HASP Student Payload Application for 2014

Payload Title:
Maximum-Altitude Dust Aerogel Collection (M.A.D.A.C.)

Payload Class: (check one) ☑ Small ☐ Large	Institution: Arizona State University	Submit Date:

Project Abstract

Maximum-Altitude Dust Aerogel Collection payload for H.A.S.P. 2014 proposes to collect cosmic dust particles and other particles from the stratosphere and safely return them to Earth of analysis. Our collection method uses a ~225cm^2 aerogel block that will passively collect dust particles as they fall through the atmosphere. Our aerogel will be housed within a 3D printed plastic box with an electronically controlled lid that will open at altitude to allow the aerogel to be exposed. Because of their high velocities, comic dust particles will be trapped within the aerogel, while other particles will only settle on the surface. The box will be sealed prior to descent with an electronic latch to prevent contamination. The particles will be removed from the aerogel and subjected to imaging and elemental analysis using a scanning electron microscope. They will then be compared to known cosmic dust samples for authentication.

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Arizona State University 2014

M.A.D.A.C.

Maximum-Altitude Dust Aerogel Collection

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Mission Overview

The Arizona State University Maximum-Altitude Dust Aerogel Capture (MADAC) payload proposes to collect Interstellar Dust (ISD) particles from the stratosphere and safely return them to Earth for analysis. Our aerogel block will have a collection surface of ~225 cm^2 that will passively collect cosmic dust particles as they fall through the atmosphere. Our payload will be composed of aluminum plates with foam core for insulation. The aerogel will be isolated to a 3 cm deep compartment with a lid controlled by a servomotor. The particles will be extracted from the aerogel and analyzed using a SEM microscope at the LeRoy Eyring Center for Solid State Science.

As cosmic dust particles have a low density, collections taken in 2007 by the Montana State University Borealis Team prove that cosmic dust particles can be collected at this altitude using a high altitude balloon.

In addition to cosmic dust particles, we may expect to collect small amounts of rocket fuel, volcanic dust and particles, and man-made space debris. We will begin our analysis by categorizing the particles and determining the abundances of each type of particle that we collect from the stratosphere. The particles that we suspect to be of extraterrestrial origins will be analyzed further for details about their shape and composition.

Science Objectives

Due to the vast number of sources of cosmic dust, it is possible that by collecting them we may collect a new type of dust particle sample. Even collecting common ISD particles may result in new scientific discoveries. As such our goal of this experiment is to collect dust particles and analyze their properties focusing primarily on composition and origin. By analyzing the returned ISD's we hope to learn about the origin and history of the particle and thus the origin and evolution of our Solar System.

The Main Science objectives are:

- *Analyze the samples for structure and composition*

The ISD's composition contains relevant information to the source of formation of the particle. By analyzing the ISD's structure and composition we can determine the origin of the particles that we collect. Determining the origin of the ISD's is relevant and necessary to make further analysis of the particles. Furthermore, it is a necessary step to compare the known structures of terrestrial dust with our samples to eliminate contaminants from any further analysis.

- *Compare and contrast collected results with the existing scientific results*

There exists a nice body of scientific work that has already been conducted on ISD's. After we have collected our samples and conducted our analysis we shall compare our samples and our results to existing scientific results and compare what he have analyzed to be the same. At the same time we can compare the discrepancies to correct for errors/contaminations or newly discovered particle types.

- *Classify the collected dust particles to focus additional analysis*

By using our analysis of the particles' composition and structure we can classify the dust particles into established categories. Depending on the particles that we collect, by placing them into the accepted ISD's types we can focus any additional analysis we might conduct onto the specific qualities of each ISD category.

Theory of Concept

Since the start of launched space missions, experiments testing the many facets of Earth's atmosphere have been conducted. Tests on atmospheric aerosols, galactic cosmic rays, Solar Proton events, and accretion volatiles have been carried out, all in a variety of ways. Experiments testing space dust, that is, material smaller than 1 mm in diameter in the interplanetary medium have seen varying results. Typically, the dust measured in the atmosphere is classified in different ways, depending on the experimental objective it can be grouped by origin, size and mass, velocity, or composition. The distinction of particle origins for the purposes of this experiment is a simple one, particles will either be labeled as cosmic (space) particles, or terrestrial (Earth based) particles. Dust particulate sizes range from about 1.0 µm to 200µm in diameter and 10^{-11} g to 10^{-5} g (Tuzzolino et al., 2001), and expected capture ranges from about 1.0 µm to 10.0 µm in diameter (Nissen 2008). Velocities range from about 11 km/s for terrestrial particles, to nearly 70 km/s for cometary dust particles. Higher velocity particles can often times be annihilated upon impact for collection purposes, depending on the collection surface. This is why the aerogel is an ideal collection medium. The composition of the particles must be determined in the post flight analysis phase of the experiment. In some cases, particles collected may terrestrial particles from the Earth that have traveled to Earth's lower atmosphere, in other cases they may be interplanetary particles from other bodies in the solar system, and even particles from the original accretion of the Earth. Composition is divided into two main groups, particles formed by the major rock forming elements, Mg, Si, Ca, and FE, and particles formed by light elements; C, H, O, and N (Hanner & Bradley, 2004). If this space dust is collected at varying altitudes over a portion of the Earth, then it's size, energy, and composition can be identified, and depending on the size of samples collected, a detailed map of dust properties can be made over the varying altitudes. Since the objective of this mission is to create a survey of dust particle properties in a section of Low Earth Orbit, all attributes of the collected dust particles are important and will be taken into consideration.

Though the scientific goal of the experiment seems open-ended, the data collected from this research can clarify unanswered questions about Earth's atmosphere, or provide information useful for a number of different future atmospheric experiments. This experiment will provide new insights into the concentration, composition, and activity of dust particles in the atmosphere, may provide information about how atmospheric dust is incident to Earth and other planetary bodies, and also be a review of the use of aerogel for the purposes of dust capture in space. The experimental data from the aerogel may additionally help identify a ratio of pollutants in lower orbit to dust. If dust populations are thoroughly mapped, then future experiments may know where (what altitude) to look for samples.

Concept of Operations

1. Proposed System - Maximum-Altitude Dust Aerogel Collection (MADAC)

An aerogel collection mechanism will be used for the purposes of this project.
The MADAC will be carried on board of the HASP balloon, (following a parabolic trajectory going up through the stratosphere and down toward the ground), that will take the collection system through Earth’s atmosphere to maximum height of about 120,000 ft above ground. The collection system will employ aerogel, with surface area of 225cm^2 will be isolated in a 3 centimeter deep compartment, which will collect the encountered particles in lower Earth Orbit. Prior to maximum altitude the collection compartment will be sealed in order to prevent [minimize] contamination from terrestrial particles.The aerogel will be be exposed and ready to take in and capture particles once the maximum altitude of 120,000 ft is reached. After the collection window has closed and collection is complete, the collection system will be resealed and ready for retrieval on ground.

2. Justification of Changes

The collection system will relay on a number of key components that shall work together at the precise time so that a successful collection operation is performed. This is a small payload that will be operated by the described below hardware and software specifications. In the scenario where one or more of these systems, or it’s components, is nonfunctional, a simple backup system will be employed to ensure the collection process proceeds. All backup systems will be described in the proposal here in.

3. Testing and Instrument Performance Analysis - On ground testing

Prior to MADAC’s flight, a number of on ground operational tests shall be performed.

a. Impact resistivity/fracture control - A test is performed on the sample of the component or on the actual component to predict its strength behaviour or its susceptibility to various failure modes when the part is in service or in operating conditions. The type of test is selected on the basis of direction of acting forces on particular structures or components or parts.
Ductility test will be performed (or bend test) will test the ability of a material to plastically deform without failure or fracture.

b. Vacuum Chamber (the exact testing location is yet to be disclosed) The below are maximum parameters

simulate high altitude/space environments with the main parameters of:

- High Vacuum: 1×10^{-7} Torr (2×10^{-9} psi)
- Cold Space: -285°F (-175°C)
- Sun Radiation (IR): Up to +150

c. Aerogel collections -
Particles are much larger than aerogel network elements
☐ Particles µm
☐ Network nm
Kinetic energy gradually converted to thermal and mechanical energy, so particle slows : expected that particles remain largely

- Compression tests will provide understanding of pressure resistivity and durability
- Collection tests will provide information about sample capture and collection
- Contamination testing

d. Software/Hardware testing -general purpose of hardware and software functionality testing is to verify if the product performs as expected and documented

- Test and verify that the opening system of the collection compartment are functioning at high altitude and at specified time, in order for collection of particles to begin .
- Test and verify that the closing system is functioning and that the collected sample is contained for retrieval

e. Thermal/pressure resistance - Testing the resistance of the materials used in the payload [system] to the pressures and temperatures that the [system] will be exposed to at lower Earth Orbit.

Pass/Fail Criteria

3.1.1 The test specimen shall show no evidence of visible cracking or breakage or any damage such as splits, punctures, fractures, disengagement of lap elements or exposure of materials not so intended.

3.1.2 When a test specimen fails to meet the acceptance criteria for a tested classification, two consecutive test specimens must successfully meet the acceptance criteria to qualify for the given classification.

4. Sample collection and particle retrieval

MADAC payload shall collect space dust and such particles from Low Earth Orbit, after which these samples shall be retrieved from the aerogel collection system and analysed

5. Perform independent analysis for collected samples compared against existing data

a. **SEM microscope**

- provide information about the sample's surface topography and composition

b. SIMS Mass Spectrometer

- to analyze the composition of solid surfaces and thin films by sputtering the surface of the specimen with a focused primary ion beam and collecting and analyzing ejected secondary ions.
- to determine the elemental, isotopic, or molecular composition of the surface to a various sample depth [of 1 to 2 nm.]

c. Focused Ion Beam Analysis - uses a focused beam of ions to determine the elemental, isotopic, or molecular composition

Expected Results

Based on a simple calculation based on the amount of debris that falls to Earth daily, we can hope to collect at least 5 cosmic dust particles, along with other types of dust and particles, during our approximately 15 hour flight at a maximum altitude of 120,000 feet.

The NASA Cosmic Dust Catalog gives a significant amount of information about the chemicals to expect from a dust found in the atmosphere. Based on this and the results of the 2007 MSU Borealis team mission, we have a good idea of what type and size of particles to expect at this altitude, even though our collection method is different.

We should find silicates containing Mg and Fe, aluminum oxide particles, and metal-rich particles. The cosmic dust particles will be silicates and metal-rich spherical particles (NASA). The spherical aluminum oxide particles that we expect to find are constituents of rocket exhaust, and they will serve as an indication that we collected samples at altitude (Nissen 2008). It is also likely that we will find some terrestrial contamination at altitude. Only the cosmic dust particles will be moving with enough velocity to penetrate into the aerogel. That will serve as our main method of separating the desired particles from terrestrial contamination.

Most of the cosmic dust particles we collect will be between 1-10 μm, although there is a chance the we will capture something larger (Nissen 2008). There may also be smaller particles, but they would be very difficult for us to detect or analyze.

For the exact calculations of the expected results, see Appendix A.

Payload Design Details

Our module is composed of 1/8” thick aluminum plates, and utilizes foam core for insulation. The aerogel containment system will be made of ABS plastic. Aerogel with a surface area of 225 cm^2 will be isolated in a 3 centimeter deep compartment. The compartment’s lid will be controlled via a servo motor. An electrical latch will be used to join the compartment lid and body when the compartment is sealed. Our system will contain two temperature sensors, two pressure sensors, and a humidity sensor. An arduino will relay the data from the sensors to control the servo motor of the aerogel compartment lid.

Requirements

Science Requirements

Table 1: Detailed Science Requirements

Req #	Requirement	Rationale	Verification
1	The system shall collect space dust samples using aerogel at the maximum altitude of 120,000 feet.	Basic design requirement	Ground testing
1.1	The system shall collect space dust at the maximum altitude for approximately 15 hours.	Basic design requirement	Ground testing
1.2	After the flight, the samples shall be analyzed using the following instruments primarily focusing on origin and composition. a. SEM microscope b. SIMS mass spectrometer c. Focused ion beam analysis	To verify origin and composition of ISD's	Lab analysis
1.2.1	The SEM microscope will provide information about the sample's surface topography and composition.	Surface topography and composition	Lab analysis
1.2.2	The SIMS mass spectrometer will determine the elemental, isotopic, or molecular composition of the surface to a various sample depth.	Analyze surface composition	Lab analysis - Sputtering the surface of the specimen with a focused primary ion beam and collecting and analyzing ejected secondary ions.
1.2.3	The focused ion beam analysis will use a focused beam of ions to determine the elemental, isotopic, or molecular composition.	Determine elemental, isotopic, or molecular composition	Lab analysis

Technical Requirements

Table 2: Technical Requirements

Req #	Requirement	Rationale	Verification
2	The surface area of the aerogel shall be 225 cm^2.	To maximize the ISD collection surface area	Ground testing
2.1	The system shall be composed of an isolated aerogel compartment that is 3 cm deep.	Basic design requirement	Ground testing

2.2	The aerogel compartment should contain a sealing system composed of a lid that is fitted with a rubber seal to prevent aerogel contamination upon ascent and descent.	To avoid contamination of terrestrial dust and other unwanted particles during flight	Ground testing
2.3	The aerogel compartment lid will be opened and closed via a servo motor.	Basic design requirement	Ground testing
2.4	An electrical latch shall be used to join the compartment lid and body when the system is sealed.	Basic design requirement	Ground testing
2.5	The system will have a GPS unit, two temperature sensors, a humidity sensor, and a servo motor.	Basic design requirement	Ground testing
2.6	An arduino will relay data from the sensors, to control the servo motor of the aerogel compartment lid.	Basic design requirement	Ground testing
2.7	The temperature sensors shall be used to regulate thermal conditions of the payload to prevent overheating.	Basic design requirement	Ground testing
2.8	The GPS shall be used to verify the system’s altitude.	Basic design requirement	Ground testing
2.9	The humidity sensor shall be used for detecting water contamination.	Basic design requirement	Ground testing
2.10	Power for the payload will be obtained from the HASP power supply.	Basic design requirement	Ground testing
2.11	A backup battery will be utilized in case of a power failure.	Basic design requirement	Ground testing
2.12	A backup servo motor will be utilized in case the first one fails to operate properly.	Basic design requirement	Ground testing

Detailed Mass Budget

Table 3: Detailed Mass Budget for Complying with Requirements

Subsystem	**Mass (g)**	**Amount**	**Total Mass (g)**
Strong & Flexible Plastic Aerogel Containers	72.7	2	145.4
6061 Alloy Aluminum Box	128.99	1	128.99

Foam Core Box	7.7	1	7.7
Arduino	40	1	40
GPS w/ batteries	700	1	700
Servo Motor	15	2	30
Aerogel	20	2	40
5000mAh, 4 Cell LiPo Battery	535	1	535
Total Mass			1627.09g (1.627 kg)
Mass Under Requirements			1.373 kg

Detailed Electrical Budget

Table 4: Detailed Electrical Budget for Complying with Requirements

Subsystem Component	**Voltage**	**Current**	**Power Requirements**
Arduino	5 Volts	25 mA	0.125 Watts
Servo Motor	5 Volts	60 mA	0.3 Watts
Backup Servo Motor	5 Volts	60 mA	0.3 Watts
GPS Unit	12 Volts	120 mA	1.44 Watts
Temperature Sensor	3 Volts	0.5 mA	0.0015 Watts
Temperature Sensor	3 Volts	0.5 mA	0.0015 Watts
Humidity Sensor	3 Volts	0.5 mA	0.0015 Watts
		Power Total	2.1695 Watts

Mechanical System

The team has selected to design a small payload made of 1/16” thick aluminum plates for durability and Foam Core for insulation of electronics.

The Aerogel containment system will be made of 3D printed Nylon plastic. It will contain the Aerogel within a 3 cm deep compartment that is angled at a 45 degrees. The upper aerogel compartment will be opened and closed using a servo motor at the payloads maximum altitude. A back up servo motor will be in place to make sure that the lid is opened and closed without error. It is critical that this opening and closing system be completely sealed to prevent contamination on assent and dessent. Therefore the sealing system will be made of the compartment lid, a latch, and a hinge. The compartment lid will be fit with a rubber seal to prevent contamination of the Aerogel and dust particles. When the compartment is sealed the lid and body will be joined using an electrical and mechanical latch. The compartment will be able to open and close using a hinge that is mounted on the compartment body and lid.

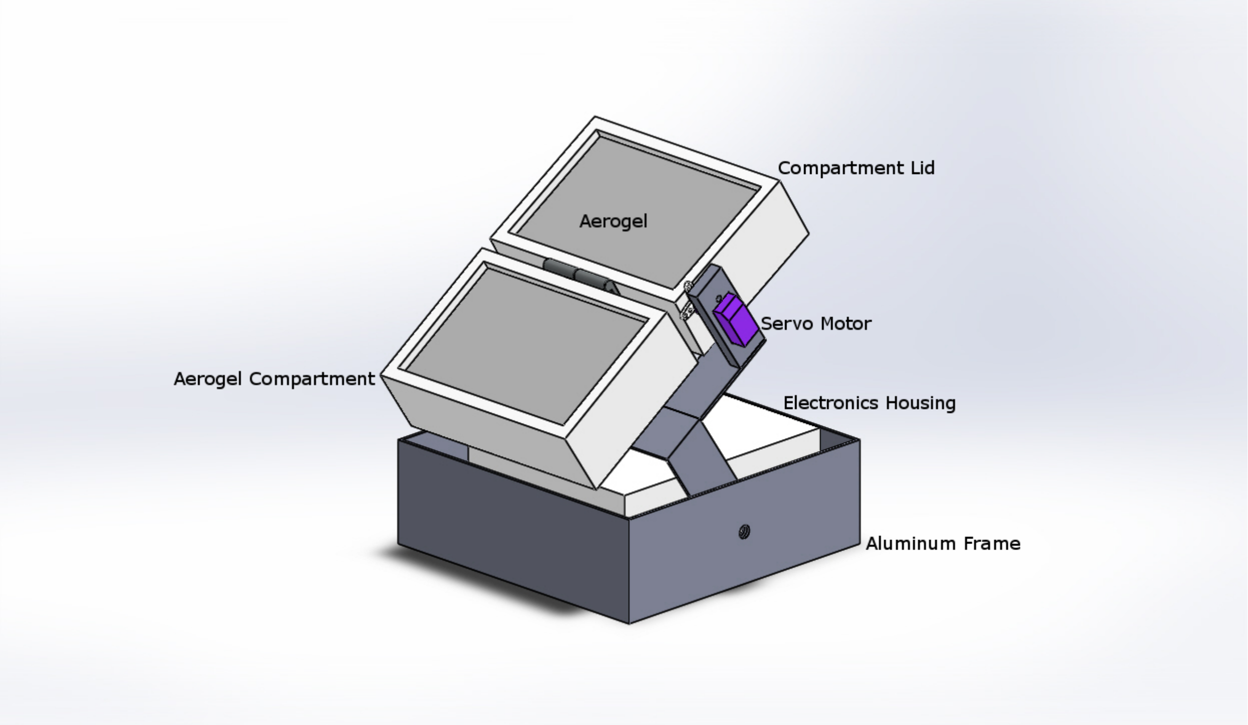


Figure 1- Mechanical Model

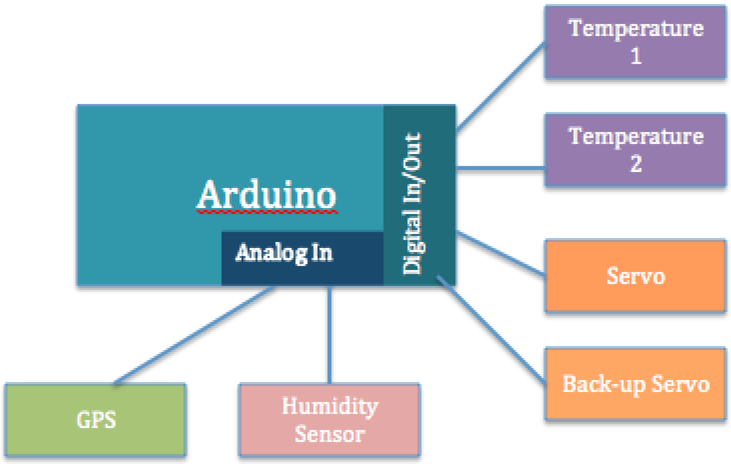
Electrical System

The electrical system is centered around a microcontroller, specifically an Arduino, that will receive data from two temperature sensors, a humidity sensor, and a GPS unit. This data will be received by the Arduino and sent to a datalogger that will store the data on an onboard SD card. The Arduino will activate a servo motor at the correct altitude to open the Aerogel compartment. There will be a second servo motor to open the compartment lid in case of failure. After the balloon is ready to descend the Arduino will activate the servo motor once more until the compartment is closed. An electrical latch will be used to keep the Aerogel compartment sealed during ascent and descent. The payload will be utilizing the main HASP power supply, while also having an onboard backup battery to take away any power failure possibilities. The battery chosen by the team is a 4 cell lithium-polymer battery of 5000mAh.

Software System

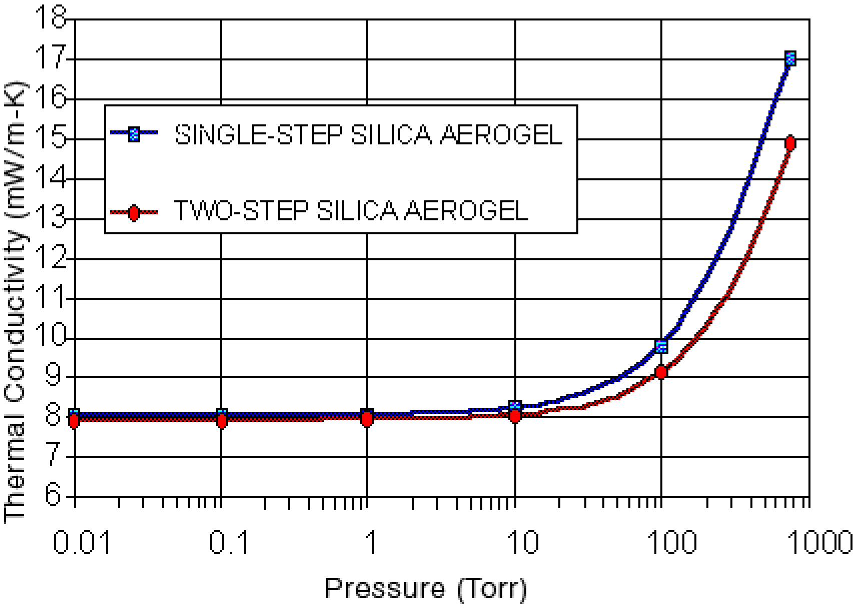
We will use an Arduino programming system on our payload. The Arduino's open sourse The Arduino will be connected to two temperature sensors, a GPS, a humidity sensor, and a servomotor. We have also included a back-up servomotor incase the first one fails. The Arduino will be used to gather data from the sensors and then relay it on to the servo motor to tell it when to open and close the lid of the payload. The temperature sensors will be used to regulate the thermal conditions of the payload to help prevent overheating. The GPS will gather data on the location of the payload, which will help verify it's altitude. Once the height of the payload reaches its peak height, the servomotor will open the lid to the aerogel compartment to gather samples of space dust. The arduino will send a signal to the servomotor to close the door when the altitude begins to drop. The humidity sensor will be used to verify the result of the project by telling us if there has been water contamination. If the sensor has water contamination, then it was unsuccessful. Below, Figure 3 shows a diagram of the overall layout of the how data will be handled in the software system of our payload.

Figure 2- Data Handling Diagram



Thermal Management

Over the entire course of this mission, the payload will experience drastic temperature swings over a large range. The payload must be able to tolerate stratospheric temperatures as low as -60° C to temperatures as high as 40° C upon retrieval in the Sonoran desert in August. Each component of the payload will be tested for functionality at temperatures within the range of -60° to 40° C both at surface and simulated atmospheric pressures as low as 10 millibars.



The chart on the right illustrates the thermal conductivity of silica aerogel. Aerogel is a very poor conductor of heat due to its highly porous nature and can withstand a wide range of temperatures. The temperatures experienced during the HASP mission will have no effect on the aerogel collection plate.

FoamCore has been chosen as the material for the MADAC housing due to its light weight and low cost. FoamCore has a thermal conductivity of about 0.033 W/(m-K). Other materials used like aluminum (thermal conductivity 237 W/(m-K)) and other metals have higher conductivities, but will not be compromised structurally at the low temperatures of the stratosphere.

Solid state electronics such as the circuitry and processors of the onboard computers should have no problems operating at low temperatures. The housing will be covered in reflective material to protect components from thermal radiation. Any component with moving parts: the servo motor and capsule hinges, will be tested extensively in simulated high altitude environments to make sure they are operative at conditions similar to the HASP mission. Components will be insulated with foam packing materials, and small heating elements may be used to temporarily warm electric motors to their operating temperature.

Prototyping and Analysis

To ensure that the payload will be fully operational throughout its flight, it is important to build and test a prototype beforehand. The prototype will be built to perform all the operations of the payload in conditions similar to those that will be experienced by the payload during its flight. The prototype will also be built from the same materials proposed for the payload, so that modifications can be made if necessary to the final design. The most important function of the prototype that needs to be tested is the anti-contamination system. The compartment containing the aerogel must be able to remain tightly sealed in extreme conditions, so as to not compromise the entire experiment. The sealing system will be controlled by a servo motor controlled by and Arduino programming system, which will open and close the compartment at predetermined altitudes. The Arduino system will also be used to control the pressure and temperature of the payload based on data from various sensors. Exposing the prototype to extreme conditions similar to those it will experience during its flight will allow us to test the various sensors as well as the software controlling the payload.

Upon completion of the prototype, design flaws in the mechanical and electrical systems can be more readily identified. This will allow us to improve upon the initial design to make sure that the mission goals are all achieved. The prototype will be tested under various temperatures and pressures, to make sure that the final payload will be able to adapt to any condition it may face.

Systems Level Testing

When the components of the entire system have been assembled the system as a whole will need to be properly tested to further ensure its efficiency and functionality, to observe and confirm that all separable components work together properly and timely, and to observe whether or not there may be unforeseen problems or issues that may need to be resolved before the system is ready to be mounted on the HSAP balloon.

If the entire system is allowed to run its full operations at least three times then all anomalies are likely to be found. Rather than at an altitude of 120,000 ft the system will be allowed to run on the ground outside where there is enough space to observe all components and to utilize sun, wind and possibly rain conditions.

The mechanical components that will be observed include the hatch which encompasses the servo motor, the rubber lining, and the electrical latch. The software systems will include the two temperature sensors, the two pressure sensors, and the humidity sensor.

During each test, the system will be set for timing for when it reaches maximum altitude. It will be allowed to run through its sample collection procedure encompassing the Aerogel capturing process. The sensors will also be subjected to some various differences in temperature and humidity during the process. Testing the altitude sensors will be limiting without a way to get the system high off the ground.

For one test the system will run on the ground in the middle of a field (or similar) where the system can be in direct sunlight and the humidity, temperature, and pressure sensors can be tested with ground conditions during this time. The Aerogel compartment will open and close as it will be at 120,000 ft. If necessary the altitude will be manually inputted in order to operate the latch opening and closing process. What will be the primary observation is how the Aerogel capturing process, encompassing opening and closing of the latch as well as how the latch aligns, seals, and latches; as well, the sensors will be observed how they correlate with the Aerogel capture and what they are sensing by what the natural conditions produce when just on the ground in direct sunlight.

For a second test the system would be allowed to operate at a slightly higher altitude such as a multiple story building that is available at the Arizona State University campus. The system will be allowed to operate its full procedure as the first test yet some differences will be used to see how they affect the process. The sensors will be tested will differences in humidity which can be done with a simple mister or spray bottle, the temperature can be tested with an electric heater or being subjected to ice that will be provided by the testers. The increased height of testing may allow a better wind usage for testing while also being subjected to direct sunlight. The primary observation for the second test will be observing how several differences in environmental conditions affect the overall process by how the sensors react and operate will the mechanical components. Furthermore, all safety operations regarding temperature or humidity will be tested during this time such as precautions for overheating of electrical or mechanical components. In addition, if a higher wind resistance testing is necessary the system would be subjected to a high power fan or blower.

For a third and final test the system would be allowed to operate the full process during the late evening on the ground which will allow for an environment with no direct sunlight and natural lower temperatures. The primary observation for this test will be reexamining how systems operate among the individual components while in no sunlight as well any additional subjugation that is developed during the previous two tests such as other variations in temperature, humidity, or wind.

For every test the main observations will be to confirm that all mechanical, software and electrical systems are capable of operating systematically in varying ranges of environmental factors.

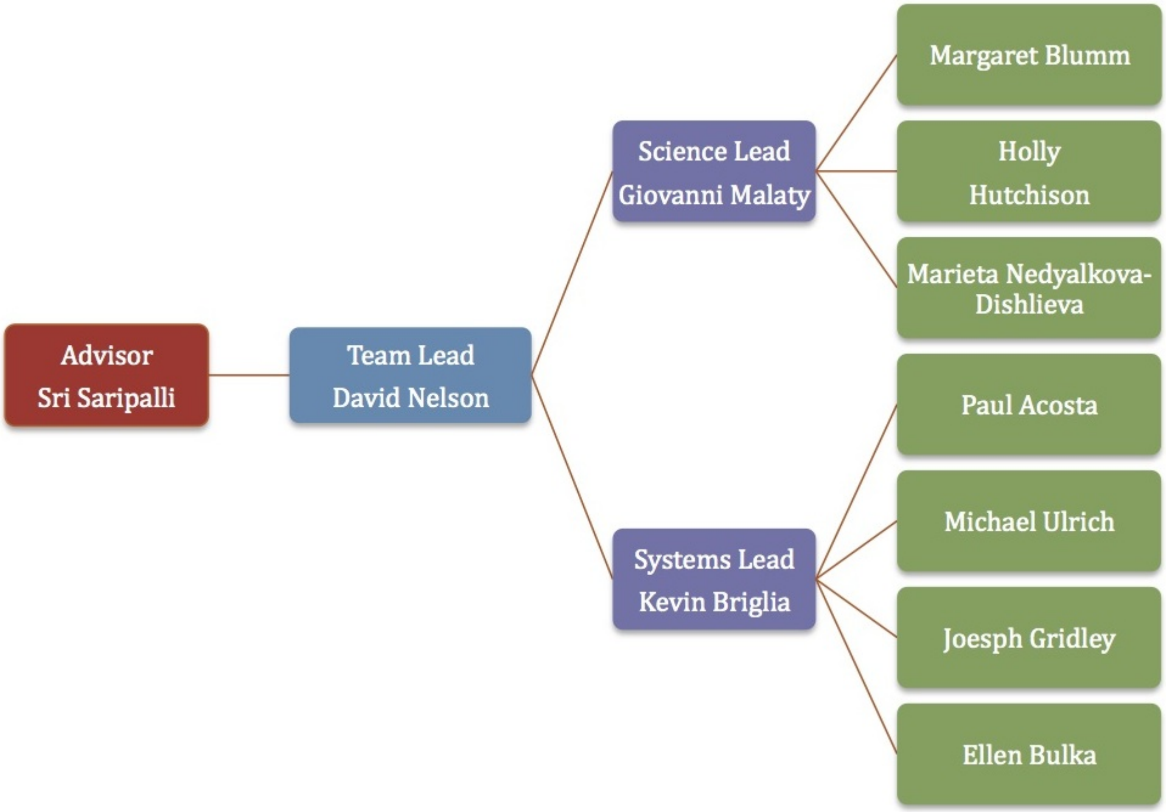
Risks

- Condensation - an expected major risk to damaging the aerogel collection plate. This risk can be mitigated by using hydrophobic aerogel products that resist moisture absorption, even when cracked.
- Damage to capsule on landing - a possible and moderate risk. During the testing phase the capsule will be tested to ensure it can withstand at least a 10 g-force impact without breaking open. In response to testing, the capsule design may be made thicker, or changed to a stronger material.
- Failure to receive power from HASP supply - A possible major risk. Should any system that draws power from HASP's power supply fail to receive it, the system will be able to draw on backup battery power on the payload. This will be tested by connecting MADAC to an external power supply and cutting power to ensure the switch to backup battery power is seamless.
- Failure of communication between electronic systems - an improbable major risk, only sensors that are compatible with the arduino as stated by the manufacturer will be used. The risk of communication failure will be mitigated during the software design, testing, and debugging processes.
- Failure of servo motor - a possible catastrophic risk, this can be mitigated by testing in simulated high atmosphere environments and adjustments made to the design in response to weaknesses revealed in testing. A back up servo motor will be available in case the first one fails to operate properly.

Project Management Plan

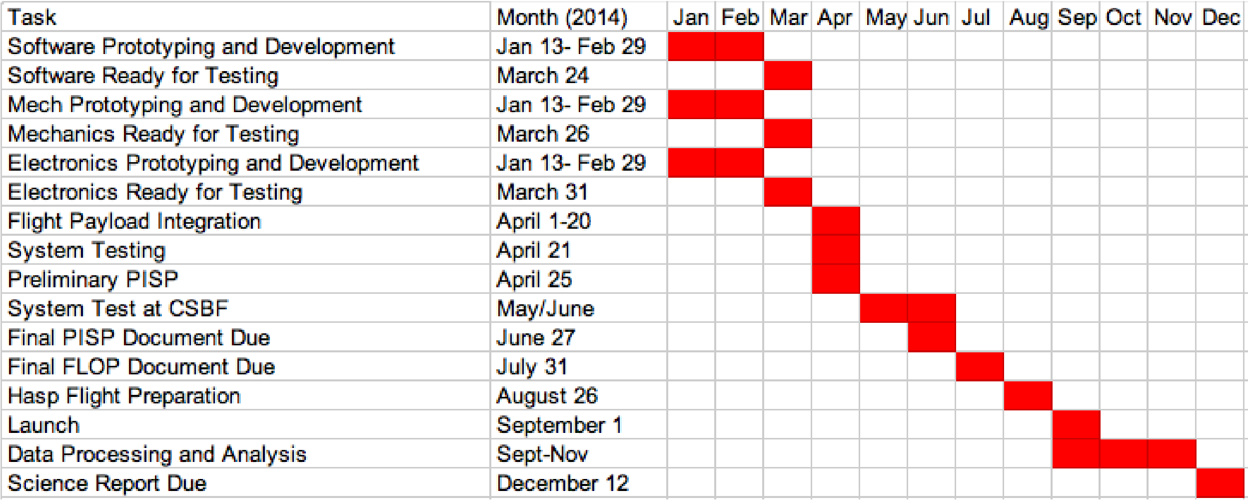
The MADAC team is comprised of 11 seniors in a variety of concentrations from the School of Earth and Space Exploration at Arizona State University lead by David Nelson and advised by Dr. Sri Saripalli. All of the team has a strong science background, and a few have engineering experience. It will be a learning experience for the team to build and design a payload for a H.A.S.P mission.

Figure 3- Work Breakdown Structure



The team is broken down into a science and an engineering team to maximize efficiency and productivity. The team lead is David Nelson. The science team is led by Giovanni Malaty and the engineering team is led by Kevin Briglia. The rest of the group was divided into teams based on experience and interests.

Schedule



Task	Month (2014)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Software Prototyping and Development	Jan 13- Feb 29	🟥	🟥										
Software Ready for Testing	March 24			🟥									
Mech Prototyping and Development	Jan 13- Feb 29	🟥	🟥										
Mechanics Ready for Testing	March 26			🟥									
Electronics Prototyping and Development	Jan 13- Feb 29	🟥	🟥										
Electronics Ready for Testing	March 31			🟥									
Flight Payload Integration	April 1-20				🟥								
System Testing	April 21				🟥								
Preliminary PISP	April 25				🟥								
System Test at CSBF	May/June					🟥	🟥						
Final PISP Document Due	June 27						🟥						
Final FLOP Document Due	July 31							🟥					
Hasp Flight Preparation	August 26								🟥				
Launch	September 1									🟥			
Data Processing and Analysis	Sept-Nov									🟥	🟥	🟥	
Science Report Due	December 12												🟥

Table 5- Gantt Chart

Budget

The build cost is fully funded by *School of Earth & Space Exploration* Grant up to $5,000. However, the total budget for MADAC is expected to be less. There is a 15% buffer in the budget for unexpected increases in cost due to availability. The budget of primary components is given in Table 5.

Table 6 - Estimated Project Budget

Item	Cost/Item ($)	Cost Total	Item	Cost / Item ($)	Cost Total
Arduino	21.00	21.00	Aerogel (15x15x3) cm	1.00 / cm3	675.00
1/16" Al (5 ft2)	5.50 / ft2	27.50	Servo Motor (2)	80.00	80.00
Foamcore	18.00	18.00	Battery	88.92	88.92
Temp. Sensor (2)	50.00	100.00	Datalogger: Temp	70.00	70.00
Copper Wire		18.00	Humidity Sensor	120.00	120.00
GPS Unit	625.99	625.99	3D Printed Capsules	50.00	50.00
Datalogger: Humidity	80.00	80.00	**Total Budget Cost for One Unit:**		$1,974.41

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Appendix A: Calculation for the Expected Number of Cosmic Dust Particles

Based on estimates of 40,000 tons of comic dust falling to Earth annually, we calculated the number of particles that we expect to capture (Kress 2001).

Approximate areogel surface area: 225cm^2
Average diameter of the dust particles we hope to collect: 4 μm
Average density of space dust (Love 1994): 2 g/cm^3
Average flight time: 15 hours
Average Earth radius: 6.37 x 10^6 m

1. Converting 40,000 tons/year to g/hr

$$\frac{40{,}000tons}{1year} * \frac{1year}{365days} * \frac{1day}{24hrs} * \frac{9.07 \times 10^6 g}{1ton} = 4.14 \times 10^6 \frac{g}{hr}$$

2. Calculating the amount of dust that falls over the surface of the Earth

$$SA_E = 4\pi r^2 = 4\pi(6.37 \times 10^6 m)^2 = 5.10 \times 10^{14} m^2$$

So, by dividing the rate of the particles by the surface hour, we have:

$$\frac{4.14 \times 10^6 \, {}^{g}\!/_{hr}}{5.10 \times 10^{14} m^2} = 8.12 \times 10^{-9} \frac{g}{hr * m^2}$$

3. Calculating the rate of particles hitting the Earth's surface:

Volume of particles: $$\frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(4\mu m * \frac{1cm}{1 \times 10^4 \mu m}\right)^3 = 2.68 \times 10^{-10} cm^3$$

Mass of particles: $$\frac{2g}{1cm^3} * \frac{2.68 \times 10^{-10} cm^3}{1particle} = 5.36 \times 10^{-10} \frac{g}{particle}$$

Rate of falling particles: $$8.12 \times 10^{-9} \frac{g}{hr * m^2} * \frac{1particle}{5.36 \times 10^{-10} g} = \frac{15.14 particles}{hr * m^2}$$

4. Calculating the total number of particles during flight:

$$\frac{15.14 particles}{hr * m^2} * \frac{15hours}{1flight} * \frac{1m^2}{1 \times 10^4 cm^2} * \left(225cm^2\right) = 5.11 \frac{particles}{flight}$$