MISSE-11 Ground Experiment Control

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Back during the Apollo missions, when astronauts were being sent to the moon to explore and further scientific knowledge by conducting experiments and collecting samples for scientists back on Earth, they were faced with a surprising problem. It was discovered that the moon's surface is covered with dust that has electrostatic properties, which would stick to suit and equipment. This hindered the functionality of the astronauts' space suits, solar panels, optical instruments, among other exposed surfaces due to the jagged geometry of the dust which would damage said equipment.

To resolve this issue, the Electrostatics and Surface Physics Laboratory (ESPL) came up with the solution of using an Electrodynamic Dust Shield (EDS)[1] that uses electrostatic forces to move particles across a surface. Varieties of this dust shield have been developed for different applications. The purpose of the Materials International Space Station Experiments 11 (MISSE-11) is to experiment a payload that contains the dust mitigation technology to be flown to space for one year and an identical payload will be on earth, under vacuum, in the Electrostatics and Surface Physics Laboratory. The space payload was prepared prior to our arrival and shipped to fly on the International Space Station (ISS). The payload staying on the ground is going to act as a control for the experiment so that we may compare it to the payload that was flown in space.

During our time at Kennedy Space Center, we were tasked with building and start testing the ground control unit of the MISSE-11 payload. To complete our task for the ground control unit, we constructed a new vacuum chamber setup and added automated aspects, procured the necessary flight electronics, designed and communicated for the machining of the payload frame, and performed functional and thermal testing on the electronics to the same original operational standards. Some modifications were made where possible, without affecting the performance of the samples, to be efficient with the production of the control unit while keeping important aspects identical. The experiment is now nearly complete, and testing will be starting within the next few weeks.

Nomenclature

MISSE	=	Materials for International Space Station Experiment
NASA	=	National Aeronautics and Space Application
KSC	=	Kennedy Space Center
ISS	=	International Space Station
EDS	=	Electrodynamic Dust Shield
ESPL	=	Electrostatic Surface and Physics Lab
CAD	=	Computer-Aided Design
HVPS	=	High Voltage Power Supply
DCU	=	Data Collection Unit

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I. Introduction

This spring term was spent working in the Electrostatics and Surface Physics Laboratory (ESPL). Currently, the lab has several projects focused on mitigating the problems associated with the dust in lunar and Martian environments. Our duties for this semester were primarily focused around the Materials International Space Station Experiments 11 (MISSE 11) which carries dust mitigation technology to be exposed to the space environment*. Our role in this experiment was to construct and setup the MISSE 11 ground control unit which will act as a comparison to the data and visual presentation of the unit at the International Space Station (ISS).

The success of this project is important because it will allow the technology to move closer to being ready to fly on missions. Because NASA is planning on doing longer and more frequent lunar missions, it is critical that there be dust mitigation technology to alleviate and allow for greater chances at mission success.

II. Details

A. Vacuum Chamber

One of the first tasks that needed to be completed was setting up of the equipment that is to simulate the space environment for the year-long test on the ground control unit. This mainly includes a new Lesker Vacuum chamber ordered prior to our arrival. It will be made to simulate the vacuum of space with a pressure of 1×10^{-8} Torr during this experiment and able to replicate lunar and Mars's environment as well for future testing. Most of the work with this vacuum chamber was completed in a timely fashion but as we neared completion there were a couple issues that prevented us from finishing sooner.

i. Installation

The vacuum chamber set up includes two roughing pumps and one turbo-molecular pump. An early issue occurred for the installment of the Turbo Pump where we were questioned the strength of the rod attachments for the pump, the vacuum chamber, and the pneumatic gate valve in between given that the geometry of all of three of them installed made it seem unsafe for the turbo pump to be left unsupported. To add to this superstition, the recommended rod attachments from the turbo pump's manual is metric class 19.2 rods which have a yield strength of 1100 MPa; we ordered S.I. grade 8 rods with a yield strength of 896 MPa, around 82% the recommended strength. To resolve this issue, we calculated the safety factor with the acquired rod's specifications to see if it would suffice. A materials stress analysis using Distortional Energy failure theory was used with the assumption of one rod being a cantilever beam; this would overestimate its safety factor while simplifying the calculations, considering only the mass of the turbo and the gate valve, respectively 22 kg and 26 kg. We calculated the safety factor for one of the acquired rods to be 70.5, determining it safe to use the acquired rods and for the turbo to be installed without support.

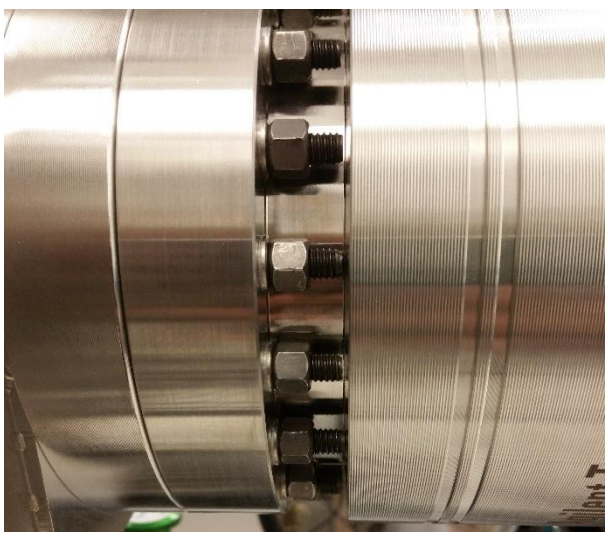

Figure 1: Current setup of turbo-molecular pump with installed rods. One of the issues while installment was the difficulty to install the rods given the small clearance to insert and tighten the nuts.

Even after assuring the safety of the setup, installing the gate valve and the pump proved to be a struggle due to the small clearance on the turbo pump. It took the assistance of one additional person to completely install the turbo since it took one person to keep the turbo in space and two others to place the nuts on both sides simultaneously to keep a good alignment that would not damage the rods and maintain an even seal around the pump.

Another issue that we came across was that the pressure sensors to monitor the pressure within the chamber could not be calibrated to produce an accurate reading. This resulted in a delay of the task being completed since new sensors had to be ordered. The final part of the vacuum chamber task was to write a program that could automate certain aspects of our experiment. The software program LabView was used to write a program that could monitor the pressure within the chamber and record all the pressure data to a file.

B. Sample Deck Plate

The deck plate of the MISSE 11 assembly contains pockets for the dust shield samples to be placed on. We define the orientation of the unit with the top being where all the dust shields are exposed. The six film samples and two glass samples are placed through the bottom of the deck plate and exposed through a window which they lay against. For them to be flat against this window, the pockets in which they are placed also contain supporting parts that consist of a Teflon sheet and a couple of layers of aluminum shims and wavy washers to give the shield a safe and tight fit.

To acquire this deck plate locally and in a short time period but still with a matching quality to the original space unit, the geometry was altered. The outside perimeter of which fits to the unique geometry of the original payload enclosure no longer serves the purpose of having to fit to this unique geometry, thus we decided to simplify it by removing features that required rarely used small tooling and engraved aesthetics. For the machining, tolerances were widened along the perimeter, increased to ±0.01 in. The aluminum deck plate was also left uncoated in contrast to the original since the coating is to avoid damage from radiation. Along with the removal of this features, we added a curve to the edges of the plate for ease of use once at the lab. None of these features have a foreseeable effect on the performance of the dust shields on the ground unit.

Essential aspects of the deck directly affecting the dust shields include the pockets in which they are placed and the supporting accessories. The tolerance of the pockets, unlike that of the perimeter, was restricted to the original ±0.003 in to replicate the tight fitment.

ii. Support Accessories

Along with the deck plate, supporting material had to be fabricated in order to support the dust shield samples to hold them in place. To have the samples lay flat against the window, alternating layers of aluminum shims and washers, with a Teflon cover for the glass samples so to not damage them, were used to stack the shields within the pockets.

The backing plate is to enclose the pockets containing the film and glass samples, along with the supporting shims and washers. Since the purpose of the back plates did not directly impact the performance of the dust shields, they were given the same tolerance as the perimeter of the deck plate.

iii. Possible Interference Issue

An issue discovered while planning for the fabrication of the ground control unit was the possibility of the borosilicate glass panels interacting with the corners of their respective aluminum pockets, and thus possibly causing damage to the shield, while the original went through a thermal testing in preparation to be sent to the ISS. The original design of the pockets for the glass panels calls for sharp corners, where in reality that is impossible for a pocket to be machined as by common manufacturing methods. Thus, the actual payload resulted in the corners of those pockets to have a radius of 0.02 in. This resulted in calculating the clearance between the glass panel and the aluminum pockets to confirm that they would interact.

During thermal testing, the payload is exposed to a temperature change of 60 ºC, causing the aluminum plate and the glass shields to expand. Calculating a linear expansion for the width, length, and diagonal distance of the shield and pocket confirmed a total clearance of 0.382 mm, 0.288 mm, and 0.031 mm respectively. Later results from the thermal testing confirmed there was no damage to the glass, thus the no interference problems had occurred.

C. HVPS Operational Test

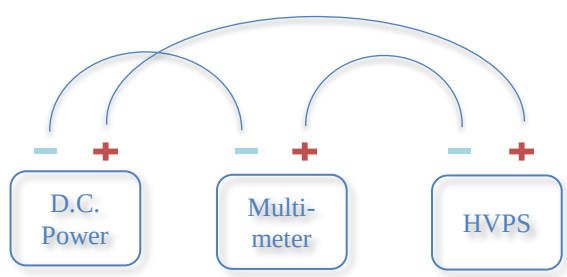

Figure 2: Simple schematic of HVPS operational test setup.

Once the High-Voltage Power Supply (HVPS) was assembled, we conducted an operational test as was done to the original to check that it was functioning correctly, thus assuring that the assembly was done correctly. The procedures for such a test are already set in place, however some additional information was noted while conducting the test. The parameters for which were being checked included current (5% of 90 mA), rising edge (5% of 645 ns), amplitude (5% of 4.0 kV), and frequency (5% of 10.0 Hz). During testing, additional safety measures were done such as conducting the test on one HVPS High Voltage output channel

at a time and placing Teflon tape under the capacitor so it could no ground with the enclosure in which it was being tested. A simplified schematic of the how the connections were made for the test is shown in figure 2.

Additional notes were taken while doing the operational test. Once the multimeter is attached to the power supply running 18 V, the current measure should read 1 Amp; when we conducted this test, our multimeter was performing questionably thus alternated to not use the multimeter. During the high voltage testing, once the power supply is enabled to the HVPS, the output current dropped to around 90 mA. Also, when looking for the parameters, between reading rise and magnitude, we switched the oscilloscope to the broad setup to read the frequency. Once switched, the power supply had to be enabled once again to gain wave readings; to read frequency, we had to fit one full wave between the cursor and then recorded the "1/Δx" reading. This additional notes may be of aid in future operational tests or if the testing for the HVPS during this scenario is questioned.

Figure 3: Before and after clearing dust while the HVPS had the faulty connection.

Figure 4: Before and after clearing dust once the HVPS connection was fixed.

D. Electrodynamic Dust Shields

The MISSE-11 payload contains a total of twelve variations of an EDS, two of which are active samples. This means that the two samples each use a HVPS to power a series of parallel electrodes embedded on them[2]. An example of one of the active samples is shown in figures 3 and 4. To further confirm that the HVPS assembled was working properly we did further tests in a bell-jar vacuum chamber. Through this we found and quickly resolved an issue in the connection of the HVPS; one of the pins wasn't correctly positioned thus resulting in a single-phase electric power to the active sample and in result, did not completely clear out the dust. Once we fixed this connection, the dust cleared out completely, assuring that the HVPS is functioning properly and is good to use.

E. Flight Electronics

One of our tasks was to procure the electronic circuit boards that make up our HVPS. We used electrical schematics to acquire quotes and purchase the needed amount of circuit boards. This task seemed to be on schedule but unavoidable issues ended up slowing down the arrival of the circuit boards. The main issue that slowed down the arrival of the electronics was the lead time on a couple backordered electrical components. These components were necessary for the construction of the boards and could not be replaced so we were forced to wait for their arrival.

F. Thermal Testing

Along with the functional testing, we also completed thermal testing on the HVPS connected to an EDS. The testing consisted of lowering the temperature of the HVPS to 0 ºC and then powering the dust shield and monitoring the current through a Hall Effect sensor connected to an oscilloscope. If the waveforms fit the testing standards, then the temperature was raised 5 ºC and the waveforms were analyzed again. This procedure was repeated up to 45 ºC.

III. Additional Work

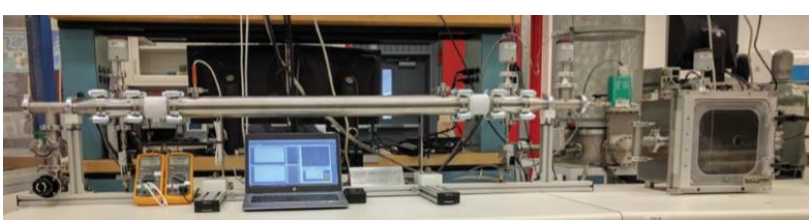

Figure 5: ESPL's Electrostatic Precipitator.

Another aspect of our work dealt with the lab's Electrostatic Precipitator[3]. With an ever-growing interest in missions to Mars there is an understanding that resources on Mars will need to be utilized in order to feasibly fly there and fly back. An important resource that is being looked

at is the gasses that make up the atmosphere. These gases can be processed to create rocket propellant that astronauts will be able to use for their flight back to earth. Currently, the technology is there for the creation of propellant, but Mars happens to have a large amount of dust particles in its atmosphere which makes the processing too difficult. In order to process efficiently, the atmosphere containing dust must be filtered through a means that does not require a large number of consumable filters or human interaction. The ESPL is currently working on ways to use an Electrostatic Precipitator to filter the atmosphere before it goes through processing. The experiments that took place during our term dealt with collection efficiency and making sure that we were replicating an atmosphere that had a particle amount similar to the Martian atmosphere.

IV. Conclusion

In conclusion, for the MISSE-11 ground experimental control we were able to compile and assemble most of the material and prepare the equipment to be used for testing. In the coming weeks, to the end of our internship, we will continue preparing the equipment and testing the product to finalize tasks unhindered by the components delaying the progress. Unfortunately, we were not able to finish all our tasks due to unavoidable complications. Though the project is currently incomplete, we have assured ease of completion once the final parts arrive to the team for most of the work and testing has been completed.

In the process we were able to acquire applicable skills and knowledge for our respective fields. In order to setup the vacuum chamber we needed to become familiar with the properties of vacuum chambers and their pump systems. Sensor cables had to be run through various ports that were chosen to be in positions that were most ergonomic for laboratory testing. To acquire the flight electronics, we had to understand the electrical schematics and specific circuit board design files to facilitate the communication to the company that will manufacture and assemble the unique circuit boards. Once the electrical hardware is completed and in our possession, we will need to verify that it is functioning correctly via electrical diagnostic testing with an oscilloscope. To have identical payload parts, we used the modeling software Creo to make mechanical drawings from the original part models that allowed machinists to manufacture them and facilitated the process by adjusting the product to our specific requirements. To make the control/data recording program in Labview, we spent time reading about the program's functions, frequently made practice programs, and consulted with knowledgeable personnel.

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