Fuel Cell to Power Scientific Instruments

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Abstract

Scientific instruments play a vital role in helping achieve NASA's vision: "Exploring secrets of the universe for the benefit of all." These scientific instruments are getting advanced in space missions and will require a lightweight power source that lasts longer durations in harsh environments. Fuel cells are a promising technology that can be used to power scientific instruments in future missions. They are electrochemical devices that use chemical reactions to convert chemical energy into electrical energy and heat. They do not run down or require recharging, as long as fuel and oxidant are supplied. Today, fuel cells are used to power small devices as well as large-scale applications, such as cars and houses. However, there is a need to understand its performance in an actual microgravity environment. To reach this understanding, the mission, Fuel Cell to Power Scientific Instruments (FCPSI), will use the Wallops Flight Facility's (WFF) Sounding Rocket mission platform. The WFF's Sounding Rocket missions will give up to 20 minutes of space time at an altitude range of 50 to 1500 kilometers. Our mission entails fabricating an instrument to monitor fuel cell performance, taking advantage of being in a microgravity environment, and being backed by a research team adopting a sound risk management plan to achieve the mission goals.

Introduction

The FCPSI mission will allow us to understand the effect of microgravity on the electrochemical processes and output of a fuel cell. This mission will be carried out using a sounding rocket mission platform at the NASA WFF. The instrumentation within the payload will use the Electrochemical Impedance Spectroscopy (EIS) to measure various fuel cell performance metrics such as electric work and voltage. This will determine whether this technology could be an alternate source to power scientific instruments in future space missions. A research team of engineers and scientists, representing a university, will be brought together under a six-month timeline embedded with WFF's sounding rocket mission life cycle. This mission will be benefited by various stakeholders that are looking to improve instrumentation in future space missions. The entire mission will be represented with a patch that will be proudly worn by the team, which reflects the mission platform and goals.

Mission Subject and Science Objectives

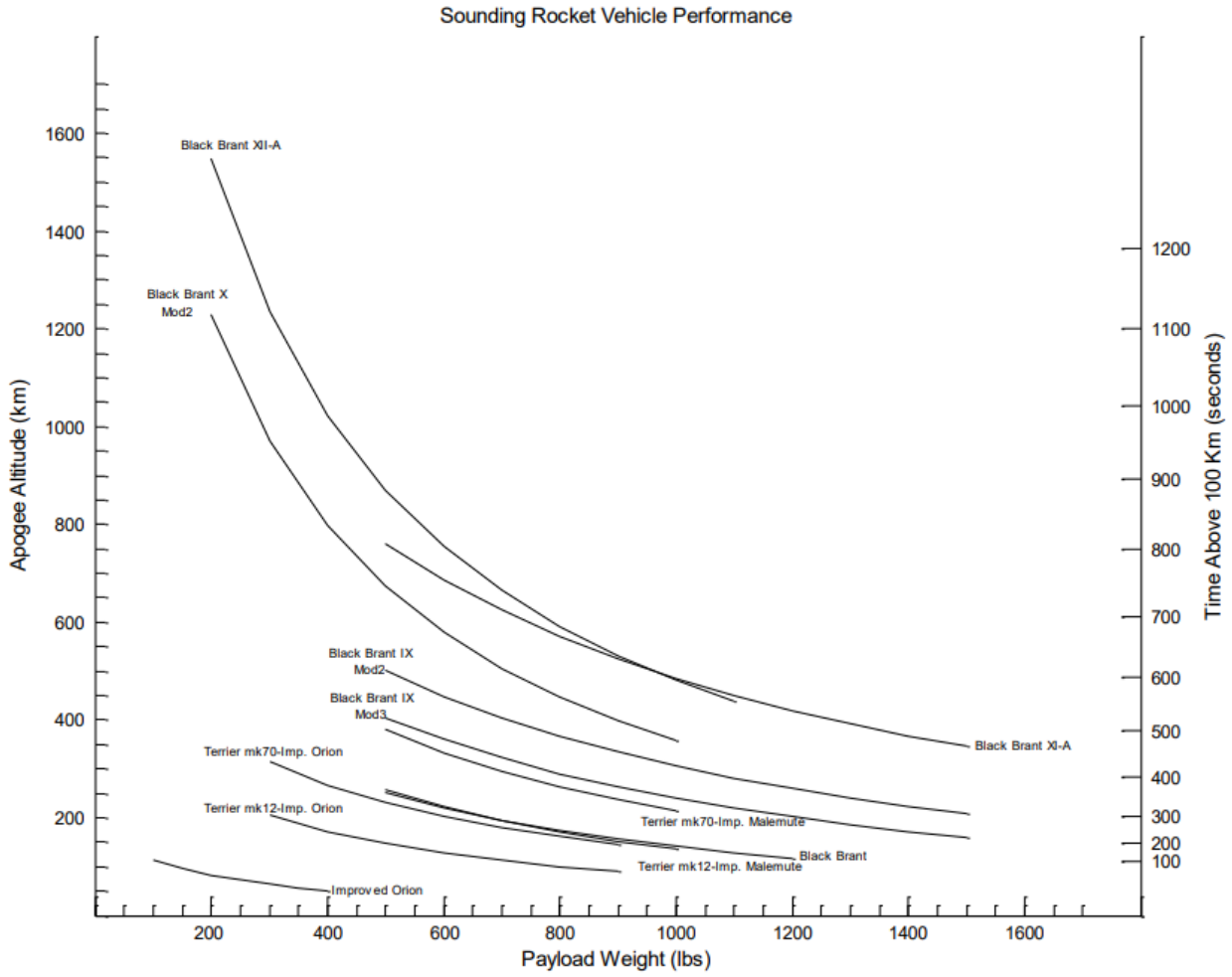
Fuel cells have emerged as a pivotal source of sustainable energy. They can be used to power scientific instruments in future space missions. "A fuel cell is a device that generates electricity through an electrochemical reaction. In a fuel cell, hydrogen and oxygen are combined to generate electricity, heat, and water." (*Fuel Cell Basics*). A fuel cell works as long as there is access to hydrogen and oxygen. The mission's goal is to study the performance of a fuel cell in a microgravity environment. The performance data collected from this mission will help to integrate fuel cell technology to power future scientific instruments. Furthermore, this data can be studied to identify calibration methods to extract the maximum performance of a fuel cell in a low-gravity environment.

Mission Platform

Our mission will use the Sounding Rocket, a suborbital mission platform at WFF. Sounding rockets can travel at high altitudes up to 1500 kilometers above the Earth's surface, as shown in Figure 1. They "out altitude" both scientific balloons and airborne science missions. The Sounding Rocket platform is the best for our mission since our experiments require a weightless environment. This platform gives up to 20 minutes of space time, which is enough time to gather the necessary data from the fuel cell. In addition, the payload and instrumentation can be recovered as a part of the mission for further analysis.

Figure 1.

Graph of NASA's Sounding Rocket Vehicle Performance



Graph from the NASA Sounding Rockets User Handbook (2017)

Mission Elements

Our experiment entails collecting data to study the effectiveness of a fuel cell in space. The mission's instrumentation will use the Electrochemical Impedance Spectroscopy (EIS) as shown in Figure 2. It measures the charge transfer activation (kinetic losses), ion and electron transport (ohmic losses), and concentration (mass transfer losses). These measurements are used by the EIS to "extract meaningful qualitative and quantitative information regarding the sources of impedance within the fuel cell" (*Electrochemical Impedance Spectroscopy (EIS): A Powerful and Cost-Effective Tool for Fuel Cell Diagnostics*). As a result, the impedance data spectrum will enable us to plot electrochemical behaviors. This will help achieve the mission goal to understand the fuel cell's performance in a microgravity environment at a high altitude (~1300 kilometers).

Figure 2.

Instrumentation for EIS of fuel cells

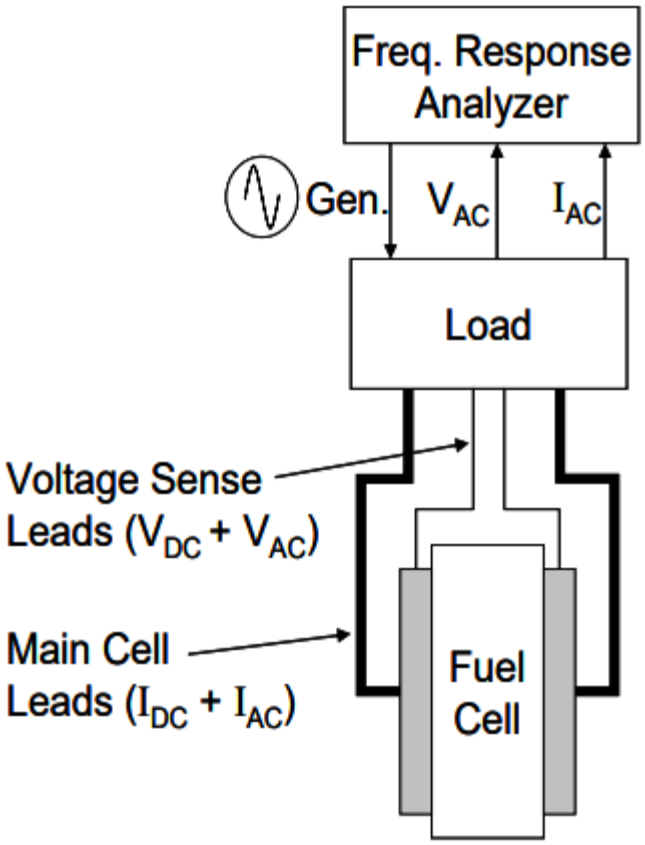


Image from Scribner Associates, Inc. (2017)

Research Team

Our mission will be represented by student research assistants from universities across the United States. Our team is composed of multi-disciplinary scientists and engineers with research areas in aerospace, chemical, electrical, and instrumentation. The research team will be responsible for the scientific experiment portion of the payload. They will provide the scientific instrumentation, process and analyze recovered data, and publish the results.

Mission Duration

The entire mission will start from the mission approval date until post launch, lasting six months. The mission duration begins with the fabrication and assembly of the instrumentation. The instrumentation will go through several tests and reviews before being integrated into the payload. Throughout the mission duration, the research team will follow the Risk Management

Plan, which is crucial for any mission since it identifies, assesses, and mitigates potential risks. Following the launch, the data from the instrumentation will be retrieved to publish the results.

Mission Patch

The mission patch is a symbolic representation of a mission and it has been a tradition to have one for every mission. Figure 3 shows the patch for our mission, Fuel Cell to Power Scientific Instruments (FCPSI). The mission patch shows the scientific goal in this mission by having a fuel cell which is measured using an EIS instrument that produces performance metrics. The patch also depicts the Wallops Sounding Rocket platform for our mission.

Figure 3.

FCPSI Mission Patch

Mission Stakeholders

This mission will benefit NASA's scientists and engineers, industry partners, and manufacturers. Our mission is to test the performance of a fuel cell in microgravity. The data collected from this mission can be used by instrument manufacturers to implement fuel cells as the energy source for the instrumentation. For the engineers and scientists, they can manage payloads more efficiently and calibrate instruments for longer durations based on the performance metrics collected from this mission.

However, the performance data collected from this mission is limited to a certain voltage capacity. The data may not exhibit the same behavior for larger ranges of voltages. This in turn might result in errors when extrapolating the metrics curve (polarization) for larger fuel cells. Another limitation is the time taken by the fuel cell to calibrate to its equilibrium. This may shorten the range of our data collection (Polarization curves 2022).

Conclusion

The FCPSI mission aims to study fuel cells as an alternative source to power scientific instruments in future space missions. This promising technology is a step towards advancing scientific instrumentation in space. Our mission takes advantage of the NASA WFF's Sounding Rockets platform to conduct our fuel cell experimentation. Our multidisciplinary research team will fabricate the EIS based instrumentation to collect critical metrics of a fuel cell's performance in microgravity. The mission duration spans six months from fabrication to post-launch data analysis. As a result, NASA and its industry partners can look to use fuel cells as a means to advance and conduct in-depth experiments. Overall, the FCPSI mission serves as a way to further space exploration and helps achieve NASA's vision to explore and understand the universe for the benefit of all.

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