HASP Student Payload Application for 2018

Payload Title: **HAAT-TRIC**	
Institution: University of Maryland	
Payload Class (Enter SMALL, or LARGE): SMALL	Submit Date: December 15, 2017

Project Abstract:

The University of Maryland HASP team proposes to continue the two system experiment HAAT-TRIC similar to that flown on the 2017 HASP Flight. The accompanying thin-film probes of HAAT will be replaced with a suite of PCB microphones. This will allow for characterization of the acoustic disturbance environment in the upper stratosphere, as opposed to the 2017 mission of characterizing temperature and velocity fluctuations. TRIC will siphon off this data and log it to a separate module which will drop halfway through the flight into a net secured onto the pallet. TRIC will demonstrate data acquisition, logging, in flight termination, and a viable tracking system (GPS) as a demonstration for an eventual full drop with a parachute.

The UMD HASP Team includes one graduate student and about a dozen undergrads. The team also includes two faculty advisors, one for overseeing the science objectives and another for her expertise in directing the Maryland Space Grant Balloon Payload Program for 14 years, launching over 70 sounding balloon flights, a sounding rocket flight, and supporting 6 previous HASP payloads.

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HAAT-TRIC

HASP Flight Proposal

UMD HASP 2018

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

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Contents

1 Abstract

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2 Terminology

UMD: University of Maryland (College Park)
BPP: Balloon Payload Program
CAT: Clear Air Turbulence
DRS: Data Relay System HASP: High Altitude Student Program
HAPL: High Altitude Propulsion Lab
HAB: High Altitude Balloon
HAAT-TRIC: High Altitude Atmospheric Turbulence - Triggered Release Information Carrier
FISH: Fluctuations In Stratosphere by Hot-film
MARS: Mechanically Actuated Release System

3 Project Overview

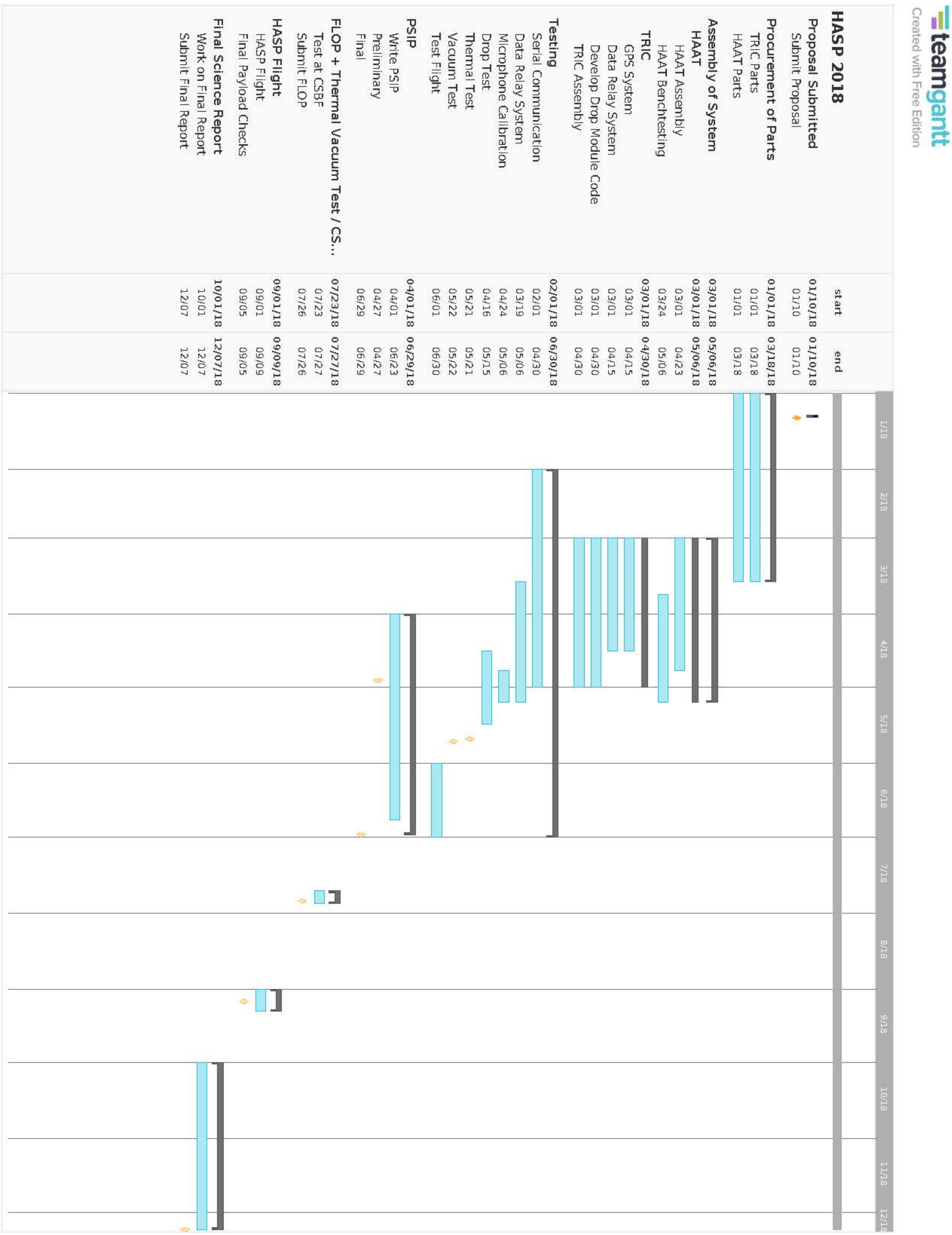
Hypersonic vehicles are being developed for flights at altitudes above 100 kft (i.e., mid to upper stratosphere), where they encounter extreme aero-thermal-acoustic environments which strongly affect the boundary layer flow over the vehicle. Specifically, free-stream disturbances can cause laminar to turbulent transition of the boundary layer, which brings with it greatly enhanced thermal and mechanical loads. Robust vehicle design therefore requires accurate prediction techniques regarding the onset of transition. However, state-of-the-art transition prediction methodologies require knowledge of the magnitude and length-scales of the free-stream disturbances. Preliminary balloon-based measurements have shown a strong influence of CAT (Clear Air Turbulence) on disturbance levels; nevertheless, in contrast to the well-studied troposphere, CAT in the mid and upper stratosphere remains inadequately characterized. Thus, despite the availability of advanced numerical tools, it is currently impossible to predict with any certainty the onset of boundary layer transition on hypersonic vehicles in atmospheric flight.

The High Altitude Atmospheric Turbulence (HAAT) subsystem of the proposed HASP experiment will measure free-stream pressure fluctuations to better understand the acoustic environment of the upper atmosphere. The stratosphere is generally a region of relative thermodynamic stability because of the positive vertical temperature gradient, but it is nevertheless intermittently populated with regions of clear air turbulence (CAT), which can extend hundreds of meters in the vertical direction, tens of kilometers laterally, and minutes to hours temporally. The goal of the HAAT subsystem is thus to obtain a general characterization of the acoustic 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.

HAAT is coupled with a simulated data drop payload called TRIC which will explore the possibility of releasing a physical payload that has data stored on it from a scientific balloon. Some scientific balloon flights can last for months at a time and gather data at higher rates than is possible to downlink to the ground over radios, making the acquisition of data before the flight is terminated very difficult. TRIC is designed to siphon off data from HAAT and log it to a separate module that will drop when given a discrete command from the ground, separate from the main payload and begin GPS transmission. For this flight, TRIC will be dropped into a net that is securely fastened to the upper half of the payload, and by extension, the HASP gondola. This years's experiment will focus on fixing data acquisition problems experienced last year as well as proving that the payload can be tracked using GPS.

Using droppable data modules such as TRIC, significant amounts of data can be retrieved part way through a long-duration flight for a relatively inexpensive cost. With this released information, researchers can assess early data from their experiments and, if necessary, make adjustments to their scientific instrumentation for the remainder of their flight. This concept was initially implemented with a UMD / HASP payload called StratoPigeon; and discussions with High Altitude Balloon (HAB) scientists at UMD and Goddard Space Flight Center have indicated that there is renewed interest in this capability. Unlike StratoPigeon, however, the primary objective of the HAAT-TRIC payload is to gather scientific data, and the engineering goal of demonstrating a data-drop module capability is secondary.

4 Project Timeline



5 Previous Balloon Flights

5.1 HASP

5.1.1 2008 - 2009

On the 2008 and 2009 HASP flights, the UMD ABC payloads (University of Maryland Advanced Balloon Communications Experiments) tested various configurations of GPS antennas and radio downlink systems. These GPS antennas successfully communicated with a ground station throughout the flight.

5.1.2 2010 - 2012

The UMD payload that was flown on HASP 2010 was the first flight of StratoPigeon, a droppable module that would acquire data for a few hours before dropping. StratoPigeon communicated with the ground station in a manner similar to that demonstrated with the first two UMD HASP payloads, and then it dropped after receiving a command from the ground station. Of these three flights, 2010 was a systems check flight to ensure that all systems worked properly; 2011 was successfully dropped, tracked, and recovered; while 2012 was never recovered.

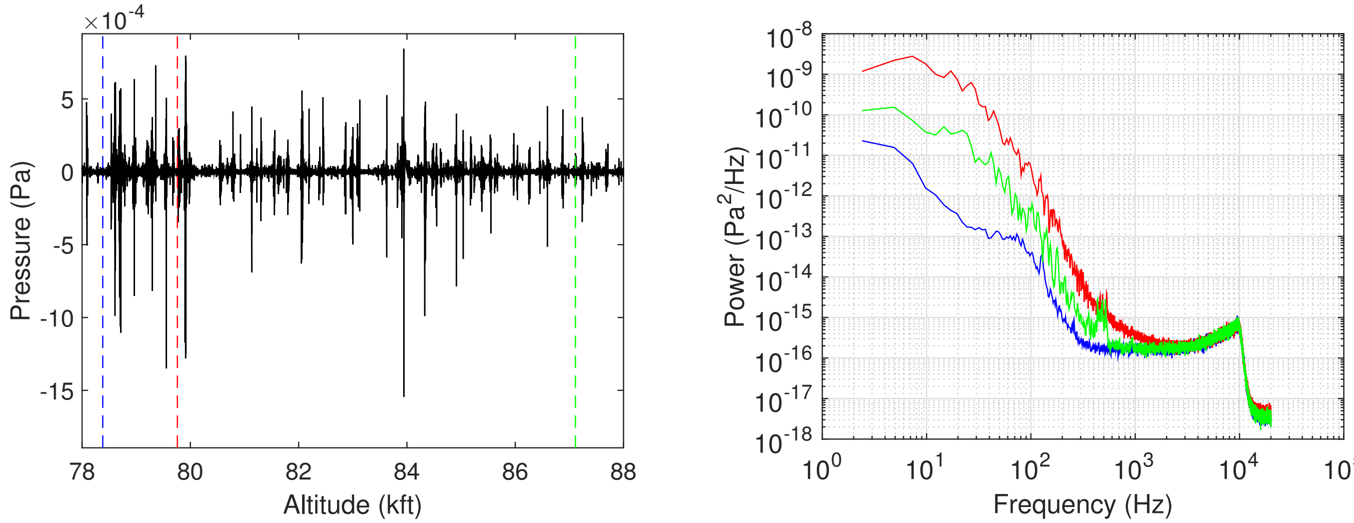
5.1.3 2017

The UMD HASP 2017 payload brought about a new version of StratoPigeon called HAAT-TRIC. This was a partnership between the Balloon Payload Program (BPP) and High Altitude Propulsion Lab (HAPL), both reserach labs in the Aerospace Engineering Department at UMD, the former of which provided the droppable module and the latter of which provided the science instrumentation. HAAT used a constant voltage anemometer coupled with thin-film probes to measure perturbations in velocity and temperature within the upper stratosphere, while TRIC contained a Raspberry Pi for data logging that was to be dropped when commanded with a HASP discrete signal. Due to hardware difficulties before flight, the drop module was dropped on a 4 hour timer instead of from the discrete lines, and there was no serial downlink of the payload status.

5.2 FISH

FISH (Fluctuations In Stratosphere by Hot-film) is a sensor package that has been in development over the past year through an Air Force Small Business Technology Transfer Program (AF STTR) with Tao Systems Inc, a small aerodynamic sensors company in Hampton VA. The most recent balloon flight of this package on December 2nd, 2017, included a hot-wire probe for velocity measurements, a cold-film probe for temperature measurements, and three PCB microphones for acoustic measurements. These are the same microphones we are proposing to fly during the 2018 HASP campaign. Representative results from the flight are shown in Figures 1a and 1b for the most sensitive microphone flown (378A04). The time-series data has been high-pass filtered in order to accentuate the regions of relatively high fluctuations. It is also worth noting that the maximum disturbance within this altitude range is approximately 0.6 mPa. The power spectra for three 10s intervals (150 ft) are shown below, where the blue trace is for a region of relatively low disturbance, red is a high disturbance region, and green is a region of intermediate disturbance. Clearly, this microphone is capable of resolving disturbances above the noise floor of 2kHz, at least in regions of large disturbances. The disturbances relative to hypersonic boundary layer transition are typically at frequencies on the order of 10kHz, so this microphone is approaching the desired resolution. Currently, techniques are being considered for lowering the noise floor even further, including the procurement of a microphone with even higher sensitivity.

Figure 1: Data Collected from FISH



(a) Pressure at Altitude (b) Power vs Frequency

5.3 DataPigeon

DataPigeon was a project, inspired by StratoPigeon, that started in the summer of 2016 until the fall when it became part of our HASP 2017 effort. DataPigeon utilized a cut-down device called MARS (Mechanically Actuated Release System) to perform a tethered drop on a balloon flight after a set time from balloon launch. A USB cable with a magnetic detachment was used to cleanly break the data line when the payload was dropped. DataPigeon flew on two flights. The first one in the late summer ended up being fairly successful despite needing to terminate the flight early. The payload logged data and then dropped, severing connection with the module it was connected to. The second flight, in the early fall, was less successful because MARS did not actuate due to a timing error in the code, and unfortunately, the module did not record data throughout the flight. After this, however, DataPigeon was combined with the FISH project for the 2017 HASP proposal.

5.4 MARS

The design for the release mechanism of TRIC is an adaptation of the MARS cut-down device. MARS is an actuator release mechanism used to disconnect the bottom payload from the rest of the payload string on one of our sounding balloon flights. Instead of serial commands from the main payload gondola, MARS uses XBee radio signals to communicate with the balloon's command and tracking module and with the ground. The first flight of MARS was in November 2015 and it has flown on a variety of flights since then. The MARS system has successfully dropped the intended payload on all but one flight.

6 Design Specifications

6.1 Data Acquisition System (DAS)

HAAT will be designed to take pressure measurements through the three PCB microphones that will then be stored within a SLICE Micro DTS data acquisition system, shown in Figure 2. This configuration is small and lightweight, with the heat sink footprint measuring 3 in x 3 in and a system mass of 187 g. The SLICE system is extremely rugged, having been engineered to military standard MIL-STD-810E. This

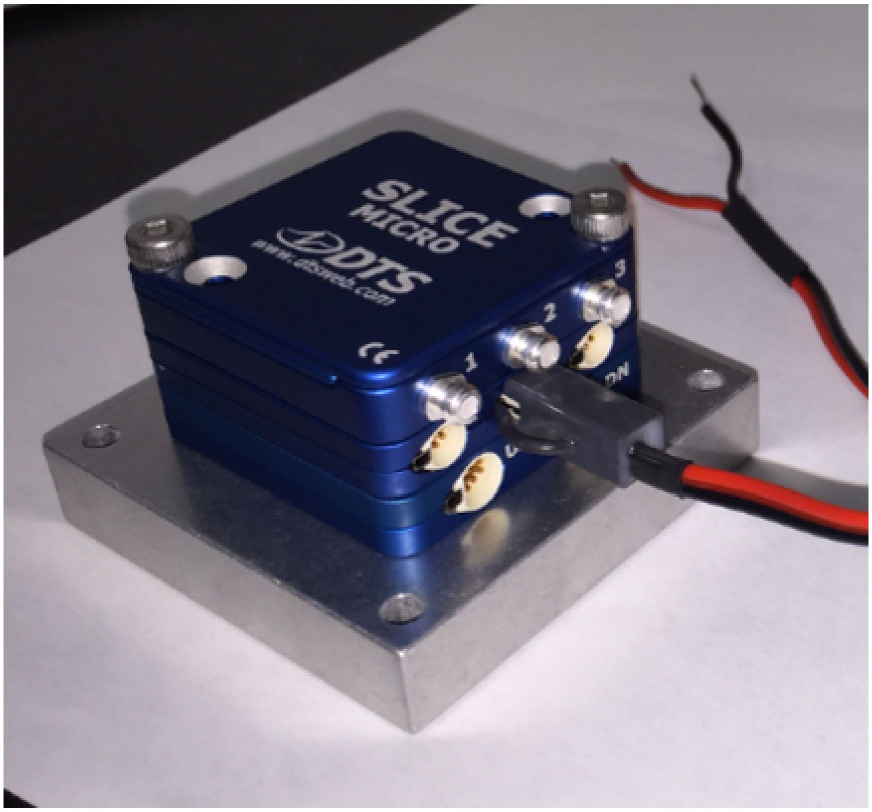


Figure 2: The Slice Micro will store data from the microphones as a part of the Data Acquisition System

means that it is capable of withstanding temperatures ranging from -40 °C to 60 °C and shock loadings of up to 500 g. The DAS will be powered entirely through HASP, with a maximum current draw of 0.18A at 10V. The system has 16 GB of non-volatile flash memory for storage purposes and can sample up to 24 channels at 200 kHz. For a sampling rate of 10kHz with 2 channels, the DAS can log over 400,000 s or 111 hours, which is more than sufficient to cover the duration of a HASP flight.

Due to the nature of the data being recorded, the data will not be downlinked via HASP. The high rate of 16-bits at 10kHz makes the link impractical to use. Instead, the Arduino unit in HAAT will be downlinking a status indication via the serial link. The DAS downlink will tell whether or not data is being recorded. The second serial downlink will be a status signal on whether or not the drop module has been dropped, and a signal about the status of the data storage on DRS.

The DRS is a modular, in house PCB that will contain all of the datalogging required for the drop module. In 2017, the board contained just an ADC to convert the signals, which was then sent via USB cable to the drop module, where it was separately stored. This year, to avoid buffering protocol between the serial line, the raw signal will be sent to the drop module, and converted and stored on the same DRS board. The data logging will also be redundant, containing both flash storage and an SD card. Power to the GPS and radio will also be routed on the DRS, although there will be no data transfer between them and the MCU onboard. This is intended to isolate the packets the radio sends down to eliminate protocol errors such as what was seen last year.

6.2 Internal Circuitry

6.2.1 HASP Interfacing

HAAT-TRIC will utilize the power and discrete lines of the provided EDAC connector. Power will be routed through a switching regulator board that will regulate the 30 V from HASP down to 5 V and 10 V lines to be used in the payload. The 10 V line will power the DAS and microphones; the 5 V line will power the Arduino Uno and actuators. It should be noted that in the Power budget (See Table 2), the peak current draw of the actuators is 400 mA. This is the worst case current draw while dropping the payload, which the duration will be one minute at most. The actual peak power is much closer in value to the average current draw, which will be what the actuators draw during normal operation.

The serial lines from HASP will be routed to the Arduino Uno on board, which will handle all internal signal processing. The Uno will be able to interpret two serial uplink commands, 0101 and 0202. The former of these will command the actuators to retract and drop the drop module. The latter will be routed to a relay on the relay board, which will trip when the serial signal has been registered, and turn on the DAS and microphones for data collection. Serial downlink will contain status updates on whether or not the drop module is still connected, and whether or not the DAS is collecting data.

6.2.2 Internals

Analog data lines from the microphones will be spliced, with one line sent to the DAS and the other routed to the drop cable between HAAT and the Drop Module. A Functional Block Diagram can be seen in Figure 3.

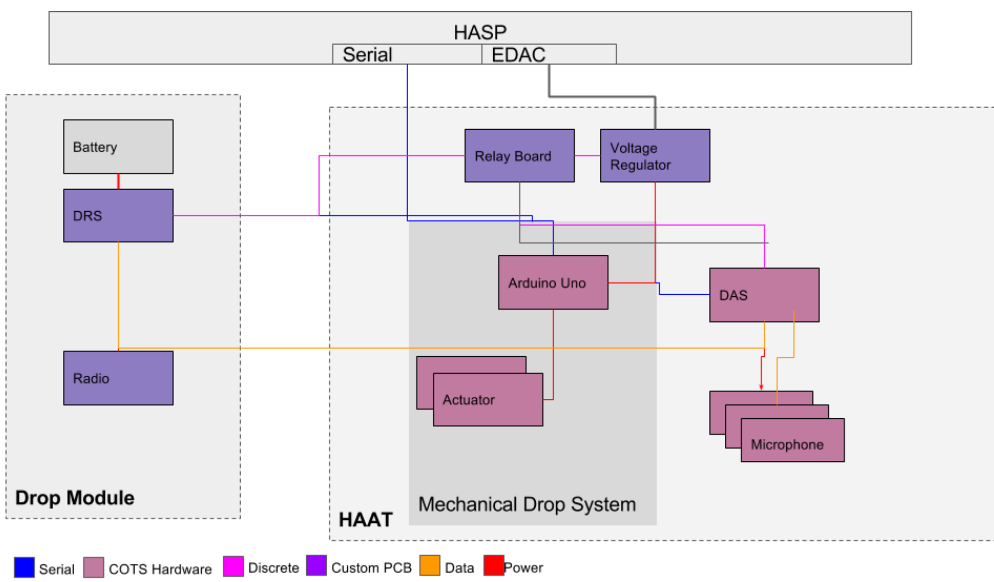


Figure 3: Functional Block Diagram

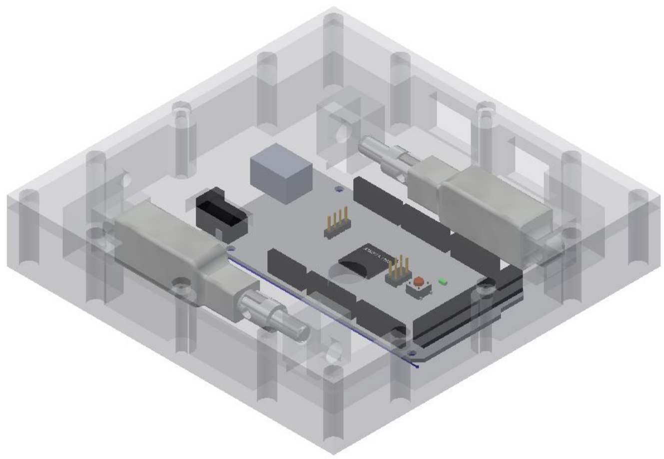
6.2.3 Drop Module

The Drop Module contains the DRS, a custom modular data relay device. It will be powered from an onboard 3 cell LiPo battery, as connections with the main payload will be terminated partway through the flight. The drop module will also contain a radio to transmit location data to the ground throughout the flight. The radio and GPS unit will both be powered from the DRS board, although there will no synchronous data lines.

6.3 Mechanical Drop System

The release system on TRIC consists of two 10 mm stroke actuators wired to a micro-controller to move forward to lock the drop module in place, and move in reverse to drop the module. The actuators use 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 will be sent to the on board micro-controller. Figure 4 shows the arduino microcontroller between the two actuators.

Figure 4: Inside view of the mechanical drop system



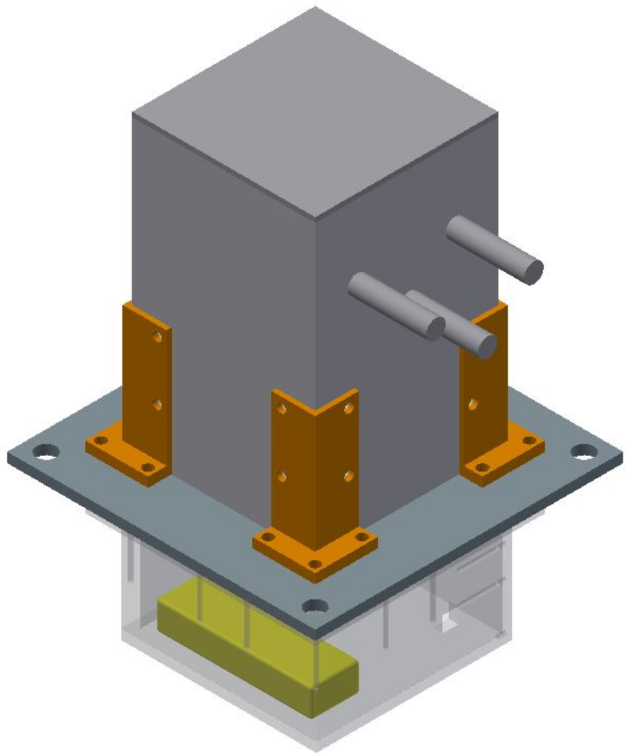
6.4 Drop Module

Throughout the flight, the drop module will be receiving data from the DRS and logging it internally. When the actuators retract, the drop module will fall into a net/basket and the DRS connection will be severed. At this point, the drop module will start broadcasting its GPS location until either the payload is recovered or the batteries run out.

6.5 Structural Layout

The main structure of HAAT-TRIC will be made of 1/16 in sheet aluminum and will be held together with metal brackets at the corners. All electronics will be placed on non conductive easily removable plates secured within the payload housing. The housing will also have a layer of insulating foam along the surface of the walls to help with thermal management. The main body of the payload will be within the allowed payload space but the microphone pickups will stick out of the payload area by 3.8 cm on the side of the payload facing away from the gondola. The total height of the system will be 30 cm above the plate and 20 cm below the plate.

Figure 5: CAD Rendering HAAT-TRIC



7 Payload Summary

In summary, HAAT-TRIC is a small class payload that will record pressure waves with microphones and record it onto a droppable module. Key information about HAAT-TRIC can be found in Table 1

Item	Units
Total Mass	2,527 g
HAAT Mass	1,384 g
TRIC Mass	1,143 g
Structure Mass	1,600 g
Average Current Draw from HASP	15.4 mA
Peak Current Draw from HASP	415 mA
Payload Size	Small
Payload Footprint	15cm x 15 cm, 4 mm additional for microphones
Payload Height	30 cm above, 20 cm below plate
Payload Orientation	Microphones pointed away from HASP Pallet
Discrete Commands	DAS On/Off (F, N) Drop Command (P, H)
Serial Downlink	1200 baud payload status
Serial Uplink	0101 Drop Payload 0202 DAS Turn On
Analog Telemtry	None

Table 1: Payload Summary

A detailed Power Budget can be found in Table 2, and a Mass Budget in Table 3

Item	**Average Current(mA)**	**Peak Current (mA)**	**Line**
Data Relay System	500	600	Internal Batteries
Total (internal power)	**500**	**600**	
DAS	60	60	HASP
Microphone	4	10	HASP
Arduino Uno	4.2	5	HASP
Actuators	7.2	400	HASP
Total (from HASP)	**15.4**	**415**	

Table 2: Power Budget

Item	**Mass (g)**	**Subsystem**
Slice System	187	HAAT
Arduino	40	HAAT
Voltage Regulator	50	HAAT
Mini-CVA	57	HAAT
Voltage Regulator	50	HAAT
Data Relay System	100	TRIC
Actuator (x2)	60	TRIC
Voltage Regulator	50	TRIC
3-cell Li-Po	133	TRIC
Mounting Struts	200	Structure
Insulation	50	Structure
HAAT Case	700	Structure
Wiring	50	Structure
TRIC Case	700	Structure
TRIC Drop Net	100	Structure
Total	2,527	

Table 3: Mass Budget

8 Integration Procedures

Upon arrival at CSBF for HASP integration, HAAT will be bolted to the top of the payload mounting plate. As for TRIC, the data drop module will have the U-bolts attached to it that will be threaded through the mounting plate for the actuators in the mechanical actuator box to then extend through, securing the data module to the balloon. Once the data module is securely attached, the catch basket will be put in place. Testing shall include ensuring that both serial and discrete signaling is properly routed and working.

Upon arrival at Ft. Sumner for HASP flight, similar testing will be done to ensure the payload is functional before flight. In addition to previous statements, the drop module will need to be turned on before the flight. This is outlined in Table 4.

9 Special Requests

In order to simulate the TRIC drop, we are requesting the use of space 20 cm below the payload interface plate in addition to the 30 cm above the plate allotted to small payloads. This will not interfere with the mass limit for the payload, but will allow for TRIC to be released from HAAT. If this request is denied, all of HAAT-TRIC will be placed above the payload plate. The data transfer system can still be tested without a physical drop, although the data termination system and dropping mechanism cannot. Without the additional space below the payload plate, the drop test will be descoped from the payload objectives.

HAAT-TRIC is also requesting use of two discrete lines. The first one, as given to all payloads, is to be used for powering on and off the DAS. This would be a redundant secondary method of ensuring that the DAS is storing data. The second set would be used as a redundant set for commanding the drop of TRIC. This would require our payload to be in a seat that has access to all four discrete commanding lines (seats 1, 2, or 5) in order to fulfill both requirements. If this request is not granted, TRIC will lose redundancy with the serial lines, but will still be able to drop.

Additionally, in order to ensure the microphones are measuring data that is uncorrupted by the surrounding structure, they must stick out slightly from the HAAT housing, and face away from the rest of the gondola. For this reason, we are requesting permission for our microphones to extend out of the prescribed footprint by 2 in. Should this request be denied, we risk reducing the quality of data acquired by the microphones.

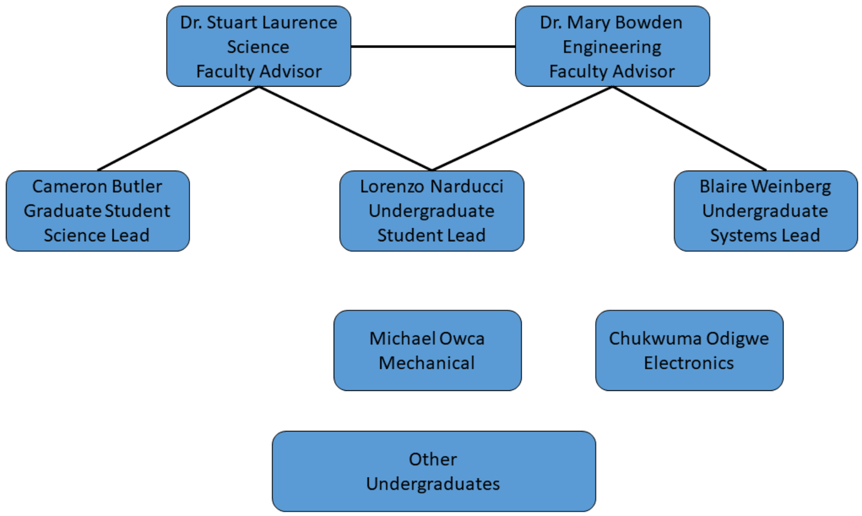
10 Preliminary Flight Operations Plan

Table 4: Preliminary Flight Plan

Time from Launch	Event Name
- 02:00:00	Turn on Drop Module (On Pad)
- 01:00:00	Turn on Payload
- 00:30:00	Turn on DAS
+00:00:00	Balloon launches
+02:00:00	Balloon reaches altitude
+14:00:00	Send command to release Drop Module
+14:00:01	Actuators begin retracting
+14:00:05	TRIC separates
+14:00:06	TRIC lands in the basket
+14:00:32	Linear Actuators stop retracting
+24:00:00	Flight Ends

11 Project Personnel

Figure 6: Team Structure



As shown in figure 6, the team is advised by two faculty advisors, Dr. Laurence, who leads the science portion, and Dr. Bowden, who leads the engineering portion of the payload. There are three student leads: Cameron Butler, who runs the science systems; Blaire Weinberg, who runs the engineering systems; and Lorenzo Narducci, who oversees the project. There are also two subsystem leads: Michael Owca who runs the mechanical subsystem and Chukwuma Odigwe who runs the electronics subsystem. Below them are several other undergraduates who will be assisting on the HASP project as well as some other advisors. See table 5 in the appendix below.

A Full Team Personnel

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	Integrations	Alum	White	Non-Hispanic	Male	No
Bianca Foltan	11/15/16	Present	Program Manager	Undergrad	White	Non-Hispanic	Female	No
Chukwuma Odigwe	12/21/16	Present	Electrical Lead	Undergrad	Black	Non-Hispanic	Male	No
Jessica Queen	12/1/17	Present	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	Present	Tracking	Program Liaison	White	Non-Hispanic	Male	No