A Multiple Payload Carrier for High Altitude Ballooning

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Professional scientific or technical experiments can take three to five years and several million dollars to develop as a standalone balloon payload. Experiments that are low mass and have limited power and telemetry requirements could be clustered on a single balloon payload carrier that provides a standardized power, telemetry and physical interface for each experiment. Such an approach reduces the payload development overburden, so the investigator can focus exclusively on experiment, or subsystem, development and, consequently, can reduce experiment cost and improve turn-around time. Here we report on our experience with the High Altitude Student Platform (HASP), the first balloon carrier specifically designed with a standard interface to support up to 12 independent experiments per flight and the lessons-learned that are applicable to future multiple payload balloon platforms.

I. Introduction

A complete balloon payload generally includes custom systems for conditioning, distributing and controlling power, downlink of experiment monitoring data, uplink of control commands, mechanical structure, interfacing with balloon vehicle tranceivers and ground systems for data handling and experiment control. A group unfamiliar with balloon payload requirements could take several years and millions of dollars to reproduce these custom systems, and even an experienced balloon group will still need a year or two to refurbish and adapt old hardware / software to a new experiment. The only choice a research group may have for a large aperture, heavy instrument may well be to develop the experiment as a dedicated balloon payload. However, for smaller packages, lightweight instruments developed by different research groups could be clustered on the same platform and flown as a single balloon payload. The advantage to this approach is that the research group can focus exclusively on the instrument, reducing the resources needed for developing, fabricating and testing payload support systems, and, thereby, minimizing overall instrument cost and improving the turn-around time.

The High Altitude Student Platform (HASP) is the first balloon payload specifically designed to carry multiple independent experiments during one balloon flight and was developed at LSU in 2005 to address a looming crisis in training the next generation of aerospace scientists and engineers. Over the last decade numerous studies, such as the Walker report on the future of the U.S. aerospace industry[1] and the Aldridge Commission report[2], have identified the declining number of students entering the workforce as engineers and scientists as a major U.S. national security and economic issue. As a response, a number of programs enabling students to be directly involved in the design, construction and operation of aerospace payloads ranging from simple balloon experiments[3] to compact Earth-orbiting satellites[4] were developed in order to attract and retain students in science, technology, engineering and mathematics (STEM) careers. These programs help students acquire practical skills, develop experience with a project life-cycle and participate in the exciting launch and flight operation of their payload. The easiest program to establish involves students developing small (~500 g) payloads that are carried to an altitude of about 30 kilometers by helium filled sounding balloons[3]. Sounding balloon flights have limited duration (~30 minutes above 24 kilometers) and payload weight, restricting the kinds of investigations possible. Student built micro-satellites can be placed in low Earth orbit for extended flight duration, but at significant cost and with flight scheduling constraints.

HASP was originally conceived to provide student groups with access to the near-space environment for flight durations and experiment capabilities intermediate between what is possible with small sounding balloons and low

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Earth orbit rocket launches[5]. Further, the platform was developed to carry multiple student payloads to an altitude of ~36 kilometers for flight durations of 15 to 20 hours. The HASP program has operated as a partnership between the Louisiana Space Consortium (LaSPACE) and NASA Balloon Program Office (BPO) since it was established and included development support from the Louisiana Board of Regents with flight operations carried out by the Columbia Scientific Balloon Facility (CSBF). To date, HASP has flown four times with two more flights scheduled for September 2011. A multiple payload balloon platform, similar to HASP, might have application to the scientific and engineering research communities beyond student training programs. In this paper, we will describe the HASP system, the standard student payload interface, the HASP flight history and our experience with the platform.

II. The High Altitude Student Platform

The HASP system, shown in Figure 1, uses a ~12 million cubic foot, thin film polyethylene, helium filled balloon to carry multiple student built payloads to altitudes of ~36 km for durations of ~17 hours. The upper part of the system is the unit, labeled HASP in Figure 1, which supports a total of twelve powered student payloads. Figure 2 illustrates the location of the multiple payloads in a top-down image of HASP prior to launch. Eight of the twelve payloads, classified as "small", are mounted on 55 cm long fiberglass outrigger booms. These booms minimize interference between the metal frame and any student payloads that may exercise data transmitters during flight, as well as maximizing the unobstructed payload field of view (FOV) including the nadir direction. Mounting plates for four large student payloads are located on the top of the HASP aluminum frame structure.

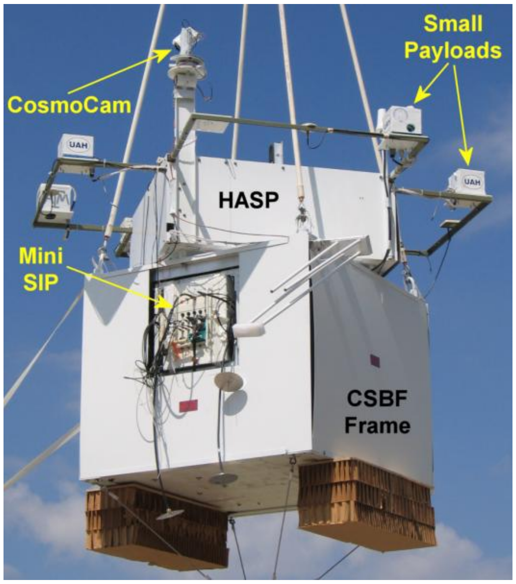

Figure 1. The HASP platform designed to carry complex student payloads.

Located within the upper unit frame is the HASP command and control system which provides the means for receiving and processing uplinked commands, monitoring the power system, collecting a telemetry bitstream from each student payload, archiving these data and passing it on for downlink to the ground, downlinking status and housekeeping information, controlling the student payloads and passing along commands uplinked to the payloads. Further, the lithium cells that supply power to the HASP systems and student payloads are also housed here.

The lower part of the HASP system is the CSBF Frame (see Figure 1) which provides support for the Mini Support Instrument Package (Mini-SIP) and attach points for suspension cables, crush pads and the ballast hopper. Suspension cables run from each of the four corners of the CSBF Frame to a pin plate that attaches to the flight train. The Mini-SIP provides the CSBF with control over the balloon systems, as well as HASP uplink and downlink telemetry. Within the CSBF frame are additional tie-down points where self-contained payloads, that require neither power nor telemetry from HASP, can be located.

Also included with HASP is the CosmoCam system provided and operated by Rocket Science Inc. (www.cosmocam.com). CosmoCam provides real-time views of the student payloads, the balloon and the Earth during launch, flight and termination (see Figure 3). In addition to live views from the edge of space, CosmoCam provides scientific value to each flight by monitoring payloads that physically change their configuration. In the lower right corner of Figure 3 the Montana cosmic dust experiment can be seen in the open state. As Montana wished to only collect dust from the upper atmosphere, this experiment is launched in the closed state and once float is reached the cover panels are opened. CosmoCam is used to visually verify the opening of these panels as well as panel closing prior to flight termination.

Figure 2. Top view of the HASP system showing location of the small payloads on booms and large payloads on top of the main structure.

One advantage in splitting the HASP payload system into two modules is that the student payload interfacing is isolated from the CSBF flight systems. We can integrate and operate the student payloads using only the HASP frame. The CSBF Mini-SIP and frame are not needed to test the individual payloads and the CSBF systems see only one interface regardless of the number and type of student payloads. The modularity is also useful if we need to change out / upgrade the CSBF flight systems. Such modifications are transparent to the student payloads as they continue to see only one interface.

In general HASP flights are scheduled once a year in September. Student groups wishing to fly on HASP need to submit an application in response to a "Call for Payloads (CFP)" which is usually issued in October. Applications are due in December and successful teams win a seat for the HASP flight scheduled for the following September. Further details about HASP are included in the CFP guidelines[6], which can be downloaded from the HASP website at http://laspace.lsu.edu/hasp/Participantinfo.php .

Figure 3. View from the edge of space recorded live during the HASP flight in 2008.

III. The HASP Student Payload Interface

A powerful feature of the HASP system is the standardized interface for all student payloads. Detailed specifications for the mechanical, electrical and data interface between HASP and a student payload are provided in the latest version of the document "HASP – Student Payload Interface Manual"[7] which can be obtained from the Participant Information page (http://laspace.lsu.edu/hasp/Participantinfo.php) of the HASP website and a summary of these specifications is shown here as Table 1.

As indicated in Table 1 the interface specifications for "large" and "small" payloads are slightly different. There are eight "seats" for small payloads each of which must mass less than 3 kilograms, while there are four "seats" for large payloads that can weigh as much as 20 kilograms per payload. The mechanical interface for a payload to HASP is a ¼" thick plate of PVC that includes holes for mounting the plate on the HASP structure, connectors for power and serial data plus a wiring pigtail for the student payloads and a payload "footprint" within which the student team can mount their experiment. The footprint for a small payload is 15 cm by 15 cm, while that for a large payload is a rectangle of dimensions 38 cm by 30 cm with truncated corners. The outer edge of the payload plate is a "keep out" area that extends 5 to 8 cm above the top surface of the plate. This "keep out" area is necessary to allow access to the holes used to mount the payload plate to HASP. Both small and large payloads are generally limited to a height of 30 cm, though an extension can be granted with an acceptable justification. In addition, above the keep-out volume a payload can exceed the footprint, but again only upon approval of a request with suitable explanation. Dimensional drawings of the payload plates are included in the Interface Manual[7] and the actual plate is shipped to the team shortly after their application is accepted for flight. Over the years, we have had very few student payload mechanical interfacing issues using this system.

Table 1: Payload Interface Specifications (v2008)

Specification:	Small Payload	Large Payload
Total number of positions:	8	4
Maximum weight:	3 kg	20 kg
Maximum footprint:	15 cm x 15 cm	38 cm x 30 cm
Maximum height:	~30 cm	~30 cm
Supplied voltage:	29 - 33 VDC	29 – 33 VDC
Available current:	0.5 Amps @ 30 VDC	2.5 Amps @ 30 VDC
Max. serial downlink:	<1200 bps	<4800 bps
Serial uplink:	2 bytes per command	2 byes per command
Serial protocol	RS232	RS232
Serial interface:	DB9	DB9
Analog downlink:	Two @ 0 to 5 VDC	Two @ 0 to 5 VDC
Discrete commands:	2 to 4	2 to 6
Analog & discrete interface:	EDAC 516-020	EDAC 516-020

Power is supplied by 11-cell lithium sulphur dioxide battery packs. Generally eight such battery packs supply all the power needs for the HASP control systems and all student payloads for the duration of the flight. The voltage supplied by these batteries is about 32 to 33 VDC during the start of the flight, dropping down to 29 to 30 VDC later in the flight. Thus, each student payload must handle a supply voltage in the range 29 to 33 VDC. The power for individual student payloads can be turned on or off through the HASP control system and is fused to prevent excessive current draw from affecting the rest of the system. Small payloads are allowed a maximum of 0.5 amps, while large payloads can consume up to 2.5 amps.

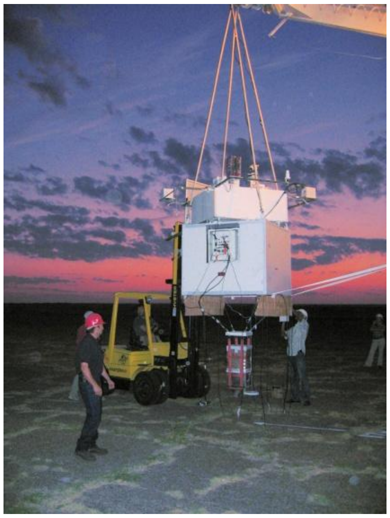

Figure 4. Pre-dawn preparation for HASP launch.

A student payload can downlink information to the ground and have commands uplinked to the payload over a serial data interface that uses the RS232 protocol over a DB9 connector. The serial bandwidth available to small payloads is limited to 1200 baud while that for large payloads must be less than 4800 baud. HASP collects data from the student payload as a bitstream: listening for and receiving data until the internal buffers fill, then packaging this buffer as a record for on-board archiving and telemetry to the ground system. Once the data stream is received by the HASP ground system, the stream is split into individual payload records, unwrapped and written to disk in the order the bits were received from the payload. The downlinked data from each payload is stored in separate files that are sized so that they fill about every 10 minutes. These files can be accessed and downloaded from the HASP website over the internet. Thus, student teams do not need to be on the flight line in order to monitor their experiment in near real-time.

It is also feasible to uplink a two-byte serial command to individual payloads. Any number of two-byte commands can be defined, but each command is entered into the ground system and uplinked separately by a HASP operator. As the same serial port is used for both downlink and uplink, the payload must periodically check the port to determine if any commands are being uploaded. Each payload must check for its own command validity as HASP merely passes the two byte command along regardless of content.

The student payload interface also includes two 0 to 5 VDC analog downlink channels. These channels are digitized and transmitted by the Mini-SIP systems every minute to provide real-time monitoring of two key payload parameters. These monitoring channels are available even if the payload does not use the HASP serial data interface. As these analog channels do not pass through the HASP data system, they are only available through the CSBF ground systems on the flight line and are not recorded.

Discrete commands are generally used as “hardware switches” to control critical, basic functions. They are transmitted to and routed through the Mini-SIP via highly reliable systems. Every payload has, as a minimum, two discrete commands assigned to (1) turn on and (2) turn off the payload power. Large payloads have an additional four discrete commands and some small payload seats have an additional two commands. Such commands are used, for example, to open / close aperture doors or chamber covers, heat motors prior to use, or boot control computers.

The standard interface described here has proven to be relatively simple to implement and verify, yet sufficient to satisfy almost all the needs of student payloads. This interface, however, can be enhanced by including “HASP services” that would provide additional capabilities for the student payloads. For example, in 2009 we implemented a GPS service. For this service a student team can request that HASP send GPS time and position data records to their payload at a pre-determined rate throughout the flight. At the given interval, HASP transmits a defined record that includes the NMEA GGA position data string obtained from the HASP GPS unit to the payload serial port. The payload has the responsibility to acquire this GPS record and decode the embedded GGA string to obtain the GPS time, latitude, longitude and altitude for their use. The simplest implementation of this service allows payloads to obtain a time accuracy of at least one second, but sub-second accuracies are feasible[8]. Other services that might be implemented in the future include azimuth pointing information and attitude orientation.

Figure 5. Balloon inflation is underway while HASP is performing a final check-out just prior to launch.

IV. HASP Flights

HASP, developed in 2005, had its first launch from the CSBF facility in Ft. Sumner, New Mexico on September 4, 2006. Full details about the HASP 2006 payload, flight and flight behavior are documented by Guzik et al, 2008[5]. Since this first flight we have had three more launches (2007, 2008 and 2009) and all four flights have, more or less, followed a typical pattern.

A flight cycle starts with integration of the student payloads with HASP, usually scheduled during the first week of August. During the first two integration days, the mechanical, power and data interfaces with each student payload are verified. Depending upon the student team experience / preparation and payload complexity, interface verification can take anywhere from 30 minutes to several days. On the third day, the HASP unit and integrated payloads are installed within the CSBF thermal / vacuum chamber and subjected to a temperature range of -65 °C to +65 °C and pressures as low as a few mbar for several hours. Each student team needs to show that their payload operates correctly during the thermal / vacuum test in order to be certified for flight. If this test is failed then the team has the fourth day to resolve the issue before a final thermal / vacuum test scheduled for the fifth day. If a student payload fails the second thermal / vacuum test then that payload is “not flight certified”. Since HASP is designed for student training, a payload must be a safety hazard before we refuse to fly it. Instead we allow the student team “funding agency” (in many cases this is the state Space Grant office) to make a decision as to whether to allow the team to proceed to flight. Following this integration and system testing, HASP and student payloads are packed up and shipped to Ft. Sumner.

Flight operations at Ft. Sumner typically begin toward the last week in August. The first few days involve a recheck of HASP followed by integration with the CSBF frame and Mini-SIP. After the communication links between HASP and CSBF are verified, student payloads are reintegrated if necessary. A complete compatibility test with all balloon systems, including “hanging” from the launch vehicle, is performed toward the end of the first week and the flight readiness review (FRR) is conducted almost immediately after the “hang test” is complete. If no issues are uncovered during the FRR then HASP is certified to fly. At this point we wait for an appropriate launch opportunity, i.e. low winds at the surface and up to about 1000 feet altitude combined with reasonably low high altitude winds.

Figure 6. HASP on climb out following launch.

On a launch attempt day, operations generally begin several hours before dawn. The HASP system is checked for correct operation, rolled out of the hangar and attached to the launch vehicle, ballast hopper, flight train and parachute. The launch vehicle then carries HASP out to the flight line where the flight train is laid out and the HASP systems are again checked. Figure 4 shows HASP on the flight line undergoing a final status check during early morning hours prior to launch. If all continues to go well and the launch weather holds, then the balloon is unpacked, laid out and inflation begins. HASP uses an 11 million cubic feet zero-pressure balloon and inflation typically takes about 35 to 40 minutes. Figure 5 shows a view with HASP hanging from the launch vehicle with the balloon being inflated in the background. Launch occurs shortly after the balloon is filled and usually takes place early in the morning. Figure 6 shows the HASP balloon vehicle immediately following launch on its way up to float. Typically it takes about two hours for HASP to reach its float altitude of about 120,000 feet.

Figure 7. Ground track of the 2009 flight of HASP from launch in Ft. Sumner, NM to landing somewhat west of Phoenix, AZ.

We generally try to launch HASP a bit before turn-around in Ft. Sumner so that the prevailing winds at high altitude are still blowing from east to west yet are moderate in speed. This allows us to have a fairly well defined ground track across New Mexico and Arizona while having a low speed to maximize time aloft. A typical ground track under these conditions is shown in Figure 7 for the 2009 flight of HASP. These conditions usually occur during the beginning of September and, consequently, we avoid impacting science flights which generally fly during turn-around in mid-September.

The altitude versus time profile for the HASP flight in 2009 is shown in Figure 8. This was, in fact, the shortest HASP flight with only about 12 hours at float. The longest flight occurred the previous year in 2008, and the corresponding flight profile is shown in Figure 9. In this case, HASP was launched later in September and fortuitously hit turn-around conditions almost exactly. During this flight, once HASP reached its float altitude of about 36 kilometers the winds were light and variable resulting in HASP staying in the vicinity of Ft. Sumner for the rest of the day. In fact, the HASP balloon was still visible by dawn of the next day. This flight was exceptionally long, with close to 32 hours at float, and will very likely not be reproduced in the near future.

With four flights, HASP now has a total of more than 75 hours at an altitude of about 36 kilometers. Thus, the average float duration per flight is about 18 hours. During this entire period of time the HASP control system has behaved flawlessly providing constant communication with all student payloads and monitoring of the HASP system itself.

Following flight termination, recovery of HASP is usually accomplished with little damage to the structure and most student payloads survive intact. Figure 10 shows HASP after landing following the 2009 flight. Part of the CSBF preparation for flight involves threading the suspension cable through a long PVC pipe in order to minimize the chance that the pin plate and flight train collapses onto and damages the payloads located on top of HASP. As can be seen in the figure this strategy appears to work well and many of the outrigger beams and student payloads have survived landing.

HASP was also scheduled to fly in September 2010 and a cohort of student payloads were accepted for flight and integrated. Unfortunately, an investigation into a balloon launch mishap that occurred during the spring of 2010, took longer than expected and, consequently, the fall 2010 flight campaign had to be canceled. These student payloads are now scheduled for launch during late August 2011. Further, a set of new payloads were also selected for 2011 and are scheduled for an early September 2011 launch. Attempting to launch, recovery, flight-line refurbish and launch again within the time period of little more than a week will be an interesting experiment. However,

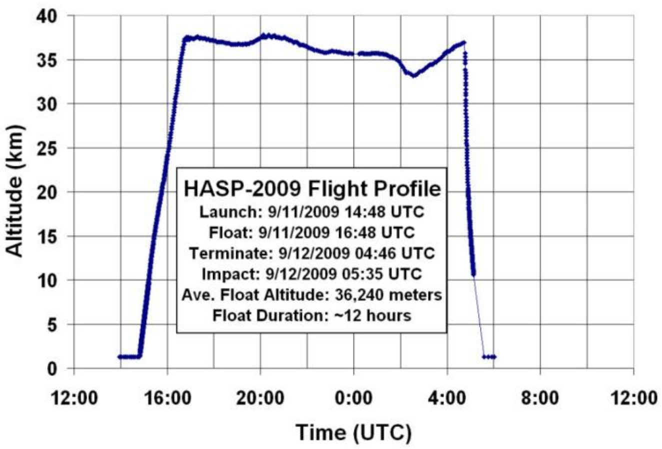

Figure 8. The altitude in kilometers versus Universal Time profile for the 2009 flight of HASP.

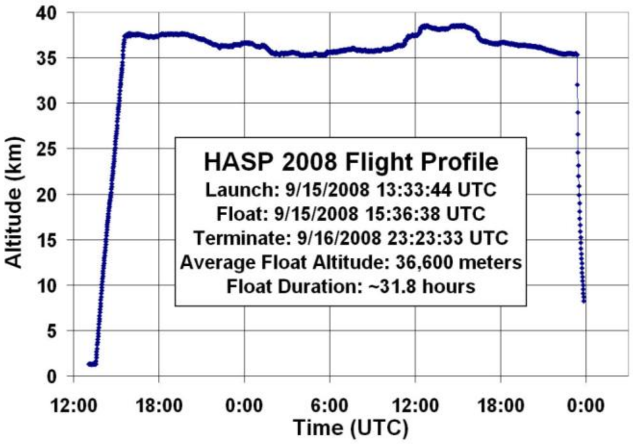

Figure 9. The altitude in kilometers versus Universal Time profile for the longest HASP flight on record.

Figure 10. Recovery of the HASP payload following its 2009 flight.

the previous flights have shown that the HASP systems are very robust and give us confidence that a quick turn-around on the flight-line is possible. Successfully completing multiple flights of HASP during a single campaign opens the possibility of flying twice the number of payloads during a given year. Alternatively, the number of payloads per flight could be reduced allowing the resources available per payload to grow. With two flights per campaign there would still be a total of four “large” payloads, but for each flight two large payloads could mass 40 kg each and have twice the footprint.

V. The HASP Student Payloads.

Over the course of the HASP program the number of payloads flown and students served has steadily increased. The states shaded in green in Figure 11 are those that have contributed student teams to the HASP program. Currently this includes 14 continental U.S. states plus Puerto Rico. Starting in 2011 we have also opened participation to international student teams and the University of Alberta in Canada is providing the first such team. The number of different institutions within the participating state contributing student teams and payloads to HASP is also indicated in Figure 11. Thus, there are 27 independent institutions across the country that have used HASP as part of their student training program.

The payload statistics for each flight from 2006 is shown in Table 2. The first two columns of the table list the launch date and float duration. The HASP 2010 and HASP 2011 flights are scheduled for late summer 2011 so their tentative launch dates are shown as bold italic and the flights, obviously, have zero hours at float. The next column lists the number of undergraduate and graduate students involved in the design, development, flight operations and data analysis of HASP payloads for the given flight year. Finally, the last three columns indicate the number of payload applications **accepted** for flight, the actual number **flown** during the flight and the number of payloads that experienced **success** during the flight. Two sums are provided in the table: the sum only over completed HASP flights and the sum for the entire program since 2006.

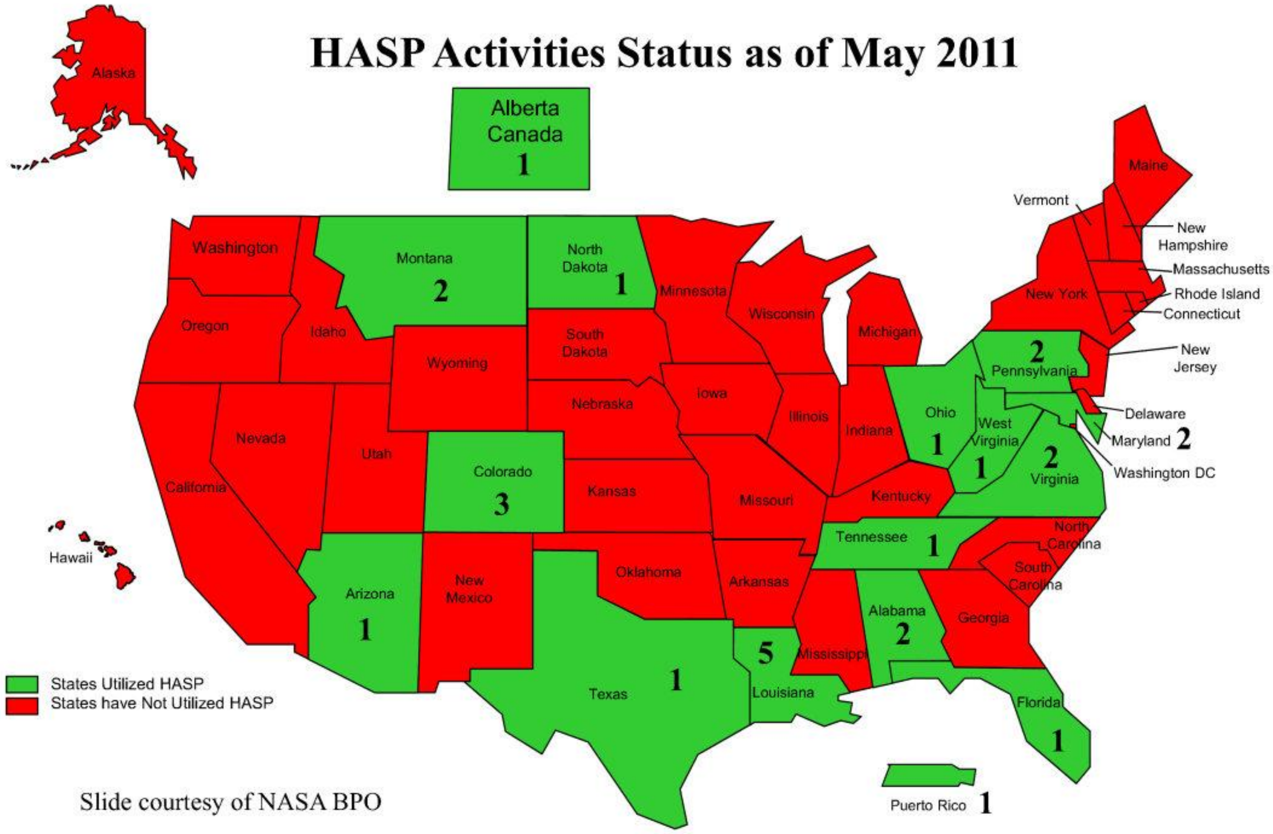

Figure 11. States that have utilized HASP as a student workforce development project are indicated by the green shading. In addition, the number of institutions within the state that have contributed student teams is indicated by the bold number in or near the state. Finally, note that our first international student team from Alberta, Canada will be participating on HASP 2011.

Table 2: Student Payloads Accepted, Flown and Successful During HASP Flights

Year	Launch Date	Float Duration (hours)	Students	Payloads		
				Accepted	Flown	Success
2006	September 4, 2006	15	25	8	8	6
2007	September 2, 2007	16.5	70	11	10	8
2008	September 15, 2008	31.8	96	13	12	6
2009	September 11, 2009	12	50	10	6	6
Total 06 to 09		**75.3**	**241**	**42**	**36**	**26**
2010	***August 29, 2011***	0	57	10	0	0
2011	***September 6, 2011***	0	70	11	0	0
Total 06 to 11		**75.3**	**368**	**63**	**36**	**26**

The number of payloads accepted for a flight are those applications that survived the initial review and were assigned a seat on the HASP flight. Note that some payloads are self-contained, requiring no power or telemetry support from HASP. Thus, there are some cases (e.g. 2008) where more payloads were accepted than there are supported seats. To date, a total of 63 payloads have been accepted for flight on HASP and 42 were accepted for HASP flights from 2006 to 2009.

The number of payloads flown on a flight are those payloads that were finally attached to HASP when it was launched. For the 2006 through 2009 flights, this includes 36 payloads or about 86% of the payloads originally accepted for flight. A few teams have organization problems during the academic year and withdraw from the flight prior to the summer. Most teams, however, proceed to integration and thermal / vacuum testing at the beginning of August, but for about 50% of them some kind of problem is uncovered. In these cases, LaSPACE and CSBF technical personnel lend a hand to mentor the student teams and help them resolve their problems. Many of these issues are resolved prior to the second thermal / vacuum test, but a few still need to take their payload back to their home institution to continue work. Since there are only a couple of weeks between the end of integration and the start of flight operations, the student teams do not have much time to ready their payload for flight. In an effort to improve the number of flown payloads, we now offer preliminary thermal / vacuum testing in May. This provides student teams with an initial check of their systems and two months to resolve issues prior to HASP integration.

Table 3: Generalized Topics of Investigations by HASP Payloads

Topic	Number
Attitude Determination Prototype Systems and Components	5
Biological Sampling and Testing	2
Capture and Analysis of Stratospheric Dust	3
Various Investigations of Cosmic Rays	9
Testing of Various CubeSat Prototype Subsystems	6
Development of a Gamma Ray Burst Detector	1
Testing of an Infrared Detector Prototype	1
Magnetic Field Prototype Sensor Testing	2
Investigations using a Microwave Detector	2
Studies of Using Optical Telescopes on Balloon Platforms	5
Radiation Detector Prototype	3
Radio Telemetry System	2
Recoverable Data Capsule Prototype Test	3
Remote Sensing Investigations	6
Rocket Engine Nozzle testing	2
Solid State Ozone Sensor Prototype Testing	4
Student Training	3
Thermal Imaging of the Balloon	5

The primary mission for HASP is in the area of student training, so payload “success” is defined in somewhat looser terms than that for a usual scientific experiment. In particular, we define a payload to be successful if at least 50% of the sensors proposed for the payload obtain analyzable results for at least ¼ of the balloon time at float. This criterion is the minimum necessary for the students to analyze the performance of their payload and gain a sense of accomplishment. In this context, somewhat more than 70% of the payloads flown are successful.

Finally, close to 370 students have been or are currently involved in some aspect of a HASP payload. This averages to be about 6 students per team or about 70 students per year. HASP is intended as an advanced program, so these students are at the university level and are a mix of undergraduate and graduate students. Most undergraduates are in the program to gain experience with aerospace projects, but three graduate students gained their Masters degree based upon their work with a HASP payload and at least one Ph.D. candidate is planning to base her dissertation work on the future flight of a payload.

Table 3 indicates the kinds of investigations proposed for HASP by the student teams. Almost all HASP investigations can be categorized under one of these generalized topics and the table includes the number of payloads considered to be in that category. For example, the nine applications proposing to investigate some aspect of cosmic rays include different payloads using nuclear emulsion detectors, Geiger-Muller tube detectors and plastic scintillator detectors. The topics investigated by HASP range from engineering studies of the performance of different rocket nozzle types to scientific measurements of stratospheric ozone and dust. In many instances HASP is used to test prototype subsystems developed for student-built low Earth orbit micro-satellites and "space test" other sensors or systems that may eventually find their way onto other balloon or satellite vehicles. One interesting concept from a University of Maryland student is a high volume (several terabyte) recoverable data capsule that could be part of a future 100-day ultra-long duration balloon (ULDB) mission. Several data capsules would be included on such a mission and would archive data from the ULDB experiment at a much higher data rate than can be effectively transmitted back to the ground. Upon command from the ground a data capsule would be ejected and recovered enabling scientists to have a complete record of the experiment data up to that point while the ULDB vehicle continues on its way. This data capsule concept will be tested for the first time on HASP 2010 in August 2011. There are also several attempts to develop attitude determination systems (ADS) for balloon vehicles as well as micro-satellites. The attitude knowledge provided by an ADS on HASP could be particularly useful for helping remote sensing and astronomical telescope / camera experiments "point" to a particular object. We expect that future HASP missions will continue to carry similar kinds of experiments developed by students across the world.

VI. Conclusions

The High Altitude Student Platform (HASP) is into its sixth year of operation providing regularly scheduled near-space flight opportunities for university level student teams. HASP has completed four successful flights from 2006 through 2009 and two more flights are scheduled for late August / early September 2011. HASP is the first balloon platform specifically designed to carry multiple payloads using a standard interface that includes mechanical, power and telemetry specifications. The HASP flight system supports the needs of the multiple payloads and presents a single interface to the balloon vehicle control systems. This modular design enables modifications to the balloon vehicle to be transparent to the payloads and the detailed handling of the multiple payloads to be isolated from the balloon vehicle. During its more than 75 hours at float over four flights, the HASP flight control system performed flawlessly monitoring its environment, controlling the student payloads, providing payload data over the internet in near real-time and, as necessary, uplinking commands to change payload configuration. To date, more than 60 payloads have been accepted for flight on HASP and almost 370 students across multiple disciplines have been involved in some aspect of a HASP student payload. In addition, HASP is a model for how a similar multiple payload balloon platform for professional scientific instruments might be developed and operated. Our experience with HASP indicates that such a platform is feasible and the HASP designs could be scaled up to support heavier experiments and higher telemetry bandwidths.

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