Air Spora Trapping and Recovery Operation (ASTRO) Payload Description

Scientific Objectives:

The objective of our high altitude biotic sampler is to collect biological particles (microbes, mainly spores) at high altitudes and characterize them using new nucleic acid sequencing techniques. Sampling the air spora at high altitudes would give useful insight to genetic modifications that may be associated with survival at low temperature and pressure, and high UV. Once particles are collected, we can use PCR to amplify genetic material and identify organisms at the species level. Then, by deep sequencing, we can compare high-altitude sequences with known sequences and identify possible genetic adaptations due to the high altitude. Our spore collection system is a proof of principle, which we hope to modify in order to enable air spora collection on a variety of platforms, such as on an Unmanned Aerial Vehicle (UAV). Air spora detection and sequencing has potential future applications in the areas of agribusiness and public health.

Payload Systems:

Background: The spore particles within the upper atmosphere are exposed to higher levels of UV radiation than those near the surface. Based on the premise of the photoelectric effect, the exposure of the spore to high frequency and short wavelength electromagnetic radiation will result in electron emission from the spore, inducing a partial positive charge on the spore. This gives rise to our use of an electrostatic particle trap to concentrate the spores using a negative electrode.

Overview: We modeled our designs after those of Taewon Han, Hey Reoun An, and Gediminas Mainelis's electrostatic precipitator. The basic function of our electrostatic collector is to channel airflow to a slightly-inclined, open-ended semicircular tube which contains a negatively charged electrode, which will be used to attract the partially positively charged spore particles. The spores will then collect on or near the strong, negatively-charged electrode. In order to harvest the spores attracted to the electrode over a particular integration period (altitude range or time period), we will use ethanol drops to run along the electrode, collecting the majority of the spores upon the surface of the droplet. The ethanol drop will then run through a multi-channel microfluidic system into a sterile evacuated sample tube. Each sample tube accounts for one sample taken over an integral altitude. We will be running a total of five samples, each of which would be taken at a given altitude range.

Control: The system will use a low power microcontroller to enable largely autonomous sampling, triggered by atmospheric pressure readings. However, serial communications with the microcontroller will be utilized to enable remote commanding or shutdown. A finite state machine approach will be used to manage autonomous and remote command modes.

Collection system: The collection device is composed of three primary mechanical systems: a funneling apparatus, an electrode and ground casing into which the airflow is driven, and a sample-ethanol concentrator. In the Solid Works schematic attached, the platform interface is not shown. However, the apparatus will be mounted onto a .25-inch thick mounting plate. This mounting plate will be attached to the student platform and support the electronics and the rest of the structure.

We assume that the greatest amount of airflow is a result of the vertical movement of the platform due to buoyancy driven movement of the balloon relative to its air mass. Thus, a funnel will be positioned facing upwards to permit airflow through the cylindrical electrode encasing, allowing spore deposition on the negative electrode. At a given pressure (corresponding to a certain altitude), the electrode will be charged and particles collected for a sampling period of up to 10 minutes.

High voltage electrostatic collector: The electrode encasing is semicircular and oriented upwards. A channel runs down the center of the encasing, in which the negatively-charged electrode is

placed. The semicircular half of the encasing (not touching the electrode) acts as ground for the negatively charged electrode. An Ultra-Miniature High Voltage Single Output DC to DC Converter (HMV Tech, UMHV, 5V input, worst case power <1W) will supply our electrode with an adjustable output down to -5 kV (NASA is using this chip on the Firefly cubesat). To avoid arcing under low pressure, we will scale the electrode voltage, with a safety factor, to under the Paschen breakdown voltage as estimated using our pressure sensor. This is facilitated with a single analog output from the microcontroller to an output scaling input on the UMHV. The encasing will also be coated with a hydrophobic spray that completely repels hydrophilic droplets, including alcohol. Once spore particulates are deposited on the electrode, a 40-microliter droplet of ethanol is introduced to the top of the electrode, which uses gravity to draw the droplet down the electrode to a collection apparatus at the bottom of the electrode. The hydrophobic border keeps the alcohol droplet bound to the electrode and facilitates spore collection.

Sample collection and storage: The collection apparatus is connected to a six-channel microfluidic chip. Each of the five output ports of the microfluidic chip are attached to solenoid-controlled Micro Inert Valves (MIV) that are closed when unpowered and have low internal volume. Each MIV is attached to a sterile, 10 mL BD Vacutainer. This vacuum will be used to draw the sample through the microfluidic chip and into a designated Vacutainer by opening the associated MIV. The fluid path will have a low dead volume to maximize the amount of sample collected. After a specified duration of time (with longer times required at extreme altitude due to much smaller pressure differences), the MIV will close, trapping the ethanol and sample in the vacuum tube and preventing further sample collection due to aspiration of the liquid sample and air. Overall, these three subsystems concentrate our spore samples, preserving them for later down-stream testing, including PCR amplification and deep sequencing using the Ion Torrent Personal Genome Machine (PGM).

Thermo Control Plan:

Our design accommodates the expected cold temperatures (-33˚C at 36 km) in multiple ways:

- Thermal insulation surrounds the experimental apparatus, insulating the entire structure, excluding the input and output airflow channels. The insulation will be semi-rigid and able to unfold, such that we can pull back individual insulating panels and access the experimental apparatuses inside. A removable thermal blanket (coated with metallized polyethylene terephthalate to retain up to 97% of radiated heat) will cover the exterior, and protect our samples by blocking UV.
- In order to prevent brittle fracturing of the support structure and keep conduction low, we will use Teflon™ or other cold-tolerant non-brittle plastics for key parts of the support structure.
- In order to prevent freezing of our collection droplets, we will use highly concentrated ethanol (90-100%), which has a low freezing point of -73˚C to -115˚C and low viscosity.
- Other components are in general selected for operation down to -45 ˚C and we have allocated part of our power budget for survival heat using resistive Kapton-coated heaters.

Mass and Power Budgets

Our design carries substantial mass and power margins of 28% and 46%, respectively.

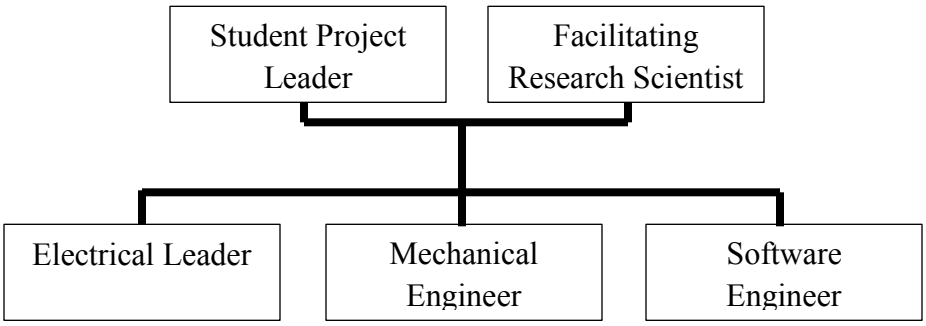
Mass Budget (3 kg)

Component	Mass (kg)	Notes
Fluidics	0.25	Microfluidic chip, valves, tubing, sample tubes
Electronics	0.30	PCB with microcontroller, sensors, connectors
Particle sampler	0.45	Funnel, semi-cylinder electrode structure, ethanol bag
Thermal	0.40	Thermal blanket, insulation
Stucture	0.75	Mating plate, fluidics support
Margin	0.85	Based on 3 kg budget

Power Budget (15W)

Item	Power (W)	Notes
Microntroller, Sensors, RS-232	0.5	Low power u-controller, sensors
High Voltage Electrode	1.0	Worst case (UMHV chip)
Valves	1.5	One valve at a time (1.2W rating)
Power Regulation Losses	2.0	High efficiency power modules
Survival Heat	3.0	Kapton heater
Margin	7.0	For 15W total power budget

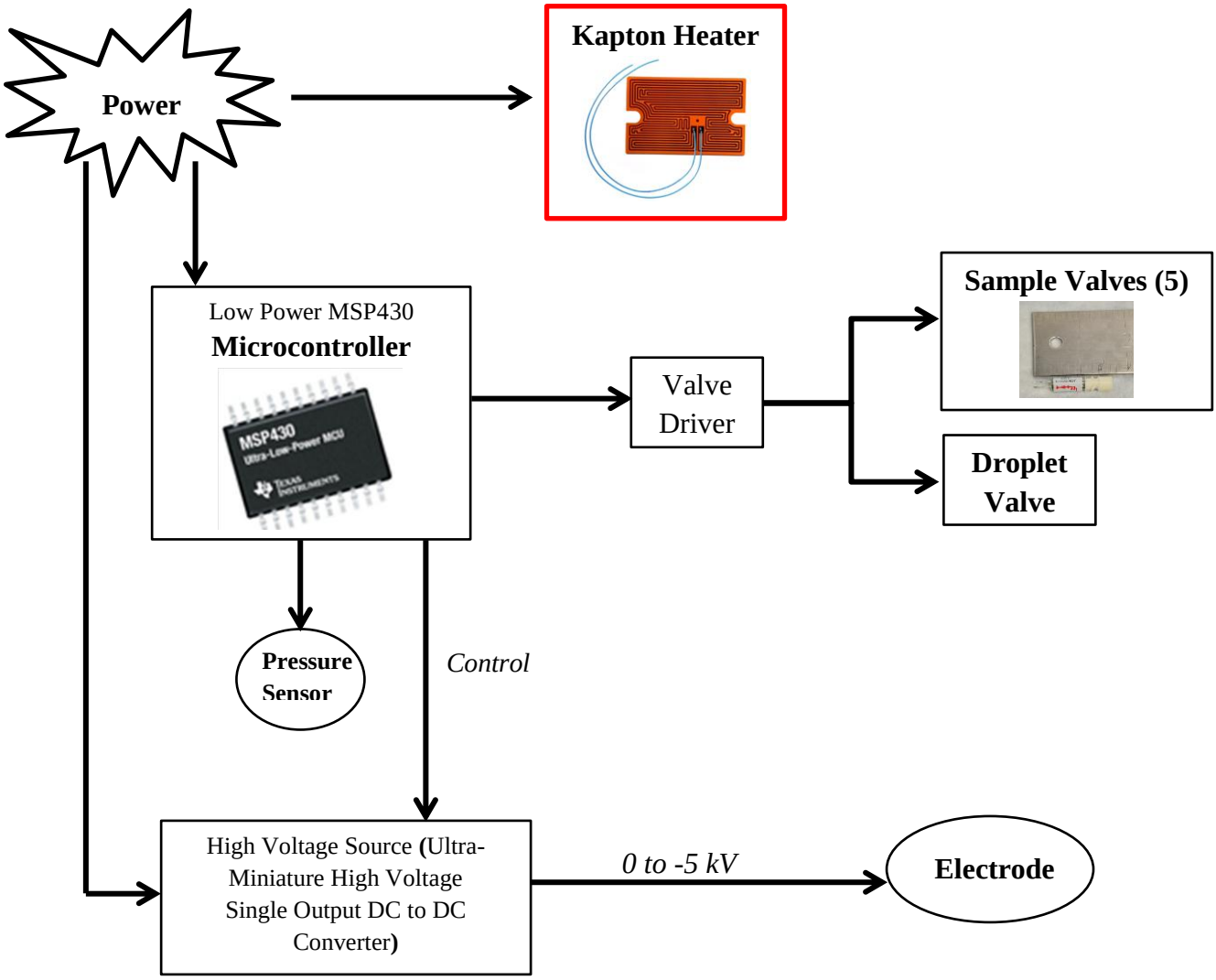
Team Structure



The team is relatively small, and consists of five individuals: a student project leader, facilitating research scientist, electrical engineer, mechanical engineer, and software engineer. The student project leader is responsible for overseeing the progress of the build, unifying the three sub-components of the team, and also contributing to the design of each sub-component. The facilitating research scientist, Christopher Carr, helps with validation of concepts and acts as a mentor for the team. The electrical engineer is responsible for assembling the subcomponents of the spore collector, while the mechanical build leader is responsible for the construction of individual parts of the apparatus. The software engineer is responsible for writing code activating various trigger mechanisms to commence sampling at a given atmospheric pressure.

Each individual on the team is also required to provide input and feedback at our biweekly meetings during which we discuss our developments on our individual assignments. This ensures that each subsystem will be compatible with one another.

Electrical Subsystem



ASTRO Projected Schedule 2013

Calendar 2013	January				February				March				April				May				June				July				August				September				October				November				December			
Week ##	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4

Milestones (Overall) *Test Prototype * HASP Flight * PCRs * Sequencing * Analysis * Final Report

Milestones for Mech *FD - Mech **PC** * Complete Assembly

Milestones for Electrical *FD - Elect **PC** * Complete Assembly

Milestones for Software *FD-CS **PC** * Complete Assembly

Student Events

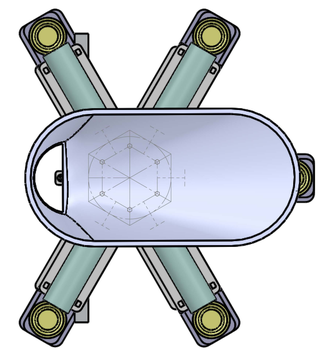
HASP Deliverables D1/D2

LEGEND	
*	Event
	Monthly Status Report
	Student Vacation

ABBREVIATIONS	
FD	Finalize Design
D1	HASP Payload Specification and Integration Plan
D2	HASP Flight Operation Plan
PC	Proof of Concepts Due (each individual subsystem)

** Please Note: During the end of January, the student project leader, Jessica Sandoval, and the facilitating research scientist, Christopher Carr, will be participating in a field study in Argentina, thus accounting for the 2 week break at the end of January during which the team will be unable to meet.

Top View



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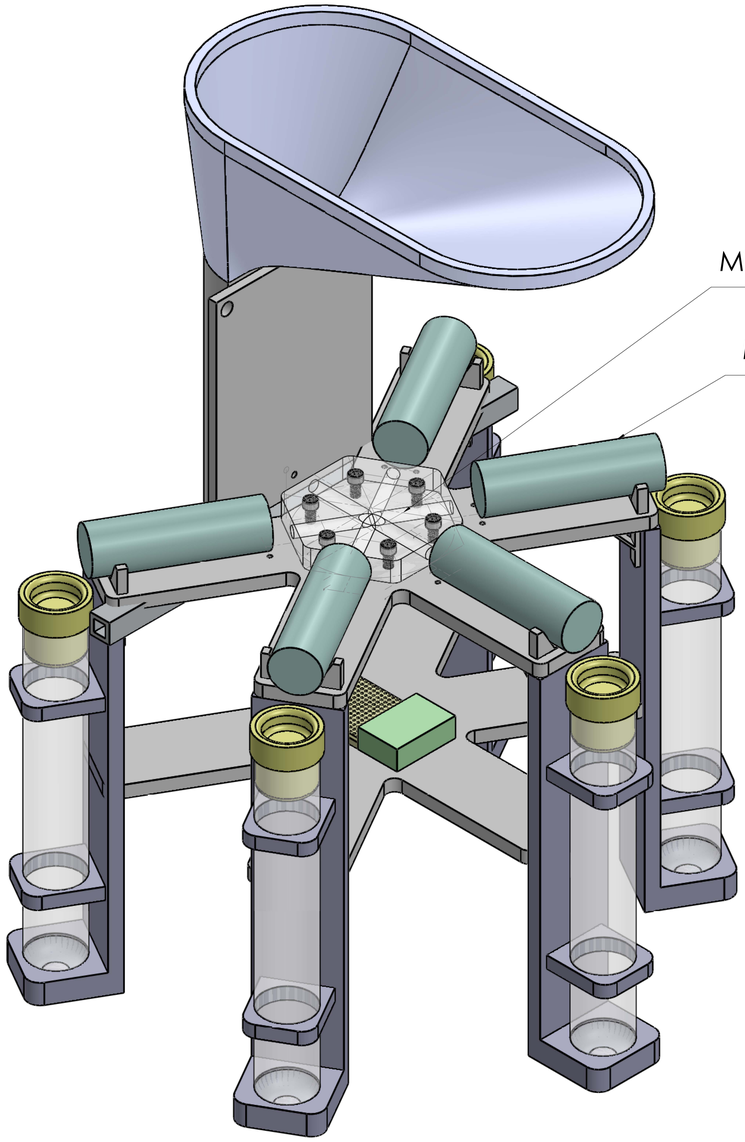
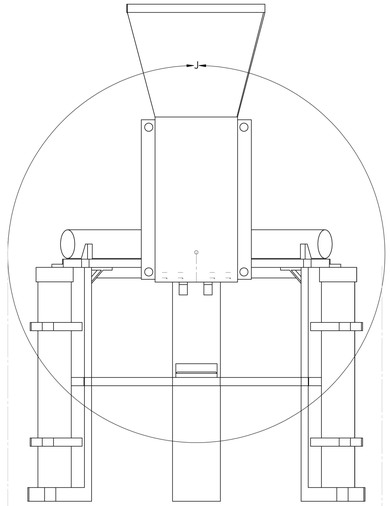
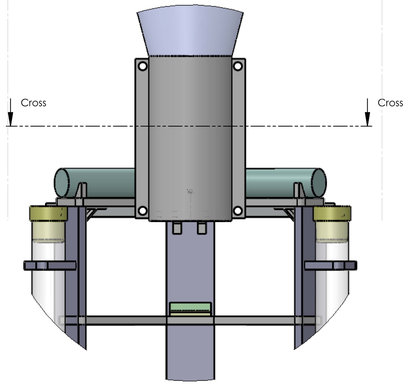




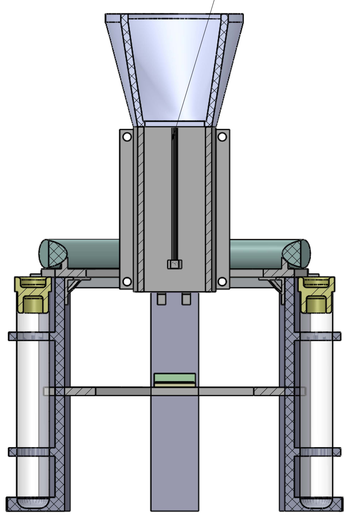


Close Up on Back Electrode Encasing

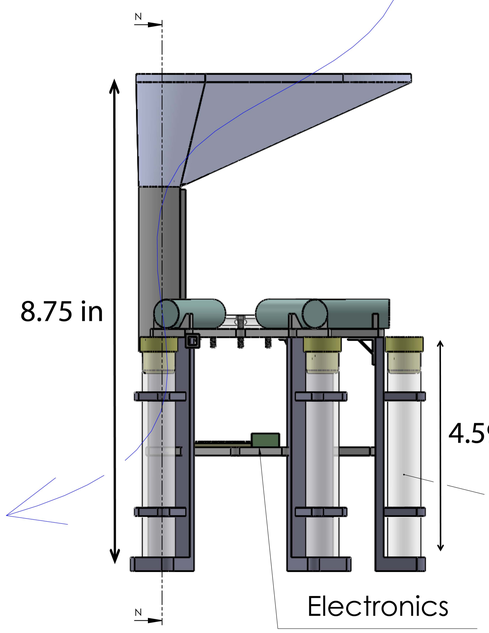
Air Flow (while moving vertically upwards)

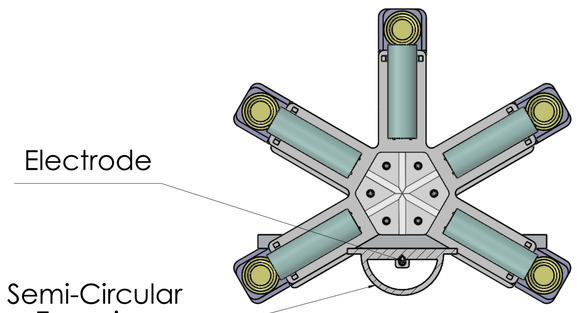
Side View

Electrode



Cross-Section Side View





Cross Section of Electrode Encasing and Microfluidic Chip

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