

MICROMETEOROID SAMPLE COLLECTION IN THE UPPER ATMOSPHERE. J. C. Coppin¹, C. A. Roig¹, A. Matchett², S. E. Massey³, and O. Resto⁴. ¹Dept. of Mech. Engineering, Univ. of Puerto Rico- Mayaguez, PR 00681 (jorge.coppin@upr.edu), ²Dept of Biology, Univ. of Puerto Rico- Mayaguez, PR 00681, ³Dept. of Biology, Univ. of Puerto Rico- Rio Piedras, PR 00931, ⁴Dept. of Physics, Univ. of Puerto Rico- Rio Piedras, PR 00931.

Introduction: The study of extremophile organisms and their possible relation to the origins of life on planets, such as that being done in the Tanpopo Mission aboard the ISS [1], show the importance of finding extremophiles that could survive the high altitude conditions in the upper atmosphere. Different transportation mechanisms of microbes above the stratosphere exist, making it possible for microbial life to reach the upper atmosphere and even space [2]. Whether through human activity such as planes, weather balloons, or rockets or natural phenomena such as volcanic eruptions, climatological events or meteorite impacts, the abundance of such microbes is unknown. Because of this, field experiments have looked for microorganisms with the use of weather balloons, as well as the previously mentioned ISS experiments. While the ISS orbits at a height of approximately 400 km, and most weather balloons can reach a maximum height of around 40 km before bursting, sounding rockets provide the opportunity to collect samples within a relatively unexplored section of the atmosphere at heights of 70-160 km above sea-level. With the RockSat-X program, students researchers at the University of Puerto Rico have the access to fly experimental payloads once a year for the purpose of collecting micrometeoroid samples for different research purposes.

Collection Process: This collection process will employ the use of a Terrier-Improved Malemute sounding rocket carrying a student-built payload fitted with the Organic Sample Collector for Astrogenomic Research (OSCAR). To collect micrometeoroid samples, the OSCAR deploys at apogee (~160 km). Three stepper motors then move a plate along a set of guide rails that compresses the edge-weld vacuum bellow and exposes an aluminum mount that contains three rows of polyimide aerogel tiles arranged in a triangular prism. Once the aerogel tiles are exposed to space they will gradually stop the micrometeoroids that are travelling at speeds of up to 1 km/s. The collection period takes place until the sounding rocket reaches an altitude of approximately 75 km above sea-level. At this altitude the OSCAR retracts and seals the samples in vacuum conditions. After the OSCAR retracts, and the payload is powered off, the OSCAR goes through atmospheric reentry and splashdown. Afterwards, the payload is recovered.

The reason for collecting at these heights comes from the Arecibo Observatory measurements of micrometeoroid and interplanetary dust particles which show that after meteoritic activity, the majority of

particles which are captured on Earth's orbit tend to accumulate at heights of 90-115 km [3]. Additionally the sounding rocket launch occurs sometime during the dates of August 11-15, which annually coincides with the peak of meteoritic activity for the Perseids Meteor Shower caused by the Earth Passing through the trail of comet 109P/Swift-Tuttle.

Payload Design: The RockSat-X program sets a standard for student payloads to fly on the Terrier-Improved Malemute sounding rocket. These restrictions limit payloads to fit within the volume of a cylinder that is 12" in diameter and 10.75" in height, and have a max weight of 30 lbs. The rocket's ground support equipment provides the payloads 28V with a max capacity of 1 Ah.. The student payload consists of five main systems: sample collection, cross-contamination mitigation, video validation, power and avionics.

The sample collection system consists of the Organic Sample Collector for Astrogenomics Research (OSCAR). The collector consists of a custom-built, edge-weld vacuum bellow that safeguards the micrometeoroid samples from contamination and maintains samples in their near-space vacuum environment, inside the bellow there is an aluminum 6061 mount that contains polyimide aerogel tiles, and two aluminum 6061 lids with silicone o-rings to hermetically seal the inner bellow chamber. The vacuum bellow has an extended length of 5.3-inches and a 3-inch stroke that allows the collector to expose 2½ rows of aerogel tiles for collection. The vacuum bellow is housed within a truss composed of the three stepper motors and three linear bearings that provide support to withstand the strong vibrations on all three axes and impulses of up to 50g's.

The cross contamination mitigation system consists of a set of UV-C Lamps that denature DNA and microbes on the surface of the payload to clean the payload surfaces after integration into the rocket for decontamination during flight, up until the point of OSCAR deployment. The video validation system is composed of a Leica SL camera for recording 4k footage of collection and flight, as well as a secondary endoscopic camera to validate proper seal of the OSCAR's vacuum bellow. The power system is composed of two DC-DC power converters and the avionics system is composed of the flight computer, a Raspberry Pi 2b, with a secondary Raspberry Pi Zero computer for operating the secondary camera.

An additional component of the payload includes an Oxford Nanopore VolTRAX sample

preparator, which will be flown to test the hardware capabilities of the device in the harshest conditions of sounding rocket flight, this device will be used on future payloads as part of an in-flight autonomous DNA sequencing system for collected samples.

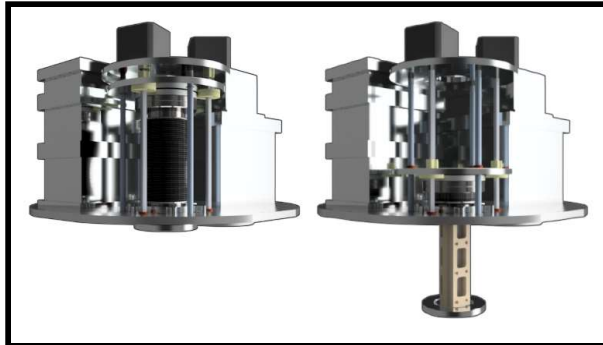


Figure 1: Payload with Closed Collector and Open Collector

Cross-Contamination Mitigation: A key aspect of the sample collection process is ensuring outside contaminants do not affect the results of the sample analysis. To avoid this, cross-contamination mitigation protocols were developed in line with current planetary protection protocols and ancient DNA sample studies. The cross contamination mitigation protocol is divided in three stages according to the mission profile. The before, during and after flight protocols ensure that cross-contamination is avoided throughout all aspects of the experiment.

Before flight, aerogel tiles are heated at 170°C for a period of 1 hour. Once heated, the aerogel tiles and the collector mechanical components are transferred to an ISO-3 clean facility where they are cleaned with 5% sodium hypochlorite and 70% ethanol solutions. Afterwards, all components and aerogel tiles are exposed to UV-C (254nm) radiation on each surface for at least 20 minutes in a standard UV decontamination hood. Once fully assembled and hermetically sealed, the OSCAR collector is heated at 170°C for a period of 1 hour before full payload assembly.

The payload is wrapped in sterilized anti-static saran wrap and transported to Wallops Flight Facility for sounding rocket integration, the protective saran wrap is removed at the exact moment the payload is loaded into the rocket skirt, in which it prepares for the in-flight contamination process in which a set of UV-C (254nm) lamps decontaminate all payload and rocket surfaces in the launchpad, this process last a period of around 20 minutes during pre-flight checkout testing, just enough time to neutralize any stowaway microbes or DNA during the payload rocket integration [4].

For post flight mitigation, the OSCAR deployable system will be de-integrated from the rest of payload and all outside surfaces of the sealed vacuum bellow will be cleaned with 5% sodium hypochlorite and 70%

ethanol solutions and exposed to UV-C (254nm) radiation on each surface for at least 20 minutes. Afterwards, the bellow will be connected to a load lock vacuum chamber to transfer the samples. The vacuum chamber will be fitted to replicate the thermosphere environment in which the samples were collected for all further analysis that will be done.

Post-Flight Analysis & Sample Curation: To analyze the different samples and determine curation methods, all samples will be divided into two different analyses, one biotic and the other abiotic. The Astromaterials Sample Analysis will include testing the morphology, structure and organic/inorganic composition of the micrometeoroids. The Astrogenomic Sample Analysis will focus on the detection and sequencing of DNA and other cellular material that could be found within the samples. In Figure 2 a downstream analysis of samples is planned and outlined.

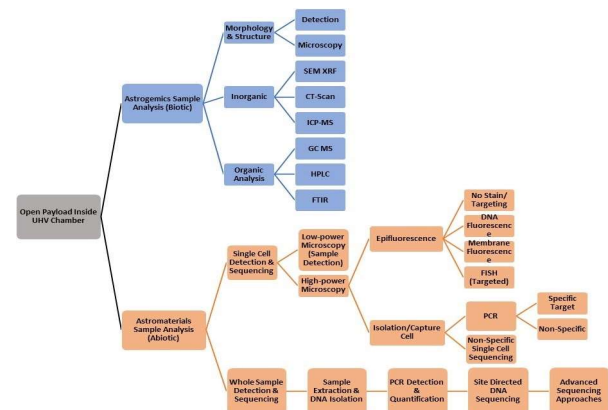


Figure 2: Downstream of the analysis of the aerogel samples

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