HASP Student Payload Application for 2012

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

Project Abstract

Antarctic research flights are becoming increasingly long with durations of up to 100 days. During that time, scientific payloads generate terabytes of data. Only a fraction of this data can be down linked over the TDRSS link or line of sight radios. In addition, research payloads are heavy and time consuming to retrieve, often requiring multiple plane trips and experienced personnel for recovery. Access to these payloads can also be difficult in bad weather or if the payload lands in bad terrain. The purpose of the StratoPigeon payload is to provide science payloads with access to a full set of data during flight in addition to the data-downlink and to provide an easier method of data storage, delivery, and recovery.

In the HASP 2010 flight, a prototype of StratoPigeon capsule was successfully tested and recovered as a proof of concept system. StratoPigeon III is the final design iteration of the capsule. The capsule will expand the capabilities and features of the original system with more automation during flight operations. The payload will represent a low cost, efficient system designed for Antarctic environments. The capsule design will take into account input from research payload designers in order to the payload configuration into a highly useful system. This input is a key final component of the final payload design.

StratoPigeon III will expand on previous experience and incorporate new technologies into the payload design. This payload is also specifically for an Antarctic environment. The capsule will utilize commercially rated components to reduce cost and allow modification of storage capacity for individual scientific experiments. The capsule will allow testing of large data transfers up to 240 GB total.

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Project Premise

Antarctic Long Duration Balloon (LDB) Flights provide increased opportunities for scientific research payloads in the fields of space instrumentation testing and atmospheric science experimentation. Ultra Long Duration Balloon (ULDB) flights further increase those opportunities for longer duration flights and collection of massive amounts of data. Most research payloads on these LDB flights collect amounts of data on the order of many terabytes in some cases. While there are several options for data downlink, such as TDRSS, most payloads can only send a fraction of the onboard data during the flight. On future ULDB flights, the on board storage requirements will be even higher and a smaller percentage of the total data will be available during the flight. In addition, payload recovery is difficult due to weather and terrain conditions, large size of the payload, and transportation and personnel requirements. Many payloads can take weeks to recover in bad weather.

Project Description

The proposed payload, StratoPigeon III, is the final iteration of the Antarctic data storage and delivery capsule flown on HASP 2010. It is intended to optimize and improve on the results and design of the previous iteration and utilize all components needed for a polar environment. The capsule will satisfy the original purpose of StratoPigeon, to provide scientists access to large amounts of data during a ULDB flight with minimal time and effort spent on recovery, as well as its new objectives; to provide researchers with a highly adaptable and expandable commercially rated system for data storage and delivery and a simple, easily integrated detachment system for use with a wide range of research payloads. A fully polished design will be presented with input from the previous year's flight.

The HASP flight will provide a stable platform for thermal testing, data transfers with actual science payloads, and a test of the full communications system required for flight in a remote environment. Because scientific payloads are such an important component to the design, it is critical that this aspect, along with the ease of integration with these types of payloads, be tested. It is also important, for a final design iteration, to have a polished design with fully tested software and hardware. Due to the long nature of a ULDB flight, HASP provides a realistic environment for the StratoPigeon payload to operate in. The flight length provides the opportunity for multiple data transfers, thermal data, and the opportunity to test with high data rate scientific payloads. The HASP platform also provides a realistic environment for detachment testing and descent trajectory prediction. One of the design aspects of the StratoPigeon payload includes allowing for a predictable descent trajectory, such that the payload can be released and recovered close to McMurdo or the scientific base station. The HASP flight is closer to the operational conditions the payload is designed for and allows us to select the conditions, worst case or standard operational, in which to test the detachment system.

Science Team Integration

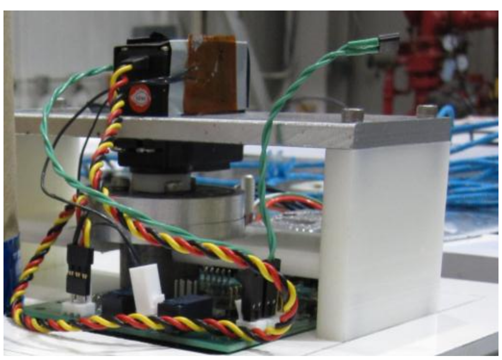
Applications for the StratoPigeon payload are constrained by the needs and interface constraints of participating research payloads. For the previous prototype unit, integration with a science payload was not necessary for a proof of concept demonstration. For a final unit, the input of research teams is necessary. Because the StratoPigeon concept is intended for Antarctic research teams, the input of these teams is necessary for a final design. In the 2012 payload, research teams will be contacted for both their input into the design of what is useful for their payload, and for the purposes of looking at how much interest there is for the StratoPigeon concept for actual use. Some of the critical aspects of StratoPigeon that require research team input are the electrical and desired data interfaces, power available on a research gondola for single or multiple StratoPigeon capsules, and mechanical mounting and interfaces to the research gondola. Contact with research teams is ongoing and expected to continue through January at least for the final design.

Testing of large data transfers is also a critical component to the verification of use for Antarctic payloads. The UMD team would like to once again attempt data transfers on the 2012 HASP flight with other student payloads, up to an expected capacity of 240 GB. Early integration with accepted science teams is essential as the interfaces must be built to compliance for both payloads. Once again, these research student teams will help shape the needs and final design for the StratoPigeon payload.

Payload Specifications

Mechanical Detachment

Detachment from the main structure will be done by a single servo driven, bolt action style locking pin, as was used on the last StratoPigeon flight. A steel sheath will be mounted to the payload, and a horn with a press fit steel pin will lock into the sheath. Actuated by the onboard servo, the horn rotates 90 degrees to release the payload. To ensure a clean disconnect, a small compression spring, fit inside of the sheath, will provide sufficient force to disconnect the electrical interfaces, even if the payload is not sitting completely perpendicular. Upon deployment the payload will fall directly down, away from the main structure, and pull out a nylon parachute to allow for a safe landing. This mechanism will be a slightly modified and optimized version of the detachment method flown on the 2010 flight shown below.



Structural Casing

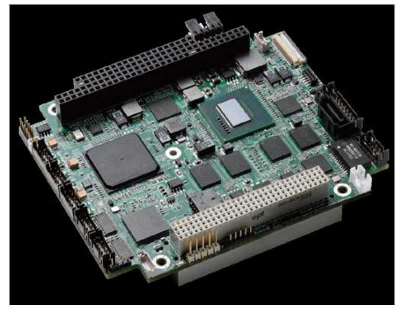
The internal structure of the electronics package will be a self-contained aluminum frame, allowing the internal electronics to be removed in a single unit. The outer casing of the payload will be a thin aluminum shell to protect the electronics during landing and to allow some level of conductive heat transfer for internal thermal regulation during flight. Both of these structures will be made specifically for the StratoPigeon payload.

Electronic Systems

Data Transfer and Supporting Systems

StratoPigeon is intended to carry several Terabytes of data that can be written to storage devices at high speed. For this purpose the use of Solid State Drives (SSD's) is ideal. With a capacity for up to 300 MB/s on using SATA II protocol, these drives can store a theoretical capacity of one Terabyte per hour. 2.5" form factor SSD's now come in up to this storage capacity. However, the StratoPigeon is designed to hold any SSD of a 2.5" form factor and storage amount is variable. The capsule is designed to hold 2 SSD's of this form factor. For the 2012 HASP flight, two 120 GB drives will be used for testing.

In order to make file transfers and utilize the SATA protocol, a more complex main computer was required. While having these capabilities, the CPU also needs to be low power and fast enough to successfully write at the SATA II maximum speeds. The Ampro Adlink Coremodule 720 has therefore been selected as the main CPU for the StratoPigeon payload. The CPU is a PC104 based and uses an Intel Atom processor with an extended temperature rating. At a maximum of 1.2 GHz, the board draws only 3.9 W. In addition, the board carries 4 serial ports and 2 SATA ports for all interfaces. The 2 SATA ports will be used for the SSD's while 1 RS232, 1 RS485, and the LAN interface will be sourced to the attached research payload. A Gigabit Ethernet connection is available on the CPU if needed by the research payload. A second RS232 port will be used for communication with lower level microcontrollers internal to the StratoPigeon payload and mounting plate electronics. This CPU eliminates the need for the SATA expansion board used in the previous prototype and increases the speed and capacity of the processor without increasing the power draw or losing the industrial temperature rating.



Adlink Ampro Coremodule 720 Datasheet

Both the serial connection and Ethernet connection will be used to test data transfer. Having both types of connections adds versatility and adaptability to the features of the StratoPigeon payload. The serial connection will be tested with low rate constant data. The Ethernet connection will transfer whole files from the attached science payload. The RS485 feature can be used for faster serial data or if a science payload wished to transmit data to multiple StratoPigeon payloads at the same time.

Software for the PC104 CPU will be Linux based. A Debian kernel was tested during the 2010 flight and found to be both difficult to work with and difficult to learn for newer undergraduate students. As Linux is commonly used along with C/C++, this will make the learning process and software creation process much easier and faster than in the previous prototype. There is also a lot of Linux experience and coding experience in that environment in the HASP 2012 anticipated team.

In addition to the CPU, there will be 3 custom printed circuit boards internal to the capsule. The topmost of these will be mounted to the top of the payload and will hold both the electrical connections to the detachment plate and the power distribution electronics. There will also be an interface backplane attached to the electronics holding the CPU, communications electronics, and 2 SSD's. The communications electronics will be mounted to the bottom of this stack.

<u>Power Distribution</u>

The power distribution PCB is mounted directly to the top plate of the payload. It houses the connectors that interface to the above detachment electronics and the connector interface for the internal backplane. The board also regulates the HASP and battery voltages and sources appropriate voltages for all internal payload components. The board is based around an Atmega1280 which is used to drive the relays distributing power to the rest of the payload systems. A summary of the anticipated payload voltages is seen as follows:

Component	Voltage (V)
CPU	5
SSD 1	5
SSD 2	5
Power board internal components	5
Heaters	30
Communications PCB	5

A TI Darlington driver chip will be used to simplify the interface circuit for the high number of relays. A mosfet driver will be used to regulate power to the heaters, allowing a variable amount of heat depending on the internal payload temperature. A switching regulator flown on previous HASP flights will be used to provide power to the remainder of the 5 V internal payload components. One serial port of the Atmega chip will be used for a connection to the detachment electronics serial port.

Detachment

The detachment electronics will be mounted to the upper side of the mounting plate along with the servo detachment mechanism. This board will hold the EDAC connection, HASP serial connection, research payload serial connection interfaces and Ethernet jack, and the connector interface to the internal payload. This board is also based around the Atmega1280 and will have a serial connection to the power electronics and also to HASP. Data will be passed from the power board to the detachment board and then to HASP. Commands will be passed to the detachment chip and then to the power board. In addition to passing power and data connections to the internal payload, the detachment electronics are also responsible for servo actuation when the release command is received. For internal connections, a pair of hypertronics connectors will be used to ensure connector detachment is as frictionless as possible.

Communications

The communications system is based around 2 transmitters. This system is designed to be used in an environment where there are no repeaters available and satellite communication is considered both expensive and hard to acquire. Therefore, a simple system will be used with two 900 MHz transmitters. These transmitters have been used on 3 previous HASP flights successfully. The Digi Xtend FHSS radio has been tested up to 400 miles and was used for tracking purposes on the first StratoPigeon flight successfully. Since there are no repeaters in an Antarctic setting, a small repeater will be flown attached to the HASP gondola. Each radio will have an attached GPS for latitude, longitude, and altitude transmission. GPS antennas will be mounted to the top of the payload and radio antennas will be fed out the bottom plate. The communications PCB will be mounted with PC104 mechanical hardware to the CPU and connected to the internal backplane in the payload.

Internal Backplane

During the 2010 payload development cycle, the wiring harness became a large issue in assembly and disassembly of the StratoPigeon capsule. In order to minimize the required free wiring internal to the payload, a top backplane will be used to which all power and data connections are linked. The board will not be active save as a routing and attachment point. The backplane will form the top of the central block of electronics to which the communications, SSD's, power PCB, and battery will be mounted. This stack will then be mounted to the top and bottom of the payload. The main stack will be attached to the top payload plate and secured on the bottom externally once the electronics are in place. The only remaining free connections inside the payload will be the radio coaxial cable and GPS antenna cables.

Repeater Function

Because the payload is designed for an Antarctic mission, the payload will be using a small Xtend repeater mounted on the HASP gondola. When the payload is released, the balloon is often the closet point to the payload for a significant chunk of time. Mounting a small repeater to the gondola takes advantage of this proximity for tracking operations. Thus the repeater will allow the payload to transmit to the balloon, often much closer to the payload than it is to a tracking team setting out from base as well, and the balloon will then transmit the signal to a much wider area. This could even possibly allow teams based out of McMurdo station to receive the payload signal on the ground and acquire a GPS location without leaving base. The team would like to test this functionality by mounting a 900 MHz Yagi antenna at the base station in order to receive signals from the balloon at the point of payload detachment.

The Xtend radio is particularly suited to this type of task. A network can be established whereby the repeater onboard the balloon is simply another configured Xtend radio. In this way, with each radio assigned a unique ID, packets can be re-transmitted through a multiple Xtend network with minimal software effort. Coordination with and approval from the CSBF team will be needed to incorporate an antenna for the 900 MHz repeater. The team will likely follow a similar configuration to the antenna flown in the 2008/2009 payload flights for the University of Maryland. This configuration will continue to be discussed with the CSBF team to meet requirements.

Thermal Management

Active and passive thermal control is particularly important for the StratoPigeon payload as it carries a number of commercially rated components. During the prototype flight on HASP 2010, the internal payload showed a distinct tendency toward colder temperatures. Especially on the servo mechanism, the temperatures reached below -30°C. Internal to the payload, heaters are required. The heaters tested as prototypes worked well in 2010 and similar heaters will be used again, although with consideration given to the thermal data from 2010 and subsequent size of heater required. The internal payload requires a heater of approximately the same size flown before, about 5 W, to keep the SSD's warm enough for operation. A larger heater can be used as the heater will be mosfet driven and adjust to the temperature values internal to the payload. A heater will also be used inside the servo enclosure. A smaller heater that will be constantly powered during ascent will be used to keep the servo mechanism above -20 °C.

Because the CPU draws approximately the same power as the previously tested CPU, a heat sink is required to maintain low temperatures. The CPU will be sinked with a copper thermal strap to side of the enclosure. The SSD's will also be sinked to sides of the enclosure to ensure heat is spread. The external of the payload capsule and servo enclosure will be painted with a high emissivity, low absorptivity white paint. This has been a successful heat mitigation strategy in previous flights and with the low power draw, should work well for both parts of the StratoPigeon payload. Temperature will be monitored internal to the capsule and around the servo during the flight. Based on these readings, the payload will control how much to turn heaters on or off to maintain the correct internal temperature. Manual input for the heaters will also be possible to turn off the automatic regulation.

Internal Power

Because the payload will be released from the HASP gondola, an internal power source is required for tracking purposes. This power source is only required for the communications system however and does not need to provide power to the rest of the payload. An internal battery was used as the backup power source on the 2010 flight but a final configuration will use this battery solely for tracking in order to extend battery life. A 9.6 V LiPO4 rechargeable battery will be used to provide power for the radios and GPSs. Since the communications equipment runs on 5 V, a higher voltage source, like the one flown in 2010 at 12.8 V, is not required. The required battery also becomes smaller.

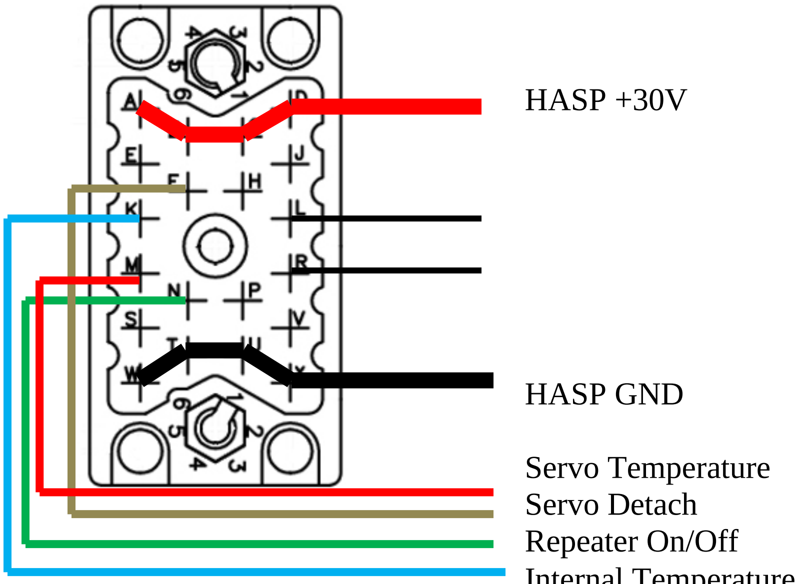
The power regulation system will be capable of switching on and off power to the communications system. In addition, it will be capable of transitioning between battery and HASP power for the communications system testing purposes when the payload is attached to the HASP gondola. A relay will allow HASP power to flow to the communications board, where an ideal diode configuration will be used to determine which power source is active. A total of 2 relays will be used to regulate power on/off, and HASP/battery to the communications board. The detachment board will be capable of turning on/off power for the on board repeater for the communications system.

An estimate of the power requirements for the system is shown below:

Component	Current (A) (@5V)	Current (A) (@ 30V)
CPU	0.78	0.13
Servo Heaters	NA	0.1
Internal Heater	NA	0.17
2 SSD (Active Write)	0.3	0.050
Xtend Radio (Transmit)	0.73	0.122
Xtend Radio (Receive)	0.08	0.0134
Servo (Instantaneous Active)	1.5	0.25
Servo (Continuous Active)	0.7	0.083

Current monitoring will be used on board the payload to ensure that the current draw does not exceed 0.5 A @ 30V. Most high current draws do not occur at the same time, such as servo actuation and data transfer procedures. Ground operation procedures can be used to further guarantee that these tasks do not happen at the same time. In addition, relay configuration in the electronics hardware will be used to ensure that multiple high power components cannot be activated simultaneously. A record of commands received on board the payload will also be used to ensure current draw is low.

Connections to the EDAC connector are shown as follows:



Payload Summary

Total Mass (payload + launcher)	~2.7 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 (Detached portion)	~6"
Payload Height (Total)	~10”
Payload Orientation	Hanging downwards (pointed at ground)
Serial Commands?	Yes
Serial Telemetry?	Yes
Analog Telemetry?	Yes (2 lines)
Discrete Commands?	Yes (2 additional)

FAA Regulation

The StratoPigeon team was very successful in working with CSBF personnel and the FAA during the 2010 flight. A similar procedure will be adopted based on this success for the 2012 HASP flight. The preliminary flight procedure is as follows:

1. The StratoPigeon team will provide a landing zone target and descent trajectory prediction to the CSBF team and through them the FAA the morning of the launch. The team will provide this information to Bill Stepp

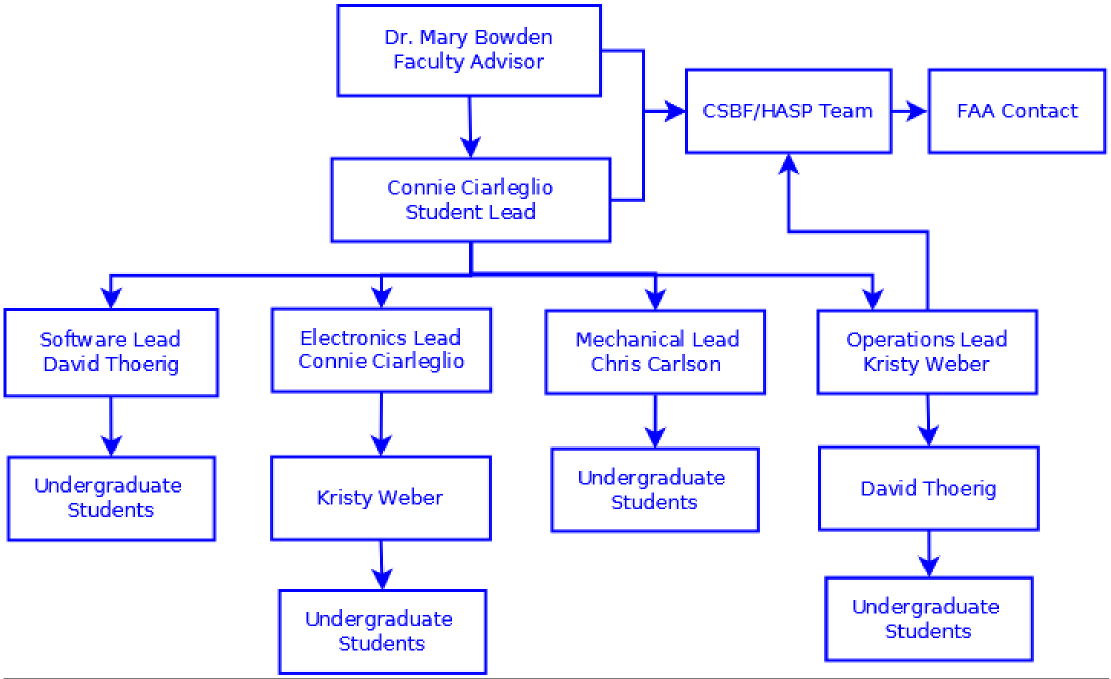
2. The StratoPigeon team will update the FAA, through Bill Stepp, as the balloon progresses at float altitude with descent trajectory predictions.
3. At 30 minutes prior to release, the StratoPigeon team will inform Bill Stepp and the FAA of impending release and the final descent prediction. The team will then wait prior to release for confirmation and go ahead.
4. The StratoPigeon payload will be configured and tested 15 min prior to release. Communications functionality using internal battery power and repeater testing will be the primary objectives.
5. If the release is unsuccessful, repeated attempts will be made until the drop window has passed. A successful drop will be confirmed through communications telemetry and CosmoCam live video.
6. The payload will be monitored and tracked by the UMD chase team until landing, with notifications to the FAA at any desired altitudes. Notifications at 60,000 and 30,000 ft will be used as the preliminary notification altitudes.
7. The UMD team will contact CSBF when the location of the payload on the ground has been confirmed. The team will contact CSBF for land owner information and go-ahead to contact the landowner for payload retrieval.
8. The team will retrieve the payload and return to base.

Flight Path Prediction

During the 2010 prototype flight, the StratoPigeon used flight path prediction software called BalloonTrack for payload trajectory prediction. The use of this software was both successful and accurate in the prediction of the landing zone for the payload as seen in the following figure showing both the predicted descent trajectory (yellow) and the actual path (green):

The StratoPigeon team will use the same software for the 2012 flight for predictions and ground operations.

Team Structure and Schedule



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Schedule

January:
- -Discussion with research teams and modification to payload design
- -Electronic PCB design (1st revision board ordered)
- -1st revision mechanical design completed
- -Funding received

February:
- -Electronic PCB's population and testing
- -Electronic PCB 2nd revision design and order
- -Orders placed for CPU, radios, and SSDs
- -Begin mechanical system construction
- -Contact with science team for coding and system integration

March:
- -Begin software design and coding
- -
- -Complete 1st revision mechanical construction
- -Populate and test 2nd revision electronics PCBs

April:
- -Allow extra time for mechanical and electronics subsystem completion
- -Coding

May:
- -Coding

June:
- -Coding
- -Begin system testing
- -Test with science payload over network connection

July:
- -Coding
- -Continue system testing and integration

August:
- -Attend HASP integration and test with attached science payload
- -Fix code

September:
- -Flight

Special Requests

In order to test the final payload configuration, the StratoPigeon payload will need to be released from the HASP gondola. Permission from the FAA, CSBF team, and HASP team is requested to perform this procedure and send a student tracking team to recover the payload.

The UMD team would also like to utilize other payloads on the HASP 2012 flight for research data generation. A notice to other payloads about the test opportunity and availability of the 2012 accepted proposals is requested for early integration purposes of the science team and StratoPigeon payload.

The UMD team would also like to work with the CSBF RF team to place a ground and flight antenna for the 900 MHz system aboard StratoPigeon. In order to fully test the repeater functionality of the balloon and its usefulness for transmission of payload location back to base, an antenna is required on the balloon itself and a directional ground antenna placed pointed at the HASP gondola during flight. The team would be using a configuration identical to that used in the UMD 2008/2009 flights. The ground station antenna used would be a 900 MHz Yagi with 14 dBi of gain and beamwidth of 30°. The UMD team would like to mount this antenna and radio to the CSBF S-Band dish to take advantage of continuous pointing directly at the balloon. The team will be discussing this option with CSBF/HASP personnel as the semester progresses. The on board antenna would consist of a thick coaxial cable (likely stranded RG-8) attached to the antenna, likely a quarter wave element with ground plane. This configuration was very successful in 2009 and caused little interference with other antennas and communications systems. Again, the UMD team would like to continue to talk with HASP/CSBF about this configuration, and to obtain permission to utilize this configuration, as the semester progresses.

Preliminary Flight Operation Plan

Three StratoPigeon team members would be required to perform the flight tasks. Two members make up the remote tracking team for the payload. The remaining member remains for base operation, including relaying payload position to CSBF personnel, monitoring the base station communications system, and giving any required commands. Most functions of the payload will be automated and the payload system simply needs to be monitored for any deviation. Commands such as payload release will be performed manually.