HAATT-TRIC

Science Report

UMD HASP 2018

UMD Nearspace Program
University of Maryland College Park
Space Systems Laboratory
HASP

Funding provided by the Maryland Space Grant Consortium

Contents

Nomenclature

ADC:Analog-to-Digtial Converter
BPP: Balloon Payload Program
Balloonduino: Ballooning Arduino Mega (developed by Camden Miller, UMDBPP)
CAT: Clear Air Turbulence
COTS: Commercial Off-the Shelf
CVA: Constant Voltage Anemometer
DAS: Data Acquisition System
DRS: Data Relay System
FISH: Standalone HAAT payload
HAAT-TRIC: High Altitude Atmospheric Turbulence - Triggered Release Information Carrier
HAPL: High-speed Aerodynamics and Propulsion Laboratory
HASP: High Altitude Student Platform
HYSPLIT: Hybrid Single Particle Lagrangian Integrated Trajectory
MARS: Mechanically Actuated Release System
MCU: Microcontroller Unit
MdSGC: Maryland Space Grant Consortium
PCB: Printed Circuit Board
PM: Particulate Matter
PWM: Pulse-Width Modulation
UMD: University of Maryland (College Park)

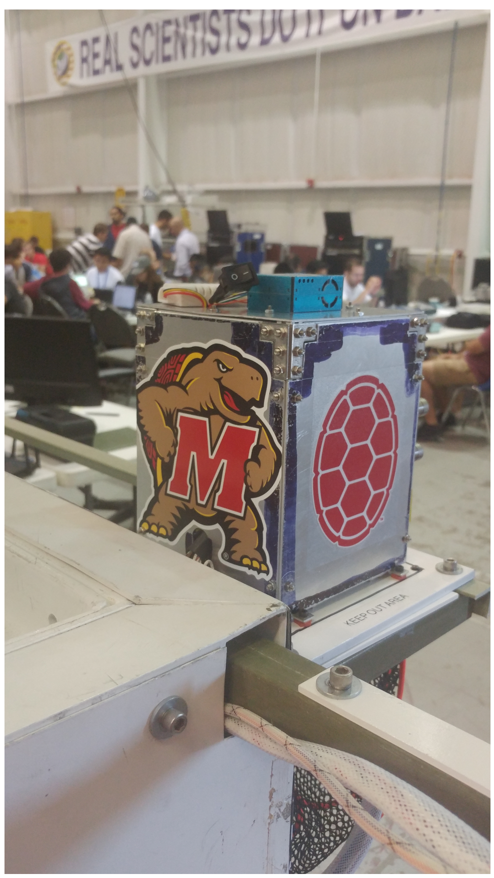

Figure 1: Payload integrated on HASP pallet outrigger

1 Mission Statement

The University of Maryland Balloon Payload Program (BPP) and the UMD High Altitude and Propulsion Lab (HAPL) collaborated for a second year in 2018 to develop a scientific payload, HAAT-TRIC, to measure turbulence in the upper atmosphere. This payload is split into two major subsystems. The first subsystem, HAAT, was designed to measure random acoustic fluctuations with three microphones extended from the payload. This data would allow for better characterization of CAT (Clear Air Turbulence) in the upper stratosphere, in an effort to aid the development of hypersonic vehicles that will operate at these altitudes. The other subsystem, TRIC, is a proof of concept data drop module that will store data until commanded to drop, severing all connections with the main payload and then dropping into a hanging net. An actual drop could be performed on long duration balloon flights to retrieve data well before balloon termination and recovery.

The relevance of CAT to hypersonic flight comes from the potential for freestream disturbances to excite unstable modes within the boundary layer. These modes then proceed to amplify as they travel downstream before eventually breaking down into turbulent spots, which coalesce into a turbulent boundary layer [1]. Large rises in surface heating and mechanical loading have been found to accompany boundary layer transition [2], meaning that effective vehicle design requires the ability to accurately predict the onset of transition.

This prediction is, however, easier said than done, as transition depends on many factors, including the freestream disturbance type (acoustic, vortical or entropic), intensity and frequency [3]. Transition data obtained from traditional ground-testing facilities cannot be extrapolated to flight performance, as these facilities typically generate significantly stronger freestream disturbance environments than those actually observed in the stratosphere [4] [5]. Numerical techniques for predicting in-flight transition location are entirely dependent on the assumed disturbance amplitude [6]. Accurate predictions therefore necessitate accurate information regarding the disturbance environment in flight. Unfortunately, literature on the disturbance levels in the mid-to-upper stratosphere is sparse. This provides the fundamental motivation behind the design of the HAAT subsystem. Until this knowledge gap regarding CAT is filled, high fidelity transition predictions for hypersonic vehicles will remain impossible despite the existence of advanced computational tools.

Our efforts in the 2017 HASP campaign focused on measuring the vorticity and entropy components of the stratospheric disturbance environment, leaving only the acoustic (pressure) flow disturbances left to be examined. The scientific objective for the 2018 version of the High Altitude Atmospheric Turbulence (HAAT) subsystem was thus to measure the random fluctuations in pressure that occur in the upper stratosphere. This data could be decomposed into magnitude and frequency components, which are the characteristics needed for predicting how disturbances will affect a hypersonic boundary layer.

Successful operation of the HAAT subsystem would have yielded a general characterization of the acoustic (pressure) fluctuations at the float altitude of a typical HASP flight, which may then serve as input to flow physics models for higher-fidelity transition prediction. Regrettably, communication issues arose between the subsystems of our payload during flight which prevented the data acquisition system from triggering, as will be discussed further. Thus, the flight must be largely categorized as a failed attempt for gathering acoustic data.

Many long duration balloon (LDB) flights can last anywhere from one week to nearly 100 days, with limited ability for data to be downlinked throughout the duration of the flight [8]. This means many payloads only radio down the most important status signals to ensure that their payload is properly functioning. This prompted the idea for a data module that can record data throughout the first part of a flight, and then be disconnected and dropped early enough into the flight to allow personnel on the ground time to process early data to ensure the payload is functioning as designed. If data problems are detected with the data dropped early, it may still be possible then to figure out what is wrong and adjust the payload configuration so that the entire flight is not wasted on meaningless data.

The idea of this droppable data module originated with some early HASP experiments flown by the UMD BPP on HASP 2008 through HASP 2012. In 2008 and 2009, the BPP investigated communicating directly with a payload mounted on the HASP pallet, including various antenna configurations, radio characteristics, and the use of a GPS receiver on the payload. Then in 2010 through 2012, we developed and dropped a module called StratoPigeon that would accumulate data for a few hours into the flight, and then, in response to a command from the ground, the StratoPigeon Module would release itself from the HASP outrigger, deploy a parachute, and descend to the ground for recovery. In order to accomplish this successfully, StratoPigeon needed to contain a full tracking system (GPS receiver and radios) so that the tracking team could follow its descent and recover the module separately from the rest of the HASP system. This was accomplished successfully on HASP 2011, but unfortunately the HASP 2012 stratoPigeon was lost. After a 5-year hiatus (and with a completely new complement of students), UMD flew last year the first HAAT-TRIC payload that included some new sensors for testing (thin-film anemometer probes for velocity/temperature measurements and a dust sensor), a new drop mechanism (using 2 linear actuators instead of a single rotational one), and custom data logging and data transfer electronics that are all new. This year, the datalogging has been redone to utilize COTS boards, and the primary scientific instrumentation has been changed to a suite of microphones.

2 Mission Requirements and Description

In order to meet the payload objectives above, there were many engineering challenges imposed on the project. These included fitting all of the required items in the payload footprint, designing custom electrical hardware to store payload data, sending down telemetry signals of the payload status, and designing a drop mechanism that disconnected but did not fully release the drop module. The initial design requirements for HAAT-TRIC are summarized in Table 1.

Item	Requirement
Voltage	30 V
Amperage	0.5 Amps
Mass	3 kg
Footprint	15 cm x 15 cm
Height	30 cm

Table 1: Initial Design Requirements

Due to the fact that the microphones needed to be extended out into the air, ideally outside the wake of the balloon and experiments, it was important that HAAT-TRIC be mounted on an outrigger boom, which meant that it was classified as a “small payload” with a smaller payload size and power allocation.

Had HAAT-TRIC remained entirely within the given payload footprint for small payloads, the microphone data would likely have been compromised by turbulent air effects from the wake of the balloon and other payloads. In order to mitigate this and reduce the potential for data corruption, the microphones were extended outwards. In order to locate the data drop module below the HASP payload plate so it could drop, our initial proposal asked for 20 cm below the payload plate. In order to constrain the drop module to the payload footprint and not lose it once dropped, a mesh basket (made of polyester cargo netting) was attached around the outside of the allowable payload area to catch the drop module once it dropped. This net was attached to the main payload plate via four standoffs that ran up through the mounting plate.

The payload this year utilized the serial downlink capabilities of the HASP interface in order to monitor the status of the payload. Uplinked commands were able to test serial connection, retract or extend the actuators for the drop module, and trigger the data acquisition system (DAS) to begin data logging. Downlinked status messages told the status of the actuators and DAS.

With the success of last year's dust sensor and the interesting results it returned, HAAT-TRIC also included an upgraded version of the the unit as part of this flight. The unit was designed to be completely independent of the rest of the payload for ease of installation. The dust sensor needed air flow through it, and therefore needed to be mounted on the outside of the payload. In order to conform with payload size requirements, the top of the box was stepped such that the dust sensor could fit there for the additional airflow. The payload measured temperature, atmospheric pressure (station pressure), and dust concentrations (in terms of particulate matter). Fundamentals for the payload (i.e. hardware, sampling rate) were based on UMD HASP 2017's dust experiment. Unlike that payload which only provided information that atmospheric dust was present, HASP 2018's sensors were able to pinpoint concentrations of different size particulate matter.

Last year, the PLA/ABS plastic that made up the main structure of the payload warped during the flight, resulting in significant structural damage. This year the payload was made out of sheet metal for durability and because of plenty of weight margin. Given that the primary source of scientific data was expected to be the microphones, the layout of HAAT was based almost entirely around ensuring they could be configured facing out into the freestream air.

3 Payload Design

The final design of the payload contained three separate components: HAAT, TRIC, and the drop module. As seen in Figure 2, HAAT was mounted above the payload plate, with TRIC and the drop module located below. HAAT was attached to the payload plate with a set of mounting screws. TRIC was attached by standoffs, with the catch net fixed by loops at each corner around the standoffs. The drop module then had two mounting rings which inserted into a slot in the TRIC plate. Linear actuators on the TRIC plate extended through the two mounting rings to hold the drop module in place. Lastly the Micro-USB cable which was to transport data from HAAT was fed through the payload plate and TRIC to reach the Drop Module.

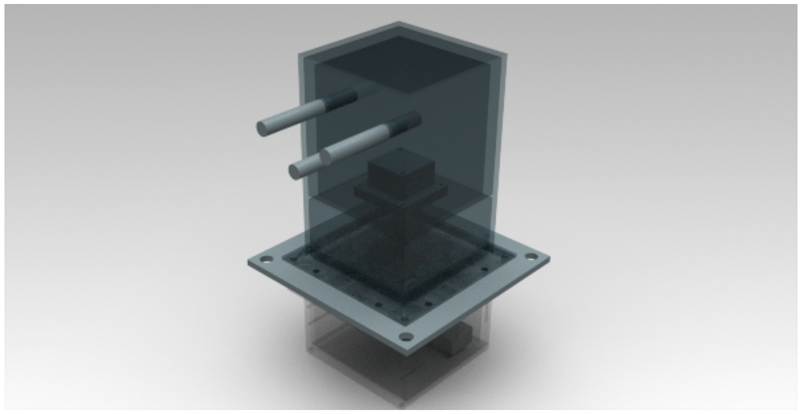

Figure 2: CAD rendering of HAAT-TRIC

As the microphones drew little power, the entire system was powered off of HASP power as opposed to using a significant quantity of batteries as in 2017. A power budget can be seen in Table 2

Item	**Mean Current (MA)**	**Peak Current (MA)**
Microphones	5.5	25
DAS	40	52
Arduino Uno	4	83
Actuators	2.5	162
DRS	55	66
Total	**107**	**388**

Table 2: Power Budget

3.1 HAAT

3.1.1 Microphones

As stated previously, the focus of this year's scientific objectives was to obtain measurements of the random pressure fluctuations within the upper stratosphere. Such acoustic measurements are best made using pre-polarized microphones. The basic operating principle of such a microphone is demonstrated in Fig. 3, where there exists a metal diaphragm some distance away from the back plate, which carries some polarization voltage due to a thin electret layer. The incident pressure waves cause the diaphragm to deform, changing the distance between it and the back plate, which also changes the capacitance between the two. This change in capacitance generates a voltage, which is the recorded signal.

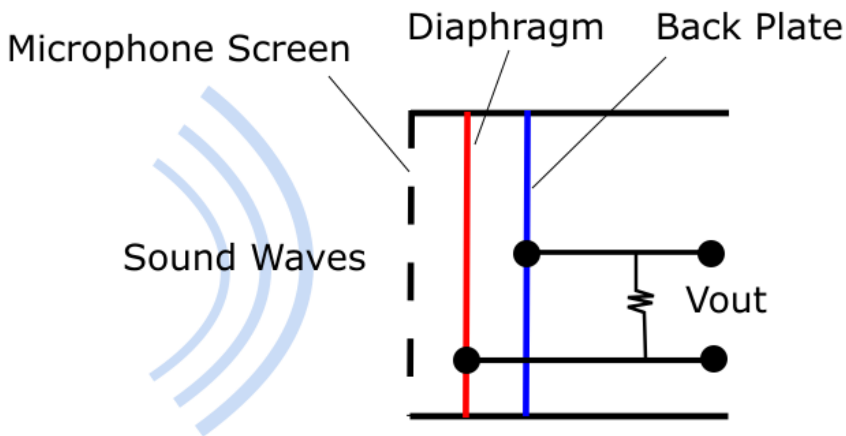

Figure 3: Microphone operating principle

In total, three PCB microphones were be implemented with varying levels of sensitivity: one 378A06 microphone (sensitivity 12.6 mV/Pa; frequency range, +/-2 dB, 3 to 32, 000 Hz), one 378B02 microphone (sensitivity 50 mV/Pa; frequency range, +/-2 dB, 4 to 20, 000 Hz) and one 378A04 (sensitivity 450 mV/Pa; frequency range, +/-2 dB, 10 to 16, 000 Hz). It is evident from these specifications that the 378A04 is by far the most sensitive of these microphones and is capable of measuring much smaller fluctuations than the other two microphones. However, it was still deemed useful to have all three microphones included so that we might correlate the signals and improve confidence in the fidelity of the measurements.

3.1.2 Arduino Uno

HAAT also contained an Arduino Uno to act as the main processing unit of the payload. It's main responsibility was to parse and act upon different serial commands, as well as send telemetry back to the ground and pulse width modulate (PWM) two digital pins for the data relay system.

HAAT-TRIC was designed to receive serial commands with discrete signals as backup through the HASP system. The Arduino unit was capable of handling four different serial commands and two discrete commands, though it did not need to use the discrete commands. The fours serial commands included commands for retracting the actuators to drop TRIC, extending the actuators, setting HAAT to record, and a ping message to verify that they payload was responsive as shown in Table 3 below.

Command Name	Command Code Character	Command Code Hex
Retract actuators (drop)	R	0x52
Extend actuators	E	0x45
Record Science	D	0x44
Ping	P	0x50

Table 3: Commanding Codes

The Arduino also sent back periodic telemetry data to show the payload's current state and health. Telemetry was also sent when the payload received a command in order to verify that the command was sent and properly executed. Health and status telemetry was sent every 5 seconds and commanding telemetry sent as soon as a command was executed by the Arduino. Health packets were set to the following format: time, "DS", DAS status, "AC", actuator status where time was the seconds elapsed from the time the payload was turned on; DAS status was the status of the science recording unit, either A for active or W for waiting; and actuator status was the state of the actuator, either E for extended or R for retracted. Expected command packets that the team could receive are shown in Table 4.

Case	**Expected Response**
Retract Actuator (Success)	[TIME],CMD,DM,R,S
Extend Actuator (Success)	[TIME],CMD,DM,E,S
Record Science (Success)	[TIME],CMD,DS,R,S
Record Science (Failure)	[TIME],CMD,DS,R,F
Ping	[TIME],PONG
Command received, could not interpret	[TIME],CMD,FAIL

Table 4: Command Responses

To verify that there were data signals being sent from HAAT to the drop module, the Arduino Uno would PWM two of the digital pins, and the Drop Module Arduino Nano would receive those signals. The Arduino Uno was set up to randomly change the frequency of the PWM signal every 5 seconds, and record the voltage on the rising edge of each change. The Arduino Nano had a low pass filter for the PWM signals such that the Analog pins would be able to tell what the voltage of the signal was. The filtered line was sampled and recorded each time the main control loop was executed.

3.2 TRIC

The TRIC module consisted of an aluminum plate attached underneath the HASP plate via four standoffs, one at each corner, as seen in Figure 4. The center of the plate contained a slit that allowed the drop module to hang mounted to the actuators. The actuators sit on one side of the slit, with a wall on the other side. When the actuators are extended, they sit flush with the opposing wall to hold the drop module in place. A bracket and threaded rod mated to the TRIC aluminum plate held both the actuators in place.

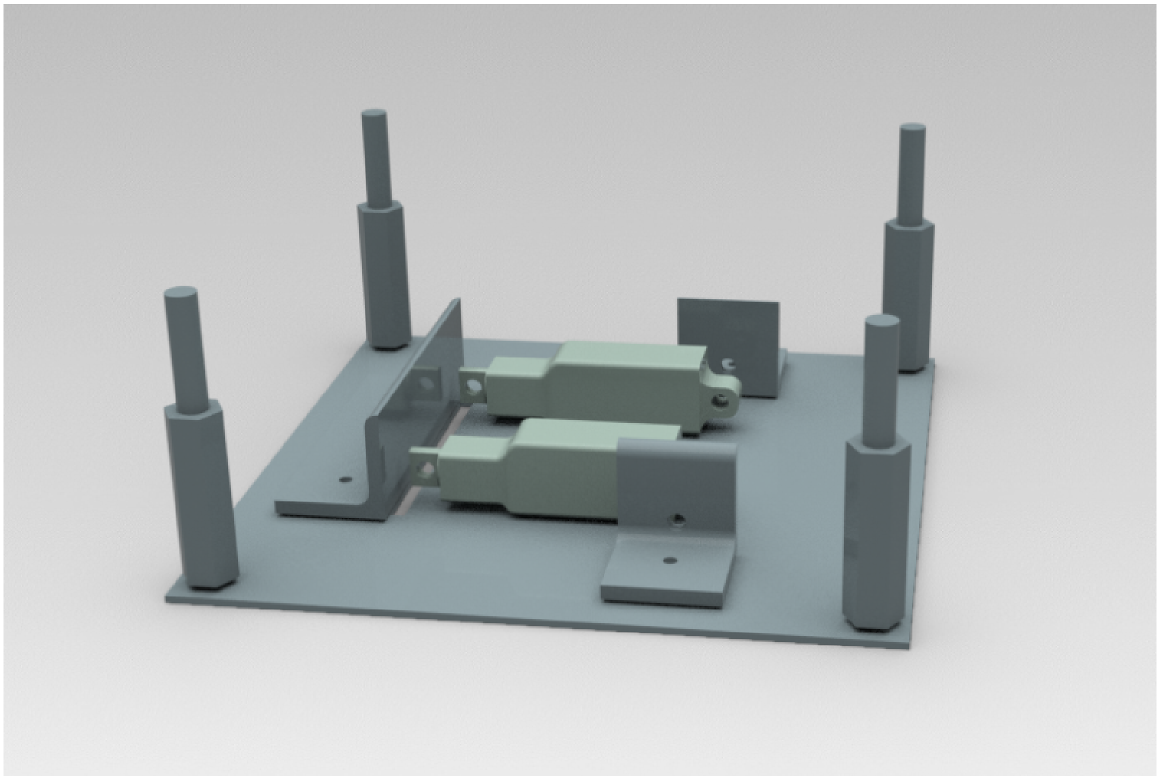

Figure 4: TRIC plate

3.2.1 Release Mechanism

The design for the release mechanism was an adaptation of a BPP payload called MARS (Mechanically Actuated Release System). MARS is an actuator release mechanism used to drop a bottom payload from the payload string on one of our sounding balloon flights. Instead of discrete signals from the main payload gondola, MARS uses XBee radio signals to communicate with the balloon's command and tracking module and the ground.

The release system on TRIC consisted of two 10 mm stroke actuators wired to an Arduino Uno to move both forward to lock the drop module in place, and move in reverse to drop the module. The actuators used quarter inch aluminum pins to hold U bolt mounting brackets on the drop module. To command the release of the drop module, a serial command was sent from the gondola to the Arduino Uno, retracting both actuators simultaneously.

3.3 Drop Module

The drop module contained an Arduino Nano, microSD card datalogger, and female micro-USB port for the cable between HAAT and the drop module. This was significantly different from the 2017 payload which did not use commercial off-the-shelf (COTS) parts. The final data relay system (DRS) was a single perf-board.

The Arduino Nano was the main microcontroller for the DRS. It was responsible for reading in the analog signals from the HAAT Arduino Uno, and sending them to be stored on the MicroSD card. The analog signal would store as an integer value between 0 and 1023, representing digital 0 and 5 V, respectively.

The microSD card datalogger was the Adafruit 5v Ready microSD breakout board, which is a small PCB with a microSD card slot. The connecting cable between HAAT and the drop module contained a magnetic interface that was mounted to the underside of the HASP payload plate. When the drop module was released from the main payload body, the magnetic pieces of the USB cable would separate, terminating all data and power transfer between payload segments. The DRS contained the Micro-USB end of the cable, and as such contained the female Micro-USB cable attachment point.

4 Mission Results

4.1 Flight

During HASP 2018 Balloon Flight, the Data Acquisition System (DAS) failed to trigger and record science data. On September 9th, ahead of an attempted launch that was eventually scrubbed due to high winds, HAAT-TRIC went through its ground checkout and the DAS signalled that it was properly recording data. When the launch was scrubbed, the launch team opened up the payload to reset the system, recharge on-board batteries and wipe the memory of the DAS. However, during flight, telemetry showed that when triggered, the DAS did not move from 'waiting' to 'active' mode. The HASP current draw logs showed an increase in current draw when the command was sent, suggesting that it was turning on, but not recording data or not properly stating that it was recording data.

After launch, when the payload was returned, the DAS logs were empty. The right number of logs were created for the 10 triggers sent to the payload when the team was trying to reactivate it, however, there was only the flat initial data that the DAS powers up with. The team strongly believes that the data line between the microphones and the DAS recorder became disconnected some time after the scrubbed launch.

4.2 HAAT

During the thermal vacuum test at CSBF, HAAT successfully measured pressure fluctuations present in the chamber throughout the test. A ten minute segment of the data taken right at the end of the low temperature cycle (circled in Fig 5 below) was extracted to demonstrate the payload's functionality.

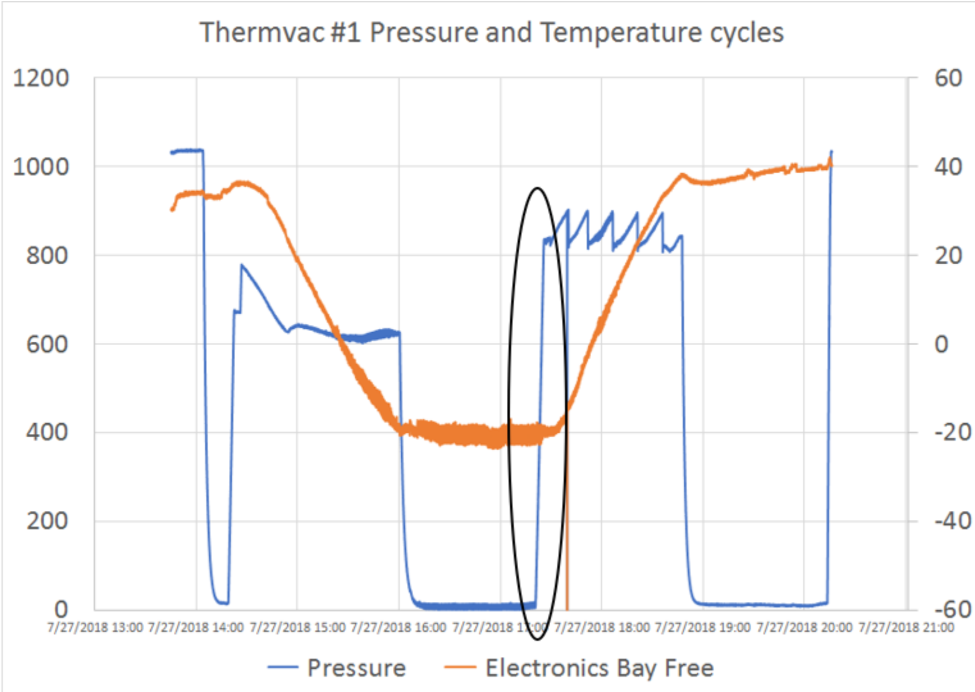

Figure 5: Pressure and temperature data from the first thermal vacuum test at CSBF with the region of interest circled

The data from each microphone is displayed in Fig. 6 as a raw time series, with an offset of 20V and 40V added to the 378A06 and 378B02 series, respectively, in order to facilitate qualitative analysis. These series are qualitatively similar, and quantitatively similar in the case of the 378A04 and 378B02 microphones, with each trace showing three distinct regions of signal intensity during the 10 minute period. From about 0-120s, the signal is too small to be discernible at the scale shown, implying that the magnitude of pressure fluctuations is very small. This is exactly what one would expect when the ambient pressure is under 1kPa and the air is relatively quiescent, as is the case for the low temperature dwell. At around 120s, the pressure in the chamber is increased significantly up to roughly 850hPa. The air rushing into the chamber during this process generates a significant amount of noise, which accounts for the region of strong microphone signal from 150-450s. Once the pressure reaches the set pressure, it dwells there for several minutes, resulting in the relatively calm signal from 450-600s. Although the air in the chamber would be fairly calm during this time period, the ambient pressure is significantly higher, which results in a much noisier signal than in the initial 0-120s region. One thing that may stand out about the raw time series is that the 378A04 signal saturates below a certain value and the 378A04 signal saturates above a certain value. This was due to improperly selected gain values when setting up the DAS and was corrected prior to flight.

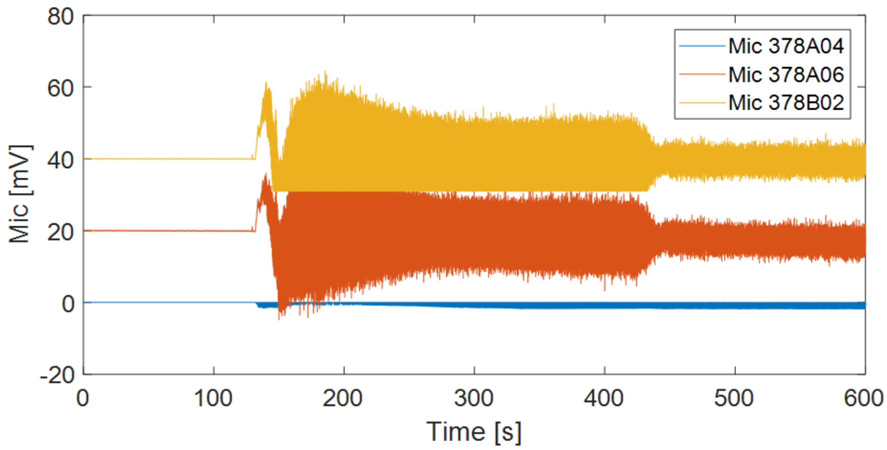

Figure 6: Raw time series for each microphone during a 10 minute time period from the first thermal vacuum test at CSBF

These regions are also compared using time average power spectral densities shown in Fig. 7 for each microphone. The 378A06 (top) and 378B02 (middle) microphones display almost identical frequency response for each time period. Both microphones show weak signal strength near the noise floor for all frequencies above 10Hz with only intermittent peaks, just as should be expected during a period of little signal. These peaks are the sort of signals that would be of most value during flight, as they denote what frequencies carry the strongest pressure fluctuations and can affect the boundary layer most significantly. The 190-290s region then displays an elevated signal level which persists for frequencies all the way up to over 8kHz. This is due to the strong, broadband pressure fluctuations generated by the fans during the filling process. A similarly elevated signal is present for the 500-600s interval, but this signal rolls off gradually because the air is being allowed to settle. Microphone 378A04 (bottom) shows the same trends of almost nonexistent signal for the 0-100s period and significantly elevated signal for the 190-290s and 500-600s intervals. However, this microphone displays odd behavior in that the 500-600s interval shows a significantly higher power than the 190-290s interval across all frequencies. This behavior is once again thought to be attributable to improper DAS settings which were altered for flight.

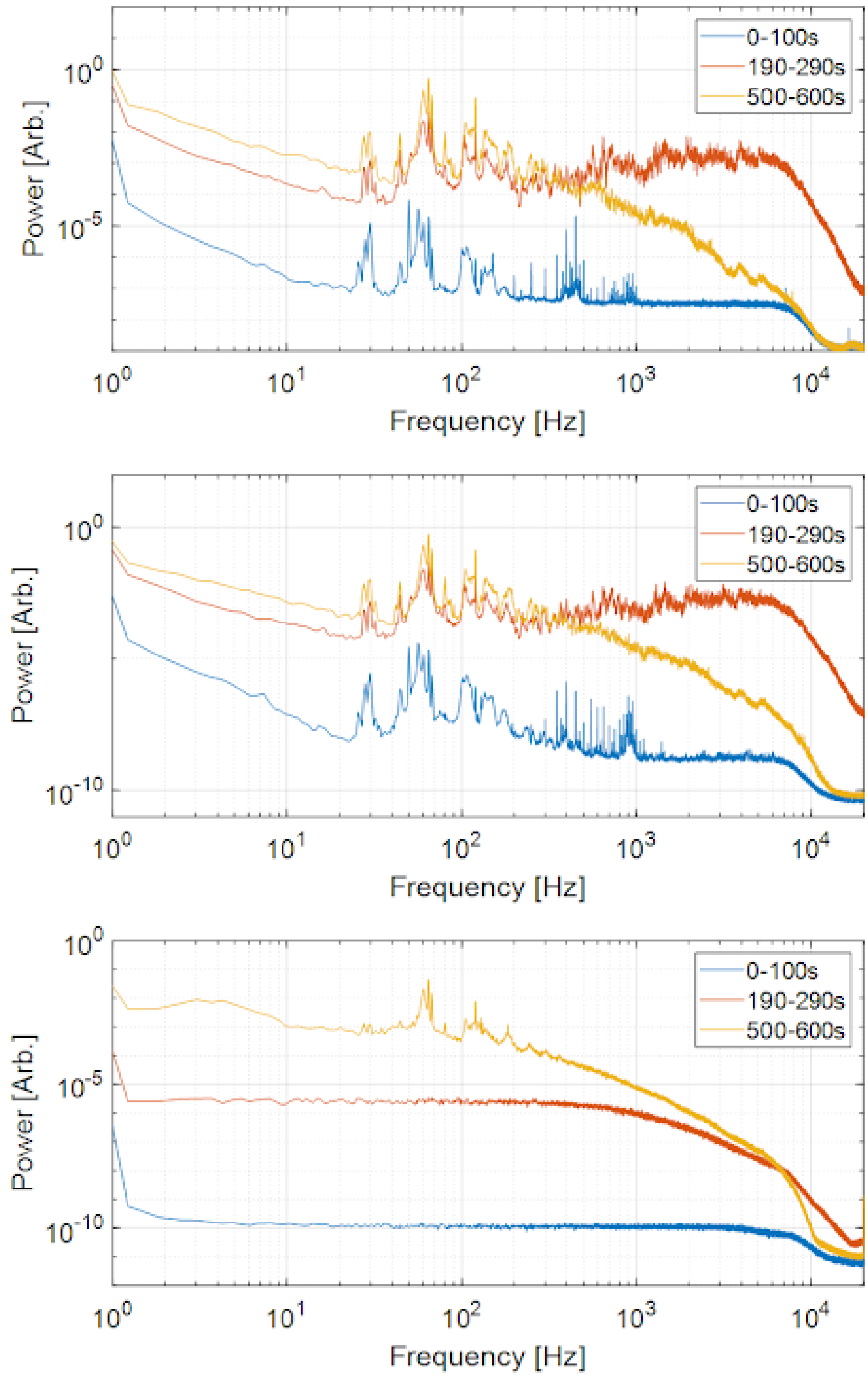

Figure 7: Power spectral densities for each identified time period for microphone 378A06 (top), 378B02 (middle) and 378A04 (bottom)

Unfortunately, no scientific results were obtained from the microphones during flight. Throughout flight, our serial telemetry indicated that the DAS was failing to trigger properly. At first, we believed that the voltage regulator routing power from HASP to the DAS had failed. However, the DAS registered turning on 10 separate times during flight, which corresponds to the number of times power to our payload was cycled when attempting to correct this triggering issue. This indicates that the DAS was in fact powering on, but not receiving the trigger. Because our serial telemetry also indicated that the arduino was sending the trigger signal to the DAS, we have determined that the most likely reason for the triggering failure is that one of the wires into the DAS was pulled out at some point.

4.3 Drop Module

During thermal testing, the team noted that during the cold cycle of the testing, the actuators were not responsive, but that they became responsive again during the heating cycle. The team decided that instead of redesigning the payload with insulation or a heating mechanism, it would be simpler to just actuate during daytime when the temperatures are warmer.

Flight also proved to be successful for the drop module. Telemetry showed that HAAT-TRIC successfully received the command and executed it. On return, the module was safely stowed in the netting below the payload instead of secured to the bottom of the payload plate as it had been when the balloon first launched.

4.4 Dust Sensor

Particulate matter (PM) in upper altitudes (above 40,000 ft) is uncommon, and PM at the altitudes that HASP payloads fly is rare. This year's flight data suggests two episodes of increased concentrations of 0.3 um and 0.5 um PM in the atmosphere below 100 mb (53,000 ft and above) (Figures 8 and 8). Figure 8 and 9 occurred above 90,000 ft and above 60,000 ft respectively. A lack of atmospheric information at these altitudes prevents a determination of the source of the atmospheric dust, but dust presence at these altitudes suggest a need for further sampling.

Figure 8 suggests an increased concentration of 0.3 um and 0.5 um dust particles between 8.4 – 9.0 mb. Figure 9 suggests an increase in 0.3 and 0.5 um dust concentrations, as with Figure 8. However, in this case, the experiment only saw increases in smaller-sized dust particles, unlike the first case.

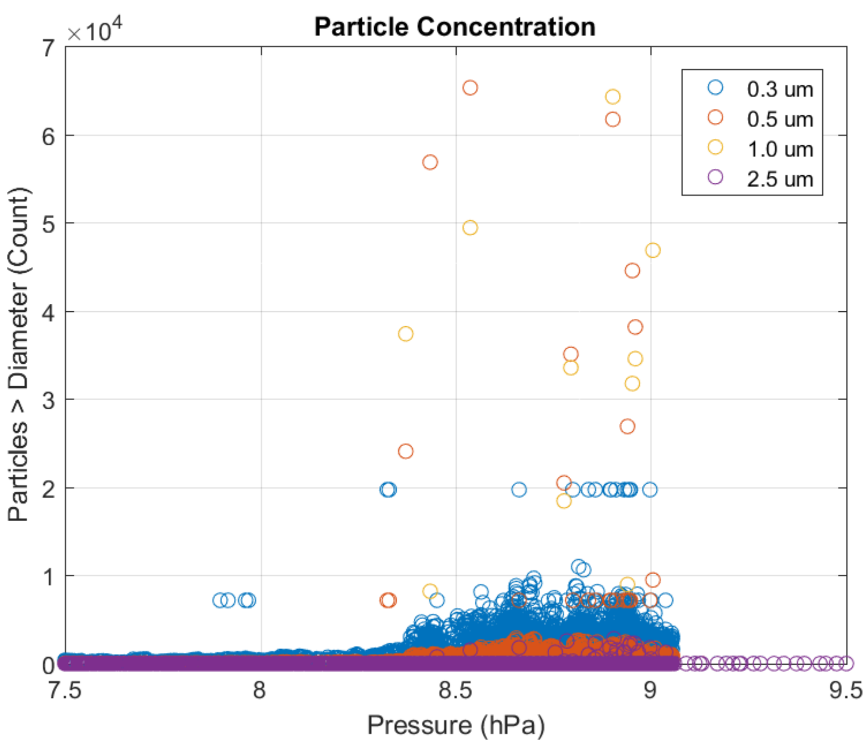

Figure 8: Particulate Matter above 90,000 ft.

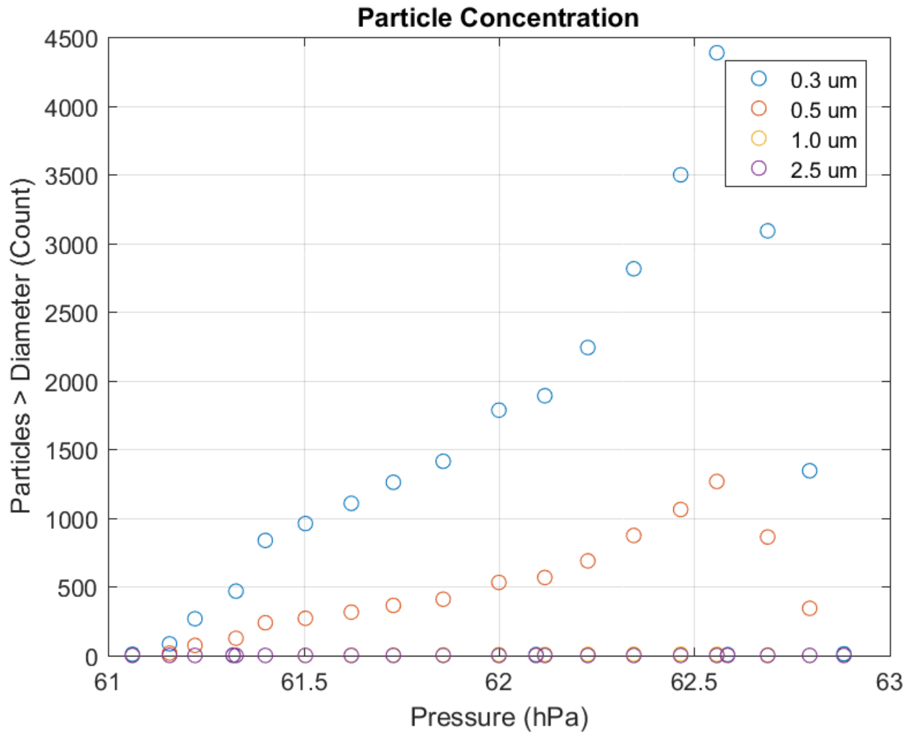

Figure 9: Particulate Matter above 60,000 ft.

5 Conclusion

The results obtained from the thermal vacuum test demonstrate that HAAT was at one point fully operational. Unfortunately, something broke just before flight, which resulted in having no microphone data recorded. This should put the focus of our future efforts on improving the robustness of HAAT's wiring and command structure. We have now learned just how important redundancy is for mission critical operations.

Although the flight itself was a disappointment, the efforts made by our HASP team this year represent a significant improvement in our capabilities for future payloads. HAAT's successful performance during the thermal vacuum test validates the payload design for future experimental campaigns. The microphones were capable of resolving pressure fluctuations even at ambient pressures representative of the float altitude for HASP and continued to operate even at low temperature.

Our successful implementation of serial commanding and telemetry this year will allow us to improve future payload designs and operations during flight. Having a decent telemetry system allowed the flight team to more accurately and quickly decide what errors were occurring and what was potentially causing them while the balloon was still in flight. This allowed the team to identify quickly the need to improve on internal integrity and redundancy of the system. Future payloads must be designed using more robust wiring connections to prevent payload failures. Additionally, testing out the full functionality of the system should be done whenever work has been done to the payload.

As noted during the subsequent revisions made to the DRS during design, it takes significant time and effort to properly design a board with a microprocessor unit (MCU). More time and testing should be allocated when designing such boards. Alternatively, another route to take is to identify a simpler system with off-the-shelf parts that accomplishes the same goal. A DRS connected to a simpler scientific instrument, such as a temperature sensor, that recorded at a slower data rate would have eliminated the need to build such an advanced MCU without reducing the meaningfulness of the experiment.

6 Potential Follow-on Work

HAPL is currently conducting research funded by a grant from AFOSR (Air Force Office of Sponsored Research) that will involve upwards of 6 or more flights on BPP balloons over the next two years. The HAAT hardware will continue flying on local UMD BPP flights to gather more data on CAT in the upper atmosphere as part of of this project. This will help refine use of the hot wire probes and microphones and allow for improvements to be made to the sensor package as a whole.

HAPL and BPP are planning on flying again with HASP with an improved on-board sensor suite for HAAT with the hope of being able to continue categorizing CAT on long duration flights. The improved sensor suite will allow new insights to be gained from the data on how the air behaves in the stratosphere. However, the team had decided to not continue forward with the TRIC portion of the payload at this point. The next step in development for TRIC would be to develop a GPS tracking system as well as a parachute deployment system, and to obtain permission to actually drop off the HASP pallet. This would significantly increase the complexity and to some extent the weight of the payload.

A References

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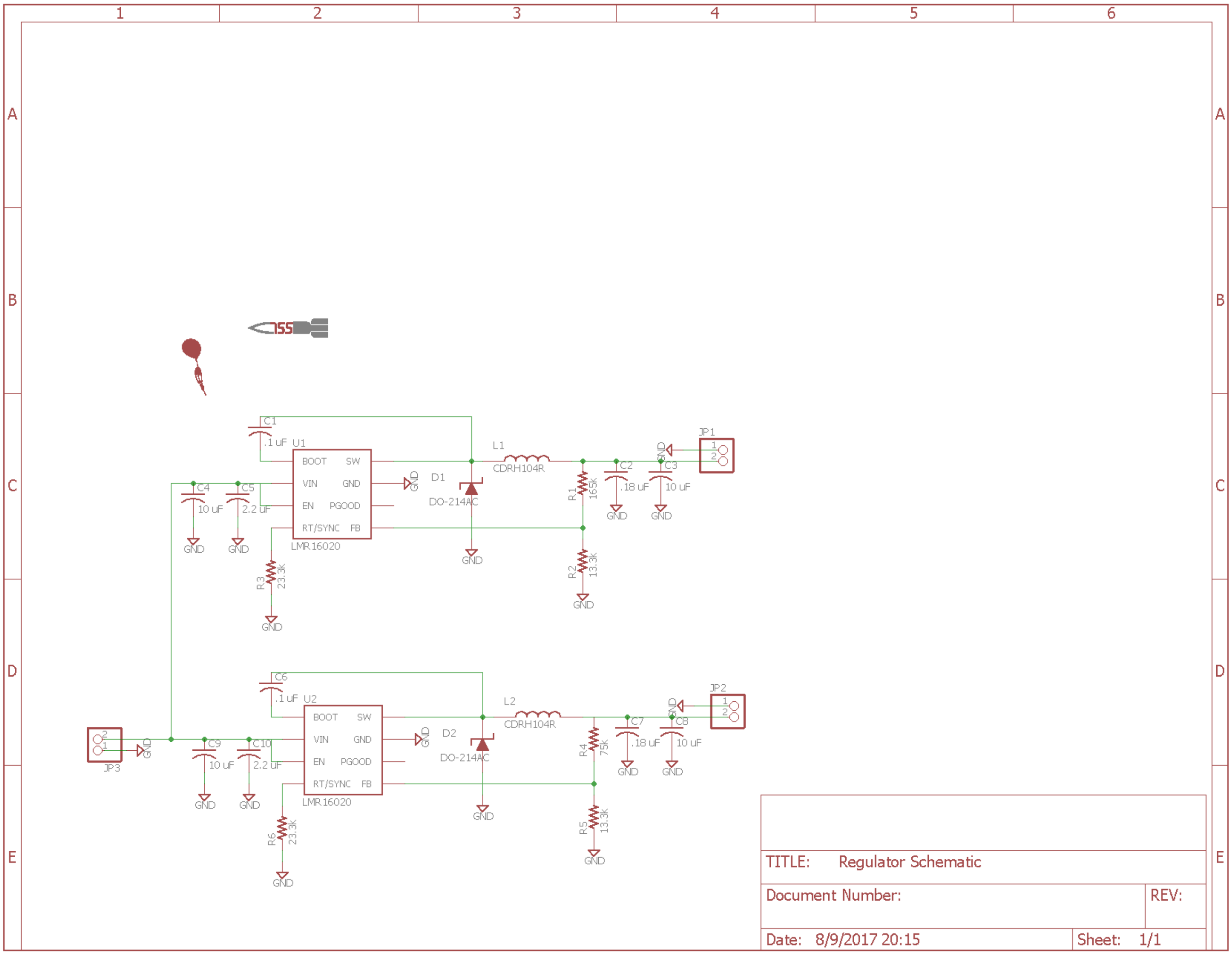
B Schematics

B.1 Regulator



C Personnel

C.1 2018 UMD HASP Team

Table 5: Personnel

Name	Start Date	End Date	Role	Student Status	Race	Ethnicity	Gender	Disabled
Cameron Butler	11/15/16	Present	Graduate Science Lead	Graduate	White	Non-Hispanic	Male	No
Lorenzo Narducci	11/15/16	Present	Undergrad Student Lead	Undergrad	White	Non-Hispanic	Male	No
Blaire Weinberg	11/15/16	Present	Undergrad Systems Lead	Undergrad	White	Non-Hispanic	Female	No
Michael Owca	11/15/16	Present	Mechanical Lead	Undergrad	White	Non-Hispanic	Male	No
Michael Walker	11/15/16	Present	Integration	Alum	White	Non-Hispanic	Male	No
Bianca Foltan	11/15/16	6/1/18	Program Manager	Undergrad	White	Non-Hispanic	Female	No
Chukwuma Odigwe	12/21/16	6/15/18	Electrical Lead	Undergrad	Black	Non-Hispanic	Male	No
Jessica Queen	12/1/17	6/1/18	Mechanical	Undergrad	White	Non-Hispanic	Female	No
Olasunbo Salami	10/21/17	Present	Software	Undergrad	Black	Non-Hispanic	Female	No
Steve Lentine	12/10/17	4/1/18	Tracking	Program Liaison	White	Non-Hispanic	Male	No
Will Sharpe	2/23/2018	5/1/18	Mechanical	Undergrad	White	Non-Hispanic	Male	No
Ryland Lillibridge	3/3/18	Present	Undergrad Science	Undergrad	White	Non-Hispanic	Male	No
Theo Kuiper	3/3/18	Present	Mechanical	Undergrad	White	Non-Hispanic	Male	No
Tyler Boyle	4/18/18	Present	Undergrad Science	Undergrad	White	Non-Hispanic	Male	No

C.2 Placement of Students from Past UMD HASP Teams

Many of the students who worked on HASP in past years are now research assistants in a graduate program or working in the aerospace field in a number of different locations and capacities:

- Dru Ellsberry, first SpaceX now Blue Origins
- Connie Ciarleglio, first JPL now SpaceX
- Kristy Weber, University of Colorado Boulder Graduate Program
- David Thoerig, NASA Johnson Space Center
- Chris Carlsen, Blue Origins
- Camden Miller, Jet Propulsion Lab
- Jackson Phillips, Innovative Concepts Engineering
- Steve Lentine, contractor at Goddard Space Flight Center

  All of the following students worked on the HASP 2018 Team or provided follow-on support from the previous year, but then graduated at the end of the semester and left for aerospace related jobs:

- Bianca Foltan, Northrop Grumman Innovation Systems
- Tyler Boyle, Glenelg Country High School Science teacher
- Ji Min Chang, Textron
- Mohammed Nassif, Georgia Tech Graduate School
- Chukwuma Odigwe, FAA Unmanned Aircraft Systems
- Michael Walker, NASA Goddard Space Flight Center

Besides being a very valuable undergraduate experience that helps our graduating seniors find great jobs in the aerospace field, the HASP Program has also provided participating students with ballooning experience that they then bring back to the much larger team of UMD students building payloads and performing balloon launch operations for our local Balloon Payload Program. This program has been underway for 15 years, involving hundreds of students, with over 80 flights of sounding balloons launched in the central East Coast Region. It has benefited significantly from numerous interactions through HASP primarily with the NASA Balloon Program Office and Columbia Scientific Ballooning Facility.