Department of Mechanical Engineering
University of Washington

Stevens Way, Box 352600
Seattle, WA 98195 USA
360-708-3285
cpj2@uw.edu

Response of Lunar Regolith from Low-Velocity Impacts

Connor Johnson Kendrick Tang Samantha Lee Alex Ching Ben Sullivan
Brendan Goodwin Patrick Brennan Conrad McGreal
Faculty Advisor: Professor James Riley Mentor: Todd Isaacson

Microgravity University Final Report — August 6, 2014

Introduction

This scientific report follows a typical format. The first section, Abstract, briefly states how this experiment intends to determine which conical geometry produces the least amount of regolith ejecta. The Abstract also summarizes how the experiment failed to record data on the zero gravity flights; however, the ground data and lessons learned are beneficial to future researchers. The Abstract briefs on general outreach results as well.

The Research Problem section discusses past research, such as Collisions Into Dust Experiment (COLLIDE) and Physics of Regolith Impacts in Microgravity Experiment (PRIME).

The Method section describes the regolith impact apparatus, i.e. the experiment involves a pneumatic impact, vacuum chamber, regolith box, reset mechanism, rotary system, and outer enclosure. The Method section also discusses pre-flight tests, the hypothesis, and data post-processing.

The Research Results sections describes the zero gravity outcome and ground data.

The Discussion section goes over how this ′all in one′ system relied on too many systems to work the first time in zero gravity; however, this system has potential to become a controlled and credible experimental apparatus. This section also validates and discusses the ground data.

The Conclusion section explains the overall lessons learned and what NASA and other researchers can take away from this study.

The Acknowledgments section recognizes the many supporters that helped bring this project together; this includes Boeing, Tap Plastics, PACCAR, Spark Fun, the departments of Engineering, many family members, and Professor James Riley.

The Education and Public Outreach section discusses outreach, e.g., the team′s K-12 activities, Discovery Days, Paw′s on Science, and Gizmoto public relations.

Abstract

There is an ever-increasing need to know the effects of extraterrestrial work when exposed to regolith. The goal of this experiment is to determine the relationship of different apertures of conical impact geometries and the density and velocity of the resulting dust plume. The zero gravity experiments were unsuccessful in producing any results. However, the ground experiment shows potential for future credible data. The limited ground data shows that the cylindrical geometry produced the least amount of ejecta at a maximum velocity of 0.22 m/s. This data is reproduced with modeling techniques.This research can potentially help with future designs that operate in a regolith environment such as the Moon and Mars. These designs will improve dust mitigation techniques. The team participated in six educational outreach events and three public relation activities.

Research Problem

The unique properties of lunar regolith create difficult working conditions in lunar environments. Lunar regolith is defined as the top layer of particles on the lunar surface, ranging in size from 1mm to 20μm. The particles themselves are a combination of glassy silicate aggregates and native FeO with highly irregular shapes, primarily formed by meteoritic impacts [6]. This high level of shape variability (ranging from spherical to extremely angular), as well as the material properties, causes the extreme abrasiveness of lunar regolith. Apollo missions found that adhered dust to suits can wear through layers of the fabric [5] even to the extent of wearing through three layers of Kevlar-like material on the sole of a boot used by Harrison Schmidt during the Apollo 17 mission. Due to these adverse properties, regolith mitigation techniques and strategies must be developed to minimize interference with human lunar activity.

Understanding the characteristics of ejecta is crucial to developing tailored dust mitigation techniques. Previous work, largely done by Dr. Joshua Colwell, has primarily focused on low-velocity impact response to spherical projectiles in a microgravity environment. In these studies, both the mass and velocity of the projectiles were varied, such as COLLIDE flown on the Space Shuttle in 1998 [1]. This specific experiment was comprised of six separate Impactor Box Systems (IBS), each with a different assigned projectile velocity. Instead of analyzing the ejecta itself, this study focused on the coefficient of restitution of lunar regolith. A follow-up experiment, COLLIDE−2, looked at the boundary at which significant ejecta is produced, as well as ejecta velocity and mass [2]. Past experiments established a linear relationship between impact velocity and ejecta mass [4]. In these experiments, the effect of the size or geometry of the impactor itself was not explored, which is something we hope to study and model.

To learn more about how regolith reacts to impacts with varying kinetic energy, Colwell led PRIME. In this experiment, spherical projectiles produced ejecta mass from impacts at 0.2 – 2.3 $\text{m}\cdot\text{s}^{-1}$ in low gravity. The velocity of the impacts were recorded with a high speed NAC HSV 500 camera and strobe lights [3]. Data was collected from 74 impact experiments to prove the theoretic power law dependence of ejected velocity V_{ej} on the kinetic energy of the impactor (KE). The theoretical power law is given by equation (1).

$$V_{\text{ej}} \propto \text{K.E.}^{\frac{1}{2}}. \quad (1)$$

PRIME revealed a general trend for the data collected in 1. Although their data is considerably scattered, there is a clear trend with the power law.

Method

The overall goals of the experiment includes the following:

- Employ a scaled atmosphere of the moon
- Reset the dust to repeat a controlled experiment
- Perform the test under 15 seconds
- Impact four geometries at constant velocities
- Measure the velocity and density

Four different impact geometries (cones with varying apertures - 60°, 90°, 120°, and 180°) were used to study the relationship between impact geometry and resulting regolith behavior. A two-stage, duplex pneumatic cylinder powered with compressed CO_2 was used to provide

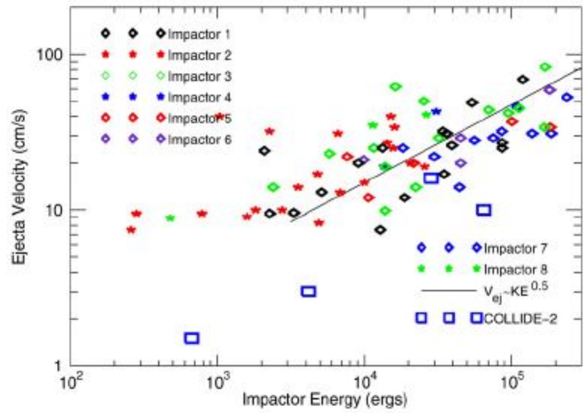

Figure 1: PRIME experiment scatter plot trending with power law [3].

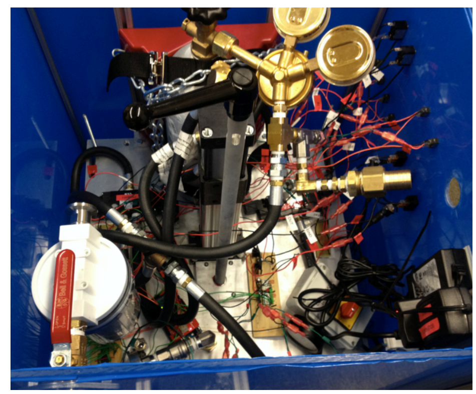

Figure 2: Top view of experimental apparatus.

the impact force. To allow the different impact geometries to be changed, a rotary system was used that held all four impact geometries. The two-stage pneumatic cylinder would descend, mating with the desired impact geometry (secured to the rotary via high-strength magnets). Once successfully detached from the rotary and attached to the pneumatic cylinder rod (again, using high-strength magnets), the second stand would descend, impacting the lunar regolith and creating the regolith plume. Figure 2 shows the top of the experiment.

Particle imaging velocimetry (PIV) was used to capture both velocity and density data of the resultant regolith plume. A class 3A laser was positioned to create a vertical laser plane that intersected the impact geometry′s centerline. This laser plane illuminated a single plane of the radial regolith plume, allowing for capture and analysis of velocity components parallel to the laser plane. An assumption was made that the laser plane was thin enough to disregard any velocity component of particles that was perpendicular to the laser plane. A high speed camera (set at 300 frames/second) was positioned perpendicular to the laser plane, and upon successful impact geometry mating, was set to record. The second stage of the pneumatic cylinder was then actuated, and the resulting impact was recorded for later analysis.

To recreate a scaled atmosphere of the lunar surface (and eliminate any effects that an atmosphere may have on regolith behavior), a vacuum chamber (16 IN X 16 IN X 16 IN) was used, capable of creating a vacuum environment of 20 in Hg. The top and bottom plates were constructed from aluminum, to allow through-holes for the pneumatic assembly as well as the rotary assembly. The four remaining sides were constructed from 1 inch thick acrylic, as visibility was required for the laser and high speed camera.

To reset the lunar regolith between each trial, a rectangular vibration box was constructed, with a vibratory motor attached to the bottom, and motorized doors that would open and close. Upon successful impact, the pneumatic cylinder rod (and mated impact geometry) was retracted, and the doors would close. The vibratory motor was then powered, re-leveling and re-settling the lunar regolith, providing a consistent impact surface for each trial. The doors were then opened, and the procedure was repeated for the next trial.The closed vibration box, geometries and piston rod is shown in Figure 3.

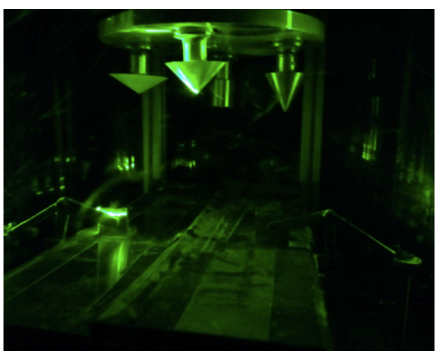

Figure 3: Inside of appartus with laser on.

Our hypothesis was that the impact geometries with a smaller aperture angle would produce less ejecta, as the steeper angles would ′slice′ through the regolith bed. This phenomenon can be seen in an Earth-like setting, though the exact relationship between resulting ejecta and gravity is not fully understood. This is what we had hoped to explore.

Pre-flight, extensive structural tests were performed to ensure experiment integrity. Repeated vacuum pump downs were done to prove vacuum strength, as vacuum rupture would be extremely dangerous to any nearby personnel. Pull-out tests of the 80/20 handles being considered to investigate the maximum allowable stress these tests proved that the handles would not be sufficient in the case of an extreme loading event, and were replaced with more substantial shackles that could withstand the expected stresses.

Pre-flight ground tests (with the objective of validating sub-assembly performance) were additionally conducted. Limited data was collected during this phase, as the main purpose was to ensure proper experimental operation.

Mock flights were conducted as well, to familiarize team members with the overall procedure (and more specifically, their individual role). The procedure was timed, and was performed until team members could complete the procedure within 15 seconds − a timeframe that was decided on to provide enough time to fully complete the procedure within the zero-g portion of the flight, with some added time to allow for inconsistencies caused by the unique environment.

Initially after the flight week, the lunar ejecta was going to be illuminated by a laser plane. However, the laser failed due to the module being impacted by a polycarbonate sheet during flight week. The solder on the leads from the laser casing to the module separated. Solder repair was attempted on the laser; however, this was unsuccessful. The experiment moved forward to a contingency plan of capturing ejecta without a laser. We captured impacts by exposing the entirety of the chamber with uniform back lighting. This allowed the camera to see the bulk ejecta.

Once data was recorded with the Casio EX F1 Pro, post processing was performed with a open source program called PIVLab [7]. The video frames were converted into images and loaded into PIVLab. The program processed adjacent images and compared the differences in pixels to calculate the velocity.

However, PIVLab needed to be calibrated. This was done by inputting a known distance and the time difference between each frame. The Casio EX F1 recorded the ejecta at 300 frames/second. The diameter of the threads shown in one of the images was used as the distance input. The thread diameter was 0.5 inches. These units are converted to metric, which is the default units of PIVLab. Figure 4 shows the calibration.

Results

The microgravity results were unfortunately inconclusive. The test failed in the microgravity environment due to a pneumatic system malfunction. The likely cause is found to be a leak present at the interface between the CO_2 tank and regulator. A small plastic ring seals the regulator nozzle to the tank nozzle. This ring that caused the leak was a replacement from the original ring sealant.

The ground results were also inconclusive. The laser failed due to the laser module being impacted by a polycarbonate sheet during flight week. The solder on the leads

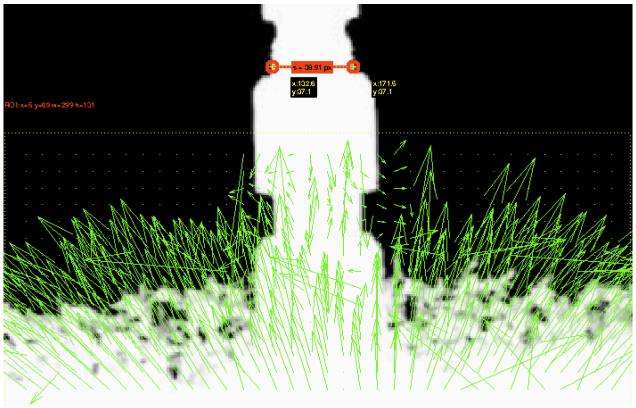

Figure 4: Calibration of PIVLab.

from the laser casing to the module separated. A solder repair was attempted on the laser; however, this was unsuccessful.

Also, the custom density meter produced unrealistic data.

The ground experiment moved forward to a contingency plan of capturing ejecta without a laser and make qualitative observations of the density. We captured impacts by exposing the entirety of the chamber with uniform back lighting. This allowed the camera to see the bulk ejecta. An example of the PIVlab results are shown in Figure 5.

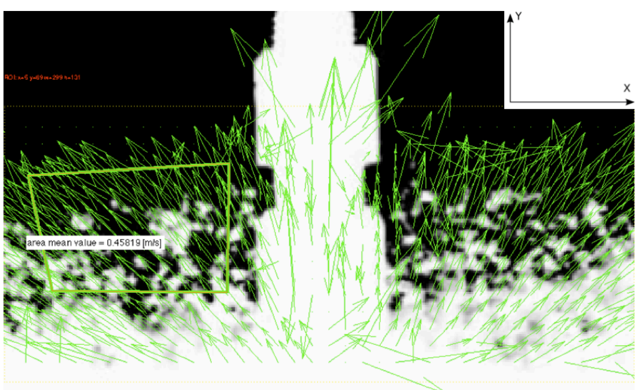

Figure 5: Extracted velocity from frame pair.

The results for these ground tests are shown in Table 1. The impact from the 120° geometry produced the most ejected regolith, as well as producing the fastest regolith ejecta. The cylindrical geometry produced the least amount of regolith ejected at a slower speed.

The 120° geometry data is modeled with equation (2).

$$v_2(t) = v_{2_0} + gt. \tag{2}$$

This equation models the ejecta with respect to gravitation direction, i.e., only the y-direction of the velocity vector is compared to equation (2). The model is validated with the measured velocity of the 120° geometry. The comparison is illustrated in Figure 6.

Table 1: Results of ground test.

	Cylindrical Geomtry	60° Geometry	90° Geometry	120° Geometry
Average Impact Velocity (m/s)	1.13	0.98	0.96	1.041
Average Ejecta Velocity (m/s)	0.22	0.48	0.40	0.60
Qualitative Density	Low	Moderate	Moderate	High

Figure 6 shows the trajectory up until the maximum height is reached by the ejecta. The model has a 4.9 average percent error up until the maximum height is reached by the ejecta. As the ejecta begins to fall, the model breaks down and the percent error averages to 38 percent. In other words, the negative velocities are not shown in the plot.

Another interesting finding from this experiment is the response of ejecta to the reset vibration motor. The vibration caused the ejecta to compact and become extremely hard.

Discussion

— Lessons Learned

With a more simple and robust system, more reliable data can be determined. The critical improvements in design include the following:

- Smaller vacuum chamber
- Use air tank cylinder for pneumatic system

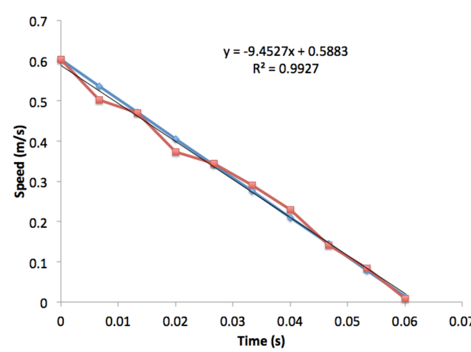

Figure 6: Linear plots representing the model (blue), the measured data (red), the measured data trend (black), and trend line data in upper right.

- Find more structurally sound laser
- Root of many of the challenges: lack of redundancy

There are several reasons for a smaller vacuum chamber. Because the Casio EX F1 was able to collect enough data way before the dust reached the side walls, there was no need to have this excessive amount of space. The vacuum chamber drove the experiment to be overweight because of the required thickness of the vacuum chamber.

If the tank contained air, there would have been no need to release CO_2 to the required parts per million. This eliminates any toxic hazard from the experiment.

The laser we purchased was of a poor quality. The laser module was unprotected from any impact or disturbance, thus compromising the laser′s solder connections. We may 3D printed a plastic support to help support the module. However, a better supplier would have been more valuable in terms of time.

One of the main problems was a lack of redundancy. This was due in part to the resettable design approach we took. The hazards involved in our experiment and protective measured we needed to implement also played a role in complicating our design procedure and preventing our use of redundancies.

The principle behind the resettable design is as follows: the single container we brought up was supposed to be capable of impacting the dust, retracting the projectile, resetting the regolith, and repeating this procedure with different shaped projectiles. Other regolith impact experiments (e.g. COLLIDE) uses single-use impacting chambers that can be reset on the ground, but will produce only one impact. The large amount of parabolas would have called for a large amount of single-use impacting chambers. We simply could not afford to manufacture all of these chambers. So instead we attempted to design a chamber with a retractable projectile, a rotary to swap out test surfaces, a regolith container which could open and close, and a means to flatten the impacted regolith. Our hopes was that if this was successful, the volume of impact experiments performed in space could increase dramatically. And the design was meant to be flexible in the sense that any kind of projectile surface could be tested by simply replacing the surfaces in the rotary.

In the end we had moving parts which needed high precision, multiple-stage mating, a complicated hinge system, and other mechanical systems. When performing the experiments in zero gravity, the particulate regolith ended up gumming up lots of the moving parts, and the zero gravity disturbed how the different mechanical parts interacted with each other − something we weren′t expecting to be a large problem. One lesson learned is that we had an overcomplicated system with too many unknown variables for us to manage. It would have been more efficient to design something similar to what COLLIDE uses and cut costs in a different way. One design could have been to build 4 X 1 arrays of test containers. This would make transportation manageable, reduce the number of walls, and still allow for PIV data recording. The array could be lit up using one high power laser which could be disconnected and mounted to a different array. If one out of four of those containers didn′t work out, we would still have three other tests to use. With multiple 4 X 1 test arrays, if one container completely malfunctioned we could have performed other tests. One problem with this design is that the containers would have to be double enclosed, which leads me to the next lesson learned.

Due to the stringent need for safety, we ended up having to change several components of our design to produce a safe experiment. The main problem we needed to work around was the double enclosed regolith. All of the systems were contained within a sealed outer enclosure which prevented us from going in and fixing anything, no matter how small of a mishap it may have been. A few years ago, the University of Washington implemented gloves sewn into the outer enclosure as an access point. Their experiment also experienced problems because the gloves ended up damaging a rotating component, which is why we stayed away from gloves. We also had to black out the outer enclosure due to the use of a laser, which would have prevented any use of gloves anyway. One lesson learned is to not use such hazardous materials and tools. While a regolith-substitute may produce different results, it would have made the safety constraints less restricting. Another lesson learned is to consider safety from day one. We spent a lot of time with the experimental design and believed incorrectly that we would be able to add protective measures without impacting major parts of the experiment. By designing with safety in mind we would have foreseen problems involving the doubly enclosed regolith and could have put more thought into adding redundancies.

— Ground Data

Overall, the data is incomplete because not enough trials were performed to accumulate a credible sample size.

However, the limited data obtained proved to be promising. The percent error in the model of the ejecta is 4.8 percent compared to data. This shows fair agreement in the model and data.

The 120° impact results are now discussed. This geometry produced the fastest and most ejecta from an impact. This corresponds to a magnitude of 0.60 m/s from an impact of 1.041 m/s. The cylindrical geometry produced the least amount of ejecta and at a velocity of 0.22 m/s, as shown in Figure 7 shows the velocity and amount of ejecta. Thus, the cylindrical geometry is the better design choice for minimizing regolith ejecta.

The reasoning behind this response can only be speculated, due to insufficient knowledge behind the impact.

As the PRIME experiment found, the square root of the kinetic energy is proportional to the ejected velocity. However, as this limited data has shown, geometry of the impact surface has a large influence in how that kinetic energy is transferred. This could be in the form of dissipated energy through particulate friction and other particles, between the geometry surface friction and particles, and absorbed energy through bulk deformation.

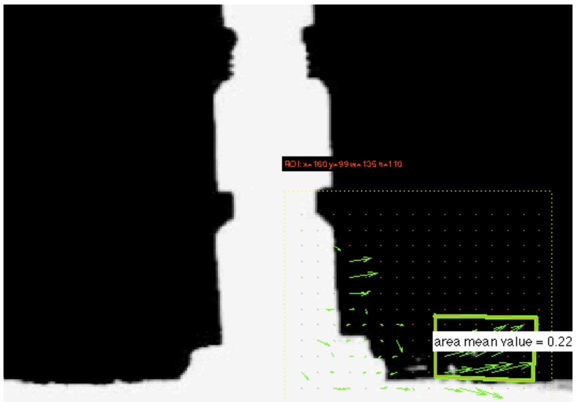

Figure 7: Extracted velocity from cylindrical geometry impact.

The other interesting observation was the response of lunar regolith due to the vibration mechanism. The intention of the vibration mechanism is to reset the regolith, i.e., once an impact occurs the vibration motor will be activated to level the regolith bed.

However, the regolith became compacted enough to have an extremely high shear strength. The shear strength was high enough to ′catch′ the impact geometry, i.e., the pneumatic system was not strong enough to create ejecta or completely extend through the bed surface. The pneumatic system was increased to a pressure of 80 psi from the test pressure of 40 psi; and still, there was no ejecta. The ground results were achieved by stirring the dust bed manually. Thus, a future regolith impact experiment must of have a reset mechanism that resets the dust to the correct density seen on the moon.

Conclusion

This experiment as a whole was a learning experience. The complexity of our experiment required many different systems. This includes a pneumatic system, vacuum chamber, reset mechanism, rotary system, PIV system, and protective outer enclosure. This leads to one of the main lessons learned: new systems under development must undergo simple design and build because of all the unforeseen issues that will occur, part due to the teams overall inexperience. In terms of lessons learned for researches in dust mitigation studies, greater impact surface areas have a large influence on the speed and amount of ejected regolith, regolith ejecta velocity follows somewhat well to equation 2 until the maximum height is reached, and certain vibration profiles may compact regolith to a high degree. Note: all these observations are with respect to a 1g environment.

Future work that will be conducted will vastly benefit from the lessons learned and observations from this study. NASA's designs toward dust mitigation for moon missions will benefit from these findings by expanding on these observations and exploring the more detailed responses of low-velocity impacts from conical geometries.

References

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Acknowledgement

We would like to acknowledge all of the people and groups who have supported the team throughout the year. A special acknowledgement goes to Professor James Riley who has advised our team for the past 5 years. The organizations who have donated to our team in 2014 include:

- University of Washington, College of Engineering
- University of Washington, Mechanical Engineering
- University of Washington, Aeronautics & Astronautics
- PACCAR

- University of Washington, Electrical Engineering
- The Boeing Corporation
- Washington Space Grant Consortium
- University of Washington, Mathematics
- Sparkfun Electronics
- TAP Plastics

Education and Public Outreach

— Educational Outreach

The educational and public outreach was a great experience for the team and the participants. The team achieved in participating in a total of 6 educational events. Our goals of the educational outreach activities included showing younger students how anyone is capable of achieving fulfilling and successful careers in STEM fields, giving younger students an idea of one of NASA's many opportunities, and to teach them something new.

The first outreach event occurred at Einstein Middle School. The team discussed our project, our experiences with college and with engineering internships. Later an activity was conducted where the students built water towers out of spaghetti noodles, tape and foam, as shown in figure 8. This was a great experience and the students were great participants.

Figure 8: Outreach activity at Einstein Middle School.

The second outreach activity was a Washington Aerospace Scholars (WAS) video conference. WAS members asked the team a number of general questions pertaining to our project, college and internships. The experience was valuable for the students because we were able to pass on lessons we learned about college on to prospective students gearing toward STEM fields of study.

The third outreach event happened at West Woodland Elementary. The Microgravity team brought an early iteration of the experiment and performed some impacts. The pneumatic system was operating at this point, which brought some excitement to the students. The pneumatic system was activated and impacted a bed of flour. We attempted to explain that this is by no means a trivial experiment, and that there is a large amount to be learned from impacting objects, just as CERN does in Europe.

The fourth outreach event was at the Paws on Science Fair at the Pacific Science Center in down town Seattle. Paws on Science is an event held every year where a large number of grade schools come to the Pacific Science Center and witness all the experiments that are being performed at the University of Washington. The experiment was performed here for 100's of grade school students. Many parents came as well. An image from the event is shown in figure 9.

Figure 9: Paw's on Science Fair booth.

The fifth outreach event occurred at the University of Washington Engineering Discovery Days. The experiment had a table and attracted quite a number of people. We demonstrated the impacts and discussed to many college engineers how they can get involved in this program. Figure 10 shows the team at the event.

Figure 10: UW Engineering Discovery Days booth.

The team participated in their last outreach event at Jane Addams Elementary and Middle School. Here we participated in a science fair. Unfortunately, the experiment was shipped to Houston at this time. However, the team was able to show videos and discuss the project to many students.

The team was unable to make two of our intended outreach activities in our proposal. This includes conducting 5 class periods at Hamilton International Middle School and attending Washington MESA's Saturday Academies. However, we attended UW Discovery Days and Paw's on Science, which wasn't in the proposal.

Attached at the end of the report are a few of the 'Thank You' letters received by the team.

— Public Outreach

Unfortunately, the team was only able to gain three public recognitions; although, the educational outreach section can be considered public outreach. The three direct public recognitions include announcing to the Mechanical Engineering department about the teams acceptance into NASA's RGEFP, announcing the team's departure to Houston, and giving an interview to a Gizmodo journalist. The Gizmodo journalist was connected to us by Oklahoma State University during the flight week. The Gizmodo interview may not count as a public outreach activity because there is no easily searchable record of Gizmodo's interview with the teams during flight week.

Attached below is one of the outreach announcements the college of engineering.

Attached below are the logs of the outreach activities.

Hello!

Thank you for participating at Paws-On Science: Husky Weekend at Pacific Science Center. The time, effort and support from yourselves and departments are the fundamental reasons why the event was such a success.

Over the course of the weekend we had well over 450 scientists and volunteers. 11,361 visitors came through Pacific Science Center's exhibits; 3,376 on Friday, 4,365 on Saturday and 3,620 on Sunday.

We have received some excellent feedback from our guests and now we would like to hear about your experience. Your feedback will be incorporated in our grant evaluation and will be used to continue to improve the event. Please take 5-10 minutes to fill out this survey.

https://www.surveymonkey.com/s/Paws2014Presenter

Again, thank you for your support and we hope to see you next year!

Best,
Val Kravis

Congratulations on another successful Engineering Discovery Days, and thank you for your participation. This tradition brought over 9,000 guests to campus to celebrate engineering innovation through over 115 exhibits and information sessions and over 1,200 volunteers. Engaging our community and exposing kids to engineering early on in their education is invaluable and essential to the health of the future United States economy.

The planning team would like to hear your feedback about this year's event, please complete the on-line survey here: https://catalyst.uw.edu/webq/survey/dass/235375.

If you are interested in participating in other K-12 outreach opportunities, please contact Jessica Perkins atjessperk@uw.edu, 206-685-8361.

Best wishes,
Mike

Michael B. Bragg, Ph.D.
Frank and Julie Jungers Dean of Engineering
University of Washington
371 Loew Hall
Box 352180
Seattle, WA 98195
206.543.1829

February 11, 2014

UW Microgravity Team
University of Washington

Dear UW Microgravity Team Members:

On behalf of the Washington Aerospace Scholars (WAS) program, The Museum of Flight, and all the WAS scholars, we thank you for your participation in the 2014 WAS Guest Mentor Online Chat Sessions. The time and effort you devoted made it possible for over 240 high school juniors from across Washington state to spend an hour interacting one-on-one with a science, technology, engineering and mathematics (STEM) professional. You can see from the sample of student comments, below, that the chat sessions were meaningful and inspiring:

"Thank you for speaking to us...It's great to hear the story of someone who has completed similar goals to the ones that we're setting now."
"Thanks for taking the time to talk to us! It was an honor to meet you this evening!"
"Thank you. This has been very helpful. I really appreciate the time you spent with us!"
"Your answers were really thorough and I learned a lot! Thanks so much!"
"This Q & A has been extremely interesting, I definitely learned a lot from listening to a professional perspective. Thanks for doing this!"
"Thanks for lending us your time. I found it very useful and wish we had more time with you!"

By virtue of your involvement with the program, our students were given the opportunity to have concrete examples of a students working towards their degrees in STEM fields. Your expertise about, and enthusiasm for, your upcoming NASA Microgravity research mission was evident and motivating, and it helped our scholars to better understand the work involved with crafting such research projects.

The WAS program, a partner of NASA's National High School Aerospace Scholars network, was founded in 2006 to increase the number of students seeking degrees and careers in STEM. In the past eight years, over 2000 students have participated in our distance learning curriculum and over 1000 of those students have gone on to become alumni of our six-day Summer Residency program. Of our reporting, post-high school alumni, 82% are currently pursuing STEM degrees with 53% specifically pursuing degrees in engineering.

Thank you again for your support of the WAS program. We sincerely appreciate your involvement and hope that you will be able to join us again in the future.

Best wishes,

Melissa Edwards

Melissa Edwards
Director
Washington Aerospace Scholars

WASHINGTON AEROSPACE SCHOLARS
The Museum of Flight – 9404 East Marginal Way South – Seattle, WA 98108-4097
(P) 206-764-5866 (F) 206-764-5707
was@museumofflight.org

December 23, 2013 | *NASA*

Microgravity team accepted into 2014 NASA Microgravity University Program

The UW microgravity team, the AstroDawgs, has been accepted into the 2014 NASA Microgravity University Program. This program provides a unique academic experience for undergraduate students to successfully propose, design, fabricate, fly and evaluate a reduced gravity experiment of their choice. The AstroDawgs will pursue an experiment to characterize the impact of different conical geometries on lunar regolith and the resulting dust cloud in a microgravity environment, in order to find a geometry that will produce the lowest dust cloud.

Reduced Gravity Student Flight Program
Outreach Log Sheet

Identifying Info

Reporting Person Info:

Your Name: Patrick Brennan
Your University: University of Washington
Your University Zip: 98195
Your Email & Home Phone: pcb8@uw.edu (253) 224-9957
Event Title: Einstein Middle School Class Visit
Event Date: January 24, 2014
Event Duration: 8am to 11:30am
Type of Event: Class Presentation

Location

Name of Event Site or School:
Event City, State, Zip: Shoreline, WA 98177
This site or school at which this event was conducted is a(n): Middle School

Approximate Participant Count

Direct Participants
Definition: those whose name, school, organization is known and there is interaction between the participant and the team.

- K-12 Teachers – how many? One
- Higher Ed Faculty – how many? ——
- Students – how many? 87
- Other Professionals – how many? ——

Indirect Participants
Definition: people whose name, school or organization is not known.

- General Public – how many?
- Other Professionals – how many?
- Others connected by webcast, TV or Radio broadcast, etc – how many?

Additional Comments

The UW Microgravity Team had the pleasure of introducing ourselves and our project with 3 classes of 8th grade students. We spoke about what we have done in other projects, what initially involved us in our majors, and what we are doing for the Microgravity Program. The team also led a class activity in which the students designed and built mini water towers. This activity aligned with the student's current coursework and brought them through the engineering design process.

Reduced Gravity Student Flight Program
Outreach Log Sheet

Identifying Info

Reporting Person Info:
Your Name: Patrick Brennan
Your University: University of Washington
Your University Zip: 98195
Your Email & Home Phone pcbu@uw.edu (253) 224-9957

Event Title: Student Flight Program Outreach Event
Event Date: February 1st, 2nd, and 3rd
Event Duration: 7pm to 8:30pm
Type of Event:

- Outreach Presentation to Students (elementary, middle, high school, college)
- Outreach Presentation to General Public
- Presentation to Professional Audience (conference or meeting title ____________)
- University Open House/Recruiting Event
- Presentation to Peer Audience (event title, if appropriate _________________)
- Other _____________

Location

Name of Event Site or School: WAS Virtual Chats
Event City, State, Zip: Seattle, Wa, 98195

This site or school at which this event was conducted is a(n):

- Elementary or Middle School (Urban, Suburban, Rural, Minority Serving)
- High School (Urban, Suburban, Rural, Minority Serving)
- Public or Private College or University (HBCU, MSI, NAI, Institution serving primarily women, Institution serving primarily people with disabilities)
- Professional Conference or Meeting
- Museum
- Public Meeting Area (like a shopping mall, Club meeting room, etc)
- Other Meeting Area ___virtual chat___

Approximate Participant Count

Direct Participants
Definition: those whose name, school, organization is known and there is interaction between the participant and the team.

- K-12 Teachers – how many?
- Higher Ed Faculty – how many?
- Students – 25 per chat total = 75
- Other Professionals – 3 mentors for the program

Indirect Participants
Definition: people whose name, school, organization is not known.

- General Public –
- Other Professionals –
- Others connected by webcast, TV or Radio broadcast, etc – how many?

Additional Comments

The UW team partnered with the Washington Aerospace Scholars (WAS) and conducted three separate video conferences with the students. We presented out experiment shortly then opened for an extensive Q and A. each student was required to ask a question and many asked more than one. This was a fun way to reach students we otherwise couldn't and spread our knowledge and passion to these students.

Reduced Gravity Student Flight Program
Outreach Log Sheet

Identifying Info

Reporting Person Info:
Your Name: **Conrad McGreal**
Your University: **University of Washington**
Your University Zip: **98195**
Your Email & Home Phone: **Conrad.mcgreal@gmail.com** **360-621-6645**

Event Title: **Student Flight Program Outreach Event**
Event Date: **April 1st 2014**
Event Duration: **1 hr**
Type of Event:

- **Outreach Presentation to Students** (**elementary,** middle, high school, college)
- Outreach Presentation to General Public
- Presentation to Professional Audience (conference or meeting title ____________)
- University Open House/Recruiting Event
- Presentation to Peer Audience (event title, if appropriate _________________)
- Other _____________

Location

Name of Event Site or School: **West Woodland Elementary School K-5**
Event City, State, Zip: **5601 4th Avenue NW, Seattle, WA 98107**

This site or school at which this event was conducted is a(n):

- **Elementary** or Middle **School** (Urban, **Suburban**, Rural, Minority Serving)
- High School (Urban, Suburban, Rural, Minority Serving)
- Public or Private College or University (HBCU, MSI, NAI, Institution serving primarily women, Institution serving primarily people with disabilities)
- Professional Conference or Meeting
- Museum
- Public Meeting Area (like a shopping mall, Club meeting room, etc)
- Other Meeting Area __________________

Approximate Participant Count

Direct Participants
Definition: those whose name, school, organization is known and there is interaction between the participant and the team.

- K-12 Teachers – how many? **3**
- Higher Ed Faculty – how many? **0**
- Students – how many? **30 - 40**
- Other Professionals – how many? **0**

Indirect Participants
Definition: people whose name, school, organization is not known.

- General Public – how many? **0**
- Other Professionals – how many? **0**
- Others connected by webcast, TV or Radio broadcast, etc – how many?

Additional Comments

Reduced Gravity Student Flight Program
Outreach Log Sheet

Identifying Info

Reporting Person Info:
Your Name: Patrick Brennan
Your University: University of Washington
Your University Zip: 98195
Your Email & Home Phone pcbu@uw.edu (253) 224-9957

Event Title: Student Flight Program Outreach Event
Event Date: April 26, 2014
Event Duration: 9am till 5pm
Type of Event:

- Outreach Presentation to Students (elementary, middle, high school, college)
- Outreach Presentation to General Public
- Presentation to Professional Audience (conference or meeting title ____________)
- University Open House/Recruiting Event
- Presentation to Peer Audience (event title, if appropriate _________________)
- Other _____________

Location

Name of Event Site or School: University of Washington Engineering Discovery Days
Event City, State, Zip: Seattle, Wa, 98195

This site or school at which this event was conducted is a(n):

- Elementary or Middle School (Urban, Suburban, Rural, Minority Serving)
- High School (Urban, Suburban, Rural, Minority Serving)
- Public or Private College or University (HBCU, MSI, NAI, Institution serving primarily women, Institution serving primarily people with disabilities)
- Professional Conference or Meeting
- Museum
- Public Meeting Area (like a shopping mall, Club meeting room, etc)
- Other Meeting Area __________________

Approximate Participant Count

Direct Participants
Definition: those whose name, school, organization is known and there is interaction between the participant and the team.

- K-12 Teachers – how many?
- Higher Ed Faculty – how many?
- Students – how many?
- Other Professionals – how many?

Indirect Participants
Definition: people whose name, school, organization is not known.

- General Public – 9000
- Other Professionals – 1200 volunteers (with their own booths)
- Others connected by webcast, TV or Radio broadcast, etc – how many?

Additional Comments

The UW team participated in Discover Days with a full booth containing a zero-g video, a poster, brochures, and out nearly completed experiment. We were able to run trial runs of our experiment for the crowds of people and answered their many questions afterward. At one point a small bot asked if the lunar regolith was hydrophobic. Needless to say we were impressed with that question as well as many others. It was busy but we were able to talk to many people and spike interest for science, space, and NASA.

Reduced Gravity Student Flight Program
Outreach Log Sheet

Identifying Info

Reporting Person Info:
Your Name: Patrick Brennan
Your University: University of Washington
Your University Zip: 98195
Your Email & Home Phone pcbu@uw.edu (253) 224-9957

Event Title: Student Flight Program Outreach Event
Event Date: April 6th 2014
Event Duration: 8am to 6pm
Type of Event:

- Outreach Presentation to Students (elementary, middle, high school, college)
- Outreach Presentation to General Public
- Presentation to Professional Audience (conference or meeting title ____________)
- University Open House/Recruiting Event
- Presentation to Peer Audience (event title, if appropriate _________________)
- Other _____________

Location

Name of Event Site or School: Paws on Science, Pacific Science Center
Event City, State, Zip: Seattle, Wa, 98195

This site or school at which this event was conducted is a(n):

- Elementary or Middle School (Urban, Suburban, Rural, Minority Serving)
- High School (Urban, Suburban, Rural, Minority Serving)
- Public or Private College or University (HBCU, MSI, NAI, Institution serving primarily women, Institution serving primarily people with disabilities)
- Professional Conference or Meeting
- Museum
- Public Meeting Area (like a shopping mall, Club meeting room, etc)
- Other Meeting Area ______

Approximate Participant Count

Direct Participants
Definition: those whose name, school, organization is known and there is interaction between the participant and the team.

- K-12 Teachers – how many?
- Higher Ed Faculty – how many?
- Students –
- Other Professionals –

Indirect Participants
Definition: people whose name, school, organization is not known.

- General Public – 3,376
- Other Professionals – 450 scientists and volunteers
- Others connected by webcast, TV or Radio broadcast, etc – how many?

Additional Comments

The UW team set up a booth for the Pacific Science Centers Paws on Science event. We brought brochures, posters, a video, and out pneumatic system to display to those who visited out booth. It was entertaining working the pneumatic system and answering the many questions about how it worked and what it was used for.

Reduced Gravity Student Flight Program
Outreach Log Sheet

Identifying Info

Reporting Person Info:
Your Name: **Conrad McGreal**
Your University: **University of Washington**
Your University Zip: **98195**
Your Email & Home Phone: **Conrad.mcgreal@gmail.com** **360-621-6645**

Event Title: **Student Flight Program Outreach Event**
Event Date: **May 22nd 2014**
Event Duration: **1.5 hrs**
Type of Event:

- **Outreach Presentation to Students** (**elementary, middle**, high school, college)
- Outreach Presentation to General Public
- Presentation to Professional Audience (conference or meeting title ____________)
- University Open House/Recruiting Event
- Presentation to Peer Audience (event title, if appropriate _________________)
- Other _____________

Location

Name of Event Site or School: **Jane Addams K-8 School**
Event City, State, Zip: **11051 34th Ave NE, Seattle, WA 98125**

This site or school at which this event was conducted is a(n):

- **Elementary or Middle School** (Urban, **Suburban**, Rural, Minority Serving)
- High School (Urban, Suburban, Rural, Minority Serving)
- Public or Private College or University (HBCU, MSI, NAI, Institution serving primarily women, Institution serving primarily people with disabilities)
- Professional Conference or Meeting
- Museum
- Public Meeting Area (like a shopping mall, Club meeting room, etc)
- Other Meeting Area __________________

Approximate Participant Count

Direct Participants
Definition: those whose name, school, organization is known and there is interaction between the participant and the team.

- K-12 Teachers – how many? **2**
- Higher Ed Faculty – how many? **2**
- Students – how many? **30 - 40**
- Other Professionals – how many? **2-3**

Indirect Participants
Definition: people whose name, school, organization is not known.

- General Public – how many? **40 - 50**
- Other Professionals – how many? **2-5**
- Others connected by webcast, TV or Radio broadcast, etc – how many?

Additional Comments