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The Effects of Charging by Ultraviolet Light on Granular Lunar Simulant in a Microgravity Environment

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Technical/Required Format

Team Information

Table 1 lists the members of the Applied Flight Research Group of the Microgravity Research Team at Utah State University and their roles within the group.

Table 1. Team Members and Roles.

Flyer	Ground Crew	Faculty Support	Press
Sydney Chamberlin *Physics, Math*	Jeffrey C. Boulware *Mechanical Engr.*	Dr. J.R. Dennison *Physics, Professor*	Not Applicable
Sarah Isert *Mechanical Engr.*	Landon Hemsley *Computer Science*	Dr. Jan Sojka *Physics, Dept. Head*	
Troy Munro *Mechanical Engr.*	Nathan Inkley *Mechanical Engr.*	Dr. Charles Torre *Physics, Professor*	
Tracy Garin Savage *Mechanical Engr.*	Vicki Ragsdale *Mechanical Engr.*		
	Alex Wright *Mechanical Engr.*		

Flight Week Preference

First: Flight Week 2: June 5-14, 2008
Second: Flight Week 3: June 19-28, 2008
Third: Flight Week 4: July 10-19, 2008

Advisor/Mentor Request

Not applicable to this project.

Synopsis/Abstract

With constant developments in space technology and manned flight, it is only a matter of time before humans or human-made probes return to the surface of the moon, Mars and perhaps beyond. With such impetus for exploration in space, it will be necessary to design equipment to tolerate abrasive dust particles. The Apollo missions evidenced the degree to which such dust particles can adhere to equipment, causing potential risks to the welfare of both sensitive instruments and the humans manipulating them. The charging of materials on planetary surfaces could further enhance the adhering properties of lunar and planetary dust, should this charging be evidenced on individual dust grains.

A primary question is what the key cause of charging on such grains could be. Planetary surfaces are constantly irradiated by solar wind ions and cosmic fluxes, an effect that is well documented – but other factors have been less well-documented. One such potential factor is the charging of dust grains in some type of photoelectric effect. Light meeting a minimum frequency causes the emission of electrons from some materials; this could result in a net charging of lunar dust grains. Such effects have been investigated in terrestrial laboratories, but the presence of gravity makes it very difficult to assess the charge of the grains since attraction due to gravity is significantly greater than that of a single electron.

An experimental setup in a microgravity environment could yield the net charge accumulated by dust grains from a photoelectric effect. This experiment will measure the attraction of charged dust grains using a variety of frequencies to verify the accuracy of this hypothesis. Conducting the experiment in the absence of gravity will make it possible to observe the dynamics of charged dust grains in an electric field of moderate strength.

Test Objectives

The objectives of this experiment are as follows:

1) To determine the net charge accumulated by dust grains as a result of electron emission from the photoelectric effect.

2) Given a range of minimum light frequencies at which the effect may be observed, to determine the frequency which evidences the most charging of dust grains.

3) To use this frequency to evaluate potential causes of charging on planetary surfaces and the potential for utilizing the charging effect to remove dust from surfaces.

Hypotheses

As introduced by the test objectives, our primary and secondary hypotheses are:

1) Dust grains will exhibit a charging effect when exposed to light of a minimum frequency corresponding to the work function of elements in their mineral composition.

2) The frequency at which the charging of dust grains is maximized will correspond to light wavelengths typical in the inner solar system environment.

The correlation between photons of a given frequency and electron emission of the irradiated surface is discussed in the Photoelectric section. The effect should be observed if the frequency of light used is great enough to exceed the work function of the mineral composing the dust grains. If no net charging effect is observed for any frequency of light, it will be possible to rule out light as a potential parameter in the charging of planetary dust. Other means may then be sought out to test the validity of the second hypothesis.

This experiment is not a follow-up to a previous experiment.

Test Description

Background and the Charging of Planetary Surfaces

Several factors lead to a charging effect on the surfaces of planets. In the case of the moon, such factors include interactions with plasma electrons, bombardment from solar wind ions (including the sputtering of atoms from the lunar surface) and photoelectron currents on the planet surface (Halekas).

One potentially noteworthy effect of this charging could be the enhanced adherence of lunar dust grains to surfaces. Understanding the dynamics underlying this adherence could lead to better methods to manipulate dust grains – thus, a potential system to mitigate dust problems.

While some sources of the charging of surfaces are very complex, such as plasma interactions, the sun provides a fairly simple process of charging through the photoelectric effect. A better understanding of the means by which this photoelectric charging occurs could lead to better understanding of the charging process, making complex variables more accessible.

The Photoelectric Effect

In 1921 the Nobel Prize in physics was awarded to Albert Einstein for his work in unraveling the then-mysterious interaction that takes place between a solid and a light source of the correct frequency. Several experiments had shown that metallic surfaces illuminated with certain light sources would emit electrons, and in fact, some classical theory even supported this effect, making the following predictions: first, that classical physics predicted that some non-zero time interval would elapse between the light hitting the surface and the electron being released (since it would take time for energy from a wave-like entity to transfer); second, that the energy of electrons released from the surface would be proportional to the intensity of the light emitted; and third, that light of any frequency should be able to eject electrons from the surface if exposed to it for a long enough period (Beiser).

But experimental work shows just the opposite: that electron emission occurs right when the light hits the surface, that the energy of electrons released is proportional only to the frequency of the light (greater intensity sees only more electrons ejected, but with the same energies), and that for each surface, only light of a certain threshold frequency will cause electron emission. The curious nature of this effect is due in part to the wave-particle duality of light, and the emergence of the concept of quanta, or packets of energy.

With regards to solids today, the key idea is that light with a frequency meeting the minimum required for that object will cause the emission of some electrons from the solid. What then, if any, is the observed effect for solids in the space environment? One may also further this question by asking whether the photoelectric effect can be observed for the lunar surface, and specifically, if light from the sun is in the frequency range to produce the effect.

First the mathematics underlying the photoelectric effect must be introduced. As was noted in experiment, the energy of electrons emitted from a surface is proportional to the frequency of the light hitting the solid. From modern physics we have that,

$$E = h \cdot f \qquad \text{(Eq. 1)}$$

where h is Planck's constant (approx. 6.63×10^{-34} Joule-seconds) and f is frequency in Hertz. Also as noted before, for a given surface there exists a minimum threshold frequency at which the photoelectric effect will take place. This frequency has to do with the chemistry of the solid involved – to remove an electron, there must be an energy greater than or equal to the binding energy of the electron within the solid. This is typically given as the *work function* of the solid where,

$$\phi = h \cdot f_s \qquad \text{(Eq. 2)}$$

again with h as Planck's constant and f_s the minimum frequency to remove an electron from some surface s. With this established, we can characterize the photoelectric effect with,

$$h \cdot f = KE_{\max} + \phi = KE_{\max} + h \cdot f_s \qquad \text{(Eq. 3)}$$

simply combining Equations 1 and 2 with KE_{max}, the maximum kinetic energy characterized by an ejected electron.

Our objective question of whether dust grains will be able to experience some photoelectric effect may now be addressed.

Dust Experiment - Setup

As stated in our hypotheses on page three, our first objective is to measure the effect of the photoelectric effect on lunar-simulant mineral grains. We propose a method to conduct such an experiment.

The dust grains will be composed of amorphous silicon dioxide, an abundant lunar dust element. The choice of silicon dioxide, rather than other abundant lunar simulant choices such as crystalline aluminum dioxide (sapphire), is due to the transmission threshold of the amorphous silicon dioxide. Crystalline silicon dioxide (quartz) has an electron band gap of approximately 8 eV, while the amorphous silicon dioxide has a smaller band gap of about 4.6 eV; the optical transmission curves of these along with that of aluminum dioxide may be seen in Figure 1.

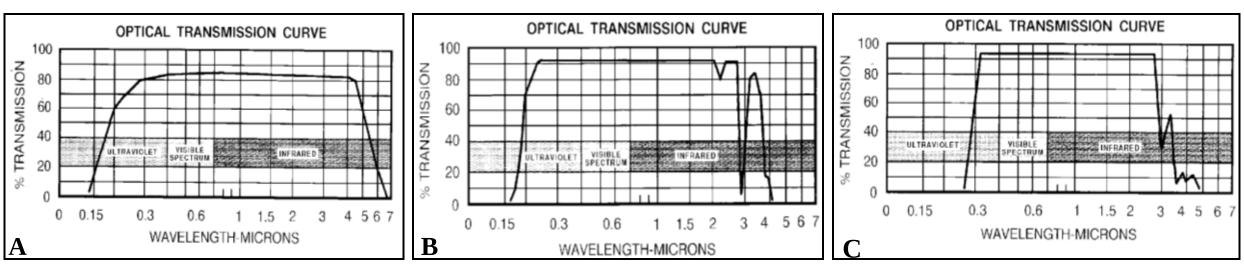

Figure 1. Optical Transmission curves for A) Crystalline aluminum dioxide (sapphire), B) crystalline silicon dioxide (quartz) and C) amorphous silicon dioxide. Graphs obtained from Huntington et al.

Following the methods of Hoffman et al. the dust grains will be formed by pressing silicon dioxide power into pellets using conductive copper tape. The samples will then be pressed with a 12 ton hydraulic press. The resulting pellets (Figure 2) can then be crushed to a finer consistency to resemble small grains less than 1 mm in size, which is typical lunar grain size (Kring). The work function of Silicon is in the range of 4.4 - 4.8 eV; furthermore, the oxidization of a surface has been shown to increase the work function (Burton). Thus in our study we consider $\phi_1 = 4.4eV$ to be a lower bound on the work function corresponding to a grain of silicon dioxide. To account for the increase of ϕ_1 from the oxygen in SiO_2, we anticipate a work function of approximately $\phi_2 = 5.3eV$.

Using Equation 3 with ϕ_2 we determine that the minimum frequency that will yield electron emission is about $1.28\times10^{15}\,Hz$, which falls into the ultraviolet range of the light spectrum. Thus a light source emitting at a frequency $f \geq 1.28\times10^{15}\,Hz$ should cause photoelectric emission of electrons from silicon dioxide grains.

The experiment will be carried out in a series of four rectangular boxes of dimension $1m \times 1m \times 0.05m$ (Figure 2 shows similar pellets that could be crushed into smaller grains), constructed with a parallel plate capacitor on two sides such that a reasonably uniform electric field will be generated inside each. The boxes will be constructed with a polycarbonate since it is an insulator and will make the process visible. They will be filled with nitrogen through a one-way valve in the top of the box prior to boarding the aircraft. Three of the boxes will have a deuterium lamp mounted in the top. These will provide light of frequency greater than the threshold ultraviolet frequency and will range the ultraviolet spectrum of electromagnetic radiation. The fourth box will be a control box and will not have any light. Grains in this box will be released to compare to those irradiated by light.

In an aim for neutral dust grains, an ionizing device will be utilized to treat the grains prior to their placement in the boxes. The grains will be placed in a containment basket that will be fastened to the top support of the box. The basket will have a release level on the outside surface of the box to allow for their release inside the box during periods of microgravity.

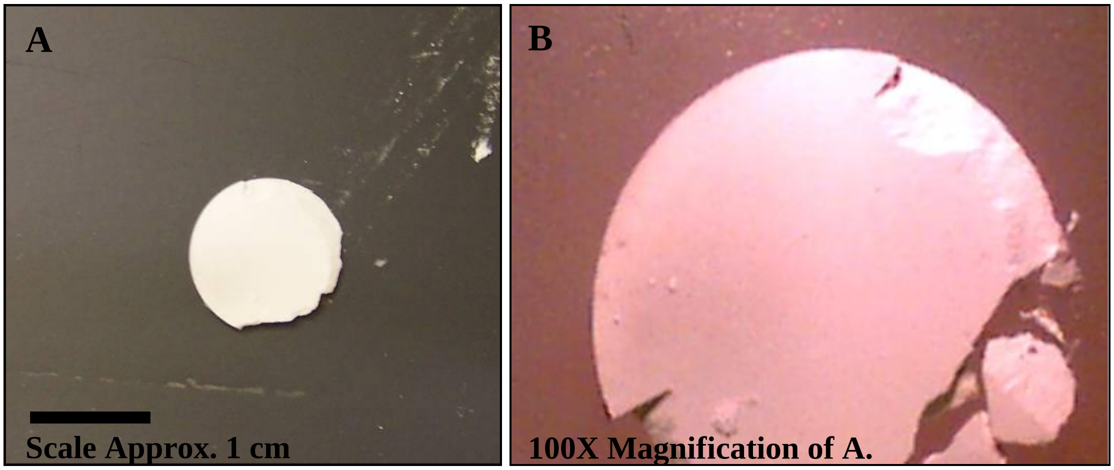

Figure 2. Silicon dioxide pellets pressed by Hoffman et al. at Utah State University.

For each box a parallel plate capacitor will be constructed to provide the necessary electric field. From the theory of electromagnetism, the electric field generated in the region between plates of a parallel plate capacitor is given by

$$E = \frac{C \cdot V}{\varepsilon_{\circ} \cdot A} \qquad \text{(Eq. 4)}$$

where $\varepsilon_{\circ}$ is the permittivity constant $8.85 \times 10^{-12} \frac{C^2}{N \cdot m^2}$, A is the area of the plates, V is the supplied voltage and C is the capacitance in farads given by

$$C = \frac{\varepsilon_{\circ} \cdot A}{\delta} \qquad \text{(Eq. 5)}$$

where δ is the separation of the plates (typically defined such that δ<<A). The acceleration of a particle of mass m and charge q in a relatively uniform electric field E is given by

$$a = \frac{q \cdot E}{m} \qquad \text{(Eq. 6)}$$

and from this we obtain the force acting on the particle to be

$$F = m \cdot a = m \cdot \left(\frac{q \cdot E}{m} \right) = q \cdot E\,. \qquad \text{(Eq. 7)}$$

To produce an electric field adequate to move charged grains of silicon dioxide of less than 1 mm we then propose a direct current voltage source of 220 V. This will produce an electric field of approximately 8985 N/C, which should be sufficient to move the charged grains.

Experiment

The tests will vary frequency. That is, each box will have light of a specific frequency with the minimum frequency of light being greater than the minimum required for electron emission. Successive runs will allow for the acquisition of statistically acceptable data. The first runs of the experiment will allow for the calibration of the ammeters to determine the total number of charges adhering to the box sides. This is similar to the original 19th century photoelectric experimental setup designed by Phillip Lenard who measured current produced by ultraviolet light on electrodes (Knight).

Actual tests will consist of releasing the dust grains from the containment baskets and supplying voltage to the capacitors while the light is directed on the grains. Again from the theory of electromagnetism we have that the charge obtained by a particle is given by

$$Q = (N_p - N_e) \cdot e \qquad \text{(Eq. 8)}$$

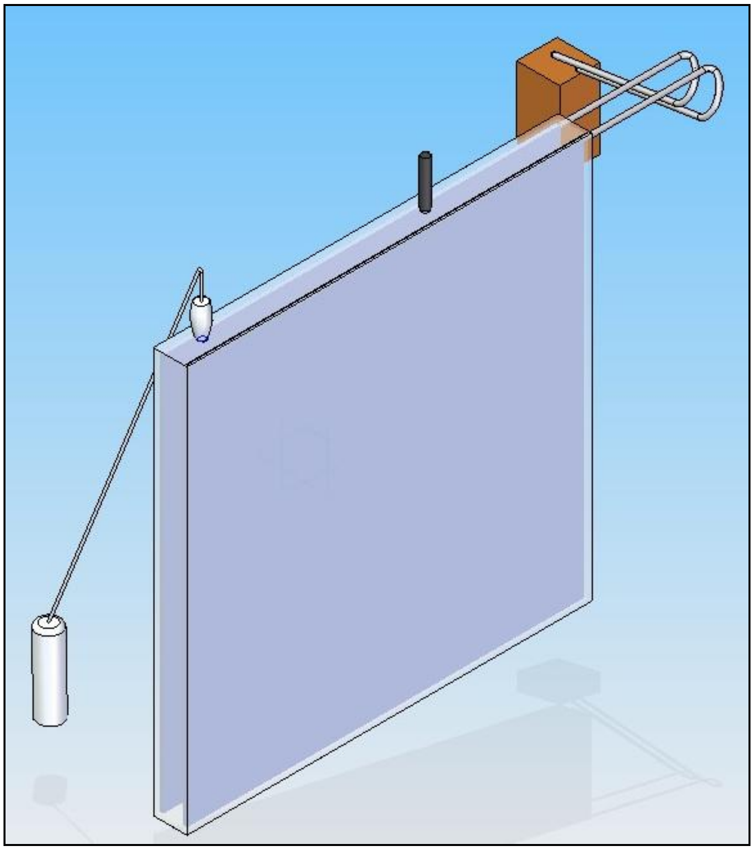

Figure 3. CAD drawing of the apparatus.

where N is the number of protons and electrons, respectively, and e is the fundamental unit of charge in Coulombs. From the photoelectric effect it is anticipated that the emission of an electron from an initially neutral particle will result in a charge of

$$Q = \left[N_p - (N_e - 1)\right]e = 1 \cdot e = e \,. \qquad \text{(Eq. 9)}$$

This leads to our hypothesis that the grains will adhere to the sides of the boxes corresponding to the negative surfaces of the capacitors. Additionally, the approximate weightless time of 25 seconds per parabolic aircraft maneuver will be sufficient time to collect data since photoelectric emission results immediately when the photon reaches the solid surface, well under one second for the speed of light.

Data will be collected from both visual observations of the flyers and through the use of computers. The ammeters used to determine the number of charges adhering to the sides of the boxes will input data to software used in the Utah State University intermediate physics laboratory. This software can later be utilized to analyze recorded data.

Following each collection of data and the discharge of the capacitors, the grains will be subjected to the ionizing device and recollected into the containment basket. An alternate possibility, depending on the availability of the silicon dioxide powder, would be to evacuate the dust grains by some means and replace them with new ionized grains.

Other Work on Photoelectric Charging of Dust Grains

The charging of lunar dust has been of great interest in planetary science. In fact, it is not just independent dust grains that see charging – there is sufficient evidence that the lunar surface itself sees a negative charging effect that is dependent not on terrain type or electron density, but instead is at least somewhat dependent on the angle from the sub solar point (Halekas).

In addition, charged dust poses a fair obstacle in new initiatives to return to the moon. Work by Clark et al. shows that an electrostatic approach to controlling dust could provide a method for dust mitigation. Here then is evidence that further research is needed to study charging effects of grains exposed to an electric field.

In a study conducted by Abbas et al. the correlation between lunar grain size and photoelectric electron yield was investigated, suggesting that the yield is proportional to the grain size. In this study, grains of micron/sub-micron size were irradiated by ultraviolet light and their electron emission determined via an electrostatic balance (Abbas). In light of the results obtained in this study, it is a necessary step further to determine the electron yield for grains of less than 1mm since these are the primary lunar grain sizes (Kring). Additionally, it is important to understand the dynamics between electron emission and net charging since it is possible for an emitted electron to be attracted back to its parent grain.

Another study investigated the charging of dust particles by photoelectric electron emission from the particles and their surroundings (Sickafoose). This project's objective is very similar to that proposed in this experiment, but the test completed by Sickafoose et al. was not completed for grains of lunar species, nor did it neglect forces due to gravity. In this case the experimental setup relied on the dropping of grains through a chamber with a Faraday cup on the bottom to determine the charge collected. The results of this study indicate that ultraviolet light does cause electron emission on grains of the right species; however, it is unclear if this result is the same for lunar minerals. Also, the use of the Faraday cup makes it difficult to discern the charge on single particles; complete end results may only suggest the net charge from the dose of grains as a whole.

Motivations for This Study

Current motivations within the National Aeronautic and Space Administration (NASA) to return to the Moon and to further explore the planet Mars are suggestive of the forces of exploration for humans. In past such explorations, the problems arising from lunar dust were non-trivial (Clark). The only solution for future work in the space environment is to mitigate the dust problem by some means.

Should dust grains yield the same electron emission, and hence charging effects, as planar surfaces, it may be possible to establish a system of dust control by exposing dust grains to light of some frequency. In other words, it may be possible to direct photo-electrically charged dust grains via an electric field.

Equipment and personnel exposed to dust may be able to enter work stations through some type of dust alleviation entry in which a light source charges the grains while an electric field allows for the grains' removal from spacesuits and sensitive equipment.

Alternatively, it may be possible to mitigate the dust through careful prevention of light exposure. Once some region of dust has become electrically neutral, it may be necessary to cover the region with a surface which will not allow photons of the threshold frequency to pass. For instance, some types of polycarbonate block light of ultraviolet frequencies, which are the frequencies most likely to lead to the charging of dust on the lunar surface.

These concepts serve only as mere examples of the potential output of this experiment. Further understanding of photoelectric emission and charging of dust grains could clearly yield important results for the continuing exploration of our solar system. It is our hope that we may investigate, and hence better understand, the photoelectric emission of electrons on grains in this interest.

Necessity of Microgravity

The two primary long-range physical forces of the universe are the attraction provided by Coulomb force interactions and gravitational attraction from Newton's law of gravity. In an effort to better understand the dynamics underlying the first of these two forces, it is best to then isolate it, which requires in this case the absence of gravity.

A setup similar to Sickafoose et al. involving the dropping of dust grains through a chamber can, as previously discussed, give some details about the charging of the grains. From the attraction due to gravity, all the grains must fall into the bottom of the chamber. This could pose a problem – while the use of a Faraday cup in the bottom elicits some information about the net charging of the grains, their individual charges remain ambiguous. In other words, all the grains fall to the bottom because of gravity, but this means that some information about each grain is lost since there is no indication of precisely how much charge each grain received. In an effort that leads to eventually controlling lunar dust with charging, it is important to establish the level of charge that will actually move grains in *absence* of gravitational attraction. Perhaps without the influence of gravity, the study conducted by Sickafoose et al. would not have seen the motion of any grains, and it would thus be difficult to infer the net charge of the dust.

It may also be suggested that this experiment be set up in a terrestrial lab similarly to that proposed by Millikan with his famous Oil Drop experiment. In this experiment, for which Millikan won a Nobel Prize, the size of his oil drops required him to put electric and gravitational forces on the same scale since gravity was a dominating force at the oil drop size. In the fashion of Millikan's experiment, simulant grains could be released from the top of a chamber. As they fall due to gravitational attraction, an electric field within the chamber would also exert a force on the grains. The electric field could then be adjusted in strength until the grains were in equilibrium between gravitational and electric attraction. The strength of the electric field needed to place the grains in equilibrium thus would yield some information about the net charge of the dust. Again, however, it fails describe precisely what charge each grain is experiencing and treats the grains as a single body under two forces. Also, it requires the precise difficulty that Millikan had to overcome – the two long range forces must be put on the same scale so that the correct one dominates the dynamics of the system. The absence of gravity would make it possible to conduct the experiment such that only electric forces dominate, and no rescaling of forces is necessary.

Our experimental setup also seeks to overcome the problems associated with the charging of individual grains by conducting the test in the absence of gravitational attraction. The data obtained from the ammeters will give the number of charges adhering to each plate, and using this data concurrently with visual observations of the grains on the plate we can establish the average amount of charge on each grain. It will also be possible with the absence of gravity to learn about the dynamics of the grains in motion; under gravitational attraction, the grains would either not move (if the electric field was not strong enough) or they would only show motion constrained by gravitational force. In the microgravity environment, we will be able to study the motion of the grains, and in line with our third objective on page three, to determine the feasibility of moving the grains with light.

Justification for Follow-Up Flight

Not applicable to this project.

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Experiment Safety Evaluation

Flight Manifest

Sydney J. Chamberlin	Troy Munro
Sarah Isert	Tracy Garin Savage

None of the proposed flyers has any previous experience with the RGSFOP.

Experiment Description/Background

The objectives of this experiment are as follows:

1) To determine the net charge accumulated by dust grains as a result of electron emission from the photoelectric effect.

2) Given a range of minimum light frequencies at which the effect may be observed, to determine the frequency which evidences the most charging of dust grains.

3) To use this frequency to evaluate potential causes of charging on planetary surfaces and the potential for utilizing the charging effect to remove dust from surfaces.

As introduced by the test objectives, our primary and secondary hypotheses are:

1) Dust grains will exhibit a charging effect when exposed to light of a minimum frequency corresponding to the work function of elements in their mineral composition.

2) The frequency at which the charging of dust grains is maximized will correspond to light wavelengths typical in the inner solar system environment.

The proposed experiment has not flown before. This is not a follow up experiment.

Equipment Description

The following equipment will be used for our experiment:

- Laptop Computer
- Test Cell
- Parallel Plate Capacitor
- Voltage source and requisite wires for hookup. If possible, the aircraft power system will be used.
- Various ultraviolet lights of different frequencies.
- Still digital camera
- Voltage sensor equipment
- Ammeter
- Digital Multimeter
- Ionic Hairdryer
- Eye protection

Structural Design

The following describes the structural design of the experiment. See figures 1 and 2 for details.

- The base of the experiment will be a polycarbonate box. Its dimensions will be $1m \times 1m \times 0.05m$ and it will have two holes on the top, one to admit the light and the other to admit the ionizing hairdryer. Inside the box will be a device to hold the dust until it is time to be released. There will be 4 of these boxes.
- A parallel plate capacitor will fit over the box. On either side of the plate will be another sheet of polycarbonate to protect the experimenters from accidentally touching the capacitor.
- Each box will have a light attached to the top.
- All the boxes will be attached to a baseplate that will in turn attach to the aircraft floor using the stud/spacer floor assembly.
- Each capacitor will be hooked up to a voltage sensor, which will in turn be attached to the computer, and will have an ammeter inserted on the negative side of the capacitor to measure the current.
- Voltage and current necessary for the experiment has not yet been determined. If possible, the test cell (capacitor) will use DC power supplied by the aircraft and the computer, light, and ionizing device will use AC power supplied by the aircraft.

Electrical System

Electrical components used in our experiment are the parallel plate capacitor, laptop computer, lights, voltage sensor, and hairdryer, as well as all the equipment needed to hook everything up. We will also be using a digital multimeter and a digital still camera to record data; they will run on internal batteries.

Laptop computer:	Power: AC Voltage: TBD Frequencies: TBD Electrical Currents: TBD
Lights 1-3 (Spectral Output 180nm – 400nm):	Oriel deuterium Series Q 66080 Power: Oriel 68942 Power Supply Voltage from Power Supply: 60-90 V DC Voltage into Power Supply: 120/220 V AC Frequencies: 50-60 Hz Electrical Currents: 300mA
Digital Camera:	Canon PowerShot SD600 Power: DC (Battery) Voltage: 3.7 V
Parallel Plate Capacitor	Power: DC Voltage: 220 V Capacitance: 177.079 pF
Ionizing Device	Conair Infiniti Nano Silver Tourmaline

(Ionic Hairdryer)
Power: AC
Voltage: 110-125 V
Frequencies: 60 Hz

Pressure/Vacuum System

Whether or not a pressure/vacuum system is to be employed has not yet been determined. If it is to be used, the test cell will be filled with gaseous nitrogen.

Laser System

This section is not applicable to our experiment.

Crew Assistance Requirements

Loading/unloading assistance will be helpful, as will attaching the equipment to the aircraft floor and making all necessary connections with the aircraft power system.

Institutional Review Board

Not applicable to this project.

Hazard Analysis

Hazard: Test cell rupture (if nitrogen is used to fill the cell)
Risk: Dust and flying pieces of the cell will fly all over the cabin.
Prevention: The test cell will be built out of shatter resistant material. The pressure in the cell will monitored, and an overflow valve will be added to prevent the pressure from becoming too high.

Hazard: Electric shock from capacitor.
Risk: Capacitor may deliver high voltage shock to one who accidentally brushes against it.
Prevention: The capacitor will be insulated on the outside to prevent accidental contact. After the flight, and between parabolas, the capacitor will be discharged using a large resistor and an indicator circuit. The capacitor will be stored with the leads shorted to prevent any buildup of charge.

Hazard: Light bulbs shattering.
Risk: Glass pieces released.
Prevention: The bulbs will be handled carefully and electrical protection elements will be implemented to prevent too much voltage or current from entering the system. Also, the bulbs will be inside the cells, protecting them from damage and containing the pieces in the event of breakage.

Hazard: Various voltage/current overloads.
Risk: Explosions and other undesirable effects.
Prevention: All electrical devices will be grounded and will have circuit breakers/fuses built into the system. There will also be a general kill switch located in the system.

Hazard: Ultraviolet light leakage through the box.
Risk: Eye damage.
Prevention: All people in the cabin will wear eye protection when the UV lights are on. Also, all personnel will wear sun protective lotion and will have the least amount of exposed skin possible.

Hazard: Ozone generated by deuterium light source.
Risk: Respiratory problems, especially for those with asthma sensitivities.
Prevention: Ozone-free lights will be ordered. Also, the deuterium light sources will be fully contained within the boxes to prevent the escape of any ozone, and if necessary an ozone removing vacuum may be implemented.

Tool Requirements

Basic tool set (screwdrivers and wrenches), specifically tools that will facilitate attaching the experiment to the aircraft floor.

Ground Support Requirements

Ground power (AC and DC) to test the equipment.

Hazardous Materials

Not applicable to this experiment.

Procedures

Ground Operations

Assemble experiment and examine equipment for any damage caused in transport. The capacitor will be specially checked to make sure it is discharged.

Pre-flight

Equipment will be set up on the plane. Prior to flight all electrical connections will be tested to make sure they are working properly. The data collection will be set up and set for calibration. Immediately prior to flight the capacitor will be discharged and placed in the safe mode.

In Flight

The equipment will be run during the micro-g phase with 3 test lights and a control box. Just prior to the 2-g phase the experiment will be switched off and the charged particles will be allowed to return to equilibrium. They will be assisted by an ionic hair dryer. The capacitor will be in safe mode during the 2-g phase.

Post Flight

Experiment data will be evaluated. If the data is worthy, lights in the test cell will switched out to lights of different frequencies and the second flight will follow the same format as the first. If more data is necessary the lights will remain in place and the experiment will be rerun.

Outreach Plan

Direction and Purpose

Our goal is to interest students in science and engineering careers. We believe that this is best achieved through hands-on learning, social interaction with those in the field, and the creation of mentoring situations. We hope that our outreach activities will show students the excitement of working with modern space technology. If we can get just one student interested in science, our activity will have been a success.

We have decided to focus our outreach on high school students, as they are in the process of determining their future career possibilities. We will be able to help those who are inclined towards science, but are not sure how to pursue their interests, by giving them an opportunity to see how undergraduate research is conducted. We have been given permission to make presentations to physics classes at both Twin Falls High School (TFHS) in Twin Falls, ID, and Sky View High School (SVHS) in Smithfield, UT. These activities will take place in the spring 2008 and will complement the efforts of the teachers as they teach the basics of the photoelectric effect.

Our secondary purpose is to spread the excitement of scientific research within Utah State University (USU) faculty and students. Many USU students do not know what kinds of valuable research opportunities exist on campus; with motivating presentations and outreach activities, more students will have first class research at their fingertips. Additionally, encouraging college students will help them to realize what kind of research they can be involved in prior to graduate work or employment. This opportunity is very exciting for incoming students, and fosters a more well-rounded learning environment by leading students in non-class projects.

Expanding the role of our team on campus will also help to develop multi-cultural ties with various groups at Utah State and will provide an organizational base for minority students to conduct research.

High School Presentation

Dr. Candace Wright and Mr. James Stephenson, physics teachers at TFHS and SVHS respectively, have requested presentations from our team in the spring of 2008 when they will teach students aspects of modern physics (including electromagnetic radiation). The presentation will similar for both schools.

We will begin our presentation with a short video describing the basics of the photoelectric effect; this will introduce students to the concept of light having a dual particle-wave role and to the idea of quanta. We will then discuss the application of this scientific theory to our experiment, and discuss its applicability to returning to the Moon. Depending on the month of presentation, it may be possible to discuss some analysis of this project with its results and their implications. The engineering aspects of this project may also be discussed with the students to facilitate their interests. Some type of demonstration will likely also take place, possibly with equipment from this project.

Following this, we can also delve into the underlying mathematics of the scientific theory, should some students be interested. Emphasis at this point is encouragement of students' interests –

mathematics often seems an intimidating subject to high school students, and it is our hope that we can alleviate some of the stigma attached to the hard sciences. By demonstrating to the students that they too can participate in “real” NASA related research in college, it is hoped that they will feel empowered by science.

University and Local Press Plan

There are many opportunities to spread the word about our project around our campus, especially through our connections with the Society of Physics Students, Associated Students of Utah State University, and the Society of Women Engineers. With the support of the Utah Statesman, Utah State University’s newspaper, it will be possible to reach students with majors ranging from electrical engineering to interior design. An online newspaper will also feature our team research. We have been interviewed by several local broadcasting news agencies in the past, and maintain connections to further communicative efforts. We also may submit press releases to local Utah newspapers, such as the Herald Journal, to spread news of our research.

Physics Day at Lagoon

Each year the Physics Department at Utah State University hosts a “physics day” at local theme park Lagoon in Centerville, Utah. The event brings thousands of middle and high school students from across the state for competitions relating to physics, including a quiz bowl, roller coaster design competition, and more. The Microgravity Research Team has, for the past several years, taken part in this event under its alias as the Get-Away Special research team (GAS team). The role of our team at Physics Day is to provide physics and specifically, space related activities for the students attending the event. Should this proposal be selected, our team will have the opportunity to present our experiment with a demonstration, and possibly to display our results (depending on our flight week) to more than 6000 middle and high school students.

MISSE

Previous outreach, other than community related affairs, has been conducted via research with NASA. As the GAS team, we participated in a project known as MISSE, which sought to design an experiment to study charge induced contamination on samples in space. Such projects are a continuing possibility for our team. Taking part in industry-led research allows us to expand our borders and extend the experience of students. Our previous outreach research is an indication of our willingness to look past the conventional methods of community interaction and of our team’s potential within the science and engineering disciplines.

Partnerships

Society of Physics Students (SPS)

The SPS advocates the study of physics and professional development of future scientists. It is thus the perfect partner for our team. We will present our project, including a description of our experiment and the results we expect to obtain, to the USU SPS chapter on March 11, 2008. With the help of USU’s SPS chapter, we will be able to recruit a greater number of students interested in physics. We will also have many opportunities for joint activities, giving students an opportunity to develop communication and leadership skills necessary in the research community. The USU SPS chapter has also extended our group an invitation to make future presentations at other student events. Possibilities for conference presentations, especially with the American Physical Society's annual Four Corner's Meeting, are present.

Associated Students of Utah State University (ASUSU)

Working with ASUSU will allow us to make presentations concerning our experiment and results in events such as college fairs and new student orientations; such occasions will allow us to promote the advantages of undergraduate research. Through ASUSU we will also be able to greet visiting high school students and demonstrate the excitement of a career in science or engineering. By showing our team in action, students will be able to see what real people doing real jobs can achieve. At these events, we will give a poster presentation describing our project and activities with illustrations. This will provide a perfect opportunity to answer questions about our team and create a spark of interest in space-related research.

Society of Women Engineers (SWE)

SWE is a nonprofit group that advocates and supports women in the field of engineering. Partnering with this group will allow us to talk to women already interested in engineering and show them various ways to gain real world experience. This will be a fun group to talk with because they already have an interest in science and engineering and will be able to give us some great feedback. SWE is willing to have us make our presentation on March 19, 2008. This will consist of a power-point presentation with photographs and videos of our experiences, a description of our anticipated results, and will conclude with a discussion about research opportunities around campus.

Project Website

The Internet is one of the most effective tools we have at our disposal for the dissemination of information. A link to our team website is located from the Microgravity Research Team homepage so that students researching Utah State University can find us; our university is well known in the mountain west as *the* university that has sent more experiments in space than any other (under our former alias, the *Get-Away-Special Team*). This website is available via the following link: http://www.mrt.usu.edu/afrg.

To explain our experiment in a logical manner and create as much interest as possible, we have set up our website in the following manner:

- Title page: short descriptions and backgrounds of each team member and the faculty advisor; includes contact information
- Fundraising page: provide contact information; discuss main areas of cost; present different methods of project support (monetary and non-monetary)
- Thank you page: a letter of thanks to our donors and NASA describing how their contribution helped the project and providing links to their websites
- A Series of informative pages: history of the photoelectric effect and why it is important; practical uses for results of the experiment; why our theory works
- Experiment description pages: experimental apparatus and setup will be included; discussion on the necessity of performing our test in microgravity
- Outreach page: provides dates that we will be at schools; includes links to College of Science at USU for prospective students; quotes of team members talking about the team ("real words from real people"); place for students to contact the team with questions

- Photo and video gallery: page with images (experimental and non-experimental) documenting our design, construction, testing and microgravity experiment
- Where are they Now: A page dedicated to former members who left our team with their Bachelor's Degree and their current endeavors

The website is currently under construction, and content will be added as team abilities dictate. Our outreach plan will soon be added to the site as a reference for high school teachers and to attract cooperative efforts with other local secondary schools. If selected, information regarding this proposal may also be put added to the website. Following the completion of this project, any resulting publications will grace the website.

Administrative Requirements

Institution's Letter of Endorsement

Our institution's Letter of Endorsement can be found following this section (paper copy only).

Statement of Supervising Faculty

Our Supervising Faculty Statement follows our institution's Letter of Endorsement (paper copy only).

Funding/Budget Statement

The following is a list of anticipated expenses associated with this experiment including experiment equipment, transportation of team and experiment to Houston, and accommodations in Houston.

Table 2. Budget Statement.

Experiment Equipment	***Quantity***	***Cost***
Silicon Dioxide Powder	TBA	Free
Polycarbonate material	TBA	~$500
Deuterium light source	3	$300-$1000
Digital Video Camera	1-3	$500
Laptop Computer	1	Free use from USU
Shipping Costs (Experiment)	--	$250
Vacuum Pump	1	$125
Ionic Hair dryer	1	$55
Subtotal		**$2430**
Travel Expenses		
Transportation to/from Houston	N/A	$1400
Accommodations in Houston		$500
Food ($25 *8days * 4 people)		$800
Vehicle Rental		$400
Subtotal		$**3100**
Total		**$5530**

The Microgravity Research Team budget provided by Utah State University has funds available to cover these expenses.

In addition to our team budget there are several organizations that may donate additional funds for this project. These include the Rocky Mountain NASA Space Grant Consortium, the Utah State University Department of Mechanical Engineering, the Space Dynamics Laboratory and several local private companies. Even without this additional funding, our team has the available funds to cover the expenses listed above.

Institutional Animal Care and Use Committee (IACUC)

Not applicable to this project.

Parental Consent Forms

Not applicable to this project.