Colorado Space Grant Consortium

DemoSat
Design Document - Final Draft

Team Biology

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04.27.15
Revision D

Revision Log

Revision	Description	Date
A	Conceptual Design Review	See Website
B	Preliminary Design Review	See Website
C	Critical Design Review	03.20.15
D	Analysis and Final Report	04.26.15

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1.0 Mission Overview

The mission for team biology is to encourage design and conduct individual experiments while working together on the technical, experimental, electrical, and collaborative aspects of our payload box. Four unique experiments will involve specialties in different fields to gain experience completing a research project. Each of the four experiments has a specific question to answer and factor to test, and by sending up the payload the question will be answered using teamwork and assistance to ensure the completion of the experiments.

1a. Mission Statement: Test melanin's ability to absorb and reflect radiation outside of a skin cell
1b. Mission Statement: Test naphthalene's ability to expel infrared radiation after reacting with the ultraviolet radiation in Earth's upper atmosphere
1c. Mission Statement: Test the amount of light in Earth's upper atmosphere using lumen sensors
1d. Mission Statement: Test the ability of specifically genetically modified fruit flies to withstand pressures obtained during balloon flight and any behavioral changes while maintaining temperature
1e. Mission Statement: Ensure collection of relevant data, structural integrity of box, sensor setup, and cost/weight limits are taken into account.

2.0 Requirements Flow Down

Melanin As An Independent Barrier Against Ionizing Radiation

My experiment requires very little for completion. In order to run this experiment, I will need lab time and the following supplies:

- Payload box
  - Must possess a central tube for attachment to balloon for launch
    - § Tube must accommodate a flight string 4.7 mm nylon cord
  - Must be under 1.1 kg in weight
  - Must pass whip/drop/cold test
  - Must not contain anything that can interfere with tracking information of balloon
- 4 High altitude test tubes (for transport and containment of *S. cerevisiae*)
- *S. cerevisiae* (specifically-Brewer's yeast)
- Nutrient (to keep *S. cerevisiae* alive)
- Synthetic melanin (to coat two of the test tubes)

Polycyclic Aromatic Hydrocarbons (PAH) and the Production of Infrared Radiation After Exposure to Ultraviolet Radiation in the Upper Atmosphere

To test for Infrared radiation in this experiment, lab time and the following items and supplies are needed:

· Payload Box
- Must possess a central tube for attachment to balloon for launch
  - § Tube must accommodate a flight string 4.7 mm nylon cord
- Must be under 1.1 kg in weight
- Must pass whip/drop/cold test
- Must not contain anything that can interfere with tracking information of balloon

· 2 (two) High altitude test tubes - for transport and pressure containment of organic chemical naphthalene - One control, one for payload box -
· Total of 1.392 grams of naphthalene, solid state -
· 3 (three) SI 1145 Light Sensors from Adafruit. One will measure ambient UV and IR radiation and the other will measure UV radiation and IR radiation directly in contact with the sample of naphthalene. One control will measure the UV and IR radiation on the ground.

Fruit Flies Withstanding Atmospheric Pressure and Noticing Any Behavioral Changes

In order for completion of this experiment, detecting how fruit flies withstand pressure and if any behavioral changes occur, the following will be needed:
· Payload Box
- Must possess a central tube for attachment to balloon for launch
  - § Tube must accommodate a flight string 4.7 mm nylon cord
- Must be under 1.1 kg in weight
- Must pass whip/drop/cold test
- Must not contain anything that can interfere with tracking information of balloon

· 4 (four) plastic test tubes- each test tube will contain a solidified nutrient, 2 tubes will contain wild type fruit flies and the other 2 tubes will contain modified Alan Shepard fruit flies- one set of each (wild type and Alan Shepard) will be a control and the other set will be for the payload box.
· A GoPro will be facing the test tubes in the payload to record the behavior of both sets of flies, a second GoPro will capture the behavior of the flies in the control box.
· 2 (two) small LED light bulbs will be placed next to each of the GoPros to provide a light source for the cameras.
· A heat sensor will detect the temperature of the test tubes, while heating strips will keep the fruit flies alive.

	Requirement	Information	Source

1	Structural Integrity	Ensuring that payload box passes several structural tests	Mission Statement 1e
2	Thermal Control	The sensors required for the box must have adequate thermal control. Maintenance of life support for fruit flies is also a factor	Mission Statements 1d and 1e
3	Cost Limits	The budget for team spending is adhered to	5.0 Budget
4	Mass Limits	The limits for mass (1.1kg) will be met for the payload box	Mission Statement 1e
5	Data Collection	After successful launch and experimentation, data collection and interpretation will be conducted for each experiment from information obtained from sensors stored in sd card	Mission Statements 1a, 1b, 1c, 1d, 1e

3.0 Design

Overall Design

· Payload Box
- Must possess a central tube for attachment to balloon for launch
  - § Tube must accommodate a flight string 4.7 mm nylon cord
- Must be under 1.1 kg in weight
- Must pass whip/drop/cold test
- Must not contain anything that can interfere with tracking information of balloon

· 4 (four) High altitude test tubes - for transport and pressure containment of organic chemical naphthalene and melanin with yeast - three for control, three for payload box.
· Total of 1.392 grams of naphthalene, solid state
· 3 (three) SI 1145 Light Sensors from Adafruit. One will measure ambient UV and IR radiation and the other will measure UV radiation and IR radiation directly in contact with the sample of naphthalene. One control will measure the UV and IR radiation on the ground.
·1 (one) Lumen sensor to measure light in the upper atmosphere - BACKUP
·1 (one) Temperature sensor to measure and control temperature of sensors and fruit flies

The sensors throughout the experiment will connect to one arduino with four lithium batteries, and the data from all sensors will be collaboratively gathered. This means that some sensors, such as the temperature sensor, are multitasking for more than one experiment. The design does not include any radio frequencies, does not exceed 1.1kg, and does not transport any illegal or harmful substances, thus complying with the requirements for the DemoSat program.

Melanin - $60.62 paid for with Space Grant funds
2 Sparkfun Luminosity Sensors - $11.90 total paid w/ COURSE grant
1 Adafruit IR bulb pack - $7.95 paid w/ COURSE grant
3 Adafruit light UV sensors - $29.85 total paid w/ COURSE grant
1 Adafruit UV bulb - $4.95 paid w/ COURSE grant
1 Sparkfun Sensor kit $139.95 paid w/ Space Grant
1.392g Naphthalene - Donated through Pikes Peak Community College
1 OpenLog $24.95 - https://www.sparkfun.com/products/9530 - Paid w/ Course grant

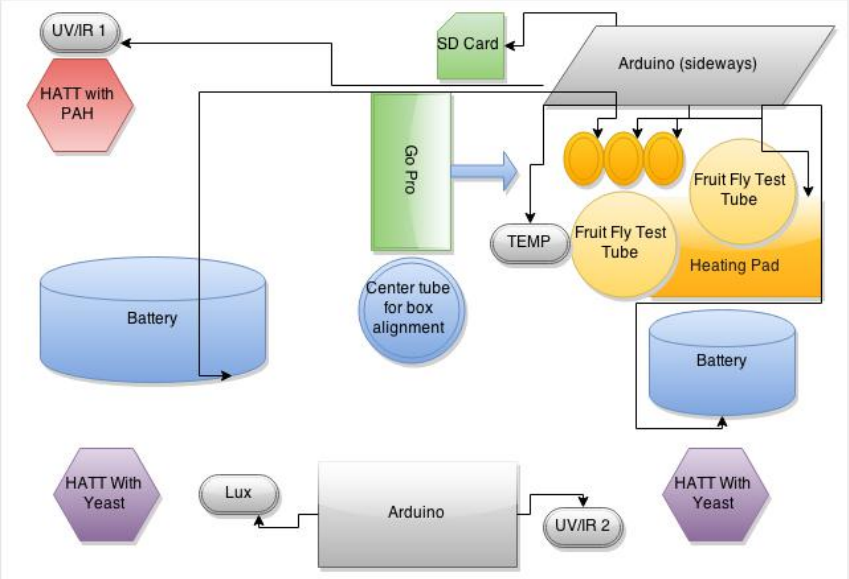

Fig. 1 - Payload Box Plan

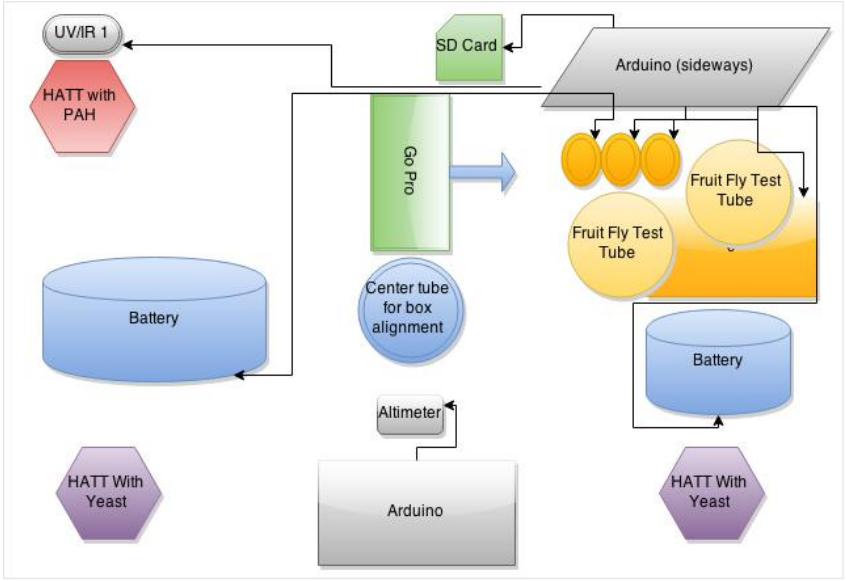

Fig. 2 - Control Box Plan

Melanin As An Independent Barrier Against Ionizing Radiation

In order to test melanin's ability to absorb and reflect radiation outside of a skin cell, I elected to create a coating to place on the high altitude test tubes containing a living microorganism that otherwise has no defense against ionizing radiation. I was able to obtain synthetic melanin and selected *Saccharomyces cerevisiae* (the type used for brewing beer) to be the organism I exposed during our flight. The melanin came in a powdered form, in order to adhere it to the high altitude test tubes I mixed the melanin powder with distilled water.
Eumelanin[1] is insoluble in water (Salano, 2014) therefore the actual melanosomes[2] would not dissociate in the liquid, allowing me to adhere them to the tubes while maintaining the structural integrity of the melanin itself. After viewing under the microscope, the water spread the melanosomes more evenly, which supported the use of water as the liquid to use to make the solution for the coating.

The solution of distilled water and synthetic melanin will coat two high altitude test tubes. One of these test tubes (ctt1) will be placed in a payload box to be sent up on a hydrogen balloon under the DemoSat program to nearly 30 km. A second coated test tube (cct2) will be in a control box on the ground as a

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[1][1] Eumelanin is melanin that is brown to black in color. This color of melanin, humans produce. Melanin that is yellow to reddish brown is pheomelanin. (Salano, 2014)
[2] Melanosomes are vesicles that contain melanin

control. Included in the payload box, there will be a high altitude test tube not coated with the solution (tt1). Another high altitude test tube without coating (tt2) will be in a control box on the ground as a control as well. All four test tubes will have 0.5 mL of *S. cerevisiae* placed inside of them for the launch.
Before launch day, I will be observing *S. cerevisiae* under the microscope to analyze the cellular composition under normal conditions. Upon the payload box return, I will observe *S. cerevisiae* under the microscope to detect any damage on a cellular level. The results of my examinations before and after will be compared against each other to support or dismiss my thoughts of melanin providing a defense for organisms autonomous of human skin cells.

Polycyclic Aromatic Hydrocarbons (PAH) and the Production of Infrared Radiation After Exposure to Ultraviolet Radiation in the Upper Atmosphere

Polycyclic Aromatic Hydrocarbons are uniquely suited for this experiment. In the interstellar medium, many of these PAH molecules collect, either clumping or floating individually, and can indicate the beginnings of life. PAHs are fascinating in that when exposed to high levels of ultraviolet radiation, the bonds in the molecules vibrate intensely, creating an energy buildup that is expelled as infrared radiation. Earth sensors have detected “Unidentified Infrared Bands,” streams of IR radiation with no known source. A leading theory is that these incoming IR radiation streams come from PAH compounds. This theory is widely accepted, to the point where the name of these IR bands are referred to by some as “Aromatic Infrared Bands”. This experiment strives to discover whether the UV radiation in our upper atmosphere is enough to catalyze the above reaction, and produce an amount of IR radiation detectable by sensors. One UV/IR sensor will be situated near the test tube of naphthalene in the payload box, and another sensor will be placed as far away as possible while still remaining in the payload box to record ambient radiation. Another sensor will serve as control on the ground. The high altitude test tube containing the naphthalene will maintain pressure so that the only factor affecting the organic chemical is predicted to be ultraviolet radiation, and theoretically will catalyze a vibrational reaction strong enough to be detected by sensors.

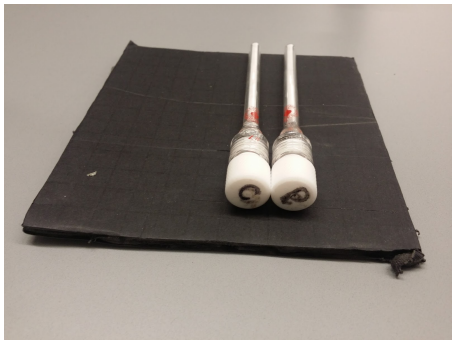


Figure 1: Naphthalene in High Altitude Test Tubes

Parts List

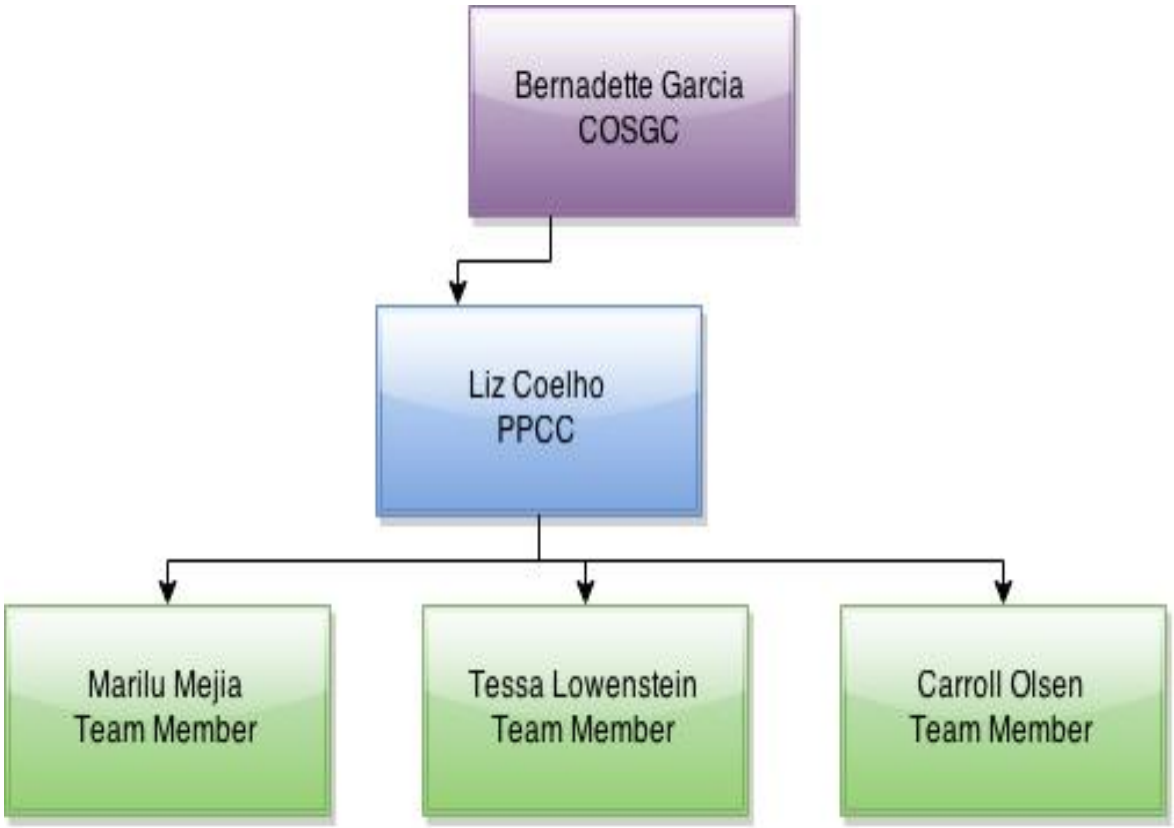
3 SI 1145 Light Sensors from Adafruit, $9.95 each:
http://www.adafruit.com/products/1777a
2 High Altitude Test Tubes - PPCC

Fruit Flies Withstanding Atmospheric Pressure and Noticing Any Behavioral Changes

Regular fruit flies (or Wild Type Fruit Flies) feel pressure and when placed in an enclosed test tube, they have the tendency to keep crawling upward, while modified fruit flies (or Alan Shepard Fruit Flies) do not feel pressure and will just stick to the bottom of the test tube. In this experiment, I will identify whether 100,000 feet is an elevation high enough to make the regular fruit flies behave like the the modified fruit flies and stick to the bottom of the test tube. A temperature sensor will record the temperature of the flies while a heating pad while keep them from freezing. A GoPro will also be inserted into the the payload to observe the behavior of the flies.

4.0 Management

Team Biology has several more scheduled tests to complete at the writing of this paper, and has a calendar of dates to complete these important steps. Also included is the organizational chart of management.



April 2015

Sun	Mon	Tue	Wed	Thurs	Friday	Sat
			1	2	3	4
					1. Bench Test 2. Battery test 3..Cooler Test 4.2pm-5pm Repair of systems and Launch Readiness Review slides workshop	
5	6	7	8	9	10	11
				LLR Slides Complete	1. Final Box Review 2. Experiment finalization 3. 2nd Bench Test 4.Launch Plan Completion	Launch!
12	13	14	15	16	17	18
						Symposium
19	20	21	22	23	24	25
26	27	28	29	30		
		1. Final Reports Due				

5.0 Budget

Funding/Spending 2015
Supplies
Melanin - $60.62 paid for with Space Grant funds

2 Sparkfun Luminosity Sensors - $11.90 total paid w/ COURSE grant
1 Adafruit IR bulb - $7.95 paid w/ COURSE grant
3 Adafruit light sensors - $29.85 total paid w/ COURSE grant
1 Adafruit UV bulb - $4.95 paid w/ COURSE grant
1 Sparkfun Sensor kit $139.95 paid w/ Space Grant
Space Grant Total = $200.57
COURSE Grant Total = $54.65
Total Supplies= $255.22
Stipends
3 student stipends of $650/each - paid w/ COURSE grant
Total stipends = $1950
Overall Total, Supplies + Stipends = $2205.22

6.0 Test Plan and Results

On March 13, 2015, our team completed an initial whip test and initial drop test. It appears that the payload box will survive launch and landing. A cooler test, battery test, and bench test will be conducted at the dates listed on the above schedule.

Melanin:The cold test will be completed before launch, though the cold is not an issue in this experiment. The cold will slow/stop the *S. cerevisiae* metabolism but not kill the organism. The radiation can still affect *S. cerevisiae* if it is in a “dormant” state. There will need to be another round of whip and drop tests to ensure the spaces that have been removed from the spray foam for equipment placement do not interfere with the structural integrity of the box.
March 31, I will be in the lab for my initial observation of *S. cerevisiae* under the microscope.
April 7, I will be in the lab to mix my solution of synthetic melanin and diH_2O, and coat two high altitude test tubes.
April 9, I will put *S. cerevisiae* into the high altitude test tubes in preparation for launch.
April 11, the DemoSat balloon will be launched and recovered.
April 14, I will be in the lab to observe and compare my samples.
April 18, I will present my results at the 2015 COSGC Undergraduate Space Research Symposium.

PAH: **On April 3rd, an experiment will be conducted on the naphthalene to ensure that the level of UV radiation obtained from a UV lamp are enough to catalyze an expulsion of IR radiation in the organic chemical.**
April 11th, Launch will take place and recovery of payload.
April 18th, A presentation of results will take place at the 2015 COSGC Undergraduate Space Research Symposium.

Fruit Flies: April 3, will finish up any last wiring or electrical that needs to be done.
April 9, obtain the flies from Dr. Killian and look at them under the microscope, while preparing them for the launch.
April 10, last day to make sure everything is ready and functional for the launch.
April 11, launch will occur, along with the recovery of the payload.
April 14, review results.

7.0 Expected Results

Melanin

It is expected that the *S. cerevisiae* cells that are on the ground as a control will have the least damage to their DNA, and appear the same as before the launch when viewed under the microscope. The *S. cerevisiae* cells in the ctt1 tube will have little or no damage to their DNA when viewed under the microscope. The *S. cerevisiae* cells in tt1 will have the most damage to their DNA and will most likely not survive the experiment.

I hypothesize that the *S. cerevisiae* sample in tt2 should have no damage on a cellular level.

I hypothesize that the *S. cerevisiae* sample in ctt2 should have little to no damage on a cellular level.

I hypothesize that the S. cerevisiae sample in ctt1 will have only slight damage on a cellular level.

I hypothesize that the *S. cerevisiae* sample in tt1 will have the most damage on a cellular level.

When directly comparing the sample in tt2 to the sample in tt1, the sample in tt1 will have a great deal more damage than the sample in tt2. This is due to the sample in tt1 being exposed to intense ionized radiation, without the protection of melanin, while the sample tt2 was not exposed to intense ionized radiation. These two samples with show the extremes for the range of this experiment.

When directly comparing the sample in tt2 to the sample in ctt1, the sample in ctt1 will have more damage than the sample in tt2. This is due to the sample in ctt1 being exposed to intense ionized radiation, while the sample in tt2 will be exposed to no radiation.

When directly comparing the sample in tt1 and the sample in ctt1, the intense ionized radiation in the upper atmosphere will have caused more damage to the sample in tt1 than to the sample in ctt1. The sample in tt1 will have more damage because it did not have melanin to protect itself.

Polycyclic Aromatic Hydrocarbon:

Due to the nature of PAHs, it is expected that both the test tube containing naphthalene in the payload box, and the tube in the control box will have some reaction resulting in the expulsion of IR radiation. I hypothesize that the test tube in the payload box will have a much stronger reaction resulting in higher levels of IR radiation detected. This will give researchers an indication of the amount of UV radiation required to detect PAH molecules, and from what distance.

Fruit Flies:

8.0 Launch and Recovery

All three members of the team were able to attend launch, with Tessa Lowenstein taking the role of payload handler. After initial launch, which landed in a tree, a second attempt was made and was successful. At an altitude of 91,000 feet, the payload landed approximately 30 miles away from launch site in Eaton, Colorado. After obtaining permission, all payload teams walked a distance to the boxes and retrieval was attained. The payload box was in good condition, though on the inside it was apparent that the batteries had disconnected from one of the Arduinos obtaining information from the temperature sensor, UV sensor closest to the Polycyclic Aromatic Hydrocarbon tube, and the extraneous lux sensor. Unfortunately that did affect certain tests, as will be described below in section 9.0

After the launch, the Polycyclic Aromatic Hydrocarbon experiment was to be brought to a computer and the results from the SD cards examined. One arduino, connected to the ambient UV/IR sensor and an OpenLog, had information to examine. The primary arduino with greatest importance to the experiment had a battery malfunction, and thus was unable to be read.

The yeast samples from the melanin experiment saw the capillary tubes lose their plugs, so much of one sample was mixed with melanin, while the other was just mixed together. The samples were taken to the Rampart Lab, slides were made of the returned samples and yeast was plated to grow out for further examination.

9.0 Results, Analysis, and Conclusions

The yeast samples from the Melanin As An Independent Barrier experiment were viewed under the microscope and compared for obvious differences. Though the sample of yeast not given a melanin barrier did show a larger percentage of lysed cells than the melanin protected sample, the difference in the samples was not large enough to determine that the melanin was definitely the reason for the difference. Much of the sample protected by melanin returned viable. Sample colonies that were grown on SAB plates did not show any permanent change from the exposure to radiation.

These results lead to the conclusion that further testing is needed to determine the effectiveness of melanin as an independent barrier. Subsequent testing should allow for an organism that is more sensitive to the radiation in the upper atmosphere. *S. cerevisiae* appears to be a hearty microorganism and able to tolerate higher levels of radiation than was expected. Moving forward, I hope to create a transgenic yeast that can detect varying wavelengths of

radiation and respond with appropriate pigmentation. I would like test that yeast's ability to pigment and protect another microorganism from radiation.

Polycyclic Aromatic Hydrocarbon: The limited data recovered from the single arduino did provide selective information, however the second, more vital arduino was important for this particular experiment. As such, there was some creative maneuvering in an attempt to compare the ambient payload UV/IR data with ground control UV/IR data. I hypothesized that, though unlikely because of test data, I could potentially detect infrared radiation expulsion all the way to the other side of the payload box where the ambient UV/IR sensor was placed behind aluminum foil. If there was a spike detected, it would have been even greater proof that the UV in our upper atmosphere could catalyze the reaction. After retrieving baseline data, there did not seem to be data that would prove my theory, such as a spike of IR radiation seconds after a UV spike. Data below shows both the entire launch and control data, as well as specific sections I chose to highlight indicating the final ascent, peak height, and a small amount of descent data.

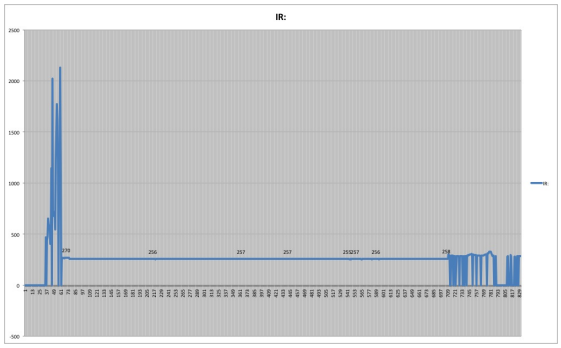


Fig 1. (above) IR Payload Sensor FULL

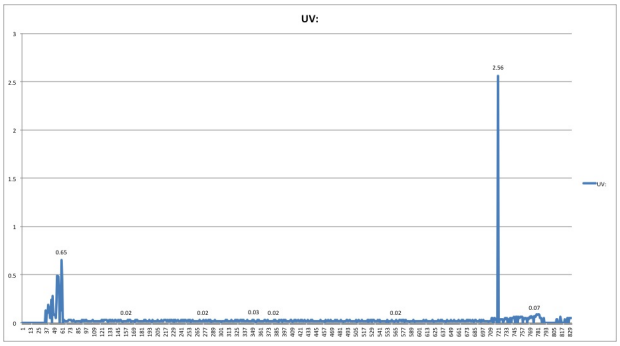


Fig 2. (above) UV Payload Sensor FULL

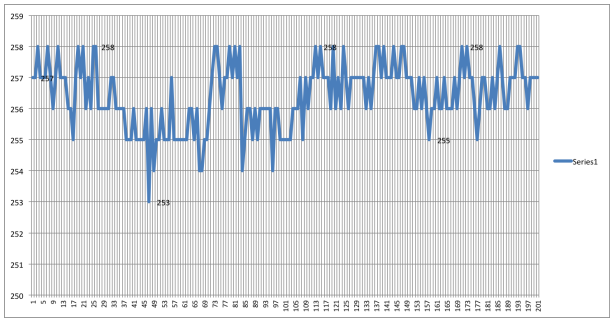


Fig 3. Payload IR sensor 500-700 sec.

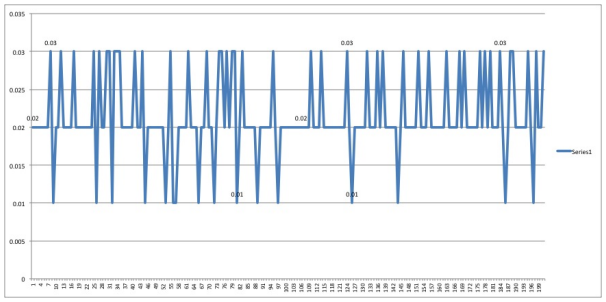


Fig 4. Payload UV sensor 500-700 sec.

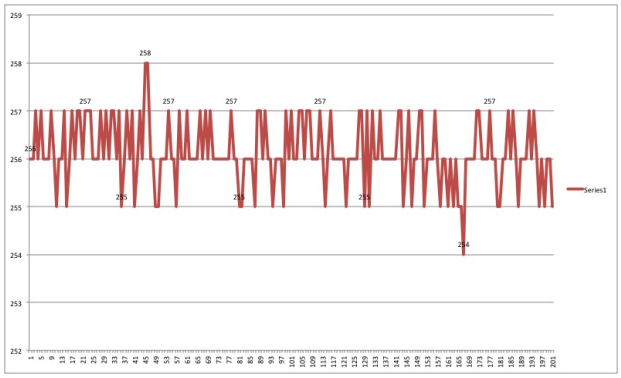


Fig 5. (above) Control IR 500-700 sec

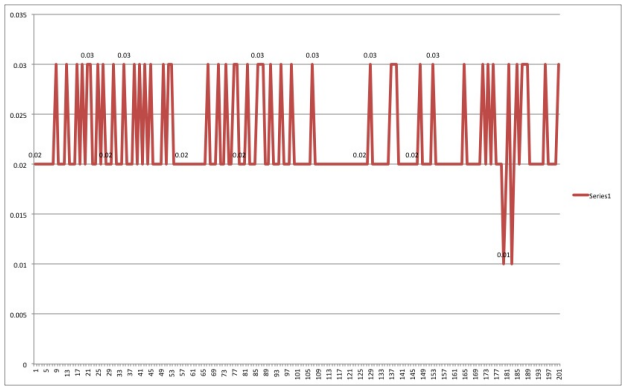


Fig 6. (above) Control UV 500-700 sec

As can be observed above, there is no discernable spike in IR after a rise in UV based on the numbers above. This does not give adequate information to confirm my revised hypothesis, and as such concludes the experiment with a question mark. The experiment was fascinating to test, intriguing to study, and exciting to prepare, and the hope is that polycyclic aromatic hydrocarbons can be studied thoroughly in the future

Fruit Flies: The video from the GoPro for the Fruit Fly experiment showed that once the heater began to get too hot, the solid nutrient that was in the test tubes started to melt. After the batteries for the heater died any of the nutrient that had melted began to solidify once again. As the nutrient solidified any of the fruit flies that were on the nutrient became stuck.

The few flies that survived had no wings or were missing legs, this happened because when the nutrient solidified these flies were stuck on the top of the nutrient and while struggling to get out of the nutrient they ripped off appendages. I believe I obtained this outcome because our team had the misfortune of having our payload get stuck in a tree because the balloon was not properly inflated. My theory was that if the payload was sent up within a timely manner then the heater would not have gotten as hot because as it rose the temperature would be decreasing.

10.0 Ready for Flight

The team is moving on from Pikes Peak Community College, and as such will not be conducting the various experiments in the same payload box.

11.0 Conclusions and Lessons Learned

This year's experiment was disappointing due to my results. I'm excited it doesn't end the line of thinking of pigmentation as a barrier from radiation, I just wish my results had been more conclusive. It has lead me to believe that *S. cerevisiae* is a great microorganism to use in

creating a biological barrier to protect humans from radiation in space. The fact that yeast is so hardy when it comes to temperature and radiation, was a detriment to this experiment but will benefit my future endeavors. I look forward to continuing experimentation with pigments and microbes.

PAH: There is certainly a lot to be said for preparation of materials, and I feel responsible for the battery problems. In the future, I will attempt to ensure the security of both the batteries and sensors, and perhaps advance in the technology by recruiting a team member who has more electrical skill or fostering the ability myself! I truly believe that there is much to be discerned by looking into polycyclic aromatic hydrocarbons, and hope that even if I am unable to continue research, there are those who see the potential in the discovery of these unique molecules in the interstellar medium.

FF: This was a great experience and I am very happy to have been a part of the team and the program. Something that I would have done differently is that I would have put in a temperature controlled heater, so that if it began to get too hot it could shut off and vice versa if it got too cold.

12.0 Message to Next Year

Start early! It seems like there is a lot of time to work with, but it goes by quickly. Do the extra work, it's worth it. Listen to Liz, she knows exactly what she's talking about. Ask for help, your instructors will help if you just ask them. And, always orientate your GoPro outwards, not up and down.
Carroll

I agree with Carroll! Early bird gets the worm, and the sooner you think up an experiment the better. Also, don't just test sensors for your experiment - that may seem cool, but what's even more exciting is creating a relatively unique, observable experiment that could affect the scientific community! Remember, when times get rough, just think: you're sending something into (almost) space, how cool is that?! Also, remember that your battery is important, you should probably do more than we did to ensure its longevity. Good luck. - Tessa

Definitely, think of all the possibilities and outcomes (good or bad) that you could get from your experiment and do anything to either try to prevent them or embrace them. Do your research and have blast doing it!
-Marilu