronomy from Boston University, and is the Principal Investigator for the SHM instrument.

Jordan Klepper: Project Manager
Jordan Klepper is a senior mechanical engineer at New Mexico Tech. He has recently worked on the development of a plug-and-play Langmuir probe for AFRL. Jordan will oversee the structural design of the SHM system, sensor placement, and structure characterization.

Matthew Landavazo: Project Engineer
Matthew Landavazo is a senior electrical engineering student at New Mexico Tech and will oversee electrical development of the SHM. Matt also contributes to the Langmuir Plasma Probe for the BUSAT project.

3.4 SPIFF Development, Coordination, and Development Plan

Beyond the scientific and technical objectives that have driven this project, we hope that the SPIFF will set a successful precedent for many more fruitful collaborations between Boston University, Georgia Tech and New Mexico Tech, as well as Louisiana State University and the HASP program. However, the facts that the participating institutions are (quite literally) located at different corners of the nation and that the participating students have different backgrounds have the potential to introduce confusion during the development and integration of the SPIFF payload.

Coordination and oversight of the integration process will be carried out by Nathan Darling (SPIFF PM) and Joshua Mendez (GT PM). Integration will be accomplished in stages, and we propose a three-pronged approach described in the sections below:

3.5 Weekly Teleconferences

Throughout the spring 2011 semester, student project managers and engineers from the three institutions will meet online once a week (currently scheduled for Tuesdays at 14:00) to discuss developments regarding each institution's subsystem.

3.6 Lab Notebooks and Online Repository Using Confluence

While much information pertaining to subsystem design can be communicated, discussed and analyzed during the weekly telecons, we require that each participating member of the SPIFF project keep **written AND digital** records of his or her progress. These practices will decrease the potential for misunderstandings, while will increase the level of accountability.

3.7 Lab Notebooks

We request that detailed written records be kept in individual lab notebooks. Given that digital media is more volatile, we adhere to a strict ***"IF YOU DID NOT WRITE IT DOWN ON PAPER, YOU NEVER DID IT!"*** policy. Each Project Manager has the responsibility of periodically checking his team's written records for consistency and quality.

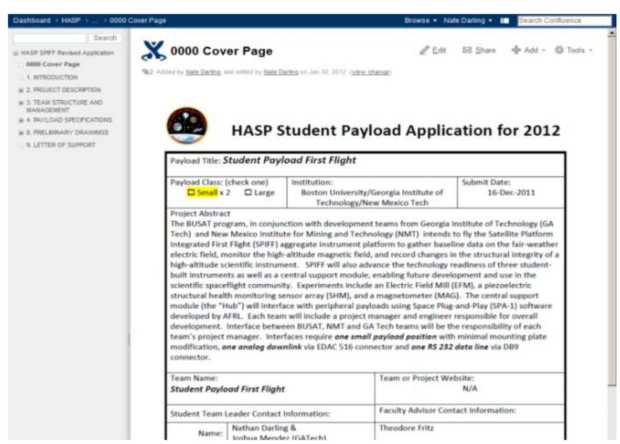


Figure 11: The SPIFF revised application in editable wiki format on the BU / GaTech / NMT Confluence document management site.

3.8 Confluence Interface Control Document (CICD)

In addition to individual lab notebooks, each SPIFF member will have access to a group *Confluence* account to store and **share subsystem interface information,** commonly known as **Interface Control Documentation.** *Confluence*, an enterprise wiki software marketed by Atlassian, allows online teams, such as SPIFF, to share organize data into file structures be easily exported to PDF and Microsoft Office formats. Succinctly, *Confluence* allows us to create a project Intranet. A screenshot of our current *Confluence* account is presented in Figure 11.

The repository will be divided into three main sections:

1) two **Subsystem Level ICDs** and
2) one **Global Project Integration Manual (GPIM)**.

The ICDs will contain all information referring to the mechanical, electrical, and software interfaces between the EFM and the SHM with the HUB, i.e. all information regarding the internal integration and operations.

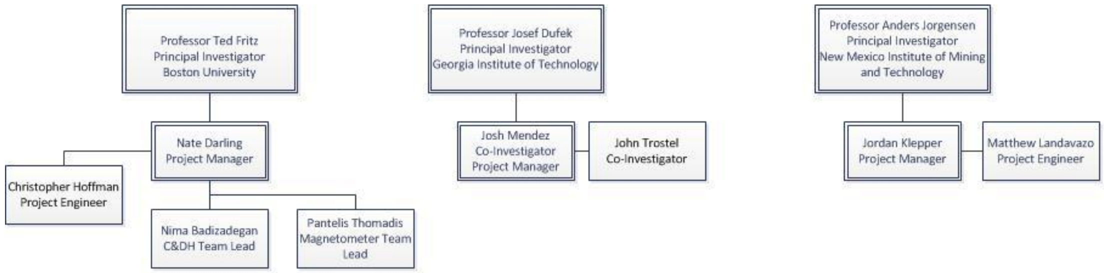
The GPIM will detail the integration procedures needed to mount the full SPIFF system to the HASP structure, as well as in flight operation guidelines.

Confluence also allows automatic document change control.

3.9 Physical Integration

During the six-month development period between February 1st and August 1st, members of all three teams will meet twice at Boston University to perform both protoflight and flight integration testing. The first meeting, in April, will coincide with the BUSAT Critical Design Review. The second meeting will occur in late July after instrument delivery to BU. Since funding for travel by GaTech and NMT team members has only partially been allocated, a contingency plan will be to conduct these meetings via videoconference.

3.10 Organizational Chart and Contact Information



SPIFF / BUSAT Point of Contact:
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EFM / GA Tech Point of Contact:
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Email: ub313@gatech.edu

Address:
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School of Earth and Atmospheric Science
Room 2112
Atlanta, GA 30332

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Email: jklepper@nmt.edu

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NMIMT
Mechanical Engineering Department
801 Leroy Place
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Figure 12

3.11 Work Breakdown Structure

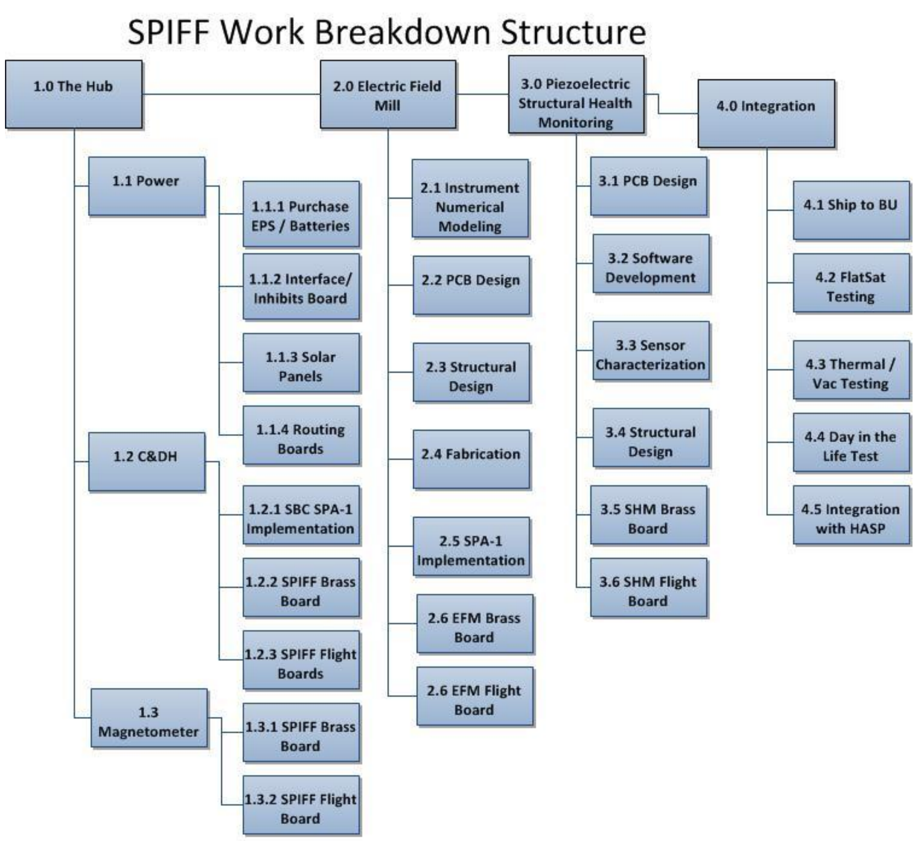

Figure 13

3.12 Scheduling

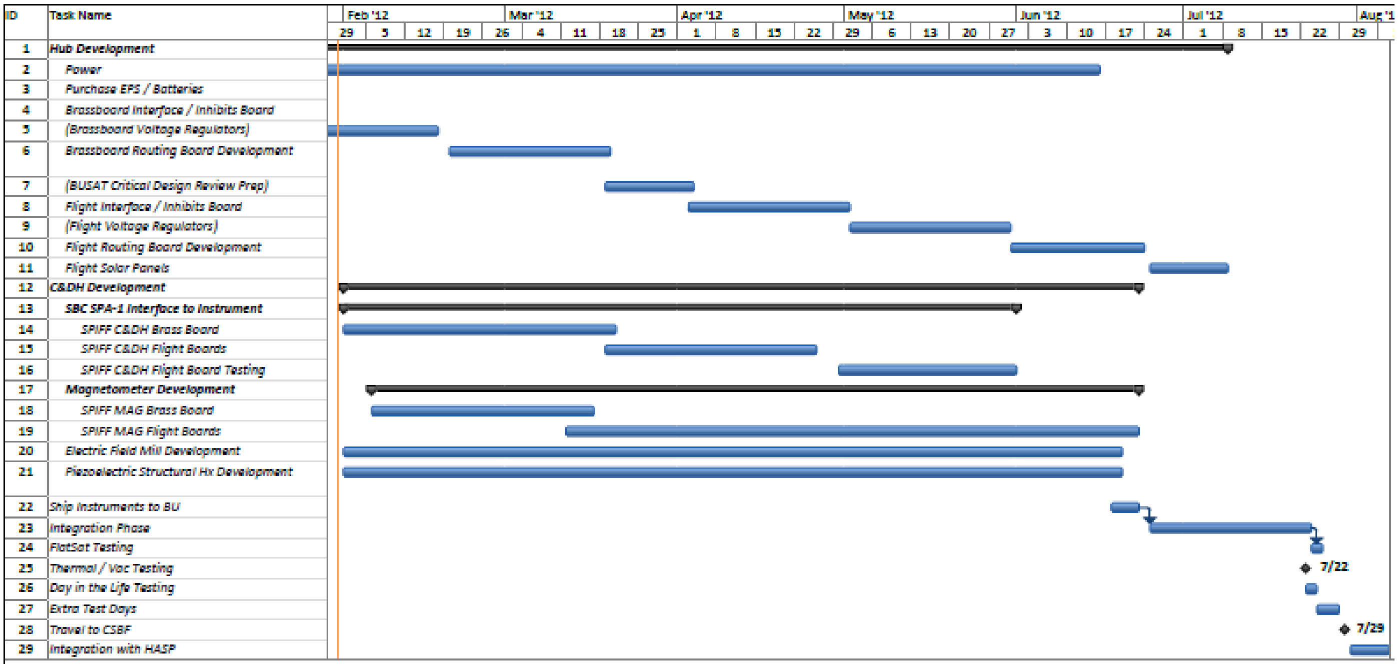

Figure 14: Revised Gantt chart showing extended integration phase

3.13 Number of Personnel Needed for Integration

The SPIFF instrumentation will require four personnel on site for integration. The BUSAT project manager will coordinate personnel, oversee transportation and logistics, and manage testing and the SPIFF team during integration. The BUSAT project engineer will oversee technical details of testing and integration. One representative from each of the collaborating universities will also be present during this phase to ensure appropriate steps are taken in mounting and integrating each instrument to the HASP vehicle via the SPIFF Hub.

4. PAYLOAD SPECIFICATIONS

4.1 Space Plug and Play

As mentioned in the project description, SPIFF plans to integrate the HUB with the magnetometer, EFM and the SHM using Space Plug and Play (SPA) protocol. Developed by the Air Force Research Laboratory Space Vehicles Directorate, the Air Force office of Operationally Responsive Space and other agencies and teams, SPA-1 "is a collection of standards developed to facilitate rapid constitution of spacecraft systems using modular components." What this means is that SPA allows a large number of instruments to be connected to a central SPA system (in this case the HUB) without the need to install drivers and adjust software interfaces (see Figure 15) Additionally, SPA networks are agnostic and self-organizing.

A differential I2C physical layer is used to implement SPA on the SPIFF payload. Additionally, each subsystem incorporates an ASIM, a pre-programmed chip containing information about a given subsystem and allows the device to communicate using SPA messaging protocols. In a number of ways, the ASIM is similar in functionality to the popular FTDI chips which allow devices to communicate using USB protocols.

4.2 High Level Descriptions and Interfaces

To correctly assess the performance of the SPA-1 protocol we are requesting one small payload on the 2012 HASP launch. Figure 15 depicts a high level system block diagram of what will be encased in that package.

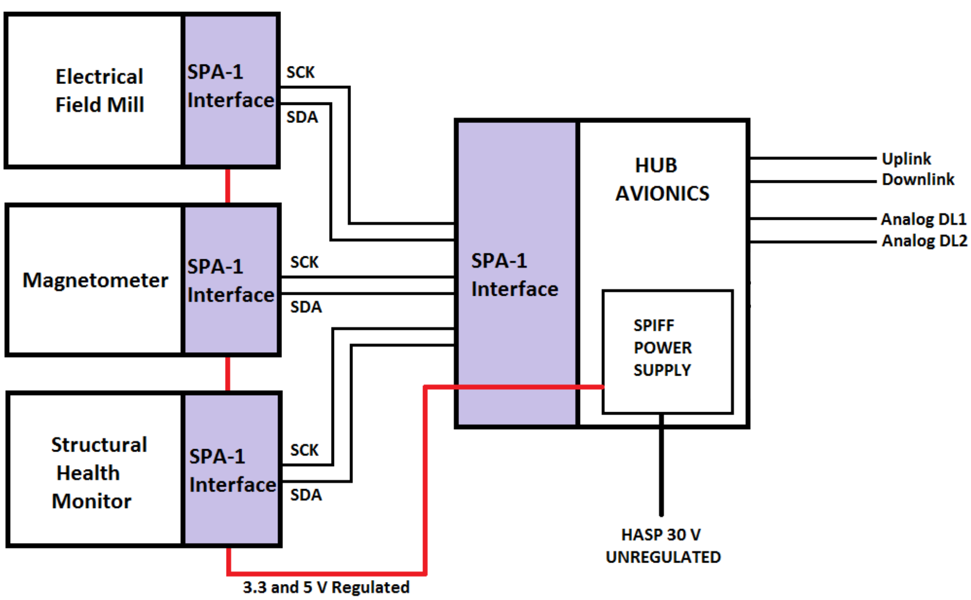

Figure 15: Overall system block diagram, showing interconnecting between two small payload packages

4.3 Intra-instrument Connector interface

Each subsystem will be interconnected to the HUB routing board using standard 15 pin D-subminiature connectors. The pin-out for this connector can be seen in Table 1.

Function	PIN Number		Function
SDA -	9	1	SDA +
SCK -	10	2	SCK +
GND	11	3	5V+
GND	12	4	5V+
GND	13	5	GND
GND	14	6	3V+
GND	15	7	GND
GND	-	8	3V-

Table 1: SPIFF inter-system 15 pin connector

4.4 SPIFF-HASP Connector interface

Additionally, the SPIFF payload will interface with the HASP launch vehicle via the specified EDAC connector (see Table 2).

Function	EDAC Pins	Description
30 V+	**A, B, C, D**	**Unregulated Power**
PWR GND	**W, T, U, X**	**Unregulated GND**
Analog 1	**K**	**Power Supply Temp**
Analog 2	**M**	**Raw EMF Data**
Signal Return	**L, R**	**Signal Return**
Discrete 1	**F**	**Emergency Power Down**
Discrete 2	**N**	**Power ON**

Table 2: SPIFF - HASP Connector Interface

4.5 Weight Budget

TOTAL EXPERIMENT MASS: 2908 g

HUB MASS: 1841 g

EFM MASS: 587 g

SHM MASS: 480 g

Subsystem: HUB	Item	Quantity	Mass ea. (g)	Total
Structure	External Panels	6	166.7	1000
	Mounting	8	25	200
	Fasteners	18	1	18
PCBs	C&DH Board	1	40	40
	EPS	1	140	140
	Batteries	2	260	520
	Solar panels	6	10	60
	Magnetometer	1	3	3
	Extra boards	2	30	60
TOTAL MASS:				1841

Table 3: Mass budget for HUB

Subsystem: EFM	Item	Quantity	Mass ea. (g)	Total
Structure	Sleeve	1	84	84
	Shielding plates	4	48	194
	Stand-offs	12	1.4	16.8
PCBs	Processor board	1	40	40
	Motor driver	1	3	3
	Front-end analog	1	20	20
	Stepper motor	1	130	130
	Fasteners	100	1	100
TOTAL MASS:				587

Table 4: Mass budget for EFM

Subsystem: SHM	Item	Quantity	Mass ea. (g)	Total
Structure	External Panels	4	25	100
	Fasteners	8	25	200
	Misc.	1	100	100
PCBs	Processor board	1	40	40
	Piezo Transducers	10	2	20
	Misc.	1	20	20
TOTAL MASS:				480

Table 5: Mass budget for SHM

4.6 Mounting Plate Footprint

Payload	Footprint
Payload 1: HUB and SHM	5.800 in x 5.800 in (14.732 cm x 14.732 cm)

TABLE (4): Mounting footprint

NOTE: See Figure 20

4.7 Payload Height:

Payload	Height
Payload 1: SPIFF (HUB, SHM, EFM)	11.811 in (30 cm)

Table 6: Instrument height

4.8 Power Budget

TOTAL EXPERIMENT POWER: 9.995 Watts

HUB POWER: 4.2 Watts

EFM POWER: 3.3 Watts

SHM POWER: 1.7 Watts

Subsystem: HUB	Op. Voltage	Current (A)	Power
NanoCDH	3.3	0.500	1.650
FlexUEPS	3.3	0.350	1.155
Honeywell Mag.	12	0.033	0.400
Atmega	3.3	0.300	0.990
TOTAL:			4.195

Table 7: Power budget for HUB

Subsystem: EFM	Op. Voltage	Current (A)	Power
Mill Motor	5	0.280	1.400
Processor	3.3	0.500	1.650
MISC	5	0.050	0.250
TOTAL:			3.300

Table 8: Power budget for EFM

Subsystem: SHM	Op. Voltage	Current (A)	Power
Piezoelectric Trans.	5	0.010	0.050
Processor	3.3	0.500	1.650
TOTAL:			1.700

Table 9: Power budget for SHM

SPIFF will employ a commercial Electrical Power System (EPS) and lithium polymer battery pack from Clyde Space to power the three instruments. Given that the input range of the EPS is 8-28 V, we will employ a high efficiency switching regulator from Linear Technologies to convert the raw 30 V from HASP to a suitable input range. Refer to Figure 15 and Figure 16 for more information.

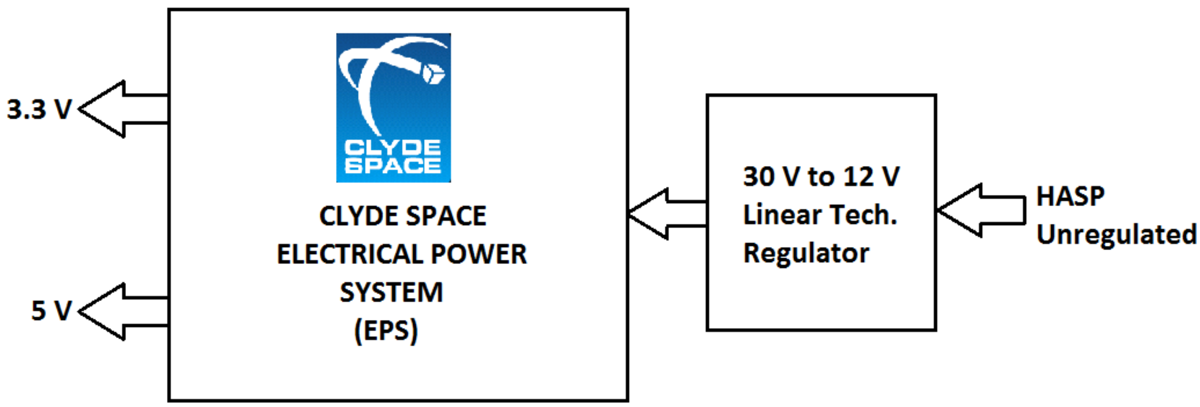

Figure 16: Overall block diagram of switching mechanism between the Lithium Polymer Batteries and the HASP power supply. A Linear Technologies step-down regulator is used to convert the HASP 30 V supply to the acceptable input range for the Clyde Space EPS

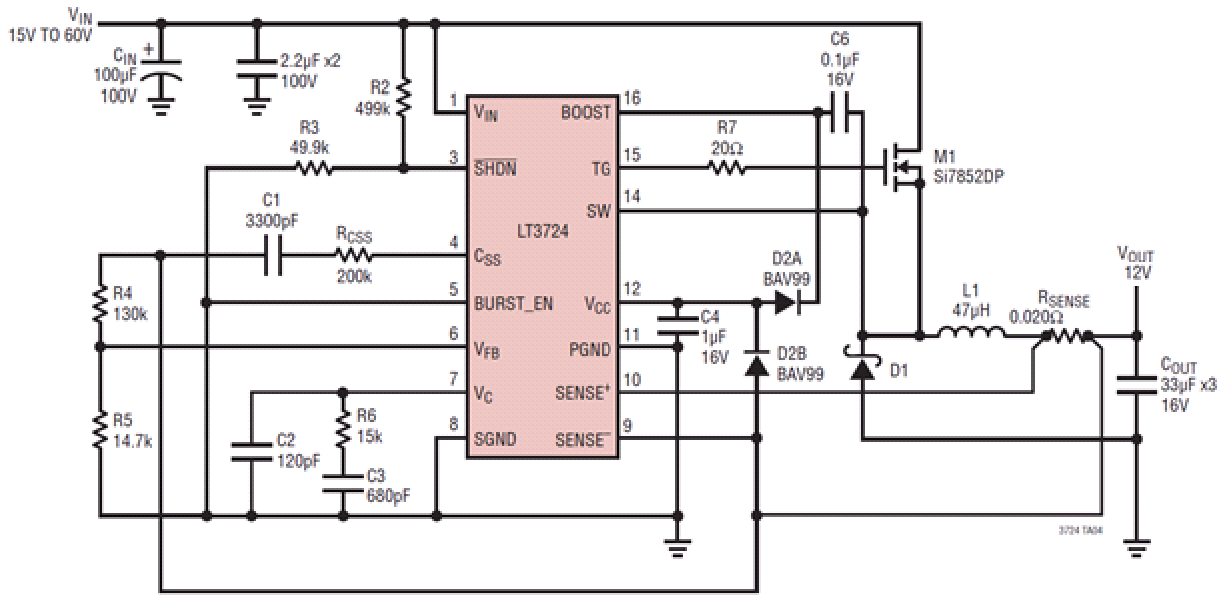

Figure 17: The LT3724: the proposed buck-regulator (made by Linear Technologies) to convert HASP's unregulated 30V to the input voltage range SPIFF's Clyde Space Electrical Power System (8-28 V) in the event of battery discharge. Figure from http://linear.com/.

4.9 Downlink Serial Telemetry Rate

Mode	Rate
Nominal telemetry rate	277 bytes/min

Table 10: Packet Description

Description	Length
DOWNLINK PACKET	
Starting word	1 byte
System time	4 bytes
Packet ID	2 bytes
Number of payloads	2 bytes
System status	2 bytes
Number of payload packets	2 bytes
Payloads packets	N packets
Checksum	8 bytes
PAYLOAD PACKET	
Instrument code	1 byte
Instrument status	1 byte
Time of packet arrival	4 bytes
Packet length	2 bytes
Data	N bytes
HUB DATA (incl. mag.)	
Subsystem data	N = 8 bytes
EFM DATA	
Subsystem data	N = 8 bytes
SPH DATA	
Subsystem data	N= 8 bytes

Table 11: Packet Description (2)

4.10 Uplink Serial Command Rate

In addition to the downlink, we are requesting uplink capabilities to send commands to the HUB. Succinctly, we would like to change the configuration of the SPA-1 protocol during flight to test the robustness of the network between the HUB and the two scientific payload. We implement the command format suggested by the integration manual.

List of commands:
1. On/Off (sleep state)
2. Carry out calibration sweep on selected sensor
3. Measure and compare preset bandwidths on selected sensor or all.
4. Measure and compare custom bandwidths on selected sensor or all.
5. Return Latest Measurement Data.

6. Return Auxiliary Measurement (Thermometer and Accelerometer)
We are expecting to send a command **every hour.**

Description	Bits	Byte
Least significant 4 bits of the command checksum	**0-3**	**First**
Student Payload ID	**4-7**	**First**
Command byte	**0-7**	**Second**

Table 12: Two byte command format

4.11 Use of Analog Downlink Channels

Our mission requires two analog downlink lines. The first one will download the temperature of the electrical power system. The second link will be used to collect raw electric field mill data.

4.12 Additional Discrete Commands

Our mission does not require additional discrete commands.

4.13 Desired Payload Location and Orientation

We do not require any specific location on the HASP structure; any of the 8 small payload locations will be adequate.

5. Description of Integration Procedures

After arrival at the integration facility, the four SPIFF team members will test the payload in "flat-sat" mode (i.e. without mounting to the launch vehicle) using a laptop computer to interface via custom umbilical before bolting the payload in place. Once in place the SPIFF payload will be powered up for a short time to make an approximation of the magnetometer hard iron errors due to the launch vehicle. At this time the SPIFF payload will be interfaced with the launch vehicle and any necessary testing will be performed as required by HASP integration procedures / personnel.

6. Request for Waivers

N/A

7. PRELIMINARY DRAWINGS

7.1 Dimensioned Drawings of Payloads

The SPIFF Payload including EFM

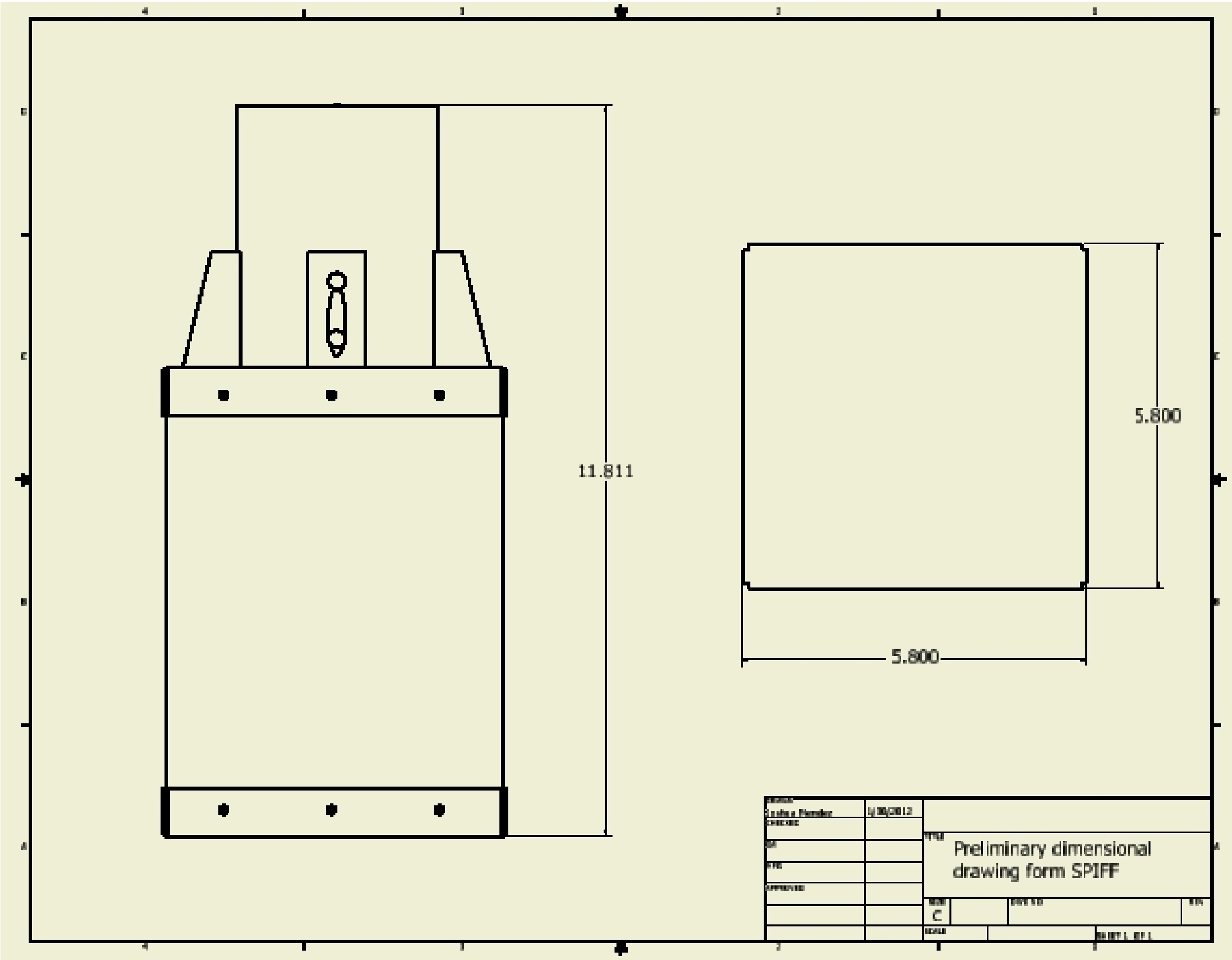

Figure 18: Dimensional drawing for the BUSAT HUB

EFM

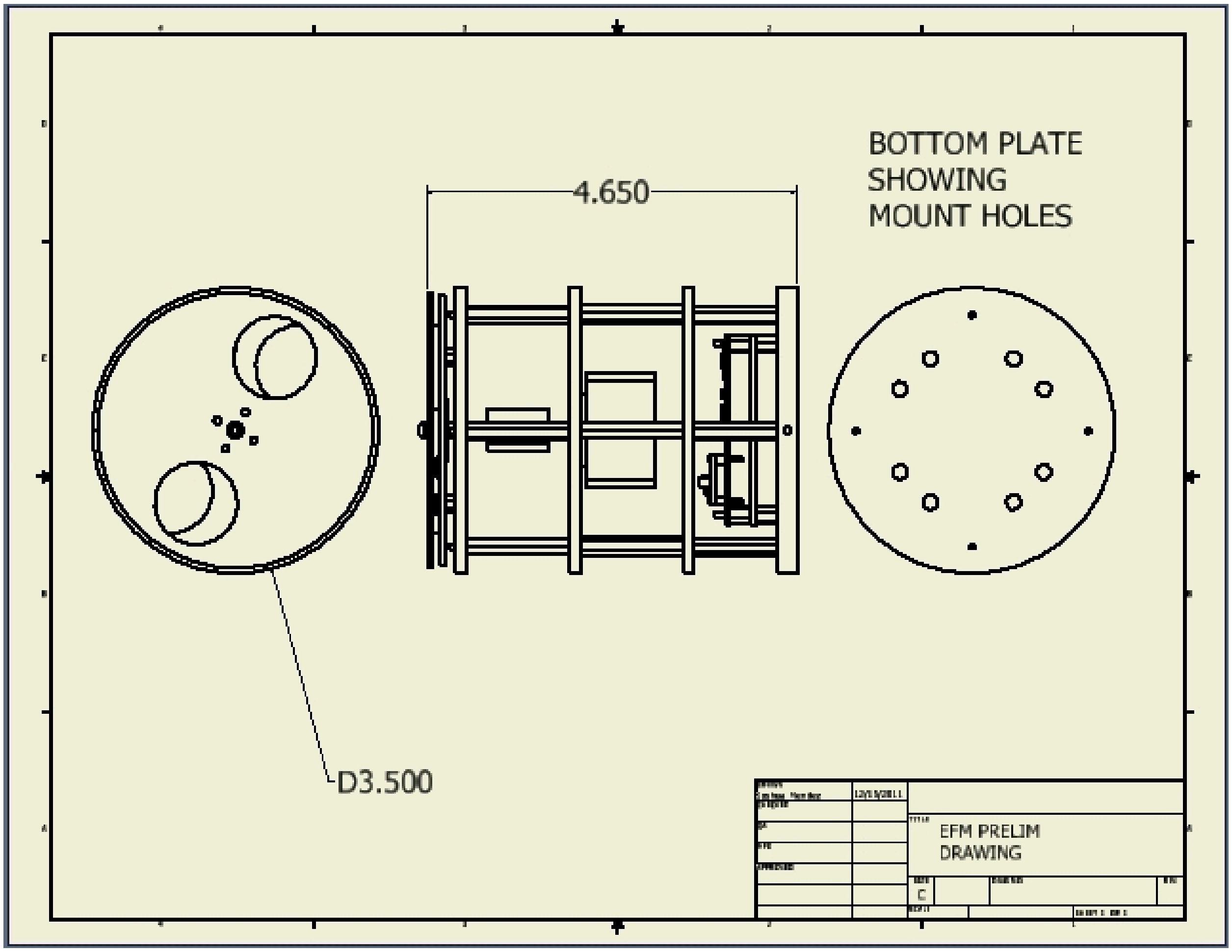

Figure 19: Dimensional drawing for the EFM

Anticipated Modifications of Mounting Plate

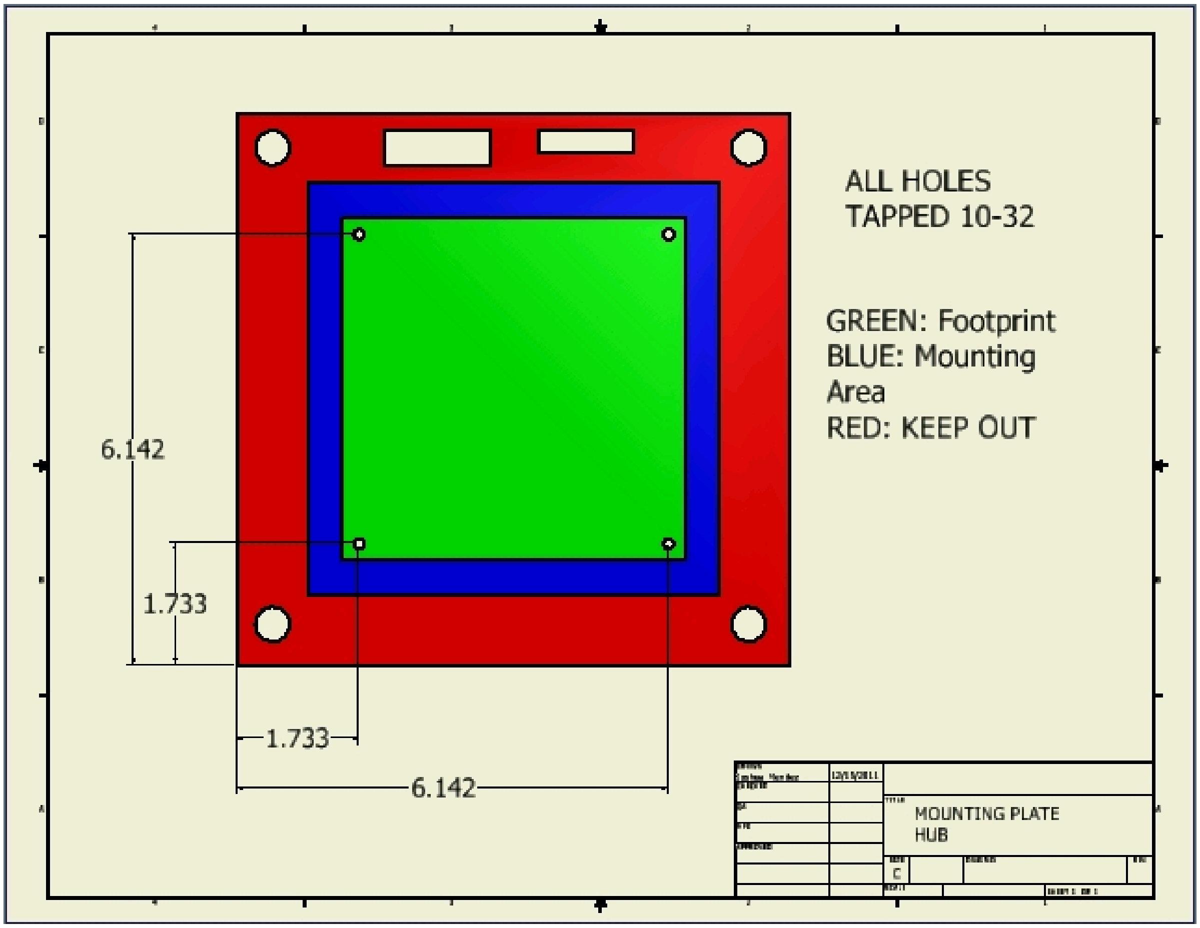

Figure 20: Diagram of modified mounting plate for the BUSAT Hub

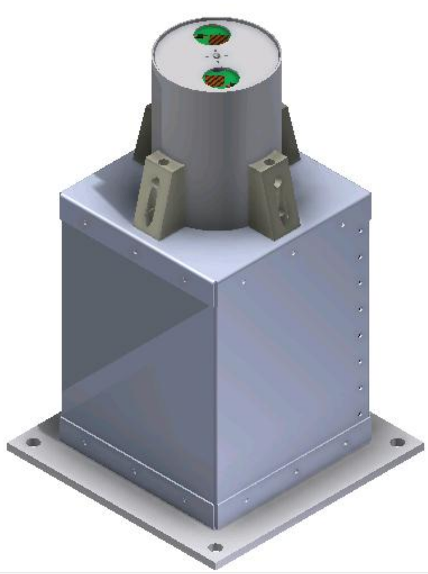

Figure 21: CAD rendition of completed HUB mounted on the HASP interface

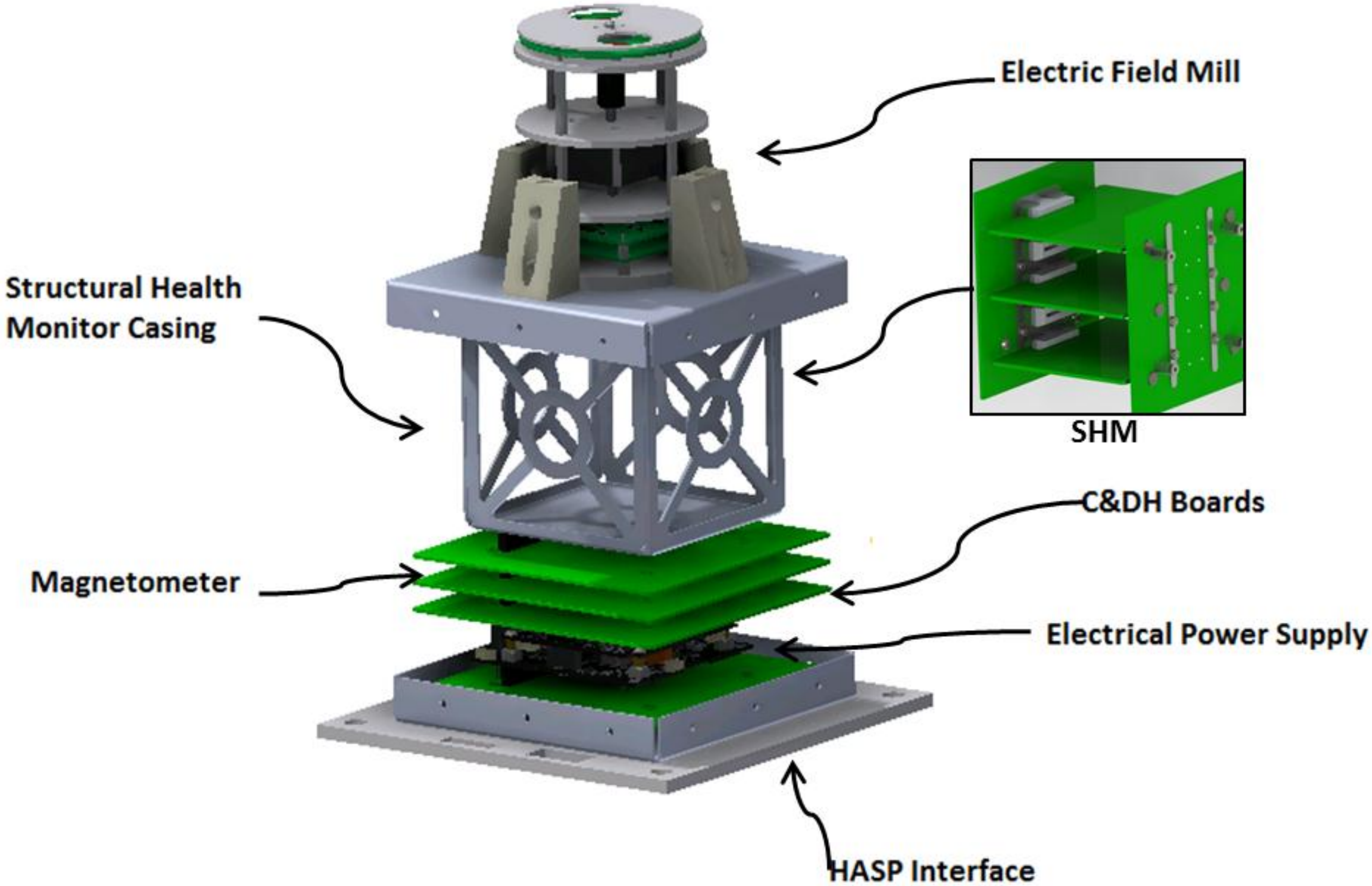

Figure 22: CAD Rendition of completed SPIFF payload on mounting surface with casing removed

8. LETTER OF SUPPORT

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13 December 2011

This letter is to confirm the full support of the Center for Space Physics for the proposal "Student Payload First Flight (SPIFF)" submitted to the HASP call for proposals. The Principal Investigator for this proposal is Prof. Ted Fritz, the Project Manager is Nathan Darling, and the Project Engineer is Christopher Hoffman.

Sincerely,

John T. Clarke
Director, Center for Space Physics