SPS Chapter Research Award Final Report

Project Title	High Altitude Rocket Assisted MicroOrganism Capture (HARAMOC)
Name of School	University of Tennessee - Knoxville
SPS Chapter Number	7158
Total Amount Awarded	$2000
Total Amount Expended	$508 or $860.42 Based off amount in the account or itemized accounting respectively
Project Leader	Peter E. Tarlé

Abstract

The Society of Physics Students at the University of Tennessee Knoxville is seeking to use a high powered transonic rocket to collect high altitude bacteria and viruses known as bioaerosols. These poorly understood microorganisms may play an important role in cloud seeding and atmospheric chemical processes which have climate implications.

Statement of Activity

Overview of Award Activity

There is a question of what life exists off our planet. Astrobiology seeks to answer that question by examining extremophiles here on earth. The purpose of this experiment is to examine microorganisms and viruses that live in the middle to upper troposphere, collectively referred to as bioaerosols. The identity and role of these organisms is currently unknown but it is believed they may play a role in cloud seeding and even climate change. These organisms have likely adapted to sustained airborne life, but as of yet their growth needs and ecological niche have yet to be determined.

Previous studies have been unable to collect samples under sterile conditions. The prior experiments have relied on gondolas, which are carried under a giant balloon that was inflated on the ground, mountain top collection where the units are lying on the ground nowhere near unadulterated air, and from hurricane case planes whose samples are highly contaminated by material ripped into the upper atmosphere by storms as they inch towards the land. Carbon-14 analysis in these limited studies indicate that these organisms live out their lives high above the ground.

We planned to build sterile collection payloads for a high-power rocket to be tested in the spring in Kentucky and then launched in the Spaceport America Cup competition in June in New Mexico. These payloads will sample approximately 1-2 cubic meters of air collecting between 5-10 thousand individual microbes per flight, although the microbial population density is not well-understood and will be a part of our exploration. Due to setbacks, our first successful payload sampling mission did not occur until June of 2019 in New Mexico.

Once a sample was collected, the sample would be divided in half and plated in agar plates. One plate was kept on the bench top and the other was led in an incubator at 38 degrees Centigrade. These plates were examined daily to watch for growth, but it became clear that a more frequent sample was necessary in the first day due to highly virulent microbial life overtaking the melamine foam, which proved to be an ideal growing media.

This project pulled personnel, resources, and facilities from Physics, Chemistry, Microbiology, Ecology and Evolutionary Biology, Aerospace Engineering, Material Science Engineering and Electrical Engineering. This work will pave the way for other interdisciplinary work and help to expand interest in our growing Biophysics subfield. It has allowed new physics students to get involved and make connections with experts and future experts across the sciences and engineering.

Description of Research - Methods, Design, and Procedures

Previous studies have used aircraft, balloons, and mountain top collects to recover samples of these microbes but have difficulty reducing contamination. Mountain top capture methods introduce ground contamination. Balloon gondola methods introduce contamination during the filling stage where the balloon is laid out on the ground yet remains above the collection media for the remainder of the flight. The study using hurricane chase planes noted significant amounts of storm blown human and animal waste. For this year’s competition the flight will reach a maximum altitude of 10,000 feet which is the lower bound of where these organisms have been reported. By next year our team should have the infrastructure in place to enter into the 30,000 foot competition allowing for an order of magnitude increase in the time of collection of bioaerosols as per rules regarding drogue decent rate for the rocket. There is a minimum descent rate of 75 feet per second before main deployment to ensure that the rocket does not drift onto White Sands Missile Range. Our payload test flight in Kentucky will be able to spend more time at altitude, as we will not have the same constraints regarding minimum descent rate.

After consulting with Prof. Jaan Mannik and Prof. Maxim Lavrentovich in The University of Tennessee Physics Department's two biophysics professors); Prof. Steven Ripp, Professor of Ecology and Evolutionary Biology specializing in microbiology and genomics; and Prof. Kevin Kit, Professor of Materials Science Engineering specializing in electrospun polymers we concluded that it would be best to use a commercial off the shelf electro-spun filter element that can perform a size exclusion separation of the desired bioaerosols. While it is possible to purchase borosilicate filters capable of viral capture, they are more expensive and would require a higher pressure gradient maintained to push air across the membrane. The ABS electrospun membranes are ideal for capture the full range of microbial life down to 0.2 microns. By only collecting samples larger than 0.2 micron, we will be able to sample a larger amount of air and still be able to capture most microbes.

The initial plan of using a 0.2 micron filter was investigated, with filter samples from Tisch scientific being tested in a feasibility study. We quickly determined that the air flow that was possible with a centrifugal pump and these filter elements was simply not enough to capture enough material to sequence; this led to the use of open cell melamine foam blocks as an alternative capture media. The melamine foam is autoclavable, meaning it can be handled without gloves and sterilized prior to each mission; in addition, the blocks could be moistened with deionized water to greatly enhance capture efficiency, as the surface tension of the water would retain particles too small to be captured by the foam cells. This new capture media proved to not only be an effective alternative to the more expensive 0.2 micron electrospun filters, but also served as an ideal growing medium.

The use of a centrifugal pump to enhance airflow was investigated as well, with several small prototype pumps being manufactured. To achieve the required cubic meter of air flow through the payload during our allowed sampling time, the pumps would have to spin around 20,000 rpm; this results in a large torque being applied to the rocket which could spin the airframe and tangle recovery hardware. A second, counter-rotating centrifugal pump could be attached to the primary pump using gears or pulleys to counteract this torque, but the added complexity was less than ideal and designing a system which would not be damaged either through the high loads experienced at launch or during operation of the pumps was simply not feasible for our timeline. The team decided to abandon active airflow enhancement in favor of a passive air collection system utilizing thermo-formed polycarbonate panels, which would open after the rocket reaches the peak of its flight and induce flow separation around the panels which would suck air into the payload bay.

With the capture mechanism completely changed, our payload processing had to be changed as well. Prior to launch, melamine foam blocks were autoclaved in a clean room and the payload sanitized with 200 proof ethanol. The blocks were tacked inside the payload bay using cyanoacrylate glue, and the panels closed and locked. The payload assembly was then placed in a sealed and sterilized bag for transportation to minimize the possibility of contaminating the payload. Once the rocket is ready to be assembled, the payload is attached to the rocket and placed in the launch tower. Just before the area is cleared of personnel, the entire outside of the rocket is wiped down again with 200 proof ethanol to maintain as sterile an environment as possible.

Discussion of Results

Due to numerous complications with the rocket and payload mechanisms, with issues programming the locking tabs used to prevent the payload panels from opening during high speed flight and possibly destroying the rocket. The first sampling mission was carried out at the Spaceport America Cup in Truth or Consequences, New Mexico on June 22nd, 2019. Issues with the sampling panels required we leave them closed, but add a vent to allow air out of the rocket at launch and pull air back into the airframe as the rocket descends and air pressure increases. The rocket reached a maximum altitude of just under 7,000 feet and was successfully recovered, with the outside of the payload once again sterilized and sealed in a bag for transportation back to the University of Tennessee campus.

The week after the competition, the University of Tennessee's Center for Environmental Biotechnology (CEB) received the melamine foam blocks flown on the June 22nd sampling mission. They divided the melamine foam into several samples and placed them into incubators to attempt to grow bacteria for genetic sequencing. By the following day, the capture media had become over-run with multiple unknown fungal colonies which could not be separated and separately analyzed. Due to the hyper-virulent nature of the fungal colonies captured, bacterial colonies possibly captured during the flight were quickly killed off. Experts with CEB were unable to identify the species of fungi responsible and believe it is possible they were captured during the flight; however contamination is also a possibility. After a month of attempting to isolate individual species of fungi, CEB determined gene sequencing would be impossible and proceeded to sterilize and discard the samples. In September of 2019 a second sampling mission was attempted, but issues with the rocket's ground support equipment malfunctioned, making it impossible to load nitrous oxide onto the rocket. This sampling mission was aborted and the payload used as a control to check the effectiveness of our sterilization methods. CEB once again attempted to sequence any bacterial or fungal colonies; however, after two weeks of incubation they were unable to find any life in the melamine foam. This indicated that the payload was able to remain sterile for long periods of time when there was no vent through the panel arm screw holes.

Dissemination of Results

The team presented on HARAMOC at both the University of Tennessee's Senior Design Showcase and the Spaceport America Cup's Conference and Poster Sessions.

Bibliography

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[4] Smets, W., Moretti, S., Denys, S., & Lebeer, S. (2016). Airborne bacteria in the atmosphere: Presence, purpose, and potential. *Atmospheric Environment,139*, 214-221. doi:10.1016/j.atmosenv.2016.05.038

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Impact Assessment:

How the Project Influenced your Chapter

This project required extensive collaboration between the University of Tennessee's Mechanical, Aerospace and Biomedical Engineering, Ecology and Evolutionary Biology, and Physics departments, encouraging future collaboration between the two departments. Students gained hands on experience in a challenging project, learning how to reason through a project the likes of which has never been attempted. Unlike many projects where a clear path to completion may be seen, students had to combine concepts from numerous sources in an attempt to capture a sample of high altitude bioaerosols. The out-of-the-box thinking and creative problem solving strategies required for our success have left a lasting impression on many of the students.

Key Metrics and Reflection

How many students from your SPS chapter were involved in the research, and in what capacity?	5 from SPS, there were a handful of high school students who conducted the biological side of the experiment, and 17 members of the Student Space Technology Association.
Was the amount of money you received from SPS sufficient to carry out the activities outlined in your proposal? Could you have used additional funding? If yes, how much would you have liked? How would the additional funding have augmented your activity?	We could have used additional funding, we had to make the prototype flyable which lead to significant startup issues. This could have been rectified but the final $1000 arrived too late to be made useful prior to competition and the initial $1000 was held up by the university for a couple months creating an artificial time crunch.
Do you anticipate continuing or expanding on this research project in the future? If yes, please explain.	There is a grant we could apply for within the university to pay for a larger program but there is insufficient interest to get this going.

If you were to do your project again, what would you do differently?	Develope the doppler shift and time of arrival telemetry system for which we have reallocated funds.

Press Coverage (if applicable)

State Senator Ken Yager's twitter from the October Sky Festival in Oliver Springs, TN.
https://twitter.com/YagerTweets/status/1185593674417295361

Muse Knoxville Facebook from STEAM Carnival
https://www.facebook.com/MuseKnoxville/photos/ms.c.eJxFVMmNRTEI62jEvvTf2OjBx7laEINtIhFqwSKkzi76Jx~;gbaxRTpoLBFVplFXTAdbT0nFA0lfRVAe4DiAOoJO4xOXHUl7fG1lgoQECtML8AaZ2g3VMhfWvgpnmUWK0DAu1YPStUL43pD5AS68lZxeNAPCtb0kYTKYiGBWuw~_K3rdhOSobBhoX7WChGwma69UtG5Ceh~_ExacZP60j6gdIAQALyAwZdaX~;JYIr5HzWBDy7Bww2xds1FBy2InIUuP~_6e6l~;M8GrdLZ~_4cpwfHGGUJFhogFcBGqhtv7OiB0bt9AEdFjLdqWN9lWxDcpY1EPmokNIfIbbNLwajKMbtfgmxDB4BsrEQcuGZ9VljZ05J~_Law5FQlfZCpCGHGwjYNB02Exh3ObMUPGSFcxuyOUmhOLPufEdheMzrEpNMWkOWYXKmSXwxEKDUsmWHStpNNUZHwxuQo2GU01QKtLi~;PwSVC~_0InsET5gvxyHyO3TUhi9Yu8Fscwd~;f1SvAkSJCj2PAoiN69RAHL~;oADtflt135ZXbnDjrb96MDKmvWYjluybdUi4sdTsf21EGsQ~-.bps.a.2663458383685140/2663462140351431/?type=3&theater

https://www.facebook.com/MuseKnoxville/photos/ms.c.eJxFVMmNRTEI62jEvvTf2OjBx7laEINtIhFqwSKkzi76Jx~;gbaxRTpoLBFVplFXTAdbT0nFA0lfRVAe4DiAOoJO4xOXHUl7fG1lgoQECtML8AaZ2g3VMhfWvgpnmUWK0DAu1YPStUL43pD5AS68lZxeNAPCtb0kYTKYiGBWuw~_K3rdhOSobBhoX7WChGwma69UtG5Ceh~_ExacZP60j6gdIAQALyAwZdaX~;JYIr5HzWBDy7Bww2xds1FBy2InIUuP~_6e6l~;M8GrdLZ~_4cpwfHGGUJFhogFcBGqhtv7OiB0bt9AEdFjLdqWN9lWxDcpY1EPmokNIfIbbNLwajKMbtfgmxDB4BsrEQcuGZ9VljZ05J~_Law5FQlfZCpCGHGwjYNB02Exh3ObMUPGSFcxuyOUmhOLPufEdheMzrEpNMWkOWYXKmSXwxEKDUsmWHStpNNUZHwxuQo2GU01QKtLi~;PwSVC~_0InsET5gvxyHyO3TUhi9Yu8Fscwd~;f1SvAkSJCj2PAoiN69RAHL~;oADtflt135ZXbnDjrb96MDKmvWYjluybdUi4sdTsf21EGsQ~-.bps.a.2663458383685140/2663461423684836/?type=3&theater

Expenditures

Our expenditures do not match the amount left in the account. This seems to be due to a “funny money” issue. Currently we have “spent” $506 while the cost of the materials received and paid for are $860.42,

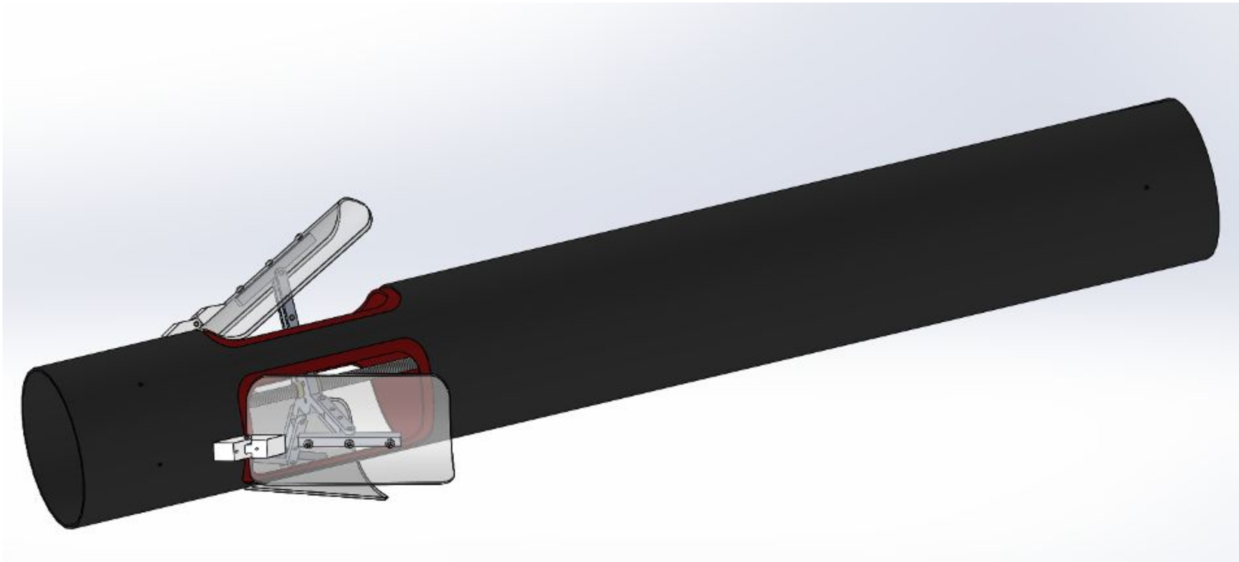
Expenditure Table

Item	Please explain how this expense relates to your project as outlined in your proposal.	Cost
Stepper Motor Driver TB660	Communicates to stepper motor	$23.98
Arduino pro Mini 5V	Control the payload	$9.99
perf board breadboard	Test connections before soldering	$13.10
Buck Regulator LM2596	Used to control voltage going to servo motors used to lock sampling panels during the boost phase of the rocket’s flight	$9.98
9v battery clip	Hold batteries in place during launch	$7.99
Geared Micro Servo	Open the payload	$21.99
Fuse holder	For holding 10A fast blow fuse	$6.99
Servo wire extender	To extend wires so that servos can be mounted	$11.99
10A fast blow fuse	For protecting the stepper motor and motor driver from power surges	$7.96
18 AWG stranded wire multipack	For general wiring in the payload	$29.98
Female Threaded Hex Standoff	For mounting electronic components	$12.50
Steel Socket Head Screw	For threaded hex standoffs	$4.05
Nema 23 Stepper Motor	Open the payload	$81.09

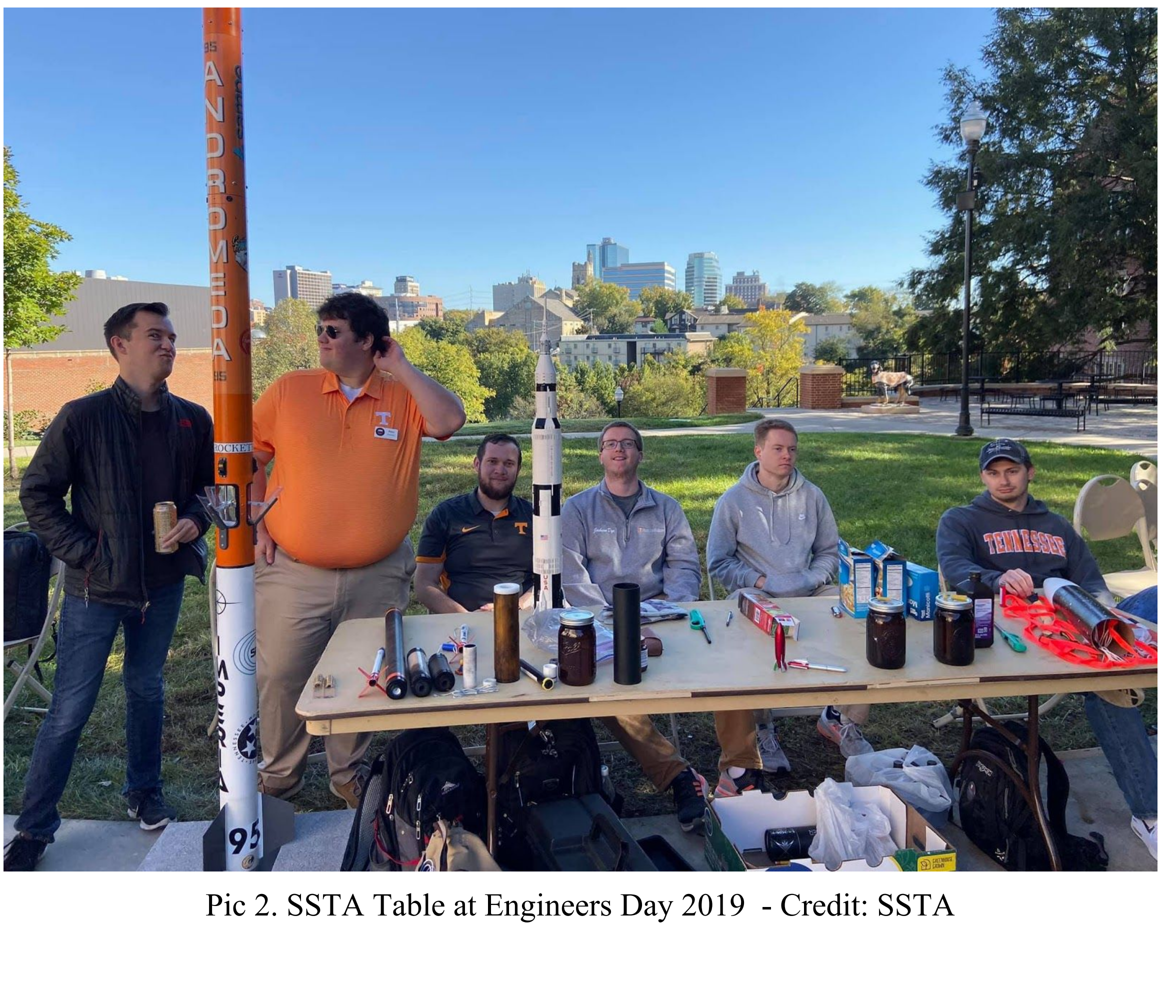
22 AWG JST Male and Female Connector Set	Quick connect for disconnecting power to components and making it easy to swap batteries.	$7.89
M2.5 Standoff Screw Set	Smaller standoffs for custom printed circuit board	$14.98
M2.5 Hex Nut	Hex nuts for retaining standoffs	$7.89
ACS712 Current Sensor 5A Range	Used to detect current flowing from pyro channels on the rocket's altimeter and trigger opening and closing of the payload.	$9.99
18650 Cells	Modular rechargable battery cells	$29.97
18650 Holders	Used to link 18650 cells together to create a battery with customizable voltage and current capacity	$31.39
Servo Motors	Open the payload	$35.97
1/64th inch Viton Gasket 6"x6"	For sealing between sampling panels and the rocket's airframe.	$37.28
Surgilube Lubricating Jelly	Used to enhance the seal between the panels and airframe. Sterilized to prevent contamination.	$18.99
6061 1/8" Thick Al Plate	Small linkage components for panel opening mechanism	27.72
6061 ¼" Thick Al Plate	Pusher plate and mounts for panel opening mechanism	33.12
Tight-Tolerance Air-Hardening A2 Tool Steel Rod Hardened, 1/8" Diameter	Low friction pivot points for panel opening mechanism	75.69
Stainless Steel Precise Metric Hex Socket Head Cap Machine Screws	Screws used for attaching various components	22.89

L298N H-bridge Motor Controller L298N	Stepper motor driver used to communicate between arduino and the stepper motor used to drive the panel opening mechanism.	3.99
Aluminum Alloy Shaft Coupling Flexible Coupler	Connecting the shaft to the stepper motor in a way to eliminate excessive stresses.	7.76
1/8-Inch C-Clip	Retaining pins in arm linkage	9.27
Lead Screw shaft	Driving panel doors	39.99
Optical Limit Switches	Determining when to stop the panels	9.99
DC-DC Buck Boost Converter Module Power Supply	Used to power various payload components	16.95
Black PRO Series PETG Filament - 1.75mm	Printing the structure of the payload. PETG was needed due to high operating temperatures expected, with a glass transition temperature of around 100 C.	185

Activity Photos



Pic 1. CAD rendering of the HARAMOC payload - Credit: SSTA



Pic 2. SSTA Table at Engineers Day 2019 - Credit: SSTA

Pic 3. Drew Nickel at the October Sky Festival - Credit: SSTA

Pic 4. UTK's Spaceport America Cup team at conference and poster sessions - Credit: SSTA

Pic 5.Waiting for launch window at Spaceport, New Mexico - Credit: SSTA

Pic 6. Examining the rocket as it is finally ready for launch at Spaceport - Credit: SSTA

Pic 7. Andromeda lifting off from the launchpad at Spaceport - Credit: SSTA

Pic 8. Recovery deployment of the parachute at Spaceport - Credit: SSTA

Pic 9. Presentation table at the senior design showcase in TBA   - Credit: SSTA

Pic 10. Successfully securing the rocket after the launch - Credit: SSTA