HASP Student Payload Application for 2015

Payload Title: High Altitude Greenhouse Gas Survey (HAGGS)		
Payload Class: Small	Institution: Arizona State University	Submit Date: 12-16-2014
Project Abstract: The HAGGS payload is designed to monitor ultraviolet flux within the ozone layer. The payload will contain three ultraviolet sensors and a gas analyzer. The UV sensors will measure the intensity of ultraviolet light coming from different directions. The gas analyzer will measure the concentrations of various greenhouse gases such as CO_2, CH_4, N_2O, and fluorinated gases. This data will be compared to timestamped GPS data to try and determine if the difference in ultraviolet flux between the azimuth and nadir changes in regions of high gas concentration.		
Team Name: HAGGS		Team Website: sese.asu.edu
Student Leader Contact Information		Faculty Advisor Contact Information
Name	Muadin Latifi	Srikanth Saripalli
Department	School of Earth & Space Exploration	School of Earth & Space Exploration
Mailing Address	1337 W 13th Street	781 E Terrace Rd, Rm 663
City, State, Zip Code	Tempe, AZ 85281	Tempe, AZ 85287
Email	mlatifi@asu.edu	srikanth.saripalli@asu.edu
Office Telephone		(480) 727-0023
Cell	(858) 735-8369	
Fax		(480) 965-8102

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Science:

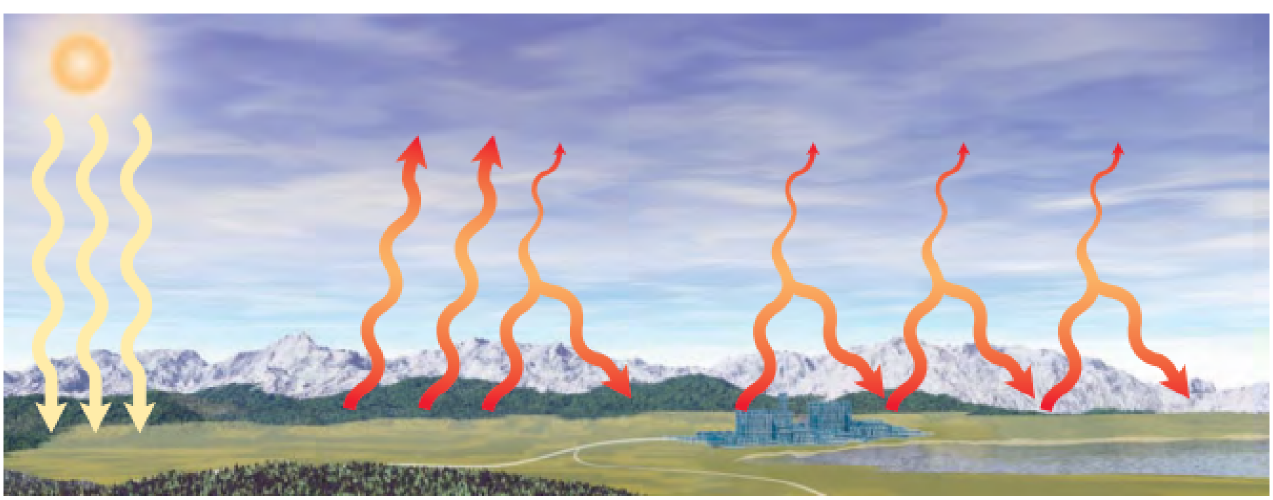
<u>Science Question:</u> What is the ultraviolet intensity for the three directions azimuth, nadir and astronomical horizon within the densest layer of ozone within the stratosphere?

<u>Hypothesis:</u> Due to the Chapman cycle within the stratosphere there should be an observed asymmetric ultraviolet flux in the azimuth and nadir directions.

<u>Science Goal:</u> Characterize the ultraviolet intensity from three directions within the stratosphere's ozone creation and destruction region.

<u>Background Concepts:</u>

- Chapman cycle: UV light from the sun interacts with an O_2 molecule in the Earth's atmosphere, causing it to split into two single oxygen atoms. The oxygen atoms then quickly combines with an O_2 molecule in the atmosphere to create an O_3 molecule.
- Greenhouse gas: one of several gases (e.g. carbon dioxide, methane, chlorofluorocarbons, and other pollutants) in the Earth's atmosphere that block the radiation of energy into space, trapping heat and raising overall planetary temperatures.
- Global warming: a gradual increase in the overall temperature of the Earth's atmosphere generally attributed to increased levels of greenhouse gases.
- Ozone layer: the band of the stratosphere approximately 20-30 km above sea level containing high concentrations of ozone gas (O_3), which blocks certain wavelengths of ultraviolet light.
- The figure below illustrates the greenhouse effect. The sun's ultraviolet radiation (in yellow) enters the atmosphere. Then the radiation (in red) is released from the surface of the earth and theoretically should escape the atmosphere. However, near urban areas, the radiation is absorbed and reflected back toward the Earth's surface by "greenhouse gases". Therefore, little radiation escapes the atmosphere.



Relevance: Knowing the UV flux from three directions will give a better understanding of the amount of incident rays from above, scattering from the astronomical horizon, and backscattering, reflection, and emission from below that is permeating the region with the highest concentration of ozone.

Science Objectives:

- Measure the concentration of greenhouse gases (CO_2, CH_4, N_2O, and fluorinated gases) at high altitudes which could be used to absorb thermal radiation from the Chapman cycle.
- Measure the amount of UV radiation permeating the lower atmosphere from three directions using ultraviolet-B sensors (280-315 nm).
- Build a profile of the density of greenhouse gases at high altitude and the intensity of ultraviolet radiation coming in three directions (zenith, astronomical horizon, and nadir) along the path of the HASP balloon.

Requirements:

Functional:

1) The payload shall integrate with the HASP infrastructure for power and communications.
2) The payload shall be capable of sending and receiving data through a DB9 serial connector using a standard 8N1 structure.
3) The system shall monitor and store data from the experiment.
4) The system shall maintain appropriate interior environmental conditions for the experiment.
5) The payload shall implement COTS components in order to minimize cost.

Performance:

1) The payload shall be capable of storing the UV sensor and gas analyzer data from the duration of the flight.
2) The payload shall transmit data to a receiver computer at a given location.
3) The payload shall maintain operational and survival temperatures of all core electronics for the entire mission duration.

Constraints:

1) The payload mass and volume budgets shall be constrained by the HASP class guidelines (available in the HASP payload interface manual).
    a) Mass cannot exceed 3kg.
    b) Max footprint of payload cannot exceed 15 cm x 15 cm, and a height of 30 cm.
2) The payload design for the PDR shall maintain 35% (TBR) mass, volume, and power budget margins.

3) The payload shall be mounted such that it remains intact under a 10 g vertical and 5 g horizontal shock with a safety factor of (TBD).
4) The payload shall draw no more than 0.5 A or 2.5 A (TBR) depending on proposed class size.
5) The payload shall be capable of handling input voltages of 29-33 VDC.
6) The payload shall have a stabilization feature that allows minimum movement to be seen while taking data.
7) The payload shall cost less than the provided budget of $10,000.
8) Must withstand the extreme environment in space at 36 km altitude with temperatures of -65°F (-54°C, 220K), air pressure of 3 mbar (300 Pa), and up to 100 mph (160 km/hr) winds in the jet stream.

Verification:

1) All performance and functional requirements shall be met while the system is under simulated mission conditions in a thermal-vacuum chamber.
2) All instruments will be calibrated prior to testing and again prior to launch.
3) A full systems check will be performed prior to launch after instrument calibration to ensure compliance with a predetermined mission start checklist.
4) Positioning and time measuring instruments will be tested for accuracy prior to payload integration.

Design Choices:

- There are two gas analyzers so the data collected can be averaged.
- There is enough room and plenty of money in our budget to afford two analyzers.
- The UV sensors are placed inside of the payload in order to get three different angles to better gather data.
- The Arduino microcontroller will make it easier to build and make the components more interactive with the system as a whole.

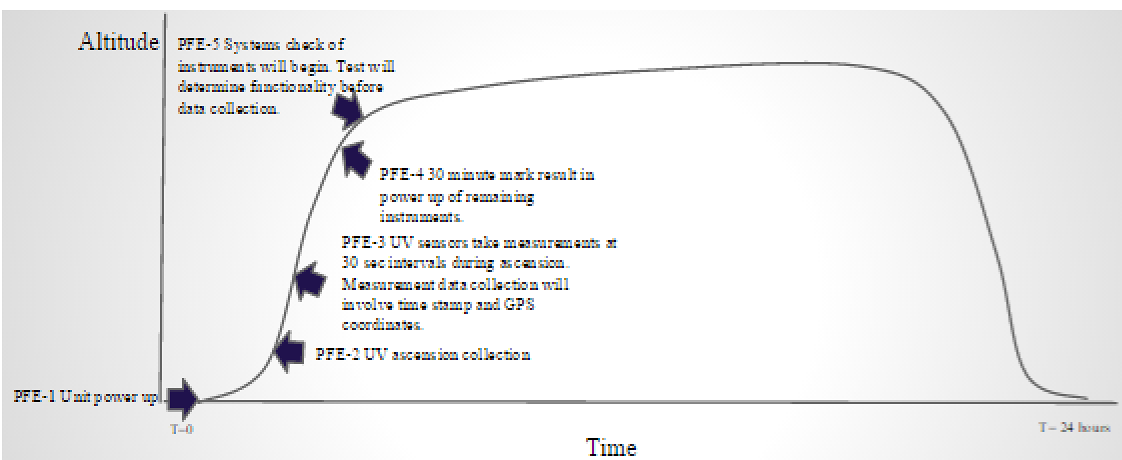
Detailed Mass Budget:

- 2 Gas Analyser: 0.38 kg per
- Microcontroller: 0.1 kg
- 3 UV sensors: (negligible)
- Casing: (TBR)
- Tripart UV sensor holder: (TBR)

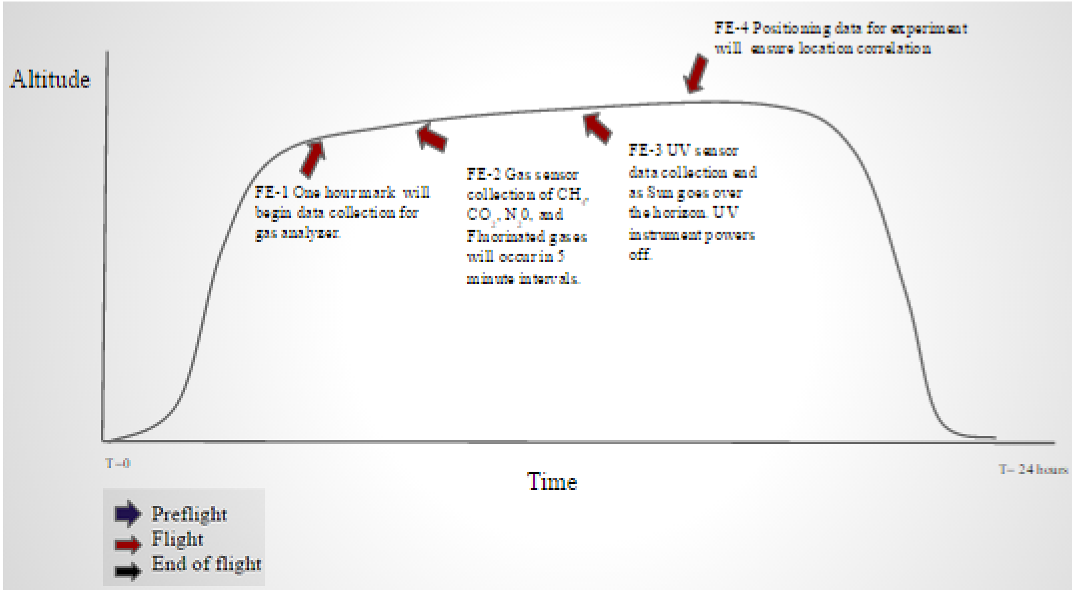
Concept of Operations:

1. Prior to launch, the UV sensors and Arduino microcontroller will be powered up and initialized.

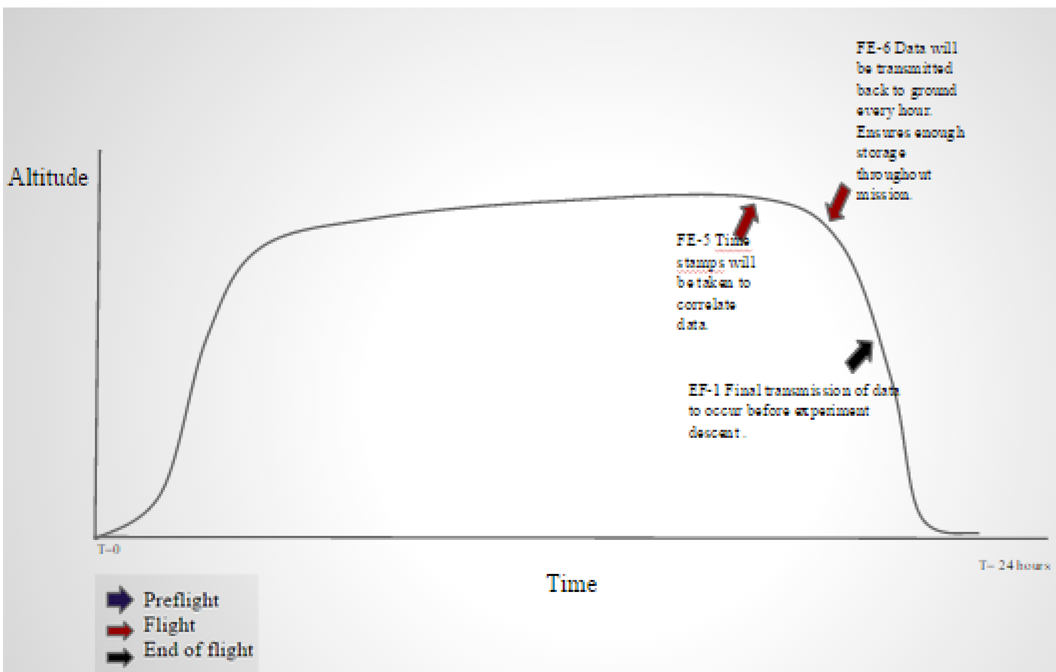
2. At launch, the UV sensors will begin taking UV intensity measurements as the balloon ascends.
3. The frequency of UV intensity data will be taken every 30 seconds as the balloon ascends toward its final height. Each measurement will be logged with the time, the current GPS coordinates, and the altitude that the data was taken at.
4. Following initial launch, 30 minutes into flight, power up of remaining project instruments will be initiated.
5. Upon instrument start-up, a pre-determined systems check process will begin. This will test each instrument to ensure that they are functioning properly before data collection begins.
6. At the one hour mark, data collection for the experiment will begin.
7. Data on the percentages of greenhouse gases (CO_2, CH_4, N_2O and Fluorinated gases) in the atmosphere will be collected approximately every 5 minutes throughout the flight.
8. UV intensity readings will continue until the sun drops below the horizon, at which point the UV instrument will power off.
9. Positioning data will be tracked to ensure that data can be correlated to locations.
10. Time stamps will also be used to ensure correlation of data to location.
11. Data will then be transmitted to the ground team approximately every hour, to ensure enough storage is available throughout the mission.
12. Final data transmission will occur before descent of the balloon begins.



Graph showing the conops for the preflight.



Graph showing the conops for the flight.



Graph showing the conops for the end of the flight.

Testing:

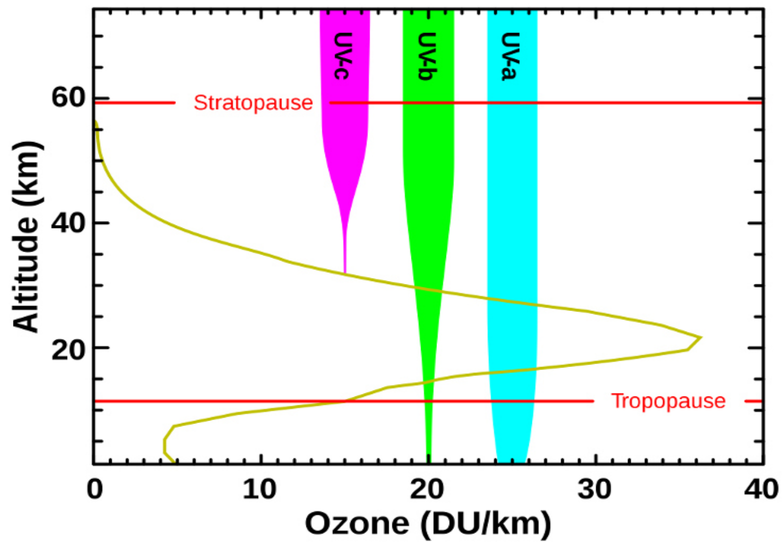
- The G460 and Ventis MX-4 gas analyzer will be tested for pressure, temperature and battery life conditions.

- Pressure tests will determine if the unit can function at the HASP high altitude. Current pressure specs are about 5 - 1,013.25 mbar. If it is not able to meet the pressure conditions, we will then determine options to improve performance through alterations.
- Temperature ranges for the unit are -60 to +30℃. We will test to see how low temperatures will affect unit performance, then determine insulation possibilities to bring the device up to flight specifications.
- Current battery life for the unit is 24 hours of continuous use. We will need to see how the flight conditions will affect this. Also, we must determine if this is enough time for the flight duration.
- If the G460 or Ventis MX-4 does not pass testing, we will then go to the back up sensor options and repeat the above tests for the backup sensors.
- The tests for the SIC01S-B18 UV sensors will consist of temperature, pressure and power at flight conditions.
- Pressure tests will focus on unit use at different pressures due to the unit being used at ascending and descending portions of the flight. Current specifications for pressure limitations are not listed; we will determine if the unit can withstand flight operations.
- Temperature range for UV sensors are -55 to +170℃. Testing will determine if this is within range of flight conditions.
- UV unit testing for connection to HASP power to determine how it will perform during flight conditions. Current maximum allowable voltage for the selected UV sensor is 5 V.
- Secondary UV sensors will be considered if the primary sensor does not pass above testing.
- The efficiency of the UV sensors will also be tested. An artificial UV lamp will be used as a stand in for the sun and will be set to the sensor’s peak wavelength. The sensor will be rotated from 0° to 90° while the lamp stays fixed in order to determine how the angle affects the amount of UV intensity that is received.
- Clock Drifting tests will be conducted in order to sync the time on the instruments to the GPS on HASP by letting clock run over estimated flight time on the ground.
- The payload design will be shock tested to check if it can withstand the maximum g-forces expected from the HASP landing.
- The program code on the Arduino will be stress tested in order to ensure it performs as expected and that there are no bugs that could hinder data collection.

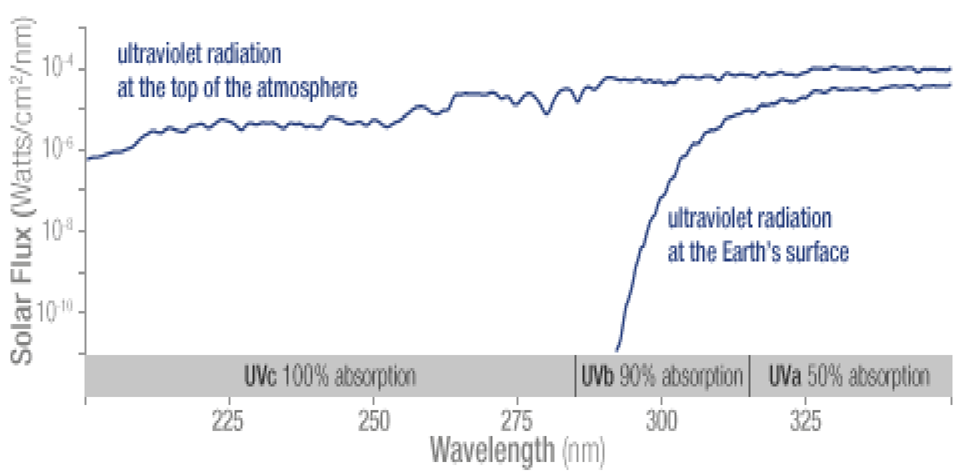
Data Analysis Strategy:

- The three UV data sets (azimuth, nadir, and horizon) will be compiled into a single spreadsheet with one time column.
- The gas analyzer data will be written to a separate spreadsheet with columns for the concentration of each gas and a common time column.

- The UV data will be graphed as three plots on common set of axes (time and UV intensity)
- Vertical lines will then be marked on the graph at each point the gas levels went above or below a certain concentration.
- The differences in UV intensity measured by each sensor in regions of high gas concentration will then be compared to the differences measured in regions of low gas concentration.



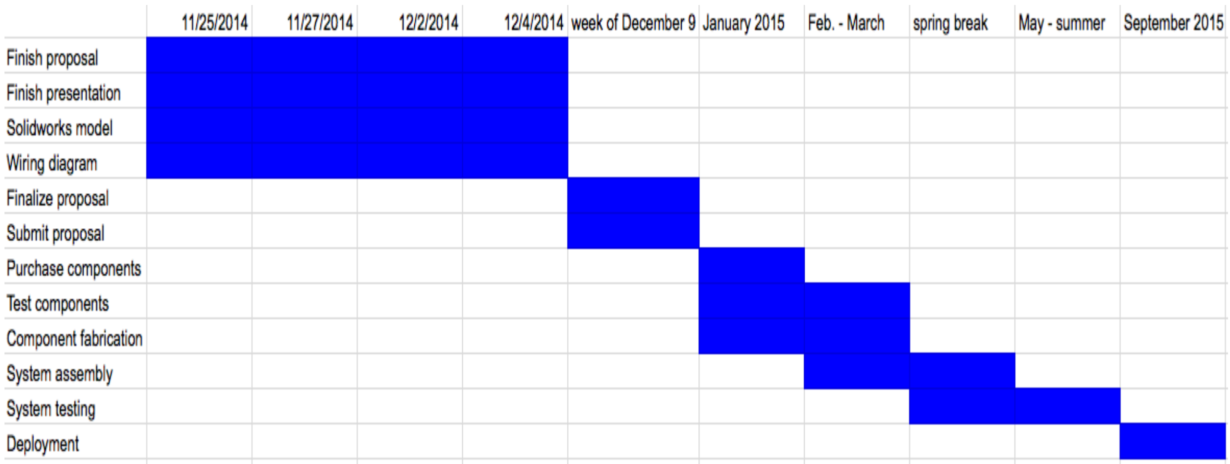
Graph showing the three different wavelengths of UV light and how they are absorbed by atmospheric ozone.
(Source: https://www.espo.nasa.gov/solveII/implement.html)



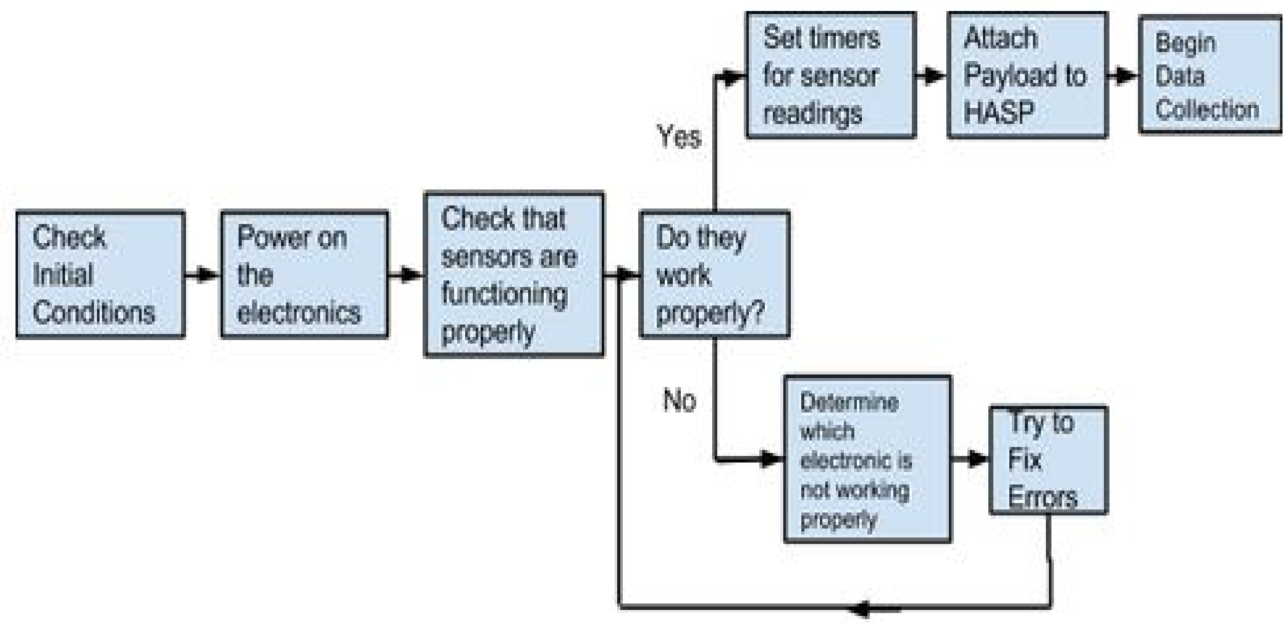
Another graph showing a similar data set. Illustration purpose being that as the balloon ascends, the radiation curve shall evolve from the lower line into the upper line.
(Source: http://ozonewatch.gsfc.nasa.gov/facts/SH.html)

Expected Results: The team expects that there will be a higher flux observed for the azimuth directed detectors meaning the UV sensor directed in the nadir direction will show a smaller amount of flux. The detector pointing to the astronomical horizon will have a flux between the two corresponding to the horizontal scattering of the UV rays in the stratosphere.

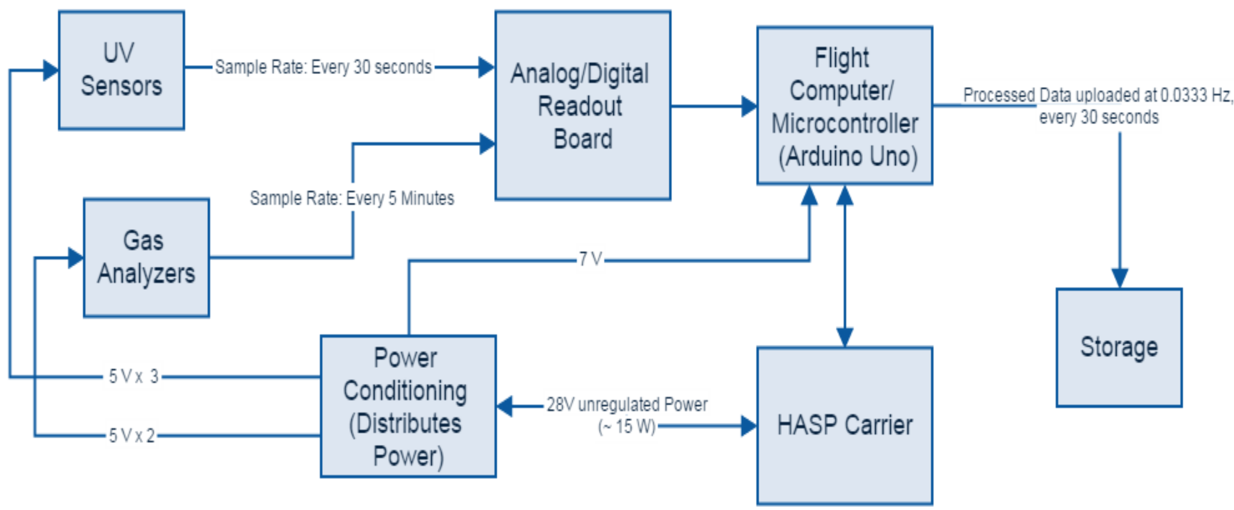
Gantt Chart:



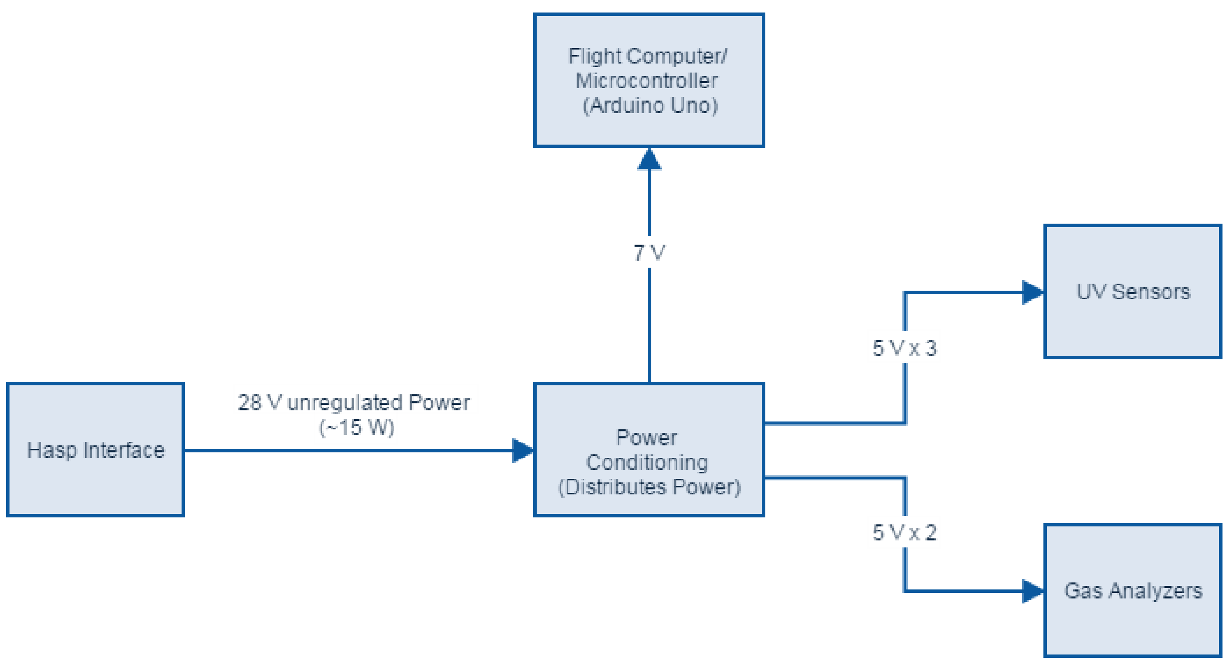
Functional Block Diagram for Set Up:



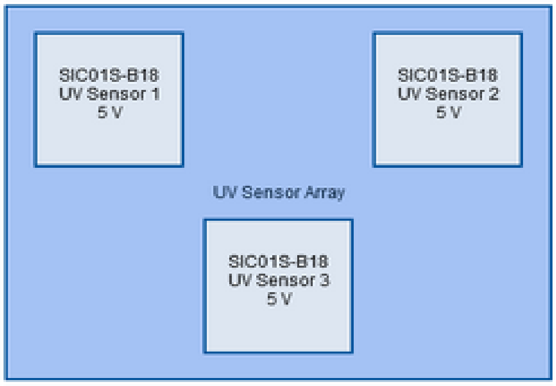
Functional Block Diagram for High Level:

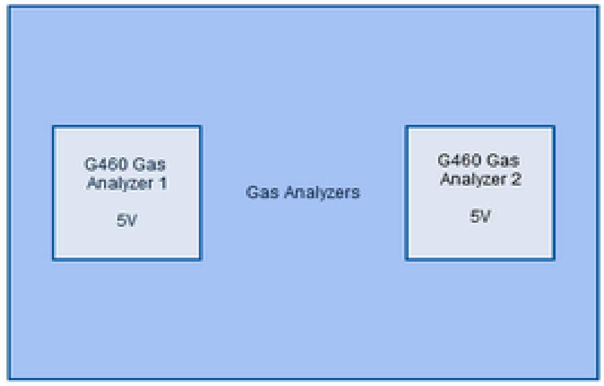


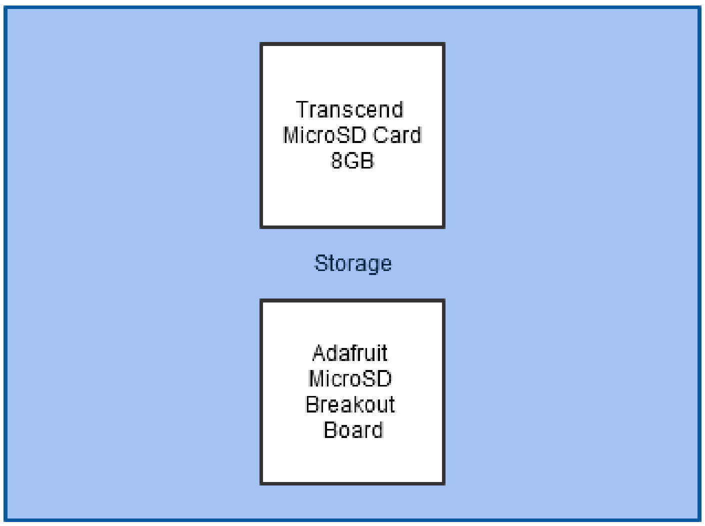
Functional Block Diagram for Power:



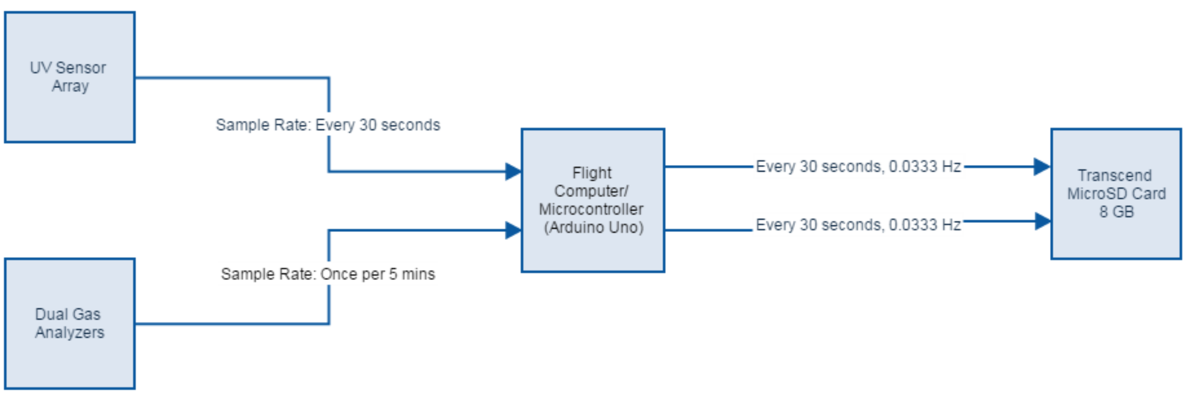
Functional Block Diagram for Instruments:



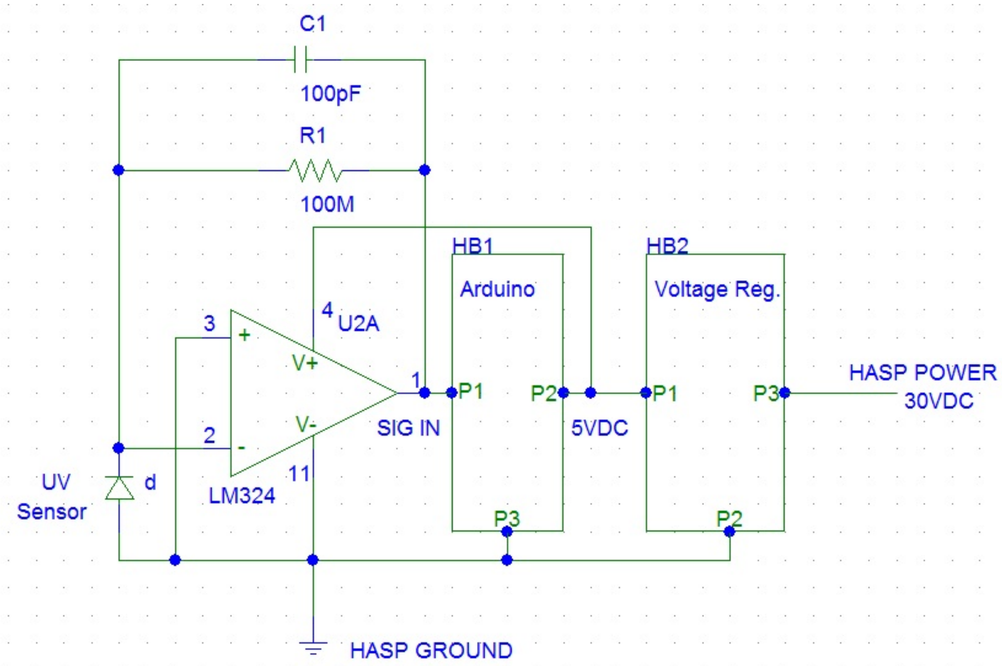




Functional Block Diagram for Data Transfer:

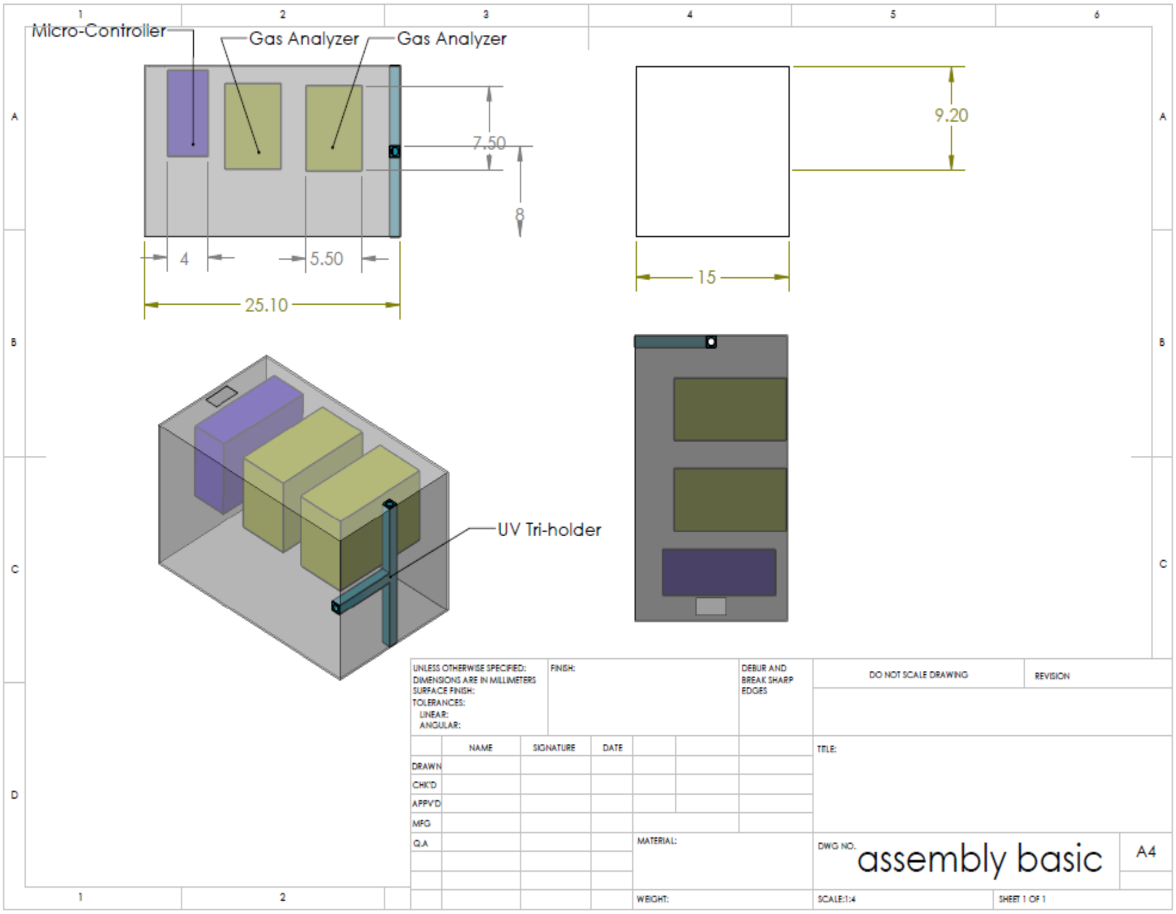


UV Sensor Electrical Schematic: The UV sensors output is read by observing it's fluctuations in its current. The recommended setup is a transimpedance amplifier circuit in which the fluctuations in current are then converted at the output of the amplifier to a change in voltage. The change in voltage will be read by the analog input of the Arduino and saved to memory. Below is an example of the electrical layout of one UV sensor with its amplifier.



Mechanical Design:

- The current view is of the module with transparent casing, the final product will be made out of a lightweight material.
- The dimensions and sensor orientations for this are fluid and adaptable using the TBR volume in the casing and we have a decent margin in the volume to allow for additional alterations.
- Manufacturing will be creating the outer casing which will form the module.
- Create openings for data collectors in the casing.
- Insert devices and use holders to secure the devices, wires and other parts of the module within the casing.
- The module will be mounted on HASP using screws drilled into the base.



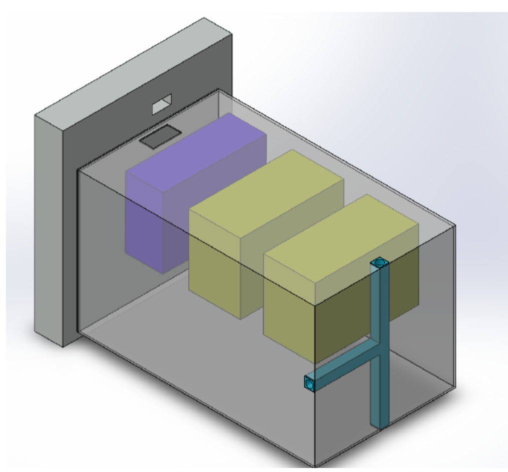


Image shows how the current module will attach as such, likely screwed into the base.

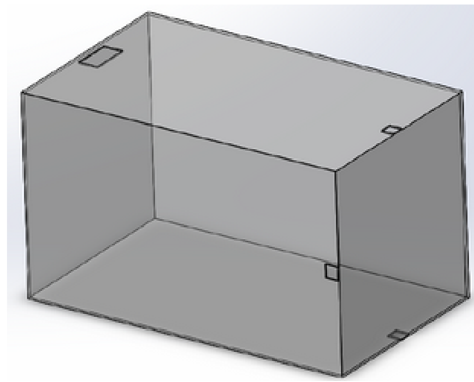
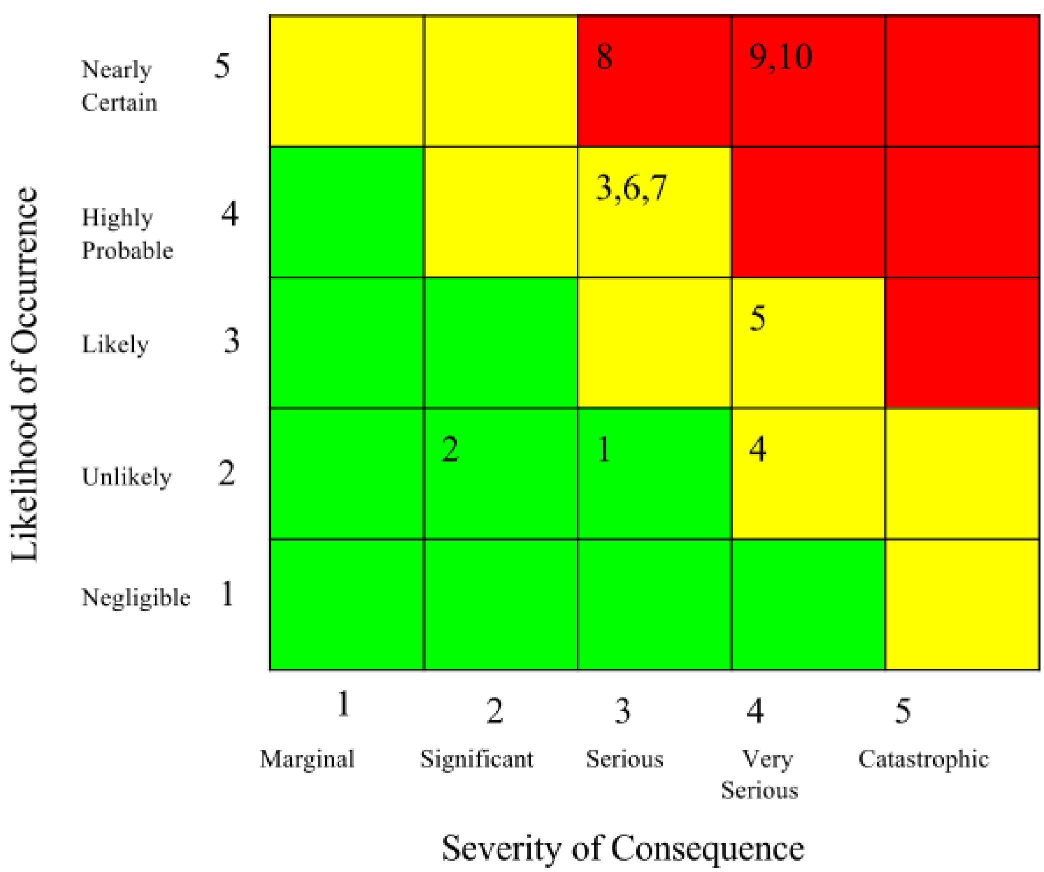


Diagram for the outer casing of the payload.

Risk Analysis: This chart represents an initial risk analysis, which evaluates areas with in our project that will require more attention. The temperature and pressure areas are rated at high risk simply because those factors are out of our control and are something we will have to test for to ensure our system operates within those requirements. Following PDR and component testing it is expected for the possible risk levels to drop all within low to moderate levels.



Number	Risk Area	Possible Risk
1	UV Sensor	Low
2	Cost Budget	Low
3	Gas Analyzer	Moderate
4	Data Storage	Moderate
5	Power Requirements	Moderate
6	Software	Moderate
7	Schedule	Moderate
8	Integration	Moderate
9	Temperature	High
10	Pressure	High

Team Management: The team is broken down according to both general design elements and subsystems. Students were free to work on areas of their own choosing. They will consult faculty members, including Dr. Srikanth Saripalli, as necessary to complete the project in the most efficient manner.

Organization by Design Element:

Element	Lead	Other Members
Mechanical	Daniel Mathews	James Enos and Natalie Snow
Systems	Ben Mackowski	Christina Findley, Victor Hernandez, and Colin Williamson
Electrical	Adrian Sinclair	Emily Bafia, Odell Lopez, and Seth Sebastian

Organization by Subsystem:

Subsystem	Lead	Other Members
Ultraviolet Sensor	Colin Williamson	Christina Findley, Seth Sebastian, James Enos
Gas Analyzer	Muadin Latifi	Sean Amidan and Justin Mathews

Team Availability Matrix: All team members are available to meet during the assigned class period Tuesday and Thursday 1:30-2:45. Outside of that, not all members are available at any given time. As such, most meetings will take place online via Google Drive or email. The individual times each member can meet in person are listed in the table below. Muadin and Srikanth are reachable by email 24/7 and can direct questions to the necessary person.

MST	Monday	Tuesday	Wednesday	Thursday	Friday
7:00 AM	Seth, Emily, Colin	Seth, Emily, Colin	Seth, Emily, Colin	Seth, Emily, Colin	Seth, Emily, Colin, Sean
8:00 AM	Emily, Colin	Seth, Emily	Emily, Colin, James	Emily	Seth, Emily, Sean, Muadin, James
9:00 AM	Emily	Seth	Emily, James	**Nobody**	Emily, Colin, Sean, Muadin, James
10:00 AM	Justin, Emily, Daniel	**Nobody**	Justin, Emily, James, Daniel	**Nobody**	Justin, Emily, Colin, Natalie, Daniel, James
11:00 AM	Emily, Daniel	**Nobody**	Emily, James, Daniel	**Nobody**	Emily, Colin, Natalie, Daniel, James
12:00 PM	Emily, Colin, Natalie, Sean, Daniel	Emily, Colin, Natalie	Emily, James, Colin, Natalie, Sean, Daniel	Emily, Colin, Natalie	Seth, Emily, Colin, Natalie, Muadin, Daniel, James
1:00 PM	Emily, Sean, Daniel	**Everyone**	Emily, James, Sean, Daniel	**Everyone**	Seth, Emily, Colin, Victor, Daniel, James
2:00 PM	Emily, Sean, Daniel	**Everyone**	Emily, James, Sean, Daniel	**Everyone**	Seth, Emily, Colin, Victor, Daniel, James
3:00 PM	Emily, Colin, Christina, Natalie, Sean, Daniel	Odell, Seth, Colin, Natalie, Sean	Christina, Emily, James, Colin, Sean, Daniel	Odell, Seth, Colin, Natalie, Victor, Sean	Ben, Seth, Emily, Colin, Natalie, Victor, Sean, Daniel, James
4:00 PM	Justin, Emily, Colin, Christina, Natalie, Sean, Daniel	Odell, Seth, Colin, Christina, Natalie, Victor, Sean	Justin, Emily, Colin, Christina, Sean, Daniel	Odell, Seth, Colin, Christina, Natalie, Victor, Sean	Ben, Justin, Seth, Emily, Colin, Christina, Natalie, Sean, Muadin, Daniel

5:00 PM	Emily, Colin, Christina, Natalie, Sean, Daniel	Ben, Seth, Emily, Colin, Christina, Victor, Sean	Seth, Emily, Colin, Christina, Sean, Daniel	Seth, Emily, Colin, Christina, Natalie, Victor, Sean	Ben, Seth, Emily, Colin, Christina, Natalie, Sean, Daniel
6:00 PM	Emily, Colin, Christina, Sean, Daniel	Seth, Emily, Colin, Christina, Victor, Sean	Ben, Seth, Emily, Colin, Sean, Daniel	Seth, Emily, Colin, Christina, Victor, Sean	Ben, Seth, Emily, Colin, Christina, Natalie, Sean, Daniel
7:00 PM	Emily, Colin, Christina, Daniel	Seth, Emily, Colin, Christina, Victor, Sean	Seth, Colin, Daniel	Seth, Emily, Colin, Christina, Victor, Sean	Ben, Seth, Emily, Colin, Christina, Muadin, Daniel

Summer Availability: Some members of the team are graduating next semester; however, others are available during summer to ensure completion of the project. The availability of each member is listed in the following table.

Available	Members
Yes	Ben Mackowski, James Enos, Odell Lopez
No	Christina Findley, Victor Hernandez, Seth Sebastian, Colin Williamson, Muadin Latifi

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