HASP Student Payload Application for 2010

Payload Title: University of Maryland StratoPigeon (UMDSP)		
Payload Class: (check one) ☐ Small ☐ Large	Institution: University of Maryland, College Park	Submit Date:

Project Abstract

Science payloads on LDB and ULDB flights generate large amounts of data, only some of which can be down linked during the flight. Communication during the flight is limited to the fastest speeds of 333 kbps line of sight link or 100 kbps TDRSS link. On landing, the science payload is often far away and can be difficult to retrieve due to size and location, especially with bad weather or restricted plane schedules. The purpose of this experiment is to provide a complimentary method of data storage and delivery in a manner that reduces the effort and time spent on payload recovery for ULDB flights.

The experiment will be a prototype data capsule that can store large amounts of data and be released from the main gondola during the flight with a manual command. The capsule will descend on a parachute to a predicted landing site chosen for location and accessibility. During descent and on landing, the payload will transmit exact coordinates through satellite link and line of sight radio. Once retrieved, the payload will provide large amounts of onboard science payload data on 2 solid state hard drives.

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Project Premise

Scientific ballooning flights provide one of the most stable platforms for space instrumentation testing and atmospheric science experimentation, such as cosmic ray analysis. Antarctic ballooning in particular provides a longer duration flight, stable platform at higher altitude, and better access to some solar properties such as cosmic rays. Science payloads such as CREAM, ATIC, and POLAR-BESS are flown each year to take advantage of these increased opportunities. ULDB flights of up to 100 days will increase the opportunities for flight and data collection even further in coming years.

Science payloads collect and downlink gigabytes to terabytes of data. The POLAR-BESS flight in January 2005 collected 2 terabytes of data on 900 million cosmic-ray events over 8 days and 17 hours of flight. In January 2008, the payload recorded 4.6 billion cosmic-ray events onboard, just over 5 times the data from the previous flight, over 29.5 days of flight and 24.5 days of data collection limited by data storage space. Science payloads like BESS can downlink data during flight over TDRSS, another satellite link, or line of sight radio. If a high speed TDRSS link, 100 kbps, was theoretically used continuously for the entire flight, 1.03 gigabytes of data could be received per day. Over a 20 or 40 day flight, 20.5 gigabytes or 41.2 gigabytes could be received over the link. If a theoretical line of site link could be maintained for the entire flight, 68.6 or 137.2 gigabytes could be transmitted over 20 or 40 days. In spite of the data link chosen, science payloads can only downlink a fraction of the data onboard during the flight.

Payload recovery can also be a difficult and long process for many science payloads. Because recovery of payloads is not a priority for NSF, scheduling a plane to pick up the payloads can take significant amounts of time. Plane choice is also important due to payload size and weight. Typical planes used for payload recovery have been the 4-engine C-130 Hercules and 20 passenger Twin Otter. Even with a recovery plane of significant size, recovery can take many days due to weather and landing conditions around the payload. In February 2009, CREAM recovery took multiple trips over 3 days to recover all payload components. Recovery of the ANITA payload flying at the same time took 5 days to recover completely. The POLAR-BESS flight in 2005 took 7 Twin Otter flights to recover all payload components.

Project Description

The UMD payload will be designed as a data storage capsule. The purpose of the capsule is to collect as much science data as possible and return it to the scientists during the ULDB flight, with as little time and effort spent on recovery as possible. The data set would a complimentary one to the data over TDRSS or line of sight radio. In an ideal payload, multiple hard drives would be used to capture several terabytes of data. Many times the data currently available during flight would be accessible. The capsule would be particularly useful on ULDB flights where there is the potential for huge amounts of data.

The capsule will also be designed to decrease recovery effort and difficulty. The payload will transmit coordinates over satellite link and line of sight radio so it is easy to locate during descent and landing. Due to the smaller size of the payload and simpler instrumentation, more plane recovery options are available. Since many large payload recoveries do take 3-5 days to complete, the capsule will be designed to take a single trip to recover. No disassembly of the payload will be required and a single person will be able to retrieve and handle the payload. To reduce the effort put into retrieving the payload, it is designed to be easy to locate, handle, and transport, while having all the data storage benefits of a larger system.

The payload will also be designed to reduce the time for recovery. Science payloads often land anywhere from 100 to 500 nautical miles from a usable base and sometimes on bad terrain during unfavorable weather conditions in that area. The storage capsule will be designed to reduce the risk of the above three factors. The payload can be released at any point during the flight. Using predictions, a landing site can be chosen for the payload near a usable base site, preferably one where the payload can be accessed by helicopter. The payload can also be released near preferable terrain for retrieval, during a period of favorable weather. Ideally, all these factors coincide. However, a payload capable of reducing the risk determined by any of these conditions will reduce the time spent on recovery. With a shorter recovery time, the data will be sent back to the scientists sooner during the flight.

Payload Specifications

I. Mechanical Systems

The mechanical systems will consist of a launcher for the data capsule. The launcher will have a mechanical release component and a driver for the servo that provides the rotation needed to release the payload from the plate. The HASP plate will be attached to the booms normally, and the payload will be attached hanging under the plate in the designated payload space. The HASP plate will be customized to accommodate launcher and data connections. To prevent the payload launching prematurely during transport or ascent, the attachment mechanism will use a locking method.

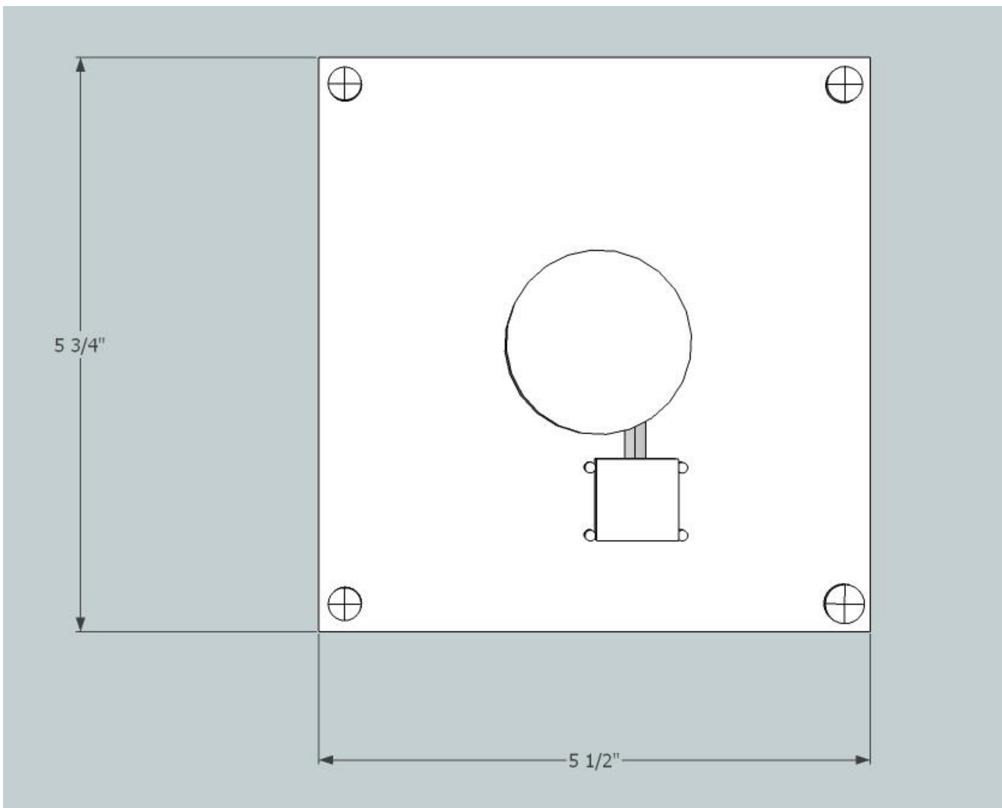
The payload will be attached to the launcher with a rotating peg. A pin will connect the payload structure to the grooved peg. The pin will support the weight of the payload and withstand launch and flight loads. The groove in the peg will run flat around the outside of the peg and then gently slope down to the end of the peg. The pin will be placed in the flat section of the groove so that it will naturally stay in place. To prevent the pin being jostled out at any point other than launch, the launcher will include 1 inch length sides around the payload on the plate. This will keep the payload in place and prevent rotation of the payload when the launcher is active.

When the payload is ready for launch, a servo will turn the peg and force the pin downward in the groove. The servo is chosen for high torque at slower turning rate and voltage operation range of 4.8 to 6V. This This downward motion will disconnect the power and data connectors from HASP. The data connectors are friction based and will be disconnected by the combined downward motion and gravity. When the pin reaches the bottom of the peg and the open end of the groove, the payload will detach from the launcher. The following drawings show the concept of payload attachment and launch mechanism.

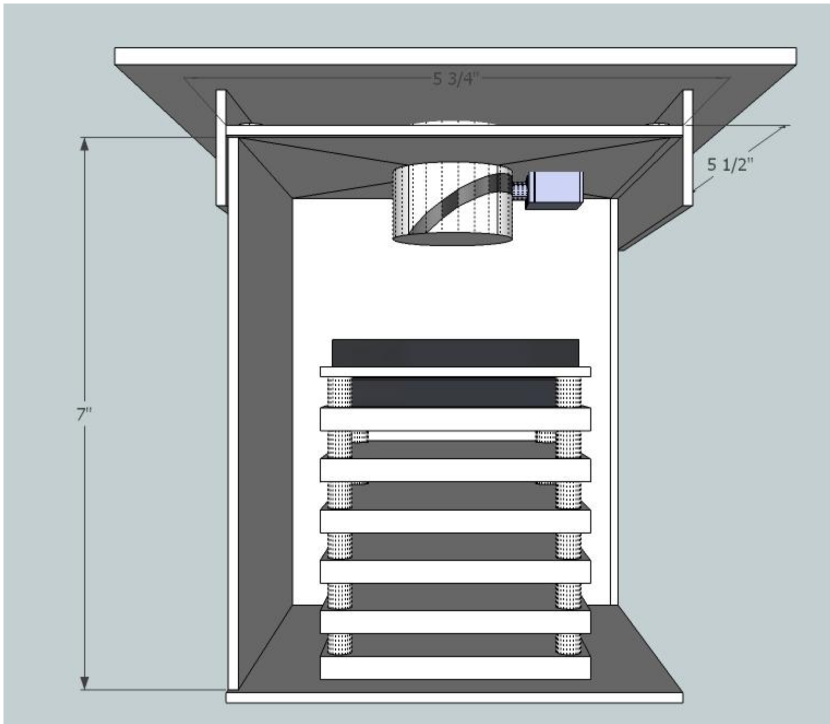
The parachute will be placed on top of the payload. A tube will be used to contain the parachute and keep it from tangling during launch. A hole will be cut in the HASP plate and the parachute placed in a tube through the hole. This way, the parachute will be already deployed on exit and will allow the payload to be as close to the plate and data connectors as possible.

II. Mechanical Drawings

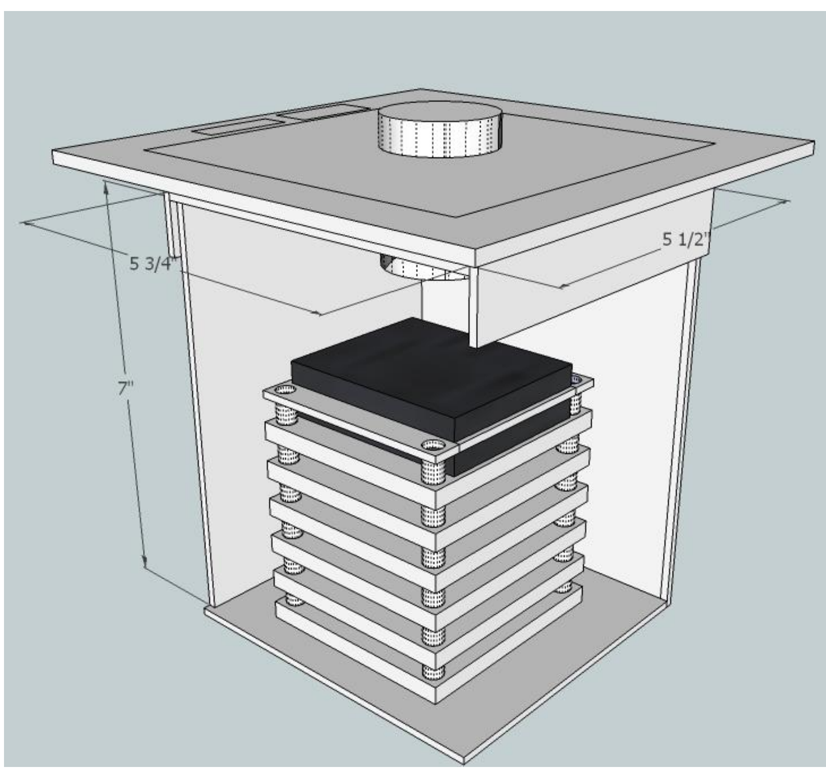
Top View (payload)



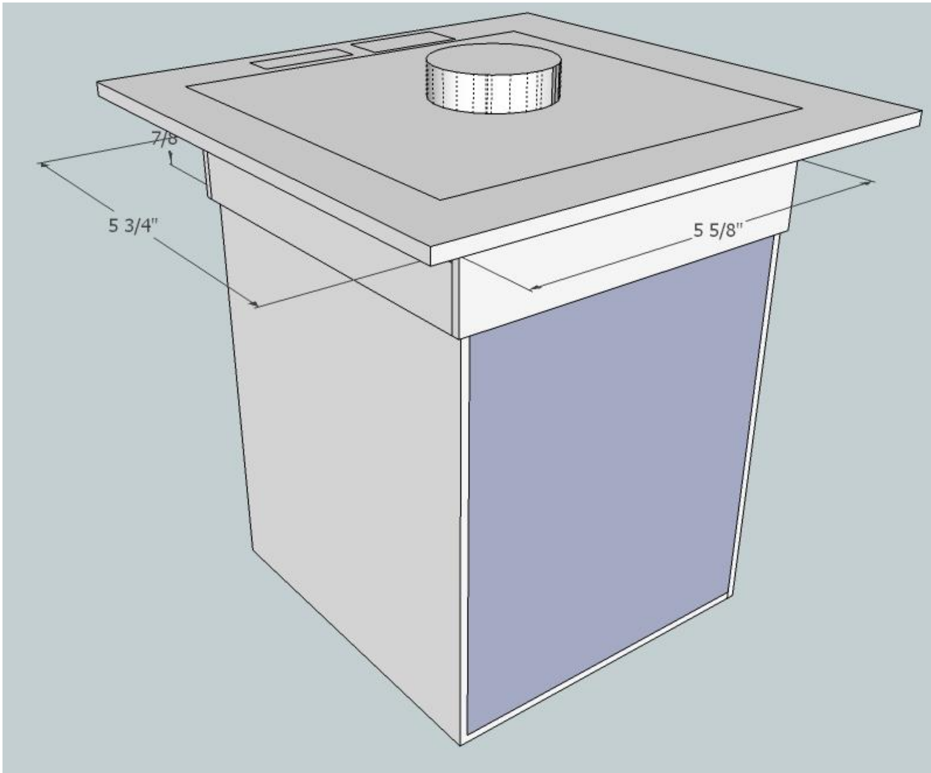
Side View



Angled view



Closed View



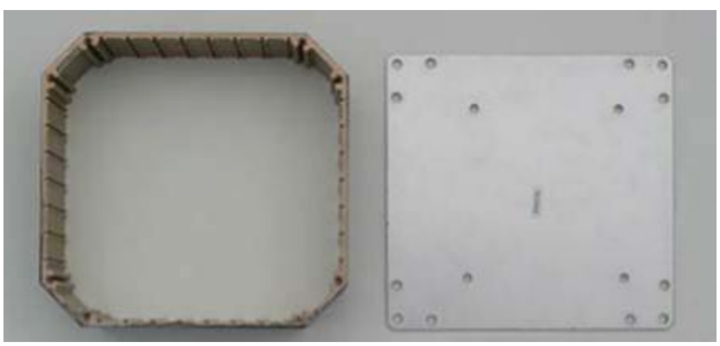
III. Structure

The main payload structure will consist of the commercial Pandora PC104 enclosure. A generic 7” enclosure will be used with blank end plates. The PC104 stack will be mounted to the bottom endplate, to maximize cooling for the CPU board. The top endplate will be customized to match the design for data connectors and launch mechanism. The hard drives will be mounted on top of the stack.

The parachute will be attached to the 4 corners of the payload. If the string connecting the payload to the corners is in danger of tangling during the first part of descent, a hoop spreader will be used so that the parachute is fully deployed and slows payload descent rate.

The following are more detailed images of stack mounting and enclosure dimensions.

The above image on the left shows how the hard drives will be mounted on the stack and inside the enclosure. The above image on the right is an enclosed Pandora structure. The end plate pictured is standard with the enclosure. Our payload would use a customized end plate for data connectors and launch mechanism. The bottom end plate for mounting is shown below, along with a side view of the structure.



IV. Controller

The processor for the PC104 stack is based on the Vortex86DX, a low power x86 compatible system-on-chip for industrial applications. It is compatible with PC104 and PC104+ expansion boards. The board is standard 90 X 96mm and capable of wide temperature range operation. At 5V the board draws approximately 740mA. The processor board will fit into the standard commercial enclosure and mount to the bottom plate to aid in heat dissipation.

Two additional Atmel based controllers will be used to control the servo operation and communications system. The communications system will use an integrated GPS to determine the position of the payload after it detaches from the HASP gondola.

V. Electronics Systems

The electronics stack consists of boards that mechanically compatible but do not utilize either the ISA or the PCI bus of the PC/104 (Plus) standards. Instead they are based on a distributed architecture utilizing serial communications and provide more options for operating parts of the system independently. The decision to keep within the mechanical constraints of the PC/104 standard allow the easy integration of the custom electronics alongside the more typical computer used for the data transfer.

The power board has two main functions, namely the power conversion from higher to lower DC voltages and relays that control the distribution of the voltages. The DC-DC conversion is done from either the 30 volt HASP supply or the 12 volt internal batteries. Two Texas Instruments PTN78060s which convert to 5v and 3.3v used by most of the onboard systems. The board itself operates off of an independent 5v linearly regulated line for the power controller and the relays that is independent from the main line so it can continue to operate while switching power sources for the rest of the payload. The controller is an Atmel ATmega328 that drives the latching variants of the TX2 series of relays to control the power distribution and monitors the voltage levels.

The plate interface board is responsible for converting the inputs from HASP and for driving the release mechanism. The board takes the HASP inputs (power, serial, Ethernet) and converts them to the headers that connect the plate to the internal payload stack. The release mechanism is controlled by an ATmega328 that controls a servo for the release mechanism. The board includes its own 5v linear regulator so it can operate without the main converter board.

The communications board is the most complex board in the custom electronics stack. It controls the line of sight and the satellite radios as well as a GPS unit used for positioning. The line of sight radio is a Digi XTend 900MHz frequency hopping spread spectrum radio that was used by the UMD team in the 2008 and 2009 HASP campaigns. The satellite radio is a VHF transceiver that works with the Orbcom network. This radio only runs off of the internal batteries and will only be used to send a couple transmissions while still attached to the HASP gondola (for testing its operation prior to release) and is primarily for use during decent and post landing. The GPS is an Inventek ISM300 GPS module with a custom firmware that operates up to 135 kft. The controller for these radios is an ATmega1280 that is similar to the ATmega328 used in the other boards, but features 4 hardware serial ports that are needed to communicate over the different radios.

VI. Data Storage and Transfer

The payload will use two 8 GB solid state PATA hard drives. Western Digital solid state drives are being used for the current design. The drives are standard small 2.5” form factor with a thickness of 0.37”. In such small form, the hard drives will fit on top of the PC104 stack on the standard mounting board for the commercial enclosure. The drives will each operate at 5V and consume a maximum of 0.375 Watts.

To transfer data, a direct Ethernet connection will be used. The Ethernet connection will run at normal speed of 100Mbps. At this rate, the connection can deliver a maximum of 43.9 gigabytes per hour, more than enough to demonstrate the storage capability of the payload.

The HASP serial connection will be used to transmit minimal housekeeping data during the attached portion of the flight. A standard rate of 1200 bps will be used. A command will also be sent through the serial connection for stopping data collection before detachment and an acknowledgment if the hard drives have been filled.

The PC104 stack will utilize Linux or QNX for an easy data transfer format. Since the connection is Ethernet based, the transfer would occur using SSH or FTP format.

VII. Thermal

Thermal issues are of concern with the payload electronics and launch mechanism. Both systems will be thermal chamber tested at UMD prior to integration. If overheating issues arise in the processor, a heat sink will be added. The CPU board will also be mounted at the bottom of the enclosure on the endplate. The endplate will act as a heat sink to some degree as well. The electronics and other systems are also designed to minimize power consumption. Minimal power consumption will minimize heating. All electronics and mechanical components used are also industrial, -40-80° C, rated.

The materials for the launch mechanism will be chosen for stability at high and low temperatures. Any brittleness in the material will be tested prior to integration. Spacing of the components in the system will also be considered to include material expansion and contraction. The servo chosen for the release mechanism has also been selected with a wide temperature range.

Payload Summary

Total Mass (payload + launcher)	~2.5 kg
Payload Mass	~2.1 kg
Continuous Draw	< 250 mA
Maximum Draw	< 500 mA
Payload Size	Small
Payload Dimensions	~5.875" x 5.875"
Payload Height	~7.5"
Payload Orientation	Hanging downwards (pointed at ground)
Serial Commands?	Yes
Serial Telemetry?	Yes(1200 bps)
Analog Telemetry?	Yes (2 lines)
Discrete Commands?	Yes (2 additional)

FAA Regulations

There is some ambiguity over exactly how the FAA would prefer to treat our payload under Federal Aviation Regulations Part 101. The main question we are looking at is if the payload can be treated as if it was its own balloon payload post separation (same as if it was flown independently) assuming that the dropped payload operates independently and transmits its position in real time. We are currently awaiting a reply from the FAA over this interpretation. This would allow us to fly the payload independently as a balloon payload and dropped from HASP under the same rules and would clearly separate the UMD/CSBF responsibilities for operation of the payload.

Even if the payload cannot be operated independently, the relevant section of the FAR is 101.7 as quoted below:

101.7 Hazardous operations.

> *(a) No person may operate any moored balloon, kite, amateur rocket, or unmanned free balloon in a manner that creates a hazard to other persons, or their property.*
>
> *(b) No person operating any moored balloon, kite, amateur rocket, or unmanned free balloon may allow an object to be dropped therefrom, if such action creates a hazard to other persons or their property.*

It should be noted that the FAA places the same hazardous operations requirements on the main balloon and an object dropped from it. To meet these requirements, we intend to design and operate the payload in the same manner that one would do so for an independent balloon payload. By keeping the same procedures and a similar design to what the FAA is familiar with, we are confident that we can provide both the same levels of safety and confidence in the operation.

Our preliminary plan on operating with the FAA is as follows:

1. FAA will be notified prior to flight with as much information is available about the predicted flightpath and timing. If requested, a NOTAM will be filed.
2. The responsible ATC will be notified with the updated flightpath (of the dropped payload) and timing prior to release.
3. ATC will be notified when the payload passes below 60 kft and when it is on the ground.

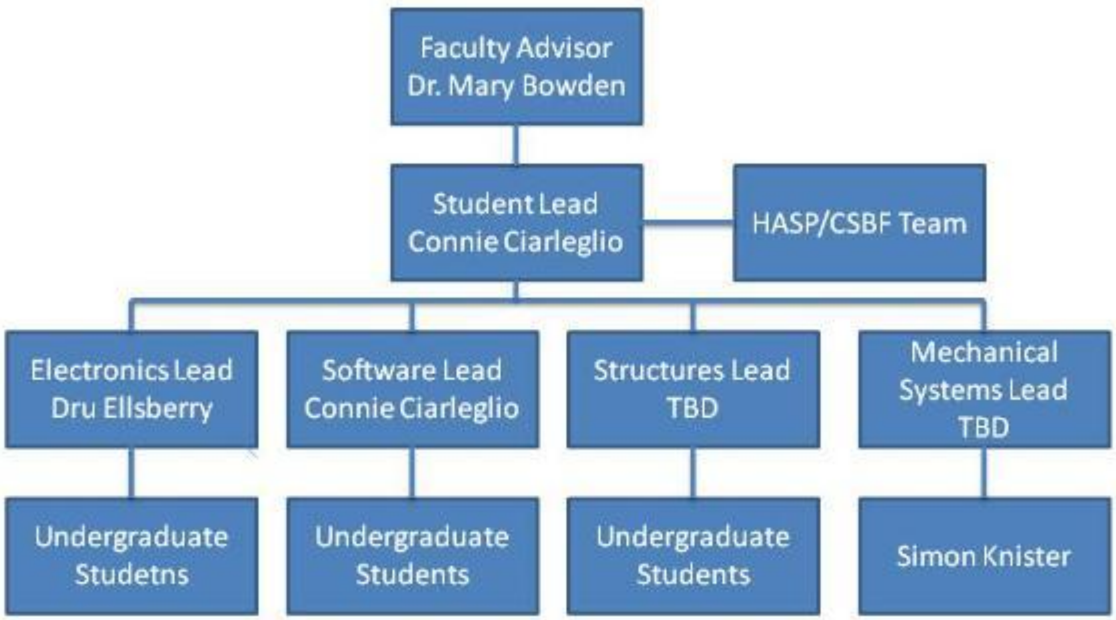
This procedure will be discussed with the FAA and adapted based on their requests prior to the flight.

Special Requests

The payload will need to gather large amounts of data in order to demonstrate a proof of concept. A data connection, Ethernet based, will be needed between the main HASP system and the payload. The prototype will test data storage capability through the connection by gathering all the data collected by HASP during the attached portion of flight. An Ethernet connection to HASP and a downlink of all HASP data is therefore requested to test the abilities of the capsule. Not having a full data connection will reduce the demonstration of the payload to store and deliver large amounts of science data.

To fully test the payload, it will need to be launched off of the HASP gondola. Requirements by the FAA and ATC will be addressed as above.

Team Structure and Schedule



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Schedule

January-February:
- Communications design
- Electronics design
- acquire CPU board and hard drives

March-April:
- complete mechanical design
- complete structure design
- begin programming
- electronics testing

May-June:
- continue programming
- mechanical systems testing
- system release testing
- full systems testing

July:
- Integration at CSBF

August:
- payload support operations during launch and flight

Flight Operations

I. Integration

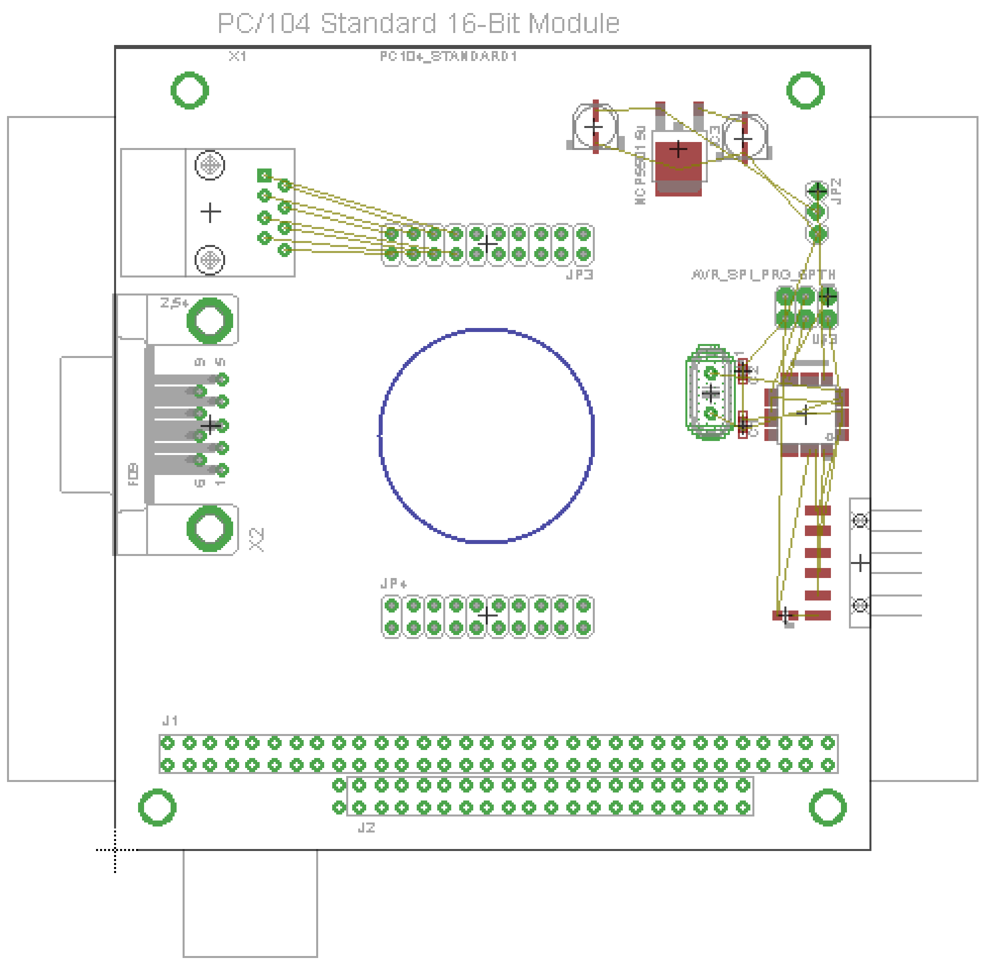
We expect to send 2-4 people for payload integration in July. Integration will consist of mounting the payload, testing electrical and data connections with HASP and especially testing discrete commands. Testing will also include a test of the detachment mechanism from the gondola, data storage testing, and successful completion of the TV test.

II. Flight Procedures

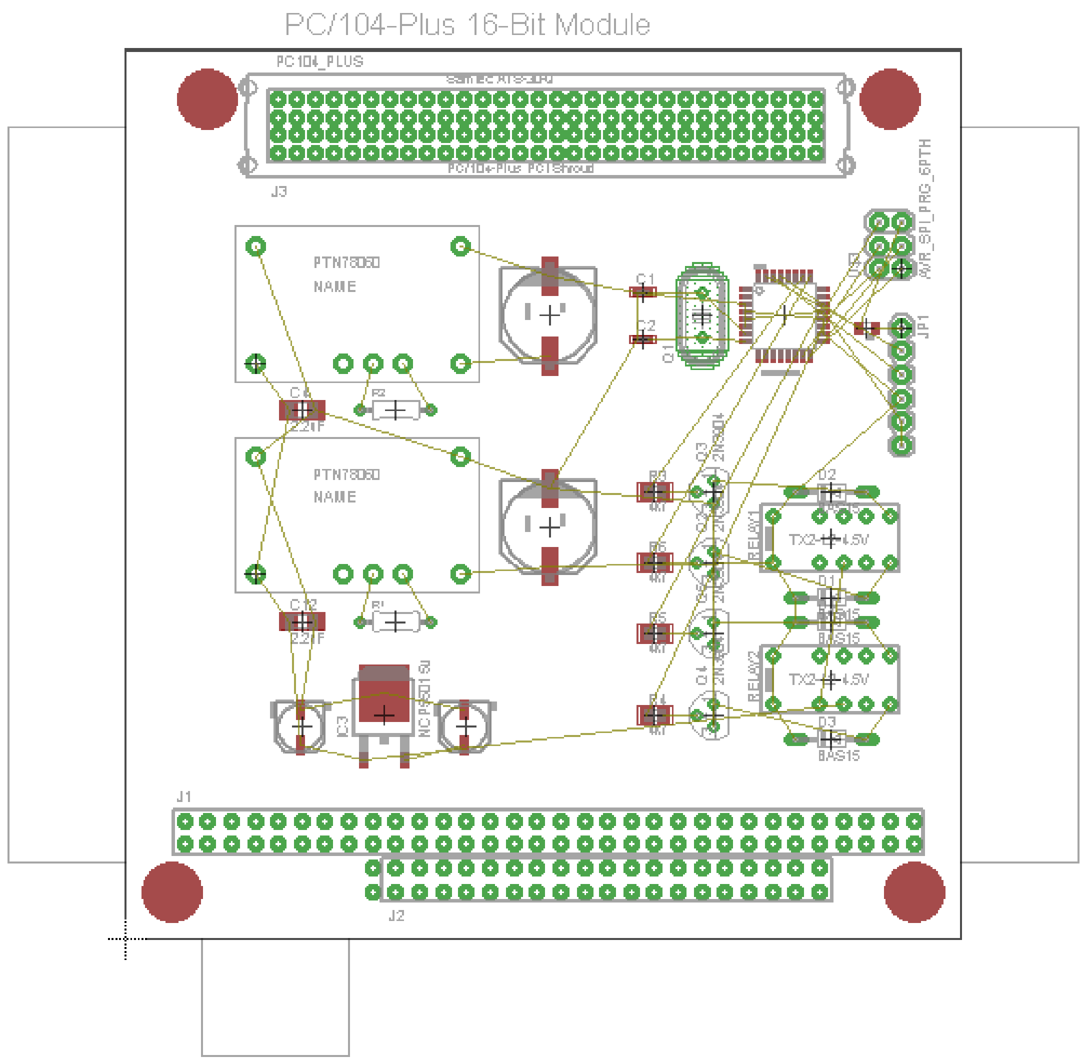
At least 3 team members will be sent to Ft. Sumner for the HASP launch in September. We hope to have 1 student present for a longer period of time and minimize the time spent by other undergrads for missed classes. Since payload recovery will occur during the flight, this does not extend the stay of the students significantly. Two team members will be needed to track and recover the payload and return it to base. They will leave from the base before the payload is detached to be close to the payload as it descends. The mobile team will monitor GPS coordinates and housekeeping over the digital radio link.

One team member will remain at the site to monitor incoming data and give the commands needed to stop data collection, restart, and detach the payload. Minimal housekeeping will be monitored through the HASP link during the attached period of flight by the student. The student at the base, in conjunction with the mobile team, will also decide the best place to drop the payload through analysis of the current balloon track and landing predictions. The student will provide all FAA and other notification prior to payload launch.

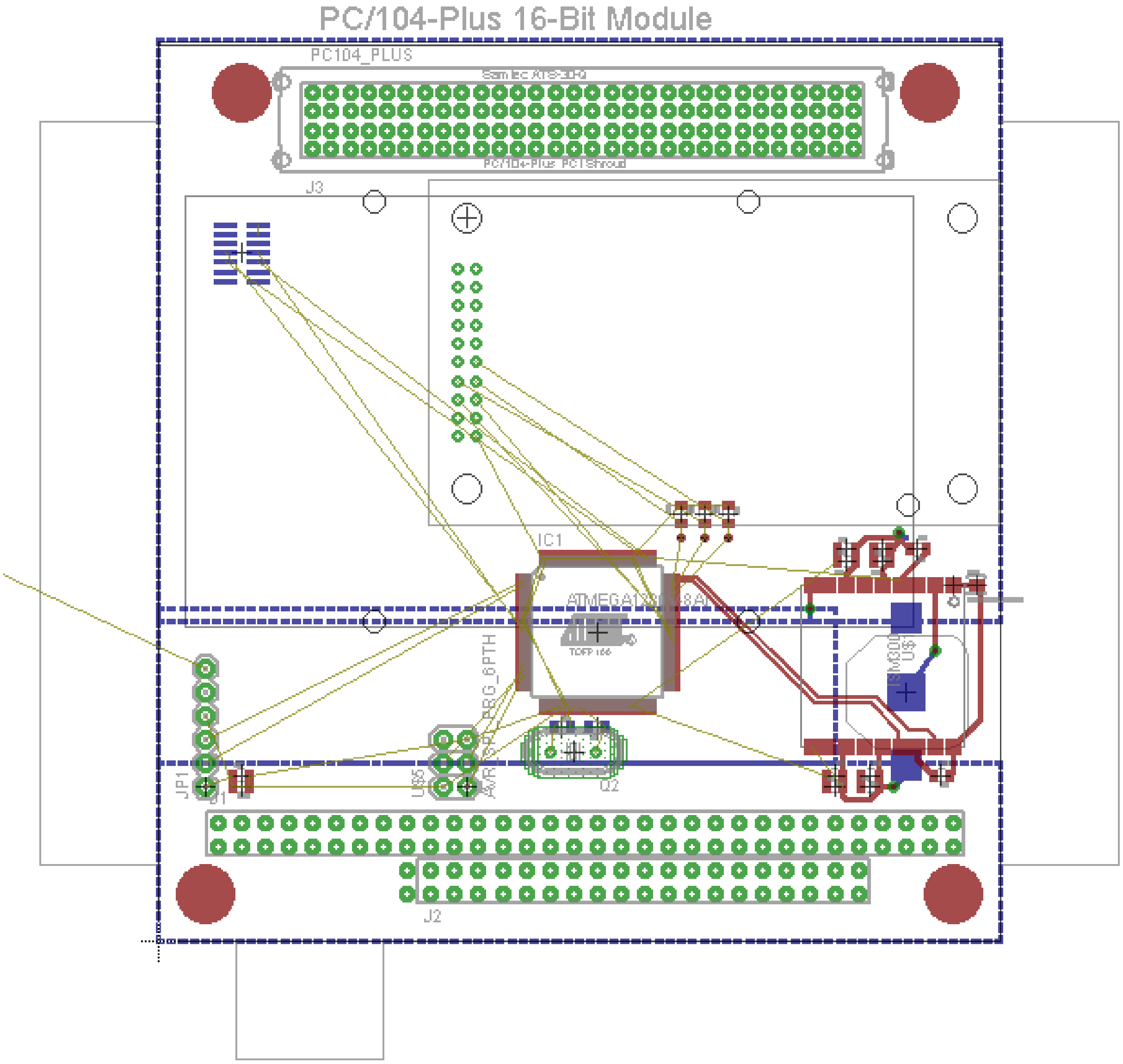
Appendix I: Preliminary Board Designs



The interface/motor board shown above performs two major tasks: interfacing the HASP interfaces to the release connectors and driving the release mechanism. The board will convert the Ethernet, serial, and power connections from the HASP gondola to the two DIL connectors that will pass through to the main housing. Also, on the left side of the board is an Atmel ATmega328 based circuit that is responsible for the release of the payload. It operates independently off of a 5v linearly regulated supply and can interpret and act upon the release commands sent over the serial connection from HASP. The circuit can either be programmed in C or it can utilize an Arduino bootloader to simplify operation.



The power board converts and distributes the power used by the systems internal to the data return capsule. It includes two DC-DC and one linear regulator as well as the relays used to select the power supply and turn the payload on and off. The DC-DC converters are Texas Instruments PTN78060 modules that regulate the 30V DC from HASP to 3.3V and 5V DC. There is also a 5V NCP5501 linear regulator that is used to independently power the relays as an independent source is needed while switching the main power supply. The relays that control the payload are latching variants of the TX2 relay series and are commanded by a very similar ATmega circuit as used on the interface/motor board.



The most complicated board is the communications board, shown here. It features line of sight and satellite communications as well as a GPS unit for positioning. The line of sight transceiver is a Digi XTend 1W FHSS radio as used in the last 2 years of UMD HASP payloads. The satellite communications are handled by a D10 Orbcom transceiver. The GPS unit is an Inventek ISM300 with a custom firmware image to operate up to 135kft while utilizing the performance of the SiRstar III chip. All of the radios listed above use external antennas (the enclosure is aluminum). The controller for this board is an ATmega1280, it is similar to the ATmega328 used for the other boards, but features 4 hardware UARTS that are used for interfacing with the two radios and GPS along with the main bus. The board performs all of the descent tasks with the exception of power conversion and operates with the “main” x86 CPU off for descent and recovery, greatly increasing the battery life.