AWSOME Mission Report
HASP Flight 2019 Payload 06

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Abstract:

Earth's precipitable water vapor (PWV) has become critical in being able to understand processes like weather and climate to which PWV, a strong greenhouse gas, significantly impacts. Weather satellites have been designed to do this, but instrumentation limitations only allow them to take measurements for some area once per day or less. Thus, ASU engineers have designed a novel radiometer that would use remote sensing at millimeter-wave frequencies to take multiple spectral measurements a day for some location and give a detailed three-dimensional profile of PWV in return. Eight undergraduate students at ASU have been given the opportunity to build and launch a payload built around this radiometer with two primary science goals in mind. The first is to determine the relationship between PWV and surface temperatures in arid or semi-arid locations so that a deeper understanding of the processes that affect such an environment may be better understood. The second is to take measurements of PWV and then compare them to data taken by ground stations, weather satellites, and other pertinent sources. This will help provide justification for the CubeSounder's efficacy and accuracy for a CubeSat on NASA's SWARMS mission. Besides the radiometer, team AWSOME's payload will have a camera for visual confirmation, a gyroscope for orientation, temperature sensors to monitor heat, a calibration system to standardize all data, and a computer to store said data.

Introduction:

Team AWSOME flew an innovative millimeter-wave atmospheric sounding radiometer aboard the NASA HASP weather balloon for purposes of remotely measuring features in the vertical profile of atmospheric water vapor. The Radiometer used six of the filter bank channels to attempt to answer the following questions: (1) during lateral travel, how does the surface temperature change in relationship to water vapor content and (2) how do these measurements of water vapor compare to those taken by satellites and direct measurement?

This project will focus on the impact that precipitable water vapor (PWV) has on weather and climate, especially concerning desert drylands. The millimeter-wave sounding radiometer has 6 spectral channels with a frequency range of 158-182 GHz, nearing the 183 GHz water vapor band.

Science Objective	Measurement Objective	Measurement Requirements	Instrument	Instrument Requirements	Data Products	Mission Functional Requirements
Surface temperature of earth and water vapor content of the atmosphere	Measure the temperature and density profiles of water vapor content in the atmosphere	Detect 183 GHz water vapor line	Millimeter-wave atmospheric sounding radiometer	Operating conditions from -40 to 60 degrees Celsius Minimum of three spectral channels. Ground resolution of 13.2 km^2 Smear rate 1/10th of the area per second Integration time: 1 second	Atmospheric temperature as a function of frequency.	Temperature calibration of the radiometer is required, so a blackbody object and a temperature probe will be used for calibration. Temperature needs to be accurate within +- 1 C and temperature probe needs to be accurate to +- 0.1 C Position and orientation information to provide context to the radiometer data through HASP telemetry and camera images. Visual images to detect if the radiometer is obstructed. The camera used shall have a minimum of 100 pixels for the ground resolution of 13.2 km^2 taking pictures once per second.
Comparing radiometer data on water vapor content to NOAA satellite data on water vapor content	Obtain data from NOAA satellites over the HASP flight path	NOAA data comparable to radiometer collected data	NOAA satellite data	N/A	Temperature and water vapor profiles of the atmosphere	N/A
Comparing radiometer data on water vapor content to radiosonde data	Obtain data from Radiosonde group	Radiosonde data compared to radiometer data	Radiosonde's Hygrometer	N/A	Water vapor profile of atmosphere	N/A

Figure 1. Science Traceability Matrix

The Radiometer Payload:

The payloads consists of the Radiometer device that is continually taking data from the outside scene. It is composed of two low noise amplifiers that boost the signal taken from the scene where it then goes through the filter bank. The filter bank splits off the signal into one of 6 channels; 158Ghz, 164Ghz, 170Ghz, 176Ghz, 182Ghz, and the through channel for all other frequencies. From there, the signal notifies the connected diode which takes that signal and translates it into an analog voltage difference. From there, the voltage difference is further amplified by an audio amplifier that was built by Philip Rybak. The signals coming out of the LNA's are very weak, roughly 1 mV, and require to be amplified for digitization. A third low noise amplifier was built to amplify these signals to within +/-1V to +/-10V. The AD8429 was used to do most of the amplification at a low noise level followed by an LF411 with variable gain positions. The low noise audio amplifier consists of 6 channels to match the filter bank outputs. From there, the signal is registered by an Analog to Digital converter where it is digitized and then sent to the Raspberry Pi computer for information storage. The Pi computer also runs the calibration system which consists of a blackbody temperature reference for the Radiometer signal, a spinning reflective wheel for signal calibration, and an optointerupter which lets the system know when data is being taken from the outside and when it is calibrating. Additionally, a raspberry pi camera was added to provide visual context for the data collected

Our system also included an RS232 serial converter so that our Pi computer could communicate with the HASP system. The entire system was powered by the HASP gondola which connected to three DC-DC converters that stepped down the voltage for our system.

Data Analysis Method:

To analyze the Radiometer data, our computer engineer took each of the 18,000 files and time averaged each file that contained about 10,000 sample points each. This was done because the 10,000 sample points in each file were taken over 4 seconds of time. After these files were averaged, they were plotted for each spectral channel. This process took a few months as each file needed to be analyzed and handled individually.

Data Results:

Our data was inconclusive due to the low responsivity of the channels during flight. We saw this in our original analysis of our files back in October, but we were determined to find at least a few clean data files. Unfortunately, the entire flight had inconclusive data.

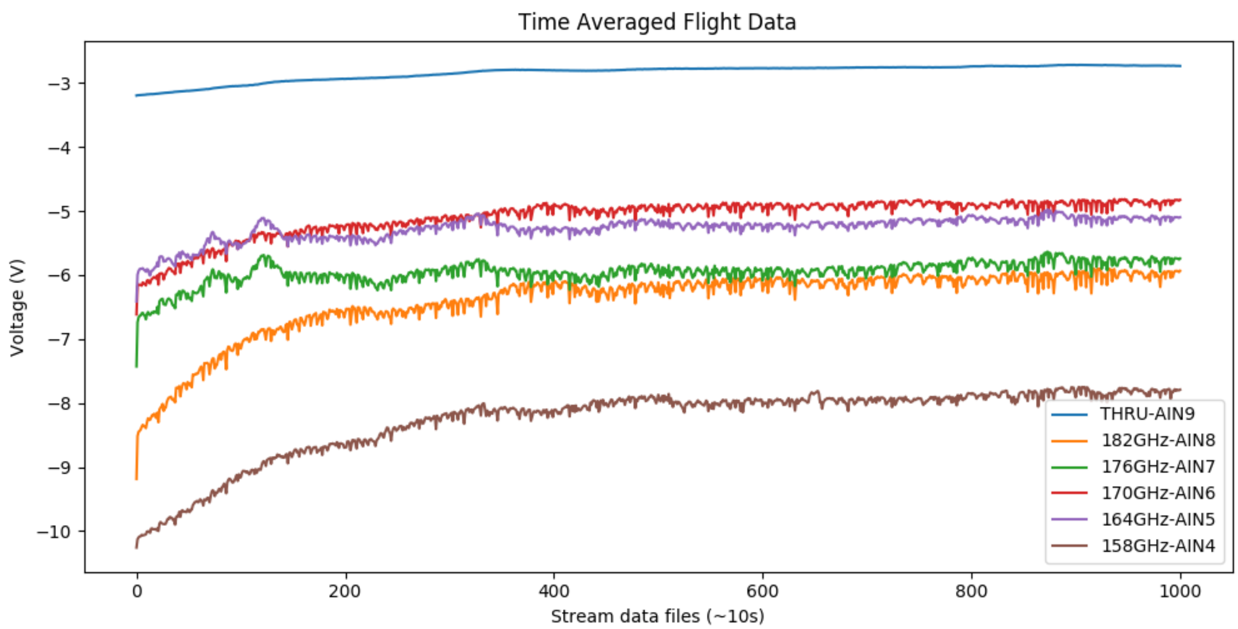

Figure 2: Flight Data showing noisy and unresponsive channels

We found that there were two main reasons that our flight data was inconclusive. First, the low noise amplifiers that are built into the Radiometer were unsuitable for this project. This information was recently discovered after reading the spec sheets for them and then testing them separately to see how accurate the spec sheet was (see figures 3 and 4). The LNAs show little to no responsive after 165Ghz which compromises most of our channels.

Radiometer Physics
A Rohde & Schwarz Company

Test Report

Serial Number: 100013

D-LNA 110-170 30 6
Fullband Low Noise Amplifier

Part-No.: 03000025

Technical Specifications	
RF-Range	110 to 170 GHz
RF-Interface	WR 6.5 (UG387/U flange compatible)
RF-Input Power max.	-50 dBm
Noise Figure	typ. 6 dB
Gain	typ. 30 dB
Case Temperature max.	+45 °C

Power Requirements[1]	
Input Voltage	+3 VDC
Input Voltage max	+7 VDC
Supply Current	typ. 60 mA

Figure 3: Screenshot of the LNA data sheet that states the RF-Range of the amplifiers

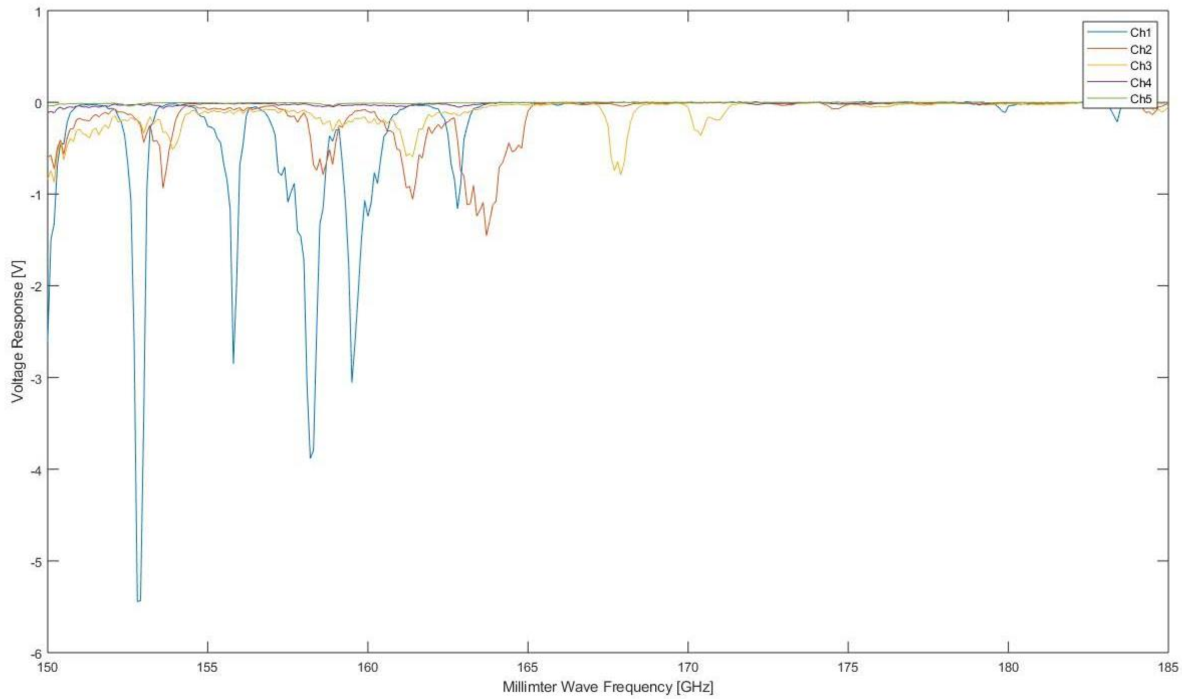

Figure 4: Voltage responsiveness of the LNAs at our Radiometer's frequencies

The second issue our payload had was with the noise of the DC converters. We did not realize until later that the DC converters were creating noise that was being mistaken as clean data. In figures 5 and 6, you can see the difference between clean powered data using lab power supplies, and the dirty data powered by DC converters stepping down a lab power supply.

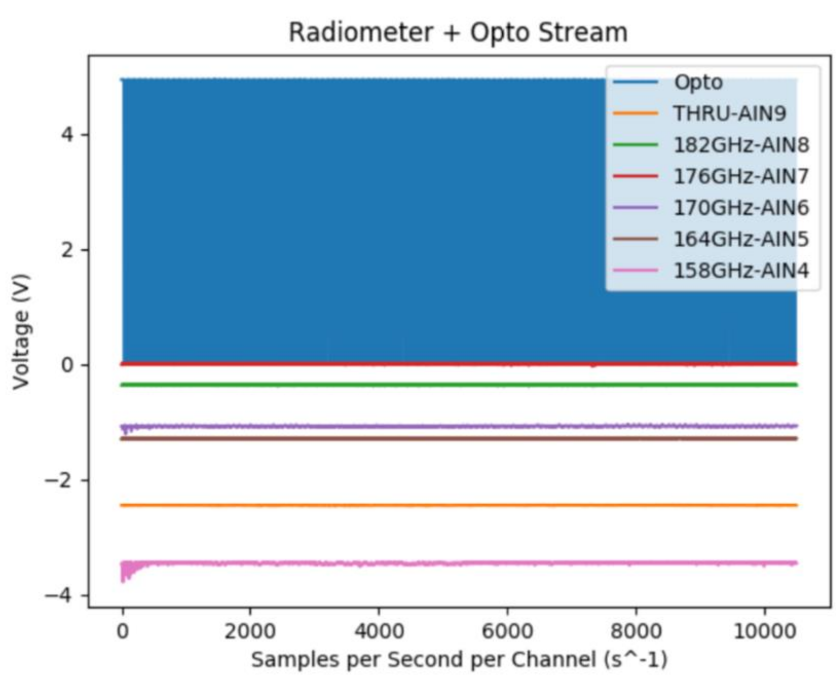

Figure 5: System powered with clean power supplies

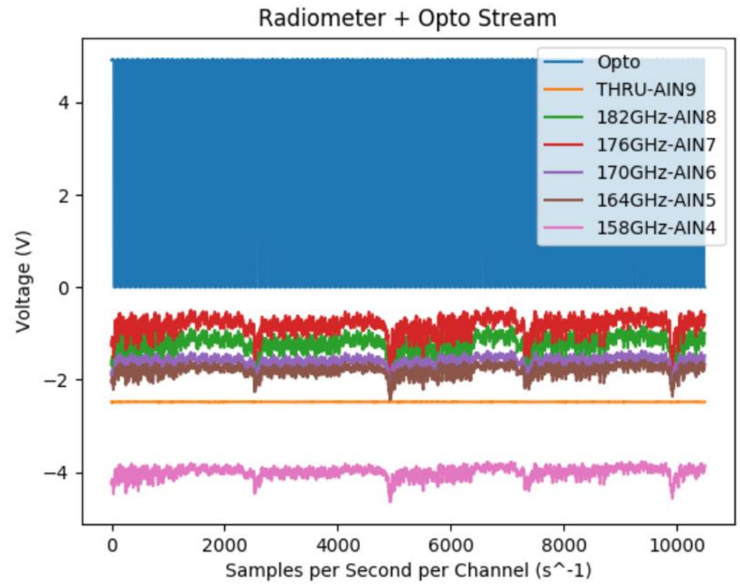

Figure 6: System powered with DC Converters stepping down a power supply

During flight, however, we were able to downlink data to ensure our payload was turned on and functioning. We communicated with the HASP Flight Operator as needed and provided our team with in-flight data analysis with the provided downlinked data.

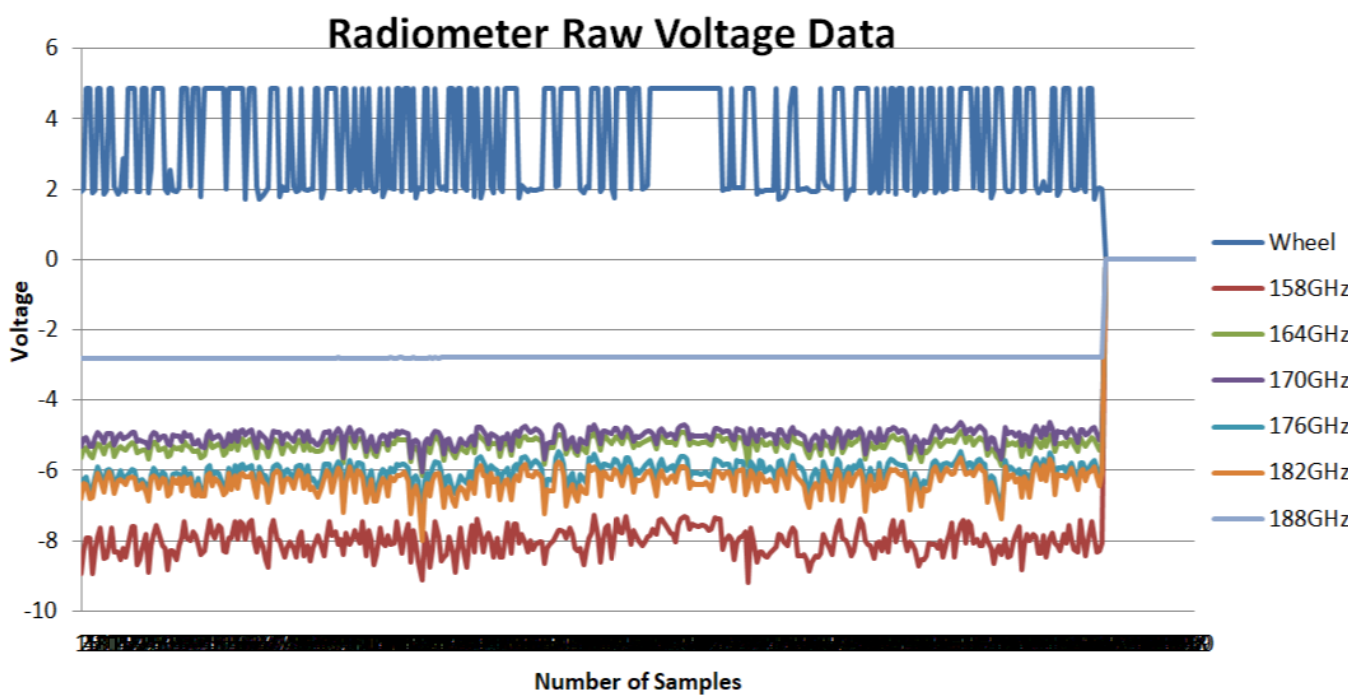

Figure 7: In-flight data analysis that allowed our team to monitor the payload

Conclusion:

The payload successfully launched on September 5th 2019 with all systems powered on. In total we collected over 18,000 data files and pi camera images. Even though the data was inconclusive due to issues with the LNA's and the noise from the DC-DC Converters, the team learned a great deal about proper balloon flight mission operations and regulations. The HASP program assisted at least one of our students acquire an engineering job in the field and provided many other with the experience necessary to pursue careers in this field. Although the science mission failed and our questions were unanswered, the class mission to learn about the industry and balloon launches was a success.

Team Roles and Responsibilities:

Name	Start Date	End Date	Role	Student Status	Race	Ethnicity	Gender	Disabled
Alexa Drew	08/16/18	9/27/19	Science	Graduated	White		Female	No
Alvaro Martinez	08/16/18	05/03/19	None	Graduated	White	Hispanic	Male	No
April Davis	08/16/18	9/27/19	Assist Role	Undergrad	White		Female	No
Bianca Pina	08/16/18	Present	Systems Engineer; Testing; Electrical; Calibration; Mechanical	Undergrad	White	Hispanic	Female	No
David Halperin	08/16/18	9/27/19	Volunteer	Graduated	White		Male	No
Katherine Morin	08/16/18	9/27/19t	Volunteer	Undergrad	White		Female	No
Peter Wullen	08/16/18	Present	Computer; Orientation; Communications; Thermal	Graduated	White		Male	No
Philip Rybak	08/16/18	Present	Amp 3; Radiometer	Graduated	White		Male	No

Team Graduation and Career Information:

Name	Graduation Date	Degree	Status
Alexa Drew	May 2019	Astrobiology	Office Assistant for The School of Earth and Space Exploration
Alvaro Martinez	May 2019	Astrophysics	Enlisted into United States Air Force
April Davis	Student	Geology	N/A
Bianca Pina	May 2020	Astrophysics	Student
David Halperin	May 2019	Exploration Systems Design	N/A
Katherine Morin	Student	Astrobiology	Student
Peter Wullen	May 2019	Astrophysics	Test Engineer for DS Electronics
Philip Rybak	May 2019	Astrophysics	Test Engineer for DS Electronics

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Dr. Christopher Groppi, Professor and Mentor, School of Earth and Space Exploration
Dr. Sean Bryan, Mentor, School of Electrical, Computer and Energy Engineering
Dr. Paul Scowen, Mentor, School of Earth and Space Exploration

Outreach Efforts:

Our team organized a fundraiser through ASU to raise money for multiple team members to attend launch. We were able to raise over $5000 for our students to participate in the launch activities and to be part of the amazing learning process.

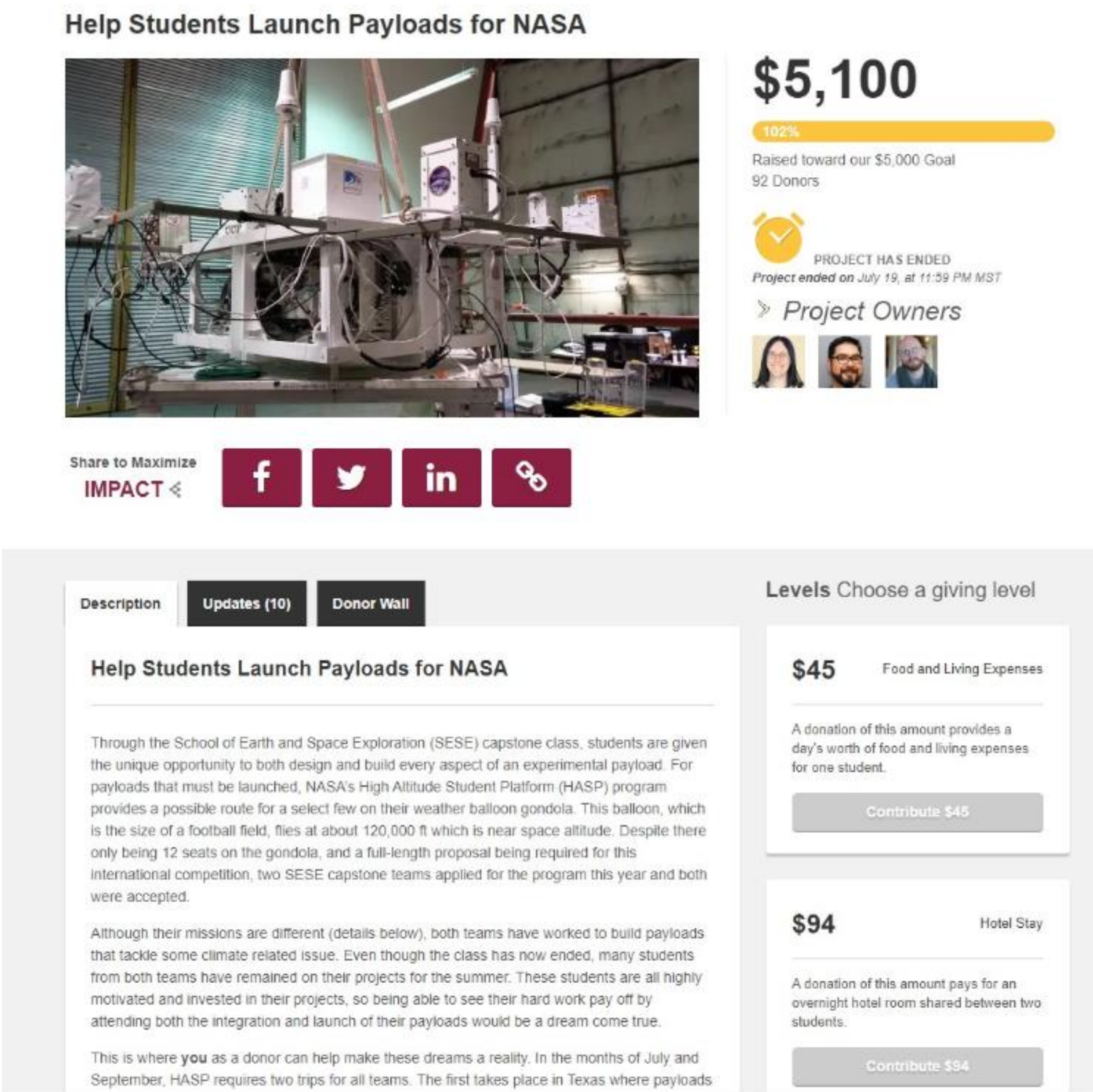

Figure 8: A screenshot of the pitch funder page